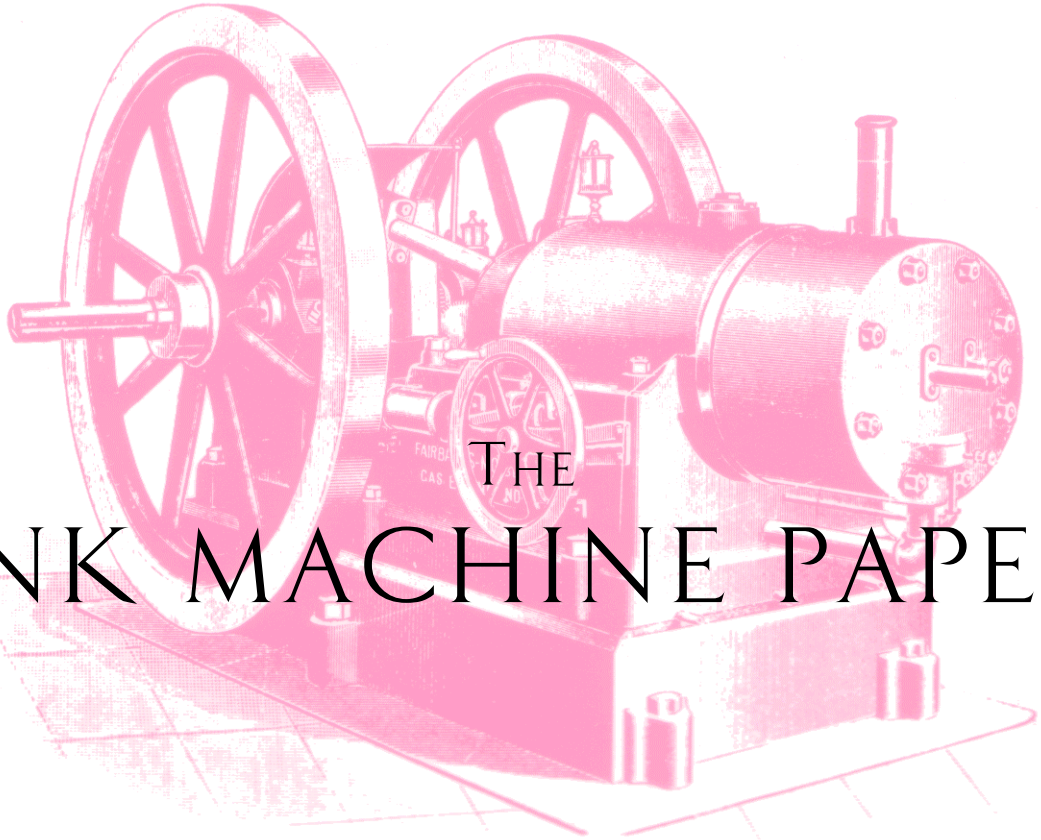

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The Way of the Engineer

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I've written this paper in order to describe the use of the Swedish term 'ingenjörsmässigt', which means something like "in the manner of an engineer"; in a way, it's about that thing called the *art of engineering*. I'm interested in 'ingenjörsmässigt' because I have the feeling that it's a concept that can explain quite a few things about the nature of the work of engineers.

You see, I'm working on the subject of engineering beauty: 'Engineering beauty' is related to the concepts of elegant technical designs and the pride of a job well done. These are in resonance with various engineering ideals: efficiency, simplicity, economy, robustness, reliability, order, and so on. All of them are closely connected with the assumptions of rationality: I think I mean by this that those values originate in a rational view of the world.

But the word 'beauty' does not pertain to the rational view of the world. Beauty stands apart from it and opens a different door: that of the unnecessary, the luxurious, the non-serious. These values are not very present in our understanding of engineering and I want to write a thesis about them. And I was thinking that it could be a good idea to start from the more official side of engineering and then move on towards its frivolous aspects. So this is a study of what engineering officially is, a very small study, mind you, that uses the word 'ingenjörsmässigt' as a key.

Being an engineer, I have heard this word many times, but in order to make sure that I got the official view, I arranged interviews with some professors at the KTH so that they could tell me what they thought. These interviews were carried out in the spring of 2001, in case anyone needs to know; and I studied at engineering schools between 1987 and 1994 (and worked as an engineer until 1998). You never know, someone might find this paper fifty years from now and wonder at which point in the story of Swedish "ingenjörsmässigt" had this meaning. Because, as we all know, meanings change with time. Well, this is a picture (limited) of the word "ingenjörsmässigt" as we go from the 20th to the 21st century.

It would be foolish to claim that there exists something as the true use of the word and that it is only my shortcomings that keep me from presenting it to you. Shortcomings I have, plenty, but that is not the main problem. The main problem lies somewhere in the incompatibility between the ideal of the definition of a word and

what language actually allows. But this is a major problem, and I do not want to get entangled in it. In order to avoid it, I have deliberately chosen to limit this paper to the discussion of only two words. They both struck me as central connotations of the concept of 'ingenjörsmässighet' while carrying the interviews and they came to me repeatedly afterwards while studying them. Those two words are 'seriousness' and 'elegance'.

one connotation: seriousness

I'm not sure "connotation" is strong enough to express this. I'd rather say that it is a matter of "ingenjörsmässighet" being marinated in seriousness. It is a connotation so contagious that it flavours everything that comes into touch with it. You make a sentence that includes "ingenjörsmässighet" and the whole thing gets this solemn taste. Very decent and dignified, something to do with propriety and good manners and, yes, maleness as well.

It is difficult to find something equivalent in English, especially for me, a Spaniard, could "the art of engineering" help? "The art of engineering" is more a, what should I call it?, compounded substantive? Well, a substantive of some sort whereas "ingenjörsmässigt" is an adjective but I think that, just for the purpose of clarifying, it just might work. Nevertheless, I am not sure that it carries the same connotations and, in fact, it is not very important.

Anyway, "ingenjörsmässigt" is something that imposes respect and veneration, a word to use to stop quarrels and legitimise budgets. If something has been done "ingenjörsmässigt" (in the manner of the engineers) then it deserves all our trust. It sounds a bit like "expert" and "knowledge" and even "science". This is part of the introduction to the Britannica.com article on engineering:

> *the application of science to the optimum conversion of the resources of nature to the uses of humankind. The field has been defined by the Engineers Council for Professional Development, in the United States, as the creative application of "scientific principles to design or develop structures, machines, apparatus, or manufacturing processes, or works utilizing them singly or in combination; or to construct or operate the same with full cognizance of their design; or to forecast their behaviour under specific operating conditions; all as respects an intended function, economics of operation and safety to life and property." The term engineering is sometimes more loosely defined, especially in Great Britain, as the manufacture or assembly of engines, machine tools, and machine parts.*
>
> *The words engine and ingenious are derived from the same Latin root, ingenerare, which means "to create." The early English verb engine meant "to contrive." Thus the engines of war were devices such as catapults, floating bridges, and assault towers; their designer was the "engine-er," or military engineer. The counterpart of the military engineer was the civil engineer, who applied essentially the same knowledge and skills to designing*

> *buildings, streets, water supplies, sewage systems, and other projects.*
>
> *Associated with engineering is a great body of special knowledge; preparation for professional practice involves extensive training in the application of that knowledge. Standards of engineering practice are maintained through the efforts of professional societies, usually organized on a national or regional basis, with each member acknowledging a responsibility to the public over and above responsibilities to his employer or to other members of his society. [...]*
>
> *Britannica.com (on "engineering", June 2001)*

Some words speak for themselves: "scientific principles", "responsibility", "optimum", "efficiency". This is the oil, vinegar and spices of the marinade. And the taste of it is "seriousness". Not only engineering is serious, it seems that anything that wants to receive attention and respect from the public spheres has to put on the grey suit of seriousness (I have to read Gustafsson's *Produktion av allvar* and Guillet de Montoux's *Handling och Existens* again). As Provine writes in his study of laughter:

> *Have you ever encountered a leader of high authority who has a giggle? How many really funny generals are there? Would such a person be considered a "serious" or "formidable" member of an organisation? (Provine 2000, p31)*

So, from the perspective of seriousness, "ingenjörsmässighet" finds its place amongst other sober words, like "democratic" and "profit" and "economical factors" and "science" and a few other. All of them share a common trait: they are considered important and not to be taken lightly. In the case of technology the argument could be: Something that is in charge of creating and keeping up the means for our own security, for our own heating and transportation, our food and our health must be put inside the domain of the decent. The weigh of these significant tasks encumber "ingenjörsmässighet" and make of it a heavy and serious adjective.

I don't mean to say by this that engineers are all serious persons or that all engineering is related to the question of the survival of the human species. It's rather the other way round, at least as far as the second item is concerned. A lot of engineering is not carried out in order to satisfy the basic human needs. Engineers design toys, fanciful computers, advanced building structures, satellites, voyages to Mars, formula one cars, Smarts, luxury houses, special effects for the movies, Caribbean cruisers and amusement parks. None of these can be considered as essential for the human race but, still, "ingenjörsmässighet" is pervaded by seriousness.

So, if "ingenjörsmässigt" is considered serious in the public sphere, you can imagine that it is considered also serious by those in charge, or at least partly in charge, with its maintenance. It might prove tricky to deny that the KTH is on of the engineering strongholds in Sweden and it would be imprudent to believe that "engineering" would be anything but serious there. Engineering *is* a serious matter at the KTH, in fact, I don't think it is wrong to say that it is a matter of life and death. One might try to

rationalise this in some way or another, like: "given the society in which we live, anything less than very serious would be suicidal since it seems only serious undertakings are considered important. And if engineering were not important, if it were not central for Sweden's present and future, then KTH would not be important and would disappear, or loose its central role." This is a nice little exercise in rationally explaining observed phenomena but I really don't believe that professors at the KTH think along these lines, or any other lines. For most of them, as for many engineers, engineering is important, it is an activity to be carried out in earnest, for no reason in particular, this is just the way it is.

So, naturally, when I asked them about "ingenjörsmässighet" or about what it means to be a good engineer, most of the conversation turned around serious issues: the need for a solid basic knowledge, for being able to collaborate with other professionals, for keeping oneself updated, for seeing the "big picture" and so on. None of these is exclusive to engineering, my guess is that professors in psychology, sociology, management, medicine and whatnot would say something similar. They would probably also consider their own fields to be serious. Very much in this line is the word "professionalism" used very often to express emotional detachment and seriousness in one's job. Even football players (and I hope no-one actually believes that football playing is central to the survival of our species) talk about being professionals and doing one's job regardless of the circumstances around it.

The word "professional" can help me a bit more in trying to explain "ingenjörsmässigt". The sentence "She is a real professional" can mean something like "her mother died yesterday but nevertheless, she came to work today". That person takes her duties seriously and doesn't let personal emotions get in the way of her work. This sort of thinking is strongly moralising, it presents "work", "professionalism" and "seriousness" as virtues. All this is pretty close to Weber and his reading of the influence of the protestant ethics in the spirit of capitalism. Claes Gustafsson has also written about the moral power of concepts like "work", "usefulness" and others in his *Produktion av allvar*. "Ingenjörsmässigt" can, in this sense, be considered as the equivalent of "professionally" in the field of engineering.

Now, the sentence "She is a real professional" can also mean something like "she is a very good...", a very good whatever her profession is, including engineer. And this is where we find the next connotation, in the idea that something done "ingenjörsmässigt" is something well done.

another connotation: aesthetics

So the word "ingenjörsmässigt" does not only have the smell of seriousness in it, it also has another strong connotation: it is the feeling that doing things in the manner of the engineer (ingenjörsmässigt) is the *right* way to do things. Not all sorts of things, granted, but definitely those related with artefacts. This "right" is not a moral one, it is, rather, an aesthetic one. It hasn't got to do with what is right or wrong in a moral sense but what is right to do in a practical way. Doing things ingenjörsmässigt yields the best results... but then, why did I say "aesthetic"? Because, for an engineer, good technical solutions are elegant and neat (read Tracy Kidder's *The Soul of a New Machine* for quite a few examples). As you can see, I use the term "aesthetic" as in

"pleasurable for the senses", in a rather primary meaning. I have left aside the concept of art and transcendence, which are fairly slippery, really.

Now, what exactly this engineering manner of doing things consists of is a bit unclear. I cannot say that I have been able to discover any engineering method, a set of rules to follow in order to do things right. No, "ingenjörsmässigt" does not seem to be the name of a working method, it is more an adjective that means "good" or "well done" and so it focuses on the result and not so much in the method. Now, what would be something that is well done, according to the KTH (to my interviewees, that is)? Let's listen to one of them:

> *- "... if I say 'they have solved the problem 'in the manner of engineers' (ingenjörsmässigt)'..." I said.*
> *- "Then I feel this is an objective and thorough way of solving the problem, one can really trust the result", he commented.*
>
> *(from my own material, April 2001)*

That's not very clear either, is it? That a problem that has been solved "ingenjörsmässigt" means more or less that it has been solved by someone (or a group) who has a "solid background knowledge", who has "started with a thorough consideration of the problem", who has "identified and presented the problem" and who has "applied the knowledge to the problem" (all these quotations from the interviews). As you can see, the word is difficult to capture.

So we have the aesthetic feeling (pleasing to the senses) of things done right (technical problems solved in an ingenjörsmässigt way) and we also have what I said before: Doing things ingenjörsmässigt yields the best results. One is tempted to believe that we are dealing with a reversed definition: instead of defining what "doing things in the manner of an engineer is" and showing that it is the best way, one could choose the best results and then decide that the method applied to reach them is the "ingenjörsmässigt" one. It does sound like Feyerabend describing the scientific method, looking for examples of it, not finding any, and finally giving up with a frustrated 'obviously, anything goes'. But it is not exactly like that. It is true that I cannot find an engineering method but there is some sort of engineering mode of thinking, even if it is difficult to describe. After a few years of training at engineering schools in order to get your degree, you do learn a few things. This is an extract from one of the interviews:

> *There is a difference between knowledge (as in things one knows) and capability (things one knows how to do), and it is obvious that it is the second one which is most important... an engineer should be trained in capabilities, attitudes, method more than in specific knowledge. It's not always easy, it's easier to evaluate knowledge than attitudes... Students are often put under tough time constraints, they have to acquire knowledge and pass an exam... and this is valuable in itself. But otherwise it is a question of method, of attitude... to identify a problem, describe it and solve it.*
>
> *(own material, April 2001)*

I think that the following simplification might be meaningful: the patterns of engineering beauty are imprinted in the "capabilities, attitudes, method", whereas "knowledge" is what is necessary to see the patterns at all. By this I guess I mean that if you have to study at the KTH and go through all the courses, you will develop a feeling for what is an elegant technical solution; in other words you will absorb it indirectly, because there aren't any courses called "ingenjörsmässighet" or anything of the like. It is all those things you learn that distinguish which solutions are "ingenjörsmässigt" and which are not, in other words, which are proof of good engineering and which not. However, one has to keep in mind that the fact that you can distinguish a neat solution from an inelegant one doesn't make you a good engineer.

Well, and finally, what characteristics does engineering beauty have? What is it that good engineers will seek in their designs? And, can I maybe see where these values came from? In this paper I shall only deal with one of the more obvious.

order and structure

I'd say that one of the main characteristics an "ingenjörsmässigt" solution possesses is order. But a system that feels in order for an engineer might not feel obviously so for the rest of the world. Especially for the user of the system. This different appreciation of what "order" in the design of a system implies is a good path to follow.

Order, for an engineer, is related to the relationship between the elements of a system. Those elements should be clearly separated, for instance in groups according to their inner functionality, and the links among them should also be obvious. A user, on the other hand, might very well never see, or need to know about, nor the elements of the system neither their inner functionality. Anyone interested in the receiving system of the TV? Or the system that triggers the electron rays to the screen? Or something as ubiquitous as the AC-DC transformer? But this are the elements upon which the engineers base their design. It is not so difficult to see that a very neatly engineered artefact doesn't need to be user-friendly at all. So the user might say that the artefact is a complicated useless bunch of cables and buttons and switches when the engineer feels it's the work of a master.

Why this difference? Well, I think we might seek the origin of the structure minded engineer in the sort of courses that he or she has to study. What do those technical courses all have in common? or even better, why not ask the professor at the KTH what characterises a good engineer? Only one of the professors I interviewed had a problem with the idea of a "good engineer" (of the sort "what is a good engineer, after all?") and most of them started their answer by telling me that a good engineer should have "a solid background knowledge". I think this "solid background knowledge" is strongly related to the "attitude" and to the aesthetic values in engineering. So, what should this solid background knowledge include? A knowledge of mathematics, physics and the actual technological field. In what way are these the origin of the strive for engineering order?

The **mathematics** that are taught at engineering schools are almost exclusively applied mathematics, that is, the mathematics needed to solve numerical problems (in

my experience, how advanced these mathematical methods are differs from one country to another and from one field to another). This means that engineers do not get into the inner workings of the body of mathematics. I do not know a lot of mathematics but I know enough to say that what engineers learn of it is quite uninteresting for most mathematicians. We stay at a very practical level, one in which mathematics works, in the sense that the results obtained through it are completely trustworthy. If you use some algebra to design a self-correcting code, you know that it will work, that algebra at that level is totally predictable; the same goes for differential calculus, if you calculate the forces that a wing will have to support you can be sure that the mathematics work.

The subject of **physics** is a bit different than that of mathematics. Physics is, in a sense, applied mathematics, so it has that in common with engineering. The main difference between physics and engineering is that physicists are interested in how the world works, full stop. Engineers interested in constructing artefacts, and therefore need to know about how the material world works. The Britannica.com says, about engineering:

> *The function of the scientist is to know, while that of the engineer is to do. The scientist adds to the store of verified, systematized knowledge of the physical world; the engineer brings this knowledge to bear on practical problems. Engineering is based principally on physics, chemistry, and mathematics and their extensions into materials science, solid and fluid mechanics, thermodynamics, transfer and rate processes, and systems analysis.*
>
> *(britannica.com on engineering, April 2001)*

Both mathematics and physics are, for all we engineers care, complete systems that describe a coherent world (I shall not discuss whether this coherent world actually is the real world or only an abstraction of it). What I mean by this is that the formulas we use and the mathematics needed to yield them are faultless. Example: a very common sort of mechanical problem one has to solve in the first year courses deals with things sliding down on inclined planes. You are supposed to know how far the ball (or rope or whatever) will go, or how fast or how much energy it will have when it reaches the end (or any other moment in time). In order to do this you are given some data (like the weigh, the inclination of the plane, some friction coefficients and so on). And this is the important thing: all this different values can be related to each other in an exact way by means of mathematical formulas. The energy is one half of the mass times the square of the speed; force is mass times acceleration, and so on. All these concepts (force, energy, speed, acceleration, time, etc.) form a perfect system, they are exactly defined and related to each other. The problems get more and more complicated but the basic idea is the same.

Mechanical problems (like the ones with falling things) are a but a sort of technical problems. Mechanics is considered as a basic subject in most engineering schools, probably because it is a very good example of a coherent system. Once one has passed the first years one starts to learn more and more about one's own subject. Like telecommunications, for instance, and then the questions are different (how many bites can you send with these atmospheric conditions and this sort of equipment if

you need to have a signal-to-noise ratio of at least 3db) but the basic idea is still the same: a coherent system of concepts with exact mathematical relations among them.

This quality of technical problems (coherent system) reminds me of what Wittgenstein said about super-mechanisms: "Cf. a lever-fulcrum. The idea of super-hardness. 'The geometrical lever is harder than any lever can be. It can't bend.' Here you have the case of logical necessity. 'Logic is a mechanism made of an infinitely hard material. Logic cannot bend'"(Lectures and Conversations, p15). He is definitely not talking about engineering or physics (he is talking about superlatives, I believe) but it struck me as very similar to the sort of mechanic relation I have described. What engineers study and the calculations they carry out are based on an ideal 'unbendable' relationships. These are technical problems.

None of the professors I interviewed did ever mention that learning engineering would make anyone better suited for management, or politics or flying air-balloons. They might mention in the strong rational ingredient of engineering but that was all. They insisted that good engineers are good at solving TECHNICAL problems, and that was all.

Sorry, what is a technical problem again? A technical problem is one which a) can be described in technical terms, that is, that can be reduced to rigid clear-cut concepts (as in the instrumental physics and mathematics we learn); and b) which can be solved if one knows how these concepts are related to one another (the formulas). As one of the professors put it, "engineers like to put apart things, see how the pieces are connected, and then put them together again". A technical problem is one that can successfully be treated in this way.

Notice that I have not said what technical problems are about, only what form they have. This form is about the nature of the concepts involved in it and the relations among them. Whether a given problem can be successfully treated as a technical problem or not is an altogether different question. Can, for instance, political and managerial problems be successfully treated in the technical manner? Hard to say.

Somehow I believe that this concept of coherent systems lies at the heart of the engineering order. The elements that form a TV have 'unbendable' relationships amongst them, very clear and very functional. This means that they will adapt better to a special sort of structure (that of the engineering design) than to other sorts of order.

There exists a gap between engineers and users, a gap that comes from the difference in technical knowledge (and interest) and one of the professors said: "I think there will be a shift... there's already a shift underway, engineers must stop designing for other engineers and start designing for the users". Users are more often than not very uninterested in engineering beauty and their measure of success is rather the ease of use. Obviously, engineers want their own designs to be successful and widely used but this doesn't change the importance of technical elegance and the pride taken in designing neat artefacts. In Kidder's story about the building of a new Data General computer in the late seventies there are several examples of engineers that refuse to work on an "ugly" model, even if it was more likely to attract buyers (it would be cheaper than one designed from scratch):

> *Not everyone associated with the Eclipse Group liked the looks of this proposed new machine. They thought it would be just a refinement of the Eclipse, which was itself a refinement of the NOVA. "A wart on a wart on a wart," one engineers said. "A bag on the side of the Eclipse." Some even said that it would be a "kludge," and this was the unkindest cut. Kludge is perhaps the most disdainful term in the computer engineer's vocabulary: it conjures up visions of a machine with wires hanging out of it, of things fastened together with adhesive tape. (p 45)*

Steve Wallach worked in Data General at the time, he was one of the stars in the engineering firmament at the company "a walking dictionary and encyclopedia of computers. He's the best guy in the world for that job". What job? Nothing less than drawing up the architecture for the new machine, the "crucial first technical act in the making of this [new machine]".

> *Accordingly, West called Wallach to his office in the spring of 1978 and asked him to draw up the architecture for a 32-bit Eclipse. Steve Wallach glared at West. Wallach got to his feet and, coining a phrase, said: "Fuck that! I'm not puttin' a bag on the side of the Eclipse." Then he stomped out of West's office.(p 68)*

I'm considering that there might be more to this issue of 'unbendable' elements: it is not only that the technical coherent systems are based on 'unbendable' relationships, this rigidity is guaranteed by the fact that artefacts are made of dead things. Cogwheels, microchips, cables, transformers and the such are known to be inflexible entities. So the very nature of the elements used to construct artefacts requires a rigid sort of thinking. This thinking has to be different if there are humans in the design (as elements) for they are known to be quite flexible; for instance they are capable of simultaneously holding opposite opinions about the same matter and making a decision that involves them, all this without crashing. This has, as we all know, both positive and negative effects, but the point is that the nature of technology as we know it today requires "this sort of capability, the attitude towards problem... some sort of rationality that is taken to the limit... calculating in a broad sense, analysis of given data." (from the interviews). This rationality "taken to the limit" is what reminds me of the super-hardness in that quote of Wittgenstein, and the image of rationality taken to the limit must be total order of the parts.

So much for order and structure as aesthetic values in engineering. There are other values, like economy (in the sense of austerity), efficiency and creativity. All these are generally present in those beautiful solutions, but that will have to be another paper. I also wonder whether the connotation of seriousness isn't somehow related to order (you know, frivolity and playfulness are not directly ordered), but that'll be another paper as well.

Thanks for you attention.

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Pink Machine is the name of a research project currently carried out at the Department of Industrial Economics and Management at the Royal Institute of Technology, Stockholm. It aims to study the often forgotten non-serious driving forces of technical and economical development. We live indeed in the reality of the artificial, one in which technology has created, constructed and reshaped almost everything that surrounds us. If we look around us in the modern world, we see that it consists of things, of artefacts. Even the immaterial is formed and created by technology - driven by the imperative of the economic rationale.

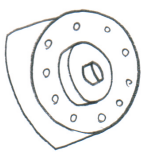
As Lev Vygotsky and Susanne Langer have pointed out, all things around us, all these technological wonders, have their first origin in someone's fantasies, dreams, hallucinations and visions. These things, which through their demand govern local and global economical processes, have little to do with what we usually regard as "basic human needs". It is rather so, it could be argued, that the economy at large is governed by human's unbounded thirst for jewellery, toys and entertainment. For some reason - the inherent urge of science for being taken seriously, maybe - these aspects have been recognised only in a very limited way within technological and economical research.

The seriousness of science is grey, Goethe said, whereas the colour of life glows green. We want to bring forward yet another colour, that of frivolity, and it is pink.

The Pink Machine Papers is our attempt to widen the perspective a bit, to give science a streak of pink. We would like to create a forum for half-finished scientific reports, of philosophical guesses and drafts. We want thus to conduct a dialogue which is based on current research and which gives us the opportunity to present our scientific ideas before we develop them into concluding and rigid - grey - reports and theses.

Finally: the name "Pink Machine" comes from an interview carried out in connection with heavy industrial constructions, where the buyer of a diesel power plant worth several hundred million dollars confessed that he would have preferred his machines to be pink.

Claes Gustafsson



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