[simula . research laboratory]

How to Become an Excellent IT-research Institute

(with substantial impact on the IT-intensive industry)

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Simula Research Laboratory

”By Thinking Constantly About it”
“Basic, applied research”
“The industry is our lab”

[simula . research laboratory]

The Story About
Simula Research Laboratory

In the beginning there was …

- the decision to close down the airport near Oslo (early 1990s)
- political discussions about what to do with the premises of the old airport.
- an industry forum suggesting that an IT-park was a good idea. The ship owner and investor Fred. Olsen – he also produces the Timex watches – was the main initiator of this idea. The idea got political support in 1997.
- the vision was to make the IT-park the most attractive knowledge centre in Europe by the year 2005 and a transfer of Norway into a knowledge society less dependent on export of natural resources. (similar to Costa Rica?)
- a minister of education (a man with only elementary education!) who decided that the IT-park needed a research center.

The Beginning

- In 2001 three research groups (all from the University of Oslo) were selected to form the IT-research center:
  - Two of the groups (software engineering (SE) and Networks and Distributed systems (ND)) were selected based on the relevance of their topic for the IT-park and the third (scientific computing (SC)) based on their scientific quality.
- The research center was (and still is) organized as a limited company owned by several research institutes and the government, who has the main share.
- Many of the researchers keep a 20% position at the university (teaching and supervision).

The Beginning

- The “allowance” from the government has been about 8 mill USD per year.
  - This covered in 2009 about 50% of the funding, the rest is from other types of national research funding, international research programs (EU) and IT-companies.
- In 2001 the vision of an attractive knowledge center faced problems (e.g., through the .com bubble bursting) and the IT-park development was delayed and consisted mainly in property development.
  - Fortunately, the funding to the IT-research center (Simula Research Laboratory) continued in spite of the other problems.
  - Today, the IT-park is a success with more than 12,000 knowledge workers at the old airport and more is coming.

Achievements of Simula in the 10-year period

- Simula's future existence has always been dependent on good evaluations!
- Every fifth year we are evaluated by international (independent) experts. The highest evaluation ("excellent") is very hard to get.
- The evaluations shows a very progress on the research quality:
  - 1999-evaluation (pre-Simula): One group was "excellent" (SC), the other two (SE and ND) were "good". ["Good" is not really good, but average or below …]
  - 2004-evaluation: One group is "excellent" (SC), one group is "very good, on its way to excellent" (SE), one group is "good, with some very good elements" (ND).
  - 2009-evaluation: Two groups are "excellent" (SC and SE), one group is "very good, with some excellent elements" (ND).
- The Software Engineering (SE) group was recently ranked as the second best software and systems research institute worldwide by Journal of Systems and Software.

Achievements of Simula in the 10-year period

- Seven companies generated in the period (none of them, however, are big successes, yet …)
- Substantial (but difficult to measure) impact on software processes in the Norwegian software industry.
  - Examples of very high return of investment, e.g., related to our fault prediction and testing research.
- An increase in external funding (from industry and government) enabled an increase in number of employees, now at about 100.
- Simula’s reputation has the last years enabled the attraction of international highly recognized software engineering researchers:
  - Strong industry background/understanding
  - Strong research record
  - Dedicated to research goals corresponding with Simula’s goal

The platform of Simula's success

- Full-time research! *[at least that is the goal ….]*
- Basic, applied research.
- Quality culture.
- Organization of activities are more like those in private companies, e.g., less bureaucratic hiring processes.
- Free research within a directed topic.
- Good contact with the politicians - explaining them why we are doing what we are doing and what they get from their investments.
- Creation of new businesses based on our research.
- Good PhD-students, recruited internationally.
- **Strong collaboration with the industry. They fund more and more of our research, without we becoming consultants.**

Full time researchers

- How did you come up with the law of gravitation?
  - ”*By thinking constantly about it ….*” (attributed to Isaac Newton)
- The best researchers are those who get fully absorbed by what they are doing and are not too much “disturbed”.
- Golden rule in project management: At least 80% effort on your main deliveries leads to the best quality and efficiency. The same goes for research.
- Universities:
  - Many other obligations, little time for research
  - Can easily kill the research enthusiasm
- How do we find dedicated, enthusiastic researchers?
  - Headhunting (through networking)
  - Luck
  - Create dedication (not easy, if the personality/trait is not there)

Basic, applied research ….

"Our aim is to conduct long-term basic research with a clear view to application of the research results. The projects focus on fundamental and complex challenges that are important for society at large."

Projects that are interesting, but not sufficiently fundamental or without an important applications will not be started, even when there is funding available. [*well, this is at least the ideal – there are exceptions ….*]

Basic, applied research

- It is a myth that applied research cannot be on basic (core) problems, e.g.:
  - Mathematical problems that improve the simulation of heart attack (to prevent it)
  - Methods for higher quality of service in communication networks
  - Understanding the mental steps in people's judgment of time to complete work.
- If your research is both basic and applied, you may (as we did) experience that this enable:
  - More industry attention (funding, partners, collaborations)
  - Longer term focus (applied IT-research is frequently short-term)
  - Higher quality research
  - Expertise and knowledge that is not outdated or irrelevant when the technology changes

Quality culture

- From the document: “The Simula culture”:
  - “Quality should be all-important in everything we do, everything we deliver, in our whole working day.”
- This means that (examples):
  - “All our publications will go through a thorough quality control.”
  - “Everyone at Simula is free to express their opinions in the media, preferably in the form of letters to the editor, feature articles or similar contributions. But if an author signs any piece of work as a Simula employee, it must be of a high quality; careless work, tactless remarks etc. must be avoided.”
  - Simula employees should be on time for appointments and should meet agreed deadlines.
  - ….
- If we cannot do something with high quality, we should not do it at all.

Organization as a limited company & more directed research

- University characteristics (in Norway):
  - Research freedom (nearly unlimited, as soon as you've got a permanent position)
  - Hiring people at the universities takes months (typicaly 8-12 months)
  - The organization is not designed (managed) to provide support for high quality research, but more towards teaching obligations.
- Simula breaks with all these three university characteristics:
  - Less freedom. Not much freedom to choose the topic, but large degree of freedom when it comes to how to do the research and problems addressed within the topic.
    - Good researchers will typically get the opportunity to do side-activities, which may evolve into new research topics.
  - Quicker hiring processes (much based on headhunting)
  - Management processes more designed to support high quality research

Innovation Support = Simula Innovation

- Supporting a culture for creation of company and product innovations among the researchers
- Providing financial and advisory support
- Connecting with industry and investors
- Expertise on non-technical issues of starting companies etc.

Good PhD-students

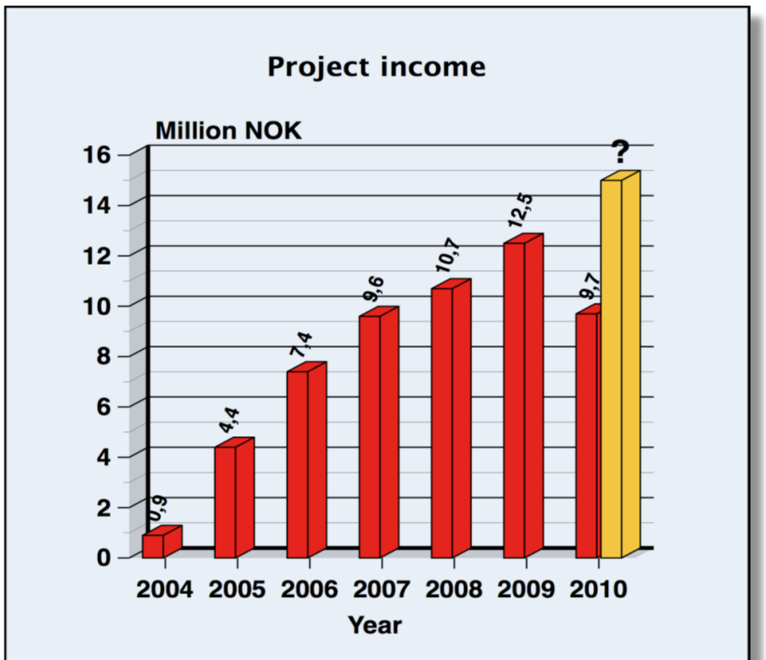
- Active recruitment among the best qualified means that you have to recruit internationally.
  - **Core idea of Simula: Get the best brains to come to Norway.**
- You will lose some of them (going back you their own country or to other countries), so this is a fine balance between quality of PhD students in the research they do and the long-term benefit from educating them.
- Good PhD students frequently have to be headhunted, i.e., you need an international network.
- We want PhD-students with industrial experience (needed for optimal industry collaboration), but do not always succeed in that.

Collaboration with the industry

- Enabled through:
  - Basic, applied research
  - Industry experience and understanding of their problems
  - Good reputation as researchers doing relevant, high quality research
- Challenges:
  - Avoidance of short-term process improvement for the company
  - Partner re-organizes frequently (lack of stability of collaboration)
  - Lack of industrial understanding of the researchers (you have to speak their language!)
- Our main categories of industry collaboration:
  - One big company funds our research (more an more common)
  - Publicly funded research involving several industry partners (who fund their own work and sometimes some of our expenses)
  - Informal collaborations with companies, not in need of funding

Example 1: Collaboration with the Oil Industry
Scientific Computing

- Focus on hydrocarbon exploration
- 100% funded by Statoil. Total 45 MNOK (8-9 Mill USD) by end of 2009.
- Long-term research goals, that require both basic and applied research on computation (50/50). The applied part generated a spin-off company.
- Collaboration enabled through the SC group's world-leading research on numerical methods and software for solving partial differential equations.



Example 2: Testing of software

- Det Norske Veritas (DNV) provides certificates for the Maritime and Energy sector
- The safety of, for example, the vessels/ships depends on the software for the steering and navigation.
- The SE group at Simula collaborate with DNV on methods for providing evidence for the safety of the software and other issues related to verification and validation of embedded software.
- DNV finance the research (PhD-students, etc.) made by Simula personnel.
  - Research on core problems (e.g., how to provide evidence of software safety).
  - Nevertheless, highly applied.

Example 3: My Own Research on Effort Estimation

- **Basic research problem**: Better understanding of the mental processes involved in estimation of time and effort.
- **Applied research problem** (the "same" problem): How to get software developers to estimate the required effort more realistically
  - Average overrun is about 30% and about 70% believe they are better-than-average).
- **Typical collaboration models**:
  - Action research (Case studies/process improvement) to improve problem understanding and evaluate proposed methods and tools
  - Controlled experiments in field settings
  - Controlled experiments in laboratory settings with software professionals
  - Surveys on industry conferences
  - Advisory work and industry seminars in Norway to conduct transfer results
- Different problems and phases of require different types of collaborations with the industry.

An example of how I collaborate with the software industry in generating knowledge and improve processes

My research question:
How to make the assessment of the uncertainty of effort estimates more realistic?

Number of inhabitants in Norway

Minimum

Maximum

Be 99% confident to include the true value in the minimum-maximum interval!

Radius of the (dwarf) planet Pluto

Minimum

Maximum

Be 99% confident!

Overconfidence in the accuracy of effort estimates

Step 1: Motivate research and review existing work

- Findings from case studies and review of existing knowledge gave that:
  - Overconfidence regarding accuracy of estimates leads to poor plans, budgets and investment analyses in many software projects.
  - Inherent uncertainty in effort estimates.
  - Neglected topic. The current method (PERT) used in the software industry lacks evidence that people are actually able to produce meaningful uncertainty (minimum-maximum) interval on the required format, e.g., 90% confidence intervals.
  - Related work in psychology, forecasting and cognitive science show a general bias towards overconfidence in judgment accuracy.
- This is clearly a basic (overconfidence in time estimation), applied (improving project plans) research topic.
- Collaboration with researchers in forecasting and psychology.

Overconfidence in the accuracy of effort estimates

Step 2: Improved understanding of the problem

- Completion of several case studies of state-of-practice in software companes suggested that:
  - Most companies did not have any formal assessment of effort uncertainty (just added a expert judgment-based risk buffer)
  - Some companies provided minimum-maximum values without any indication of confidence level.
  - Very few provided effort prediction intervals, e.g., “90% confident in including actual effort in the interval [1000; 1500] work-hours”.
  - “90% confident” or “almost certain” minimum-maximum interval included actual effort in only 60-70% of the cases.
  - Narrow, overconfident prediction intervals were rewarded by the management.
  - Poor learning opportunities. The feedback (if any) was on a format difficult to learn from.
- Overconfidence led to frustrated clients and poor project control.

Overconfidence in the accuracy of effort estimates

Step 3: Small scale experiments (with software professionals and students) to better understand the underlying cause-effects.

- **Example of experiment**: Does the developers understand what "90% confident" means?
- **Experimental design**: Same development task. Different confidence levels.
  - Group A: Minimum-maximum interval, when 50% confident.
  - Group B: Minimum-maximum interval, when 75% confident.
  - Group C: Minimum-maximum interval, when 90% confident.
  - Group D: Minimum-maximum interval, when 99% confident.
- **Main result**: No! The minimum-maximum values were about the same for all confidence levels.
- **Possible implications**: Meaningless to ask people to be "90% confident" without training/support? We need to change how we elicit uncertainty and how we train software developers.

Overconfidence in the accuracy of effort estimates

Step 4: Invention of alternative uncertainty assessment processes. **Evaluation of them through small scale experiments with software professionals**

- Experiment: Does a change in elicitation format improves the realism?
  - Traditional approach (PERT): “What is the minimum and the maximum effort? (Be 90% confident to include the actual effort)”
  - Alternative 1: “How frequently have similar projects overrun their estimated effort with more than 50%?”
  - Alternative 2: “What is the maximum effort? How likely is it that the actual effort will be higher?”
  - **Main finding**: Alternatives 1 and 2 were better than the traditional approach

Overconfidence in the accuracy of effort estimates

Step 5: Evaluate the most promising processes in representative field settings

- A randomized controlled trial in field setting showed the same positive effect of using Alternative 1 and 2 compared to use of the PERT approach.
- Experiment:
  - The company randomly allocated the use of one of the three alternatives to uncertainty assessments of new software projects.
  - We paid them for the extra work (actual work on the uncertainty assessment following the alternative processes + administration).

Overconfidence in the accuracy of effort estimates

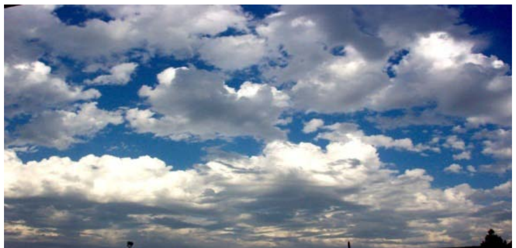
Step 6: Transfer of results to the software industry

- This takes time, and we are still not there to see that this has impacted many companies – although it should. It should also lead to a re-writing of parts of project management books.
- Some positive results:
  - The methods are implemented in at least two software estimation tools.
  - The results have been included as one of the forecasting principles at the main forecasting site (www.forecastingprinciples.com).
  - The results are spread through articles in practitioner's magazines (IEEE Software), industry conferences and industry seminars. It is however hard to say how many companies that actually use the alternative methods.
- It takes time to transfer results ….

An Example of Collaboration Made Possible When the Funding is Good:

“*The Impact of Irrelevant and Misleading Information on Software Development Effort Estimation*”

“Clouds Make Nerds Look Better”



- Sunshine increases tipping, impacts stock-market, and, increases happiness.
- Study of university applicants:
  - 12% higher chance when sunshine compared to worst cloudcover.
  - Nerds had significantly higher chance compared to non-nerds on cloudy days.
    - Nerd-factor measured as academic rating divided by social rating (e.g., leadership).

Irrelevant information is everywhere …

- Requirement specifications and other information provided in an estimation situation typically include
  - some misleading information (on purpose or accidentally)
  - much estimation irrelevant information
  - much information of low importance for the estimation work
- There are good (and not so good) reasons for this, e.g.,
  - information may be relevant for other purposes than effort estimation,
  - ”copy-paste” of general information about the clients’ processes and organization from previous specifications,
  - lack of competence in how to write a good requirement specification
- Are we more rational than stock investors and university applicant assessors, or do we get impacted by irrelevant information when estimating effort?

A randomized, controlled trial in field settings

- Forty-six companies from various countries estimated the same five projects: Russia (15 companies), Ukraine (5), India (7), Bulgaria (4), Romania (3), Pakistan (5), Belarus (2), Moldovia (1), Poland (1), Serbia (1), Slovakia (1), and Vietnam (1).
- We accepted only estimators with professional experience from projects similar to those to be estimated, i.e., we allowed only reasonably experienced estimators.
- The companies were hired and paid for their estimation work, i.e., they did not (seen from their point of view) participate in an experiment.
  - The companies were on average paid about 1500 USD for the estimation work, ranging from 400 to 4000 USD.
  - The effort a company estimated to spend on the estimation of the five projects varied from about 40 work-hours to about 200 work-hours.
  - They were told that they would not be invited to develop the systems, but that their job was to provide realistic effort estimates.
- Random allocation to different “manipulations” of requirement specification.

Length of specification ...

- **Hypothesis 1:** A reduction in number of pages of the requirement specification leads to lower effort estimates, even when the written content is exactly the same.
  - Manipulation: Text identical. One version 3 pages, the other 12 pages.
  - Length of specification is clearly not relevant for the development effort, but will it be used as an indicator?
- We had previously found an effect of the length of the specification on the effort estimation in laboratory settings with computer science students. The question was whether this was a relevant effect in more realistic settings, as well.

Results: Length of specification (H1) [System: DocAssist]

The Effect of the Reduced Length of Specification

Group	**Median**
Manipulated (3 pages spec.)	295 work-hours (n=24)
Ordinary (12 pages spec.)	330 work-hours (n=22)

A small effect – perhaps not even that ...
Effect seems to be reduced (perhaps removed) with more time to do the estimation work and expertise.

Client expectation ...

- **H2:** Presenting the actual effort of the system to be replaced (a low numerical value in our case) early in the requirement specification leads to lower effort estimates.
  - The following text was included early in the manipulated requirement specifications: "*The preliminary budget of the new system is $10 000 [corresponding to about 100 work-hours with typical pricing in the country in which it will be built]. The preliminary budget is not built on any knowledge about the actual cost of developing the new system, and will, if needed, be extended to cover the expenses necessary to build a quality system with the desired functionality.*"
  - 100 work-hours is a very low value for this project and the companies were instructed to not use this as input to their effort estimate, but they may use it unconsciously.
- Several experiments in laboratory settings found large effects of client expectations on the realism of the effort estimates.

Results: Client expectation (H2) [System: IMWOS]

Numerical Anchor

Group	**Median estimate**
Manipulated (client's expectation)	724 work-hours (n=23)
Ordinary	956 work-hours (n=23)

A significant, large effect.
However, lower effect than in our previous laboratory experiments.

Time schedule presssure ...

- **H3:** Information about that the client requires a short development period leads to lower effort estimates.
  - The following text was included early in the manipulated requirement specifications: "[the client] *expects that the system development starts February 3, 2008 and can be launched February 23, 2008. This three week period should include all development and testing.*"
  - A short development period should lead to, if anything, more rather than less use of effort, but may also induce "wishful thinking".
- Previous experimental results in laboratory condition indicated that there was wishful thinking involved (we don't have much time ➔ it cannot take much time) when estimating under these conditions.
- Opposite effect of what most people would considered as "normative" estimation behavior, where compressed time typically means more, not less use of effort.

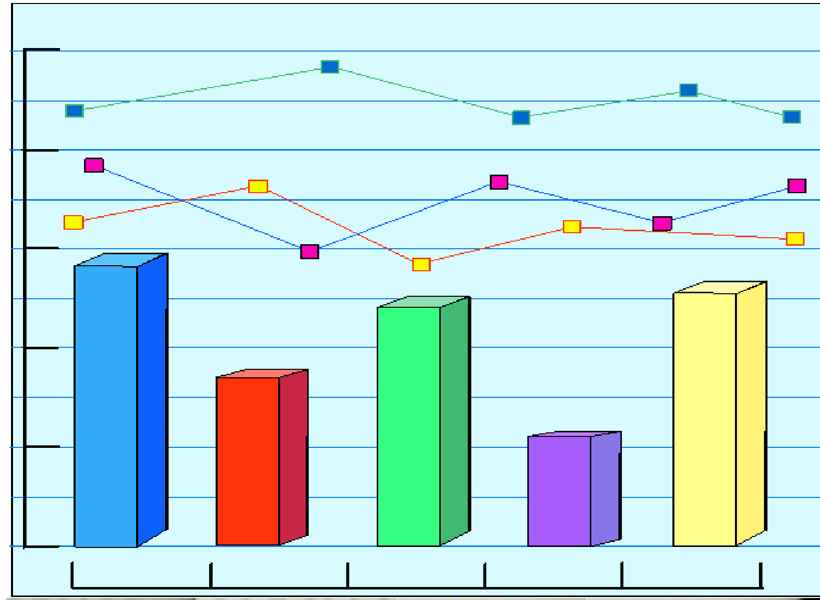
Results: Time schedule pressure (H3) [System: DES]

The effect of time schedule pressure

Group	**Median**
Manipulated (Informed that the client expected the system to be developed during 3 weeks period.)	142 work-hours (n=24)
Ordinary	214 work-hours (n=21)

Very large, significant effect! Similar to the effect found in the laboratory conditions.

How to impact the industry with your IT-research?



Evidence-Based Software Engineering

- Improve the acceptance of Evidence-based SE (EBSE)
  - Teach software professionals EBSE (Training in formulating decidable questions, collection of valid evidence (including experience-based evidence), evaluation of strength of evidence and synthesis of evidence.)
  - Promote evidence-based principles at conferences
  - Train software professionals in completion and understanding of empirical studies
  - Write Software engineering books that are evidence-based
- Like medicine, we should try to get to a stage where the professionals only accept evidence-based principles and methods.
  - It's a looooong way to go, and there may be inherent problems that stop us from reaching the stage where medicine currently is.

Basic, applied research

- Select research topics where impact is more likely (**basic, applied research!**)
  - Increase the emphasis on relevance. Robert Glass in IEEE Software March/April, 2009 recommends that all studies should go through an “applicability check”.
  - Do not conduct research where there are no opportunity to impact. Timing may be important.
- Include more research with high potential of impact. (Think bigger!)
- Emphasis money saving potential. A rough guideline by innovation advisors is that an idea should be able to save at least 10 times its implementation cost to be convincing for investors.

There is in my opinion far too much IT-research of low industry relevance! It’s sometimes like doing research on typewriter improvement.

High quality + convincing research methods

- Higher quality studies.
  - I think I have reviewed more than 50 studies that show that their own estimation model is better than the other models. Most of these empirical evaluations have in my opinion been poorly designed.
- More convincing studies.
  - Inclusion of real-life success stories, less use of students and small scale systems.
  - Experiments and evaluations in real-life settings, including large-scale software projects.

Collaborate with the IT-industry

- Conduct the research in collaboration with the software industry.
  - Let them tell convincing success stories. Nothing beats success stories that can be linked to your research results
  - Mean values and statistical significance may convince scientists, seldom software professionals.
  - Make win-win situations out of research results (see picture)

Learn how to package and sell your results

- Better packaging/wrapping of research results
  - Tools
  - Processes/methods
  - Standards/certificates
  - Courses

Learn how to transfer your results

- Better transfer of IT-research results
  - Publish in practitioners' magazines
  - Write books without academic jargon
  - Be were practitioners meet
  - Package the research results as "experience" and "success stories"
  - Educate journalists to write about IT-research (accept that good IT-researchers are not necessarily good communicators)
- Software practitioners are typically not even aware of our studies. If they find them, the studies are in a language they do not understand. This slows (or even inhibit) the impact.

Timing is important …

- Better timing of research studies.
  - We are far too often lagging behind.
  - When a method already is established, it is difficult to have an impact.
  - Being able to impact sometimes means that the research-based knowledge has to be there (and be known) when (or before) new technology emerges.
  - Example: If I had collaborated with the Planning Poker guru (Mike Cohn) published it, I could have shared with him relevant research results on group-estimation and improved the method before it was distributed.

Avoid fashion-based research

- Avoid "Is Method A better than Method B"-studies, where the methods consist of many (ill-defined) elements.
  - This "reductionism" may sound like a paradox, since the software industry wants exactly that kind of studies.
  - However, such studies do in my experience seldom produce results that are convincing, they seldom produce insight in cause-effects, they seldom have the timing to enable impact (studies of already established practices are typically used to sell methods, not to improve them).

Final Words …

- The Simula-model has created a success in terms of research quality and industry collaboration/industry benefit.
  - The model could probably be applied in Costa Rica, as well.
- Industry collaboration/benefit is frequently not in opposition to completion of basic research in IT.
- IT-researchers need to improve how they interact with and their skills in impacting the software industry.
- The perhaps most important elements of building a successful IT-research institute are:
  - Direct the research on basic problems of importance to the industry.
  - Enable full time research (or at least 70-80%)
  - Emphasize quality and improvement culture of research.
  - Do your best to recruit research talents with industry background(and make them stay).
  - Close collaboration with the software industry, without becoming a consultant.
  - Public funding that enable the above elements.