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The Evolution of CERN's Capacitive Touchscreen

From control room to mainstream

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Abstract

"The Evolution of CERN's Capacitive Touchscreen – From control room to mainstream."

By Benjamin Henriksen, Jesper Munch Christensen and Jonas Stumpe.

Finishing project, IT-University of Copenhagen, summer 2012.

Our problem statement was based on the following questions:
Based on the touchscreen developed at CERN during the 1970s, why did the diffusion process not proceed more rapidly?

Research questions:

- What is the history behind the touchscreen developed at CERN?
- Why was CERN successful in developing the touchscreen?
- How does the technology transfer process used in the 1970s deviate from an approach using a modern model for technology transfer?
  In the future research section of the report we will answer the following question:
- What cultural barriers or potentials have influenced the history of this touchscreen?

We have conducted interviews, desk studies and technology transfer studies. The main interviews were with Giovanni Anelli, group leader of CERN's Knowledge Transfer Group and Electronics Engineer Bent Stumpe. Our sources have been examined using historical methods because we had to start by establishing a historic foundation of CERN's capacitive touchscreen and therefore we have gathered documents that have never been combined in this matter before.

Our results outline a history about an innovation that had its origin in the early 1970s and had its closure in 2008 with the decommissioning of the last of the original capacitive touchscreens from CERN. This innovation was spawned as a result of the challenges associated with the construction of the Super Proton Synchrotron. Frank Beck, who had read about touchscreens, asked Bent Stumpe if he had an idea to make a touchscreen using a different technology than the various experimental types known at that time. CERN's success with the first version of the touchscreen was due to the right environment, some time pressure, courage and vision from the right people and support from CERN with the necessary resources.

CERN did not have a technology transfer department in the 1970s and therefore there was not a structured approach to transferring the technology to society. Though Bent Stumpe did a lot of practices described in modern technology approach based on his common sense, there was no awareness of the importance of such a department at CERN in the 1970s.

The diffusion process did not proceed more rapidly because the costs were too high for general-purpose usage and the software and hardware available at that time were limited. Furthermore CERN did not have a need for further development and stopped founding for further research of the X-Y touchscreen.

Finally we look into the cultural barriers in relation to CERN's convention and the physicists etc.

Prologue

Touchscreens have been around a whole lot longer than most people realize. They have been used for a variety of different purposes since the first touchscreen prototypes[1] saw the light of day. Touchscreens can at least be tracked back to the early 1970s.

There are different types of touchscreens. The difference lies in the way the technologies work and how people interact with the touchscreens. There are at least five different types of capacitive touchscreens. Each one of them has the same basic idea, but they are fundamentally different inventions because of the technology behind the screen. Some of the main technologies besides the capacitive touchscreens are resistive and surface acoustic wave touchscreens, which both are entirely different from the capacitive touchscreen. This points to an important thing, you have to be very clear and exact when you look at the touchscreens and categorize them. This also goes for the subcategories. Otherwise you cannot answer the questions: Who invented what and when?

If for instance the researcher makes a faulty identification of a source and then draws a conclusion in the light of this, other scientists might continue to build upon a wrong foundation. This being said, this historical research in general is an eternal quest where the truth only lives until the next valid proof emerges from the hidden treasures of the incredible and wonderful corners of Earth. That is why the historical method is important and the correct use of it is essential.

In this research project we look into a specific capacitive touchscreen genesis. More precise the touchscreen developed at CERN during the 1970s. You can within good reason ask yourself: Why is it interesting to look at a delimited and obsolete technology as the capacitive touchscreen developed at CERN?

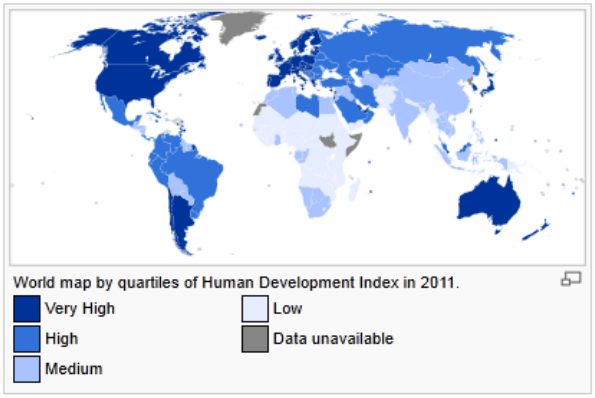
First of all this is an innovation that has had a remarkable development and transition through time starting in the 1970s and up until today. In the beginning it was used for assisting the basic physics research at CERN. Later the usage expanded to include nuclear power plants and at research institutions before it went into hiding for at least a decade.

The capacitive touchscreens have now in general become mainstream, a thing most people in countries with high Human Development Index (HDI)[2] now use on a daily basis in the form of a smartphone or a tablet computer.

When a new time period called the post-modern big data age (Wiki, 2012, List of time periods) arrived around the year 2001 (Meta Group, 2001, 3D Data Management: Controlling Data Volume, Velocity, and Variety), computers became even more important for everyday work and living. That is why people of today have become more dependent on this extraordinary phenomenon known as information technology. The demand for faster units and to be online twenty-four seven has risen with the evolution of smarter

[1] As you can read in this report there were experiments with different types of touchscreen before the CERN's started their development.
[2] The HDI is a comparative measure of life expectancy, literacy, education, technology and standards of living of a country. It is a part of the United Nations Development Programme. (Human Development Report Office (HDRO), 2012, Human Development Reports and index)

devices. A component of these faster smarter devices are the capacitive touchscreen as it was a part of the Super Proton Synchrotron[3] control device developed at CERN in the 1970s.



(Wikipedia, 2012, World map by quartiles of Human Development Index in 2011)

The history behind the touchscreen is very interesting because of its long journey through time until the potential now with smartphones and tablets has unfolded. Who knows what still lies ahead of this noticeable invention?

Background

The reason why we began looking into the capacitive touchscreens genesis was because it came to our attention that this type of touchscreen was much older than we thought. Therefore we found it very interesting to explore the history and find the original sources to understand the development of this specific and today widespread technology.

How does a thing like the capacitive touchscreen fade out of existence to reappear and become a central player in one of the world's most widespread devices called the smartphone? Is it possible to go back in time and find the root source? Has the capacitive touchscreen been used for other purposes in the past and why? Questions like these drove our curiosity and we also find it interesting because of the impact the touchscreen and not least the smartphone has had on the modern society[4].

Though it is considered that the concept of technology transfers[5] originated in July 1945 (National Science Foundation, 1945, Science The Endless Frontier) technology transfer[6] offices has emerged in recent years so inventors and research institutions can improve the success rate of getting technology, skill and knowledge out into society. Getting these things into society can enable you to make further developments and maybe create new products out of existing inventions.

Some use the concept knowledge transfer for this discipline and says that technology transfers and knowledge transfers are two sides of the same coin (University of Guelph, 2007, Creating knowledge for a better future). You can say that technology transfer is a way of transmitting promising research topics and making them more mature so that they at a point can be made ready for production.

[3] The Super Proton Synchrotron is a particle accelerator. (CERN, 2008, SPS - the Super Proton Synchrotron)
[4] We know this is a different perspective than our methods covers, but this was a driving force for us to start with.
[5] The term was not made in the report: *"Science The Endless Frontier"*. It was only described.
[6] This is also called Transfer of Technology (TOT) or Technology Commercialisation.

Another reason why we decided to have a look at the capacitive touchscreen was that we had the possibility to travel to CERN. CERN as an organization has provided the world with some of the most influential and important inventions that exist today, including what we know as the World Wide Web that was invented in 1989 (CERN, 2008, Where the web was born), which from an information technology standpoint also makes it extremely attractive to us.

With the aid of Electronics Engineer[7] Bent Stumpe, the uncle of one of the writers of this project, Jonas Stumpe, we were able to get access to many areas of CERN, which are normally restricted to the general public. Subsequently we narrowed down the scope of our project to research of the capacitive touchscreen developed at CERN during the 1970s. The fact that Bent Stumpe was a firsthand witness to this invention at CERN, tricked our curiosity even further.

We were able to make a new link between CERN's fundamental research, the IT University of Copenhagen, information technology history and information technology in general, which was an entirely new form of project for us. We could make contact with new academic disciplines and approaches. This beforehand knowledge gave us the impetus to continue in the quest to make ends meet and hopefully reveal new information to be used in the broader perspective.

We knew beforehand that we could get access to some of the original documents from the 1970s. Among these documents, some which have not been made available online. It is our assumption, that unlike ourselves most people think it is a few big multinational companies who have invented this type of touchscreen. It was very interesting for us to see if we were able to get a little bit closer to the truth by hopefully finding another story hidden in old documentation and notes. Hereafter we started our research.

Preconceptions

We had the following preconceptions:

- The evolution of the capacitive touchscreen was initially affected by factors CERN and other organizations could not control.
- We believe that Bent Stumpe was one of the first to describe and physically implement what we know as the capacitive touchscreen.
- The reason why the capacitive touchscreen was not further commercialized might have been an absence of ownership at the big technology corporations.
- If CERN had promoted the capacitive touchscreen technology back in the 1970s the commercialization of the capacitive touchscreen might have happened earlier.
- A lot of people think a few big multinational companies have invented this type of touchscreen. This, we assumed, was not the case.
- We believe that innovations are a key competitive factor especially for technology companies and they can help change the way we experience the world.

By submitting our preconceptions to the reader we will try making our background more visible. Later in the project we will look at our preconceptions again and compare them to our results.

[7] We have decided to address Bent Stumpe as Electronics Engineer through the project because that is what he is according to the interviews with him. Some of our sources are entitling him otherwise.

Problem statement

We believe that innovations are a key competitive factor especially for technology companies and they can help change the way we experience the world.

We think it is interesting to examine how a simple idea for a specific innovation can lie unused for several decades and then fundamentally change the way we interact with technology products such as tablets and smartphones.

Based on the touchscreen developed at CERN during the 1970s, why did the diffusion process not proceed more rapidly?

Research questions:

- What is the history behind the touchscreen developed at CERN?
- Why was CERN successful in developing the touchscreen?
- How does the technology transfer process used in the 1970s deviate from an approach using a modern model for technology transfer?
  In the future research[8] section of the report we will answer the following question:
- What cultural barriers or potentials have influenced the history of this touchscreen?

To investigate we will do literature studies based on a variety of sources including data from CERN, and to perform empirical studies such as interviews. We will also use the historical method. This is elaborated in the methods section in this report.

See amendment for the problem statement in appendix 10.

[8] This section is the perspectivation of this project.

Methods and theories

In this section we will describe the scientific methods and theories we have used in order to answer the questions in the problem statement. We have decided to use a large number of quotations within the report to make it easier to verify our interpretations. Under other circumstances these could have been placed in the appendix, however we decided to use a *"show me don't tell me"* approach.

To establish a comprehensive picture of the history behind the capacitive touchscreen and to be able to analyse the evolution and journey from industrial technology to mainstream use, we needed to understand the background of the capacitive touchscreen and hereby gain an understanding of history and technology transfers.

To do this it was necessary to include a wide range of academic disciplines. The project basically consists of two phases, of which the first was the establishment of the history behind the capacitive touchscreen[9]. This part was a prerequisite to the analysis of what could have been done differently to promote the change from industrial to commercial use and how we can benefit from this knowledge in the future.

To establish the history and timeline of the capacitive touchscreen, we used publications, articles and other relevant information. We knew that we would have to adapt an established method to localize, organize and validate the information we would build upon in our research. Therefore we decided to use *"Historisk Metode[10]"* (Egaa Kristensen, B., 2007, Historisk Metode). The book addresses all of the above and takes the reader through the necessary questions in the process of documenting history. We also conducted an interview session with Master of Arts in history Marie Skouenborg whom elaborated on the historical method and gave us additional tools and not least a lot of her own invaluable experience which we found important in regards to our own greenness in using historical methods which is outside our normal information technology research field.

Marie Skouenborg also provided us with an overview of theory scriptures used in the history subject. We were informed about the de facto standard methods within historical research, which also included method books. These we have not selected to use in our project:

- *"Historisk Teknik[11]"* by Kristian Erslev.
- *"Kildekritik i et samfundsvidenskabeligt perspektiv[12]"* by Vibeke Ankersborg.
- *"Til kilderne![13]"* by Sebastian Olden-Jørgensen.

The three above mentioned books all use their own variation of the historical method. We have supplemented this with the chapter "*Historisk Metode og materialekritik[14]*" from the book *"Grundbog i Danmarkshistorien[15]"* by Peter Frederiksen, Knud Ryg Olsen and Olaf Søndberg. This chapter has the

[9] The second phase is the technology transfer section, which will be covered later.
[10] Translation: "*Historical Method*"
[11] Translation: "*Historically Technique*"
[12] Translation: "*Source criticism from a social science perspective*"
[13] Translation: "*Straightforward to the Sources!*"
[14] Translation: "*Historical Method and material criticism*"
[15] Translation: "*Textbook on the history of Denmark*"

advantage of being an open *"iBog*[16]*",* which means that it is on the internet for everyone to read. Furthermore this gives access to some research questions that are not to be found in the original book.

Our project relates to more recent events in a historical research perspective, which to some extent make some of the common historical research issues less likely to occur. We do not expect to come across ancient documents in forgotten languages or corroded documents. Though you can argue that the handwritten note[17] we use as a source can be difficult to read and therefore analyse. Because of this we have chosen to focus on a simple and single method framework within the Danish historical research tradition.

We are aware that there are also English historians but we decided to go with the Danish tradition because of the fact, that we had a direct contact to a Danish Master of Arts in history and because we are from a Danish university.

During our research it became clear that the amount of references found within almost every single source was extremely extensive. But in spite of this we still think that we have a fair amount of sources included in our research and therefore it was not possible to investigate every reference to the full extent. In other words we had to set a limit or spend at least five years on investigating the source material. We still think that we have located most of the important sources and thus have a solid ground to stand on source wise.

In traditional historical research there is a lot of focus on understanding the gathered information because there are a lot of other factors in play including ancient fonts, missing and inaccurate information. Since the majority of our sources originate from the 1950s and later we do not have to worry about a lot of the usual pitfalls. Most of our information is of a scientific nature and therefore it is easier to identify our sources and validate the information.

> *"The research process requires a pre-theory of the subject the historian wish to study."*
> (Egaa Kristensen, B., 2007, Historisk Metode)

Establishing the history of the capacitive touchscreen is one of the most critical parts of this project and an imminent danger of collecting information that is incomplete, obsolete, inconclusive or inaccurate is present. This is why we have taken a large amount of time to locate and analyse our sources into details. Furthermore we try to explain and document how we came to our conclusions. This should minimize the risk of making false assumptions and thereby avoid drawing the wrong conclusions based upon the available material.

We are aware that when it comes to historical research the truth is often temporary. It is worth mentioning that this method is used only on sources relevant to our problem statement and especially the historical questions. We have a lot of other references but these are not direct sources and are mainly used to verify the information from the direct sources.

[16] Translation: *iBook.*
[17] A handwritten document from Bent Stumpe.

After having made these key considerations and having read the theories we made it concrete. It was clear that the historical method was not a book full of answers, but we had to make it fit the research field making it a flexible method. Even though it is a flexible method there are some basic central elements.

The central part of the historical method is the questions you are asking during the source identification. When asking the right questions and answering them correctly, you stand a better chance drawing conclusions in relation to the actual events (Egaa Kristensen, B., 2007, Historisk Metode). Another aspect of this is the credibility of the sources. If you are able to find indicators of their trustworthiness you are in a better position to conclude if what the sources are telling you is correct.

From the book "*Historisk Metode"* and based upon the interview with Marie Skouenborg we defined the following fifteen questions, which are central to our historical research.

- Title or name: What is the title of the source or sources name?
- Authorship: Who produced the source?
- Source type: Is it used as a relic or a narrative or maybe both?
- Text types: What type of source is it? This could be a legislative text, judicial document, letter, speech or history writing. In our case it would be articles, handwritten notes, academic projects etc.
- Dating and chronology: When? Contemporaneity with events?
- Localization: Where was it produced? Publisher and/ or production place.
- Purpose: Why was this source written? Are there hidden purposes?
- Analysis: From what material was it produced? Which references is mentioned in the source?
- Context: In what context was the source written? In what general context was the source written?
- Source tends: Derogatory, praising or both?
- Is it a first or second-hand source? Has the writer or interviewee witnessed what he describes? Or is it as a second-hand knowledge?
- Who is the original receiver?
- Relation with other sources?
- What historical events or conditions may shed light on the source?
- What does the source tell? The main points.

Usually when analysing the source you write the analysis in pure text form (Skouenborg, M., 2012, interview with Marie Skouenborg). We decided to make what we call source identification schemes[18] to get a better view of the large amount of data, to make it easier for the reader and get a better structuring of our sources. We still think these schemes are within the boundaries of the historical research. This structured approach is not a quantitative based approach, although it might seem so, but strictly a qualitative approach founded on text, which is important to understand.

The fifteen questions were divided into three parts for use in different sections of the project. The three parts are:

[18] The schemes are our own invention, but the method is not! The source identification schemes are located in the appendix 1.

1. The source evaluation of interviews and documents.
2. The results of source evaluation.
3. The source identification schemes.

Part one is a general view of the source material in which we go through all the sources and try to assess their credibility. Part two is a look at what the sources are telling us with a focus on the main points. Here we make an interpretation of what the sources are telling us. Part three is a look at each source isolated in a scheme to avoid them being distorted by the other sources. This is another important point.

The split is also composed to make it easier for the reader because part one and two is the report itself. Otherwise it would be an at least fifty pages long analysis of the sources which we did not find reader friendly. All the documentation of what is in the report is substantiated in the appendix for the reader to find. All the sources used in these three parts are important for answering our problem statement.

It is also important to be aware of the difference between concluding from a relic and a narrative source like it is important to know if you are dealing with a first or a second-hand source. (Egaa Kristensen, B., 2007, Historisk Metode)

In this report we try to distinguish between these categories though it is never a final judgement. It depends on in which context you use the source. The crucial difference between concluding from a relic and concluding from a narrative lies in the credibility assessment. You only have to make a credibility assessment for a narrative (Egaa Kristensen, B., 2007, Historisk Metode). We have done it for both because a lot of the sources can have both characteristics. The same applies with the distinction between first and second-hand sources. A firsthand source is something the writer has experienced personally or has concluded. A second-hand source is communicating something she or he has learned from others. One source text can be both a firsthand and a second-hand source. We have made an overall assessment of our sources form each sources tendency.

It is important to emphasize that this is not only a paper on historical research, but also on diffusion of innovations and how universities and other research institutions can use and promote new technologies.

Before we could initiate the analysis we completed semi-structured interviews to establish a knowledgebase related to how innovations and research is and was being handled at CERN. Another goal was to learn from their experiences and be able to build upon this when we did our analysis. We chose the semi-structured approach because we were aware of the diversity between organizations and we did not want to limit the interviewees' creatively, our mission was not to collect quantitative data.

We have tried to handle the issue related to intersubjectivity[19] by doing the interview guide in plenum and try to reach a consensus when going through the recordings and extracting the valuable information. This is done to limit the risk of not being objective. When doing it in plenum until consensus is reached, this risk is reduced. Obviously we could all be influenced in a similar manner in which case doing it in plenum adds little value, but in general this will minimize the risk as we are in some case able to pinpoint subjective interpretations of the sources we are working with.

[19] Intersubjectivity means that we have tried to avoid subjectivity.

As with any interpretations culture, assumptions are always a risk, we have tried to be as objective as possible during our handling of data to minimize these risks. The theory used here is from the book *"Doing Interviews"* (Kvale, S. 2007, Doing Interviews). We have chosen not to transcribe the interviews because we estimated that it would take too long and it would be a too big addition to an already large Appendix. Instead we have used selected quotes and translated them where necessary.

The technology transfer methods and theories we have selected to include in our project are included to establish an understanding of how technology transfers were done in relation to the touchscreen at CERN during the 1970s. This is the second phase.

It is important for us to understand the most important aspects of technology transfers if we are to address some of the main questions within our problem statement, which relates to the diffusion of the touchscreen.

The book *"The Art & Science of Technology Transfers"* (Speser, P.L., 2006, The Art & Science of Technology Transfer) provides a comprehensive guide to the elements that could be included when doing technology transfers. We have decided to include a few of the more commonly known models in our project to aid in establishing a picture of the technology and market situation. The models we use in this project are Technology Readiness Level Model, Porters Five Forces and SWOT analysis[20]. There are other well known models described in the book which we have not included, like PESTEL and the Four Ps etc. The decision has been made on the basis of the data available.

We used Porters Five Forces and SWOT to reveal or exclude potential possibilities and risks in relation to investing in commercialization for the touchscreen. This could help us reveal some of the factors that affected the diffusion.

The creating of SWOT is credited to Albert Humphrey who led a convention at Stanford Research Facility between 1960 and 1970 (Johnson, G., Whittington, R. and Scholes, K., 2011, Exploring Corporate Strategy). It was during this time period the method was created. The method is used to evaluate internal and external factors before embarking on a business venture. The method includes both micro and macro-environmental factors.

Porters Five Forces was created by Michael H. Porter from Harvard Business School in 1979 (Johnson, G., Whittington, R. and Scholes, K., 2011, Exploring Corporate Strategy). The framework is used to determine the attractiveness of a market based on five forces. Three of the forces are based on external factors and the two others are internal. We have tried to estimate the potential for industry profitability for the touchscreen in the period of 1971 to 1980.

We have also chosen to use theory and methods from the book *"Diffusion of Innovations*" (Rogers, E.M., 2003, Diffusion of Innovations). Some of the models descried in this book were also mentioned in *"The Art & Science of Technology Transfers".*

This book describes a lot of diffusion research, developing theories and models within this field. We use this to help address the main question from our problem statement.

[20] See appendix 7, 8 and 9.

> *Diffusion research is thus emerging as a single, integrated body of concepts and generalizations, even though the investigations are conducted by research in several scientific disciplines."*
> (Rogers, E.M., 2003, Diffusion of Innovations)

The book describes some very interesting research theories on rate of adoption, which can assist us in finding potential barriers and explain the diffusion factors.

Variables determining the rate of adoption are split into five main parts:

1. *Perceived attributes of innovations.*
2. *Type of innovation-decision.*
3. *Communication channels.*
4. *Nature of the social system.*
5. *Extent of change agents.*

These variables determine an innovation's rate of adoption, with the first part being the most extensively investigated area among diffusion researchers. We will in our report focus on the perceived attributes of innovations.

We hope that the technology transfer combined with the desk study and the interviews will help us find some of the answers.

Studies

In the following section we have listed the most relevant results from the interviews and the desk studies. All remaining information from the source identification schemes can be found in appendix 1.

We have looked at the interviews and the desk studies separately to differentiate the sources from each other and thereafter compare the findings to see if there are similarities or variations. This is done so that the results will not be distorted to begin with.

The purpose of the choice of form is to give an overview of each source's weaknesses and strengths. It is noteworthy that not all points are equally important for all sources. For example you do not have an author for an interview[21]. The important thing is the relevance and significance of each point in the scheme.

A historical introduction to CERN

A part of the historical method is to put the sources in a general context. We therefore have made this section in relation to our early sources and to some of our later sources as well because this is central in the understanding of the entire source context.

In the aftermath of the Second World War (Wikipedia, 2012, World War II) Europe experienced a decline in the science community, to counteract this a group of visionary European scientist dreamt of creating a European atomic physics laboratory, which both would unite the Europeans but also bring down the costs of nuclear physics facilities (CERN, 2008, 1954: Foundation for European science). On September 29th 1954 after several meetings and ratifications this resulted in CERN becoming a reality and that Geneva was chosen as the location of the laboratory.

The CERN convention covers twenty articles; in relation to this specific project *article II* is important and it states that the results shall be published or otherwise made generally available.

> ARTICLE II : Purposes
>
> 1. The Organization shall provide for collaboration among European States in nuclear research of a pure scientific and fundamental character, and in research essentially related thereto. The Organization shall have no concern with work for military requirements and the results of its experimental and theoretical work shall be published or otherwise made generally available.

(CERN, 1953, Convention for the establishment of a European organisation for nuclear research)

To summarize; Europe was going through a hard time after the war and many scientists had migrated to the United States (Wikipedia, 2012, Manhattan Project), to counter this Europe joined forces and CERN was born.

[21] Therefore you cannot answer the question of authorship, though you can argue that the interviewers and interviewee are the authors.

Interviews

During our visit at CERN we did an interview with Giovanni Anelli and Bent Stumpe from The European Organization for Nuclear Research (CERN).

Giovanni Anelli is the group leader of CERN's Knowledge Transfer Group[22]. He kindly explained important parts of CERN's work with technology transfer and told us about both good and bad experiences. The interview with Electronics Engineer Bent Stumpe focused on his work with the capacitive touchscreen back in the 1970s and how he perceived its history. In addition both were able to tell about important parts of CERN's history.

Guide to interviews

In appendix 3 – 5 you can find the interview guides containing the questions we have defined prior to each interview. In the following you can find the main points of each interview.

Source evaluation of interviews

The historical method only addresses text documents as sources. Because interviews become texts when they are written down we have used the historical method on our interviews as well. The important thing here is to know that we use the historical method on the interviews not the person. But we have to look at each person in relation to the research field.

Source evaluation of the interview with Giovanni Anelli

In our research questions we have a question concerning the technology transfer process at CERN and this is where Giovanni Anelli becomes an important firsthand source to the project. Giovanni Anelli is the current group leader of the Knowledge Transfer Group at CERN (CERN Knowledge Transfer, 2012, Anelli, G.). He has held this position since August 2011 (CERN Knowledge Transfer, 2012, Anelli, G., Our team, Read CV). Furthermore he has been a member of the Knowledge Transfer Group since 2010 where he worked as a Technology Transfer Officer.

As the Head of the Knowledge Transfer Group Giovanni Anelli is in our point of view the source with the greatest authority. In other words we could not get a better source from CERN to help answering these questions, although it would have been great with a source from a third party outside of CERN. This could have helped substantiate and maybe give new ways to approach the questions. But we can still hold his words against other text sources, which we consider to give sufficient backup to this interview.

Giovanni Anelli has been employed at CERN from October 1995 till June 2007 and again from June 2010 till present day (LinkedIn, 2012, Anelli, G.). His long-term engagement at CERN gives Giovanni Anelli a strong credibility, as he must have a great insight of CERN as a research institution.

The historical method implies that you have to cover potential bias in relation to our sources, being leader of the Knowledge Transfer Group would to some extent limit Giovanni's possibilities to be very critical about the importance of technology transfers, his group and the results generated by his group.

[22] We have not been able to verify when CERN's Knowledge Transfer Group was established. Our best guess is sometime during the early 1990s. (Wikipedia, 2012, Knowledge transfer)

Giovanni Anelli was to some extent critical about the current culture at CERN in relation to technology transfers, which sometimes made it difficult to take advantages of the many innovations created at CERN in relation to technology transfer activities.

Another important fact is that Giovanni Anelli is an IEEE senior member (CERN Knowledge Transfer, 2012, Anelli, G., Our team, Read CV). This is important because we also use IEEE in our reference list for other purposes. This also gives his statements a stronger value.

Finally he is author and co-author of more than seventy publications. This gives a solid base for his entire career and as a source. All in all we believe that we can conclude that the interview with Giovanni Anelli is a valuable source with good credibility.

Source evaluation of the interviews with Bent Stumpe

We consider Bent Stumpe to be a firsthand witness to the developments at CERN in the 1970s and early 1980s due to the fact that he was there during the actual events. But it is important to mention that he is not a firsthand witness to all the events surrounding the capacitive touchscreen. For example Bent Stumpe points out in one of the interviews that he does not know everything about the production of the touchscreens at Ferroperm[23]. Because of this he recommends that we ask his brother-in-law Søren Karl Larsen about this matter as he took part in the production of the touchscreens in the 1970s at Ferroperm.

Regarding the events at Ferroperm Bent Stumpe is only a secondary witness but regarding the events at CERN he is a firsthand witness and Bent Stumpe is furthermore our main source.

Clearly Bent Stumpe has a lot of interest in this project because it is mainly about his own work and inventions at CERN in the 1970s. But who would not have a fondness and interest in their own life's work?

 [24]

Bent Stumpe in front of the first prototype console in a room next to his office at CERN in the 1970s. (Engineering Weekly online, 2011, Kom bag om CERNs bedste opfindelser.[25])

[23] Ferroperm was back in the 1970s an electronics company. The company is still in business: "*Today's Ferroperm-EMC is a designer and manufacturer of hi-tech electronic components used in many sections of the electronic industry."* Part of it is still based in Denmark:"*Development of new materials and components and the manufacture of proprietary ferrite products are based in Denmark."* (Ferroperm, 2012, About us)

[24] Photo: Bent Stumpe.

[25] Translation: *"Get backstage with the best inventions from CERN."*

This being said historians rarely get the chance to speak to a living firsthand witness to past events[26]. And even though we are not historians this fact gives great value to the project. Bent Stumpe can fill in the gaps in our sources and provide extra details. Even better is the fact that we can make a comparison to the documents and thereby underpin the words in the interviews with Bent Stumpe and vice versa.

Bent Stumpe has had a long-term engagement with CERN from 1961 till 2003 (Stumpe, B., 2012, CERN – CV Bent Stumpe) which, combined with the entire official CERN documents he has written, gives his words credibility. This is very important in relation to Bent Stumpe as a source. Another important fact is that we have another firsthand witness hidden in our text sources. That person is Bent Stumpe's manager at the time Michael C. Crowley-Milling who was the leader of the SPS Division at CERN (Crowley-Milling, 1978, Recommendation). Despite multiple attempts we were not able to locate Michael C. Crowley-Milling and therefore we could not set up an interview.

The source from Michael C. Crowley-Milling's hand is a recommendation of Bent Stumpe's work at CERN described in details. The document has an official CERN naming convention: *"SPS-DI/MCCM/tr"* (Crowley-Milling, 1978, Recommendation).

> *"To provide the equivalent of a very large number of push-buttons in a small place, B. STUMPE developed the "touch-button". The buttons are drawn by computer on the fact of a cathode-ray tube over which is placed a transparent glass touch-screen."*
> (Crowley-Milling, 1978, Recommendation)

Michael C. Crowley-Milling wrote this recommendation to nominate Bent Stumpe for the award by the LK-NES foundation. This was a prestigious Danish industry price at that time and was awarded every second year. (LK-NES pressetjeneste, 1978, LK-NES-Prisen for 1978[27])

(Erhvervs-Bladet, 1978, LK-NES prisen blev overrakt[28])

[26] When looking at the entire history as a research field. For example you cannot interview the historical Jesus, Vóóhéhéve (chief Morning Star) from the Northern Cheyenne tribe or John Lennon from the Beatles, because they are no longer alive.
[27] Translation: *LK-NES press office, 1978, LK-NES award 1978.*
[28] Bent Stumpe receiving the LK-NES award by director Erik B. Rasmussen. In the picture you can also see Michael C. Crowley-Milling and his wife.

> *"These three aspects of B. Stumpe's work, namely the technical developments, their dissemination for public benefit, and the collaboration with industry, make him an outstanding candidate for the award by the LK foundation."*
> (Crowley-Milling, 1978, Recommendation)

The words of Michael C. Crowley-Milling's support Bent Stumpe's credibility even further.

Previously we mentioned that Bent Stumpe is the uncle of Jonas Stumpe. We are conscious of the potential nepotism problem and we are addressing this through the way we use our methods. Benjamin Henriksen performed the interviews with Bent Stumpe and the review of Bent Stumpe's written documents. Jesper Christensen and Jonas Stumpe attended the interviews as observers.

Just like all the documents written by Bent Stumpe are evaluated for content in the result of desk studies by Benjamin Henriksen and Jesper Christensen to avoid subjectivity and get intersubjectivity. All of this is done to give a better credibility to the project and not least to Bent Stumpe as a firsthand source. After the evaluation we can conclude that the interviews with Bent Stumpe have a good credibility.

Source evaluation of the interviews with Søren Karl Larsen

Bent Stumpe mentioned Søren Karl Larsen as an important source in relation to Ferroperm because Søren Karl Larsen was employed at Ferroperm from 1975 to 1978 (Interview with Søren Karl Larsen, 2012, Karl Larsen, S.).

Jonas Stumpe conducted the recorded interview; this is a deviation to the precaution described earlier, because Søren Karl Larsen is his father. The interview was setup ad-hoc because of the reference giving by Bent Stumpe and it is an extremely short interview related mostly to the amount of touchscreens sold. We do not think the relationship between the two were an issue because the answers was not praising and had some uncertainty. The interviewee said, *"I don't know"* to some of the questions, which points to an intension of honesty.

The interviewee's answers are based on his personal memory and cannot be verified by other sources. There is some degree of uncertainty, which affects the credibility.

But from this time period at Ferroperm Søren Karl Larsen is our best and only firsthand witness. Therefore we have chosen to include this interview in spite of the uncertainty.

Results of interviews

We have conducted four recorded interviews, the first one with Giovanni Anelli and Bent Stumpe, followed by two additional interviews with Bent Stumpe. In this chapter we have tried to extract the most essential information related to our project for each of these interviews. Lastly we did a short interview with Søren Karl Larsen.

In addition to these four interviews we have conducted a range of interviews during our pre-study phase of the majority of these was with Bent Stumpe. Furthermore we have interviewed Head of the CERN Library

Jens Vigen[29], Master of Arts in history Marie Skouenborg and Journalist Mie Stage[30] from Engineering Weekly online.

The first recorded interview with Bent Stumpe was lost because of technical issues. Therefore we conducted a second recorded interview with Bent Stumpe based on our experiences in the first interview.

Interview with Giovanni Anelli and Bent Stumpe at CERN, Geneva, Switzerland April 26th. 2012

The interview with Giovanni Anelli primarily focuses on the work they do within the Knowledge Transfer Group at CERN. Bent Stumpe is also a participant in the interview, but his part is to shed light upon some of the different aspects related to the touchscreen.

Giovanni Anelli gave his perspective to how CERN could have handled earlier technologies like the World Wide Web. We have divided the result of this interview into two. The first focuses on the work being done today and the second on the past. The interview does not cover the complete structure of the Knowledge Transfer Group, but clarifies some of the most important barriers the group has to overcome in their work at CERN.

Giovanni Anelli explains that the goal of the group is passing knowledge from CERN out into society, the business world and other research facilities. When the group was created the focus was on generating financial output for CERN.

This is no longer the case; the primary focus has shifted and is now related to getting technology out to the broad society and to spread the knowledge about technologies developed at CERN.

We think one of the reasons could be the fact, that the primary focus to a lot of the scientists at CERN are not economical gain but being the first to publish progress within a given field of research. Having to wait for patent approvals and others to write the patent description does not contribute to this agenda. To this Giovanni Anelli says:

> *"Without the scientist there won't be any knowledge transfer."*
> (Interview Giovanni Anelli, 2012, Anelli, G.)

The scientists initiate the transfer process and the Knowledge Transfer Group's work consists of aiding the scientist in regards to licenses, contracts, intellectual property management and patenting. Basically the group tries to find the best way for dissemination and helps with the different tasks related to this.

If the scientist only want the invention published it is easy[31], but if the scientist wants it developed it become more difficult and complex. When you have a technology based on an idea and you want to disseminate it, then the group really comes into play. The development of technologies does not always support this vision and CERN's vision is not to make money but to bring their inventions out to as many people as possible in as many ways.

[29] This was also a semi-structured interview that had the character of instruction in CERN's Document Server aka library database, so we better could search for information.
[30] This was a very short text-based interview to get some facts about how Engineering Weekly online handles their articles.
[31] But this might not bring dissemination, as companies might not adopt it as it is available to everybody.

When having a new technology and want a company to buy it, one has the following two options: You can try to sell the idea to a company and then they develop and sell it, or you can believe in the technology and try to get the patent. The good thing about getting the patent is that you can control the technology even though you may be forced to give out exclusive licenses.

CERN does not like giving out exclusive licenses because it can limit the exposure and use of the technology, which is the exact opposite way of how CERN wants to handle their technologies. A way to work around this is giving limited licenses. Splitting the technology in functional areas does thereby limit the company's power over the technology, which also limit their possible financial gain making them less likely to invest in a technology.

CERN has not always handled their inventions this way. The Knowledge Transfer Group was created years after some of CERN's most interesting inventions and Giovanni Anelli gives his view on how CERN could have handled these. Giovanni Anelli's statements seem very loyal to CERN's approach and core vision.

CERN has done a lot to make the general public aware of the inventions they are responsible for. For instance they have created Wikipedia sites underlining their role in the development of the touchscreen and the World Wide Web. Talking about how CERN could have handled the World Wide Web back in the 1980s, Giovanni Anelli says that the only thing he would have done differently was making sure that the whole world knew about the technology and the fact it was created at CERN. He feels that if CERN had tried to commercialize the World Wide Web people would have worked their way around it, and the World Wide Web would have not been largely adopted.

Interview with Bent Stumpe in Copenhagen, Denmark July 22nd. 2012

The purpose of this interview was to get Bent Stumpe's version of the story and to find out what was done to promote and commercialize the touchscreen and to get a better understanding of technology transfer during this time frame. We also wanted to find out where the idea came from, and why CERN spent resources on this new technology. But as mentioned this interview was lost because Murphy's Law[32] struck the recordings. Instead this interview became an inspiration for a later interview with Bent Stumpe.

Interview with Bent Stumpe in Copenhagen, Denmark August 23rd. 2012

This is the previous mentioned second recorded interview with Bent Stumpe. The purpose of this interview is to fill some of the gaps.

Bent Stumpe elaborates on how he got involved with the SPS project, he says that Frank Beck who worked in the Data Handling Division with Bent Stumpe, came into the office one day and explained that he would become the group leader of a new group being in charge of the new Central Control Room for the new accelerator called the Super Proton Synchrotron and asked if he could discuss some ideas he had concerning the control methods to be used in the new control room. At this stage the Super Proton Synchrotron was only a paper project, but it had been approved in terms of funding.

The touchscreen became a topic because Frank Beck had read about touchscreens and asked Bent Stumpe if he had any idea to make a touchscreen using a different technology than the experimental types known at the time. These types both Frank Beck and Bent Stumpe found to be unsuitable. The experience Bent

[32] *"Anything that can go wrong will go wrong."* (Murphy's laws site, 2012, Murphy's laws)

Stumpe had from the television industry gave him the idea. If you could deposit copper onto a transparent material, then it might be possible to etch a part of the copper away thus leaving the copper necessary to make a fine grid on the transparent screen. The structure of the conductive grid left on the transparent material could be made as a number of capacitors also called "touch bottoms". The touch buttons were transparent because the lines were so thin that they could not be detected by the human eye.

Frank Beck was not yet leader of the group responsible for the control room layout, but he asked if Bent Stumpe would be his employee once the organization was in place and Bent Stumpe immediately started working on the touchscreen development.

During the initial phase there was a lot of scepticism in whether the proposed touchscreen would work. The development process continued strongly supported by Frank Beck. The attitude towards the touchscreen changed once the first successful prototype was made. After that a large number of programmers started writing programs via Nodal[33] to interface with the touchscreen.

The idea for the X-Y touchscreen was sparked after the initial touchscreen was made.

> *"From day one after seeing the touchscreen work, I had an idea in the back of my head that this could be done better via an X-Y touchscreen[34] giving greater flexibility in use."*

Bent Stumpe says that the development time was extremely fast for the transparent capacitive touchscreen as he profited from other laboratories experiences at CERN. Whenever he had a problem there was someone at CERN who was an expert within the field and willing to assist.

> *"The first type of touchscreen proposed in 1972 is known as the "self capacitance touchscreen". The second type of X-Y touchscreen proposed in 1977 is called "the mutual capacitance touchscreen."*
>
> *"I have pictures from 1973, in which I sit in front of a console with integrated touchscreen, computer, trackball and so on, so the development time until the console was fully operational was about 18 months which is extremely fast.*
> *This was because I had access to a large number of specialists at CERN[35] and also the very early involvement of the industry."*

During the interview Bent Stumpe mentions that he had written a CERN report for development of an X-Y touchscreen and that money from a Danish research fund was granted for a development in technology that could lead to a production of a future X-Y touchscreen.

The development was done at Aarhus University where methods for metallization on the transparent touchscreen were studied. The research work resulted in new methods method to do this. The university and researchers wanted to patent this, and Bent Stumpe was asked to a none-disclosure agreement, but

[33] Nodal is a programming language.
[34] The original quote in Danish: *"Fra den første dag hvor jeg så den self capacitive transparent touchskærm virkede, så havde jeg i baghovedet også en ide om at man måske ville kunne gør det smartere med en X-Y touchsskræm"*
[35] The original quote in Danish: *"Jeg har billeder fra 1973, hvor jeg sidder foran en konsol, hvor der er integreret touchskærmen, computer og trackerball osv. Og da min første rapport blev skrevet i 1973, har der været omkring halvandet års udviklingstid indtil en fuld operationel konsol var til rådighed, hvilket var enormt hurtigt.*
Dette skyldes at jeg havde adgang på CERN til en masse specialister"

since CERN's purpose is to publish, he declined. According to Bent Stumpe they were awarded two patents and build manufacturing facilities. Bent Stumpe is not certain about the further use of these patents.

In relation to the fact that the touchscreen was developed, commercialized and sold in limited numbers Bent Stumpe says:

> *"CERN's purpose was not to produce or sell touchscreens, CERN's purpose was that we should have enough to make the actual consoles and have some spares - approximately 20 touchscreen - it wasn't more than that.[36]"*

Bent Stumpe said that they got a large number of requests following the article in Design News.

> *"The Yellow Report was at such high academic level that it was distributed among the big universities across the world including Stanford University in the USA. The journalists who read their publications including the one from CERN thought the touchscreen was unique and revolutionary, so they wrote an article in Design Ideas where they actually included most of what was in the Yellow Report.*
>
> *Then quickly thereafter, we got a lot of inquires from the USA, I have documentation that more than 200 companies requested additional information.[37]"*

When asked if something could have been done differently in relation to technology transfer to further support the diffusion of the touchscreen, he answers that he does not think that the firm Ferroperm, who produced the touchscreen, was really in the business of making the electronics associated with the touchscreen.

When looking at economical prospects for Bent Stumpe personally and the incitement setup at CERN, there really were none, Bent Stumpe says:

> *"In principle, no employee could enter contract involving money without CERN's general director's written authorization.[38]"*
>
> *"When I held lectures for WHO in 1977 regarding the touch terminal, they came back with a different project where they would develop a device for detecting of leprosy at an early stage[39]"*

[36] The original quote in Danish: *"CERNs formal var ikke at vi skulle sælge en masse, CERNS formal var at vi skulle have nok skærm til at kunne lave de virkelige konsoller og nogle reserver, det dreje sig jo omkring ca. 20 skærme, mere var det jo ikke."*

[37] The original quote in Danish: *"Den gule rapport var allerede den gang på så højt niveau, at den blev distribueret på de store universiteter verden over bl.a. Standford University i USA. De journalister der læser deres publikationer dvs. også CERNS publikations, de interesserede sig for den der touch-skærm de synes var enestående og revolutionerende, så de skrev en artikel i Design News hvor de faktisk gengav det meste af det der stod i den gule rapport.*
Så skete der meget hurtigt, så fik vi mange henvendelser fra USA, jeg har i dag dokumentation for at mere end 200 firmaer henvendte sig for at få mere information."

[38] The original quote in Danish: *"I princippet, kunne ingen ansatte gå ind i en betalt aftale, uden at have vores general direktørens underskrift tilladelse til dette."*

[39] The original quote in Danish: *"Da jeg fx holdt et foredrag for WHO i 1977 angående denne her touch-skærm, kom de tilbage med et projekt hvor de ville udvikle en tester til tidlig detektion af spedalskhed."*

WHO then contacted CERN's general directory to ask for permission to do the development. Bent Stumpe continues:

> *"I got the answer from my general director: he congratulated me with this job, and said I was welcome to accept it, as long as I did it in my spare time.*[40]*"*

However Bent Stumpe says that NESELCO quickly saw the opportunities by producing in the CAMAC modules being developed at CERN. CERN bought these modules for internal use, but NESELCO also sold these to others. NESELCO was aware that there was a potential market for the CAMAC modules. NESELCO also saw the potential in the X-Y touchscreen and together Bent Stumpe and NESELCO submitted an application for economical assistance and got it. But eventually they got into financial troubles because the purpose of their existence disappeared and they closed.

After the article in Design News the industry realised that there were a lot of applications for the touchscreen, but the cost of the computer was still high. There were practical barriers. The integration level of the electronics at the time was not on the same level as the ideas.

When asked if he has any idea as to why the touchscreen was primarily sold to power plants and research instructions he says:

> *"The companies able to pay for a touchscreen system, that required a large computer, was companies like power plants where you could sit in a central console and control the power plant.*[41]*"*

When asked about the gap in sources from 1983 to 2010 he says that this could be because this was about the time he stopped working with the touchscreen, after he refused to sign the none-disclosure agreement.

Bent Stumpe mentions that things have changed at CERN and that CERN is now very much aware if a new innovation has a commercial potential. In case an agreement is made, the inventor might get a financial gain out of it.

Bent Stumpe says on the physicist's opinions to technology transfers and personal economic gain, as opposed to publishing:

> *"Physicists is a special kind of people with only one thing on their mind: to discover something new and publish it in their own name as fast as possible.*[42]*"*
>
> *"There are very few, and I do not know anyone who thinks about the economical perspectives, at least not anyone at CERN. They are in a fierce competition and just want to publish.*[43]*"*

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[40] The original quote in Danish: *"Fik de et svar fra min general direktør, hvor han ønskede tillykke med dette arbejde, men sagde at dette matte jeg meget gerne, men i min egen fritid."*
[41] The original quote in Danish: *"Det miljø som kunne betale for et touch-skærms system der jo krævede en stor computer, var jo et miljø som på kræftværker, der kunne betale sådan nogle installationer som man kunne styre fra en central kontrol pult."*
[42] The original quote in Danish: *"Fysikerne er et folkefærd som kun har en eneste ide i hoved, og det er at finde noget nyt og publicere det i deres eget navn så hurtigt som muligt."*
[43] The original quote in Danish: *"Der er ikke ret mange, og jeg kender ikke nogen der tænker på de økonomiske perspektiver, i hvert fald ikke nogen ude fra CERN, de er i enorm hård konkurrence og ønsker kun at publicere."*

This interview gave us a lot of new information and also confirmed existing knowledge, the physicists seem to be driven by being first to publish. Even though the sales were only limited, the commercialization seems to have faded when NESELCO and Ferroperm experienced economic issues. CERN had no incensement to invest resources in boosting sales, as their only interest in the touchscreen was to solve an issue at hand.

Interview with Søren Karl Larsen in Copenhagen, Denmark August 25th. 2012

Søren Karl Larsen was employed from 1975 – 1978 at Ferroperm. He says that he thinks that the capacitive touchscreen was produced from 1973 – 1974 up to at least one year after he stopped working at Ferroperm. But he thinks that the capacitive touchscreens could have been produced at Ferroperm all the way up until 1985. He also says that the capacitive touchscreen was delivered in series of five, approximately three to four times a year.

> *"I do not have access to the order books from Ferroperm.*[44]*"*
> (Interview with Søren Karl Larsen, 2012, Karl Larsen, S.)

He knows that he delivered the capacitive touchscreens to the Frenchmen but does not know of any other nations or customers apart from NESELCO that Ferroperm have delivered to.

Søren Karl Larsen is firsthand witness from the years 1975 – 1978 and the other years are purely speculative. We can therefore only give an estimate on the number of produced units. When you multiply uncertainty with uncertainty it gives some level of uncertainty. We have used the following formula to calculate the number of touchscreens produced between the years 1975 and 1978.

> 3.5 Series x 5 units x 3 years (1975 – 1978) = ~53 touchscreens.

Our best estimate is therefore 53 touchscreens produced for this period of time.

The interview with Søren Karl Larsen clearly states that production started prior to his employment and continued at least a year after he left. Bent Stumpe's collaboration with Ferroperm was in the beginning with Jens Sørensen. This means that a lot more units were most likely produced at Ferroperm. We have not made a source evaluation scheme of the interview with Søren Karl Larsen. This interview is not counted in the twenty-two sources mentioned in the source evaluation of documents, as it is supplemental. See appendix 6 for the interview guide

Desk studies

Our desk studies consist of two main parts; in the first part source evaluation of documents we go through all the sources in chronological order and evaluate each document separately. This individual evaluation is to be found in appendix 1. Hereafter we take a look at the sources in a general matter to evaluate their credibility. The splitting of the individual and general findings is mainly done to prevent the report from exploding in size. We believe that the general source considerations fill less than the individual considerations.

In part two we have made technology transfer studies. The technology transfer studies combined with the interviews all of our findings will end up in the results section.

[44] The original quote in Danish: *"Jeg har jo ikke adgang til ordrebøgerne på Ferroperm."*

Guide to desk studies

The findings in the desk studies will in the results be compared and combined with the results of the interviews.

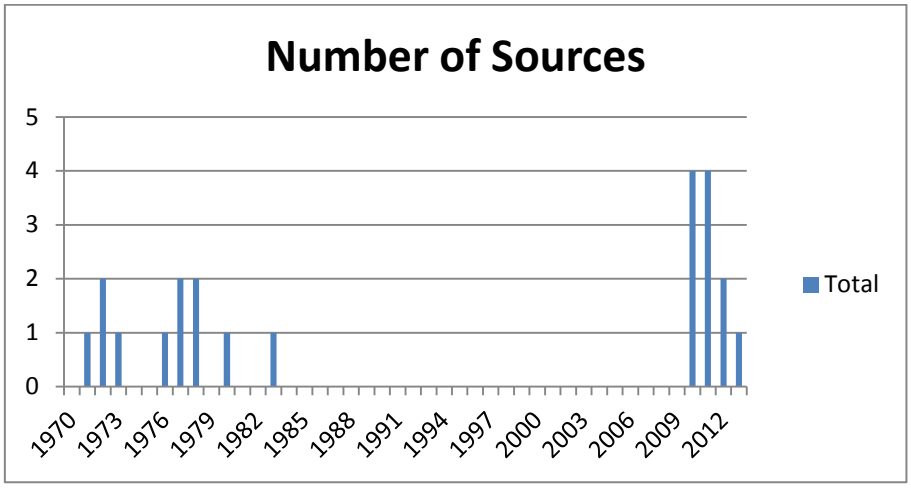
Source evaluation of documents

This section mostly contains general considerations. We have made a trustworthiness assessment for both the relics and the narratives even though you normally only have to do this for narratives. But it is all about how you apply the method to each document. You can either use part of it as a relic or a part of it as a narrative or you can choose for one of the two. Therefore we decided to make a full evaluation for every source. This would also add value in relation to the validity of the project and minimize the risk of missing something.

The historical method states that you have to identify the sources that are within the area you are researching. The historical method requires you to identify sources that are in line with the problem statement. We have identified twenty-two sources, which we have used in this project. For all of them it applies that we are only focusing on the text using this method. Pictures and the like is not a part of this source evaluation. Those types of sources demand other methods to be used, which is out of scope for this project.

In this section we will review the sources and try to give an overview of them in a general context with the use of the historical method. See more in appendix 1 (source identification schemes) in which we have analysed each source individually.

Our sources range in time from early June 1971 till post 2012 because we have used a first draft of a chapter from a forthcoming book set to be published in 2014. We have taken the logical year from each source and put it in a block diagram:



As you see, there is a leap in time in our text sources from 1983 till 2010. We have been unable to find any documents from this time period this might be because there are none. Two of our sources are the interviewees and it can be argued whether they should be counted in. The interviewees are counted in for the year 2012. We also have two indirect sources that are also included. They are both from 2011. We do not think that it makes a great impact to remove these four sources from the graph. The point is still the

same without them. Our last interviewee Søren Karl Larsen is not counted in either. If he was included it would be in the year 2012 but this would not make a big difference to the point either.

The sources take their beginning in the early 1970s with one of our first found sources being a handwritten note from a meeting, and a Yellow Report from CERN based on the handwritten note. We have then tracked sources that have relation to the first two. We made research in the time period before and after but only two sources are earlier than the first two[45]. The rest of the sources are of a later origin.

The time gap is an indication that there is a lack of coherence with direct text sources from 1983 till 2010. With this said we know of a few sources that have an indirect relation with our sources but these are out of scope for our project due to resource constrains. These sources would be interesting to investigate at a later point in time. The vast amount of information available is illustrated by fact that in three of our sources we have respectively thirteen, sixteen and thirty-three direct references. If you dig deeper all of those references will have new references et cetera. Because of this we limit our scope to sources, which brings value in relation to our problem statement and can assist in giving answers.

To sum up we have a logical two-way limitation of our sources and a few sources that have no direct link with our primary sources. Those chosen few only have an indirect relationship to the primary sources and are used because of the value criteria. Besides this we have our interviewees. Especially our firsthand source Bent Stumpe is heavily overlapping all of our other sources and therefore he could be the main key to find out more about the wider context and not least the missing link alias the time gap. You can state the same for the other interviewee Giovanni Anelli but it goes only for the time period 1995 – 2007 and 2010 till present day where he has been an employee at CERN.

You can also use this time gap to define what are first and second-hand sources. Sources from 1983 and prior are mostly firsthand sources because people that have been witnesses to the events have written them. Like in the evaluation of Bent Stumpe there are also bits of the early sources that are secondary.

Let us begin by having a look at our source types. Which kind of documents do we have and where were they produced? Are they official or unofficial? Are they validated from a trustworthy institution or similar?

After having formed an overview of our chosen sources it was soon clear that the main part of our source material was based on scientific work or released by scientific magazines. To be more specific we have the following types of documents:

Year	Document type	Publisher and / or production place
1971	Publication / paper.	From the Joint Accelerator Conferences Website and also from the digital library The IEEE Xplore. Produced at Stanford University. Copyright IEEE.
1972	A laboratory report from Rutherford Laboratory.	From the Fermi National Accelerator website. Most likely produced at the Rutherford High Energy Laboratory.
1972	Handwritten note from a meeting at	From the CERN Document Server and Symmetry Magazines webpage. Have an official document

[45] The first two are references from the second document written by Franck Beck and Beck Stumpe (Beck, F. And Stumpe, B., 1973, Two Devices For Operator Interaction In The Central Control Of The New CERN Accelerator).

	CERN.	number and was produced at CERN.
1973	CERN report also called a Yellow report that is the highest classification for documents at CERN.	From the CERN Document Server. Have an official document number and was produced at CERN.
1976	Doctor thesis.	From the CERN Document Server. Have an official document number at CERN. Was most likely produced at L'Universite Louis Pasteur de Strasbourg or CERN.
1977	Internal Group Report from CERN.	From the CERN Document Server. Have an official document number and was produced at CERN.
1977	Article from the magazine New Scientist.	Can be found on the CERN Document Server and Google Books. Published by New Scientist magazine.
1978	Internal Group Report from CERN.	From the CERN Document Server. Have an official document number and was produced at CERN.
1978	A recommendation of Bent Stumpe for the LK-NES price of the year 1978 from M.C. Crowley-Milling.	Have an official document number and was produced and published at CERN. Part of Bent Stumpe's personal archive.
1980	Commercial from the CERN Courier from September 1980.	This commercial is a part of the CERN Document Server.
1983	Afgangsprojekt: a thesis from Aalborg Universitetscenter[46].	It is a collaboration between and published by both Aalborg University but also by CERN. Produced at CERN. Can be found on and is a part of the CERN Document Server.
2010	Article from Symmetry Magazine.	Published and produced by the particle physics magazine Symmetry.
2010	A newsletter from the CERN bulletin in the CERN Document Server.	Published and produced by CERN and is a part of the CERN Document Server.
2010	An article from the CERN Courier.	Published and produced by CERN and is a part of the CERN Document Server.
2010	Scientific article in the International Journal of Computer Applications.	Published and produced by the International Journal of Computer Applications.
2011	Report on knowledge transfer activities at CERN.	Published and produced by CERN.
2011	Article in the Engineering Weekly online magazine.	Published and produced by the Engineering Weekly online magazine.
2011	Online video interview and article in the Engineering Weekly online magazine.	Published and produced by the Engineering Weekly online magazine.
2011	Article in the Engineering Weekly online magazine.	Published and produced by the Engineering Weekly online magazine.

[46] Translation: Aalborg University.

2012-14	A chapter from a forthcoming book.	Will be published by Wiley publications and is produced in Bent Stumpe's private home.

It is clear when you read the above listings that all of them have official character in one form or another. To elaborate you will have to look at the publishing and production place to verify how acknowledged and grounded the sources are in the scientific world. We have eight different publishing and production places in our sources. These institutions are all grounded on years of research and on a solid scientific foundation. To prove this statement you will have to look at what and who those research institutions are. The first thing that comes to mind, when looking at our sources from this point of view, is that there are eleven of the sources have direct relation to CERN and nine can be found in the CERN Document Server, which is a digital library of documents, pictures and papers etc. with direct link to work done at CERN. The CERN Convention was established in July 1953 and on September 29th 1954 the European Organization for Nuclear Research became official (CERN, 2012, 1954: foundations for European science).

About CERN:

> *"CERN, the European Organization for Nuclear Research, is one of the world's largest and most respected centres for scientific research. Its business is fundamental physics, finding out what the Universe is made of and how it works. At CERN, the world's largest and most complex scientific instruments are used to study the basic constituents of matter — the fundamental particles. By studying what happens when these particles collide, physicists learn about the laws of Nature."*
> (CERN, 2012, About CERN)

About the CERN Document Server:

> *"The CERN Document Server (CDS) is the institutional repository that provides acquisition, search and collaborative tools to manage collections of documents produced at CERN. The collections include HEP documents, Multimedia documents, Bulletins, Administrative (Directorate, HR, Finance) documents, EU Project documents (OpenAire, EMi), Library, Project document types, and also all IT related documents."*
> (CERN IT Department, 2012, CERN Document Server)

CERN has twenty member countries that all contributes to capital and operation cost (CERN, 2012, A global endeavour). At least eighty countries around the world participate in CERN's research (CERN, 2001, A Laboratory for the world). So CERN is indeed a huge international organization that collaborates with universities and scientist from all over the world. With that in mind we can say that the scientific foundation CERN is build on is very strong. This gives a strong credibility to our sources from CERN where the majority of our sources also come from.

> *"Scientists from some 608 institutes and universities around the world use CERN's facilities."*
> (CERN, 2012, A global endeavour)

If we dig a little bit deeper into the remaining part of our sources we see that more of them have an indirect relation to CERN. We have the Joint Accelerator Conferences website (JACoW) which is an international collaboration started in 1996 (EPAC, 2004, Joint Accelerator Conferences Website (JACoW)). It

is an open access website for the publication of conference proceedings from at least fifteen collaborating conference series. Amongst them is the European Particle Accelerator Conference (EPAC).

On their web site you can read the following:

> *"This site is located and maintained at CERN, Geneva and is mirrored to KEK, Tsukuba for the convenience of users."*
> (JACoW, 2012, JACoW Home Page)

Therefore it is clear that there is a strong relation between JACoW and CERN.

The next thing we see is the name IEEE that is the Institute of Electrical and Electronics Engineers.

> *"IEEE is the world's largest professional association dedicated to advancing technological innovation and excellence for the benefit of humanity. IEEE and its members inspire a global community through IEEE's highly cited publications, conferences, technology standards, and professional and educational activities.*"
> (IEEE, 2012, About IEEE)

Where CERN is an international governmental organisation the IEEE is a non-governmental International association based in USA. It goes all the way back to 1884. It has more than 400.000 members in 160 countries with over fifty percentages coming from outside of the United States. Like CERN we can conclude that the IEEE has a strong credibility.

> *"On 1 January 1963, The AIEE[47] and the IRE[48] merged to form the Institute of Electrical and Electronics Engineers, or IEEE."*
> (IEEE, 2012, History of IEEE)

The next is published at Rutherford High Energy Laboratory, which transformed into the Rutherford Appleton Laboratory in 1979. This is seven years after the making of the source. Back then it was a part of the Science Research Council, now it is a part of the Science and Technology Facilities Council (STFC) that is a UK government body. The council was formed in April 2007 and the Minister for Science and Innovation appoints its members (STFC, 2012, Our structure).

> *"Formed in 2007, following the merger of the Particle Physics and Astronomy Research Council (PPARC) and the Council for the Central Laboratory of the Research Councils (CCLRC), the Science and Technology Facilities Council (STFC) inherits a reputation for excellence in scientific research that dates back to 1920."*
> (STFC, 2012, Our history)

The Rutherford Appleton Laboratory is one of the national scientific research laboratories in the UK. It is grounded on a solid scientific base and therefore we can conclude that sources from the Rutherford Appleton Laboratory also have a strong credibility.

Our doctor thesis source from L'Universite Louis Pasteur de Strasbourg is from a now defunct university. On January 1st 2009 the Louis Pasteur University became part of the rebuilt University of Strasbourg that is the

[47] American Institute of Electrical Engineers.
[48] The Institute of Radio Engineers.

largest university in France. Thereby it lost its status as an independent university (Wiki, 2012, Louis Pasteur University). The origins of the University of Strasbourg date back to the early 16th century (University of Strasbourg, 2012, Introducing the University) and according to Wikipedia all the way back to 1538. We can conclude that this is also grounded on a solid base and have a strong credibility.

Five of our sources come from three different magazines if we do not count in the CERN Courier and the CERN Bulletin, which is a part of CERN and thereby is part of that credibility assessment. Thus we have New Scientist magazine, Symmetry magazine and the Engineering Weekly online magazine. New Scientist was launched in 1956 and online in 1996. It is a weekly international science magazine for a general audience. It is not peer reviewed.

> *"New Scientist magazine was launched in 1956 "for all those men and women who are interested in scientific discovery, and in its industrial, commercial and social consequences". The brand's mission is no different today - for its consumers, New Scientist reports, explores and interprets the results of human endeavour set in the context of society and culture."*
> (New Scientist, 2012, Introducing New Scientist)

The scientific foundation for this magazine is not as grounded as other of our sources but the source from this magazine is also a part of the CERN Document Server, which underpins its credibility.

Symmetry magazine is a United States based magazine about mainly particle physics.

> *"Symmetry is a magazine about particle physics and its connections to other aspects of life and science, from interdisciplinary collaborations to policy to culture. It is published online 11 times per year by Fermi National Accelerator Laboratory and SLAC National Accelerator Laboratory, both national laboratories funded by the Office of Science of the US Department of Energy.*"
> (Symmetry magazine, 2012, About Symmetry)

Fermilab is a US Department of Energy national laboratory and SLAC is a United States Department of Energy National Laboratory. So it has a solid base in scientific work. We cannot tell how old Symmetry magazine is but both Fermilab and SLAC goes at least back to the 1960s. You can say that Symmetry is a medium for those organizations. We can conclude that Symmetry is based on a solid scientific base and have a good credibility.

The last of the magazines is Danish based Engineering Weekly online, which is not peer-reviewed. Mie Stage says:

> *"We are not scientists but there is an editorial secretary who check that everything looks fine. It is the journalist's own job to check facts. The editorial secretary checks for language and tell us if there is missing a source.*[49]*"*
> (Interview, 2012, Stage, M.)

[49] The original quote in Danish: *"Nej, vi er ikke forskere. Men der er da en redaktionssekretær, der går over den for at tjekke at alt ser fint ud. Ja, det er journalistens eget arbejde at tjekke facts. Red. Sek. Tjekker sprog og siger, hvis de synes der mangler forklaringer eller en kilde."*

It stands out language wise since it is only published in Danish. This of course sets a limitation for the audience but it is released in 80.000 copies in Denmark. Its history goes all the way back to 1892 with the online magazine being started in 1994 as the first Danish media on the Internet. This indicates a progressive magazine that is aware of the new developments and also actively uses them. The Engineering Society in Denmark named IDA owns the magazine (Engineering Weekly online magazine, 2012, About). Like Symmetry we can conclude that it is based on a solid scientific base and also have a good credibility. The majority of the readers consist of engineers, scientists, researchers et cetera, but people with common interest on the topics and without a professional background, also read the magazine.

The International Journal of Computer Applications is a scholarly peer-reviewed research-publishing journal published by the Foundation of Computer Science.

> *"At FCS, we are driven to help professionals, scientists', technologists, researchers and students to bring in technological innovation and scientific discoveries. We want to bring value to the field of research that benefits the society. In the process, we are constantly working towards disseminating latest research amongst the international scientific communities and act as a catalyst to curb the practice of plagiarism.*"
> (IJCA, 2012, Vision & Mission)

The Foundation of Computer Science is based in the United States. It has the support of a group of universities.

> *"Foundation of Computer Science, FCS is a premier research organization, which publishes international journals including International Journal of Computer Applications (IJCA). Founded by a group of intellectuals and researchers; and supported by prestigious organizations such as Harvard University, University of St Gallens, University of Karlsruhe, Georgetown University Library et. al, FCS strives to provide best publication opportunities to the research community.*"
> (FCS, 2012, About Foundation of Computer Science)

We cannot read how old the foundation is but it is clearly based on a scientific foundation and thereby has a good credibility.

Our last publisher is Wiley publications or John Wiley & Sons, Inc. It is an international publishing firm with roots back to 1807. It is a global publishing company that specializes in academic publishing. We know that the chapter we use is written for a more general audience but nonetheless we can conclude that Wiley Publications have good credibility.

Sources dating from 1972 till 1983 are written, if not at the time of the event, then very close to the innovation of CERN's capacitive touchscreen. Some of the sources are written just before the technical development occurred, some during and some after. We have decided to draw a line in sand at the year 1983. Because from that point on it seems that the innovation had reached its final state though it continued to be in function at CERN up till the year 2008 and our early sources also seems to end this year. The fact that we have all these early sources from the development time gives great value to this project.

Sources from 1971 till 1983 are from a time when the internet was not yet invented. This tells us that all these early sources from the time of the invention of CERN's capacitive touchscreen were logically not

available online. Thus they were not as easy and as fast to retrieve as they are today. This is very interesting. Either it could be that other scientists back then did not know of their existence or that they only had access to a part of the source material. Some close to the events may have had full access to all of these sources but to geographically separated scientists, from universities for instance, it was more difficult to get to the information.

Previously scientists must have had an entrance to the material that must have been from somewhere else than the internet[50]. Of course there were computers in the 1970s but their capacity were not developed enough to hold all that storage of documents. Paper must have been the main source to scientific studies back then. One of our sources is from the international scientist magazine New Scientist. The magazine is for a general audience and it is written in a non-technical language but still this international magazine could cross borders back then and give scientists a clue of where to search for information to their scientific studies.

We will not go deeper into this but only conclude that the search for information was substantially different from what it is today and that information did not flow as freely as it does in the age of the internet. This indicates that it was harder to get the full perspective back then. It even is today but in an entirely different direction called an overflow of information. Still scientists of today have access to more sources than they had before the internet. The fact is that information logically did not flow as freely back then as it does today.

There are still documents out there that have not been put online. We have used some sources in this study because we have had access to a private archive and a first-hand interview source. This brings value to this project in form of a gathering of information that has not been done before as the information has not been available for neither the public nor scientists. There could still be documents that we do not know of.

For all of our sources it applies that they all point to a great historical event[51] namely the invention of the Super Proton Synchrotron, which were the first particle accelerator at CERN.

Control room for the Super Proton Synchrotron. (CERN Document Server, 2012, At the SPS Control Room)

[50] Or password protected online intranet databases.
[51] This paragraph could also have been a part of the prologue but it is actually a part of the historical method to put the sources in a general context.

The Super Proton Synchrotron needed a control system and this is where the touchscreen came into the picture. The touchscreen was an important invention for this control system. CERN could save both money and time using this system instead of the old one. This is elaborated in the results of desk studies section.

There does not seem to be any researchers out there who have criticised the CERN invention yet. This either tells us that there is nothing to criticise or that no one have looked into this matter. Under all circumstances it is noticeable that we have not found any critics in this day of age. This could tell us that it is difficult to put a finger on any of the sources used in this project.

To underpin the validity of the sources we use, we will make a comparison to a source that in our opinion does have a credibility problem. This source is only used as an example and therefore it is not in the appendix. The source is a PDF-file by the Institute of Physics (IOP) called *"How physics drives the supermarket industry"*. The topic has nothing to do with our research field by it is still interesting in relation to source evaluation. Let us start out with a quote from the document.

> *"Our journals content is available on IOPscience, a platform providing access to more than 130 years of leading scientific research, hosting over 350,000 articles dating from 1874 to the present day."*
> (IOP Institute of Physics, 2012, IOP Publishing)

It looks like a source with good credibility based on the age of the institute and the enormous base of publications. Let us take a deeper look into the text source.

> *"The first modern touchscreen was created in 1973 by two physicists, Frank Beck and Bent Stumpe, seeking to find an easy way to control the high-energy particle beams at the CERN particle accelerator near Geneva (now the site of the search for the Higgs boson). Their invention built on decades of physics research into the electrical properties of materials and utilised capacitors contained within the screen itself to sense the position of a user's finger though the way it interacted with the screen's electric field."*
> (IOP Institute of Physics, 2012, How physics drives the supermarket industry)

What is wrong with that? If you look closer you will see that the source tells us that two *physicists* invented the first modern touchscreen. All of our other sources telling us about this matter tell us that it was two engineers: One was the inventor and the other had the idea. This may seem like a petitesse but it makes a huge difference regarding the understanding of the history. At CERN the physicists and engineers works in a kind of symbiosis where they require each other. But what they do is fundamental different from each other and this is an important point regarding the understanding of CERN.

It is quite remarkable that a recognized institute makes this kind of mistake and physicists make it. This could indicate another valuable point, which is that some physicists may only have their focus on physics. It could also be a simple mistake. This may not be important for the publication but it is important from a historical point of view. Another important lesson is that you should not always trust a source blindly even though it is from a credible source. You should always read the text with a critical eye.

Another example of a source that has a questionable credibility is a newspaper article about Bent Stumpe from 1978 (Unidentified source, 1978, á jour). The questionable lies in that we cannot assess which newspaper this article is from and thereby we cannot ask the correct questions. Fortunately we have four

other similar newspaper articles from other newspapers to verify the information from the unidentified source.

Overall we can conclude that our sources have either a strong or a good credibility. They are grounded in many years of research from a lot of different and acknowledged research institutions, many also with an international angle. Most of our sources even have an official character in the way of an official naming convention or being a part of an official database. This gives the project a good empirical base.

Results of desk studies

In this section we will build the history behind CERN's capacitive touchscreen and look deeper into technology transfer processes and models to answer the questions of the problem statement. This section could also have been in the appendix, but we think it is a too essential part of the project.

An Innovation In Control Panels For Large Computer Control Systems (1971)

The document describes a touch panel made using Rayleigh wave beams crossing in an X-Y grid.

> *"This panel, called a touch panel, 1 consists of a glass plate placed in front of a computer driven cathode ray tube display. Ultrasonic surface (Rayleigh) wave (8.5 MHz) beams are transmitted in a crossing X-Y grid through the glass. The intersection points of the beams form the "buttons" on the panel. The computer furnishes legends for these buttons. The presence of an operator's finger on the glass "pushing" a button is detected by the absorption of an X and a Y beam."*

Clearly this is a screen that can be pressed by a finger. The difference lies in the technology. Here we have absorption of an x and y Rayleigh beam (Wikipedia, 2012, Rayleigh scattering). It is clear why this is a reference and inspiration to Frank Beck and Bent Stumpe's work at CERN later on.

A Transparent Touch-Screen Device for Interactive Computer-Graphics Displays (1972)

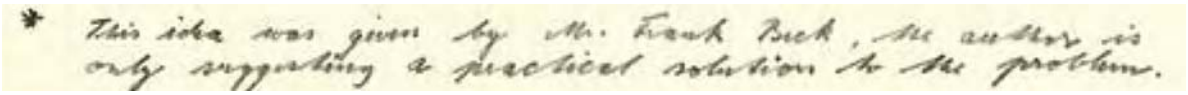
This document describes a touchscreen made via a system of intersecting light beams and detectors used to identify the selected position.

> *"The electronics were deliberately kept as simple as possible and hence inexpensive and the principle used to read position information from the TV screen does not hinder viewing of the screen or involve the use of 'light pens', 'joy-stocks', 'cursors' etc., but simply requires one to touch the screen with a finger. The TV screen is covered with two sets of parallel light beams crossing at right angles; each of the set of points thus defined corresponds to the intersection of a unique pair of light beams. A display pattern is produced which includes areas which might be termed 'light buttons' that are in registration with nominated points of intersection and serve to mark their position for the operator. When such a 'light button' is 'pressed' the coordinate is read by observing the failure of light beams, corresponding to that position, to reach their associated detectors."*

A device called a *"light button"* is mentioned and it says you can touch the screen with one finger. The idea is that the coordinate is read by observing that the light beam fails when the finger presses on the button. This is a different technology from CERN's capacitive touchscreen but the idea of a finger pressing the screen sounds similar. The relevance as a reference to Frank Beck and Bent Stumpe's work at CERN is clear.

Proposed outlay for a fast interactive computer display system (1972)

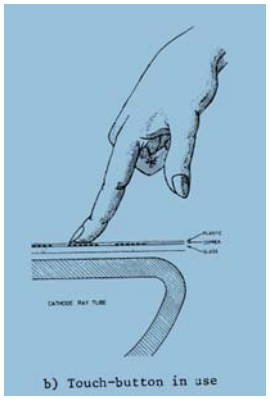
The handwritten note is the first written source from CERN related to the touchscreen, the document is written by Bent Stumpe. The document outlines the idea of using touch displays. The most important historic piece of information enclosed in the document is the following phrase which appears on the bottom of the page[52]:



As you can tell from the picture Bent Stumpe clearly states that Frank Beck gave the idea of using touchscreens to him. We are aware that the document is longer than one page, but neither CERN nor ourselves have been able to locate the missing pages[53]. We know from a later source[54] that the handwritten meeting note was sixteen pages long[55].

Two devices for operator interaction in the central control of the new CERN accelerator (1973)

One of the most essential documents is *"TWO DEVICES FOR OPERATOR INTERACTION IN THE CENTRAL CONTROL OF THE NEW CERN ACCELERATOR."* The document describes two new devices, which would be installed in the Super Proton Synchrotron control room. The document is dated May 24th 1973.



The document describes the Super Proton Synchrotron control room layout as it was planned prior to implementation. The two new devices outlined in this document make the Super Proton Synchrotron control room different from existing accelerator control rooms at CERN.

The two devices are the touchscreen and the computerized knob. The control room layout is described as three control desks with a mini computer and only a few knobs and switches and half a dozen displays at the most. This will enable the operator to control the many thousand digital and analogue parameters of the accelerator.

The room layout is described in details, and one could imagine that this was required because the design was so different from what would be considered normal at the time. The touchscreen is described as *"a panel having a number of buttons with legends on them"*. The other device that is not in scope for this report is *"a knob with feedback from the computer"*.

The knob is essential. It is a computerized knob, which is used to replace the many knobs normally used to control the accelerator; it is possible to control the knob settings via the mini computer, allowing it to change behaviour to adapt to the device it is controlling.

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[52] The phrase says: *"This idea was given by Mr. Frank Beck, the author is only supporting a practical solution to the problem."*
[53] We know that Bent Stumpe have the remaining pages in his private archive in Geneva but Bent Stumpe was not in Geneva at that time when we discovered that pages were missing.
[54] See the source:*"Logbook: CERN touchscreen."*
[55] We are missing fifteen of the original pages.

The document states that both devices have been interfaced with the CAMAC[56] system, which is being used throughout the Super Proton Synchrotron control project.

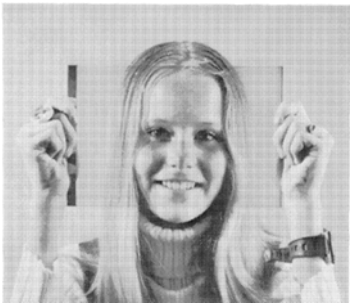
The document lists advantages and disadvantages with this new approach, the advantages are that the new system uses few but powerful controls and displays. Today we might say that this is the switch from hardware controls to software controls, which can obviously be manipulated at will and with limited cost. The disadvantages of the old system listed in the document is that the old approach is more clumsy and as the operator had to move physically around in a big control room to adjust all the equipment in the accelerator.

As you can see the panel is placed on top of a CRT monitor, the legends[57] are displayed on the CRT monitor and the finger press is detected by the touchscreen, both connected to the mini computer.

The new system allows the operator to get information concerning accelerator parameters to be multiplexed to him and hereafter perform a central control, rather than operator is multiplexed to the individual controls sitting in a high number of racks distributed in the controls area.

> *"The device which has been constructed uses a set of capacitors, etched into a film of copper on a sheet of glass and made of line elements sufficiently thin and well separated to be effectively invisible."*

The screen is described in details with emphasis on the fact that it is transparent. The screen is created via normal circuit production techniques. Various techniques for creating the circuit on the glass are described, and iron sputtering is chosen as the most reliable method. The document also contains electronic diagrams of the detector circuits in detail. The panel used for the pilot has a 3 X 3 matrix (9 buttons), planned expansion the more computer friendly 4 x 4 (16 buttons) is planned. The programming options are described; a legend is created like this



DO LEG(5, ' Button Five ')

Touching button "Five" with the finger will cause a bit to be set in the register connected to the button interface, and an interrupt to go to the computer. The controller board, as you can see only nine of the sixteen planned buttons are wired.

Various other input methods are described and discussed, the fact that the method outlined has no moving parts and is purely electrical is described as an advantages over the other listed technology which is:

- The Light-pen

[56] Computer Automated Measurement And Control (CAMAC) is a standard bus for Data acquisition and control used in nuclear and particle physics experiments and in industry.
[57] Legends are the text displayed on the touchscreen.

    - Described as a working technology, which is how ever difficult to master, making it unsuitable.
- Ordinary button
    - A mechanical button made out of transparent material, found difficult because of the switches and wiring would be hidden between the buttons, making a lot of the screen area unusable.
- Optical Method
    - Described as expensive and quite bulky.
- Rayleigh waves
    - Described as a working technology where acoustic waves are used, but it requires a bulky frame.
- Hum pick-up
    - Described as a working technology which would be troublesome to make transparent.
- Cross-bar
    - A mesh of wires suspended above a mutually perpendicular set. This method has according to the document been used in air traffic control and at the Stanford Linear Accelerator.

The document contains a number of references:

1) J.A. Mattis and H.R. Camenzind, A new phase-locked loop with high stability and accuracy, Signetics Inc. Applications Note 1971.

2) E.M. Mott, A transparent touch-screen device for interactive computer-graphics displays, RHEL/R 248, February 1972.

3) D. Fryberger and R. Johnson, IEEE Trans. Nuclear Sci. NS 18 No. 3 (1971).

The first reference is related to one of the components used by the detector circuit. The last two references have been described earlier in this project.

It becomes clear from the way the document is written that the technology is ground breaking, the fact that you can control the thousands of controls, using three computers a few knobs and half a dozen displays is new approach. The document also mentions pros and cons with the selected approach, and gives insight to other methods available at the time.

The fact that you do not have every possible control available at all times is described as a disadvantage. It is important to note that the buttons and legends on the displays are controlled via the computer allowing the programmers only to enable buttons, which are usable in the current context, and thereby enhancing usability.

During our review of references we think that an earlier reference might have been missed. We found the following description within the document:

2.7.6 *Cross-bar*

A mesh of wires suspended above a mutually perpendicular set. The pressure of a finger brings one wire from each set into physical contact. The wires and supports can be made so thin and delicate that they are inconspicuous. The whole is protected by a plastic sheet. This method, although presumably having the unreliability of a home-built switch, has been used in Air Traffic Control and at the Stanford Linear Accelerator.

This could be a reference to article by N.W. Orr and V.D. Hopkins called *"The Role of Touch Display in Air Traffic Control"* from 1968 (Orr, N.W. and Hopkins, V.D., 1968, The Role of Touch Display in Air Traffic Control).

The Design And Construction Of A Control Centre For The CERN SPS Accelerator (1976)

Frank Beck's doctor thesis is dated April 1976 and describes the Super Proton Synchrotron setup in great detail from computers used, control language to central control philosophy.

The report mentions the computerized system implemented for the Accelerator in Illinois that used a control language to control the accelerator. Frank Beck mentions that using a knob or a button is much easier than typing in a series of commands. The document also contains pictures of the actual control layout:

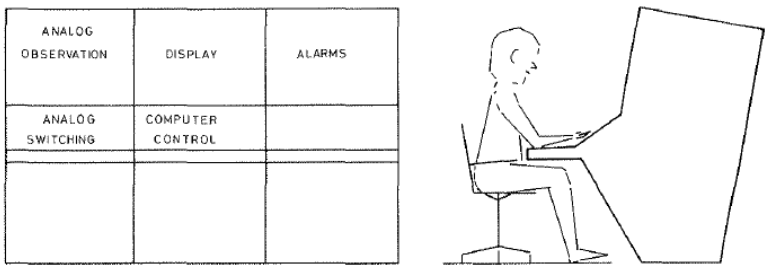


Fig. II.1 The console layout

The thesis is quite technical and includes circuit layouts, but also more general areas related to the control room layout. Frank Beck also mentions some of the other people involved in the project, including Bent Stumpe the author of a number of documents also in scope for our report.

The actual work of realizing the equipment required much detailed engineering design and computer programming. This was done by a team of CERN staff members under the supervision of the author, and many original ideas were contributed by each of them in the implementation. The members of the team with their major responsibilities were:

Mr. B. Stumpe, Technical Assistant
(touch-buttons, knob, ball and scan converters)

Mr. S. Summerhill, Technical Assistant
(TV monitors, display devices)

Mr. M. Wenger, Technician
(plasma panels, electronic thumbwheels)

Mr. P. Anderssen, Programmer
(graphics, word store, video switching)

Mr. P. Farley, Programmer
(systems and interfacing, hard-copy)

Mr. R. Koremann, CERN Fellow
(alarm system)

Mr. P. Harris worked with the team as an agency technician throughout the project.

Frank Beck concludes on the use of the touchscreen in relation to the control room and as you can see on in the picture, he also mentions that marketing of the device is being prepared.

1.4 Conclusions

Method 6, the capacitive method described above, has been successfully installed. Simpler methods of detection for the change in capacity have subsequently been tried both at CERN and elsewhere, but no published record of reliable success yet exists. The screens are now being marketed in Denmark by one company (Ref. C3), and a complete copy of the device is being prepared for marketing by another (Ref. C11). See also Refs. 32 and 33.

The thesis is a complex document we have only reviewed the parts that directly relates to our project. It is clear that Frank Beck has some interesting ideas in relation to usability and management of the Super Proton Synchrotron in this document. Frank Beck mentions that simpler methods for detecting change in capacity have been described but that no successful implementation has been published yet.

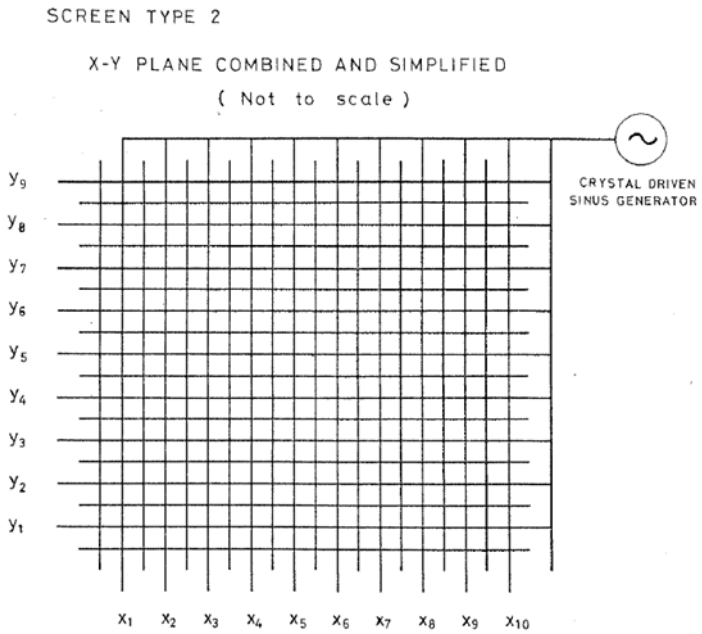
C 3 Christian Røvsing A/S,
46b Marielundvej, Herlev, Denmark.

C11 Ferroperm Aktieseskab,
Stubbeled 7, Trørød 2950 Vedback, Denmark.

The reference C3 refers to *"Christian Røvsing A/S"*, we suspect that the reference should have been to Christian Rovsing A/S, which we have not encountered elsewhere during our study. The reference C11 refers to Ferroperm, which was also mentioned during the interviews with Bent Stumpe and Søren Karl Larsen.

A New Principle for an X-Y touchscreen (1977)

This document describes a new principle for the touchscreen with more than the sixteen buttons. It is clearly stated in the introduction that the new touchscreen is developed based upon the experiences from the first model. There are, according to the author, many benefits with the new design, additional operation modes and reduced operating cost. The difference between new and the old screen is that the new one does not have the fixed buttons, but is a grid.



The main new thing is that this screen does not have any fixed buttons but an X-Y grid.

The document describes different methods to eventually achieve the same thing, an X-Y touchscreen. The difference lies in how the grid of wires is created, and is mostly related to the manufacturing process.

Attention to cost is also given especially to the detector design; the X-Y touchscreen will require a lot more detectors due to the grid layout. The document mentions *"as high as 100"*. It is stated that the detector has already been produced. The advantages described are mostly related to the fact that the new design has higher resolution than the old one with the sixteen fixed buttons and that the screen is not size restricted like the old one.

Other technologies are described similar to what was described in the document "TWO DEVICES FOR OPERATOR INTERACTION IN THE CENTRAL CONTROL OF THE NEW CERN ACCELERATOR".
The section related to *"Suggested applications"* is very interesting; in this section it is clear that thoughts regarding technology transfers were given attention by the author and maybe by others. Two ideas are described. The first idea is that the screen could be used for ticketing system at railways/busses and that the touch panel could be connected to a central computer via a modem.

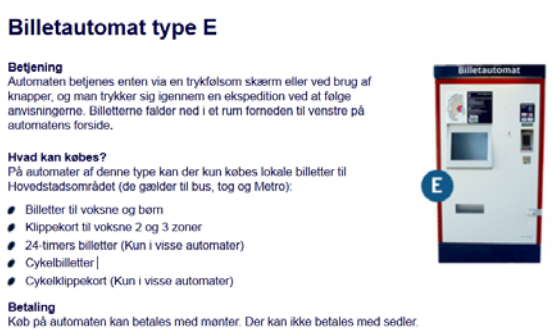
> *"Open up the possibilities for a user service never seen before."*

The second idea is related to news information through TV, it is described that experiments are being done to make the TV usable for other purposes that existed today (1977), and that the touch panel could be "attached" to the TV itself or to a separate unit.

In the conclusion a future paper is mentioned of how to build a "touch control unit" for universal use (scientific and domestic) where everything is integrated into one "handy" unit.

"This device could be the first pocket sized mini-terminal for use with any computer system."

To us the change from fixed buttons to an X-Y grid is a fundamental change; it gives the programmer control over button size and location, allowing more freely software controlled user interaction.



Looking at the two ideas the author had for future usage of the touchscreen, we learn that both ideas have been implemented today. The ticketing system, which utilizes touchscreen, is used in the Metro in Denmark, and around the world.

Some TV vendors[58] do ship a touchscreen unit with their TV and others[59] allow interaction via touchscreen devices (iPad[60]/iPhone[61]/Android[62]).

The document contains two references, one being to the *"TWO DEVICES FOR OPERATOR INTERACTION IN THE CENTRAL CONTROL OF THE NEW CERN ACCELERATOR."* which is a part of this study. The second one is related to detector circuits.

How CERN broke the software barrier (1977)

The document by Michael C. Crowley-Milling focus on the fact that software was used to control the Super Proton Synchrotron, this is a fundamental change, because software combined with the touchscreen, rolling-ball and dimensional knob allows you to manipulate controls via software. Previously thousands of buttons, knobs and individual cables were required, but by using a computer network and the devices mentioned above it was possible to do this using a minimal amount of resources.

The article mostly talks about an interpreter versus traditional compiled code, which is outside the scope of this project.

This source can help support the other sources in relation to the Super Proton Synchrotron setup. The dimensional knob was described in earlier sources as the computerized knob, and the rolling-ball was described as the tracker ball.

Experiments to find a manufacturing process for an X-Y touchscreen (1978)

This document is about production of the X-Y touchscreen after a visit to Polymer-Physik GmbH in Germany.

[58] Samsung 8000 series. (CNET, 2012, Reviews, TV and Home Teater)
[59] Panasonic 50 series. (Panasonic, 2012, VIERA Remote)
[60] Tablet computer from Apple. (Apple, 2012, iPad)
[61] Smartphone from Apple. Newest version is called 4S. (Apple, 2012, iPhone)
[62] A Linux based operating system. (Google Android, 2012, Android)

The entire document is related to manufacturing techniques and results from the visit. The conclusion is that the first result looks promising, and a plan for future actions is outlined.

The document clearly shows that initiatives were taken to find manufacturing techniques for the X-Y touchscreen.

Recommandation (1978)

The recommendation written by M. C. Crowley-Milling is used in relation to the interviews with Bent Stumpe. The document is a recommendation for Bent Stumpe and mentions his work at CERN.

The first touch-terminal developed by CERN and commercialized by NESELCO (1980)

This is a pricelist and is used to support the fact that the touchscreen was commercialized. The entire document is included in appendix 2.

Man-Machine Communication (1983)

This document will only be briefly discussed as it is mainly a technical report which is not really within the scope of our work. However those are some pointers which are interesting for us.

The report describes a MMC[63] module which can handle all the operator input from the touchscreen. A prototype module has been developed and more are planned. The intention is to make the touchscreen usable in other fields at CERN.

It is clear from the efforts made to make the touchscreen more usable, that it is the intention to utilizing the touchscreen outside the Super Proton Synchrotron.

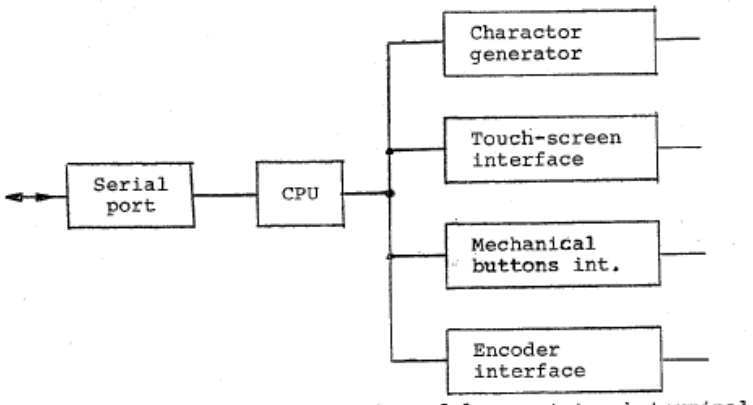


Figure 22: Configuration of low cost touch-terminal

The idea is to make the touchscreen a cost effective, independent and self-contained unit which can be utilized regardless of platform making the touchscreen a "shelf product".

Logbook: CERN touchscreen (2010)

The article from Symmetry magazines logbook is not very long but it has some interesting points. The most important piece of information is page one of sixteen from Bent Stumpe's handwritten note, which described the touchscreen, developed by Bent Stumpe. It also has some points related to other touchscreen technologies.

[63] Man machine communication.

> *"On March 11th 1972 CERN engineer Bent Stumpe proposed a new type of interactive computer display for controlling the lab's new Super Proton Synchrotron accelerator. His 16-page handwritten proposal describes what was apparently the world's first capacitive touchscreen, a technology now widely used in ticket machines and smart phones."*
>
> *"Existing touchscreens—including one based on acoustics, invented at what is now SLAC National Accelerator Laboratory—were too bulky."*
>
> *"So Frank Beck, who would become head of SPS Central Controls, asked Stumpe for a more streamlined solution."*
>
> *"The SPS control room opened in 1976 with three 16-button touchscreens, some of which continued to operate for 30 years."*
>
> *"By 1977, CERN's touchscreens were being sold to other research institutes and companies, including Rutherford Laboratory in the United Kingdom and Mitsubishi in Japan."*

Another of CERN's many inventions! (2010)

This article from the CERN bulletin describes the inventions made during the planning of the Super Proton Synchrotron control room. The article features an interview with their inventor Bent Stumpe.

It covers the history setting with the planning of the Super Proton Synchrotron control room:

> *"A specific goal, a lot of motivation and the technical skills to do it: that's all you need to create something nobody else has ever done before."*
>
> *"Back in the 1970s, the SPS was being built and its control room required the installation of thousands of buttons, knobs, switches and oscilloscopes to operate the machine. Frank Beck, newly recruited from the DD Division to be in charge of the central control hub in the SPS control room, asked Bent Stumpe for solutions to the following problem: how to build the hardware for an 'intelligent' system which, in just three console units, would replace all those conventional buttons, switches, etc."*

The article also touches technology transfer aspects:

> *"The technology developed for the capacitive touchscreen was immediately transferred to industry, in particular to the Danish firm Ferroperm. At CERN the touchscreen was used for a number of other control applications. CERN touchscreens were also used by other big laboratories."*
>
> *"However, despite the numerous publications on the subject by CERN and specialist reviews, the use of touchscreens was limited for a number of years partly because the system needed considerable computer power, which was very expensive at the time."*

The source is new and obviously builds upon many of the earlier sources we have also included in this project. Bent Stumpe mentioned many of the same things during our interviews with him.

The first capacitative touchscreens at CERN (2010)

The article outlines the history of the touchscreen at CERN and has some interesting points related to the commercialization of the touchscreen.

According to the article Frank Beck took the prototype developed by Bent Stumpe and showed it to those in charge of the Super Proton Synchrotron project even before reliability tests had been performed. It was decided to go forward with the touchscreens and start development of the control software on Nord164 and later Nord10[65].

The development continued and the touchscreen with sixteen buttons got completed. The Danish company Ferroperm was involved because multiple screens were required. This led to development of a robust glass screen with reduced reflection. Another Danish company NESELCO was involved in producing the electronic modules required to drive the touchscreen. The screens were taken into production use in 1976 and continued to operate for thirty years until 2006.

CERN made a popular demonstration of the touchscreen at the Hanover fair in 1977. CERN presented the Drinkomat with complete operational touchscreen console. The machine developed by Alain Guiard allowed the users to compose a drink via the touchscreen display and follow the process visually.

In 1977 the touchscreen was commercially sold to other internal customers, external research institutions and companies like JET, Rutherford Laboratory in the UK, KEK, Mitsubishi, TOYO Corporation, Rigshospitalet in Denmark and the Hahn-Meitner Institute in Germany.

The article describes use of an industry standard for the electronic modules (CAMAC) as one of the reasons for its success. The modules followed by the CAMAC crate computer (featuring a Motorola 68000 CPU), were integrated into one unit in 1980 (The touch terminal), which was sold by NESELCO.

The article describes some of the things that were done to promote the touchscreen/unit and shows that CERN was successful in bringing the unit on the market. The application for the units was not ticketing systems or television related devices as mentioned in the document *"A New Principle for an X-Y touchscreen"*. The customers were to some extent using the device for similar purposes. We have included the touch terminal price sheet and product specifications in Appendix 2 (Bent Stumpe has added the handwritten notes in the specifications).

Comparative Study of Various Touchscreen Technologies (2010)

We have reviewed this article and find some of the conclusions to deviate from the data we have available.

[64] NORD-1 was a mini computer developed by Norsk data (Wikipedia, 2012, NORD-1).
[65] Two computers.

This deviation is related to durability of the touchscreen, the touchscreens installed in Super Proton Synchrotron control room were operational for more than thirty years, which deviates significantly from the predicted two-year lifespan.

Properties	4-Wire Resistive	5-Wire Resistive	Surface Acoustic Wave	Capacitive	Infrared
Type	Surface Technique(Electrical)	Surface Technique(Electrical)	Surface Technique(Acoustic)	Surface Technique(Electrical)	Edge Technique(Optical)
Durability	3 Year	5 Year	5 Year	2 Year	5 Year
Transparency	Bad	Bad	Good	Normal	Good
Stability	High	High	Higher	Normal	High
Touch	Anything	Anything	Finger/Pen	Conductive	Finger/Pen
Response time	<10ms	<15ms	10ms	<15ms	<20ms
Sensitivity	Very sensitive to scratch	Very sensitive to scratch	Sensitive to scratch	Sensitive to dirt	ambient light

Three of the references within these documents are to documents, which are also among our sources; we cannot find any explanation to the limited lifespan mentioned.

Knowledge Transfer 2011 (2011)

This fifty pages long report we chose to use in our source evaluation because one of the writers is our interviewee Giovanni Anelli from CERN. It is a report on 2011 knowledge transfer activities.

The report is like a commercial for the Knowledge Transfer Group's current work done at CERN. The most important thing in relation to our project is that it underpin that CERN have a technology transfer department and that they look at other fields of research. But also that the Knowledge Transfer Group now have focus on intellectual property

> *"In 2011, CERN's support for the transfer of its technical knowledge to society has been reinforced by initiatives aiming at maximising the benefits for other fields of research, industry and education. A licence governing the exchange of knowledge in hardware design, a range of projects for medical applications in the framework of international collaborations, the 2011 series of schools of excellence to train tomorrow's scientists, are just a few of the examples of CERN's commitment to knowledge transfer."*
>
> *"The report offers an overview of the services provided by technology transfer and intellectual property management experts, the multidisciplinary projects in life sciences, the many applications of CERN's forefront technologies in diagnostics, the impact of information and communication technologies on innovation in the public and private sectors, the sharing of CERN's know-how in energy management, and the conversion of HEP technologies into clean technology," says Anelli." Last but not least, the report highlights examples of excellence in training and education which continue to represent a powerful vehicle for sharing and transferring CERN's technical expertise to society through the people who work,*

study, train and collaborate with our Organization. We all share the same passion: the transfer of knowledge from CERN to society."

"Our innovation model can lead to a significant long-term socioeconomic impact."

The remaining part of the report is based on different articles about innovations done at CERN. The report is interesting for our technology transfer question, but you can argue that it has an indirect relation to the history of CERN's capacitive touchscreen and the project statements main question. Therefore we think that there is an indirect connection. It also set the interview with Giovanni Anelli in a general context.

Danish inventor: How we steered CERN's control room with a bowling ball (2011)

In 1973 CERN initiated the process of building a new proton accelerator that was called the Super Proton Synchrotron. The new accelerator was seven km in perimeter and because of this they had to find a way to control it from a central position.

CERN bought thirty mini computers from Norsk Data and placed them centrally along the accelerator. The reason for doing so was to avoid having cables from the main control to all the components used to support the accelerator. Instead the accelerator was split up in thirty areas and all of these had a computer attached that functioned as a hub. Then the cables from the main control were connected to the computers and not to all of the individual components. But they also needed a way to control the new setup.

The manager of the new control liked the idea of a touchscreen that supported multi-functionality within a single button. However he did not see any suitable products on the market and asked Bent Stumpe if he had any ideas. Bent Stumpe used his past and creativity to make a paper where he described a possible solution for a suitable touchscreen. As Bent Stumpe says:

"Luckily if you had the right ideas at CERN, you got the financial support you needed.[66]*"*

His manager liked it and started the production and Bent started working on the development of his touchscreen. The touchscreen was developed and Danish corporation Ferroperm Piezoceramics handled the production of the touchscreens. The touchscreens were installed in almost every control room at CERN and also at corporations outside of CERN.

Video: This is how the transparent touchscreen was invented (2011)

The text talks about Bent Stumpe having to invent the touchscreen because the solution that was on the marked did not meet the requirements that CERN needed.

Bent Stumpe tells in the video about the beginning of the Super Proton Synchrotron and that CERN had a problem since they no longer had the opportunity to draw a cord for each button for every function in the new control room. They had tens of thousands of functions that they needed control of and they could not make a rack for all this and did not have the many square meters of space. Bent Stumpe explains that an idea emerged: maybe they could use a touchscreen. Touchscreens was not new but they were still on an experimental level.

[66] Original quote in Danish: *"Heldigvis var der den indstilling på Cern, at havde man de rigtige ideer, så blev der også sat penge nok af til det."*

> *"The touchscreens we knew about had some characteristics which exclude them from being used for the CERN control room."*

Then they asked themselves if it were possible to find an easier solution for a control screen. Bent Stumpe got the task of finding a solution to the problem. The answer came to Bent Stumpe by thinking of a filter for television use, which he had developed earlier on. This was a printed circuit where you press the filter instead of making a coil thus pressing the coil on the circuit. The idea came to Bent Stumpe: to print on a glass screen instead of on printed circuit boards. If he could make some capacitors that could be included in a circuit then they might be able to change the capacitors and thereby could press on different locations on the screen. After several experiments he did succeed. Then by multiple touch they could replace all those mechanical buttons.

At the end of the interview he shows what he calls the world's first personal computer with build-in touchscreen[67]. He talks about the relation to modern touchscreens.

> *"The touchscreen that is on the front of the modern smart phones is similar to the touchscreen developed at CERN in 1977.[68]"*

He tells that the difference is that the screen now is super integrated.

Dane at CERN will make isotopes for cancer treatment without side effects (2011)

Helge Ravn is a retired Danish Chemical Engineer that has been at CERN for almost forty years. He will use his knowledge about production of rare radioactivity for cancer treatment.

> *"It is my dream to see the device that I developed for basic research, be used also for more community service purposes. It is every physicist's dream and the biggest feather in the cap.[69]"*

The initial idea was to build a laboratory with an investor near CERN's Isolde[70]. This was not possible, so instead he and a few colleagues tried to get permission to use Isolde to gather small quantities of radioactive material and make this freely available for laboratories and universities.

Here he talks about his work with isotopes and the way they are used at CERN. More importantly he also talks about the way they are not being used. The accelerator was build to support nuclear and solid state physics, just like the touchscreen. The Isolde accelerator produces rare radioactive isotopes that are said to be more effective than the radiation used in cancer treatments today. Helge Ravn says that if you used the accelerator properly it could be an important part of future cancer research, diagnosis and treatment.

Helge Ravn has retired, but a new group at Isolde has sent an application to the scientific committee at CERN, requesting radiation time for their cancer experiments. Years back the group around Helge Ravn, together with an investor in pharmaceutical industry, sent a similar request to the CERN director general,

[67] It is a picture of the earlier mentioned NESELCO Touch-Terminal.
[68] The earlier mentioned X-Y touchscreen. Original quote in Danish: *"Den touch-skærm, der sidder i moderne smartphones, svarer til den touch-skærm der blev udviklet på CERN i 1977."*
[69] Original quote in Danish: *"Det er min drøm at se det apparat, jeg udviklede til grundforskning, blive brugt også til mere samfundstjenstlige formål. Det er enhver fysikers drøm og den største fjer i hatten."*
[70] Isotope Separator On Line.

but back then it was not granted because the focus was on the LHC. There is now a new general director at CERN, and he hopes the result will be different this time.

The circumstances surrounding Isolde and the touchscreen are similar in many ways. An engineer has developed a technology that is far from using its potential.

Based on the article it is obvious that Helge Ravn is not exactly thrilled about the way CERN has responded to his requests. We do not have CERN's view on the matter and do not possess the technical skills to evaluate if sharing the material created via Isolde would impact the work done at CERN.

The touchscreen revolution (2012-2014)

This is a draft of chapter by Bent Stumpe from a forthcoming book, which will be published in 2014. It contains a detailed walkthrough of the history of the touchscreen. The book is intended for audience without any degree in computers or electronics.

An important aspect touched in relation to diffusion, which are not mentioned in most of the other sources, is pricing and affordability of computers during the 1970s.

> *"In the beginning only well-equipped laboratories could afford to do the experiments and the developments associated with the use of touchscreens. The reason for this was simply that the systems required a computer controlled display, a touchscreen and a rather powerful and expensive computer at that time. Furthermore special software also had to be developed before the utility of a touchscreen could be demonstrated."*

Bent Stumpe continues to elaborate on the conditions and mind-set that was present during the 1970s, it is important to remember that the mass diffusion of computer technology had not yet kicked in.

> *"In the early 70-ties these fundamental requirements was therefore a really obstacle for the development. The industry was not yet aware of the advantages a touchscreen could offer and the possibility that it many years later would be possible to put a whole console including the computer into the size of an iPad or a smart phone was completely unimaginable."*

The advantages we find trivial and obvious today was not obvious during the 1970s. The pricing combined with the perceived advantage, which would obviously be hindered since it was an unknown technology.

The pricing also affects the adoption because it limits the trialability[71], buying an extremely expensive computer and an experimental touchscreen is a heavy financial burden combined with a high risk, making such an endeavour harder to sell. The chapter also mentions the usability of the touchscreen, which we also mentioned during this desk study.

> *"Often it is better to ask for a choice between a few "big buttons" followed by another selection of a few big buttons than to ask once for a choice between a high number of much smaller buttons or choices, however both possibilities are available to the programmer."*

[71] *Rogers* defines "*trialability*" as the degree to which the innovation may be trialled and modified.

It is also mentioned that button legends can be manipulated and buttons that are not in scope for a given context can be disabled. The requirement for a touchscreen at CERN is described in great detail, and gives insights to why CERN was motivated to allocate resources to developing the touchscreen.

> *"In 1971, the European governments decided to proceed with the construction of a new 400 GeV Proton generator of CERN. The concept of using general-purpose consoles attached to a computer system was adapted. Normally at that time a modern control room for controlling complex processes had an individual cable pulled from the apparatus to be controlled all the way to a rack in the control room. This involved the use of thousands of individual buttons, switches, potentiometers etc. and also a high number of oscilloscopes and other equipment. In addition the cost of the cables needed was a considerable burden on the budget."*

It is obvious that the accelerator size has a direct effect on cabling costs and complexity, so being able to centralize the controls has obvious economic advantages.

> *"On the basis of the proposal, the author was recruited into the new controls group and asked to go on with the development."*

The advantages of the touchscreen are described and provides an indication of the magnitude of how this touchscreen must have affected the control room layout.

> *"By using one touchscreen only having 16 fixed buttons, built into each of the 4 Central Consoles for control of the entire SPS accelerator, it now became possible from one console only and only by one person, to control the entire machine. The need for having individual control buttons, switches, potentiometers etc. Hardwired from the control room to the equipment installed in the 7 km long accelerator was completely eliminated by the introduction of the touchscreen technology and the decentralized computer system."*

Once again the change in computerized approach with a touchscreen limits the resource allocation required for cabling. Within the document we also find references to other sources used in this project.

> *"The overall software structure for the accelerator is described in full in a CERN report called "How CERN broke the software barrier"."*

Knowledge transfer also plays a part in this chapter; unfortunately we were unaware about this during our visit to Geneva, so we have been unable to retrieve copies of these hardcopy documents related to enquiries regarding the touchscreen. This would have been very valuable information and would have given us an idea of how much interest was given to this new innovation.

> *"The article in Design News was based on a CERN Publication CERN 73-6 Laboratory II Control group dated 24 May 1973. Frank Beck and Bent Stumpe "Two devices for operator interaction in the Central Control of the new CERN Accelerator". To support this hypothesis, Design News (USA) has informed CERN about all enquiries made to them after the time the article were published. The author have kept the list of all companies, persons etc., who at that time made an enquiry for more information due to the article in Design News. Today the author has a list of 288 enquiries with name address and the firms behind the enquiries made in 1974 including many well-known firms today."*

With the numbers above in mind it seems as if there were some degrees of interest from the industry. The industry was not yet aware of the advantages a touchscreen could offer and the possibility that it many years later would be possible to put a whole console including the computer into the size of an iPad or a smartphone was completely unimaginable.

During the 1970s the invention of the integrated circuit (Wikipedia, 2012, Integrated circuit) was still new and the price for electronic and especially computer was expensive. The article also touches on the price of the setup:

> *"In 1975 the total price of a Central Console for the control of the SPS accelerator with only one touchscreen and including the new Nord 16 bit Minicomputer for use by only one console cold very well be in the order of half a million Swiss Francs."*

The joint venture between the Aarhus University in Denmark, CERN and NESELCO were provided funding of *"11 444 000 Danish kroner*[72]*"* for further developments of the Mutual Capacitance touchscreen. So efforts were made to further develop the touchscreen. The touchscreen were also used at the AA accelerator at CERN:

> *"In 1980 the Touch Terminal was used to Control the newly developed AA accelerator instead of using the original much bigger and much more expensive consoles."*
> (The Antiproton Accumulator Accelerator was later discovering the particles W and Z. In 1990 the Isolde was controlled with the Touch Terminal.)

To summarize the chapter touches a lot of important aspects in relation to the efforts done towards technology transfer and it also touches on some of the barriers for diffusion, especially the hefty price task and it also gives great value to our historical method.

[72] To our surprise the document actually says approximately eleven and a half million DKK. Bent Stumpe has later confirmed this information over the telephone. Bent Stumpe got the original development reports with the exact numbers in his private archive. Those reports have according to Bent Stumpe a reference to his work done at CERN.

Technology Transfer Studies

In the technology transfer studies we begin by extracting data from our desk studies to establish what was done during the 1970s and the 1980s. Then we go through a modern approach to technology transfer and some of the most important areas and models embedded in this. We also look into some of the variables that effects diffusion.

After we have established what was done, how things can be done using a modern approach, the important variables related to diffusion, we combine these elements. This enables us to see if there is an indication of why the diffusion process did not proceed more rapidly.

Guide to technology transfer studies

In the technology transfer study we will look at modern technology transfer methods as this makes it possible for us to identify important steps, which were not taken during the 1970s. This can help us answer our primary question related to why the diffusion process did not happen more rapidly.

Even though we try to be very accurate, we are dealing with modern technology transfer methods. We will try to apply them to a situation that took place many years ago and this involves some uncertainty. This is primarily because our research is based on events that happened a long time ago and there is a risk that information could be misunderstood or inaccurate.

We have included the following models Technology Readiness Level, Porters Five Forces and SWOT because it can assist us in getting a better and more qualified estimate for the probability that the lack of a technology transfer approach could be the reason for the touchscreen's slow diffusion process. Phyllis L. Speser has presented all the models as tools to support the technology transfer approach. We have selected the specific models because we believe we are able to supply the necessary data to use them in constructive manner.

The models can all be categorized as being business models that can help reveal the marketing aspects of the touchscreen. Another reason for our focus on the business elements is that our documents has heavy focus on the technical aspects of the touchscreen and we do not think the lack of diffusion is to be found there.

Result of technology studies

We will start out with a general introduction and background information which will set the results into the proper perspective. After the introduction we will summarize what was done during the 1970s and the 1980s, ending with a look at what methods, which could have been used with benefit at CERN in relation to the touchscreen.

The definition of technology transfer is as follows:

> *"The bottom line for technology transfer is the commercialization of technology into the form of useful products that are sold to customers in the marketplace."*
> (Rogers, E.M., 2003, Diffusion of Innovations)

Like the quote says, technology transfer is about taking a technology and turning it into a usable product. There are different views on technology transferring, and how it should be done, which makes sense. If you take a company like Apple or Google and compare it to CERN, there will be alot of focus on the legal

aspects like patenting, licensing and intellectual property management. CERN's primary focus is getting the technology exposed to the public (CERN, 1953, Convention for the establishment of a European organisation for nuclear research). But no matter how it is done, organizations that do research will most likely benefit from having a technology transfer process.

If we take a quick look at the 1960s to the 1980s, companies like Apple, HP and Intel began to make their impact on history with the introduction of personal computers, printers and microprocessors becoming successful in technology transfers. Unlike these companies, which were successful in taking technology from the lab and making it into products, others failed to exploit their technologies. An example of this could be Xerox PARC (Palo Alto Research Center) that was founded in 1970 (Rogers, E.M., 2003, Diffusion of Innovations) and is associated with both greatness and failure by many people. Xerox PARC was the place where many of the technologies we use today were invented, for example the Alto[73], the mouse, icons, drop down menus, laser printing and the Ethernet technology. But except from the laser printer which were commercialized by the Xerox Corporation none of these technologies were made into useful products by the Xerox Corporation.

Instead it was Apple, with Steve Jobs in the leading role, which took the technologies and made some of them into useful products. There is also published a book called *"Fumbling the Future: How Xerox Invented, then Ignored, the First Personal Computer."* that looks at the failures in technology transfer from Xerox PARC to the Xerox Corporation.

In the book "*Diffusion of Innovations*", E.M. Rogers gives his view on what went wrong at Xerox PARC. There was not established an effective mechanism for the transfer of technologies and a lot of the technologies developed at Xerox PARC did not have a connection with the core business Xerox Corporation was in. Therefore they did not manage to see the potential market value of their technologies and transfer them. Steve Jobs saw the potential in a lot of them, but then again, he was in the microcomputer business.

> *"The Xerox Corporation was the leading company in the paper copier business in the 1970s, and it perceived itself as only in the office copier business, not in the microcomputer business. The one PARC technology that was commercialized effectively by the Xerox Corporation, laser printing, was incorporated into a Xerox copier."*
> (Rogers, E.M., 2003, Diffusion of Innovations)

Another unfortunate fact is that Xerox Corporation had marketing and sales divisions; however these were never engaged in transferring these technologies. Xerox PARC was located in California and marketing and sales were located in Connecticut, which is not optimal because the geographical distance and cultural barriers made technology transfer more difficult.

The last element was the bottom-down organizational structure at Xerox Corporation headquarters, which clashed with the hippie culture at Xerox PARC. This meant that Xerox PARC executives rejected the culture and personal computer technologies at Xerox PARC. Apple saw the potential and quickly absorbed the technology which resulted in the first Macintosh five years later.

We think the history of the touchscreen at CERN and are related in some ways. The touchscreen developed at CERN was outside the core business at CERN and due to this fact received limited support in its further

[73] The world's first computer designed for an individual.

developments. The purpose of CERN was nuclear research and to make the results public available which we think could have limited CERN from being as effective in technology transfer as for example Apple. CERN has changed since the 1970s and has now a fully staffed technology transfer department; however the convention remains the same, we think that this might conflict with some of the technology transfer initiatives:

> *"the results of its experimental and theoretical work shall be published or otherwise made generally available."*
> (CERN, 1953, Convention for the establishment of a European organisation for nuclear research)

A cultural change towards a more market orientated approach to technology transfer should come from management, and efforts done by the technology transfer department should have management backup in order to be successful. We have only had limited information available about the culture in relation to technology transfer during our study but we can tell from the interview with Giovanni Anelli that there is still some work to be done, in order to change the hearts and minds of the scientists at CERN. Any journey begins with the first step, and hopefully the management at CERN has clearly stated that the cultural shift is important in order to ensure continual support from the member states.

We will sum up what was done at CERN and afterwards compare it to a modern technology transfer process. Our primary source is Phyllis L. Speser and her book *"The Art & Science of technology transfer"*. The book gives a complete guide to the elements that must be included when you want to do technology transfer. It uses a lot of common and well-known models like PESTEL, SWOT, Porters Five Forces, and Four Ps etc. In additional to Phyllis L. Speser's explanation we have found inspiration in book "Exploring Corporate Strategy" by Johnson, G., Whittington, R. and Scholes, K. to provide additional details about these models.

We will not include every step of the model, just the ones that could have been of most relevance to CERN in their handling of the touchscreen. If CERN had applied a structured approach, could the history and late exposure of the touchscreen have been different?

A modern approach

The premise for our approach and choice in models is based on the work CERN could have done to assess whether they had a valuable technology. Depending on the result, they can try to determine if a patent would be worth the efforts.

The model described by Phyllis L. Speser is consists of four phases each containing different fields of study. Modern technology transfer work is often multidisciplinary including economists, engineers, lawyers, marketers and scientist.

The approach to the model will be sequentially and include the phases we have valued as being of most importance to the transfer of the touchscreen. The work done by CERN can in some ways be related to all the phases defined by Phyllis L. Speser, but it is important to remember that there was only limited structure and it was not completed in accordance with the approach defined by Phyllis L. Speser. Most of the technology transfer efforts conducted by CERN in relation to the touchscreen were conducted by Bent

Stumpe. As mentioned earlier in this project technology transfer work is multidisciplinary and it might be a large mouthful for a single individual to digest.

Phyllis L. Speser's model for technology transfer[74]:

Part 1 – The game of technology transfer	
Part 2 – Market Research	1) Finding the Customer 2) Competing Technology 3) Markets
Part 3 – Strategy	4) Positioning the Technology for the End User 5) Launch Tactics
Part 4 – Doing Deals	

Market research

We look at market research to establish an overview of what can be done to identify potential customers, competing technologies, market barriers and market forces. On the basis of some of the modes we will try to do market research based on the 1970s. This is also usable when we want to look at what was done in the 1970s and try to make a qualified answer to if things could have been any different. Doing market research on a market situation from the 1970s is difficult which is why we will only try to draw a high level overview.

Finding the customer

The field of market research consists of finding a customer who needs, and therefore wants to buy, the product. Phyllis L. Speser defines this as a four-step process, where you define what it is you are trying to sell, what kind of products the technology enables you to create, who will want to use the product and who will buy the product.

Phyllis L. Speser splits up the definition of the technology into three parts: functionality, characteristics and features. To sum up the different phases, they basically help determine what the technology consist of in regards to physical performance and readiness, how it is used. When you look at these elements, remember that your technology will have to offer something better than existing products. This can be better performance, lower costs or ease of use.

Looking at functionality, CERN could have done a Standard International Units and Bohl Knowledge Analysis to substantiate further research on possible products. The Standard International Units is used to measure what the technology can actually do and the Bohl Knowledge Analysis determines how valid the Standard International Units results are. CERN could also have done a Technology Readiness Level[75] assessment to determine if the technology was ready for commercialization. Technology Readiness Level can help

[74] We have selected not to include part 1 and part 4, which are not directly related to our study. This is done to limit speculation required to reach a tangible result.
[75] Technology Readiness Level. (Brookhaven National Laboratory, 2012, Technology Readiness Levels Definitions and Descriptions)

determine the path for the technology and map where you are in the overall process on regards to when you have a technology and when you have an actual product to sell. We have tried to assess the touchscreens Technology Readiness Level (see Appendix 7 – Technology Readiness Model) on the basis of interviews and the desk studies. There are different Technology Readiness Level models that vary depending on the type of technology. We have used a Technology Readiness Level model developed by the US Department of Energy, because this is the closest match to the touchscreen technology.

With this knowledge you can start defining the end users and buyers for the product. The end users are defined by looking at how our technology might be used, why it would be used and how often. During this process CERN should be able to define who their end users are.

When looking at the companies you have to remember the type of technology, for example are the products the first of its kind or products people already know, Rogers refers to this as compatibility.

Organizations are different from each other as some are innovative and can be considered as first movers in regards to new technologies. Phyllis L. Speser defines a range of company categories, like diversified product companies or niche player. For example diversified product companies focuses on new technologies that can support their range of products targeting different customer segments. The possible buyer type can in most cases be predicted by looking at their strategy (Table 1).

Strategy	Buyer Type
Price leadership	Price
Diversification	Value
Access	Availability
Focus	Technical Performance

Table 1 - (Speser, P.L., 2006, The Art & Science of Technology Transfer)

It is also possible to predict when buyers are likely to buy a technology. You can use this knowledge to compare the state of the technology with the companies that have an interest in buying the technology with the state it is in. You can see the state of the technology by looking at the Technology Readiness Level. If your technology is at level 1, you will have to focus on a diversified/focus product companies that are innovative. Looking at table 2, one can get an idea of the expected diffusion curve for a technology like the touchscreen.

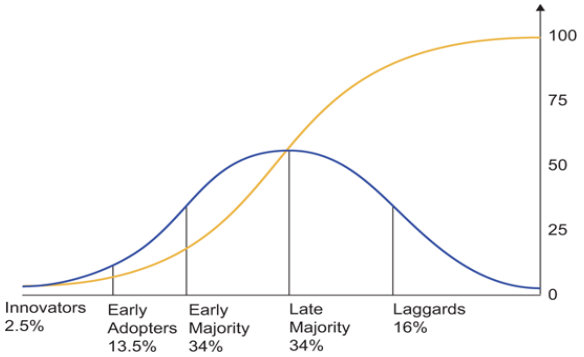


Table 2 – (Emerald, 2012, Innovation Adoption Curve)

Competing technology

One of the most important elements when it comes to new technologies is competitive advantage[76]. Basically it means you have a technology that does something better than the others on the market. To determine possible competition we look at things like redundancy, companies selling the technology and future competitors. Companies selling the same technology with a loyal customer group can be hard to convince to buy your product. This means that the competitive advantage would have to move this customer segment towards your products.

When searching for possible competition on the market, you look at things like patents, R&D data bases, referred journals, grey literature[77], trade literature and business press (Speser, P.L., 2006, The Art & Science of Technology Transfer). The focus for the search will be identical technologies that accomplice the same thing as your technology. We have to know if the competition is too powerful or if we have a competitive advantage. Functionality, characteristics and features aside, a factor like brand loyalty also has to be encountered for.

It is important to make sure that the technology is not already patented by someone else, if the technology is already patented it would be a waste of resources.

Competition do not have to be a replica or equivalent technology, every product or technology that accomplishes the same as another technology, is to be seen as competition. Actually every technology that the end users think accomplish the same thing is competition, so in this regard perception is reality.

> *"Relative advantage is the degree to which an innovation is perceived as better than the idea it supersedes."*
> (Rogers, E.M., 2003 Diffusion of Innovations)

As obvious from the Rogers quote above, it is the perception, which a social system will react upon, this means that marketing is important. As for the touchscreen one of the advantages mention is cost saving, but if you were to make a payment system for a cafeteria, the cost benefit analysis would be different, and in terms of cost the touchscreen would be advantageous.

When looking at competition it is not enough to look at the current substitutes, it is also necessary to look at the future substitutes. Looking at emerging technologies found in data sources like scholarly journals, professional society presentations, dissertation abstracts and similar sources can do this. Again it is about being creative. You also have to keep in mind that companies have different timeframes in the development cycle. The collected data can be used with an appropriate Technology Readiness Level model. With all this data, it will be possible to get an idea of how far competitor technology is from market entry.

[76] A strategic advantage a business entity has over its rival entities within its competitive industry. Achieving competitive advantage strengthens and positions a business better within the business environment.
[77] Written material such as reports that is difficult to find via conventional channels such as published journals and monographs because it is not published commercially or is generally inaccessible.

Markets

To be able to understand the value of an innovation it is important to understand its market. The market is where buyer and seller meet to do transactions. Knowing market barriers and market forces is important to determine total addressable market size and the share that could be captured by the product.

Market barriers are factors that somehow constrain the buyer or seller of a given product. It can be caused by many different factors. The examples below can help illustrate how market barriers can hinder market entry.

- Owner of smartphones might be unlikely to change platform if their purchased apps and music/movies content cannot be used on the alternative platform that you are selling.
- Laws and regulations can prevent market entry for the new vehicle you are selling.[78]
- Suppliers can be reluctant to distribute your product based on relationship/deals with existing vendors.

For the touchscreen there were no existing markets to capture because we are dealing with the first of its kind. Another possible market barrier could be the price tag and the complexity. Suppliers also had an established market so they might be reluctant to risk that by promoting the touchscreen.

Market forces affect the buyer, the product or the seller in some way. An example of this is the pneumatic tire, which was invented by Robert W. Thomson in 1845. The invention was rejected, because it did not have any real benefit over conventional solid rubber tires, which were used by carts and automobiles at the time. With the invention of the modern bicycle by Ernest Michaux in 1861 the marked for the pneumatic tire was expanding. The reason for this is that the pneumatic tire has superior compared to solid tires when used on a bicycle. Other factors can be the surrounding infrastructure (pavement and the rise of automobiles).

There are some similarities between the pneumatic tire and the touchscreen, because they were both to some extent inactive for a period of time and then took of piggybacking on another innovation. The touchscreen's rate of adoption really took off when the invention of the smartphone, like the pneumatic tire did in the bicycle case. We think that supporting technologies which for the smartphone was miniaturization and inexpensive integrated circuits are required for some of the touchscreen related innovations to flourish.

Some of the ideas for suggested applications for the touchscreen like for example the mentioned touchscreen device which could interact with a television. We do not think it was feasible to make such a device in 1977 which would be within reach of normal consumers because of the limited access to inexpensive and miniaturized[79] electronic components.

It is also important to know the market size. This can be retrieved in four ways. Looking at sales within the technology category, comparables[80], sales by the numbers of users and frequency of purchasing, or parsing down from aggregate market size data. As Phyllis L. Speser says:

[78] Segway is a good example. (Wikipedia, 2012, Segway PT)
[79] Miniaturization allows smaller and more powerful components.
[80] A valuation technique in which a recently sold asset is used to determine the value of a similar asset.

> *"The easiest way to find out a market size is to find data giving you the market size."*
> (Speser, P.L., 2006, The Art & Science of Technology Transfer)

For instance if you want to know the size of the potential market for smartphones, you can go to IDC (IDC, 2012, Smartphone Market Hits All-Time Quarterly High Due To Seasonal Strength and Wider Variety of Offerings, According to IDC) or Gartner (Gartner, 2011, Forecast Analysis: Mobile Devices, Worldwide, 2008-2015, 3Q11 Update) and use their analysis for historical and future growth within the smartphone market. Before entering a market it is also important to extrapolate into the future, which the analysis can help with. Porters Five Forces can shed some light upon most of these questions because it looks at how attractive an industry, sector or market is to invest in. It has a more narrow focus than PESTEL, which looks at macro economic factors.

From a technology transfer perspective information about the market can help you decide how to proceed with your innovation. If the market is growing and only limited market barriers exist, this can affect the profit you will be able to generate from your innovation. Profits can be in terms of delivering a finished product if your analysis shows that market entry is doable for your organization, but it could also be in terms of royalty.

Strategy

You have to get a clear picture of how the product is to be sold to the end user. This is done by positioning the product and defining the launch tactics.

Positioning the technology for the end user

There are always two customers for any technology, the end user who actually uses the product to gain an advantage and the other one is she or he who licenses, enters a joint venture. In the 1970s the computers used in relation to the cost screen was extremely expensive and was priced around half a million CHF. The price tag excludes end users as decisions makers and target customers, the customers would therefore be managers of research facilities power plans etc. which might be able to save money investing in a system like the touch terminal. Therefore the customers in regards to the touchscreen will properly be a corporation. With this knowledge we have to identify where our product fulfil our customers' needs better than other offerings.

Launch Tactics

We know who our customers are, and need to spread the knowledge about our products competitive advantage to them. This can be defined by first using SWOT[81] and thereafter The Four P's[82].

If our product does not give our customers a competitive advantage we have an issue we need to address, in order to ensure a competitive advantage for our customers. The SWOT analysis gives us a path into the market, the path can be described using The Four P's which our launch tactic is. The Four P's should not only aid us in reaching end users, it should also allow us to identify potential partners and how to reach them.

[81] Strengths, weaknesses, opportunities and threats.
[82] Product, price, promotion and place.

Diffusion

In order to address some of the questions in relation to our problem statement that deals with diffusion, we will look at some of the variables determining the rate of adoptions of innovations, namely the perceived attributes of innovations.

> *"Diffusion is the process in which an innovation is communicated through certain channels over time among the members of a social system. It is a special type of communication, in that the messages are concerned with new ideas."*
> (Rogers, E.M., 2003 Diffusion of Innovations)

As we briefly mentioned in the methods and theories chapter, Everett M. Rogers' book "Diffusion of Innovations", includes methods about acceptability of innovations which is split into five main parts:

1. Relative advantages.
2. Compatibility.
3. Complexity.
4. Trialability.
5. Observability.

The rate of adoption is described as the relative rate with which the members of a social system adopt an innovation. The rate is measured by the number of adaptors, what is even more important is that there are some key variables that affect the rate of adoption. The relative advantage is the perceived advantage the innovation brings compared to the technology it supersedes. The advantage can be economic, social etc. For the touchscreen during the 1970s it could be seen as an economic advantage if you were building a large accelerator. As we saw during the desk studies the touchscreen and surrounding innovations at CERN brought substantial cost saving to the SPS project.

Now we cannot know what decision makers thought about the touchscreen at the time, and because it is the perceived advantage that counts we can only speculate. For use in train terminals as ticketing automat as Bent Stumpe suggests might not has been perceived as an advantage because of the economics involved. E. M. Rogers mentions that the initial cost affects adoption rate and for the touchscreen the initial costs were quite substantial. The flexibility and usability it provides is an advantage, but once again the price tag for the advantages will not be sufficient to justify the investment.

The touchscreen had no appeal towards consumer market like for example today's smartphones. For normal consumers there were no social aspects at play. During the smartphone boom we think that prestige associated with owning a smartphone might be one of the many factors supporting the diffusion of smartphones.

Rogers uses the VCR as an example and states:

> *"When the price of a new product decreases so dramatically during its diffusion process, a rapid rate of adoption is encouraged. In fact, one might even question whether an innovation like the VCR is really the same object in 2002, when it costs $50, as in 1980, when it cost twenty four times as much."*
> (Rogers, E.M., 2003 Diffusion of Innovations)

We think we see a similar pattern in relation to the touchscreen, it is difficult to compare the minicomputer and CAMAC crates with today's smartphones.

Compatibility is the degree, which an innovation is perceived as being consistent with current values experiences and needs of potential adopters.
If we look at the compatibility setup related to the touchscreen. We think that others, who were planning an accelerator control room or power plant at that time, might have been reluctant to use a computerized approached. One of the reasons could be that they were used to operating via directly connected buttons and knobs, which they might see, as more reliable than a computer, which could lag or even crash.

We think we see a similarity to the history of Fly-By-Wire, which also encountered resistance initially, however with this innovation it, was possible to manipulate the innovation to be compatible.

> *"The hydraulic circuits are similar except that mechanical servo valves are replaced with electrically-controlled servo valves, operated by the electronic controller. This is the simplest and earliest configuration of an analog fly-by-wire flight control system. In this configuration, the flight control systems must simulate "feel". The electronic controller controls electrical feel devices that provide the appropriate "feel" forces on the manual controls. This was used in Concorde, the first production fly-by-wire airliner."*
> (Wikipedia, 2012, Fly-By-Wire)

Since the use of the touchscreen and the computerized knob was a drastic change compared to how things were done previously, compatibility could be an issue.

Complexity relates to how difficult an innovation is perceived to understand and user. The build-up of the control room and programming required to use the touchscreen, made this innovation quite complex to use and understand. The efforts to make the innovation using standard components as described in the desk studies does help to bring the complexity level down a bit. For decisions makers there was no easy way to calculate potential cost saving, as they would most likely not have the knowledge to estimate the cost associated with implementing the touchscreen.

Trialability relates to how easy it is to experiment with the innovation on a limited basis. For the touchscreen it was not possible to try it without investing in a lot of resources. The touchscreens trialability was a hurdle. The cost of the initial setup was very high.

Observability is the degree to which the result of an innovation is visible to others, how easy is it to see and the effect of an innovation. In relation to the SPS project it should be obviously from comparing another analogy control room with the Super Proton Synchrotron control room that there is an advantage. But this did require some knowledge of the control room and might not span easily across sectors or industries.

What was done in the 1970s?

Based on our interview with Bent Stumpe and desk studies dealing with the touchscreen, we try to determine what was done to transfer the touchscreen.

The steps taken during the 1970s reflect the time and place, CERN is a research institution and far from a consumer orientated corporation in relation to commercialization and marketing. Furthermore, during the 1970s technology transfer processes was not a common practice.

There was conducted a market analysis and developed documentation describing the technology and possible ways to use it. For example CERN described different ways to use the touchscreen, ways that could benefit companies in terms of scalability and flexibility. There was done research on similar technologies on the market.

The Hannover fair is an example of what we consider as very effective promotion of the touchscreen, to displays a brand new and to some extent unknown innovation in a known setting (Serving of alcohol), makes the innovation very east to relate to. We have been told that it was quite an attraction showing some of the applications that the touchscreen could have been used for.

Could a modern approach have changed the diffusion?

In this section we will try to use the knowledge gathered about a modern approach, diffusion and the initiatives taken by CERN to commercialize the touchscreen. This is done to see if we can find out what could have affected the diffusion.

First of all we try to see if the technology was ready for commercialization using the Technology Readiness Level to rate the technology, we found the technology as being ready for commercialization. Bent Stumpe was involved in commercializing the touchscreen during the 1970s, so we can assume he was already aware that the technology was ready for commercialization.

Porters Five Forces and SWOT were used to determine the positive and negative factors regarding the touchscreen from both a micro and macro perspective. The models give an overall positive result when you look at the current situation, but looking ahead things could change significantly. We predict that competition could be a challenge.

If the touchscreen began to diffuse, the factors that speak for the current attractiveness will be minimized. If you do not believe the technology will make a breakthrough, then there is no reason to start with the business venture. One of the factors that are considered critical is that the technology is published for everyone to see. This means that everyone can engage in making touchscreens.

The fact that research and developing of prototypes is expensive is also an issue. This will probably make it easier for big corporations to advance in regards to development and research. The fact that the touchscreen requires an expensive computer to be used is also a problem because it limits the market significantly, so we have a device which is expensive to develop and hard to sell.

There was no competition on the market. CERN located potential customers and got the technology sold and implemented. CERN managed to transfer the technology to Ferroperm and NESELCO. We have a successful transfer but the rate of adoption was limited and it never reached beyond innovators. We think this is related to the perceived advantage.

Based on the technology transfer study we conducted, we think that the main issue was that the touchscreen was ahead of its time[83]. We think that the touchscreen was dependent on other technologies to flourish[84]. Technologies which was not developed or had not diffused in the 1970s.

[83] The touchscreen was used by some research institutions, but in relation to mass diffusion it was ahead of its time.
[84] This is seen in relation to our problem statement. CERN were satisfied with the first version of the touchscreen, but this fact does not change the fact that the cost was overwhelming for the consumer marked.

Furthermore computers required to use the touchscreen were unavailable to the general public during the 1970s and we think potential customers saw the perceived advantages as being large enough to justify a purchase.

Results

We will try to summarize[85] the results in relation to our problem statement.

We think that the successful development at CERN was possible because of the environment at CERN and a few individuals[86] who played a vital part in the creation of this innovation. We will mention them briefly, besides their efforts there were many specialists involved during the design and manufacturing process.

Bent Stumpe's experiences and ideas from working at a television factory in the early 1960s gave him an advantage in developing the touchscreen at CERN. During his former employment Bent Stumpe had experimented with etching small inductors directly onto a printed circuit board. This gave him the idea to etch a film of copper on a sheet of glass making the first touchscreen in the early 1970s. Frank Beck supported Bent Stumpe in his efforts, and once the first prototype was completed Frank Beck quickly took it and started to program an interface. Besides skills and management support there were a lot of factors which combined was as a perfect match at the right time. We think it was the combination of risk taking, skills, need, urgency and people that made creation of the touchscreen at CERN possible. The need was due to the large size of the Super Proton Synchrotron which caused conventional cabling to become too expensive.

The technology transfer process used in the 1970s was not as extensive as a modern approach suggest. The process was performed in an informal manner, but many of the key considerations expected today were addressed. Even though a modern approach would have been more extensive and structured we do not think it would affect the history as we know it[87]. We also have to take into account that CERN is not a privately held company so many of the normal market factors does not apply directly. The touchscreen was fully commercialized and sold on the market by NESELCO, but only in limited numbers.

Nobel Prize winner Simon van der Meer has the Touch Terminal from NESELCO by his side.
(CERN Courier, 2009, The Nobel path to a unified electro theory)

[85] To get the additional details of the history of CERN's capacitive touchscreen look into the desk studies section for more information.
[86] Among these were also Michael C. Crawley-Milling who played a significant part in the development of the Super Proton Synchrotron and thereby are setting the story in a general context.
[87] We only focus on the touchscreen developed at CERN and the technology transfer process.

In 1977 Bent Stumpe wrote a report on the X-Y touchscreen which would further improve the touchscreen. CERN supported the touchscreen until it was able to meet the requirements to fulfil the identified need, when that was accomplished the support faded. This is why CERN did not support the X-Y touchscreen. For CERN the history of this innovation came to a closure when the last of the original touchscreens was decommissioned in 2008. We think that this indicates that the original touchscreen were able to stand the test of time.

> The SPS touch-screens originally developed by Bent Stumpe were in operation from 1973 until the new LHC Control Room was installed in 2008.

(CERN bulletin, 2010, Another of CERN's many inventions)

It is clear from our research that the touchscreen was spawned because there was a need due to the large size of the Super Proton Synchrotron. The development was made possible because Frank Beck had faith in Bent Stumpe's abilities to create this innovation. The environment at CERN and CERN's challenging task of building the Super Proton Synchrotron spawned this innovation. The first touchscreen was developed with great support from management.

The development process was finished swiftly and it did not take many months from idea to working prototype. We have learned during the interviews that the amount of scientists and workshops at CERN was a factor enabling Bent Stumpe to seek advice among experts and have expensive processing facilities available.

We are also to identify some of the barriers that might have prevented this innovation from diffusing as rapidly as we initially thought to be realistic. The cost associated with buying a mini computer, a touchscreen and configuring it was enormous, which affected the relative advantage. The cost saving identified at CERN was due to what we might call an uncommon construction[88], which to some extent were unique. We saw adoption at a number of power plants and were able to estimate the number of screens to well above fifty, but customers were not lining up. It was a complex, expensive and people were unlikely to see or hear of the touchscreens possibilities. The communication channels used were mainly scientific publications. We can see from our sources that there was some level of interest from the industry[89] and that economic resources were awarded by the Danish Development Foundation[90] to sponsor further development.

The efforts to kick-start the diffusion process by Bent Stumpe was numerous. From our study we can tell that there were barriers[91], which were hard to overcome. From the diffusion research we see similarities to the diffusion of the pneumatic tire as earlier mentioned. The touchscreen was commercialized and the team at CERN did a lot to change the first prototypes into CAMAC standard components for everyone to use with minimal efforts. During the late 1970s and the 1980s the touchscreen developed at CERN was being sold by NESELCO.

[88] Particle accelerator.
[89] According to Bent Stumpe there was a large interest from the industry at least in the USA. Bent Stumpe documented over two hundred inquiries made to the magazine Design News in late 1970s.
[90] The foundation is financed by the Danish government.
[91] Barriers like costs, trialability and compatibility. Look at the technology transfers section for additional information.

Discussion

In this section we will discuss if we have used the theory in the analysis and if our empirical studies and results has reliability in relation to the result as initially planned and outlined in the methods and theory section. We will also look into the validity of the entire study. This will help us support our conclusion.

Discussion of empirical studies

One could argue that we have spent too many resources on research, too much time on the story and too many pages in this project on the historical method and thereby the desk studies. What you have to remember is that the history of the touchscreen at CERN has never been described before. One could also argue that we could have settled with fewer sources, less references and less quotations. For us this was not an opportunity because there was relatively little academic material available to build upon and it is important to establish the history while firsthand sources who witnessed the actual events are available. We were not willing to settle for less so we made a choice. Even with the number of sources we went through there are still sources out there to be found, and there is most likely still information contained in the documents we covered which we have missed.

We have collected data that has never been combined before in this manner. The project has a lot of pages but we did this because we found the historic events interesting and important. We had a unique opportunity to travel to CERN and get a feel about the culture and people working at CERN. We also had an opportunity to gather sources and bring value to the history of information technology. Moreover we did not have shoulders to stand on history wise. These events are relatively recent from a historical perspective, but from an information technology perspective it all happened ages ago.
All of our sources are the foundation for answering the questions we have asked ourselves in the problem statement. We needed a thorough evaluation of the source material, which give a good reliability to our study. A good portion of this evaluation is found in the appendix 1.

We have tried to address the issues regarding nepotism by not letting Jonas Stumpe evaluate or analyse sources with Bent Stumpe[92].

We have conducted the interviews in a semi structured way, which practically means a focused, interview-based two-way communication with the interviewee. We found this very suitable in relation to the nature of the knowledge we wanted to acquire. We would not limit our interviewees, but give them a chance to enlighten us in our path towards the final goal. We conducted several interviews and had ongoing conversations with our main interviewee Bent Stumpe. The first recorded interview with Bent Stumpe which got lost ended up in giving us an advantage. It meant that we got a chance of doing an even better interview and the initial questions we asked were transformed into new ones.

When we did our desk studies we continually got more knowledgeable about the subject. We did another extensive interview with Bent Stumpe and this ended up giving us the chance to do a last minute interview with Søren Karl Larsen. We were not aware that Søren Karl Larsen held important information regarding the rate of adoption of the touchscreen. Though Søren Karl Larsen brought us valuable information he did

[92] A deviation for this approach is that Jonas Stumpe interviewed Søren Karl Larsen.

not have access to the order books, a source which could contain valuable and more accurate information than what we were able to collect through the interview.

The technology transfer study was quite a challenge and we try to relate a modern approach to our empirical data. The modern approach included a large number of models of which we chose to include some of the most important ones. Modern models require a vast amount of data, some which were not included in our empirical study which was problematic.

In relation to our visit at CERN we did an interview about technology transfers with Giovanni Anelli. Additional interviews with Giovanni Anelli were difficult because of the distance. The structure of this interview was like a conversation between fellow professionals, which ended up in a good debate because Bent Stumpe also took some part in this interview. This approach brought new information to the table.

We think that it would have been valuable getting interviews with sources like Frank Beck and Michael C. Crowley-Milling, who were also firsthand witnesses to the events and could elaborate further on the firsthand documents in which they were authors. We also think that they might have been able to contribute even further to some of the cultural aspects that happened during the 1970s and the 1980s.

In this study we only have very few, if any, quantitative methods[93]. This could affect the methodological triangulation, a thing we have been highly aware of from the beginning, but much historical research is based on written sources, which has a qualitative nature. Qualitative analysis methods are qualified in the extension of quantitative studies to achieve methodological triangulation. A qualitative analysis can therefore be seen as an initial study and it is difficult to generalise[94] on a qualitative study. This we will not argue. When looking at the aforementioned parameters it is apparent that additional sources and methods could have been included, but we think we have a good indication of that the effect on the conclusion would have been limited.

We have analysed the empirical data in plenum to strive for intersubjectivity and avoid subjectivity. This combined with our analysis brings more validity to the empirical studies. We also have had several third party reviewers go through the project and providing useful and valuable feedback. The reviewers have been looking at content, form and language. However in some parts of the project the language is not as easy accessible due to the historical and technical content. We have tried in our best ability to address this during the whole project.

[93] We could have done a quantitative study of smartphone diffusion or a comparative study of technology transfers success rate between different research institutions.
[94] Here we think of the term generalisability.

Discussion of results

The amount of data may seem too extensive and unmanageable. We are aware that in the light of all of this material can be things we have overlooked or points we have missed. But sometime you have to be bold. The result of our desk studies is the history of CERN's capacitive touchscreen. This history is our basis for answering the remaining questions in the problem statement.

Most of our preconceptions were answered by the project. However there are still some of them that need answering. That is because our sources changed the project's direction as we learned more about the actual events. That also made us change some parts of the problem statement.

It has come to our attention during our study that culture can have a major influence on how organizational dynamics work and therefore we added an extra question to our problem statement, which we will address during our future research section.

Most of our sources are of a praising nature. This is due to the fact that we did not find any direct academically projects that had references to our sources and therefore we only have scientific sources that are not derogatory of nature. We have both relic and narrative sources, but we have made a full evaluation of them all. This should counteract low credibility in the source evaluation and thereby the final results.

A lot of our sources are from firsthand witnesses or of second-hand sources grounded on firsthand sources. Many of these has in one way or another a relation to CERN. In the overall picture this gives us a lot of material from the same main source, which could potentially do that the results lack intersubjectivity. We do not think that it is an issue, because CERN as an institution is grounded on many years of research and documents from CERN is internally peer-reviewed.

The result from the Giovanni Anelli interview was done without initial studies and therefore our understanding in regard to CERN, the touchscreen and technology transfers were very limited. Something that is very noticeable when looking back on the interview and its results. However the data collected in the interview worked as a valuable introduction to all the above. Bent Stumpe participated in the interview, which gave us an advantage because he managed to ask a lot of important questions. We are aware that this could also be considered as an issue, as he could have his own agenda. On the other hand, a lot of the written sources underpin the statements by Giovanni Anelli and Bent Stumpe. Therefore we think that the desk studies and interviews are solid foundations.

The interviews with Bent Stumpe included one that were recorded and a series of unstructured ad hoc interviews. We will discuss all the results of the interviews with Bent Stumpe as a whole. The interviews gave us an essential and important look into the history of the touchscreen which helped us move in the right direction. That being said we made our own decisions in regard to our problem statement and the project in general. This was also an important factor for Bent Stumpe; a thing we think gives credibility to results and exactly for that reason all the information provided by Bent Stumpe was validated with our written sources. Though there is information that we have been unable to document and verify.

The historical method approach in the desk studies gave on a solid overview of the evolution of CERN's capacitive touchscreen. Our first source was the "Yellow Report" by Frank Beck and Bent Stumpe. It was on the basis of this source that we located many of the other sources. We separated the evaluation of the individual sources to avoid that they affected each other. In the report we decided to write the first part as

a general evaluation to set the sources in general context. Here we looked into who the source sender was and the shoulders they were standing on. Because of this we were to verify that our sources had the necessary credibility, which also were important in relation to the final result.

The second part of the source evaluation in the report was an extraction of the most important parts in relation to the history and in relation to the technology transfers studies. We could have spend more time on our source evaluation because there is extensive material on this subject. We have knowledge of more sources, which we could not get hold of. Such new sources could of course bring new things to the table, but the sources we actually got, tell a good part of the history and are grounded on universities, research institutions and scientific magazines, which all are in one way or another have a long tradition for writing scientific material. However some of the documents are peer reviewed and therefore more credible than the articles from scientific magazines. Furthermore the information in our sources is verified by other sources or by the interviewees.

Our studies in regard to the modern approach were based on Phyllis L. Speser and her book *"The Arts and Science of Technology Transfer"*. Phyllis L. Speser is a renowned scientist with a PhD and more than twenty years experience in regards to technology transfer work. However we had preferred if her book had included more quantities studies and relied less on her own experiences. Because of this we included a Technology Readiness Model, Porters Five Forces and a SWOT analysis to substantiate our data. We used the data gathered in our desk studies on the models. Furthermore we also used Everett M. Rogers and his book *"The Diffusion of Innovations"* to compliment Phyllis L. Speser. We have intentionally due to our time schedule excluded some methods and theories from the study. This lack of thoroughness could possibly be a problem for the results in regards to the study of the technology transfer process.

More importantly, we have managed to use our own results to substantiate our primary question. The conclusion is based on our interviews and documents found and evaluated with a thorough approach to the historical data. If there have been elements where the data has not been sufficient, we have combined it and compared it to other data, or in some cases used it in acknowledged models.

The results are influenced by the fact that the authors of this project are not historians. However we have acquired knowledge about the historical method and received counselling from a historian before we initiated the research.

Conclusion

In our problem statement we started asking the following questions:

Based on the touchscreen developed at CERN during the 1970s, why did the diffusion process not proceed more rapidly?

Research questions:

- What is the history behind the touchscreen developed at CERN?
- Why was CERN successful in developing the touchscreen?
- How does the technology transfer process used in the 1970s deviate from an approach using a modern model for technology transfer?

We can conclude that the diffusion process was influenced by these four main reasons:

- A lack of need.
- Costs.
- Technological limitations.
- Missing support from CERN as there was no need from the CERN side for further developments. The first touchscreen proposed in 1972 satisfied all CERN requirements.

There was clearly a need for a touchscreen at CERN and at some other large facilities, but there was not a need in regards to the consumer market, because the costs were too high for general purpose usage. At the time the available hardware and software were limited and the prices of were extremely high. CERN did not have a need for a further development and stopped founding and support for further research and production of the X-Y touchscreen.

The history of CERN's capacitive touchscreen began in the early 1970s and ended in 2008 where the last remaining touchscreen were decommissioned. It started with an idea from Frank Beck and with Bent Stumpe developing the touchscreen on basis of his innovations at a television factory in the early 1960s. The first version of the touchscreen went into production and the X-Y touchscreen from 1977 never had the necessary support for commercialization because there was no need for it at CERN. After the X-Y touchscreen faded out of time, it created a gap in history, source wise, and reappeared in the start of the new millennium with the rising of smartphones and tablet computers95, which finally allowed the touchscreen to hit the critical mass needed.

CERN was successful in inventing and using the first version of the capacitive touchscreen, but not the later version. Frank Beck and Bent Stumpe met at a crucial point in time and an amount of coincidence was involved. Partly because Bent Stumpe had some the necessary experience from the television factory and that Frank Beck had an idea on which Bent Stumpe could build on. Furthermore Frank Beck was under time pressure, but he also had the courage to take the, in Bent Stumpe's eyes, unfinished invention into use. Bent Stumpe had the visions to design and build a functional touchscreen, which at that time had not been done. Last but not least CERN supported the development with the necessary resources and the right environment for making this innovation unfold.

[95] This transition is not investigated in this project, but it is mentioned by several of our sources.

CERN did not have a technology transfer department in the 1970s. Therefore there was not a structured approach to transferring the technology to society. However in relation to the innovation of the touchscreen Bent Stumpe did a lot of the practices described in a modern technology transfers approach based on his common sense. We can conclude that there was no awareness of the importance of a knowledge transfer department at CERN back then.

An additional conclusion of the entire project when looking into our earliest sources from 1971 and 1972 is that the finger on a screen using it as a button seems to be an old idea that surpasses this project. This aspect has an indirect connection with our problem statement in regards to the history.

(Business Insider, 2011, touch-ipad, Apple)

Future research

In this section we will look at other potential research fields. We will also look at organizational theory in relation to our last question from the problem statement and look at the barriers and potentials, which could have influenced the history of CERN's capacitive touchscreen. The organizational theory we will address as the last part of the future research.

Bent Stumpe is a collector of documentation and he has saved many documents in his private treasure trove, which is a private archive. Some of it is already uploaded to CERN's Document Server. In this archive we assume from our conversations with him that there could be a lot more interesting information to dig in to. We think that it is fortunate that all this information even exists today even though it is no coincidence because Bent Stumpe has been aware of the value of information.

With this project we have already proven that there is a lot of unexplored territory in regarding to the capacitive touchscreens genesis. We presume that there is sufficient material to write a book or a Ph.D. about the entire history of this subject and thereby expand the story. We will encourage someone to do this before the living firsthand sources have vanished from the face of the earth. It is not only a story about a technology. It is a story about a technology that has made an impact on the way we communicate with each other through information technology. This is in our point of view the true invention.

If a book on the subject should ever be written it could be interesting to take a look into patents, intellectual property rights and the technology itself. How do you distinguish one type of touchscreen from another technology wise? Is patenting positive for an invention's diffusion or is it negative? If CERN had patented the touchscreen in the 1970s then where would we be today? Also the term prior art[96] would be an attractive study in relation to the touchscreen even though the complexity of this matter would demand quite a lot of resources.

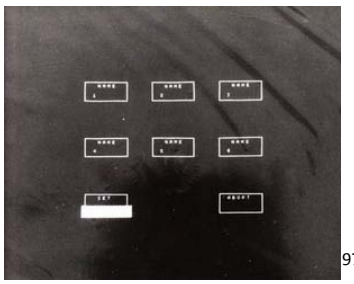
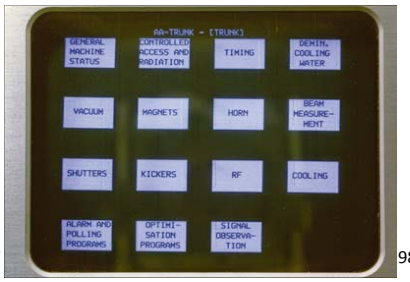
> *"..and to identify the closest "prior art" in order to decide if a patent can and should be filed."* (Giampietro, M. and Anelli, G., 2011, Knowledge Transfer 2011).

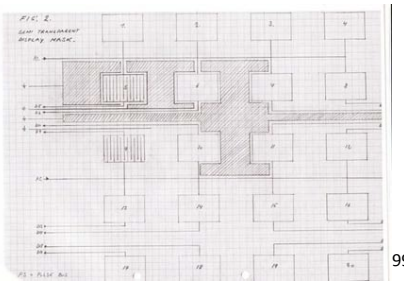
With an invention comes a predicate. Some predicates occur at the same time as an invention and other logically is given later. This aspect could be an interesting subject to look into, because you could explore if the "self capacitive transparent multi-touchscreen" was invented at CERN in the 1970s under another name. To investigate this you could let experts test and investigate some of the first touchscreens and let them evaluate if a predicate defined later in time could also be used for an earlier invention. This is also highly interesting in relation to patenting where predicates can make a huge difference.

A funny thing to mention is that Bent Stumpe's first version of the touchscreen had nine programmable buttons and the next version had sixteen programmable buttons. Some modern day smartphones can hold sixteen apps per screen with four static extra apps. This gives twenty apps, which is the same as Bent

[96] *"Patent law states "On taking up an application for examination or a patent in a reexamination proceeding, the examiner shall make a thorough study thereof and shall make a thorough investigation of the available prior art relating to the subject matter of the claimed invention. This means that prior art could disqualify your application for a patent."* (Inventors, 2012, Definition Prior Art)

Stumpe's drawing for the X-Y touchscreen from 1977. This is illustrated by the following three pictures in which the difference is noticeable.


97


98

99

Russian designer Anton Repponen (Repponen, 2012, About / Contacts) have made his vision, as you can see below, of how Apple's iOS would have appeared if it had come out around 1986 and a designer from Zeusbox studio has made a version of how it would have looked in 1984. Off course this context is purely speculative. The interesting thing here is that it is in black and white, like the NESELCO Touch-Terminal's screen was in 1980. It is clear that the icons are placed in the same position on the grid on the two touchscreens.

(Zeusbox studio, 2012, 009 smb 1984) (Repponen, 2012, iOS-86)

Regarding to patenting it could be interesting to examine what it takes to make a new invention and thereby ask the question: What is a new invention? Especially in light of the fact that CERN did not take patents on their innovations in the 1970s. We could therefore have a new preconception that says patenting is very difficult and cost a lot of money. Therefore it is only possible to take patent for people or corporations with substantial economic resources.

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97 Photo: Bent Stumpe. The first version of CERN's touchscreen with 9 buttons.
(Engineering Weekly online, 2011, Kom bag om CERNs bedste opfindelser.)

98 The touchscreen with 16 programmable buttons. *"A close-up of the screen-based controls of the Touch Terminal for the AA[98]."*
(Stumpe, B. and Sutton, C., CERN Courier, 2010, The first capacitative touchscreens at CERN.)

99 Photo: Bent Stumpe. Bent Stumpe's drawing from 1977 of the X-Y touchscreen with 20 buttons. (Engineering Weekly online, 2011, Kom bag om CERNs bedste opfindelser.)

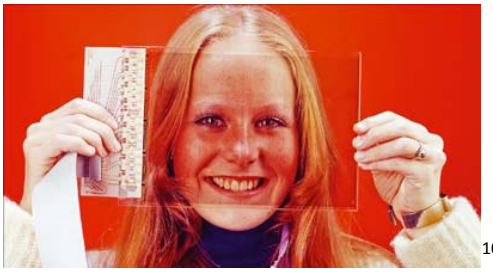
If we had access to people with expertise in this matter and to the original touchscreens we could use expert evaluations as a method to evaluate inventions. These experts could be Electro Engineers and people experienced in patent laws and regulations.

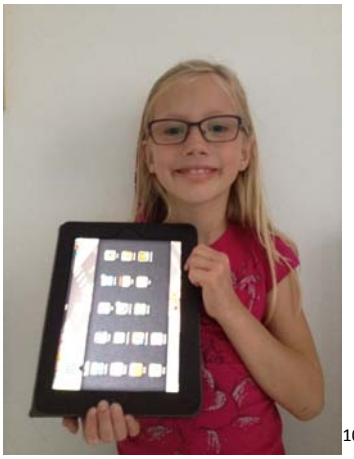
A study like this would somehow have to take the many different layers of patent laws into consideration. Patent offices are namely governmental or intergovernmental organizations (Wikipedia, 2012, Patent office). The Electro Engineers could evaluate on the technology aka the touchscreens and the patent examiners could evaluate on the Electro Engineers work plus supplement with their own knowledge about patenting.

In this project we can only speculate. If modern touchscreens are based on the work at CERN in the 1970s then CERN could have been very successful in regards to their Convention from 1953.

> *"The Organization shall have no concern with work for military requirements and the results of its experimental and theoretical work shall be published or otherwise made generally available."*
> (CERN, 1953, Convention for the establishment of a European organisation for nuclear research)

It is now obvious that the capacitive touchscreen has been made generally available[100].


101


102

Picture 1. (CERN Courier, 2010, The first capacitative touchscreens at CERN) Picture 2. (See footnote 55)

It is remarkable that a technology like the touchscreen which in the 1970s only existed in a handful control rooms, in recent years has got such a breakthrough. We know that various media have focus on this these days. Besides the ones we have used in this project we know that a book about the touchscreens is on its way[103] and that a popular science television channel will make a broadcast about the touchscreen innovations at CERN later this year.

We asked this supplementary question in our problem statement:

[100] Here we especially think of smartphones and tablet computers.
[101] Girl in the picture is Ina Douffiagues Stumpe holding the first version of CERN's touchscreen in 1973. Picture from CERN archive.
[102] Girl in the picture is Izabella Amorøe Hansen holding her iPad in August 2012. Picture taken by Jonas Stumpe.
[103] This is a book from an international publisher for professional and scholarly societies.

- What cultural barriers or potentials have influenced the history of this touchscreen?

The cultural aspect can affect employee's willingness to engage in technology transfer efforts, we found at least three vital factors, which was:

1. CERN's convention focuses on publishing experimental and theoretical work, which might to some extent, collide with Giovanni Anelli's agenda related to technology transfers.
2. Physicists' main agenda is being the first to publish, which does not leave much room for awaiting pending patent related paperwork.
3. During the 1970s and the 1980s employees were not economically encouraged to engage in transfer activities, any income they might have would be deducted in their salary. Engagements had to receive high-level approval before they could be undertaken.

There are also other organizational aspects. Henry Mintzberg defines the professional bureaucracy as being predominant among research institutions and hospitals, in the professional bureaucracy the decision-making is split among the professionals. This affects the dynamics within an organization.

A recent case is the development of Isolde, which is short for Isotope Separator On Line. The Danish magazine the Engineering Weekly online interviewed developer Helge Ravn in 2011. He talks about his work with Isotope and the way it is used at CERN. More importantly he also talks about the way that Isotope is not being used. The accelerator was build to support nuclear and solid state physics, just like the touchscreen. The Isolde accelerator produces rare radioactive isotopes that are said to be more effective then the radiation used in cancer treatments today. Helge Ravn says that if you used the accelerator properly it could be an important part of future cancer research, diagnosis and treatment.

> *"The accelerator is extremely expensive and a lot of research facilities can't afford a machine like that. That's why I feel that it is CERN's responsibility to help the industry and researchers with the delivery of isotopes to use in their medical research. It's also an excellent opportunity for CERN to gain some honour and glory.*[104]*"*
>
> *"Cancer research is not the purpose of CERN and it was my impression that nothing was allowed to surpass the LHC.*[105]*"*
> (Stage, M., 2011, Cern-dansker vil lave isotope til kræftbehandling uden bivirkninger)

The circumstances surrounding Isolde and the touchscreen are similar in many ways. An engineer has developed a technology that is far from using its potential. Is this really the best way to utilize available technologies at what should be a modern research facility? There is a technology ready for deployment and further more all the engineers included in our project have all been committed to exploit the technologies to their full potential. So what changes will CERN have to make to support current and future technologies?

[104] The original quote in Danish: *"Og eftersom det ikke er alle institutioner forundt at have sin egen – ekstremt dyre – accelerator, mener Helge Ravn, at det er Cerns pligt ikke blot at hjælpe industrien og forskerne med at levere isotoper til medicinsk forskning, men at det også er en oplagt muligt for at få mere hæder og ære i Cerns retning."*
[105] The original quote in Danish: *"Det er jo ikke Cerns formål at lave kræftforskning, og det var mit indtryk, at intet måtte overskygge LHC."*

However looking at the organization and culture is outside the scope of this project and outside our core competences, but it is an interesting topic for people with the right skills set to investigate further.

> *"The only thing left is a pretty big interest in what happened back then.*[106]*"*
> (Stumpe, B., 2012, Interview with Stumpe, B.)

[106] The original quote in Danish: *"Det eneste der er tilbage er en temmelig stor interesse for hvad der skete dengang."*

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Last but not least we would like to thank our kind advisor Paul Metelmann who is a source of inspiration. We know that it is not normal to thank your advisor in these projects but if not here then where?

We have always depended on the kindness of strangers, family, colleagues and friends.

You make us look good.

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Appendices

Appendix 1 – Source identification schemes

In this appendix we mainly describe the individual considerations.

The sources are our empirical data. The source identification schemes are as far as possible written in chronological order. Source type means that we have treated the source as either a relic or a narrative. In some cases as both. Texts written in italic are taken from the original source. In the schemes we treat the sources as individual and the more general considerations we have put in the source evaluation section in the report. We distinguish between first- and second-hand sources but most sources will have both features in regards to the context they get used in. This means that our classification of primary and secondary sources is indicative.

Source identification scheme	
Questions	**Answers**
Source name or title Identification: What?	*An Innovation In Control Panels For Large Computer Control Systems.* Used as a firsthand source.
Authorship: Writers: Who?	D. Fryberger and R. Johnson.
Source type: relic or narrative?	Concludes from relic.
Text type: What?	A publication/ paper in the IEEE Transactions on Nuclear Science. Volume 18, Issue 3. Pages 414 - 417.
Dating and chronology: When? Contemporaneity with events?	Probably produced before June 1971: From the paper: *© 1971 IEEE.* From the IEEE Xplore: *Date of Publication: June 1971.* http://ieeexplore.ieee.org/xpl/login.jsp?tp=&arnumber=4326077&url=http%3A%2F%2Fieeexplore.ieee.org%2Fxpls%2Fabs_all.jsp%3Farnumber%3D4326077
Localization: Where was it produced? Where was it found?	Maybe at *Stanford University, Stanford, California 94305.* It was found on the Joint Accelerator Conferences Website as an epaper: http://epaper.kek.jp/p71/PDF/PAC1971_0414.PDF About JACoW:

	http://www.jacow.org/ Copyright by IEEE. About IEEE: http://www.ieee.org/about/index.html History of IEEE: http://www.ieee.org/about/ieee_history.html
Purpose: Why was this source written? Are there hidden purposes?	To describe an innovation in form of a control panel for large computer control systems: *A device was required which would be at the same time compact, flexible, and (relatively) inexpensive. The touch panel was conceived and developed to answer these requirements.*
Analysis: From what material was it produced?	The following four references are listed at page 415 in the document: 1) Patent applied for. 2) S. K. Howry, R. Scho11, E. J. Seppi, M. Hu, D. Neet, "The SLAC beam switchyard control computer, " IEEE Trans. on Nuclear Science, NS-14, 3, 1066 (June 1967) 3) Lord Rayleigh, London Math. Soc. Proc. 17, 4 (1885). 4) There is now an extensive literature on Rayleigh waves. Cf. I. A. Viktorov, Rayleigh and Lamb Wave (Plenum Press, New York, 1967).
In what context was the source written? In what general context was the source written?	Probably in a scientific environment at Stanford University and Stanford Linear Accelerator Center.
Source tends: Derogatory, praising or both?	Praising.
Relation with other sources?	It is used as a reference in this document: Beck, F. and Stumpe, B. (1973): *Two Devices For Operator Interaction In The Central Control Of The New CERN Accelerator.* Bent Stumpe has knowledge of this article, as he is co-writer on the above document.

Source identification scheme	
Questions	**Answers**
Source name or title Identification: What?	*A Transparent Touch-Screen Device for Interactive Computer-Graphics Displays.* Used as a firsthand source.
Authorship: Writers: Who?	E.M. Mott.
Source type: relic or narrative?	Concludes from relic.
Text type: What?	A laboratory report: *Rutherford Laboratory Report.*
Dating and chronology: When? Contemporaneity with events?	Written before or during 1972: *1972.* *NAL LIBRARY JUN 8 1972.* (Stamp)
Localization: Where was it produced? Where was it found?	Maybe at the Rutherford Laboratory and/ or at the Science Research Council Physics Development Group, Rutherford High Energy Laboratory Chilton, Didcot Berkshire. It was found on the Fermi National Accelerator Laboratory site: http://lss.fnal.gov/archive/other1/rhel-r-248.pdf http://www.fnal.gov/
Purpose: Why was this source written? Are there hidden purposes?	From the abstract: *A unit is described which provides a simple and economic method of achieving operator interaction with a computer-graphic control system by only requiring the operator to touch the display screen. A system of intersecting light beams and detectors is used to identify the selected position. An application of the system is also described.*
Analysis: From what material was it produced?	There are no references in this report. There are the following acknowledgements: *The author acknowledges the encouragement and criticism given by J M Dickson and R H C Morgan during the development and report stages of this project.*
In what context was the source written? In what general context was the source written?	Probably in a science research environment at the Rutherford Laboratory.
Source tends: Derogatory, praising or both?	Praising.

Relation with other sources?	It is used as a reference in this document: Beck, F. and Stumpe, B. (1973): *Two Devices For Operator Interaction In The Central Control Of The New CERN Accelerator.* Bent Stumpe has knowledge of this source, as he is co-writer on the above document.

Source identification scheme	
Questions	**Answers**
Source name or title Identification: What?	*Proposed outlay for a fast interactive computer display system.* Used as a firsthand source.
Authorship: Writers: Who?	Bent Stumpe, Electrical Engineer from CERN.
Source type: relic or narrative?	Concludes from relic.
Text type: What?	Structured handwritten note from a meeting between Frank Beck and Bent Stumpe.
Dating and chronology: When? Contemporaneity with events?	11/3-1972. Written on the exact data. *11.03.1972.*
Localization: Where was it produced? Where was it found?	This document was produced at CERN. We know that it is a part of CERN's Document Server and therefore is must have a naming convention but we could not get hold of the original 16-pages document. This document was found on the internet on Symmetry Magazines webpage: http://www.symmetrymagazine.org/images/201006/logbook_image.jpg About the CDS: http://information-technology.web.cern.ch/services/fe/cern-document-server
Purpose: Why was this source written? Are there hidden purposes?	This document was written as an idea to make a new control layout for the Super Proton Synchrotron particle accelerator (SPS) at CERN.
Analysis: From what material was it produced?	According to the last two lines of text in this document, it was produced from an idea by Frank Beck. The document does not tell us if this idea was inspired by other documents or if it is Frank Becks own idea.
In what context was the source written? In what general context was the source written?	It was written in a scientific environment at CERN. General context: It was written at a time where CERN needed a new technology for controlling the SPS.
Source tends: Derogatory, praising or both?	There is a tendency for praising because this the first step of a new idea for an invention at CERN.

Relation with other sources?	It is mentioned in the CERN Courier in an article from March 2010: Stumpe, B. and Sutton, C. (31 March, 2010): *The first capacitative touchscreens at CERN.* It is mentioned in Symmetry magazine in a logbook article from June 2010: Symmetry magazine (June, 2010): *Logbook: CERN touchscreen.* It is mentioned in the Wikipedia article about Multi-touch: Wikipedia (2012): *Multi-touch.*

Source identification scheme	
Questions	**Answers**
Source name or title Identification: What?	*Two Devices For Operator Interaction In The Central Control Of The New CERN Accelerator.* Used as a firsthand source.
Authorship: Writers: Who?	Bent Stumpe, Electrical Engineer from CERN and Frank Beck in charge of the central control hub in the SPS controls room. Both part of the control group.
Source type: relic or narrative?	Concludes from relic.
Text type: What?	Divisional Report of CERN (Yellow), which are the highest classification for documents at CERN. *Yellow Reports have to be approved by the CERN Reports Editorial Board (CREB). The criteria used by the committee include a requirement of a strong and direct link to CERN, and a significant and lasting interest of the material to a broad community at CERN. In addition to stringent requirements on the scientific and technical content, the presentational quality must be of a high standard.* A part of the CERN report series also known as a Yellow Report: http://library.web.cern.ch/library/library/yellow_reports_about.html
Dating and chronology: When? Contemporaneity with events?	Between May 24th and June 1973. Must logically have been written before that time. *Geneva, 1973.* *Juin 1973.* *Laboratory II Control Group 24 May 1973.*
Localization: Where was it produced? Where was it found?	We can see that it was written at CERN because of its naming convention: *CERN-73-06.* *H/537 – 1100 – juin 1973.* *© Copyright CERN Genève, 1973.* This source was found on the internet and is a part of the CERN Document Server (CDS): http://cdsweb.cern.ch/record/186242?ln=en City: Geneva. About the CDS: http://information-technology.web.cern.ch/services/fe/cern-document-server

Purpose: Why was this source written? Are there hidden purposes?	To make a more agile control method for the SPS. Hidden purpose: If the authors would succeed in making this control device then their chances of promotion or getting recognition could increase, and that could bring them further in their career. This could be a hidden purpose.
Analysis: From what material was it produced?	There are three references at the bottom of the document: 1) Mattis, J.A. and Camenzind, H.R.(1973): A New phase-locked loop with high stability and accuracy, signetics Inc. Applications Note. 2) Mott, E.M. (1972): A Transparent Touch-Screen Device for Interactive Computer-Graphics Displays. RHEL/R 248, February 1972. 3) Fryberger, D. and Johnson, R. (1971). IEEE Trans. Nuclear Sci. NS 18 No. 3 (1971).
In what context was the source written? In what general context was the source written?	It was written in a scientific environment at CERN. General context: It was written at a time where CERN needed a new technology for controlling the SPS.
Source tends: Derogatory, praising or both?	There is a tendency for praising because this the first step of a new idea for an invention at CERN.
Relation with other sources?	Based on this document: Stumpe, B. (1972) *Proposed outlay for a fast interactive computer display system.* As reference in this doctor thesis: Beck, F. (April 1976): *The Design And Construction Of A Control Centre For The CERN SPS Accelerator.* As reference at the bottom of this internal group report from CERN: Stumpe, B. (1977) *A New Principle for an X-Y Touch Screen.* In the references in this thesis: Petersen, P. (1983-84) *Man – Machine Communication.* It is mentioned in the CERN Courier in an article from march 2010: Stumpe, B. and Sutton, C. (Mar 31, 2010): *The first capacitative touchscreens at CERN.* It has relation to our interviewee Bent Stumpe. There are possible more documents where this report is used as a reference. Some we could not get and other may exist without our knowledge.

Source identification scheme	
Questions	**Answers**
Source name or title Identification: What?	*The Design And Construction Of A Control Centre For The CERN SPS Accelerator.* Used as a firsthand source.
Authorship: Writers: Who?	Frank Beck, Membre Permanent du CERN.
Source type: relic or narrative?	Concludes from relic.
Text type: What?	Doctor thesis: *These présentée a L'universite Louis Pasteur de Strasbourg pour obtenir le grade de Docteur de L'universite Louis Pasteur section: sciences par Frank Beck.*
Dating and chronology: When? Contemporaneity with events?	April to June 17th 1976. Must logically have been written before that time. *Soutenue le 17 Juin 1976 devant la Commission d'examen.* *April 1976.*
Localization: Where was it produced? Where was it found?	It could have been produced in Strasbourg: *A L'Universite Louis Pasteur de Strasbourg.* Or maybe at CERN: *Membre Permanent du CERN.* It can be found on the CERN Document Server: http://cdsweb.cern.ch/record/1440540/files/Thesis-1976-Becklastversion.pdf Reference code: *LabII-CO 76-01.* About the CDS: http://information-technology.web.cern.ch/services/fe/cern-document-server
Purpose: Why was this source written? Are there hidden purposes?	It was written to get a doctor's degree: *pour obtenir le grade de Docteur de L'Universite Louis Pasteur. Section: Sciences.*
Analysis: From what material was it produced?	There are 33 references in the thesis and 12 commercial references. References: 1) *The 300 GeV programme*, CERN Report 1050, January 1972. 2) P. Adams, *K9 computer software system*, Report

RHEL/R240 (1971).

3) B.L. Hartway, J. Bergstein and C.M. Plopper, *The central control room man-machine interface at the Clinton P. Anderson Meson Physics Facility (LAPF),* Proc. Particle Accelerator Conf., San Francisco, 1973 (IEEE, New York, 1973), p. 633.

4) C.S. Taylor, *Linac operation and controls*, CERN MPS Linac Note 71-14 (1971).

5) L.A. Klaisner, P. Mellick, K. Rich, S.H. Smith and M. Stom, Central control system of the NAL accelerator, Proc. Particle Accelerator Conf., Chicago, 1971 (IEEE, New York, 1971), p. 424.

6) K.A. Fox, M.P. Pasturel and P.S. Showman, *A human interface for automatic measurement systems*, Hewlett-Packard Journal, Vol. 23, No. 8, April 1972.

7) M. C. Crowley-Milling, *A digital control system designed for operator convenience*, Report DNPL TM/80 (1971).

8) E.A. Gurd, E.A. Drawneck and B.S. Walker, *A multiple console interactive graphics system*, Proc. Internat. Conf. on Computer Systems and Technology, London, 1974 (Instn. Elect. Engrs. Conf. Publ. No. 121, London, 1974), p. 173.

9) J. Standeven, S. Mihailovic and D.B.G. Edwards, *Multiconsole-computer display system utilizing TV techniques*, Proc. Instn. Elect. Engrs. 11S, 1375 (1968).

10) R.J. Scott-Kerr, *Computer-aided control at Pembroke power station*, Electronics and Power, March 1972, p. 87.

11) J.T. Hyman, *The computer control system for the SPS*, Proc. Internat. Conf. on High-Energy accelerators, Stanford, 1974 (USAEC, Washington, 1974), p. 503.

12) M.C. Crowley-Milling, J.T. Hyman and G.C. Shering, *The NODAL system for the SPS*, Report

CERN Lab II-C0/74-2 (1974).

13) *Handbook of human engineering data* (US Naval Training Device Center, Port Washington, NY, 2nd ed. (rev.) 1952, reprinted 1960).

14) *Human engineering guide to equipment design* (McGraw-Hill, Inc., New York, 1963).

15) E. Edwards, *Ergonomics in control*, Proc. Instn. Elect. Engrs. 120, 1181 (1973).

16) J. Croney, *Anthropometries for designers* (B.T. Batsford, Ltd., London, 1971).

17) *Der "vermessene" Mensch*, Anthropometrie in Kunst und Wissenschaft (Heinz Moos Verlag, Munich, 1973).

18) *The Nordcom system*, Norsk Data Elektronikk A.S. (see Ref. C1).

19) G. Menzies, H.A. O'Donnel, A.J. Perry and C.J. Robinson, *Interactive video-graphic display system for use with cathode-ray tube scanning devices*, J. Phys. E 8, 676 (1975).

20) A. Muser and J.R. Lutz, *Visualisation polychrome par mosaïque*, Nuclear Instrum. Methods 113, 131 (1973).

21) *Private communication from Dr. C. Clutterbuck*, Royal Radar Establishment, St. Andrews' Road, Great Malvern, Worcs., WR14 3PS, United Kingdom; *and Private communication from Dr. C.D. Reid*, Atomic Weapons Research Establishment, Aldermaston, Berks., R67 4PH, United Kingdom.

22) C. Dean, *Computer-controlled scoreboards at the Olympic Games*, Electronics and Power, Aug. 1972, p. 322.

23) Anon., *Liquid crystal materials and device developments*, Electronic Engng., Aug. 1974, p. 30.

24) I. Gorog, *Cathodochromic image displays*, Appl. Optics 9, 2243 (1970).

25) P.T. Bolwijn and R.A. van Doorn, *On the selective erasure of cathodochromic image displays*, J. Phys. D 5, 896 (1972).

26) R.C. Duncan, B.W. Faughan and W. Phillips, *Photochromics and cathodochromics*, Appl. Optics 9, 2236 (1970).

27) Z.J. Kiss and W. Phillips, *Cathodochromism in photochromic materials*, Phys. Rev. 180,

924 (1969).

28) C. Christensen and E.N. Pinsen, *Multifunction graphics for a large computer system*, Proc. Fall Joint Computer Conf., Anaheim, Calif., 1967 (AFIPS, New York, 1967), p. 697.

29) C. Brewer and C.C.M. Parish, *An experimental data display autocode (EDDA)*, Central Electricity Generating Board Report RD/L/R/1617 (1969).

	30) E.M. Mott, *A transparent touch-screen device for interactive graphics displays*, Report RHEL/R248 (1972). 31) B.L. Hartway, *A compact programmable control panel*, Proc. Particle Accelerator Conf., San Francisco, 1973 (IEEE, New York, 1973), p. 531. 32) *Proc. Internat. Conf. on Displays*, Loughborough, 1971 (Instn. Elect. Engrs. Conf. Publ. No. 80, London, 1971). 33) F. Beck and B. Stumpe, *Two devices for the operator interface of the new CERN accelerator*, Report CERN 73-6 (1973). Commercial References: C 1 *A/S Norsk Data Elektronikk*, Økernveien 145, Oslo 5, Nonvay. C 2 *Traitement Infonnatique Techniques Nouvelles S.A.,* 1, rue Gustave-Eiffel, 91420 Morangis, France. C 3 *Christian Røvsing A/S*, 46b Marielundvej, Herlev, Denmark. C 4 *Data Disk Inc.*, 686 W. Mande Ave., Sunnyvale, Calif. 94086, USA. C 5 *Princeton Electronic Products*, Inc., PO Box 101, New Brunswick, NJ 089902, USA. C 6 *Owens-Illinois, Inc.*, PO Box 1035, Toledo, Ohio 43666, USA. C 7 *Sony Corporation*, 7-35 Kitashinagawa 6-Chome, Shinagawa-Ku, Tokyo 141, Japan. C 8 *Conrac Corp.*, 600 N. Rimsdale Avenue, Covina, Calif. 91722, USA. C 9 NV Cobar Barco Electronic, Sevenslaan 8500, Kortrijk, Belgium. C10 *General Electric Co., Ltd.*, 1 Stanhope Gate, London W1A 1EH, UK. C11 *Ferroperm Aktieselskab*, Stubbeled 7, Trørød 2950 Vedbaek, Denmark. C12 *Stabletron, Ltd.*, 266 Hunts Pond, Fareham, Hampshire P014 4PH, UK.
In what context was the source written? In what general context was the source written?	If it were written in Strasbourg at L'Universite Louis Pasteur or at CERN, it would in both cases be in a scientific environment.

	General context: It was written about the same time as the CERN SPS started operation, which was in 1976.
Source tends: Derogatory, praising or both?	Highly praising.
Relation with other sources?	It makes a reference to: Beck, F. and Stumpe, B. (1973): *Two Devices For Operator Interaction In The Central Control Of The New CERN Accelerator.* It has relation to Frank Beck. It has relation to our interviewee Bent Stumpe.

Source identification scheme	
Questions	**Answers**
Source name or title Identification: What?	*A New Principle for an X-Y Touch Screen.* Used as a firsthand source.
Authorship: Writers: Who?	Bent Stumpe, Electrical Engineer at CERN.
Source type: relic or narrative?	Concludes from relic.
Text type: What?	Internal Group Report of CERN. Definition by Bent Stumpe.
Dating and chronology: When? Contemporaneity with events?	March 16th 1977. Must logically have been written before that time. *16 March 1977.*
Localization: Where was it produced? Where was it found?	We can see that it was written at CERN because of its naming convention: *SPS/AOP/BS/jf.* This source was found on the internet and is a part of the CERN Document Server (CDS): http://cdsweb.cern.ch/record/1266588?ln=en City Geneva. About the CDS: http://information-technology.web.cern.ch/services/fe/cern-document-server
Purpose: Why was this source written? Are there hidden purposes?	To further develop the touchscreen invented at CERN and first mentioned in a handwritten note in 1972. Hidden purpose: Maybe the touchscreen development had become a passion of Bent Stumpe at that time because he could see that it had a bigger potential. Therefore he might have had a personal interested in making another new invention although he knew that it would be difficult because of the success with the first version of the capacitive touchscreen.
Analysis: From what material was it produced?	It has 2 references at page 8 of the report: 1) Beck, F. and Stumpe, B. (1973): *Two Devices For Operator Interaction In The Central Control Of The New CERN Accelerator.* CERN – Service d'Information scientifique – H/537 – 1100 – juin 1973. CERN 73-6. Laboratory II Control Group 24 May 1973. Geneva 1973. Divisional Report of CERN (Yellow). 2) Pignard, C. (1977): *Un nouveau circuit détecteur pour*

	l'écran sensitive digital (Touch Screen). PS/LIN/Note 77-1, 6 javier 1977.
In what context was the source written? In what general context was the source written?	It was written in a scientific environment at CERN. General context: It was written at a time when CERN did not need a new technology for controlling the SPS. CERN was satisfied with the first version of the capacitive touchscreen.
Source tends: Derogatory, praising or both?	There is a tendency for praising because this further development of an invention at CERN.
Relation with other sources?	It has relation to our interviewee Bent Stumpe. There are references at two Wikipedia sites: Wikipedia (2012): *Touchscreen.* Wikipedia (2012): *Multi-touch.*

Source identification scheme	
Questions	**Answers**
Source name or title Identification: What?	*How CERN broke the software barrier.* Used as a firsthand source.
Authorship: Writers: Who?	Dr. Michael Crowley-Milling
Source type: relic or narrative?	Concludes from narrative.
Text type: What?	Article from the magazine New Scientist: http://www.newscientist.com/data/html/ns/mediacenter/uk/intro.jsp
Dating and chronology: When? Contemporaneity with events?	September 29th 1977: *29 September 1977, Vol 75, No 1071 Weekly 35p.*
Localization: Where was it produced? Where was it found?	Possible at CERN, but this is not described in the source. It can be found on Google books: http://books.google.dk/books?id=CDpCvfUcbGkC&pg=PA790&lpg=PA790&dq=How+CERN+broke+the+software+barrier.&source=bl&ots=KtksXYAdXt&sig=gWj7iGu3cWMUGAPt4wXAuutmDqM&hl=da&sa=X&ei=qY8nUNaEIYrptQbV5YGgCA&ved=0CD0Q6AEwAA#v=onepage&q=How%20CERN%20broke%20the%20software%20barrier.&f=false It can also be found on the CERN Document Server but can only be accessed by CERN employees: http://cdsweb.cern.ch/record/713602 Report number: *PRESSCUT-1977-009.* About the CDS: http://information-technology.web.cern.ch/services/fe/cern-document-server
Purpose: Why was this source written? Are there hidden purposes?	This article was written to tell the story of how CERN used a new computer technique to control Europe's big accelerator. Told by a firsthand witness to the events to the magazine New Scientist.
Analysis: From what material was it produced?	Form the article we cannot see form what material it was produced. But we know the Michael Crowley-Milling wrote some documents at CERN in the 1970s and that this article probably is based on and inspired by those and of those by the other sources, Frank Beck

	and not least Bent Stumpe.
In what context was the source written? In what general context was the source written?	Most likely it was written in a scientific environment at CERN or somewhere in the United Kingdom because it's the home of New Scientist magazine. General context: It was written after the implementation of the control system for the SPS.
Source tends: Derogatory, praising or both?	Significantly praising because the head of the super proton synchrotron division at CERN did write it and in an international science magazine.
Relation with other sources?	Bent Stumpe knew Michael C. Crowley-Milling from CERN and probably has knowledge of this article. Michael C. Crowley-Milling wrote the recommendation document of Bent Stumpe: Crowley-Milling, M.C. (1978): *Recommandation.*

Source identification scheme	
Questions	**Answers**
Source name or title Identification: What?	*Experiments to find a manufacturing process for an X-Y touchscreen.* Used as a firsthand source.
Authorship: Writers: Who?	Bent Stumpe, Electrical Engineer from CERN. In addition to the above there seems to be more contributors for this report. The following is listed on page 1: *Present:* *Dr. P. Holl – Polymer-Physik* *E. Föll – Polymer-Physik* *Eng. W. Zeh – Firm Otto Dürr KG, Anlagen für Oberflächentechnik, Stuttgart.* All three contributors are also mentioned in the acknowledgements section of the document.
Source type: relic or narrative?	Concludes from relic.
Text type: What?	Internal Group Report of CERN.
Dating and chronology: When? Contemporaneity with events?	Most logically have been written between January 26th - February 6th 1978. *Submitted 6. February 1978 based on a visit to Germany from 26 — 27 January 1978.*
Localization: Where was it produced? Where was it found?	We can see that it was written at CERN because of its naming convention: *SPS-AOP-BS-jf-B-48.* Report on a visit to Polymer-Physik GmbH, Derendingn, Germany. Produced at CERN. Can be found at the CERN Document Server: http://cdsweb.cern.ch/record/1266589/ City: Geneva. About the CDS: http://information-technology.web.cern.ch/services/fe/cern-document-server
Purpose: Why was this source written? Are there hidden purposes?	It was written to find a method to put the capacitive touchscreen made at CERN into production.
Analysis: From what material was it produced?	There is only one reference in this document: Stumpe, B. (1977) *A New Principle for an X-Y*

	Touch Screen. We can see that it is produced at CERN.
In what context was the source written? In what general context was the source written?	It was written in a scientific environment at CERN and maybe also during the visit to Germany.
Source tends: Derogatory, praising or both?	Praising.
Relation with other sources?	No sources written after this document were found in our research. The mentioned contributors in the authorship section of this document are a potential source but we could not locate them in our research.

Source identification scheme	
Questions	**Answers**
Source name or title Identification: What?	*Recommandation.* Used as a firsthand source.
Authorship: Writers: Who?	M.C. Crowley-Milling, Leader SPS Division, European Organization for Nuclear Research.
Source type: relic or narrative?	Concludes from narrative.
Text type: What?	A two page official recommendation of Bent Stumpe from the at that time leader of the SPS Division.
Dating and chronology: When? Contemporaneity with events?	12. September 1978: *12 September 1978.*
Localization: Where was it produced?	It was produced at CERN. It has the correct CERN numbering: *SPS-DI/MCCM/ tr.*
Purpose: Why was this source written? Are there hidden purposes?	It was written, so Bent Stumpe could get the LK-NES price for the year 1978.
Analysis: From what material was it produced? Where was it found?	No references in the document, but it must be based on M.C. Crowley-Millings own work at CERN and Bent Stumpe's work at CERN. It was found in Bent Stumpe's personal archive in Geneva.
In what context was the source written? In what general context was the source written?	In a scientific environment at CERN. General context: It was written approximately two years after the SPS started operating and used the control system.
Source tends: Derogatory, praising or both?	Highly praising.
Relation with other sources?	It has relation with Bent Stumpe. It must have relation to a lot of our other earlier sources from CERN because it describes the work done in them.

Source identification scheme	
Questions	**Answers**
Source name or title Identification: What?	*The first touch-terminal developed by CERN and commercialized by NESELCO in 1980.* Used as a firsthand source.
Authorship: Writers: Who?	Bent Stumpe, Electrical Engineer from CERN: No author name in the document but on the CERN Document Server in the detailed record is written: *Author(s) Stumpe, Bent (CERN).*
Source type: relic or narrative?	Concludes from relic.
Text type: What?	Page 1 out of 2 is from the CERN Courier page *266*. It could be an advertisement. *Courier CERN.* Page 2 seems like a pricelist for NESELCO: *PRICE LIST FOR NESELCO CAMAC.*
Dating and chronology: When? Contemporaneity with events?	Page 1 was made before September 1980: *septembre 1980.* Page 2s was made before July 1980: *1 JULY 1980.* Page 2 has also got a stamp saying *16 OKT. 1980.*
Localization: Where was it produced? Where was it found?	Both page 1 and 2 was probably produced by NESELCO. Page 1 was a part of the CERN Courier. From the CDS we can conclude that page 2 also were a part of the CERN Courier: *CERN Cour. 20 (1980) pp.266.* This source was found on the internet and is a part of the CERN Document Server (CDS): http://cdsweb.cern.ch/record/1268401?ln=en About the CDS: http://information-technology.web.cern.ch/services/fe/cern-document-server
Purpose: Why was this source written? Are there hidden purposes?	Page 1 was written as an advertisement. Page 2 was written to sell NESELCO's products.
Analysis: From what material was it produced?	There are no references in the document.
In what context was the source written?	We presume that both pages are made by NESELCO and therefore made by a manufacturing company.

In what general context was the source written?	Probably based on the work done CERN.
Source tends: Derogatory, praising or both?	Highly praising.
Relation with other sources?	It has relation with Bent Stumpe, as he according to the CERN Document Server is the author of the document. We presume that Bent Stumpe is not the author but that the document is documentation of one of the first touchscreen computers made based on the work done at CERN. No later references could be found.

Source identification scheme	
Questions	**Answers**
Source name or title Identification: What?	*Man – Machine Communication.* Used as a firsthand source.
Authorship: Writers: Who?	Peter Petersen student from Aalborg Universitetscenter.
Source type: relic or narrative?	Concludes from relic.
Text type: What?	A research project. From the document: *Afgangsprojekt (Thesis). Aalborg Universitetscenter (AUC), Det tekniske-naturvidenskabelige fakultet.* *This report is collaboration between AUC and CERN.*
Dating and chronology: When? Contemporaneity with events?	1983-84. *1. June 1983 to 11. January 1983.*
Localization: Where was it produced? Where was it found?	Produced during a stay at CERN in 12 copies. Has an official CERN numbering: *CERN-THESIS-84-001.* Can be found at the CERN Document Server: http://cdsweb.cern.ch/record/1311136?ln=en City: Geneva. About the CDS: http://information-technology.web.cern.ch/services/fe/cern-document-server
Purpose: Why was this source written? Are there hidden purposes?	To get a university degree from Aalborg Universitetscenter. Hidden purpose: This is a thesis and the student therefore has an interest in making the project sound interesting.
Analysis: From what material was it produced?	There are 13 references at page 50 in the document: 1) Beck, F. and Stumpe, B. (1973): *Two devices for operator interaction in the central control of the new CERN accelerator.* CERN 73-6. 2) Crowley-Milling, M.C. (1975): *The design of the control system for the SPS.* CERN 75-20. 3) Beck, F. (1976): *The design and construction of a control centre for CERN SPS accelerator.* CERN-SPS-CO/76-1. 4) Stumpe, B. (1978): *Control room technique for*

	CERN's 400 GeV proton synchrotron. CERN-SPS/aop/co/Note/78-38. 5) Stumpe, B. (1981): *Current and future Touch Screen Technology for the M Machine Interface.* CERN-SPS/AOP/Note/81-15. 6) Pignard, C. (1977): *Un nouveau detecteur pour l'ecran sensitive digital.* CERN-PS/LIN/Note/77-1. 7) Motorola. (1982): *16 – Bit Microprocessor.* User's Manual. Third edition. 8) Atomic Energy Committee on Nuclear Instrument Modules. (1972): *CAMAC A Modular Instrumentation system for Data Handling.* EUR 4100e Revised version. 9) Stumpe, B. (1983): *Hardware description of an MC68000 (Fast) Independent Crate Controller – ICC68000 (SPS 3350).* CERN SPS/AOP/Note/81-13 Rev. 10) Rijllart, A. (1982): *An MC68000 Stand Alone CAMAC Microprocessor system.* CERN-EP/82-202. 11) Von Eicken, H. (1980): *M68MIL, A cross macro assembler for the Motorola M68000.* CERN-DD/80-26. 12) Crowley-Milling, M.C. and Sherring, G.C. (1978): The NODAL system for the SPS. CERN-SPS/78-07. 13) Andersen, P.S. (1982): *Programming the SPS-consoles.* CERN SPS/ACC/82-1.
In what context was the source written? In what general context was the source written?	It was written during a study period at CERN and in a scientific environment. General context: At this time the SPS and the control system had been up and running for some years.
Source tends: Derogatory, praising or both?	Praising.
Relation with other sources?	It has relation with previous sources. Look at in the analysis section of this scheme. It has relation to our interviewee Bent Stumpe. No sources written after this document were found in our research. Writers in the reference section of this document are a potential source but we could not locate more of them in our research.

Source identification scheme	
Questions	**Answers**
Source name or title Identification: What?	*Logbook: CERN touchscreen.* Used as a both a second-hand and a firsthand source.
Authorship: Writers: Who?	No person's gets credit for the authorship, but it has been adapted from an article by Bent Stumpe and Christine Sutton. Therefore you could say that Symmetry magazine is the author. *Symmetry is a magazine about particle physics and its connections to other aspects of life and science.* *http://www.symmetrymagazine.org/cms/?pid=1000001*
Source type: relic or narrative?	Concludes from mainly narrative. But is has a reference to a handwritten note by Bent Stumpe which we use as a relic.
Text type: What?	Article from Symmetry magazines logbook.
Dating and chronology: When? Contemporaneity with events?	Written before June 2010: *june 10.* *© 2010 symmetry.*
Localization: Where was it produced? Where was it found?	Both at CERN Courier qua the adaption from the CERN Courier and at Symmetry magazine. It was found on Symmetry magazines website: http://www.symmetrymagazine.org/cms/?pid=1000821
Purpose: Why was this source written? Are there hidden purposes?	It was written to tell the story of the roots of the CERN touchscreen: *On March 11, 1972 CERN engineer Bent Stumpe proposed a new type of interactive computer display for controlling the lab's new Super Proton Synchrotron accelerator. His 16-page handwritten proposal describes what was apparently the world's first capacitive touchscreen, a technology now widely used in ticket machines and smart phones.*
Analysis: From what material was it produced?	It was produced by an article from the CERN Courier and this it was produced from that article:

	Adapted from an article by Bent Stumpe and Christine Sutton in the CERN Courier. That article has the following references: Further reading 1) F Beck and B Stumpe 1973 CERN 73-6. 2) Michael Crowley-Milling 1977 New Scientist 75 29 September 790. 3) D Fryberger and R Johnson 1971 Nuclear Science IEEE Transactions 18 414.
In what context was the source written? In what general context was the source written?	In a scientific environment at CERN and at Symmetry magazine.
Source tends: Derogatory, praising or both?	Praising.
Relation with other sources?	It has relation to Bent Stumpe. It has relation to this source: Stumpe, B. (1972) *Proposed outlay for a fast interactive computer display system.* CERN 11.03.1972. Page 1. Handwritten note from a meeting between Bent Stumpe and Frank Beck. No later references could be found.

Source identification scheme	
Questions	**Answers**
Source name or title Identification: What?	*Another of CERN's many inventions!* Used as a second-hand source though quotes are firsthand sources.
Authorship: Writers: Who?	CERN Bulletin
Source type: relic or narrative?	Concludes from narrative.
Text type: What?	A newsletter: A *bulletin* in the CERN Document Server. Resembles a magazine article. Based on an interview with Bent Stumpe.
Dating and chronology: When? Contemporaneity with events?	Written before March 22nd 2010: *12/2010 & 13/2010, Mar 22 2010.* At the bottom of the webpage you can see that it has been last modified 18 February 2011. *Record created 2010-03-16, last modified 2011-02-18.*
Localization: Where was it produced? Where was it found?	It was produced at CERN and based on a CERN Yellow Report. This source was found on the internet and is a part of the CERN Document Server (CDS): http://cdsweb.cern.ch/record/1248908/ About the CDS: http://information-technology.web.cern.ch/services/fe/cern-document-server
Purpose: Why was this source written? Are there hidden purposes?	To tell the story of *the capacitive touchscreens invented for the consoles of the SPS Control Room in 1973.*
Analysis: From what material was it produced?	There is one reference at the bottom: *Further reading: CERN Yellow Report.* It links to this webpage: http://cdsweb.cern.ch/record/186242/files/p1.pdf From this webpage you can download the following reference in PDF format: Beck, F. and Stumpe, B. (1973): *Two Devices For Operator Interaction In The Central Control Of The New CERN Accelerator.* CERN – Service d'Information scientifique – H/537 – 1100 – juin 1973. CERN 73-6.

	Laboratory II Control Group 24 May 1973. Geneva 1973. Divisional Report of CERN (Yellow).
In what context was the source written? In what general context was the source written?	In a scientific environment at CERN.
Source tends: Derogatory, praising or both?	Praising.
Relation with other sources?	It has relation to Bent Stumpe. Maybe Giovanni Anelli knows about this bulletin. No later references could be found.

Source identification scheme	
Questions	**Answers**
Source name or title Identification: What?	*The first capacitative touchscreens at CERN.* Used as a second-hand source though quotes are firsthand sources.
Authorship: Writers: Who?	Bent Stumpe retired Electrical Engineer from CERN and Christine Sutton editor of the CERN Courier: *About the author* *Bent Stumpe and Christine Sutton, CERN.* CERN Courier team: http://cerncourier.com/cws/our-team
Source type: relic or narrative?	Concludes from narrative.
Text type: What?	An article in the CERN Courier. *CERN Courier* is an *International Journal of High-Energy Physics.*
Dating and chronology: When? Contemporaneity with events?	Written shortly before: *Mar 31, 2010.* (Release date)
Localization: Where was it produced? Where was it found?	At the CERN Courier at CERN. This source was found on the internet and is a part of the CERN Courier: http://cerncourier.com/cws/article/cern/42092
Purpose: Why was this source written? Are there hidden purposes?	It was written to tell the story *of what was probably the world's first capacitative touchscreen, the forerunner to the screens on the latest handsets.* CERN could tell about this story to get credit for and awareness of their prior inventions.
Analysis: From what material was it produced?	The following 3 references are at the bottom of the article: Further reading 1) F Beck and B Stumpe 1973 CERN 73-6. 2) Michael Crowley-Milling 1977 New Scientist 75 29 September 790. 3) D Fryberger and R Johnson 1971 Nuclear Science IEEE Transactions 18 414.
In what context was the source written? In what general context was the source written?	In a scientific environment at CERN.
Source tends:	Praising.

Derogatory, praising or both?	
Relation with other sources?	It has relation to Bent Stumpe. Maybe Giovanni Anelli knows about this bulletin. It is used as a reference in this source: Symmetry magazine (June, 2010): *Logbook: CERN touchscreen.* Volume 7, issue 3, june 10. Dimensions of particle physics. A joint Fermilab/ SLAC publication. http://www.symmetrymagazine.org/cms/?pid=1000821 Accessed: 31/7-2012. No later references could be found.

Source identification scheme	
Questions	**Answers**
Source name or title Identification: What?	*Comparative Study of Various Touchscreen Technologies.* Used as a second-hand source.
Authorship: Writers: Who?	*Mudit Ratana Bhalla Dept. of Computer Science and Applications, Dr.H.S.Gour Central University, Sagar (M.P.) and Anand Vardhan Bhalla Dept. of Electronics and Telecommunication, B.T.I.R.T Engineering College, Sagar (M.P.)*
Source type: relic or narrative?	Concludes from narrative. It could have been a relic also, but it is written more like an article than a thesis though it is structured like a thesis.
Text type: What?	Scientific article in the International Journal of Computer Applications.
Dating and chronology: When? Contemporaneity with events?	Written before September 2010: *September 2010.*
Localization: Where was it produced? Where was it found?	It was produced at the International Journal of Computer Applications: http://www.ijcaonline.org/ It can be found on the International Journal of Computer Applications website: http://www.ijcaonline.org/volume6/number8/pxc3871433.pdf
Purpose: Why was this source written? Are there hidden purposes?	It was written to compare the different types of touchscreen technologies.
Analysis: From what material was it produced?	There are 16 references in this document: [1) Bent STUMPE (1978), "Experiments to find a manufacturing process for an X-Y touchscreen", CERN. 2) Bent STUMPE "A new principle for X-Y touch system"CERN. 3) Beyers, Tim "Innovation Series: Touch screen Technology". 4) Frank BECK & Bent STUMPE (24 May 1973), "Two devices for operator interaction in the central control of the new CERN accelerator", CERN. 5) Holsinger, Erik. (1994) "How Multimedia Works". Emeryville, CA: Ziff-Davis Press.

	6) Keuling, Christopher "Touchscreens Press Deep Into Consumer Electronics". ECN Magazine. 7) Larry K. Baxter (1996). "Capacitive Sensors". John Wiley and Sons. 8) Lunney, Kellie. (February 24, 2000). "Texans get touchscreen access to government". 9) Mayhew, D. J. (1992). "Principles and guidelines in software user interface design". Englewood Cliffs: Prentice Hall. 10) Minsky, M.R "Manipulating simulated objects with realworld gestures using a force and position sensitive screen". Computer Graphics. 11) Patschon, Mark (1988-03-15). "Acoustic touch technology adds a new input dimension". Computer Design. 12) Potter, R.; Weldon, L. & Shneiderman, B. (1988). "Improving the accuracy of touchscreen: An experimental evaluation of three strategies". Washington, DC: ACM Press. 13) Sears, A.; Plaisant, C. & Shneiderman, B. (1992). "A new era for high precision touchscreens". 14) Sears, A.; Shneiderman, B. (1991). "High precision touchscreen: Design strategies and comparison with a mouse". Int. J. of Man-Machine Studies 15) Shneiderman, B. (1987). "Designing the user interface: Strategies for effective human-computer interaction". Reading, MA: Addison-Wesley. 16) Wilson, Tracy. "HowStuffWorks "Multi-touch Systems".
In what context was the source written? In what general context was the source written?	In a scientific context.
Source tends: Derogatory, praising or both?	Praising.
Relation with other sources?	It has relation to our interviewee Bent Stumpe. No later references could be found.

Source identification scheme	
Questions	**Answers**
Source name or title Identification: What?	*Knowledge Transfer 2011.* Used as both a second-hand and firsthand source.
Authorship: Writers: Who?	*A project by:* *Marina Giampietro (communication officer)* *Giovanni Anelli (group leader)* *Knowledge Transfer group*
Source type: relic or narrative?	Concludes from narrative because it is a kind of advertisement for the Technology Transfer department at CERN.
Text type: What?	*Report on 2011 knowledge transfer activities to CERN Finance Committee (March 2012).*
Dating and chronology: When? Contemporaneity with events?	Probably written sometime before and during 2011 and released in 2012: *Three initiatives from Physics for Health 2010* *Knowledge Transfer 2011.* *Report on 2011 knowledge transfer activities to CERN Finance Committee (March 2012).* *CERN-Brochure-2012-004-Eng* *©Copyright 2012, CERN*
Localization: Where was it produced? Where was it found?	It was produced at CERN. It was found at CERN as psychical document and online at the CERN Technology Transfer website: http://ktfiles.web.cern.ch/ktfiles/Knowledge-Transfer-2011.pdf
Purpose: Why was this source written? Are there hidden purposes?	To describe CERN's involvement and initiatives in knowledge transfers: *CERN's mission is fundamental research in physics. We push back the frontiers of human knowledge and, in doing so, drive innovation, develop forefront technologies, stimulate international collaboration and inspire tomorrow's leaders in science and technology. It is part of our mission to share all this with society, through a knowledge transfer policy that reflects our core values.*
Analysis: From what material was it produced?	It was produced from a variety of different technology projects and patent applications. *"Technologies developed for CERN purposes can find alternative applications".*

In what context was the source written? In what general context was the source written?	Scientist and members of the Technology Transfer Group at CERN wrote it.
Source tends: Derogatory, praising or both?	Highly praising.
Relation with other sources?	It has relation to our interviewee Giovanni Maria Anelli.

Source identification scheme	
Questions	**Answers**
Source name or title Identification: What?	*Dansk opfinder: Sådan styrede vi Cerns kontrolrum med en bowlingkugle.* Translation: Danish inventor: How we steered CERN's control room with a bowling ball. Used as a second-hand source though quotes are firsthand sources.
Authorship: Writers: Who?	Mie Stage, Journalist, editing, webdesk and video at the magazine Engineering Weekly online. http://ing.dk/redaktion
Source type: relic or narrative?	Concludes from narrative.
Text type: What?	Article.
Dating and chronology: When? Contemporaneity with events?	Written shortly before: *Thursday 29. Dec 2011 kl.14:01.* (Release date)
Localization: Where was it produced? Where was it found?	It is based on an interview with Bent Stumpe done at CERN by Mie Stage. It was written in Denmark at the magazine Engineering Weekly online. It was found on the Engineering Weekly online site: http://ing.dk/artikel/125236-dansk-opfinder-saadan-styrede-vi-cerns-kontrolrum-med-en-bowlingkugle
Purpose: Why was this source written? Are there hidden purposes?	It is a part of an article series about the Danes that have worked at CERN through the years. It was written to tell the story about Bent Stumpe's inventions at CERN.
Analysis: From what material was it produced?	It was produced by an interview with Bent Stumpe. The following references are mentioned in the article: Stumpe, B. (1972) *Proposed outlay for a fast interactive computer display system.* CERN 11.03.1972. Page 1. Handwritten note from a meeting between Bent Stumpe and Frank Beck.
In what context was the source written? In what general context was the source written?	It was written after a visit to CERN and at the Danish magazine Engineering Weekly online.
Source tends: Derogatory, praising or both?	Highly praising.

Relation with other sources?	It has relation to Bent Stumpe. It has relation to this reference and was published at the same time: Stage, M. (2011): *Video: Sådan blev den gennemsigtige touch-skærm til.* No later references could be located in the research.

Source identification scheme	
Questions	**Answers**
Source name or title Identification: What?	*Video: Sådan blev den gennemsigtige touch-skærm til.* Translation: Video: This is how the transparent touchscreen was invented. Used as a second-hand source though quotes are firsthand sources.
Authorship: Writers: Who?	Mie Stage, Journalist, editing, webdesk and video at the magazine Engineering Weekly online. http://ing.dk/redaktion
Source type: relic or narrative?	Concludes from narrative.
Text type: What?	Online video interview and article.
Dating and chronology: When? Contemporaneity with events?	Recorded at CERN before: *Thursday 29. Dec 2011 kl.14:01.*
Localization: Where was it produced? Where was it found?	At CERN. Maybe edited at the magazine Engineering Weekly online. It was found on the Engineering Weekly online site: http://ing.dk/artikel/124321-video-saadan-blev-den-gennemsigtige-touch-skaerm-til
Purpose: Why was this source written? Are there hidden purposes?	It was recorded to tell the story of the development of the capacitive touchscreen from Bent Stumpe's point of view.
Analysis: From what material was it produced?	It was produced from an interview with Bent Stumpe at CERN.
In what context was the source written? In what general context was the source written?	It was recorded at a scientific environment at CERN with the audience of Engineering Weekly online in mind.
Source tends: Derogatory, praising or both?	Praising.
Relation with other sources?	It has relation to Bent Stumpe. It has relation to this reference and was published at the same time: Stage, M. (2011): *Dansk opfinder: Sådan styrede vi Cerns kontrolrum med en bowlingkugle.* Accessed: 31/7-2012. No later references could be located in the research.

Source identification scheme	
Questions	**Answers**
Source name or title Identification: What?	*Cern-dansker vil lave isotoper til kræftbehandling uden bivirkninger.* Translation: Dane at CERN will make isotopes for cancer treatment without side effects. Used as a second-hand source though quotes are firsthand sources.
Authorship: Writers: Who?	Mie Stage, Journalist, editing, webdesk and video at the magazine Engineering Weekly online. http://ing.dk/redaktion
Source type: relic or narrative?	Concludes from narrative.
Text type: What?	Article.
Dating and chronology: When? Contemporaneity with events?	Written shortly before: *lørdag 31. dec 2011 kl. 14:00.*
Localization: Where was it produced?	It is based on an interview with Helge Ravn done at CERN by Mie Stage. It was written in Denmark at the magazine Engineering Weekly online. It was found on the Engineering Weekly online site: http://ing.dk/artikel/125284-cern-dansker-vil-lave-isotoper-til-kraeftbehandling-uden-bivirkninger?utc_medium=mobile&utc_source=mobile&utf_campaign=mobile&force_non_mobile
Purpose: Why was this source written? Are there hidden purposes?	It is a part of an article series about the Danes that have worked at CERN through the years. It was written to tell the story about Helge Ravn's work at CERN and how he uses it today.
Analysis: From what material was it produced?	It was produced by an interview with Helge Ravn. It is not clear if any of the mentioned things in the article are references to other sources by Helge Ravn.
In what context was the source written? In what general context was the source written?	It was written after a visit to CERN and at the Danish magazine Engineering Weekly online.
Source tends: Derogatory, praising or both?	Highly praising.
Relation with other sources?	It has not direct relation to any of our other sources

	but it has indirect relation to the interview with Bent Stumpe also done by Mie Stage for the Engineering Weekly online. It also has relation to CERN.

Source identification scheme	
Questions	**Answers**
Source name or title Identification: What?	Interviews with retired Electronics Engineer from CERN, Bent Stumpe. Used as a firsthand source.
Authorship: Writers: Who?	Interviewed by: Benjamin Henriksen Observers: Jesper Christensen Jonas Stumpe
Source type: relic or narrative?	Concludes from narrative.
Text type: What?	Partially transcribed interview.
Dating and chronology: When? Contemporaneity with events?	Recorded interviews 2012: Interviewed 26/4-2012 with Giovanni Anelli as main interviewee. Interviewed 22/7-2012. Interviewed 23/8-2012.
Localization: Where was it produced? Where was it found?	Interviewed at CERN, Geneva, Switzerland and in Copenhagen, Denmark.
Purpose: Why was this source written? Are there hidden purposes?	Why was this source interviewed? Bent Stumpe is a firsthand source and therefore a very important source for this project report. Hidden purposes could be that Bent Stumpe wants acknowledgements for his work at CERN and want to spread knowledge about his inventions at CERN.
Analysis: From what material was it produced?	N/A.
In what context was the source written? In what general context was the source written?	In what context was the source interviewed: In a meeting room at CERN and at different locations in Denmark.
Source tends: Derogatory, praising or both?	Praising.
Relation with other sources?	Bent Stumpe has relation to many of the sources we use in this report. 1) Uses Bent Stumpe's work as reference: Bhalla, M. R. and Bhalla, A. V. (2010): *Comparative Study of Various Touchscreen Technologies.*

	2) Beck, F. and Stumpe, B. (1973): *Two Devices For Operator Interaction In The Central Control Of The New CERN Accelerator.* 3) Bent Stumpe is mentioned in this source: Beck, F. (April 1976): *The Design And Construction Of A Control Centre For The CERN SPS Accelerator.* 4) About Bent Stumpe: Børsen (1978): *DIVERSE LK-NES.* 4) CERN Bulletin (22 March 2010): *Another of CERN's many inventions!* 5) CERN Document Server (CDS) (2012): *At the SPS control room: Bent Stumpe and George Shering are leaning over the desk. Ted Wilson and Rae Stiening sit at the desk.* 6) Crowley-Milling, M.C. (1978): *Recommandation.* 7) About Bent Stumpe: Erhvervs-Bladet (1978): *LK-Nes-prisen til dansk atomforsker.* 8) About Bent Stumpe: Erhvervs-Bladet (1978): *LK-Nes prisen blev overrakt.* 9) Uses this as a reference: Fryberger, D. and Johnson, R. (1971): *An Innovation In Control Panels For Large Computer Control Systems.* 10) Bent Stumpe is mentioned in this source: IOP Institute of Physics (2012): *How physics drives the supermarket industry.* 11) Bent Stumpe gets the LK-NES award: LK-NES pressetjeneste (1978): *LK-NES-Prisen for 1978 går til den danske ingeniør B.Stumpe, der er tilknyttet det fælleseuropæiske atomforskningscenter CERN i Schweiz.* 12) Uses this as a reference: Mott, E.M. (1972): *A Transparent Touch-Screen Device for Interactive Computer-Graphics Displays.* 12) Uses Bent Stumpe's work as reference: Petersen, P. (1983-84) *Man – Machine Communication.* 13) Article about Bent Stumpe: Politiken (1978): *Stor pris til dansk forsker.* 14) Article about Bent Stumpe: Stage, M. (2011): *Dansk opfinder: Sådan styrede vi Cerns kontrolrum med en bowlingkugle.* 15) Article mainly about Bent Stumpe: Stage, M. (2011): *Kom bag om CERNs bedste opfindelse.*

	16) Video article about Bent Stumpe: Stage, M. (2011): *Video: Sådan blev den gennemsigtige touch-skærm til.* 17) Stumpe, B. (2012): *CERN – CV Bent Stumpe.* 18) Stumpe, B. (1972) *Proposed outlay for a fast interactive computer display system.* 19) Stumpe, B. (1977) *A New Principle for an X-Y Touch Screen.* 20) Stumpe, B. (1978) *Experiments to find a manufacturing process for an X-Y touchscreen.* 21) Stumpe, B. (1980) *The first touch-terminal developed by CERN and commercialized by NESELCO in 1980.* 22) Article about Bent Stumpe's work: Stumpe, B. and Sutton, C. (31 March, 2010): *The first capacitative touchscreens at CERN.* 23) Chapter from a forthcoming book: Stumpe, B. (2012 - 2014): *The touchscreen revolution.* 24) Article about Bent Stumpe's work: Symmetry magazine (June, 2010): *Logbook: CERN touchscreen.* *25)* Article about Bent Stumpe: Unidentified source (1978): *á jour.* 26) Uses Bent Stumpe's work as reference: Wikipedia (2012): *Multi-touch.* 27) Uses Bent Stumpe's work as reference: Wikipedia (2012): *Touchscreen.* This article talks about the inventions at CERN and has indirect relation to Bent Stumpe: Crowley-Milling, M. (1977): *How CERN broke the software barrier.* Knows Giovanni Anelli from CERN. Knows Søren Karl Larsen who is his brother in law. Knows one of the writers of this project Jonas Stumpe who is his nephew.

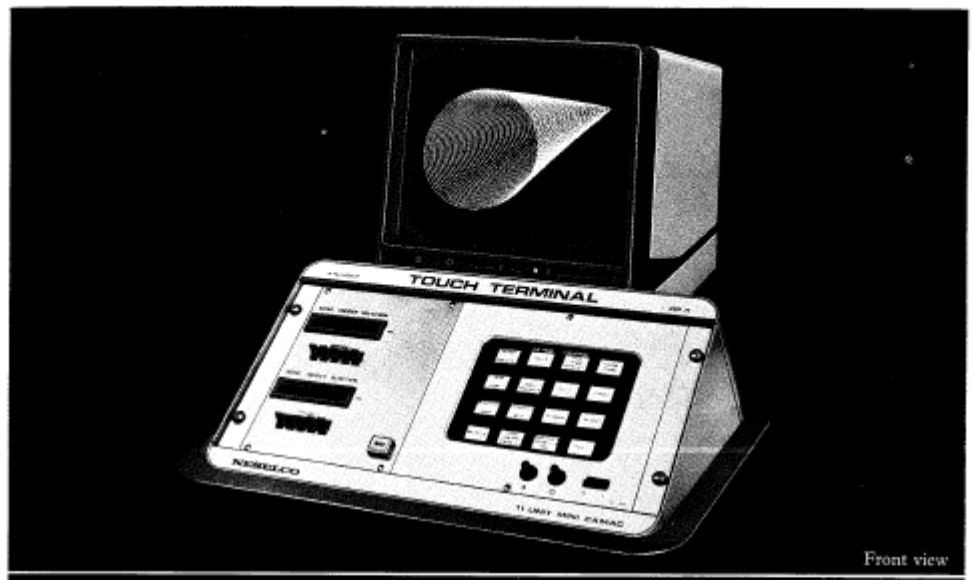
Source identification scheme	
Questions	**Answers**
Source name or title Identification: What?	Interview with Giovanni Maria Anelli the Group Leader of the Knowledge Transfer Group on CERN. CV is online at the CERN website: http://knowledgetransfer.web.cern.ch/our-team/ Used as a firsthand source.
Authorship: Writers: Who?	Interviewed by: Benjamin Henriksen Jesper Christensen Jonas Stumpe Observers: All of the above.
Source type: relic or narrative?	Concludes from narrative.
Text type: What?	Partially transcribed interview.
Dating and chronology: When? Contemporaneity with events?	Interviewed 26/4-2012.
Localization: Where was it produced? Where was it found?	Interviewed at CERN, Geneva, Switzerland.
Purpose: Why was this source written? Are there hidden purposes?	This source was interviewed to get a better understanding of the technology transfers at CERN and how they emerged and became a department at CERN.
Analysis: From what material was it produced?	N/A.
In what context was the source written? In what general context was the source written?	In what context was the source interviewed: In a meeting room at CERN. Works in a scientific environment at CERN.
Source tends: Derogatory, praising or both?	Both.
Relation with other sources?	Co-writer of this CERN publication: Giampietro, M., Anelli, G. and the CERN Knowledge Transfer Group (2012): *Knowledge Transfer 2011.* Giovanni Maria Anelli has knowledge of the existence of some of the other sources in this project. It is not clear how many. But we can verify that Giovanni Anelli has some knowledge about this matter from a powerpoint presentation made by Giovanni Anelli with

	the forthcoming date September 4th 2012 where he uses the CERN Bulletin about the touchscreen from March 22nd 2010: Anelli, G. (2012): *Knowledge Transfer at CERN.* CERN Bulletin (22 March 2010): *Another of CERN's many inventions!* Giovanni Anelli's CV from CERN: CERN Knowledge Transfer (2012): *Our team, Giovanni Anelli, Read CV.* Giovanni Anelli's CV from Linkedin: Linkedin (2012): *Giovanni Anelli.* Knows Bent Stumpe from CERN.

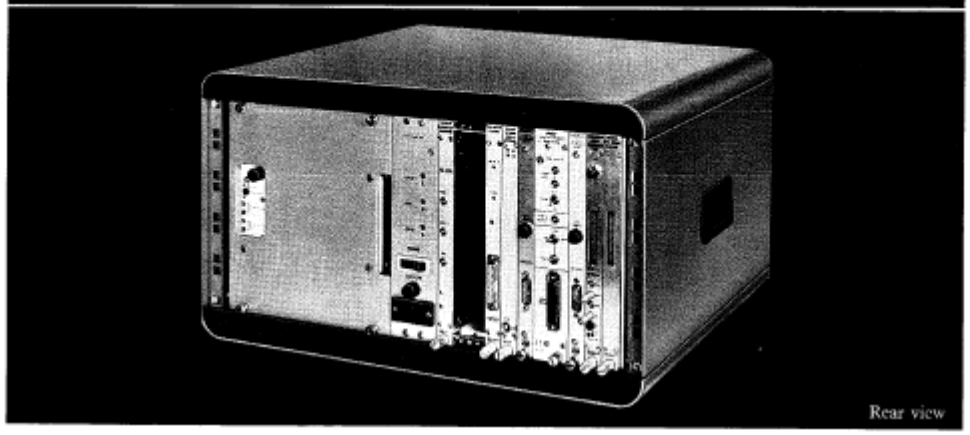
Source identification scheme	
Questions	**Answers**
Source name or title Identification: What?	Chapter form a forthcoming book: *The touchscreen revolution.* Used as a firsthand source as it is written by a firsthand source.
Authorship: Writers: Who?	Bent Stumpe, retired engineer from CERN.
Source type: relic or narrative?	Concludes from narrative.
Text type: What?	15 pages from a forthcoming book from Wiley publications.
Dating and chronology: When? Contemporaneity with events?	2012-2013. The release date is not decided yet.
Localization: Where was it produced? Where was it found?	The chapter was produced in Geneva, Switzerland in the private home of Bent Stumpe. It was found in Bent Stumpe's personal electronically achieve.
Purpose: Why was this source written? Are there hidden purposes?	It was written to tell the story of CERN's touchscreen. From the Preface: *The following chapters describe technical developments done at CERN and elsewhere, which have had a great impact on human behaviour. As the fist capacitive transparent touchscreens was developed at CERN and because this type of touchscreen is in particular used in modern devises, the full story behind this development is told here.*
Analysis: From what material was it produced?	From the preface: *The text written does not mention the names of the persons who have been directly involved in the developments described, however a list of references with names are being prepared and can be found later on a CERN Web site for the use of those persons who want to go into more details about the developments described here. This includes references to CERN articles, as well as other articles of interest to the story.*
In what context was the source written? In what general context was the source written?	In a private study room. It was written after the touchscreen had become mainstream and the innovation had unfolded more of its potential.
Source tends: Derogatory, praising or both?	Highly praising.

Relation with other sources?	It has relation to Bent Stumpe. It has relation to a lot of the sources used in this project but it is not clear how many and which.

Appendix 2 - NESELCO pricelist



Front view



Rear view

NEW Touch-Terminal from NESELCO

- Complete Man Machine Interface in one single unit, featuring full graphics and touch interaction.
For stand alone use, or in connection with your computer system.
The electronics of the intelligent Touch Terminal are realised using NESELCO CAMAC modules plugged into the terminal from the rear.
NESELCO manufactures and supplies the intelligent Touch Terminal as well as the following CAMAC modules:

Independent Crate Controller
File Module
Touch Button Interface
TV Rounded Character Generator
TV Display Memory
TV Display Controller
TV Comp. Sync. Generator Buffer
Video Mixer
Button/Keyboard/Display Interface

For further details - just call or write

NESELCO A/S
- A Subsidiary of LK-NES
Haydnsvej 2
DK 2450 Copenhagen
Tel. +1 17 33 22
Tlx. 15679 - 15622

NESELCO

266

Courrier CERN, septembre 1980

Tau/ap

NESELCO

Rev. 16 OKT. 1980

PRICE LIST FOR NESELCO CAMAC PRODUCT PROGRAM — 1 JULY 1980

ALL CERN DEVELOPMENTS !

		Dkr.
601 F 0100	Intelligent Touch Terminal, basic mechanical unit, exclusive modules in slot 15-25 and TV Monitor, incl. fans and power supply	27,900.00
601 F 0200	19" Chassis, Black or Silvermat, for 2 TV Monitors and 1 Touch Button	11,060.00
601 F 0600	Touch Button	5,600.00
601 F 0700	Touch Button Interface	5,100.00
601 F 1000	TV Display Controller, DICO ..... PACE	19,200.00
601 F 1200	TV Display Memory, Super DIME	19,800.00
601 F 1300	TV Rounded Character Generator	8,200.00
601 F 1400	TV Comp. Sync. Generator Buffer	5,000.00
601 F 1500	Video Mixer	5,050.00
601 F 1600	Button/Keyboard/Display Interface ...	3,500.00
601 F 1700	Independent Crate Controller, CPU ... MOTOROLA 68000	10,120.00
601 F 1800	Independent Crate Controller, Memory	15,170.00
601 F 1900	File Memory, 16k EPROM	12,970.00

Appendix 3 – Semi structured interview guide Giovanni Anelli

Introduction (interviewee)	Who are you and what is your background? Why are you working with Technology Transfers?
Current state (organization)	How do you handle technology transfers? How long have the organization been working with technology transfer work? How many people work full time with technology transfers? What's missing and how far are you from an optimal situation?
Future and perspective (Technology Transfer)	Thoughts on the future? Is it a growing business or do you think that all big organizations do technology transfer work?
Thoughts on the capacitive touchscreen and CERN*	Could technology transfer work have changed the history for the capacitive touchscreen? What could have been done and why do you think it would have worked?
Thoughts on the project (personal)	Can the project help or promote future technology transfer work? Other interesting approaches we could have taken? Anything we have failed to include in the project?

* The interviewee has been informed about CERN and their work with the capacitive touchscreen back in the 1970s.

Appendix 4 – 1st. Semi structured interview guide Bent Stumpe

Introduction (interviewee)	What were your take on Technology Transfers in ~1960-1970 What was your perception regarding the culture at CERN in relation to technology transfers.
Idea / Improvement	When you started working on the touchscreen was it something new for everyone or an improvement of an Idea/design from earlier? What differences (Technical and conceptual) do you see between your design and the design by E.A Johnson
Why	Why did you develop the touchscreen, what purpose did it fulfil that was not possible with the technologies available at the time.
What	What was the technology used for? What impact did It make
Commercialization	When did it become a commercial product If selling these devices happened during your time at CERN, in what way did you/your department/CERN benefit from this What changes do you think made the touchscreen go from niche technology to a mainstream product?
Technology transfers going forward	What do you think (if anything) could have been done to smoothen the transition?

* The interviewee has been informed about CERN and their work with the capacitive touchscreen back in the 70s. Included here was also an introduction to the historical timeline we developed for the project.

Appendix 5 – 2nd. Semi structured interview guide Bent Stumpe

Organization and culture at CERN	o What were the possibilities for CERN employees to commercialize inventions they were a part of during the 1970s? Could you have made money personally by commercializing the touchscreen? o How was the internal power structure in relation to physicists and support staff? o Did CERN gain anything by the touch terminals sold by NESELCO o How did you end up working on the SPS project o What happened with the organization once the SPS control room was complete? o Was CERN excited about the touchscreen, did they see future applications for the screen o Can you tell us what title and department the following people worked at during the 1970s ▪ Bent ▪ Frank Beck ▪ Michael C crawling milling o What were CERN's feelings towards the X-Y touchscreen, did they support this? o Why do you think CERN successful in developing the touchscreen? o Are you aware of any other innovations with a similar fate?
Sources	o We have no sources from 1983 – 2010 do you have any idea why?
Commercialization	o Which channels was used for promoting the touchscreen and the touch terminal? o What did you do personally to promote the touchscreen?? o What happened after your visit to Germany to test manufacturing techniques o Was any attempt made to commercialize the suggested use of the touchscreen for ticketing terminals at railways etc.? o Can you explain what happened during the Hannover fair in 1978 in relation to the "DrinkOMat"? o From the documents we have seen it seems like the touchscreens/touch terminals sold was mainly sold within the scientific environment (Power plants/Universities) o Who produced the touchscreens which were sold by NESELCO in 1980 and who produced the screen during the 1980s o When did sales of the touchscreen/terminal take place? o We have information indicating that the touch terminal was sold to the following firms, which touchscreen/Terminal did they buy, and are you aware of what it was used for? JET, Rutherford Laboratory in the UK, KEK, Mitsubishi, TOYO corporation, Rigshospitalet in Denmark and the Hahn-Meitner Institute in Germany.

Appendix 6 – Semi structured interview guide Søren Karl Larsen

Commercialization	o When was the last capacitive produced at Ferroperm? o When did the production of the capacitive touchscreens start at Ferroperm? o Which nations did Ferroperm delivered touchscreen to? o How many touchscreens were produced at Ferroperm?
Background	o When did you work at Ferroperm?

Appendix 7 – Technology Readiness Model

There are many TRL models to choose from and it's crucial you pick one that usable for the type of technology you have to evaluate. We have decided to use a model developed by the U.S Department of Energy. The primary reason for choosing this model is because it was made to evaluate technologies like the touchscreen. The model consists of the following levels:

TRL 1 – **Basic research**
Initial scientific research has been conducted. Principles are qualitatively postulated and observed. Focus is on new discovery rather than applications.
TRL 2 – **Applied research**
Initial practical applications are identified. Potential of material or process to solve a problem, satisfy a need, or find application is confirmed.
TRL 3 – **Critical Function or Proof of Concept Established**
Applied research advances and early stage development begins. Studies and laboratory measurements validate analytical predictions of separate elements of the technology.
TRL 4 – **Lab Testing/Validation of Alpha Prototype Component/Process**
Design, development and lab testing of components/processes. Results provide evidence that performance targets may be attainable based on projected or modeled systems.
TRL 5 – **Laboratory Testing of Integrated/Semi-Integrated System**
System Component and/or process validation is achieved in a relevant environment.
TRL 6 – **Prototype System Verified**
System/process prototype demonstration in an operational environment (beta prototype system level).
TRL 7 – **Integrated Pilot System Demonstrated**
System/process prototype demonstration in an operational environment (integrated pilot system level).
TRL 8 – **System Incorporated in Commercial Design**
Actual system/process completed and qualified through test and demonstration (pre-commercial demonstration).
TRL 9 – **System Proven and Ready for Full Commercial Deployment**
Actual system proven through successful operations in operating environment, and ready for full commercial deployment.

Based on our studies we can conclude that the touchscreen reached level 9 which is the highest and means that the system is proven and ready for full commercial deployment. The touchscreen went from basic research to being system proven and ready for commercial deployment. The criteria for a level 9 technology is that is in its final form, operating under the full range of operating conditions and supporting economic targets in regard to cost, yield and output.

Appendix 8 – Porters Five Forces

The framework was developed by Michael H. Porter from Harvard Business School in 1979. (Johnson, G., Whittington, R. and Scholes, K., 2011, Exploring Corporate Strategy) The framework is used to determine the attractiveness of a market based on five forces. Three of the forces are based on external factors and the rest on internal. We have tried to estimate the potential for industry profitability for the touchscreen in the period of 1971 to 1980. Furthermore the only commercial use for the touchscreen was related to the controlling of things. For examples the touchscreen was used for control purposes at hospitals and power plants. The market was therefore corporations and research facilities.

Threat of New Entrants	• Published technology • Not patented • No customer loyalty
Bargaining Power of Buyers	• Low bargain power, there is currently a limited number of suppliers
Threat of Substitute Products or Services	• Once implemented, very expensive to replace[107] • Existing solutions that are cheaper and delivering the same features as the touchscreen. For example if a power plant does not need flexibility in how "buttons" are used, they will properly not have an interest in the touchscreen solution • Competing touchscreen technologies
Bargaining Power of Suppliers	• Not an issue, very few vendors, all suppliers was equal
Rivalry Among Existing Competitors	• No competitors in Europe, but if there is a change in the market, there could be competition from the US[108] • Possible competition from existing vendors that are in the market for traditional controls

[107] The installations at the power plants have been reported to cost up to half a million CHF. (Interview, 2012, Stumpe, B.)

[108] Accordingly to Bent Stumpe the market for touchscreens was developing more rapidly in the US. (Interview, 2012, Stumpe, B.)

Appendix 9 – SWOT

The creating of SWOT is credited to Albert Humphrey who led a convention at Stanford Research Facility between 1960s and 1970s (Johnson, G., Whittington, R. and Scholes, K., 2011, Exploring Corporate Strategy). It was during this period the method was created. The method is used to evaluate internal and external factors of before embarking on a business venture. The model includes both micro and macro-environmental factors.

Strengths (internal)	• Extensive knowledge and experience with the touchscreen technology • Credibility in regard to his position at CERN (work at CERN) • Use CERN as reference customer • Ability to use CERN network to European corporations
Weaknesses (internal)	• No economical support from CERN • Expensive to fabricate which limits research and fabrication of new prototypes • Does not have any sponsors • Does not have a joint venture agreement
Opportunities (external)	• Limited competition • Possibility of creating a new market • Technology evolution is moving in a rapid way which may enable new ways to use utilize the touchscreen • First mover
Threats (external)	• A growing and innovative US market • Existing technologies that deliver the same result • No patent • Limitations in use (hardware) • Limited market • Expensive to manufacture • Customers are limited to corporations and research facilities

Appendix 10 - Amendment for the problem statement

We have changed some of the questions and terms in our problem statement after we got more knowledge about the problem area during our study.

The original problem statement was in Danish and sounded like this:
Innovationer er et afgørende konkurrenceparameter for især teknologivirksomheder og disse kan bidrage til at ændre den måde, vi oplever verden på.

Vi synes det er interessant at undersøge hvordan en simpel idé for en specifik innovation, kan ligge ubenyttet i flere årtier, for derefter fundamentalt at ændre den måde hvorpå vi interagerer med it-produkter, såsom computere og mobiltelefoner.

Med udgangspunkt i den kapasitive touch-skærm vil vi undersøge hvilke parametre, der skal være til stede før en innovation slår igennem.
Problemformulering:

Hvorfor har det taget mere end tre årtier, før den kapasitive touch-skærm gik fra at være en nicheteknologi, brugt i forskningsøjemed, til at blive udbredt i kommercielle produkter?

Forskningsspørgsmål:

- *Hvad er historien bag skærmens tilblivelse?*
- *Hvorfor blev den udviklet?*
- *Hvad blev teknologien brugt til?*
- *Hvornår skete springet fra nicheteknologi til kommercielt brug?*
- *Hvilke forandringer fik springet til at ske og hvorfor?*

The original problem statement translated into English:
Innovations are a key competitive factor especially for technology companies and they can help change the way we experience the world.

We think it is interesting to examine how a simple idea for a specific innovation, can lay unused for several decades and thereafter fundamentally change the way we interact with technology products such as computers and mobile phones.

Based on the capacitive touchscreen, we will investigate what parameters must be present before an innovation unfolds.

Why has it taken more than three decades before the capacitive touchscreen went from being a niche technology used for research purposes, to be used in commercial products?
Research questions:

- *What is the history behind the capacitive touchscreen's genesis?*
- *Why was it developed?*

- *What was the technology used for?*
- *When did the transition from niche technology to commercial use occur?*
- *What changes made the transition happen and why?*

To investigate this we will do literature studies based on a variety of sources including data from CERN, and to perform empirical studies such as interviews. We will also use the historical method. This is elaborated in the Methods section in the final report