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Is Technology Transfer Possible?

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Highlights from a talk given on the occasion of the 60th birthday of Professor Wolfgang Menz at the University of Freiburg, Germany, are presented. Three promising methods of technology transfer from university to industry are reported: start-up company, infiltration by know-how carriers, and collaborative projects. Also mentioned are notorious transfer obstacles and ways in which they may be overcome. A joint project on infrared intrusion detectors is summarized as an example.

1. Introduction

The intricacies of technology transfer can be illustrated by two seemingly contradictory statements from the electronics industry:

> "Technology transfer cannot be prevented; you better hand it over as long as you get money or good will for it".
> "It is futile to look for technology at universities ready to be transferred to industry; you won't find any".

In this case, the truth is not found by interpolating between these extremes, which are both correct in a way explained at the end of this paper.

Microsystems, at least in Central Europe, seem to have transfer problems that recently made the following kind of headlines: "Although microtechnology enhancing sensors and the sensor market in Germany has been growing by 10% per year since 1994, the translation of research results into products is sluggish. Government funding of microsystems technology development in Germany by one billion DM up to now is controversial; the predicted revenues from new microsystem products did not materialize."

The word 'transfer' is used here on three different levels: translation of physics into technology, translation of technology into products, and translation of technology transfer into revenues. In order to inform the reader about the color of the glasses through which technology transfer is perceived here, some of the author's professional experience related to the topic is summarized in the appendix.

While actively pursuing technology transfer for more than twenty years when working for, or dealing with universities, companies, government, transfer organizations, and patent attorneys, the author did not investigate 'technology transfer' as a subject of economics or sociology. Thus, the following is not a systematic study backed by statistics and references, but a compilation from the author's limited personal perspective, mainly in the field of silicon integrated microtransducers and microsystems and from work experience in Europe and North America.

2. Three Promising Methods

Foundation, infiltration, and collaboration, in that order, are three basic methods of technology transfer from university to industry that sometimes work.

2.1 *Foundation*

By 'foundation' I mean the establishment of a new company. To start a company, possibly as a university spin-off, is in my opinion the best way to translate innovation into products and revenues. By 'innovation' I mean R&D results with a clear market feedback on the customer benefit. Proven customer benefit is the first prerequisite; even the most spectacular research results without perceptible customer benefit do not qualify for transfer.

This subsection is short in view of the abundance of literature and advice offered by consulting companies on how to start a company, from business plan to personal motivation and qualification. The cultural environment may or may not be beneficial for starting a new company.

(i) The environment should allow many degrees of freedom and have a low density of rules and regulations.
(ii) The culture should reward or, at least, tolerate courage and risk-taking.
(iii) Access to capital and patent protection of innovations should be possible.

Not every inventor is an entrepreneur. A company established in the market relevant to the innovation has much to offer, provided the inventor gets the company's attention. This is usually difficult to achieve from the outside (see NIH below). Therefore, the inventor may want to join that company. That brings us to the second method: infiltration.

2.2 *Infiltration*

By 'infiltration' I mean the friendly invasion of qualified, innovative engineers and scientists who move to a company with their qualifications to do the 'missionary work' of technology transfer from within. Know-how carriers and innovators, who join in order to stay, pay attention to the needs of the customers, develop a support network, and earn the respect of their new colleagues, have a chance to make a sustainable effort towards establishing a new product. Yet this is not trivial, in particular, in big organizations; that is why infiltration ranks second.

Universities have a natural way of transferring novel ideas, concepts, techniques, and views to industry, namely through the alumni, provided that companies are keen on hiring them. Attention to the qualifications required by the companies facilitates this transfer; here is another kind of customer benefit to be taken into account!

What about infiltration and missionary work in the opposite direction? Efforts to bring the corporate world to the university have been made from time to time. For example, the ongoing 'Venture 98' at ETH Zurich is an effort to encourage the foundation of spin-off companies. Venture 98 includes an exciting competition for the best business plan. The competition is open for students, research associates, and professors. Free coaching is provided by renowned corporate managers and consulting firms. Initially, 215 groups or individuals participated; 86 business plans have resulted so far.

2.3 *Collaboration*

Technology transfer by foundation or infiltration is not trivial and requires outstanding technical and personal qualifications. Nevertheless, these two methods seem natural and straightforward when compared to the more involved collaboration between university and industry through joint projects. Such projects, however, may suffer from conflicting goals and priorities, *e.g.*, the academic obligation to publish versus the corporate need to keep trade secrets, or the different timescales for changing research directions. Nevertheless, joint university-industry projects can succeed and become a source of professional satisfaction to all involved parties under the following conditions.

1. A 'champion' is required in each partner group, i.e., a person determined to make the project happen and to see it through obstacles in their own organization.
2. The project is supported by decision makers of each partner organization; hence the involved staff gain recognition in their organization for their involvement.
3. Potentially competing corporate in-house developers should be involved from the beginning and support, or at least tolerate, the joint project.
4. Successes and failures during the course of the project are shared fairly.
5. Collaborators are located, from time to time, as required by efficiency, in the laboratory of the other partner(s); this brings us back to infiltration (see section 2.2).
6. If the project succeeds, all partners benefit; if it fails, all partners have something to lose.
7. The contributions expected from each partner and the ownership of the benefits are clearly specified in the research plan.
8. Excellent communication must be maintained at all times; this limits the useful number of partners.

A working example is the four-partner, four-year project CEMSYST funded by the Swiss national priority program MINAST (1996–99) and two industrial partners. MINAST stands for Micro and Nano System Technology. The acronym CEMSYST is inspired by the names of the corporate partners CERBERUS and EM Microelectronic Marin. Partners from ETH Zurich are the PEL (Physical Electronics Laboratory; Prof. H. Baltes) and the

IIS (Institute of Integrated Systems; Prof. Q. Huang). The goal is to fabricate a CMOS thermoelectric intrusion detector.[1,2]

A post-CMOS etching process developed at PEL and transferred to EM allows the fabrication of thermally isolated sensors on CMOS dielectric membranes. The membranes contain thermopiles designed at the PEL, which are co-integrated with signal conditioning circuits designed at the IIS. The resulting microsystem detects weak infrared signals. While EM produces the chips, CERBERUS develops the packaging. The work flow is shown in Fig. 1. A Ph.D. student of the PEL is located at EM. The Ph.D. student responsible for the packaging is shared between CERBERUS and PEL. A prototype, which resulted after the project's first two years, is shown in Figs. 2–4 and Table 1.

3. Many Transfer Obstacles

There are more ways to ruin a project than to make it work. The author has experienced or observed more than a dozen such transfer obstacles.

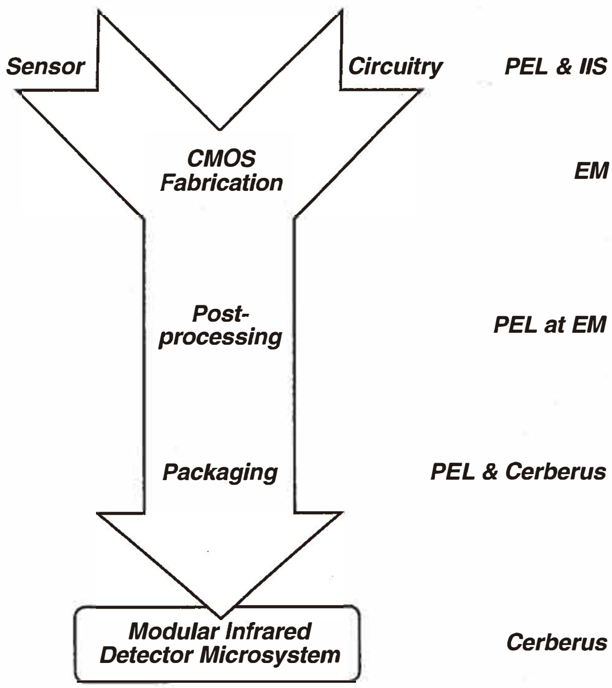

Fig. 1. Division and flow of work in the collaboration project CEMSYST.

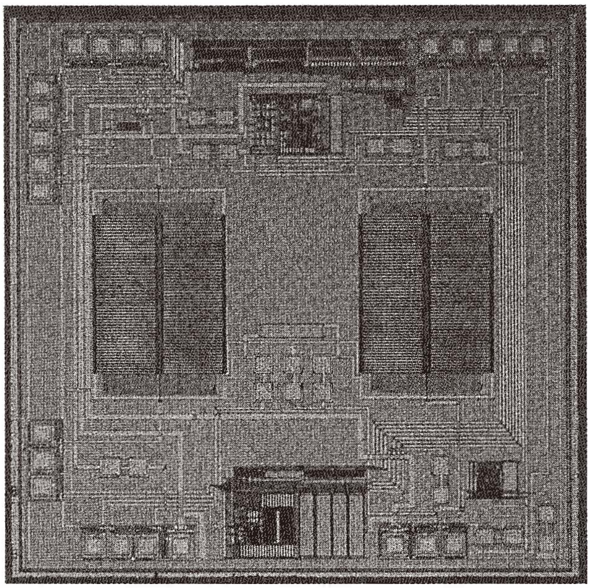

Fig. 2. Micrograph of 3.5 mm × 3.5 mm CMOS chip of infrared intrusion detector. The chip includes two thermopiles, each on a dielectric membrane, and signal conditioning circuits. See Table 1 for data.

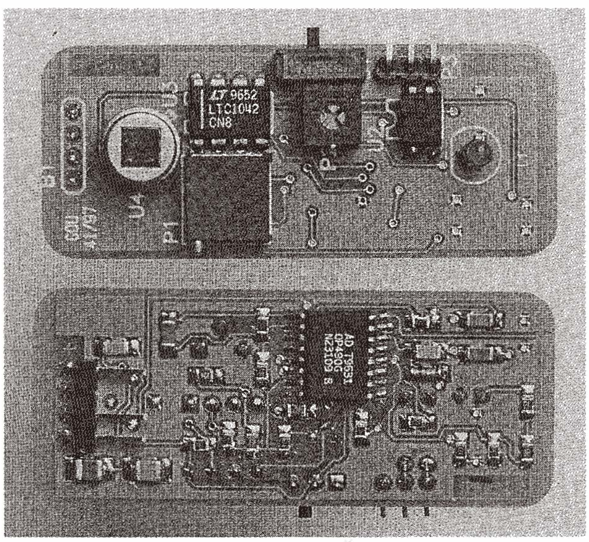

Fig. 3. Front and rear printed circuit board of intrusion detector. The chip shown in Fig. 2 is located in the round housing with infrared entrance filter on the upper right-hand side.

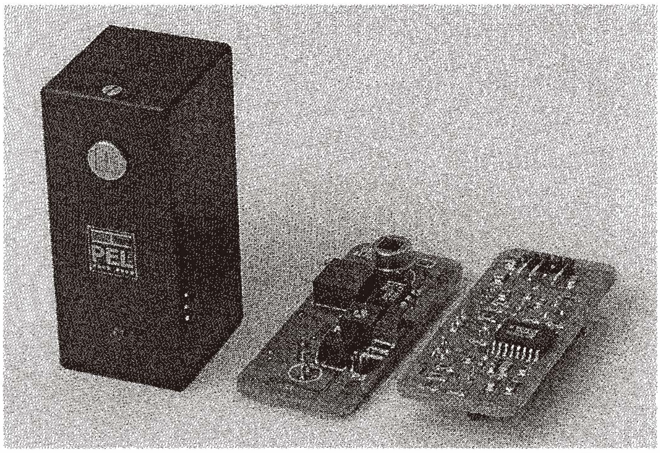

Fig. 4. Photo of intrusion detector and printed circuit board. The height of the housing is 61 mm.

Table 1
CMOS thermopile data.

Membrane size			length [μm]	1500
			width [μm]	700
Number of thermocouples				118
Thermocouple	material A	n^+-poly	width [μm]	4
	material B	p^+-poly	width [μm]	12
Thermopile resistance			[kΩ]	2260
Sensitivity			[V/W]	45.8
Response time			[ms]	13.1
Noise equivalent power			[nW]	4.2
Normalized detectivity			[cm $\sqrt{\text{Hz}}$ /W]	2.43×10^7

3.1 *NIH*

NIH stands for 'Not Invented Here' which is a very serious impediment to innovation. This spirit (or rather the lack of spirit) is illustrated by two typical statements: "We don't share our own ideas and we don't accept foreign ideas" and "If this were any good, we would have invented it long since".

Here are possible countermeasures: involve possible partners and critics from the very beginning; build a mixed team of collaborators from all partner organizations to develop team spirit; locate collaborators inside a partner organization and accept that they identify somewhat with that organization; persist in long-term missionary work; hand out prototypes only together with consulting (unaccompanied prototypes usually do not function in an alien environment).

3.2 *Innovation preventionists*

People that make a profession out of shooting down innovations can be found in any organization, corporate or academic. The excuses made for avoiding a move in a new direction are only too familiar:

This will never work — this is impossible — you must be nuts to even think about trying this — we never did anything that way — we always did everything the old way — this can never be done in Switzerland (insert your own country) — we leave this to the Austrians (insert any other nationality) — there will soon be a law to make this illegal — our company is too big to do this — our company is too small to do this — this comes far too early — this comes far too late — this is too expensive — this is not reliable...

A blunt way to handle this is to ask what else the preventionist has to contribute to the project besides those highly appreciated warnings. It may be more effective to take the objections seriously and ask the preventionist to make the points in writing, a step which is usually avoided for fear of commitment.

On the other hand, timing, cost, and reliability are serious issues that an inventor must consider. A working prototype, estimates of development time, fabrication cost, reliability, and test requirements, and, once more, customer benefits, are crucial supports of an innovation.

3.3 *Lack of motivation*

Lack of motivation for contributing to innovative products can be found in academic researchers, who could make a useful technical contribution, but whose ambition is focused on glory in fundamental research (there is nothing wrong with this). They may enter a joint project only to fund their own research, which is a motivation too weak to last. Companies may want to look for academic research partners who have already achieved a good track record in publications and scientific awards and whose interest is truly shifting to product applications.

In the past, lack of motivation could also be found in companies that had an R&D department mainly for the purpose of appeasing worried shareholders. This attitude, however, seems to be disappearing in a world competing for timely innovations. In the worst case, the inventor may have to negotiate with another company.

A lack of motivation for new ventures may also be caused by a high degree of contentment with the present situation. It is difficult to motivate a satisfied person to change. Maybe that is why many innovators and company founders are immigrants or refugees. Thus one must look for partners who are 'lean and hungry' and want to prove themselves, avoiding those with paranoid, blind ambition.

3.4 *Ego of researcher*

Some researchers (and some managers) overestimate the width of their abilities. They try to do everything by themselves, are immune to advice and blind to aspects of innovations that transcend their speciality. They may have to learn that money-making has more to do with emotional stability than with intellect. Pragmatism, openness to people gifted in other areas, and acceptance of all the help one can get for the project can be decisive for its success.

3.5 *Milestone optimism and pessimism*

Inexperienced, enthusiastic developers may get carried away by their desire for fast results and underestimate the time to achieve milestones typically by a factor of two. Influenced by an impressive sales person, they may be led astray by a factor of four!

It must be borne in mind that collaboration projects need extra time for team building. A preproject in preparation of a major collaboration can help to get a head start. Deadlines for delivering results may move towards the present time for valid reasons, irrespective of the research plan, while promised deadlines for procuring supplies may move towards the future. (This is known as the law of opposite time shifts.)

Overly cautious developers try to avoid commitments and are never done with their project, even when it is sitting ready in the drawer. Invoking their ambition may help to get them to open that drawer and move the result to production. On the other hand, ultrafast sales people may want to market innovations a tad too early. The resulting 'banana product' matures in the premises of the customer.

3.6 *Stop and go*

Researchers in industry (and their academic project partners) may feel frustrated by an unexpected termination of their project. They feel even more puzzled when, many months later, the same project is reanimated with the expectation of rapid results. This is one way, though not the best, to synchronize development and market whose signals change faster than development.

Some projects appear to be almost immortal and remind us of Nietzsche's philosophical concept of the eternal return of all things. Eighteen months seems to be a typical period for a dormant project to pop up again. The developer should try to live with this fact of project life by keeping good records, never give up a good project entirely, and keep talking to marketing. The proverbial (Japanese) advice here is "Fall seven times, get up eight times".

3.7 *Moving targets*

Another source of frustration are moving targets. Whenever the happy developer finally reaches the specifications, the bad news may be that the result is not good enough and that the specifications have been moved to a higher margin. This message often comes from the same people who had judged the previous target as being too ambitious. Management may feel encouraged by what has been achieved and now ventures for even more customer benefits in the best interest of the company. Another reason behind the moving target may be the intent to kill the innovation by requiring extravagant specs (see also section 3.2).

3.8 *Crooked bridges*

A number of organizations try to act as a 'bridge' between university and industry in order to improve technology transfer. Many of these do excellent work, such as the Fraunhofer Institutes, Steinbeiss Centers, or Hahn-Schickard-Institute in Germany, to name only a few. However, the author has also met 'matchmakers' who try to replace the university partner once they find a 'bride'. The resulting jealousy between researchers and bridge builders is detrimental to the cause of technology transfer. One solution is that university researchers build their own bridges to industry and eventually, a network of industrial partners. The alternative is to work with a proven, trustworthy bridge organization and toward a clear definition of expected contributions and benefits for each partner.

3.9 *Fence sitters*

In the course of a project, some partners are never sure whether they really want to be involved, but they shy away from deciding not to be involved. They 'sit on the fence' and watch. Should the project work out, they may want to come in and share the benefits. This attitude is almost a guarantee that the project will fail. Only proactive partners, including at least one Champion from each partner organization, with full support of their decision makers (see section 2.3), should participate.

3.10 *Lame ducks*

Again, excellent, proactive collaborators from each partner organization should be involved in the project. It is tempting to keep the most competent collaborators for in-house projects and second some 'lame duck' to a collaboration project. That person has a chance to evolve into an innovation preventionist or a fence sitter (see sections 3.2 and 3.9). The project leader should make any reasonable effort to win solid collaborators of every partner organization. If that is not possible, the partner's motivation is probably too weak anyway.

3.11 *Legal barriers and stalemates*

Law by itself is usually not a transfer obstacle, but what about lawyers? The author had the pleasure of working with some of the finest lawyers experienced in the demanding field of technology transfer contracts. Some of these had degrees in both engineering and law. They managed to keep the collaboration contracts balanced, short and transparent.

On the other hand, corporate lawyers (or university scientists) without that special experience may bring about obstacles. The author has witnessed negotiations of trivial nondisclosure agreements that have taken seven months, and of collaboration contracts that have taken in excess of 2 years. The author has also witnessed drafts of contracts which attempt to use the university as a free quarry, clauses protecting only the secrets of one partner, but not the other, conditions that would allow only one partner to terminate the contract, but not the other, etc.

If possible, collaboration contracts should not be negotiated directly by the engineers and scientists who will later collaborate in the project, but rather by their superiors or by experienced negotiators. Otherwise, the confrontations which may occur naturally during such negotiations could be detrimental to the team spirit needed later. Of course, the technical collaborators must be consulted for the contents of the contract and, in particular, for the technical content.

3.12 *Lack of patent protection*

Technology may transfer faster than the inventor would like, once an unprotected innovation is disclosed. Here are some basic rules.

1. Anything published is in the public domain and can no longer be patented.
2. Disclosing proprietary information to people not belonging to your organizations can count as a publication. Let visitors sign a nondisclosure agreement before you talk or do not talk.
3. A patent application costs time and money. To keep a patent running worldwide is even more costly.
4. There are different kinds of protection.
   A. Don't tell anybody. This saves time and money; both may be employed to put the invention to work, but benefits come only when the product is sold.
   B. Publish your idea; then nobody else can claim it anymore, but anybody can use it freely. A publication costs time, but you can add it to your CV.
   C. Ask your patent attorney about various types of patent protection. If you do not have one, get one!

3.13 *Kill by perfect planning*

Planning often replaces chaos by error and thus should not be taken too seriously. While a project outline and collaboration agreement are needed, too perfect a plan slows down the project's start and may lead to oversized projects that will be shot down. It is better to start small and let the investment grow along with the growing confidence in the results. One of the most successful projects of the PEL was never planned and never evaluated, and yet won the IEDM Best Student Paper Award 1997[3] and led to a spin-off company.

3.14 *Boards and committees*

"In the time a committee finds out why it can't be done, the cowboy gets his innovation to the market" (LSI Logic). The strength of committees is to prevent the worst mistakes, rank alternatives, and bring about a political balance by involving all interested parties. A committee cannot be expected to push innovations; the bigger the committee, the bigger the chance to have innovation preventionists among its members.

3.15 *Company size*

The author has had good and bad experiences with companies both big and small, and is not sure whether size is an obstacle to technology transfer. Most likely, size is irrelevant and only quality counts. Big companies can afford big resources and outstanding managers; one has only to find them and work with them. Small companies are versatile; decisions, often made by one person, are swift and contracts are short.

4. Conclusion

Let us return to the initial statements. It is indeed difficult NOT to transfer an innovative technology (i.e., a technology with customer benefit) once the market pull is there. This is experienced also at universities. If the transfer of a desired technology is refused, this will slow down the other party, but ultimately, they will get it going anyway (at least in the area of microsystems). For key products of a company, that time advantage may be decisive, sufficient, and worth defending. A university, however, should transfer research results, for a fair price, preferably to national companies, whose taxes help to support it.

The other statement refers to innovations ready to go to the market. Only in exceptionally lucky cases may these be found at universities. The first 'product' of a university are competent students; next come research results, while their translation into innovative products ranks third. It is, however, possible to recognize the potential customer benefit of university R&D results, to produce more such results through dedicated research programs, and to translate them into innovative products.

In this sense, technology transfer from university to industry is, indeed, possible!

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Appendix: Author's experience related to technology transfer

In 1974 – 82, the author worked for Landis & Gyr (now part of Siemens) and was responsible for, *e.g.*, university contracts and CMOS magnetic sensors for electronic watt-hour meters. In 1983–88, he held a chair at the University of Alberta (Canada) with the task of bringing university and microelectronics industry closer together. As acting President of the Alberta Microelectronic Centre (now a company with 65 employees) he negotiated a US$ 20 million technology transfer contract with the LSI Logic Corporation of Canada, of which he was a cofounder and Member of the Board. To that end, he spent several weeks in a law firm and learnt about conflicts of interest.

Since 1988, at ETH Zurich, he has been directing the Physical Electronics Laboratory (PEL), which now has 30 collaborators and 15 corporate partners. He has been strongly involved in several university-industry collaboration programs, in various roles from program director to project grant receiver. Since 1990, the PEL produced 24 Ph.D. theses, 300 publications, and 16 patents. Most PEL alumni work for electronics firms in Switzerland or the Silicon Valley; some of these have become PEL's corporate partners. Specific technologies transferred recently include two different post-CMOS etching processes, CMOS thermopiles for flow sensors (spin-off company) and infrared intrusion detectors, wafer stack technology (another spin-off company), and MEMS CAD modelling tools licensed to software companies (one of which is yet another spin-off from ETH Zurich).