Advanced Methodical Design
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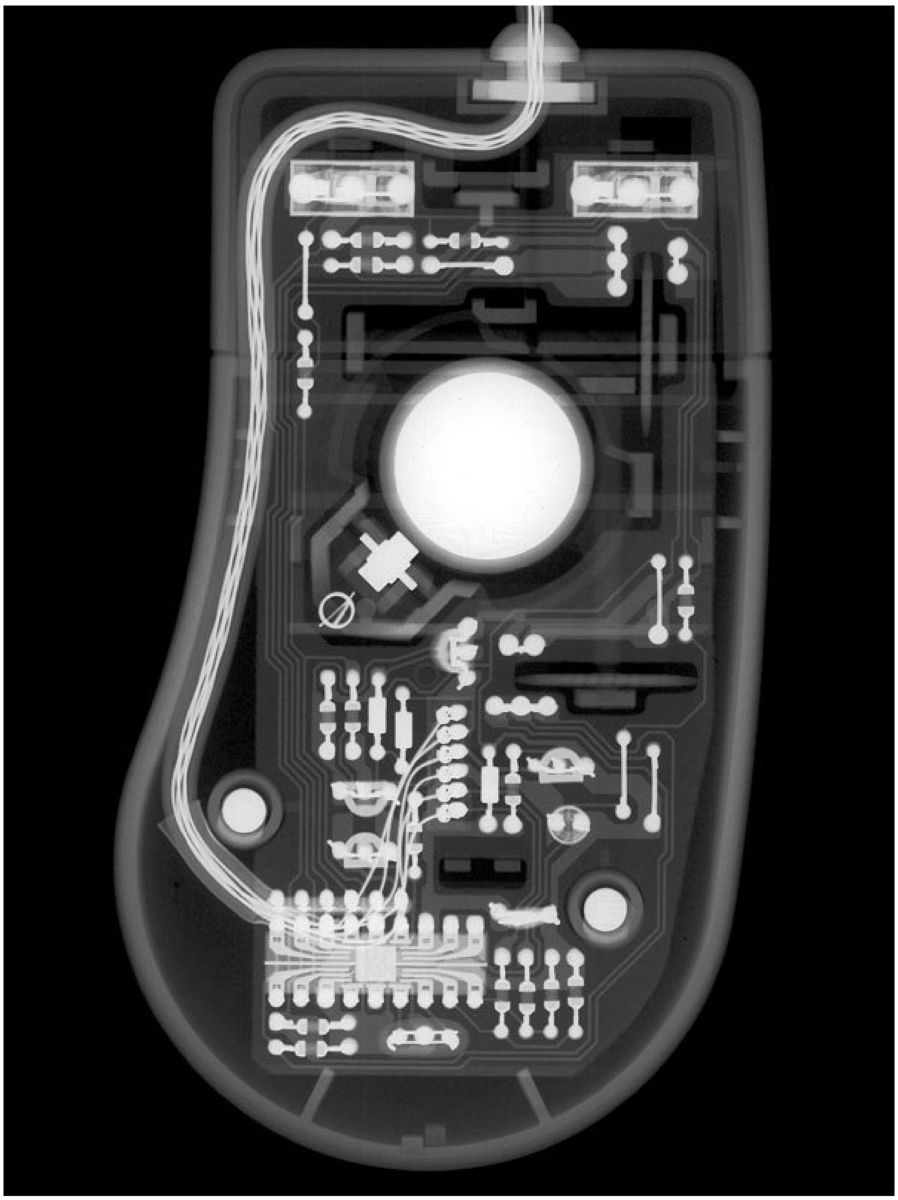
# Manufacturing techniques

## Reverse engineering the computer mouse



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**Douglas Engelbart**

Douglas Engelbart invented the computer mouse in 1963–64 as part of an experiment to find a better way to point and click on a display screen. Fashioned at the Stanford Research Institute, it had a carved wood casing and just one button. A subsequent model had three buttons, and Engelbart would have provided more if there had been room for more than the three micro switches to which the buttons were connected (Douglas Engelbart. (2011). In *Encyclopædia Britannica*. Retrieved from http://www.britannica.com/EBchecked/topic/187881/Douglas-Engelbart).

*Engelbart, Douglas: first computer mouse*. Photograph. *Encyclopædia Britannica Online*. Web. 26 Apr. 2011. <http://www.britannica.com/EBchecked/media/50966/The-first-computer-mouse-Douglas-Engelbart-invented-the-computer-mouse>.

**Fabrication/materialization**

Everything around us is manufactured somehow, if it didn't grow, crawl or walk there itself or was there before us. Especially when in the city you should be aware that all our surroundings are artificial; that someone build or made it. All civilizations are characterized and named by the craft that they mastered: the Stone Age, Bronze Age, Iron Age. Long after we're gone, all what's left of our civilization will be a black layer in the soil; remnants of plastics, oil, strange organic molecules: long strands of carbon atoms. Our time will be known as the carbon age.
Knowing that almost everything around us is somehow manufactured, means that understanding our surroundings means somehow understanding how things are made. This is what we will do the coming weeks. But in a very limited way… We will try and understand how mice are made…

**Reverse engineering**

From wars, either in conflict and space race or shear competition, engineers have always tried to topple the opponents technological advantage by trying to analyze and understand the opponents technological achievements. After the sputnik crisis (in 1958 the Russians launched the sputnik satellite in orbit, completely surprising the USA), the Americans started the space race and tried to launch probes on missions to other planets, trying to beat the Russians in setting new records; after years of trying to keep up with the Russians, in for instance building cameras that could take photo's on other planets and outer space, they gave up and secretively copied the Russian designs.
Reading someone's design is difficult because designs are influenced by technological history, culture and the personal preferences of the designer. Luckily however, the physics are the same on each side of the border and thus logic should explain why designs are as they are. This process of trying to understand the reasons of design decisions and the architecture and principles of a design are called reverse engineering.

- **Reverse Engineering (RE):** "disassemble or analyze in detail in order to discover concepts involved in manufacture." - "reverse engineer*." The Merriam-Webster Dictionary, New ed. 2004.*
- **Reverse engineering** is "the process of discovering the technological principles of a mechanical application through analysis of its structure, function and operation. That involves sometimes taking something apart and analyzing its workings in detail, usually with the intention to construct a new device or program that does the same thing without actually copying anything from the original." - *Wikipedia*

## The goal of the project

We are going to reverse engineer the Microsoft computer mouse. Now, mind you, if you do this the right way, you should be able to put it back together afterward and use it again. So any action or use of tool that might irrevocably damage the mouse is a bad move and should be substituted with a subtler one. If you are, however, interested in the deepest innards of the mouse, say the electronics or the ball, than a knife comes in handy and your mouse will be rendered damaged and useless as a pointing device. You loose a mouse but gain knowledge!
The goal of this project is to understand the reasons and decisions and principles of the manufacturing of the computer mouse: why which material is favoured over another, why the specific shapes are selected and why these are manufactured using the specific techniques. A good reverse engineering session should tell you:

- **What the function of the part is and how it works,**
- **Why this material is selected**
- **Why it is this shape**
- **And how and why it is manufactured using the apparent technique.**

Added to that you'll be asked to suggest alternatives to all the aforementioned findings.

You will do this together in a team and each team member will analyse a different part. Together you will provide a paper, in which the computer mouse is completely reverse engineered.

**4 students, 12 parts**
Decide in the team who will analyse which parts. Make an overview photo or drawing of the mouse, its parts and the part names.

- Cable
- underside, screws and stickers
- upper side and buttons
- ball
- counter wheels
- ball wheel
- electronic components
- PCB

Decide on a paper layout, and individually start working on your part. Name the probable LORAW and base your suggestions upon that.

**Requirement of the finished paper:**

- All 4 students produce one paper together
- The paper contains the entire reverse engineered computer mouse (pictures, exploded view with nomenclature drawings and drawings of the manufacturing tools used)
- The paper has one consistent layout and style
- The paper lists the separate parts of the computer mouse
- The separate parts are analyzed for manufacturing technique, used (determined) material, LORAW and design considerations
- An alternative for the part, or some parts is given based upon the LORAW

**Example… The ballpoint pen.**

The following chapters contain an example of a reverse engineered ballpoint pen. Only one part is actually analysed. My hope is that your paper supersedes my example as it took me only 2 hours to make the entire example…


The ballpoint pen. A writing device invented in 1988 by the American born, John Loud (http://www.ideafinder.com/history/inventions/ballpen.htm, 2007) and first successfully marketed by the French company BIC in 1950 (http://www.bic.fr/inter_en/corporate/history/baron.asp, 2007). Writes like a pencil, but never needs sharpening. Disperses think ink on paper by means of a tiny ball in the point of the pen: hence the name ballpoint pen. This ballpoint is integrated into the ink cartridge, which can be retracted into the handle of the ballpoint pen by a simple 'click'  motion on the button at the non-writing end of the ballpoint pen. The ballpoint pen features a clip for attaching it to cloth (the edge of a shirt pocket for instance) In the device under investigation, this clip is broken off.
If there was any manufacturer name on the ballpoint pen it was probably on the clip. The manufacturer is now unknown.

**The Ballpoint pen: LORAW**

- Device disperses ink on paper
- Device facilitates writing on paper
- Ink from device does not smear after seconds
- Device features mode to prevent dispersing ink in surrounding
- Device fits in chest pocket

- Device outing provides space for company text and logo
- Device fits in human hand to provide comfortable writing
- Device is operated as competing products
- Device should facilitate normal writing for about one week
- Device should be extremely cheap
- Device is a throw away item
- Live expectancy of all parts is greater than ink capacity
- All materials are safe in contact with user
- …
- …


**The Exploded view of the ballpoint pen**

The device consists of two separate lines: three outside parts, featuring blue transparent plastic, and the inside line; featuring 4 parts normally not visible. All parts, with the exception of the ink cartridge, can be taken apart without any tools or excessive force. Total of 7 parts can be distinguished. The ink cartridge seems to consist out of at least three parts and ink. A company name: "www.mhf.se", the Swedish based "Swedish Abstaining Motorists' Association" and its logo are printed in yellow on the largest outside part of the pen.

**Nomenclature of the ballpoint pen: exploded view left to right.**

*Grip* *clip* *button*

*Spring* *cartridge* *indexing part, male* *indexing part, female*

**The Button**: the end on the pen that can be pressed upon to loch the pen in either extended ort retracted state. Is pressed upon by the thumb:

The button can be assembled as the last part and is press-fitted on the *indexing part, female*

**LORAW**

- The button features an attractive colour
- The button has a pleasant thumb interaction
- The button has a press fit on the *indexing part female*
- The button has a loose fit within the end of the *clip*
- The button is very cheap

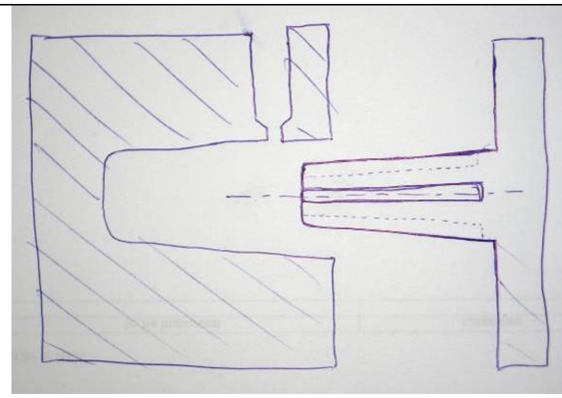
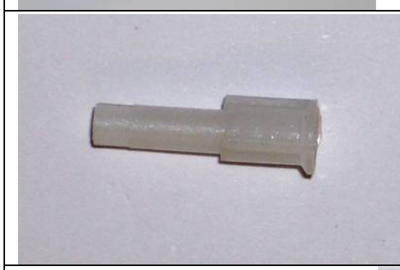
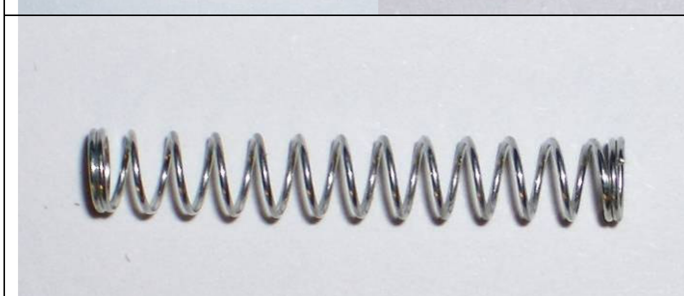
**Possible Manufacturing technique**

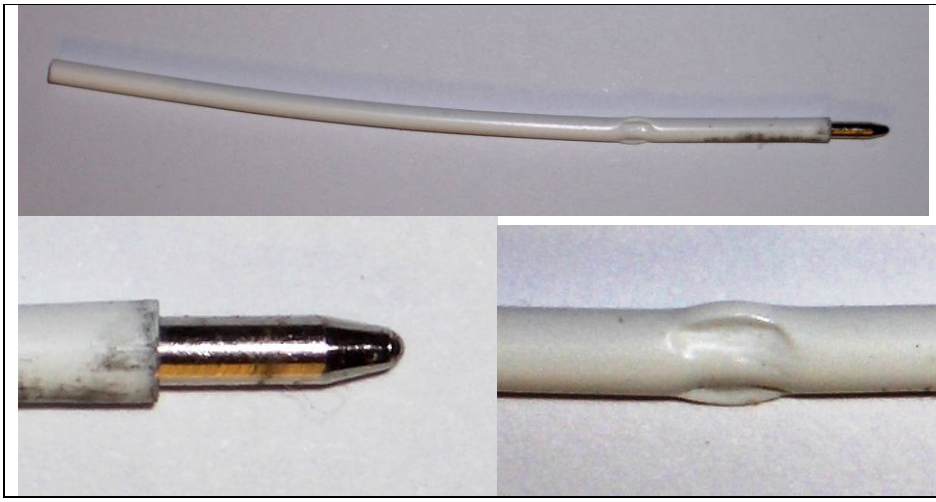
The button is slightly tapered upward and shows a distinct mark (red circle). All signs of the used injection moulding technique. Very commonly used for cheap, mass produced, plastic parts. Pity that there is no mark for the plastic used.

**Possible Materials**

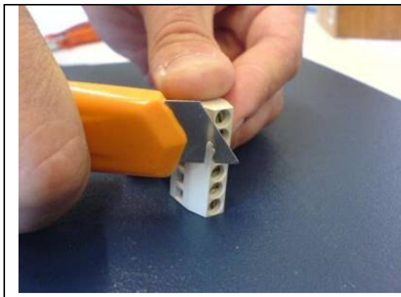
Being injection moulded, tough, transparent, smooth, relatively hard and cheap allows for the following plastics being used:
PMMA, PE, PP, PS and PC.
PMMA is ruled out as being too brittle, PC as being too expensive. Most likely PE or PS is used as PP has a maybe slightly softer feel to it.
Flame determination leads to a slightly sweet, extinguished-candle-like smell: PE it is.. PP smells like oil when burned, and PS like… Styrofoam (see table on last page).

**Verdict:**
Injection moulded PE in a mould like this:

| | |
|---|---|
| The mould clearly has release angles, the PE is injected from the side. There is no cavity number on the part, but one could assume that a dozen of these parts are produced in one mould at the same time. |  |
|   | **The clip** |
|   | **The grip** |
|    | **Indexing part, male** |
|    | **Indexing part, female** |
|  | **The spring** |

| | |
|---|---|
|  | **The cartridge** |

**Plastic determination/identification table (Vink Catalogue, 2004, Didam, The Netherlands)**

| | | |
|---|---|---|
|  |  |  |
| Cut a sample from your part. | Light the sample and watch. | **Gently** wave some smoke toward your nose. Smell, not inhale! |

| Plastic | Density ($g/cm^3$) (float in water?) | Flammability | Appearance of flame | Material change/scent of smoke | When burning |
|---|---|---|---|---|---|
| PA | 1.04-1.15 | Partly self-extinguishing | Blue with yellow edge | Burnt horn or wool | Swells and drips a lot |
| POM | 1.40-1.42 | Burns on when lit | Weak blue, hardly visible | Sharp scent of formaldehyde | Swells, might drip |
| PET | 1.39 | self-extinguishing | Yellow, smoking | sweetish | Black ash |
| PE | 0.91-0.96 | Burns on when lit | Light yellow with blue core | Stearine or paraffin scent (extinguished candle) | Swells and drips |
| PP | 0.91 | Burns on when lit | Light yellow with blue core | Burning oil | Swells and drips slightly |
| PVDF | 1.78 | Difficult to inflame | yellow | TOXIC FUME! | chars |
| PTFE | 2.20 | Difficult to inflame | yellow | TOXIC FUME! | Swells and chars |
| PC | 1.20 | self-extinguishing | Bright and smoking | Vague burnt, sweetish | Swells in little blisters |
| PVC | 1.38-1.40 | self-extinguishing | Yellow with green core, flickering, smoking | Sharp hydrochloric acid scent | Swells, drips slightly |
| PMMA GS (cast) | 1.18-1.20 | Burns on when lit | Yellow with blue edge, sparking | Sweet, fruity | Swells easily in little blisters |
| PMMA XT (Extruded) | 1.18-1.20 | Burns on when lit | Yellow with blue edge | Sweet, fruity | Swells in little blisters, might drip |
| PPO | 1.06 | self-extinguishing | Flickering yellow, smoking | colloid | Black ash |
| PS | 1.04-1.09 | Burns on when lit | Light yellow-red, black thick smoke | Sweet styrene scent (Styrofoam) | Swells and drips |
| ABS | 1.05-1.10 | Burns badly just not self-extinguishing | Yellow with blue core black thick smoke | Weak sweetish styrene scent (Styrofoam) | Swells slightly and chars |
| PUR | 1.20-1.26 | Some flammable some self-extinguishing | Bright yellow | Sharp very unpleasant isocyanate scent | Might drip, drops with threads |