// CONCEPT DEVELOPMENT OF RESCUE VEHICLE

"If you aim for the stars, you're bound to land on a moon"
A. Einstein

We have been so fortunate to have the opportunity to conduct a concept development project in cooperation with one of the leading Norwegian constructors of fire engines, namely Egenes Brannteknikk AS.

Our main objective with this project has been to materialize ideas and concepts that may serve as a pathway in to the future. Although Egenes Brannteknikk constructs and builds vehicles, which need to be reliable and durable during various circumstances, they have always strived to have an advantage over their competitors by delivering both innovative and customized products. And their main goal has always been to provide the best equipment available to a group of people that serve an imperative role in modern society.

The field of fire fighting was totally new for us as industrial designers. It has both challenged and exited us. By approaching it from a pragmatic angle, we have developed a concept that hopefully will broaden the perspective of the term "fire engine".

NTNU
Norges teknisk-naturvitenskapelige
universitet

Fakultet for ingeniørvitenskap
og teknologi
Institutt for produktdesign

Masteroppgave for student Ole Terje Østrem og student Tom André Tarlebø

Utvikling av konsept for redningskjøretøy
Concept Development of Rescue Vehicles

Masteroppgaven utføres i samarbeid med Egenes Brannteknikk AS, som er en av Norges ledende bedrifter innen utvikling og produksjon av brann- og redningskjøretøy. Bedriften utvikler sine produkter for å imøtekomme kundenes spesifikke behov gjennom å tilpasse eksisterende kjøretøysplattformer og redningsutstyr levert av eksterne leverandører.

Oppgaven vil innebefatte konseptutvikling basert på eksisterende og fremtidige klient- og brukerbehov, samt å utforske implementering av ny teknologi som kan være fordelaktige i brann- og ulykkessituasjoner.

Oppgaven vil blant annet omfatte:

- Analyse av klient- og brukerbehov, samt informasjonsinnhenting
- Idé og konseptutvikling
- Evaluering og raffinering av konsepter
- Detaljering av endelig konsept
- Konseptpresentasjon

Oppgaven utføres etter "Retningslinjer for masteroppgaver i Industriell design".

Ansvarlig faglærer: Guy Lönngren
Bedriftskontakt: Stein Asgeir Egenes, Egense Branteknikk AS

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ansvarlig faglærer

Johannes Sigurjónsson,
instituttleder

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// CONTENT

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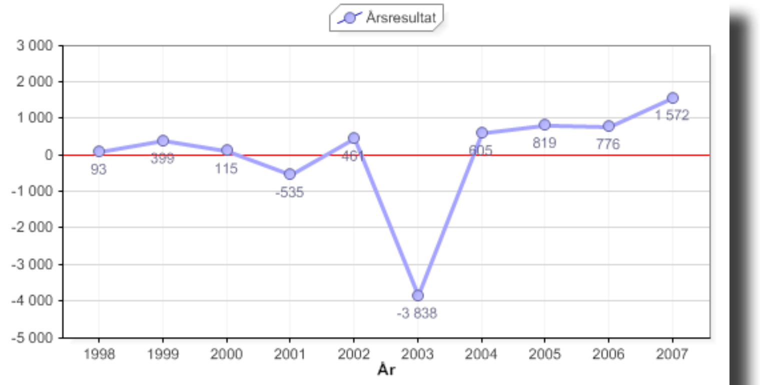
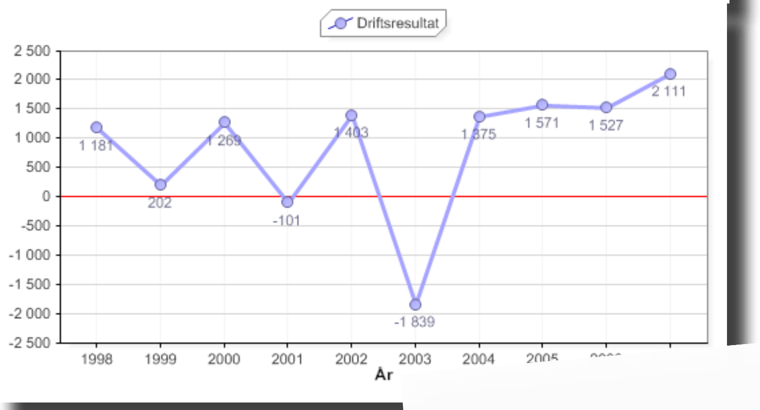
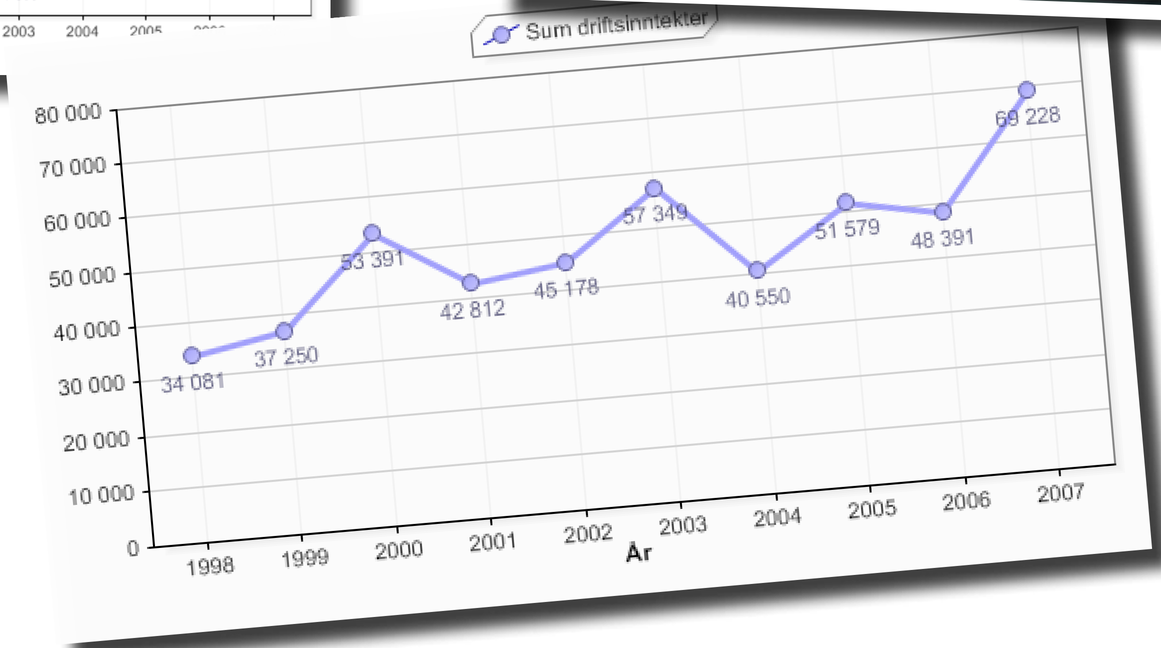
Birger Thurn-Paulsen, Firefighter, 2. Brigade, Brann- og Redningstjenesten i Sør-Trøndelag

1
BACKGROUND







EGENES BRANNTEKNIKK AS is a Norwegian coach builder located near Flekkefjord, Norway. Egenes is Norway's second largest manufacturer of emergency vehicles with an annual production of 30 vehicles per year.

The company is the official Norwegian Rosenbauer agent and delivers Rosenbauer-equipped fire trucks, primarily on Mercedes Atego or Scania chassis, as well as "Panther" airport vehicles on MAN chassis. In addition Egenes delivers command and rapid-response vehicles based on vehicles like Mercedes Vito, Mercedes ML and Mitsubishi Pajero.

In 2007 Egenes won a contract with the Norwegian Royal Air Force to deliver 22 airport vehicles. The company has just completed delivery of 43 airport vehicles to Avinor, equipping Norwegian primary and secondary airports.

Economy:
Egenes has shown a steady turnover of around NOK 50M yearly the last 5 years. Increasing to the NOK 70M turnover of 2007, primarily due to the Avinor contract. Egenes has recently expanded their workforce from 19 to 25 to cope with demand.

// EGENES BRANNTEKNIKK AS

The Rosenbauer Panther is a specialized airport fire-fighting vehicle. Since the redesign in 2005, the innovative vehicle has won the IF design award, Red Dot Design award and the German Design Price in Silver. The vehicle is constructed on a MAN chassis and employs light-weight materials like GFRP and Aluminium-sandwich to lower weight and increase performance.

The vehicle has two operators. Water, foam and powder extinguishing agents are delivered through robotic turrets, ensuring the safety of the personnel. In addition the vehicle has a self-defence system with underbody nozzles allowing the vehicle to fight aircraft fires up close even in situations with burning fuel spill.

The interface consists of a traditional steering-wheel for controlling the vehicle, two multi-function-displays (MFDs) to replace traditional instruments and joysticks for controlling the turrets.

// ROSENBAUER PANTHER

Low — Specialization — High

1 | Fire truck
The traditional fire-truck is a multi-purpose vehicle containing a tank, pumps, hoses, nozzles, ladders and other equipment needed in conjunction with fire-fighting and rescue operations. An accurate analogy is a mobile toolbox.

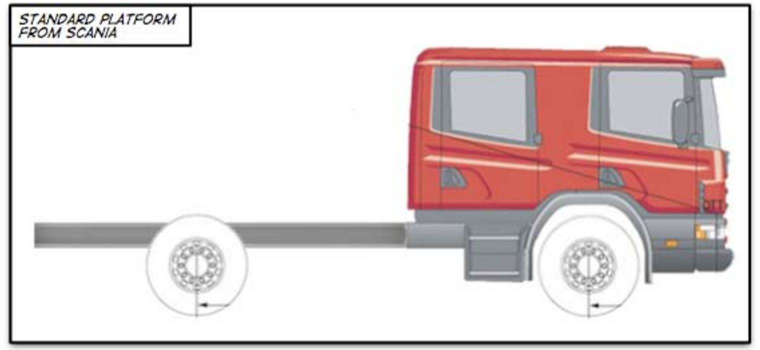
2 | Command vehicle
A command vehicle is usually a smaller rapid-response vehicle used by the on-site coordinator. It is more nimble than the fire truck and contains communication and information systems to gather information, and coordinate the effort with police and ambulance services. It may also contain equipment for transporting smoke-divers or other specialty personnel.

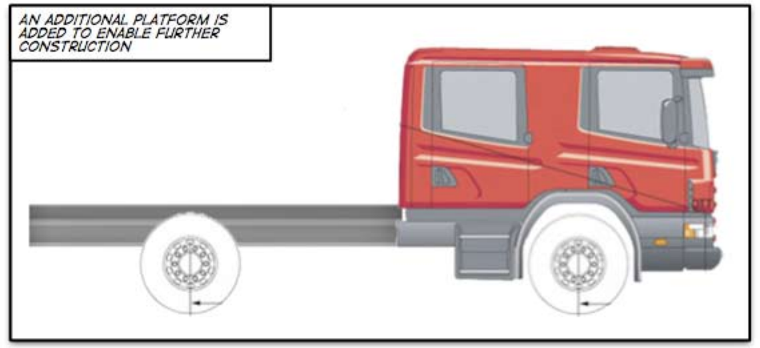
3 | Rapid response vehicle
The rapid response vehicle is adapted for traffic-accidents and/or waterside accidents. This vehicle may contain equipment like hydraulic pliers/ scissors, cutting tools, equipment for divers. Most of this will also be present in a fire truck.

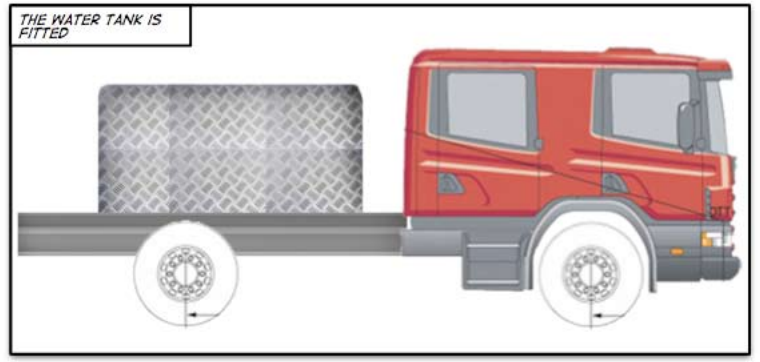
4 | Airport vehicle
The Airport vehicle is a specialized fire fighting vehicle, specially adapted to putting out fires in aircraft. Generally with an emphasis on liquid fires (gasoline, etc.). The vehicle consists of large tanks for water, foaming agent and powder, a pump, and several turrets/nozzles to deliver the extinguishing agents. The turrets are generally robotic and may be controlled from within the cockpit. This allows the fire fighters to use the protection of the cabin to approach the fire further to allow for a more effective extinguishing.

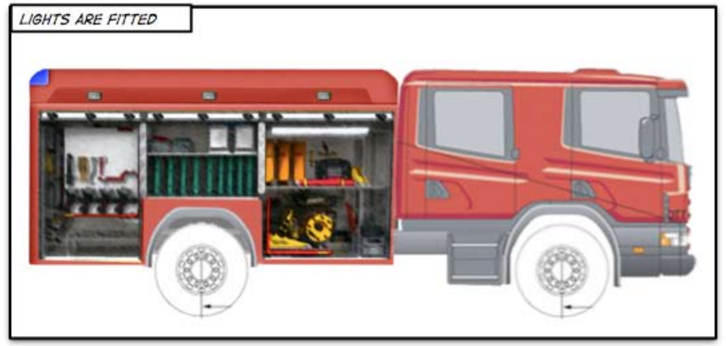
5 | Tanker
The tanker is a very specialized vehicle, consisting solely of a large water tank. The tanker is mainly used in rural areas and other areas where the water delivery system is not dimensioned to the demands of traditional fire fighting.

// PRODUCT RANGE









// CONSTRUCTION OF VEHICLES

Traditionally, fire trucks have always been built on a truck platform. This platform consists of a steel-beam chassis, usually a diesel engine using a 4 x 2 or 4 x 4 transmission. Other platforms exist, such as 6 x 4 or 6 x 6 for heavy duty of off-road use.

A steel frame is bolted onto the chassis. This contains mounting-points for the water-tank, pump, cabinets and other miscellaneous equipment. The tank is usually mounted in the centre of the vehicle with the pump directly behind this. As the pump is mechanically driven, a shaft extends from the pump to an auxiliary transmission. Cabinets are mounted on all sides and fitted with equipment as specified by the client. Finally, accessories such as ladders, lights, electric generator, winch etc is mounted on the vehicle.

This way of building emergency vehicles is not economical with regard to volume or weight. By making a platform that more closely fits the demands of a fire truck or is generally more flexible, it will be possible to build a more efficient, lighter and more nimble vehicle.

In the early 2000's Oslo Fire Department experimented with the use of a FireBus™. This vehicle is built on a bus-platform, which is much lower and more space efficient. Despite better use of space, more comfortable seating and reduced internal noise, the vehicle was no success. Long wheelbase and front and rear overhang made the vehicle difficult to navigate in the narrow streets of downtown Oslo, and the vehicle in question is now used as a command and coordination vehicle for large operations involving police and medical personnel.

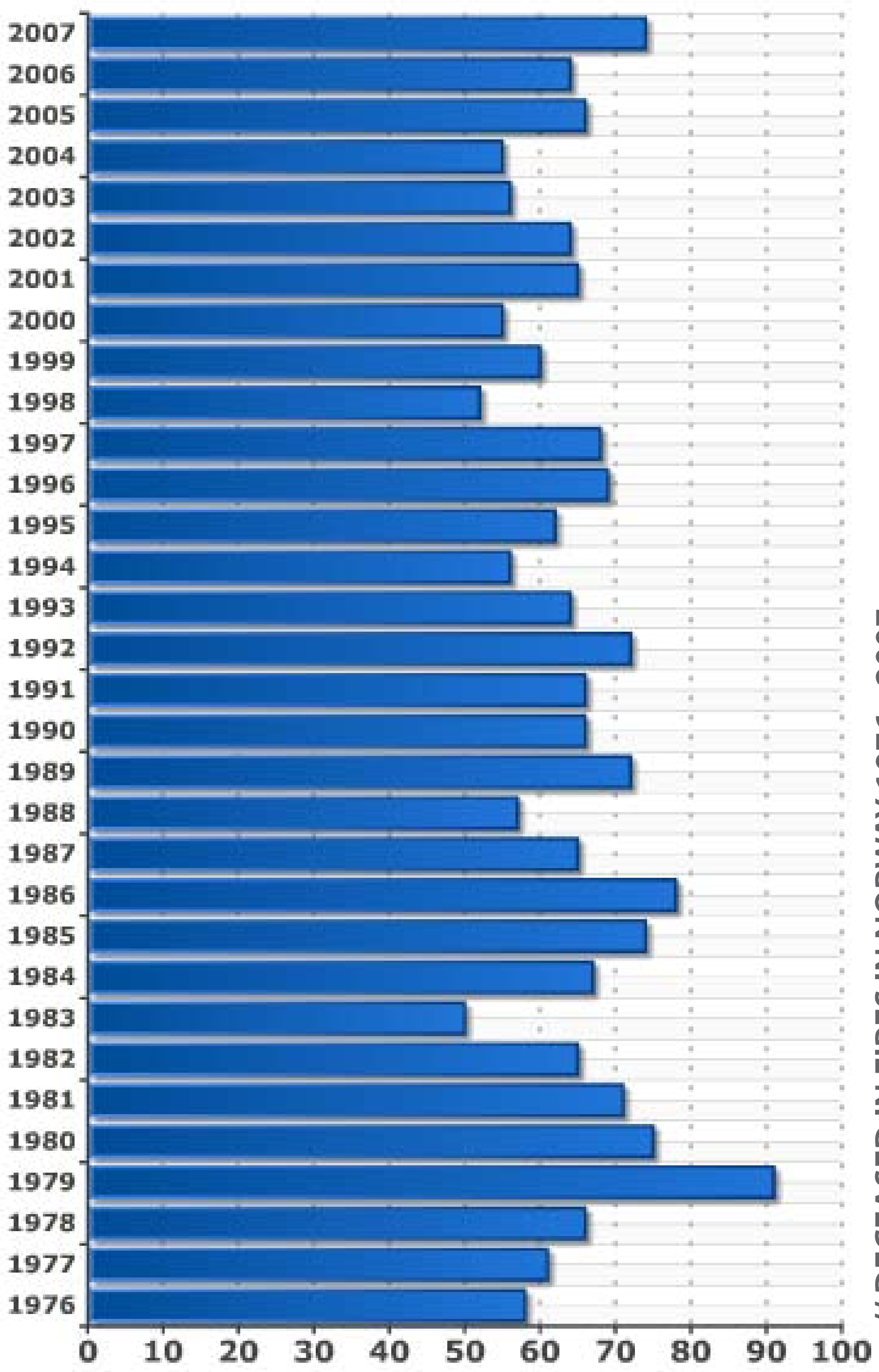
A conventional fire engine is designed to fulfill a variety of different tasks. In all aspects of life where accidents occur, the fire fighters play an essential role. The reason is mainly because the Fire Department possesses a variety of tools and equipment to solve most of the tasks.

The Fire Department plays, for instance, a key role in most traffic accidents. Not just to eliminate the imminent danger of fire that such a situation might produce, but also to free and salvage people trapped within the battered vehicles.

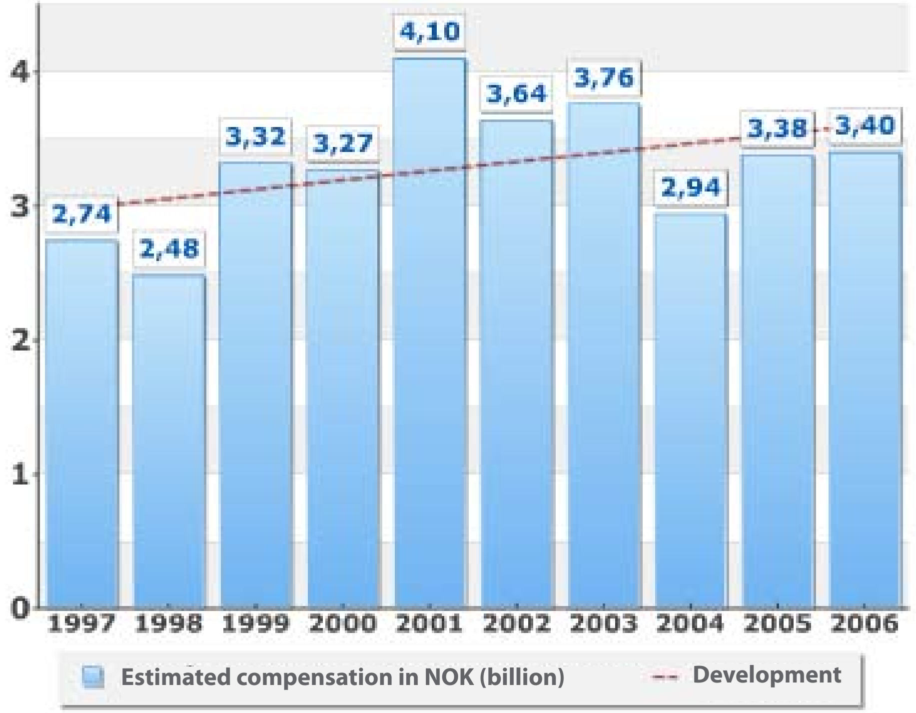
Additionally the Fire Department is the core participant when trying to locate persons that might be drowned or missing close to shore. Most major Fire Departments also consist of a diving division, which specialize in carrying out tasks under water.

We have decided to concentrate on the main objective of the Fire Department, namely to extinguish fires. Through our qualitative analysis with the three respective fire fighting units, we concluded that it would be more beneficial to investigate further into an area that has not undergone development to the same extent that the other tasks has seen.

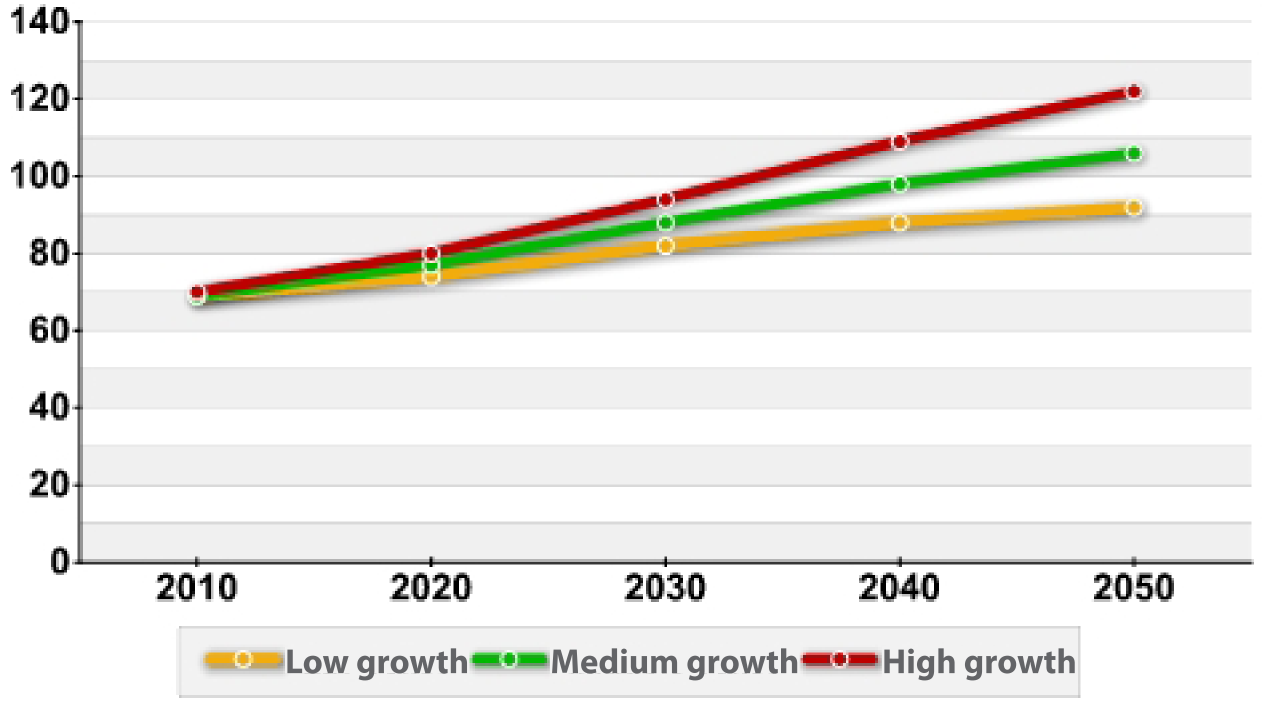
// FOCUS AREA



// DECEASED IN FIRES IN NORWAY 1976 - 2007



// FIRE RELATED COSTS



// ESTIMATED NUMBERS OF DECEASED IN FIRES 2010 - 2050

Even though a number of preventive measures have been taken on a national level in Norway, to limit the destruction caused by fires, they do not seem to have achieved as successful outcome as anticipated. In 1991 it was demanded that each and every Norwegian household should mount at least one smoke detector in their house, as well as a fire extinguisher or a fire hose. This helped limit the size of the different fires to some extent, but as the numbers tell, the amount of deceased each year remained more or less the same.

In 80 % of the cases these deaths occur in the households. The reason the numbers are higher where we live rather than where we work and play, is mostly due to the strict regulations and routines that public buildings need to accommodate. The lack of routines in the household is regarded as being the main reason why the household fires are more likely to claim lives as opposed to fires in public buildings. It is further estimated that the number of deceased will raise to at least 90, in the best case scenario, and 120 in worst case scenario, by the year 2050.

This is mainly due to a growing percentage of the population consisting of elderly people with a strong desire to live at home, rather than in more controllable institutions where there are both more assistance and routines in case of evacuation.

In addition the development regarding the amount of valuables that perish is rising each year. Where the development is going to stop is hard to anticipate, but it does not seem to decrease any time soon.

An aspect that these statistics do not take in to account is the loss of items of great personal affection. Of course this is not an amount that is possible to measure, but nevertheless a regard that cannot be overlooked.

// CONSEQUENCES

2 FIRE FIGHTING

A fire is a self-sustained exoterm reaction of a combustible material with oxygen. Fires need three key components to be sustainable:

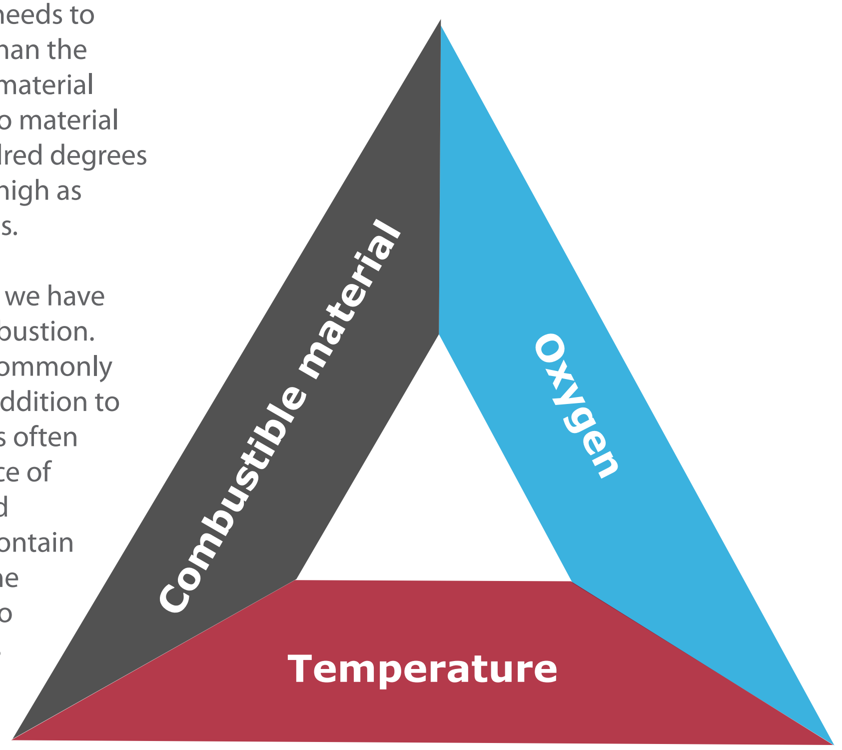
1| Combustible material
2| Oxygen O_2 > 15%
3| Temperature $T > T_{Comb}$

Combustible material
The combustion is an oxidation process, and therefore the material needs to be oxidizable. Nearly all material has this property, therefore almost any material can burn, even metal.

Oxygen
Air naturally contains 21 % oxygen which, usually, is sufficient for the combustion to take place. An oxygen content of less than 15 % will usually be inert, it will not be able to sustain a fire.

Temperature
Apart from the ignition, the fire needs to maintain a temperature higher than the combustion temperature of the material (T_{Comb}) This varies from material to material and may be as low as a few hundred degrees Celsius for hydrocarbons and as high as several thousand for some metals.

When all of the above is present, we have what is known as sustained combustion. These factors compose what is commonly known as the triangle of fire. In addition to these three factors domestic fires often have an additional factor; a source of ignition. This last factor is needed because houses do not usually contain temperatures high enough for the materials found in a household to auto-combust. Common sources of ignition includes faulty wiring, candles, sparks, etc.

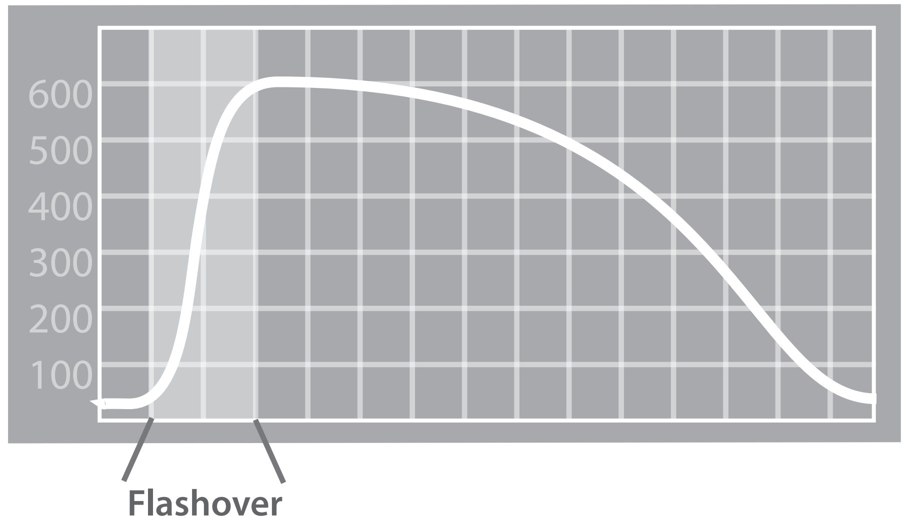


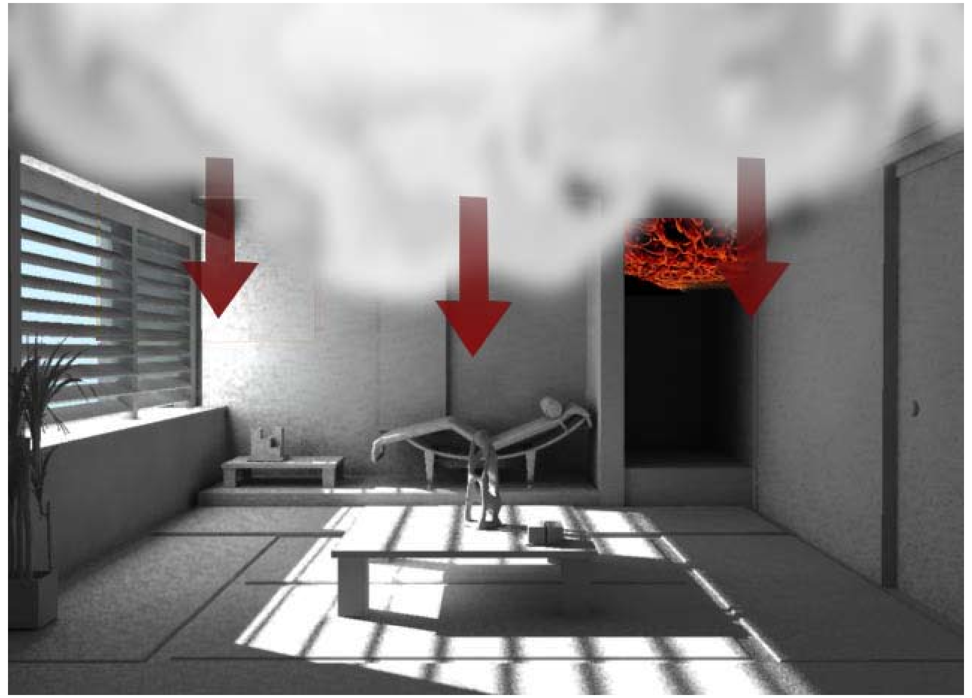
The course of the domestic fire
Domestic fires usually start when a source of ignition with a temperature high enough to combust a given material heats up said material in an oxygen-rich environment. Normally the air contains 21% oxygen, which usually is enough for combustion. As the material burns, it gives off smoke. Smoke is a sign of incomplete combustion, and consists of particles and hot gasses. Incomplete combustion means that all the potential energy is not released in the flame itself and that under the right circumstance, the gasses themselves can ignite. A gas stove is an example of a complete combustion. The flame is bluish without smoke or soot. In this combustion hydrocarbons react with oxygen to CO_2 and H_2O (steam).

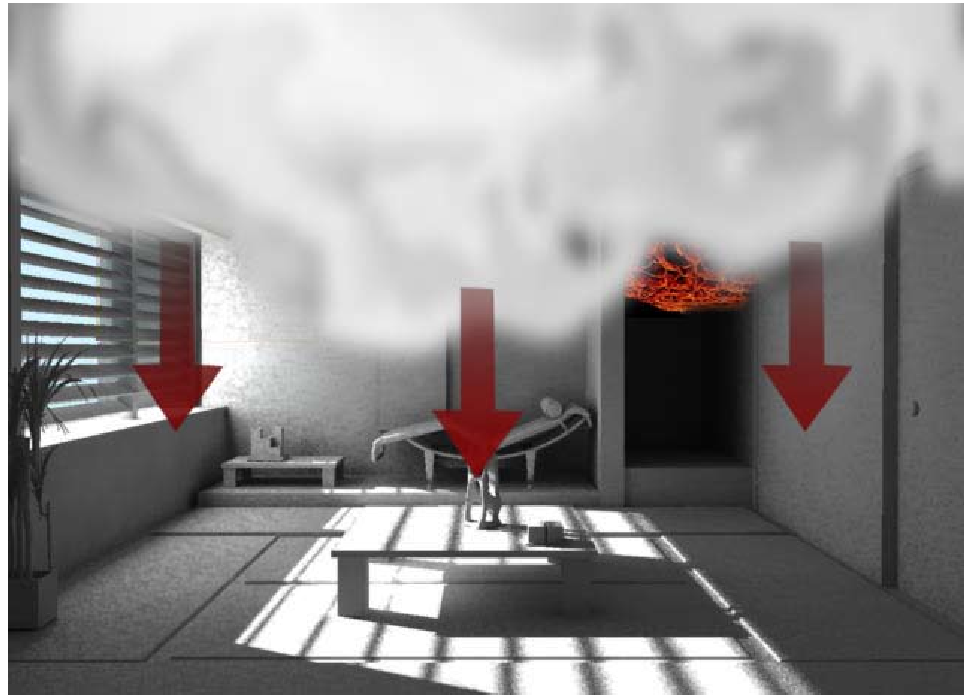
As the fire progresses, it fills the space it is in with hot smoke. This smoke has different characteristics depending on the material being burned. Some materials give off larger volumes of gas than others, some even give off toxic gasses that can be lethal to inhale, even in small concentrations. Hydrocarbon based plastics, foams, and synthetic materials generally give off more gasses than organic materials such as cotton, wool or wood.

As these gasses start to fill the room, they displace the air in the room. This causes a greenhouse-effect which in turn increases the temperature of the air. When the gasses reach a high enough temperature, they ignite their surroundings, such as ceilings, walls, furniture and floor. At this point the temperature rises quickly as more gasses are emitted from the materials. This stage, where the hot gasses ignite, is called flashover. At this point the gasses themselves burn if given oxygen and the fire engulfs the entire room. In a modern home in a developed country the time from ignition to flashover may be as little as 3 minutes.

As the temperature rises, the fire intensifies and more smoke and gasses are generated. The higher pressure presses these out of the room and into other parts of the building. As the fire-gasses enter new space with more oxygen they ignite, thus spreading the fire.







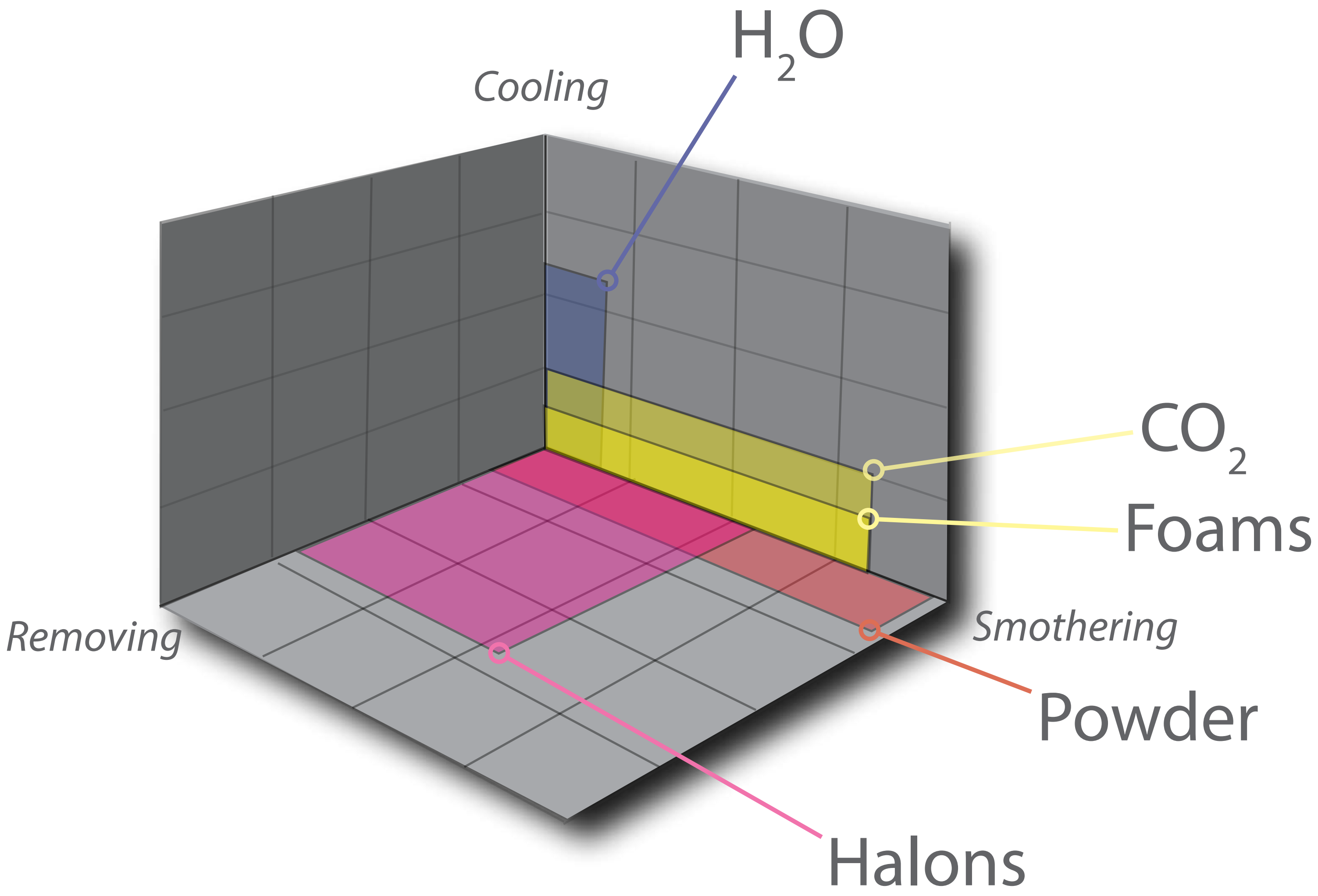
Over the last three decades, building materials have changed dramatically. Plumbing, flooring, siding, roofing - most are now made from synthetics. The same can be said about the furniture found inside the building, like foam rubber seat cushions, plastic computer cases, and nylon carpet fibres. As a result, today's blazes produce two to three times as much energy as a typical fire did in 1980, and most of that energy emerges as flammable gases. Those gases do not escape from newer buildings, which are well insulated and tightly sealed. Fires now project their energy much further from their cores, making them more dangerous and more difficult to extinguish.

The reason that the fires have started to react in this manner is due to the amount of gasses that get released during the blaze of the fire. These gasses, that gather just below the ceiling, act effectively as an reflection shield

for the heat radiation. Simply put one may say that they efficiently "lower" the ceiling, and therefore creating an efficient chamber of heat reaching 500 - 600°C. In turn the share heat will turn the air inside of the burning building into a heat torch, eventually setting fire to all of the combustible material that may be found inside.

As a consequence, the fire fighters more often now than 30 years ago, arrive at a burning building where the main objective is to limit the consequences of the fire, rather than to extinguish it.

// THE PHYSICS OF FIRES



As there are three factors that need to be present to perpetuate a fire, there are also three ways an extinguishing agent may work; by eliminating one or more of the factors in the fire triangle.

These are the three dimensions in which extinguishing agents work:
- cooling
- smothering
- removal of combustible material

Water
Primarily a cooling agent through its great specific heat capacity. Also has a smothering effect on the surface, when used in large quantities.

Foam
Foam consists of 94 – 97 % water mixed with 3 – 6 % foaming agent. The mixture is then ejected through a specially designed nozzle or injected with compressed air, also known as CAFS, to generate foam. The relatively low mass of the foam lowers its cooling potential, but the huge volume generated effectively smothers the fire by covering the combustible material. Foam is especially effective on liquid fires. An additional effect of the foaming agent is that it breaks the surface-tension of the water, allowing it to more effectively soak into porous material such as wood, fabric, padding and insulation. Sometimes a 0.5 % mixture is used for this purpose only. The extinguishing agent is then called a "premix" and is applied like regular water.

Powder
Powder is a smothering agent that covers the burning surface and effectively smothers it, analogous to putting dirt or sand on a campfire. Powder has relatively low mass, and does not evaporate. Therefore it has no cooling effect. However it may contain one or more oxidizing components that react with the combustible material rendering it inert.

CO_2
CO_2 is a smothering gas. It has a relatively low temperature, but its main use is as a smothering agent. CO_2 is inert and heavier than air and will therefore blanket horizontal surfaces creating a highly smothering effect. Other smothering gasses include most inert gasses such as nitrogen and noble gasses.

Halons
Halons is a common name for extinguishing agents containing one or more halides. Primarily gaseous or liquid Chlorine, Fluoride, Iodine and Bromide. These chemical substances are powerful oxidizers and are highly reactive. They will oxidize the combustible material far more effectively than the fire but without the high temperature or gas/smoke by-products. This efficiently renders the material inert. In addition, the vaporisation of said agents will displace air and thereby create a smothering effect.

// EXTINGUISHING AGENTS

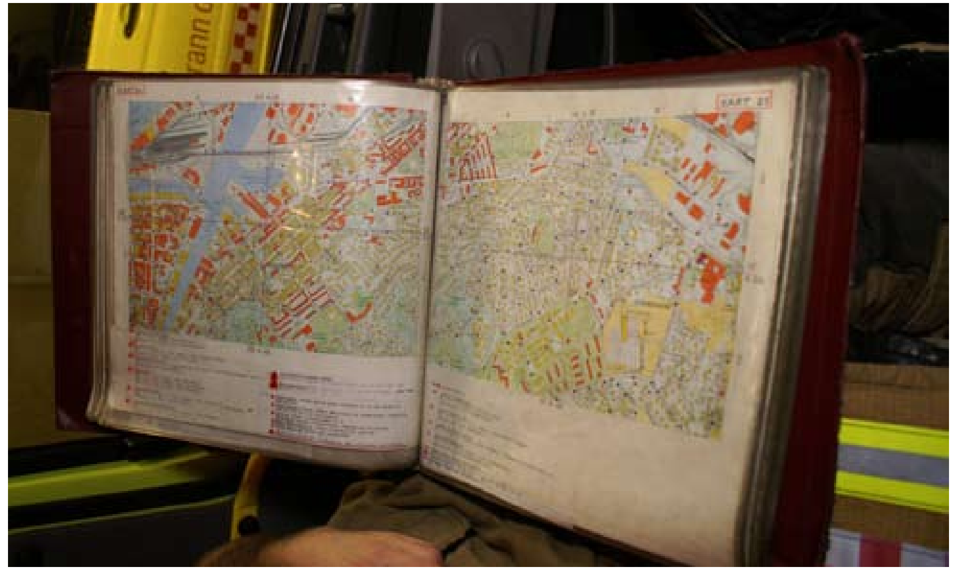
When the alarm goes off at a fire station, it normally does not take more than a minute before the crew is loaded into the vehicles, and the rescue team is off. In most urban areas in Norway, the fire stations are placed in such a manner that a fire truck is able to reach the scene within 3 minutes. During these minutes it is imperative that the fire fighters gather as much information as possible, to ensure that they are capable of solving their task as efficiently as possible. The emergency call is patched through from the operators table to the vehicle. And it is the Scene Commander´s responsibility to collect crucial information, regarding the placement of the building in question, and whether or not there are people still present inside the building.

The rest of the crew prepare themselves for what is emerging. Trøndelag Brann- og Redningstjeneste, has through the years collected large amounts of crucial information in folders that are located inside the crew cab. The folders contain information regarding city layout, placements of fire hydrants as well as the layout of the largest public buildings.

Upon arrival it is decided where it is beneficial to situate the fire engine. When the fire engine is securely placed, all the fire fighters rush out to carry out their specific tasks. The Scene Commander is in charge of getting an assessment of the entire scene. It is his responsibility to determine if the area is secure. Meaning that he needs to decide wether the crew should start extinguishing the building in question or if it is more advantageous to address nearby buildings, to ensure that they do not perish in the blaze.

The driver is in charge of the water supply. He must therefore ensure that the rest of the crew will receive a steady water supply.

The remaining crew prepare the rest of the gear to enable a internal or external operation, based on the commands from the Scene Commander. Even though it may be beneficial to insert the fire fighters rapidly into a burning building, it cannot be done before it is certain that the fire fighters will not risk their lives when entering. As it was demonstrated in the collapse of the high rise building in Ålesund 26.03.08, the fire fighters did not get an approval to enter the building or even get close, even though their aid was needed. The safety of the fire fighters always comes first.



The information folder of Trondheim Brann- og Redningstjeneste.

The fire brigade in Ålesund are reduced to bystanders, as a raging fire ravage inside a collapsed building. Due to the safety aspect, they are not allowed to carry out their work. Photo: Scanpix

// PROCEDURES

Fireman's equipment

The fireman's equipment is divided into two main categories:

- Protective equipment
- Auxiliary equipment.

All firemen
Protective equipment:
1| Wool undergarments
2| Gore-Tex ™ outerwear
3| Composite helmet w/polycarbonate visor
4| Leather gloves
5| Leather boots

Auxiliary equipment:
6| Radio

The wool undergarments provide excellent insulation from the high temperatures while being non-flammable. The Gore-Tex ™ outerwear effectively transports moisture away from the body. This is crucial as water retained in the garments will conduct heat and put the fireman at risk of hyperthermia.

The composite helmet is designed to withstand impact as well as high temperatures. Traditionally leather has been employed due to its fire-resisting qualities, but today most departments require their personnel to use composite substitutes.

The leather boots and gloves are flexible giving the fireman good mobility while

Additional equipment for Smoke Divers

at the same time providing insulation. The smoke divers are equipped with some additional gear. The most critical devices are the face piece and tanks, which comprise their breathing apparatus. This will allow the smoke divers to operate within the toxic environment inside the building. The smoke divers carry enough air for 15 – 20 minutes of operation, depending on physical activity.

The flashlight and IR-camera are used to navigate and locate persons within the building. A fireman's axe or spear can be used to open closed doors and/or access closed compartments within walls, ceiling, floor etc.

The total weight of this equipment may exceed 40 kg.

Protective equipment
7| Face piece with compressed air regulator
8| Harness with compressed oxygen tanks

Auxiliary equipment
9| Flashlight
10| IR-camera
11| Fireman's axe/pike
12| Extinguishing spear

// THE FIRE FIGHTER

A smoke diver team consists of at least 3 fire fighters, Alpha, Bravo and Charlie. All of them have specific tasks to conduct, and are thus equipped in different manners.

The Alpha is the leader of the team, and is situated in a safe zone outside the main fire area. His job is mainly to secure the fire fighters that have to enter the building. Alpha is equipped with a water hose that acts as a protective shield. In case of an emergency where the security of Bravo and Charlie is jeopardized his objective is to enter the dangerous zone and retract them to a safe zone.

Bravo on the other hand is the main fire fighter within the hazardous zones of a building. His specific objective is to save human lives within the fire, as well as fight the fire from within. Bravo is equipped with a water hose, which acts as his main tool when fighting fires. The water is also used to protect him and Charlie in case of an explosive development of the fire itself.

The main assignment of the Charlie is to assist Bravo in his work. Therefore Charlie is not equipped with a water hose himself, but helps Bravo to transport the heavy hose. Additionally he is equipped with tools to open up doors, and a flashlight to ensure better visibility.

Tactics

When Alpha and Bravo enters a burning building they are met by a wall of smoke that limits their visibility to a great extent. They therefore need to make use of prior knowledge of the respective building in order to orient themselves within the building. This knowledge is gathered upon arrival, by counting the numbers of windows on each wall, as well as assessing the specific dimensions of the building.

Before Bravo and Charlie enters a new room they try to gather information about the dangers that may lie ahead. This is mainly done by touching the door or wall, and thus assessing the temperature in the room to be entered. If it is concluded that the room is overheated, Charlie opens the door slightly, while Bravo shoots a couple of bursts of water mist into the air. Shortly thereafter Bravo closes the door, and the two fire fighters wait a few seconds while the mist cools down the room.

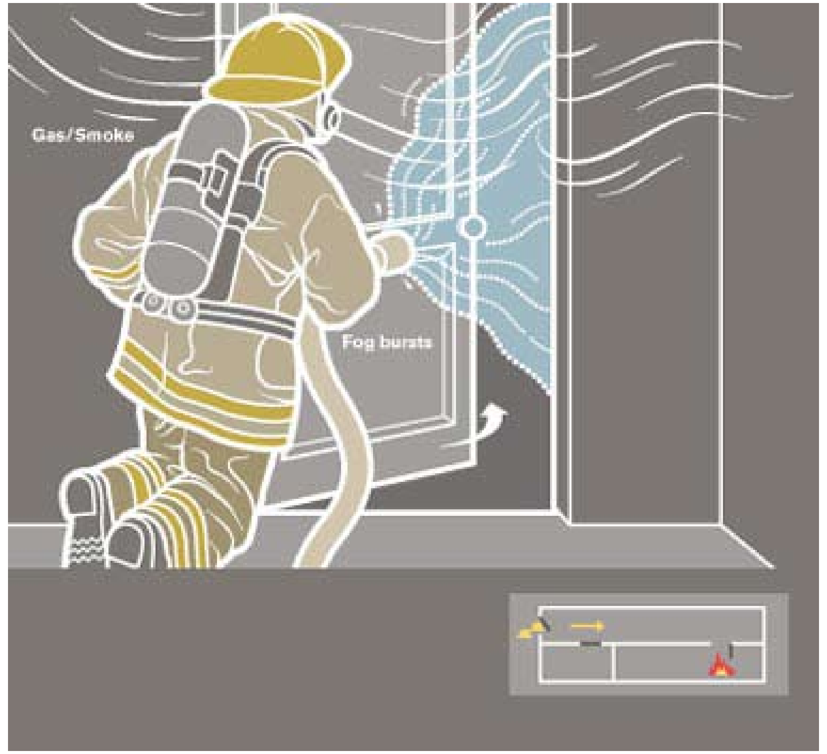
After a minute or so the room itself has cooled down to approximately 100 - 200°C, depending on the size of the room. As the danger of a flashover/backdraft is reduced, it is now safe enough for the fire fighters to enter the room.

Although the room is cooled down, the conditions within the room are still difficult, mostly because the smoke and steam make it hard to locate individuals that may be trapped within the room. Thus the fire fighters try to clear the room of smoke as soon as possible. Given the limited numbers of tools the fire fighters carry, this is done most effectively by utilizing the water hose as a fan. By opening a window in the room and putting the nozzle in right outside of the window, the stream of water will create a negative pressure, which sucks the smoke out of the window. In a normal size room, the room will be more or less free of smoke within a minute using this technique.

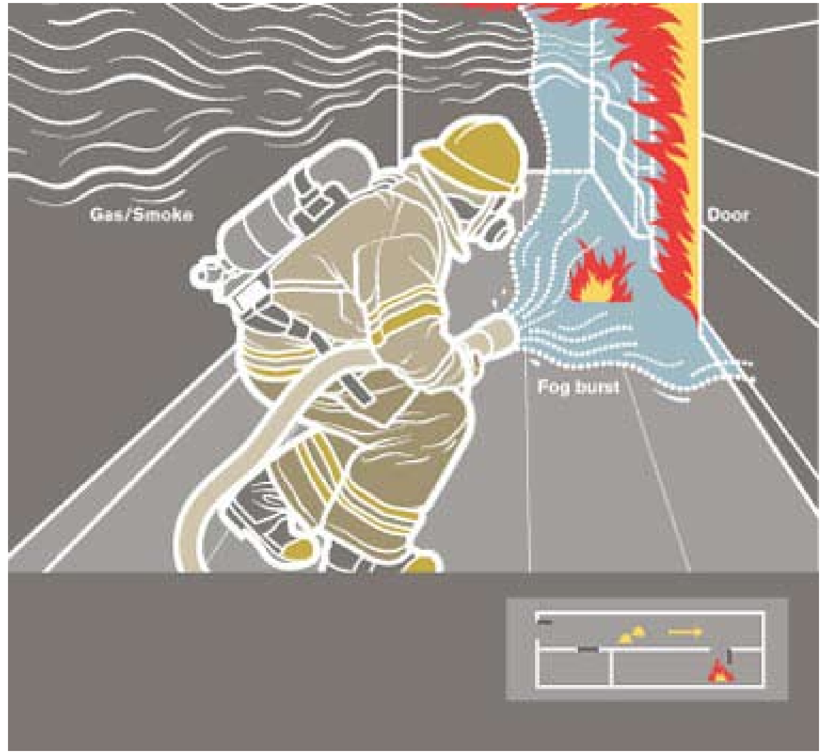
The conditions within the room are now of such a manner that it is possible to safely evacuate people inside, as well as conduct efficient fire fighting.

An imperative issue to be aware of is that sudden changes in the conditions in which the fire is thriving from, may lead to sudden bursts or uncontrolled burnouts. For instance if a fire within a house suddenly gets a new deployment of oxygen, it will rapidly increase in size, jeopardizing the lives of the smoke divers within the building. It is therefore important that they are in control of the fire fighting, giving directions to the fire fighters outside on how to assist them.

1. Fire fighters approach the front door of the apartment and use a thermal imager to check for the presence and temperature of hot gases building up inside. If not equipped with a thermal imager, the fire fighters need to remove their protective gloves and use their hands to estimate the potential danger.



2. Opening the door briefly to minimize the flow of oxygen into the hall, a fire fighter sprays a burst of fog to cool gases and prevent flashover, backdraft, or explosion.



3. With the gases cooling, the hall is now safe enough to enter. Repeated bursts of fog further reduce smoke and gases as the firefighters advance toward the flames.

4. Once close enough to the source of the blaze, the crew applies a direct stream of water, extinguishing it.

Traditional fire fighting tactics often lead to a very high consumption of water, this is evident even today, as fire trucks are built with pumps delivering 10 – 40 bar, able of putting out 3000-5000 liters per minute. The Greenpoint fire in New York is one example. On May 2, 2006 a fire in Greenpoint razed 15 buildings along the Brooklyn waterfront. The New York Fire Department used 9 trucks and 5 boats to get control over the blaze. During the 36 hours the operation endured, 6 million gallons (22.3M liters) were expended.

Another example is the Maxwell's fire in St.Paul, Minneapolis. February 20, 2008 a fire in on the third floor spread and the entire building was heavily damaged. What was spectacular regarding this fire was that the very visible result of the fire fighting effort. Around the building, the cold weather and water from the extinguishing effort had left a 1 meter thick layer of snow and the building itself was completely covered in ice. This is a very visual depiction of how large amounts of water are literally wasted in a traditional fire fighting effort.

The smoke-divers are used whenever possible and this effort hugely reduces water consumption. Unfortunately it is not always possible to use their effective technique as the intensity of the fire or the condition of the building might jeopardize the safety of the smoke-divers.

// CONSUMPTION

The traditional means of putting out water may in some cases be hugely wasteful. The main reason for this is the fact that the water is not used as effectively as possible. In some ways traditional use of water may be regarded as the fire fighting equivalent of carpet bombing, a WW2 attack strategy. As military technology has evolved, modern warfare is carried out far more effectively than the ancient methods of WW2. In stead of dropping tonne after tonne of explosive ordnance on a large area to take out a small group of buildings or a single factory, modern warfare employs a more delicate method called surgical warfare.

The key factors to successful surgical warfare is

1| Extensive information of the target (intelligence)
2| A charge or weapon specifically suited to the task (munition)
3| An effective means of delivery (vessel)

By using intelligence on the location and composition of the target it is possible to use a small but effective munition specifically designed for the task. An effective vessel ensures that the munition reaches the target in a way that maximizes the effect and at the same time ensures the safety of the operator.

This methodology can be applied in the realm of fire fighting as well. By giving the fire fighter the information he needs, he may be able to quickly assess the situation and employ the safest and most effective method of extinguishing the fire. By giving the fire fighter a better "munition" designed for the various scenarios, he may effectuate the extinguishing in a less wasteful manner. By giving the fire fighter an effective vessel, the fire fighter may extinguish the fire more effectively while at the same time ensuring his own safety as well as that of his colleagues and the public.

We will now look at some advances in fire fighting technology and tactics that could lay the foundation for surgical fire fighting.

// SURGICAL FIRE FIGHTING

Water mist

Water mist is a relatively new way to employ water as an extinguishing agent. Water is pushed through a specially designed nozzle which breaks the stream of water into a fine mist. This increases the effective surface area of the water, providing a more efficient cooling effect. Optimally, water mist is deployed into the hot gasses and smoke generated by the fire to prevent the fire from spreading. Alternatively it is mixed into the inrushing air to extinguish the fire.

As the water evaporates it expands to a volume 1680 times greater than when in liquid form. This rapid expansion prevents fresh air rushing in as the hot gasses cool down. This cooling aould normally result in lower air preassure.

The extinguishing effect of water mist is twofold:

1| Cooling
2| Smothering, through displacing
oxygen with steam (H_2O)

The first effect is obtained as long as the fire-gasses are hotter than 100°C, which they almost always will be. The second effect, however, relies on the room temperature being over 70°C. Air becomes inert (at least from a fireman's point of view) at about 15% O_2 content or less. Normally the air contains 21%. By introducing steam to replace air, it is possible to lower the content of air, and thereby oxygen, in the room.

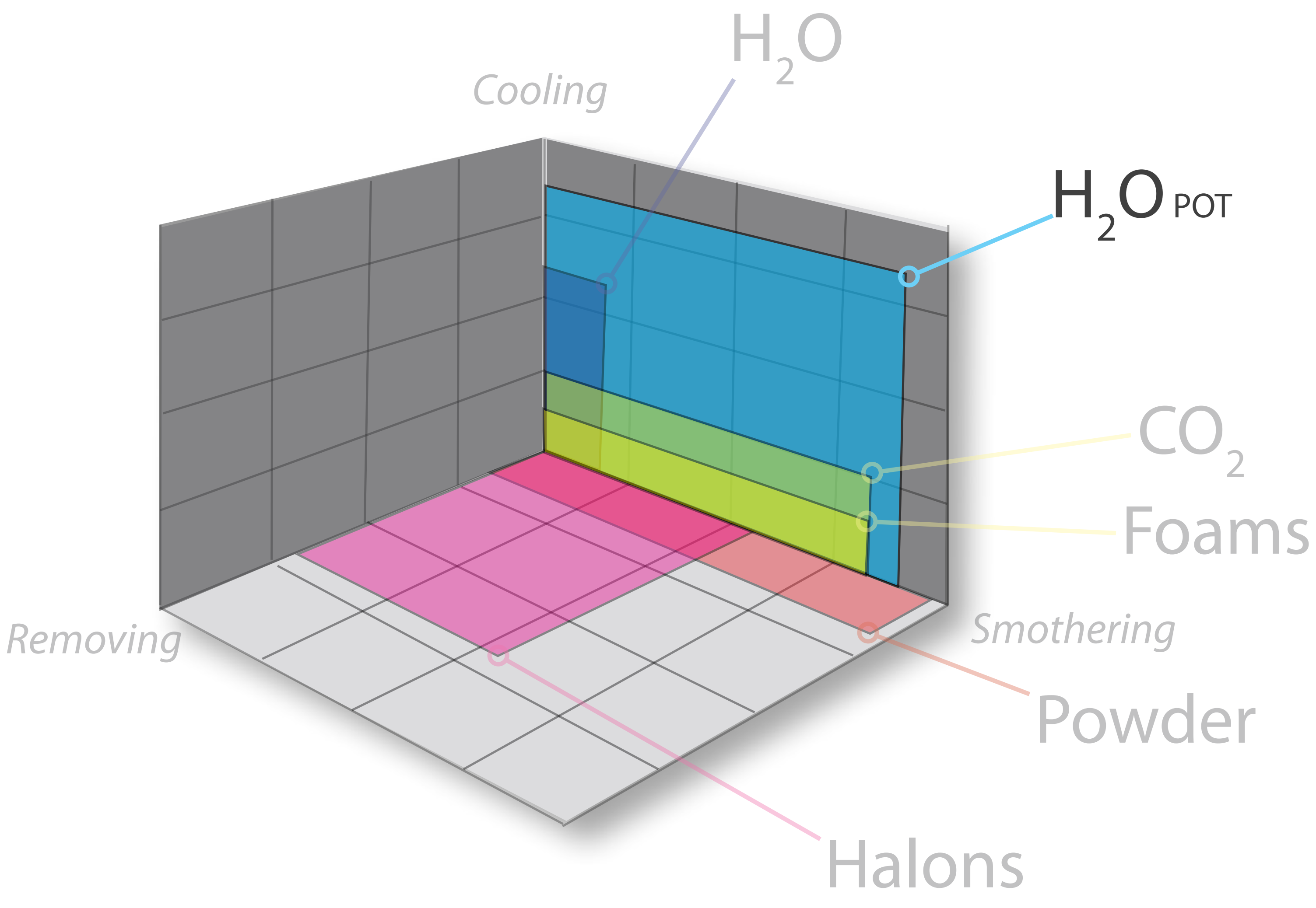
At 100°C the vapor pressure of oxygen is 100 kPa, which is the same as the atmospheric pressure at sea level. In other words, at 100°C water is able to displace air 100% without condensing. At 70°C the vapor pressure is 30 kPa. This means that the vapor from water (steam) at 70°C is able to displace roughly 30% of the air at sea level.

100% - 30% = 70%
21% * 70% = 14.7%

At 70oC the vapor pressure of water is sufficient to displace enough air to make the resulting gas mixture inert.
This actually encourages using less water to keep the ambient temperature high enough. This is contrary to traditional fire-fighting techniques.

This solution contradicts one of the oldest rules in the business: Do not put water on smoke, particularly when there are fire fighters nearby. The water will turn to steam and cook everyone. However, two Swedish fire engineers, Krister Giselsson and Mats Rosander, argued that if the water is broken into tiny droplets and deployed in extremely brief bursts, the moisture's expanded surface area would cool the gases in the smoke without turning the room into a steam chamber. So instead of simply ducking, fire fighters could continue to push forward to the source of a blaze.

This technique showed to be a success. In Sweden, the number of fire-fighter deaths dropped from 10 (1970 to 1985) to 5 (1986 to 2005). In the UK, which adopted the 3-D fire fighting approach in 1997, the results were even more impressive. The British fire service lost 12 members as a result of extreme fire behavior in the years 1990 to 1996. From 1997 to 2003, not a single fire fighter was killed due to extreme fire behavior. And after a series of flashover deaths in France in 2002, the French Ministry of the Interior made attaque 3-D its official training methodology.



// 3D FIRE FIGHTING

Perforation and flame extinguishing using a CCS COBRA system

A system that utilize the watermist principle is the CCS COBRA system. This system is both a fire extinguisher and a perforator used to cut through barricades of almost any character, including concrete walls. The CCS COBRA-system consists of pressure vessels and high pressure pumps, which produces the necessary energy in the water/abrasive for the cutting and fire fighting. The working pressure is about 200 bar and the water flow 50 liters per minute. To enable it to cut through walls iron oxide is mixed in to the water flow, making it in to a water jet cutter.

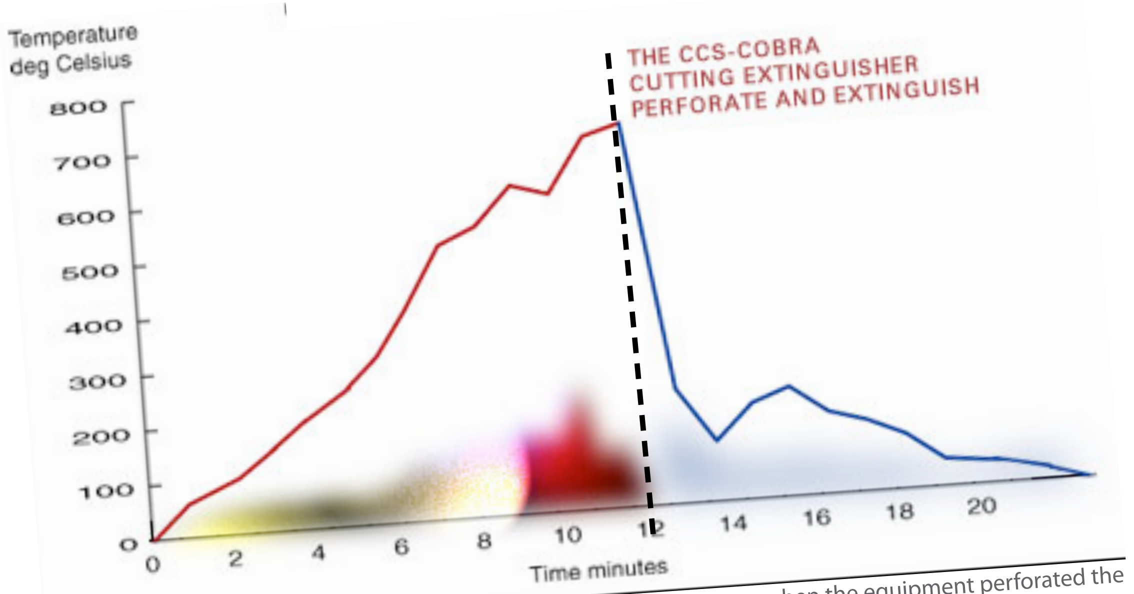
When the physical obstacle is penetrated, the iron oxide mixture is then turned off, and high pressure watermist is then injected into the burning compartment.

The main advantage by using this system is that using the technique enables fire fighters to extinguish fires without entering the building, and therefore they are not facing all the risk they normally would do. With that said, one should also take into account that this technique does not fulfill all the criteria to be a strategic and efficient fire fighting tool.

Even though the product in itself has been available for quite some time, it has failed to be successfully incorporated into a conventional fire truck. First of all it is a mechanical challenge to incorporate it, but in addition there has not been an extended demand for it due to limited use of it. Most fire fighters are reluctant to use a device that penetrates an exterior wall without being certain that they are not endangering people that might be situated on the other side of the wall. In other words; the fire fighters lack intelligence. Additionally a smoke diver cannot enter a building just equipped with watermist extinguisher. The reason is that in order to protect the smoke diver team, the Bravo must carry a nozzle that delivers 230 liters of water per minute, according to Norwegian legislation.

In addition the Cobra CCS is not equipped with a proper vessel that is capable of letting the supporting fire fighters on the outside, utilize the device. Although it has been tried to incorporate a solution that would give the extinguisher better range, the safety of the fire fighter is not fully maintained.

Egenes Brannteknikk has delivered only one fire engine equipped with this system to Drammensregionens Brannvesen IKS, but they mainly use the device to extinguish fires in ventilation systems, after all visible fires are extinguished.



Extinguishing of a container fire is shown. The fire had grown to flashover when the equipment perforated the contained wall and extinguished the fire within one minute

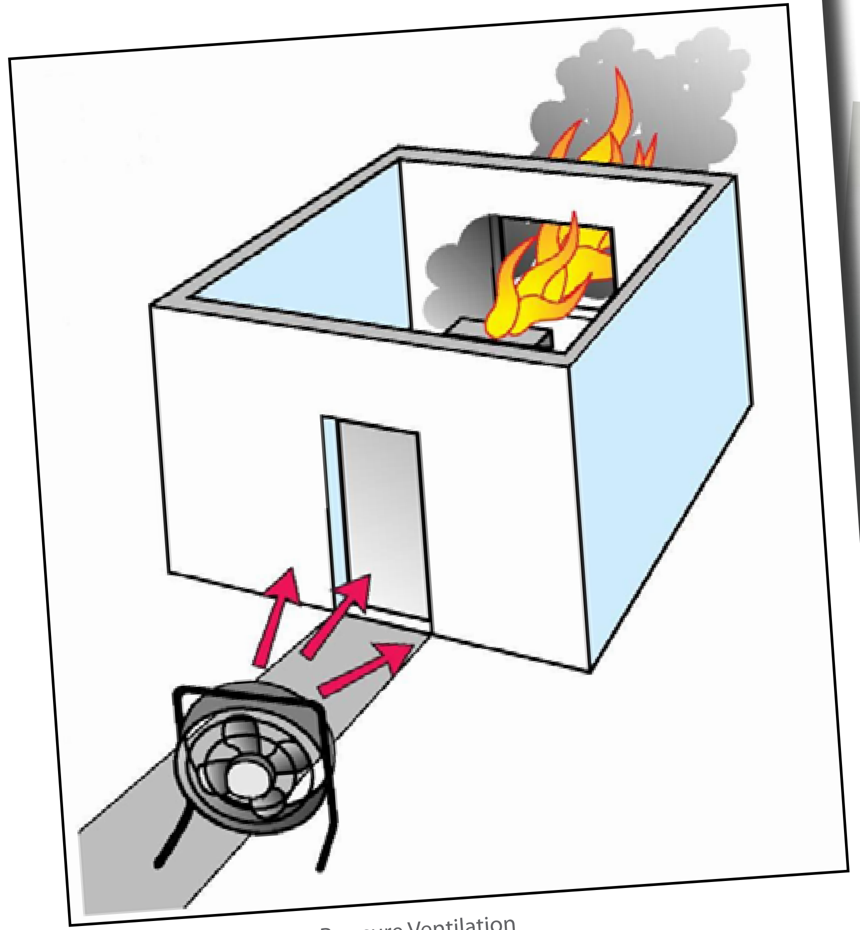
The Cage Lance is mounted on a cage and makes it possible to fight fires on roofs and other hard to reach and dangerous places while reducing the risk for the staff involved.

Positive pressure ventilation

Positive pressure ventilation is a form of 3D fire fighting. This strategy, developed in USA, targets the hot gasses and seeks to expel them from the building through the use of high-power fans. By expelling the fire-gasses, the temperature is reduced and the danger of the fire spreading to other parts of the building is vastly reduced.

The benefits of PPV are threefold:
1| Expel hot gasses, preventing spread by reducing ambient temperature
2| Increase visibility for evacuating personnel
3| Diluting fire-gasses to a point where they are no longer combustible

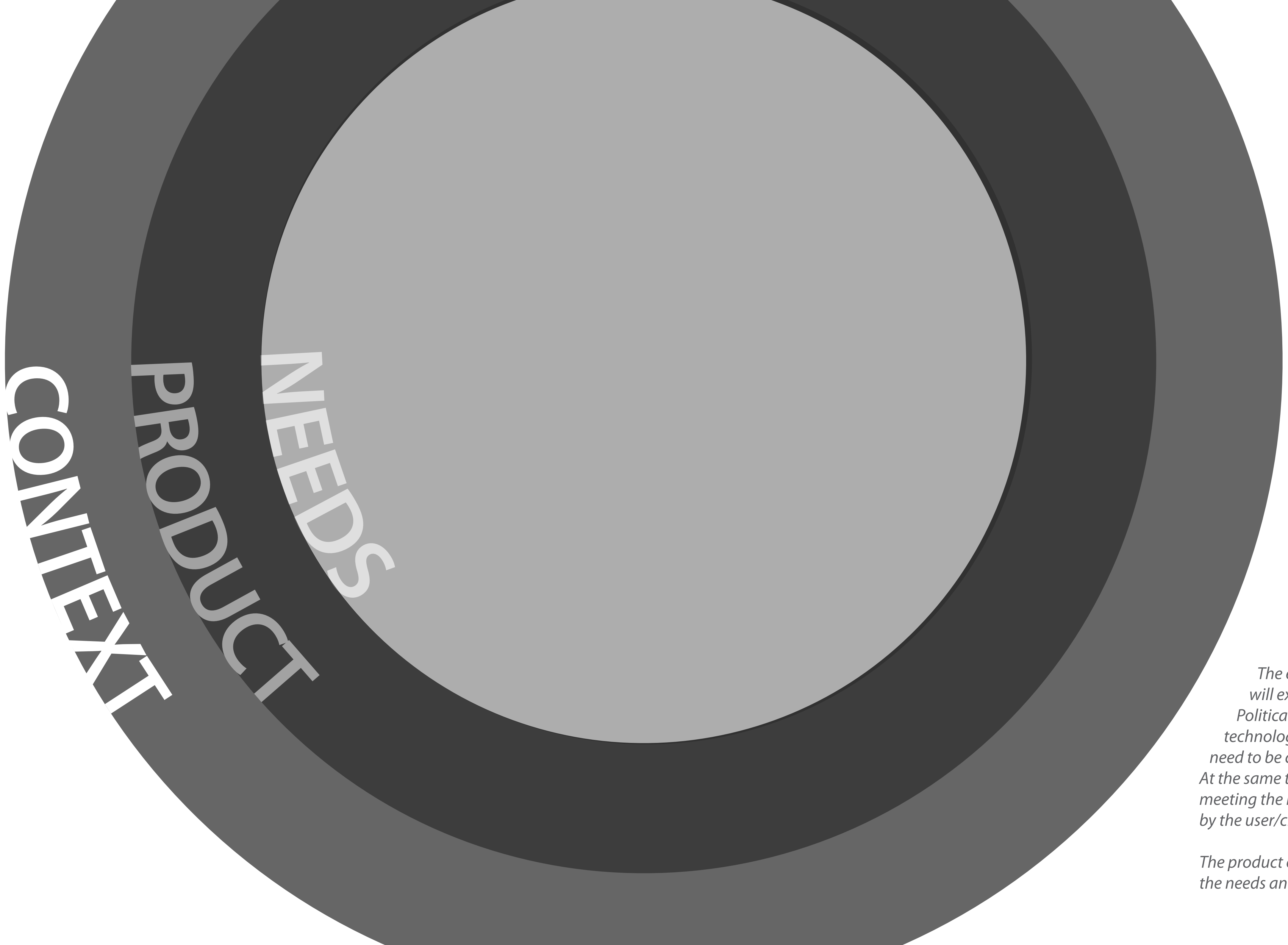
The negative effect is that the fire itself is fed more oxygen, which may lead to a more fierce fire. Other dangers include flashover/back-draft in areas where the gasses already have consumed all the available oxygen. In these conditions PPV may actually feed the fire until the mixture of air/flammable gasses is to lean to burn.



The principle of Positive Pressure Ventilation

An example of a Positive Pressure Ventilator

3 FUTURE DEVELOPMENT



The environment in which the product will exist, sets a number of parameters. Political, environmental, social technological and economic factors will need to be considered.
At the same time it is crucial that the product is meeting the needs or requirements established by the user/client.

The product exists in the space created between the needs and the context.

// PRODUCT ANALYSIS

In what world will this vehicle be put into service? What are the challenges and requirements it needs to meet? What are the contextual demands from technology, society, legislation etc?

The development of the vehicle will need take into account both the requirements of the user/client but without extending beyond the boundaries of its environment.

In this chapter we'll explore the needs and demands of the core users, the firemen. Based in this analysis we will look at the future development of the fire truck, both as a vehicle and as a tool. Lastly we'll establish a set of hypothesis to describe the contextual demands.

We decided to conduct qualitative analysis to gather information regarding fire fighting, as well as trying to unveil potential improvements that could be implemented into existing fire engines.

Additionally we determined that it would be most beneficial to gather information from professional fire fighters, as opposed to personnel that work voluntary. In this way we could get a deeper understanding of the field of fire fighting, as professional personnel deal with field on a daily basis, whereas voluntary personnel might only experience it a couple of times a year. Thereby professional personnel normally have a wider understanding and more experience regarding fire fighting, as opposed to voluntary personnel that more easily linked their information to very specific situations and contexts.

Furthermore, we chose to contact the three largest Fire Departments in Norway, Brannvesenet Sør-Rogaland IKS , Trøndelag Brann- og Redningstjeneste IKS, Brann- og Redningsetaten Oslo Kommune, since these have the biggest workload. It should also be pointed out that the decision was drawn based on the equipment that these specific Fire Departments possess. The vehicles that Brannvesenet Sør-Rogaland IKS utilize, are mainly delivered by Egenes Brannteknikk, whereas the other two Fire Departments possess vehicles provided form a range of national and international suppliers.

It is also worth mentioning that through the interviews, each of the Fire Departments exhibited three different mind sets regarding their equipment:

Brannvesenet Sør-Rogaland IKS can be described as being very "technology driven", as they already possess various state of the art fire fighting equipment. They confide in the manufacturer to build the best vehicle based on the given specifications.

Trøndelag Brann- og Redningstjeneste IKS on the other hand has a more traditionalistic approach, emphasizing on equipment and tactics that they know work. They are heavily involved in the design of new vehicles, as far as even manufacturing some interior solutions in-house.

Brann- og Redningsetaten Oslo Kommune are more experimental in their approach, and are less reluctant to try out new technology. They have experimented both with regard to platforms as well as tactics.

// INTERVIEWS

Interview with Oslo Fire Department

Oslo Fire Department is a professional task force. This department is an early adopter of new equipment. They have been using the cutting extinguisher for some years and had great success with it, especially in fires within ventilation ducts, an area that traditionally has been very difficult to attack. Their experiences with regard to this tool are concurrent to those of other fire departments; the cutting extinguisher is far more effective when used on an elevated platform. The extended reach allows for a far more efficient use of the equipment.

Hand-held IR-cameras have been in use for some time with great success, and the current equipment is about to be replaced by a solution similar to the one in use in Sør-Rogaland. The smoke diver carries a camera with a small onboard monitor. The unit simultaneously transmits the image wirelessly to an external monitor, allowing the on-site coordinator to get an image of fire from within the building.

Oslo Fire Department has experimented with the FireBus ™ concept as well, but with limited success. "The sharp corners and narrow streets of downtown areas in Oslo sometimes left us stuck, especially in winter." This is attributed to low ground clearance, large front and rear overhangs and ultimately its long wheelbase. "The concept is great, if not for its mobility issues". Today the vehicle is used as a command and coordination central for large scale operations where the fire fighting effort has to be coordinated with police and medical personnel. It is equipped as a mobile conference room allowing on-site administration to get an overview of the situation and coordinate the efforts.

Interview with Fire Fighter Birger Thurn Paulsen at Trøndelag Brann- og Redningstjeneste IKS

Trondheim Fire Department is now part of Trøndelag Brann og Redningstjeneste. Their approach to equipment is traditionalistic and they have not yet fully implemented use of thermal imaging (IR-camera) or cutting extinguisher. The force is completely professional and comprises 3 stations within Trondheim. A Brigade is the sum of the personnel that cover a shift at any of the three stations. Today a Brigade counts 17 distributed on the 3 stations. Vehicles at Station 1 include a 4 x 4 fire truck, a 27 meter ladder/lift as well as various other minor vehicles.

The main reason for not purchasing the cutting extinguisher until now has been the cost and safety aspects. The cutting extinguisher is a rather complex and expensive piece of equipment. In addition it has devastating potential if directed towards people. The safety distance in front of the unit is more than 5 meters. More importantly it does not provide the fire fighters with sufficient safety. A fire fighter has to carry, according to laws and regulations, a hose and nozzle capable of delivering 235 liters per minute. This is the absolute minimum as smoke divers will have to use the water as a shield in case of a back-draft situation. The cutting extinguisher, and other water-mist solutions, offer as little as 8 to 15 liters per minute, this is clearly insufficient for use as a primary extinguishing tool.

With regard to use on elevated platforms, the main concern is the proximity to the dangerous area and the recoil of the unit. The 300 bars of pressure forces the water out at a staggering 500 km/h. This leads to sudden recoil that is highly undesirable on 1 x 2 meter platform 27 meters above ground. Current systems in use on these platforms are fixed to the lift itself and operated as a water cannon.

Interview with Section Manager Brynjulf Sandvik at Brannvesenet (Fire Department) Sør-Rogaland IKS

The Fire Department in Sør-Rogaland has been using fire engines from Egenes for quite some time now. Their experience with the vehicles have been of a positive nature, as the Section Manager Brynjulf Sandvik eagerly points out. But the experienced fire fighter also emphasizes that one major drawback with the current vehicles is their limited mobility in densely populated areas. The province that this regional Fire Department serve has had an explosive growth of households in recent years. From 2001 to 2005 the number of households in this region increased by 10 000. This growth has in turn transformed the structure of the residential areas, by cramping more houses into an area. The result is shorter distance between each resident as well as narrower streets, thus making it harder for the huge fire trucks to reach a burning building.

"We had a similar problem earlier as well, especially with the older parts of Stavanger, which were not designed with the size of modern fire engines in mind. But the mobility is starting to become an even larger problem, than anticipated," Sandvik states. "Sometimes we need to park the fire engines far away from the burning building, and reach it by foot carrying all the equipment".

But on the other hand Sandvik is very pleased with the performance of his vehicles. Especially the comfort level of the vehicle in transit has been greatly improved. Additionally the automatically regulating pumps ensure that fire fighters always get the right amount of pressure through their hoses. This was not a guarantee earlier. If multiple hoses was connected to the same pump, and one of the operators decided to turn the hose off with the pump generating the same output, the fire fighter still operating his hose would get an extra boost which potentially could knock him off his feet, resulting in severe injuries.

The Fire Department in Sør Rogaland also possesses an IR-Camera with an additional screen. The IR-Camera is operated by the smoke divers inside the building. This device enables them to "see" the severity of the fire, and also how it is behaving, thus providing them with crucial information on how to best attack the fire. Additionally the on-site coordinator is in possession of an additional screen where the same images are depicted. In this manner the information is available to both the personnel inside and outside of the building.

"It is important to gather as much information as possible at all times", Sandvik declares, and adds: "We use the IR-equipment on a daily basis".

Sandvik also utters consent to our proposal of digitalizing crucial information, for instance the position of fire hydrants, and tagging of hazardous chemicals. "That can be an important step in both making our operations more efficient as well as safer fore our crew. But that might also be achieved by standardizing the layouts of the vehicles, thus making it easier for the individual fire fighter to switch between vehicles or even Fire Departments".

// INTERVIEW

Through these interviews we have acquired an understanding of the needs and requirements of firefighters. More importantly we got a glance at some of the challenging aspects of implementing new hardware or tactics.

As we anticipated information, or intelligence as we have chosen to call it, is the cornerstone of safe and effective fire fighting. We had, however, no idea that the degree of technological implementation still today is at such low level. An implement as common as GPS is not even standard equipment in modern vehicles. Nor do they use WWAN or other information carriers to distribute relevant information. This leaves the firefighter in the dark with regards to route planning, construction and size of the building, location of hydrants. These issues could easily have been resolved with a central database (internet), a piece of data-communication equipment (3G mobile phone) and a means of display (notebook computer).

What we did not expect before conducting these interviews was the fact that new technology and tactics sometimes were scrapped due to usability issues. The safety of the personnel is paramount and therefore the demands to the vessel are quite stringent. A promising piece of equipment such as the cutting extinguisher was in some cases taken out of service because of the fact that it, in its handheld implementation, simply did not provide the flexibility or safety to make it effective enough.

// EXPERIENCES

What will the world look like 5, 10, 20 or 50 years from now?

Based on the analysis of current and future fire fighting techniques, we can envision three different stages in the development of fire trucks:

1| Improvement of the current platform
2| Development of a newer platform more specialised to current and future demands
3| A change in the demands and requirements of fire trucks which will create a paradigm in fire fighting techniques and strategy

Stage 1 | 5 to 10 years

Based on the rate of turnover of material in fire brigades in Norway we have given an estimated time line for these stages. The average lifetime for a fire truck in the professional brigades is between 5 and 10 years after which they are "handed down" to voluntary brigades who do not have the funds nor require the latest equipment to complete their task.

According to Egenes Brannteknikk, production of a modern fire truck is estimated to about 14 months.

Based on this average lifetime of up to 10 years per truck we expect the current platform to be dominant for at least 5 years. More likely we're looking at up 10 years to see implementation of the next generation of fire trucks. Possible enhancements to the current platform include full time information-sharing, either through internet connectivity (3G, HSDPA, WLAN), through on-board databases or a combination of the above. For the fire-fighter increased situational awareness is possible through in-vehicle briefing and the sharing of information from sensors on site (IR-cameras etc.)

Stage 2 | 10 – 20 years

As global development puts increased strain on water demand we envision regulatory measures being put in action to minimize water use. This will drive a change in fire fighting techniques and equipment, shifting from the water-intensive techniques used today to more water-economic techniques in the future. In addition we expect to see an evolution of the truck-platform that is similar to that of cars. This means more fuel efficient engines and the introduction of electric motors through hybrid and maybe even all-electric platforms.

We envision a time-scope of 15 to 20 years to see the truck-platform changed, maybe as little as 5 – 10 years to see regulatory measures on water consumption.

Stage 3 | 50 years

The average life of a modern housing unit is in the scope of 50 to 100 years. This means that the buildings that are constructed today may well be the ones burning in 50 years. However if the UN prognoses for demographics are anything to go by we should see a general increase in density of population as well as increased migration to urban areas. This would indicate an increase in high-rise buildings. Domestic buildings in Norway are rarely more than 12 stories tall, in fact most often less than 8.

To see a paradigm in the way we fight domestic fires we have to see a dramatic change in the rate of fires and/or how they evolve. We assume that new buildings will have to comply with more strict regulations with regards to fire-safety and water- and energy consumption in the future. This leads us to a possible scenario where fires are fought "in-house" through intelligent systems that detect and extinguish fires before they reach a magnitude where the outcome is catastrophic to the building or the housing-unit.

Stages

1| Emphasis on information and communication. Giving the fire-fighter a more comprehensive understanding of the situation, both in transit and on-site.

2| Emphasis on the platform and the structural components of the vehicle. Adapting the vehicle to new techniques and equipment. Incorporating elements from Stage 1.

3| Decentralization of fire-fighting equipment. Limiting the magnitude and consequences through early intervention by automatic systems.

Scope

We have chosen to look at the development of fire trucks on a scope of 20 years. As the government and fire brigade personnel are conservative of nature and the brigades generally are under-funded, we feel a scope of 20 is a minimum for the implementation of the new technologies and techniques. In addition, we want to show a realistic scenario of how the future of the fireman may look.

On a 5-10 year scope we don't expect to see replacement of the current platforms, change in techniques or equipment.

We feel that the 50 year scope is too uncertain. In 50 years we will, most likely, have parted with fossil fuels completely and, as of today, an equivalent replacement in terms of energy density is yet to be found. This will limit the use of hydrocarbon based plastics, which in turn will change the typical fire scenario. As a high percentage of furnishing today is composed of various forms of plastics ,it is obvious that a replacement material is needed. Today there is no obvious replacement and we do not wish to speculate with regards to this issue.

We are developing this vehicle primarily for Norwegian application, set in a global perspective. As globalization will continue to increase the standard of living in developing nations, we expect to se a similar development as the one seen in developed countries 20-30 years earlier. In other words, as technology leaders and developed countries, the western world will serve as a model for the development of countries such as China and India among others. However, the development of these nations will be far more rapid due to globalization. In the long run they will catch up with the western world. Whether this will happen within 10, 20, 50 years, or more, is something we do not wish to make speculations about.

//INFORMATION REVOLUTION

In the near future we expect to see various forms of augmented reality entering the fire fighting arena. Already today infrared imaging is available to both smoke-divers and on-scene command. Future projections include on-line capabilities in all response vehicles. This will enable a great enhancement regarding the information that at all time is available to the firefighters and their coordinators. By combining different information carriers and structuring their output both the planning and execution of the fire fighting may be carried out in a more rational and efficient fashion, as well as making the work environment safer for the firemen through better situational awareness.

Interesting technologies include: Temperature sensors in buildings, GPS-tagging of gas-cylinders and other hazardous material, wireless live video/IR-cam feed, telemetry of smoke-divers' health, centralised command and coordination and in-vehicle briefing on the current situation.

// EMPOWERING THE FIREFIGHTER

Extensive use of new materials and technology will lead to lighter, more agile vehicles, capable of performing a number of tasks that today require several vehicles. We envision a divergence from the "mobile toolbox" of today, to a vehicle that empowers the fire-fighter. This can be done through extending the mobility and reach of the firefighter, enhanced protection, information management through augmented reality and more effective fire fighting techniques.

Interesting technologies include: Powered exoskeletons, flexible and lightweight protective clothing, use of robots or robotic implements and the use of partially- or fully automatic systems.

// ACTIVE SAFETY - PASSIVE SAFETY

The natural convergence point to this evolution will be the advent of fire-safe buildings and a higher level of active security embedded in existing constructions. This will greatly reduce the need for fire-fighter intervention and greatly reduce risk to human lives.

Projecting the path to the future.

The basis for this prognosis is the historic development of fire-trucks in general.

The time scope for the different stages of this development is clearly not fixed. However, based on the rate of replacement in the main fire-departments in Oslo, Bergen, Trondheim and Stavanger, a vehicle usually serves 5-10 years at the primary brigade before being modified, reassigned to a less critical duty or sold off to another department with lower overall activity.

The total service life of the vehicle often exceeds 20 years.

Due to the "longevity" of current (stage 0) fire-trucks, our estimates puts the implementation of the first stage in 3-8 years time. This concept, though feasible in the very near future, will be a part of stage 2.

The technology applied in this concept exists today in one form or another. However, based on current budgets and the cost of this technology today, we do not expect to see vehicles with similar capabilities implemented in the immediate future.

What will the world look like 5, 10, 20 or 50 years from now?

Given the current population growth, we can expect to see a world population of around 8 billion people (UN), with the majority of the growth in Asia. According to UN we will see desert propagation rendering two thirds of the arable land in Africa unusable, along with one third of Asia's and one fifth of South-America's. This will lead to an increased stress on water supply, especially in the emerging economies of China and India. China has already proposed to dam up the Tsampo River, diverting water from the south to the north. The Tsampo/Bhramaputra-river is transporting water from the Tibetan mountains to the entire southern Asia. These proposed plans will reduce India's current water supply by 40%. Due to this, and similar projects around the world, it is safe to assume that in the future water will be a global commodity like gas, oil or food is today. Even in water-rich parts of the world the value of water will limit its use in fire-fighting. We therefore propose the following hypothesis:

Hyp. 1 – Future fires will be fought using much less water than today.

In addition to the growth of population, globalization will continue to increase the standard of living in rapidly developing countries (China, India) this will lead to increased personal consumption. This has two consequences. Firstly each person will acquire more goods, such as cars, furniture, toys, technology etc. In addition each person will consume more food in general, particularly from high-protein sources. These include meat, fish, eggs and dairy-products. The overall water consumption per unit of energy is much higher for these food-sources (except from fish) than that for low-protein vegetable sources (grain, vegetables, fruits etc.) This reinforces Hyp. 1 and leads us to propose hypothesis 2:

Hyp. 2 – Fires in currently developing countries will be more explosive in the future.

The basis for this hypothesis is the development of fires in developed countries the last 20 years. Due to increased standard of living we fill our houses with an ever increasing volume of furniture. In addition, the material diversity is far greater. A typical Norwegian house in the 1970's would be furnished with wooden chairs and tables, and a wooden sofa with minimal padding and organic fibre fabrics, such as wool or cotton. Today, the increasing demand for comfort has lead to furniture with more padding (foamed polymers) and inorganic fibre fabrics (Alcantara, Skai, plastics). These materials generate far more smoke when burning than wood.

History has shown that, once accustomed to a standard of living it is very hard to get people to accept a reduction. People are simply not willing to give up their comforts unless they are forced. Therefore we anticipate no reduction in the volume of furniture in homes 20 years from now. As mentioned earlier it is the things we put into our homes that burn, not necessarily the structure itself. The average lifetime of furniture has decreased during the last 20 years. 100 years ago furniture would be handmade pieces of wood, often with minimal padding, inherited through generations. Today production of low-cost furniture is a multi-billion dollar industry. Companies like IKEA have made "fashion-furniture" accessible to a much wider audience through low cost. This has allowed people to change furniture more frequently, as the trends change, shortening the average lifetime of the product. Today it is possible to speak of an average lifetime of 10 years or less for certain types of furniture. This means that 20 years from now it is safe to assume that at least half the furniture found in Norwegian homes will consist of products not yet produced. This leads us to two possible scenarios.

1| The new furniture uses more material and is of more complex composition, leading to potentially more smoke generation and thereby more explosive fires.

2| Legislation on active and passive fire-security measures, such as the use of flame-retardant upholstery in furniture, leads to less explosive fires.

Of these two scenarios, scenario 1 can be regarded as the worst-case-scenario (wcs) and scenario 2 the best-case-scenario (bcs). We do not know or wish to speculate on this development, but we choose to use the WCS as our baseline. Our hypotheses number three:

Hyp. 3 – In the future, domestic fires will develop as explosively as today with regard to their rate of development.

As the standard of living increases, so does the amount of "stuff" we bring into our homes. Stuff like furniture, electrical appliances, clothes, sporting equipment etc. As mentioned earlier, we expect to see a similar development in emerging industrialized societies such as China and India.

There are several ways of fighting fire; making products that does not burn is one. Traditionally this has been accomplished through treating material with flame retardants. These are basically "halons" applied to the surface of the material. The most famous such material is brominated flame retardants. Due to the environmental damage and toxicity of such materials and their production, use is becoming restricted in the EU, Japan and US.

Locally installed fire fighting equipment like hoses, powder, foam or CO2-aparatuses is an effective way of getting the fire fighting agent to the scene. However, they are generally under-dimensioned for fighting fires in a post flashover state and are frequently operated inefficiently by unskilled operators (the residents). An automated system like robots and sprinklers is a possibility, but due to the economical considerations not a likely path to the future.

Traditional deployment of fire fighters in large cities is a very effective way of distributing equipment, knowledge and personnel. From the alarm sounds, it takes no more than 60 seconds until the fire fighters are in the vehicle ready to roll out. The average transit time from fire station to the scene is 3 minutes or less (Trondheim). This means that one will in less than 4 minutes from reporting have a professional team of fire fighters with specialized equipment and the knowledge of fire fighting on-site. This leads us to the following hypothesis.

Hyp. 4: – Fire trucks will be around for the foreseeable future as the most economically efficient way of distributing the fire-fighting effort

The water stress in Asia and Africa combined with the growth of population will lead a large number of refugees towards areas with more water per capita and lower population density. Areas like Europe, Russia and northern Asia will be expected to see mass immigration. The European Union predicts as much as 1 billion refugees by 2025. Traditionally immigrants have sought to the cities, where an established community of people with similar background already exist. Norway has traditionally been forthcoming when it comes to accepting refugees and we do not expect this to change in the future. This is part of the ideology of social democracy, a corner-stone of Norwegian politics. This leads us to the following hypothesis:

Hyp. 5: – Immigration and Centralisation will lead to higher population density in Norwegian cities.

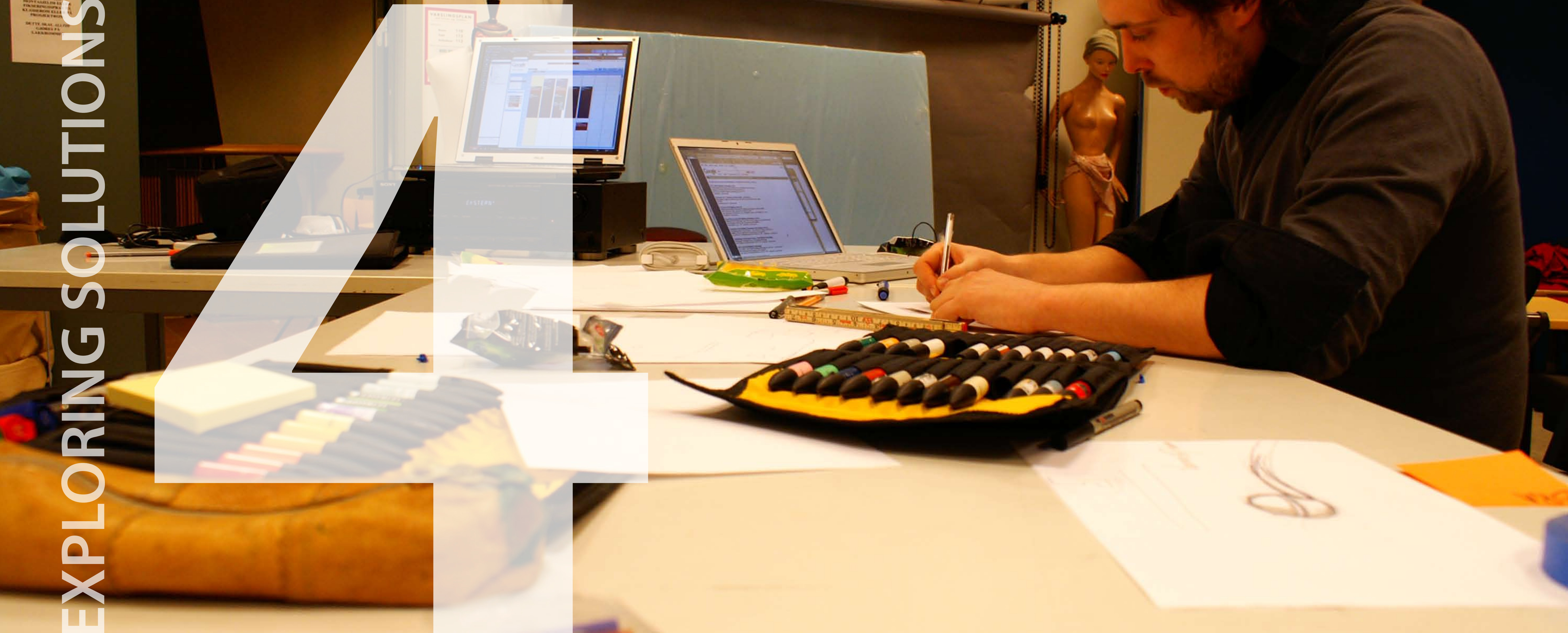
Hyp. 6: – Cities will see more high-rises to accommodate the increased population.

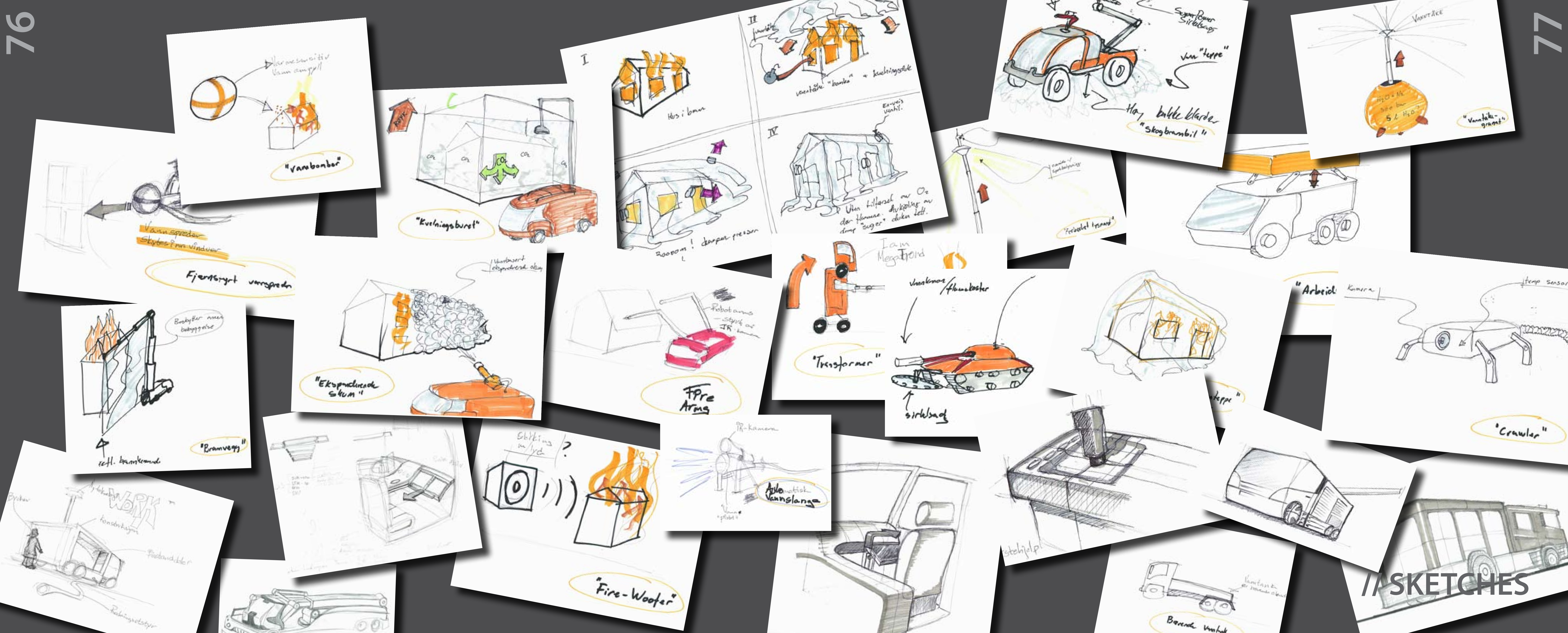
// SCENARIO


Hyp. 1 – Future fires will be fought using much less water than today.
Hyp. 2 – Fires in currently developing countries will be more explosive in the future.
Hyp. 3 – In the future, domestic fires will develop as explosively as today with regard to their rate of development.
Hyp. 4: – Fire trucks will be around for the foreseeable future as the most economically efficient way of distributing the fire-fighting effort
Hyp. 5: – Immigration and Centralisation will lead to higher population density in Norwegian cities.
Hyp. 6: – Cities will see more high-rises to accommodate the increased population.
?

// GUIDELINES

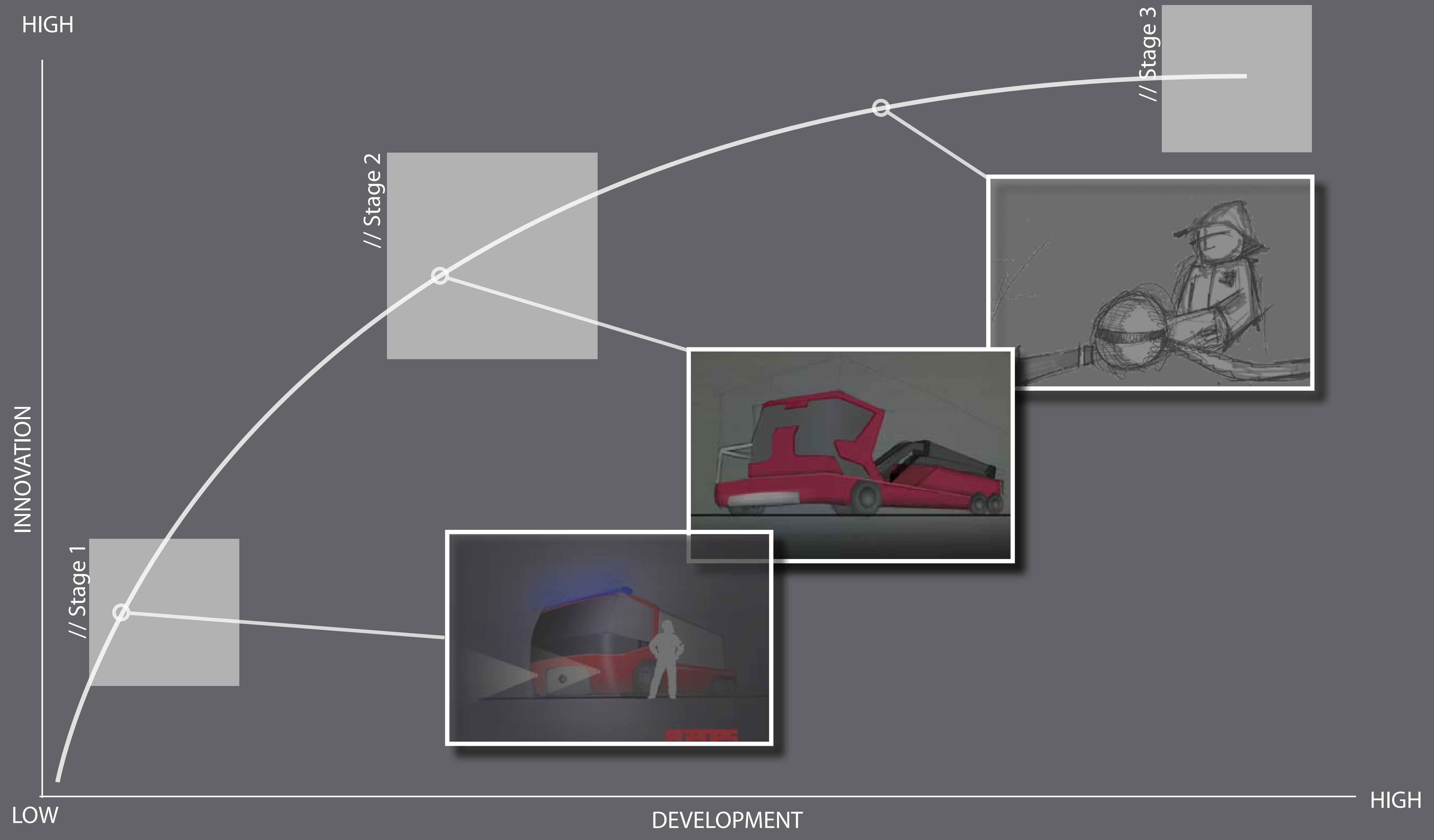
4 EXPLORING SOLUTIONS





"vannbomber"
"Kvelningsburet"
Hus i brann
Vann spreder
Skytes inn vinduer
Fjernstyrt vannspreder
"Ekspanderende skum"
"Bramvegg"
"Transformer"
sirkelsag
"Fire-Woofer"
Automatisk Vannslange
IR-kamera
"skogbrannbil"
Vann "teppe"
"Crawler"
Kamera
temp sensor
VANNTÅKE
"Vanntåke-granat"
"Arbeid

//SKETCHES



// INNOVATION CURVE

This graph shows the three stages put into a coordinate system where the degree of innovation is represented along the Y-axis and the degree of development to successfully implement the stage is represented along the X-axis. What became apparent to us after this analysis is that the development between the different stages is not a lineal one.

Stage 1 has already been successfully implemented on a number of platforms, from the Heads-up-displays (HUD) of 1970's fighter jets, to modern handheld GPS-units that download information about the traffic situation in real-time. By implementing solutions that exist on a number of platforms in a single vehicle the second stage represents a much higher degree of innovation. The degree of development is somewhat higher than that of Stage 1.

Stage 3 has a very high level of innovation but this is mirrored in the requirements of development needed for implementation. Development fire-proof buildings through the use of material technology is only part of the solution. An average building has a lifetime of more than 100 years. This implies that the majority of buildings will have to undergo implementation of active safety measures to achieve the same level of safety.

During conversations with Egenes we agreed to aim for a concept that could be would allow us to push the degree of innovation as far as possible, while at the same time keeping the degree of development low enough, making the design feasible in the foreseeable future.

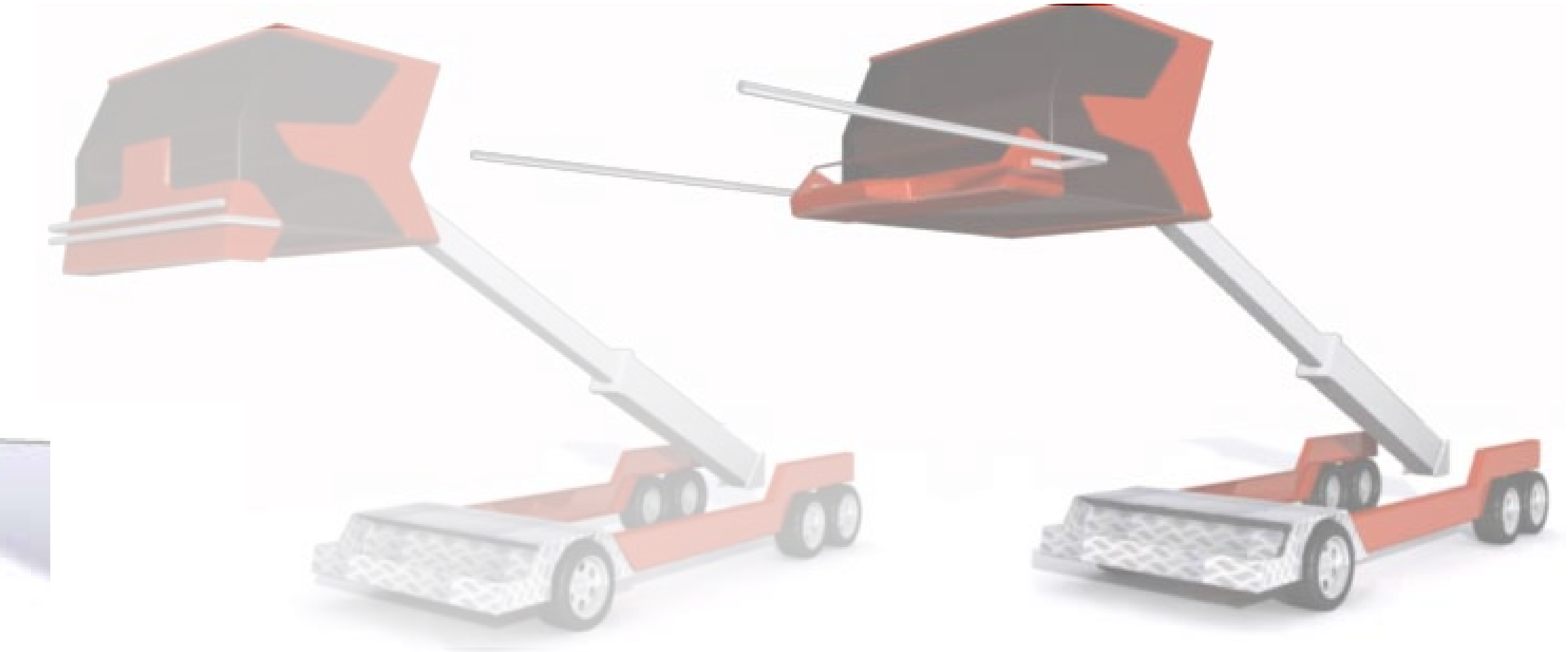
This early concept was an attempt to explore space saving through electric energy transfer and the use of composite materials. The engine is placed in a compartment on the roof of the vehicle and the energy is transferred to electric motors in the wheels. The structure of the vehicle is a carbon fiber monocoque; this eliminates the need for a large space-consuming chassis. The engine compartment on the roof increases usable space while offering flexibility with regard to type of power plant.

// CONCEPT 001

An early concept inspired by current elevation equipment. By elevating the cabin along with the platform the operator gets a better overview while saving valuable time. The cabin carries sensor equipment to give the on-site coordinator a better overview of the situation.

// CONCEPT 002

This concept is an attempt to explore the possibilities of an elevated extinguishing platform. "The bumper" is actually two rigid arms containing extinguishing equipment. This gives the fire fighters better mobility while at the same time ensuring safety when approaching fires up close.



// CONCEPT 003

Another early concept exploring stability and mobility. The flexible and minimalistic design incorporates a variable geometry chassis that is designed to increase stability when the boom is deployed. The all-glass cockpit increases visibility for the operator.

// CONCEPT 004

In most cases the fire engine acts as an efficient transportation mean as well as a steady water supplier and toolbox.

There are not a lot examples of where the machine and the fire fighter act together as unified fire extinguisher. However, exceptions do exist.

The Rosenbauer Panther, exemplifies both the efficiency and accuracy that a tighter collaboration between human and machine may provide.
The Panther acts both as an extension of the fire fighter, as well as providing a mobile shelter.

Even though one cannot find normal fire engines that provide the same amount of support for the fire fighter, there are situations where the fire fighter needs to rely fully on his vehicle.

The fireman's lift is one such vehicle.

The lift increases the fire fighter's mobility and improves range. This allows him to more efficiently attack the fire from normally unreachable angles.

By entering the basket of the lift the fire fighters are also exposing themselves to the hazards of a blazing fire. To attack the fire effectively the fire fighter often finds himself in close proximity of the flames and at times inside the baking, toxic smoke that is expelled by the fire.

Yet, this is one of the best examples of close interaction between man and machine. Instead of being a stationary utility, the vehicle extends the effort of the fireman. This is one of the core aspects of our philosophy of "empowering the fire fighter".

//SITUATION

// IRONMAN - DC Comics

As we aim to develop a vehicle for a Stage 2 scenario we have adopted the philosophy of "empowering the fire fighter". This entails giving the fire fighter super-human abilities; better situational awareness, greater range and mobility while resisting the hostile environment in which he has to operate.

Another core aspect of our concept is doing more with less. This applies both to the material cost of the vehicle itself, the versatility of the unit and the consumption of energy and other resources, such as water and energy, when in use.

We envision a vehicle that closely interacts with the operator in a manner that truly empower the fire fighter. Increased situational awareness, security and efficiency are some of the benefits that become possible when one extends the design past the "mobile toolbox" dogma of past vehicles. This is our philosophy and our goal.

// OPTIMUS PRIME - Transformers

// PHILOSOPHY

5 CONCEPT DEVELOPMENT

// EXPLORATION

Toyota Prius

Ulstein SX 124

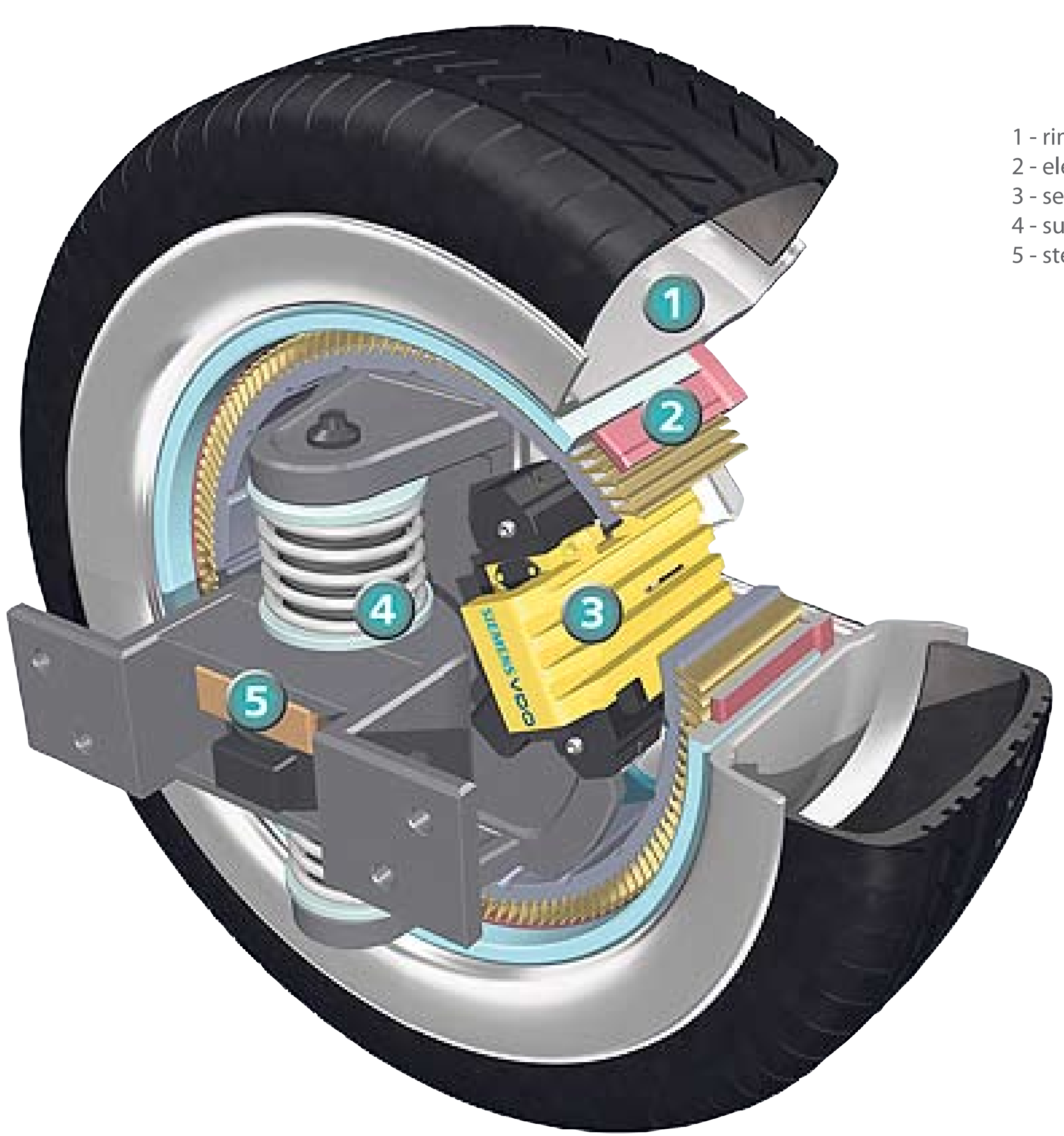
In other fields of transportation design, such as personal vehicles and shipping, there has been a tremendous development in recent years. Due to the harsh demands for more environmental friendly solutions, the development has been both looking for new sources of energy as well as means to distribute the existing energy with as limited loss as possible.

The Toyota Prius and Ulstein SX 124 are both examples of how new technology successfully may be incorporated. The Toyota Prius is a plug-in hybrid car with a combustion engine, meaning that it can draw its energy either from an electrical source or directly from the engine itself. This system enables the owner to choose which energy source he wishes to utilize, according to price, availability or other criteria.

The Ulstein SX 124 on the other hand has only got one energy source, namely an diesel engine. This is of course because a ship does not have a lot of alternative energy sources when at sea. So instead the ship is constructed around an energy distribution system that is more efficient and far more space saving, as compared to mechanical transmissions. In this ship a diesel engine powers an electrical generator, thus transforming the mechanical energy into high voltage electrical energy. The energy is then distributed out to the motors through electrical cables that only measure a few inches in diameter. It is in the electrical motors, placed outside of the hull, that the energy finally is converted back again to mechanical energy.

Even though the energy saving aspects of the Ulstein SX 124 is substantial, the most interesting aspect of the system is the flexibility it offers. The system allows the configuration of the motors to be easily altered or even upgraded. But the system also enables the motors themselves to have a great degree of freedom, allowing them to pivot 360°.

//ENERGY



1 - rim and tire
2 - electric motor
3 - sensors and hydraulic brake
4 - suspension assembly
5 - steering-servo

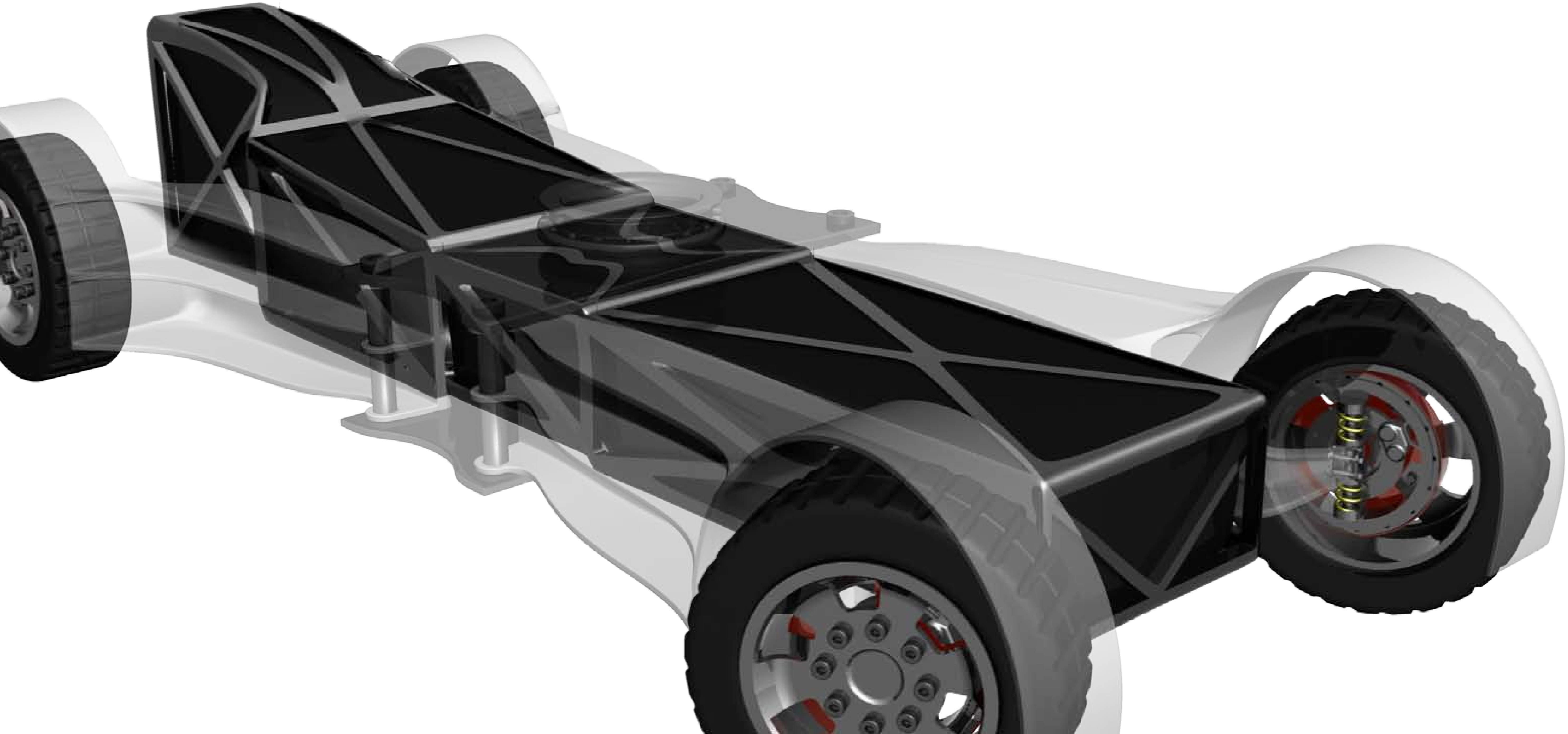
Ecorner an in-wheel-motor developed by Siemens VDO, is the automotive world's equivalent to the Ulstein SX 124's motors. This product merges several available technologies into the wheel and hub assembly of a vehicle.

The core of the concept is an electric drive motor that's integrated into the hub, and thereby enables the propulsion. The whole assembly is kept pointed in the correct direction by a steer-by-wire system. Additionally the solution also includes the Siemens VDO's brake-by-wire system. Thereby all of the hydraulic and mechanical transmissions that normally link the driver to his vehicle are fully replaced by an electrical one, effectively eliminating otherwise volume consuming parts.

The assembly is further equipped with an active suspension system which also is situated inside of the wheel.

Fitting the system at all four corners of a vehicle enables some rather interesting vehicle dynamics, with the angle of each wheel and the amount of power applied to each motor being continuously varied to keep the car pointed where the driver intends it to go.

// PROPULSION



The chassis is the backbone of the vehicle.

This chassis consists of a central housing, containing batteries and various other components such as electrically powered pumps and in itself forms the energy distribution grid. In addition it contains a flexible wheelbase "spider" and the mount for the boom-assembly.

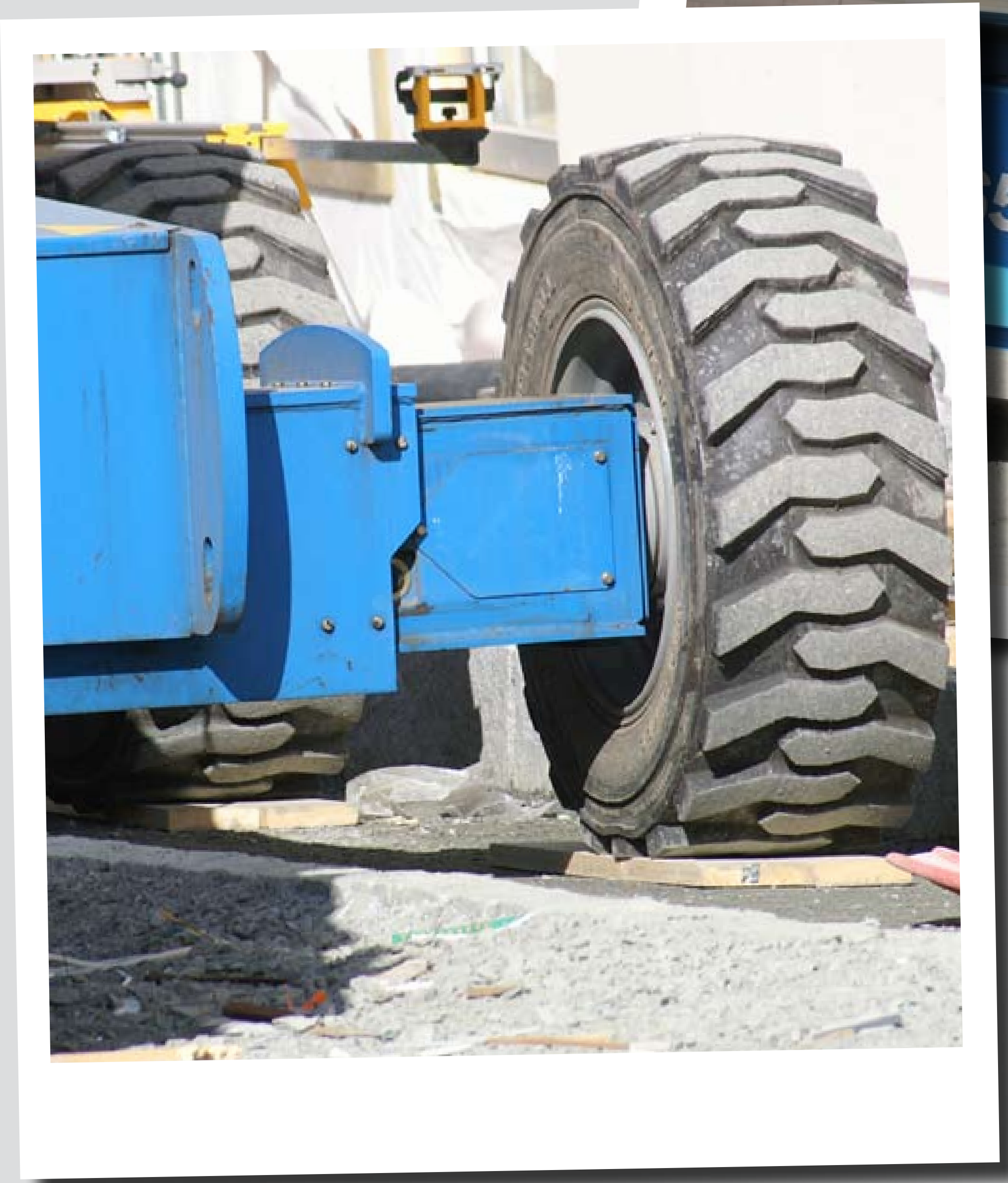
An electrically powered drive-by-wire system is implemented through four in-wheel motors. This permits all-wheel-drive as well as all-wheel-steering, greatly increasing mobility. Despite its long wheelbase, its manoeuvrability superseeds current platforms.

The spider allows for a spread of the wheelbase to enhance stability when the boom is deployed. Each wheel has an effective range of motion of 150º. This allows the vehicle to rotate around its own axis as well as traversing sideways. This allows for optimal counterweight placement, increasing effective range.

// PLATFORM

There are quite a few vehicles that need external stabilization in order to operate as intended. Such vehicles usually utilize separate telescopic arms to achieve the steadiness that needed. One interesting emerging trend among these vehicles is that all the telescopic arms is mounted in a small center. The load of the entire vehicle is thereby distributed through this center and out to the separate arms. Using this technique enables a more flexible configuration of the components.

// STABILITY



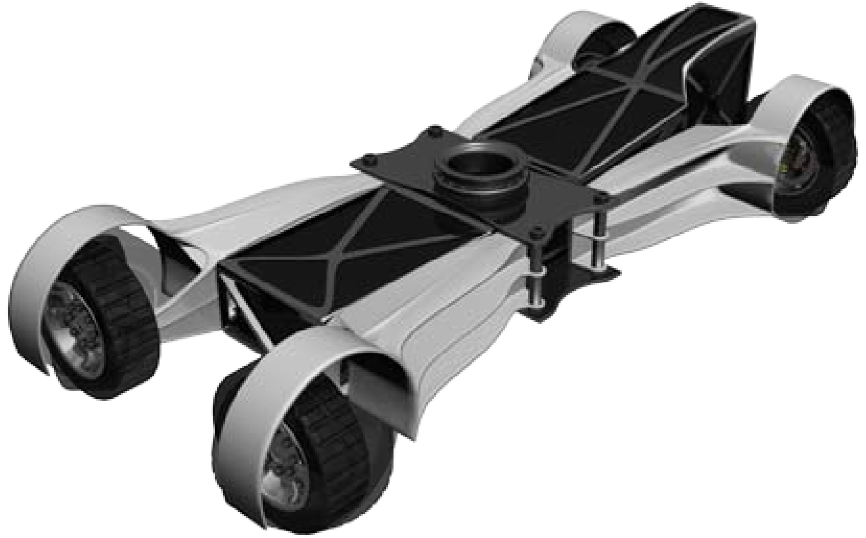
Traditionally, the stability of mobile cranes and lifts have been solved through the use of hydraulic stabilizers. These function as hydraulic arms that carry the entire weight of the vehicle. Sometimes upwards of 150 tonnes.

The benefits are threefold:
1 | Increase stability through wider stance
2 | Allow level operation on uneven surfaces
3 | Decoupling of the suspension

The increased stance allows for increased lifting moment, increasing range or lifting capacity. Decoupling the suspension is important to avoid sway and harmonic resonance that could induce sea-sickness in the operator or even result in the vehicle tipping over.

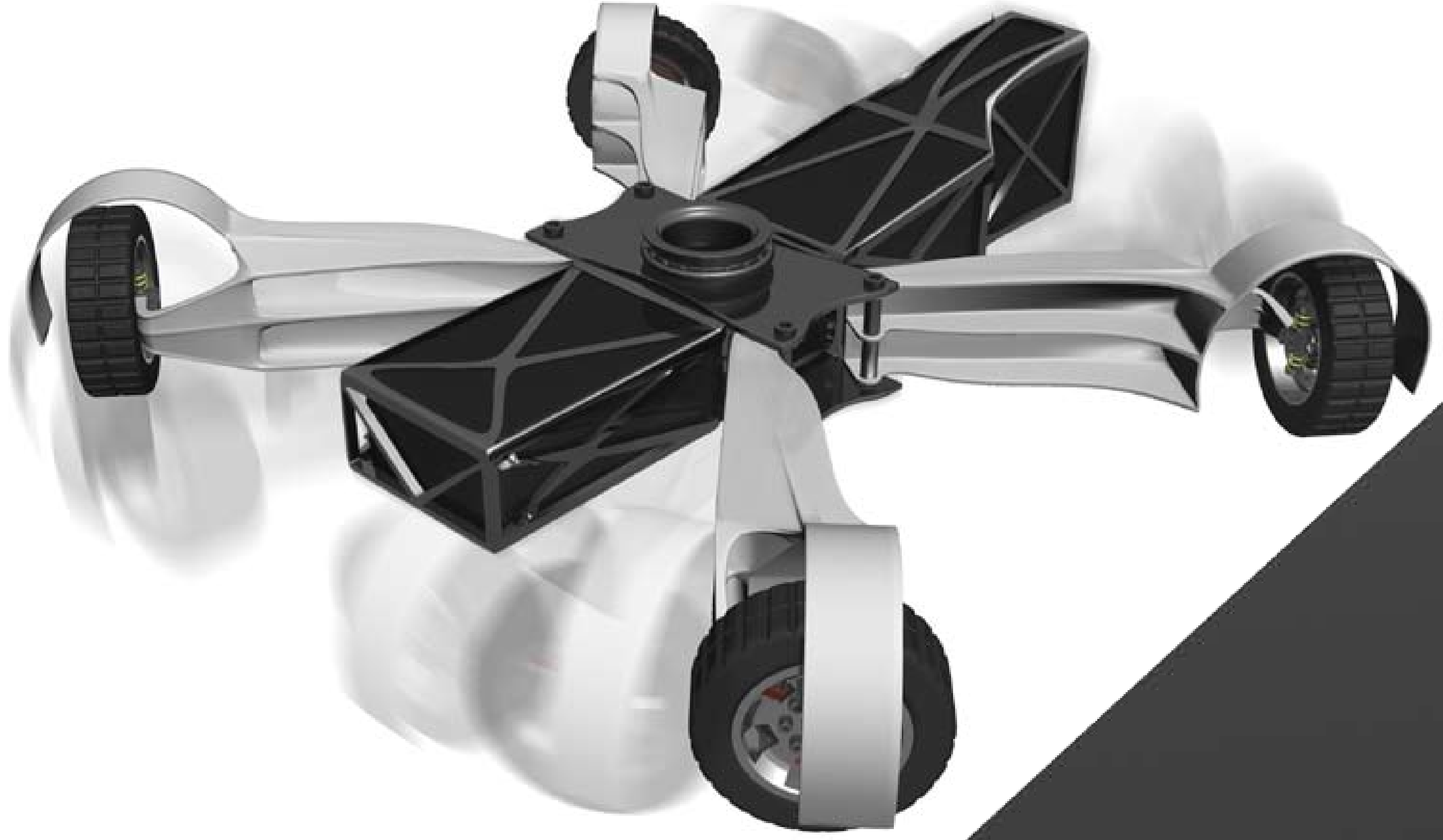
Genie lifts employ a different strategy. The wheels are solid rubber, and hydraulic pistons effectively lock the pivots of the suspension. The genie S-85 even uses a hydraulic piston to force the wheels outwards, increasing stance when needed. This brute but efficient method eliminates the need for auxiliary stabilizers.

// STABILITY



The 150° range-of motion of the in-wheel motors allow for deployment and retraction of the "spider" even when the vehicle is stationary. It also allows for a "crabbing" motion of up to 60° left or right as well as traversing sideways.

This procedure widens the stance from 240cm to 540cm enhancing stability when the boom is extended.



Various lift designs exist on the market today, from simple scissor lifts to more complex multistage telescopic booms.

A small unstabilized lift, such as the Genie S-65, have a lifting capacity of a few hundred pounds. In the other end of the scale, we find the huge mobile cranes, capable of lifting over 100 tonnes more than 100 meters up in the air.

Our solution exits somewhere between these extremes. The introduction of lighter, stiffer materials, such as carbon fiber composites, have made strong and stiff yet lightweight booms possible, allowing for greater range and/or capacity at lower weight.

// MOBILITY

Current boom designs are by and large steel designs. This leads to a heavy construction that put a strain on the stability of the vehicle. The weight of the boom itself is enough to require stabilization. A lighter boom design is important to keep the vehicle as light and agile as possible.

In order to effectively perform their duties, the fire fighters need protection that does not limit their mobility. The protection of this vehicle enhances the mobility of the firefighter by using a telescopic boom. The boom rotates 360 degrees in relation to the base, providing complete freedom with regards to positioning the vehicle.

The 5 stage telescopic boom is comprised of aluminium and carbon fiber composite. It has a total weight of just over 1 tonne. It has a horizontal loading capacity of over 6 tonnes and a lateral loading capacity of 2 tonnes.

This allows for a lighter high-capacity lift, that puts minimal strain on the platform, increasing mobility and flexibility, providing a maximum working height of over 26.5 meters and eye-level height of more than 28.5 meters.

// BOOM

The protected cabin is constructed to carry out work in an hazardous environments and act as an extension of the human body, allowing remote execution of actions like evacuating persons and fighting the flames.

// LIFT

Man has explored space, a total vacuum with temperatures near absolute zero, thanks to specialized protective equipment.

Diving suits like the Dragger allow operator to carry out operations far as 1000m below sea level, where the pressure is 100 times greater than that at sea-level.

What separates these suits from the protective clothing of a fire fighter?

Where the fire fighter wears clothing that insulates the wearer from the environment, these suits produce an altogether different atmosphere, suited to the operator.

// PROTECTION

The cockpit provides the fire fighters with a safe and comfortable environment to perform their tasks. Carbon-fibre reinforced plastics and laminated glass ensure safety from heat and blasts.

Air-purification systems supply fresh air to the cockpit. This eliminates the need for a breathing apparatus.

The "bubble" design gives a good overview 180° horizontally and 120° vertically

// COCKPIT

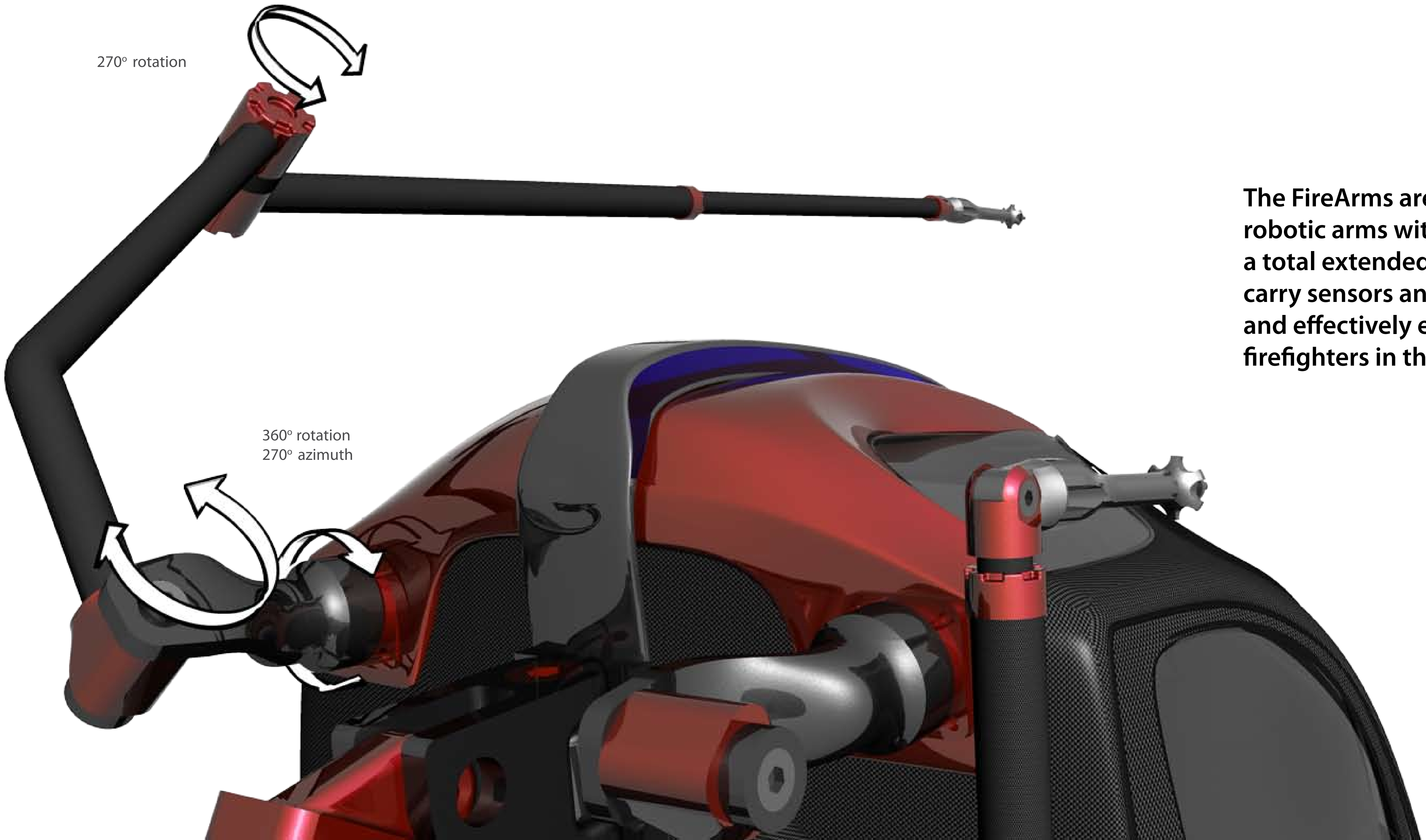
The Da Vinci surgical system performing abdominal surgery.
Operator seen to the far left.

Industrial robots have been used extensively for decades. The precision, stamina, speed and strength of these units far surpass human abilities. Robotic limbs have also been applied in space and other hostile environments.

Remote surgery is a delicate procedure. By making a small incision in the patient, the operation can be performed in a less invasive manner, greatly shortening recovery time. The surgeon operates a robotic arm form a distance as little as a few meters up to several hundred kilometers. The robotic arm is more precise than the surgeon and will not fatigue.

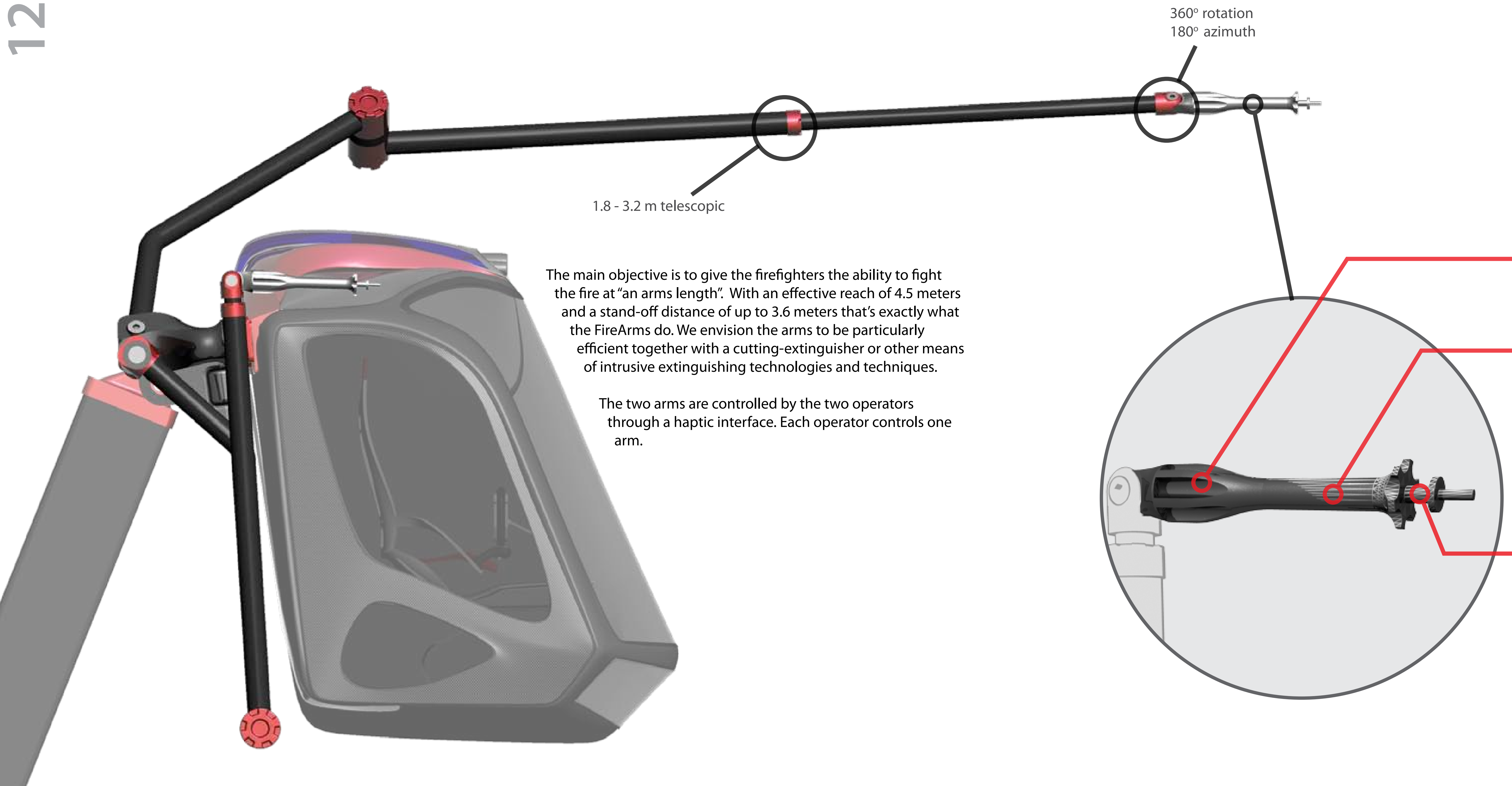
A robotic arm contains actuators and sensors allowing high precision, high speed movement. It may be controlled automatically or manually. One example of the latter is the powered exoskeleton. This is more or less a wearable robot. The robotic limbs are controlled by the operator's movement and allow him or her to perform duties with super-human strength and stamina. In layman's terms it can be regarded as power steering for one's limbs.

// ROBOTICS



The FireArms are a pair of remotely controlled robotic arms with six degrees of freedom and a total extended length of 5.25 meters. These carry sensors and fire-fighting equipment and effectively extend the reach of the firefighters in the cockpit.

//FIREARMS



The main objective is to give the firefighters the ability to fight the fire at "an arms length". With an effective reach of 4.5 meters and a stand-off distance of up to 3.6 meters that's exactly what the FireArms do. We envision the arms to be particularly efficient together with a cutting-extinguisher or other means of intrusive extinguishing technologies and techniques.

The two arms are controlled by the two operators through a haptic interface. Each operator controls one arm.

The nozzle type may be changed to fit client requirements. We envision a multi-purpose nozzle which comprises of a mixing chamber/pressure chamber, a pre-heater and a variable-geometry nozzle. This unit is specialized for 3D-firefighting.

The mixing/pressure chamber allows for rapid change between the different modes: Foam, water-mist, water-cutting and traditional spray/stream.

The preheating chamber allows for preheating the water. This is especially useful in conjunction with water-mist. A steam-pressure above 30% of 1 ATM, will displace enough oxygen to render the air inert (O_2 < 15%). The saturation pressure of steam in air exceeds 30% above70°C.

To fight a kindling fire in a confined low-temperature space, steam may be more efficient than water-mist.

The variable-geometry nozzle allows for adjustment of droplet size and spread-pattern to ensure that the water is used as effectively as possible.

// FIREARMS

The ladder-truck is perhaps the most traditional embodiment of the fire truck. Ladders have always been an important part of the equipment firefighters bring to the scene of the fire. Even today fire trucks are fitted with ladders.

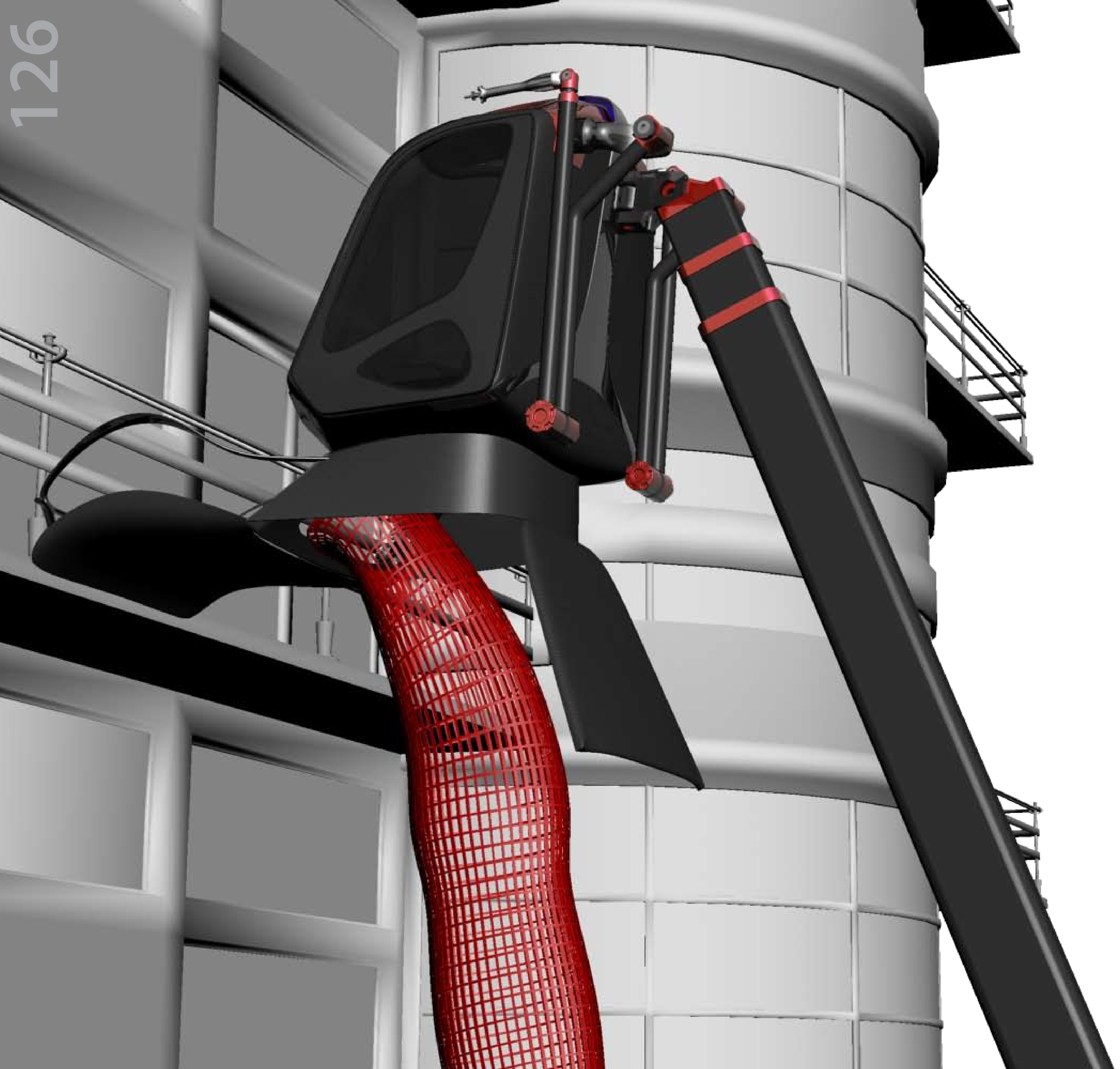
Specialised equipment such as automatic ladder trucks and hydraulic lifts have extended the reach and reduced deployment time. The lift is not necessarily a means of escape, the capacity of these is so limited that it is only possible to rescue one or two persons at a time.

One problem with ladders is that it requires a bit of effort to climb them. Clinically obese and pregnant have difficulties descending, as they can not see where they put their feet. In addition unconscious persons need to be carried down, a strenuous task.

At sea, be it on off-shore installations or cruise ships, the problem of mass evacuation is solved in another manner. Through the escape chute. The Chute is a tubular piece of mesh that allows a person to slide, by the help of gravity, to the bottom with a controlled velocity. Speed is controlled either through friction or through a zigzagging chute.

These escape routes require no training to use and require less physical effort from the user than ladders. The Viking SB 2A, pictured in yellow, has a capacity of 140 persons within the first 10 minutes.

// EVACUATION



The evacuation chute is contained in a compartment carried under the cockpit and is only deployed when needed. With simple implements, such as a rope, and the aid of a third fire fighter it is even possible to evacuate incapacitated or unconscious persons in a safe and rapid manner. As the person is contained inside a mesh tube during the descent, the psychological level of security is higher than in a ladder, while at the same time giving a sense of freedom, minimizing the feeling of claustrophobia.

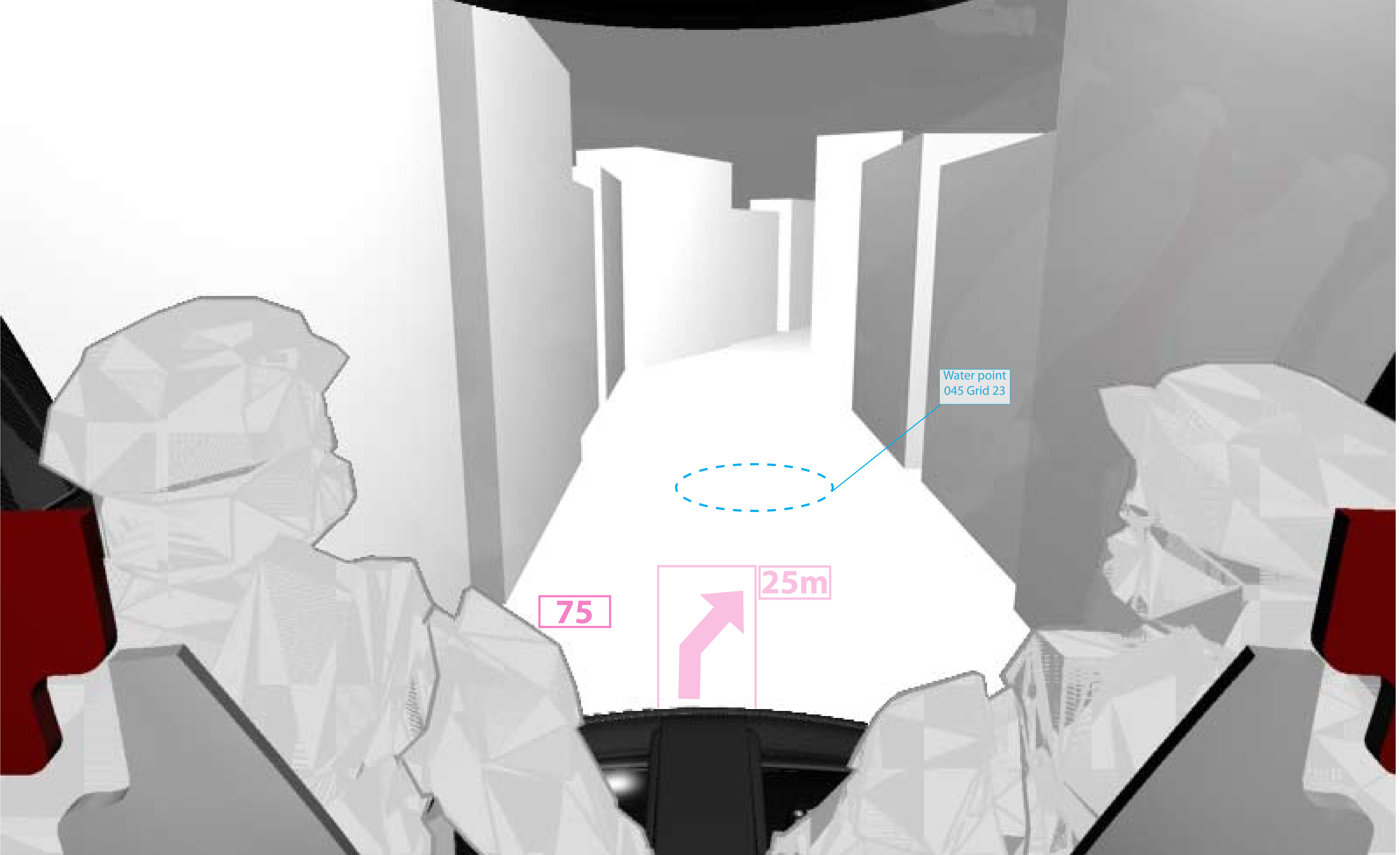
//CHUTE


// HUMAN FACTORS

Augmented reality is a way of communicating information. Information is gathered through sensors and displayed on a transparent screen, creating an information overlay on top of the real world. This overlay can display extrasensory information, this is information that is not obvious to the human operator.

The most widely known implementation is the Heads-up-Display, created for fighter jets in the 1960's. By displaying information such as bearing, velocity, altitude, and radar information, the HUD increases the situational awareness without diverting the operator's attention to an instrument panel or display.

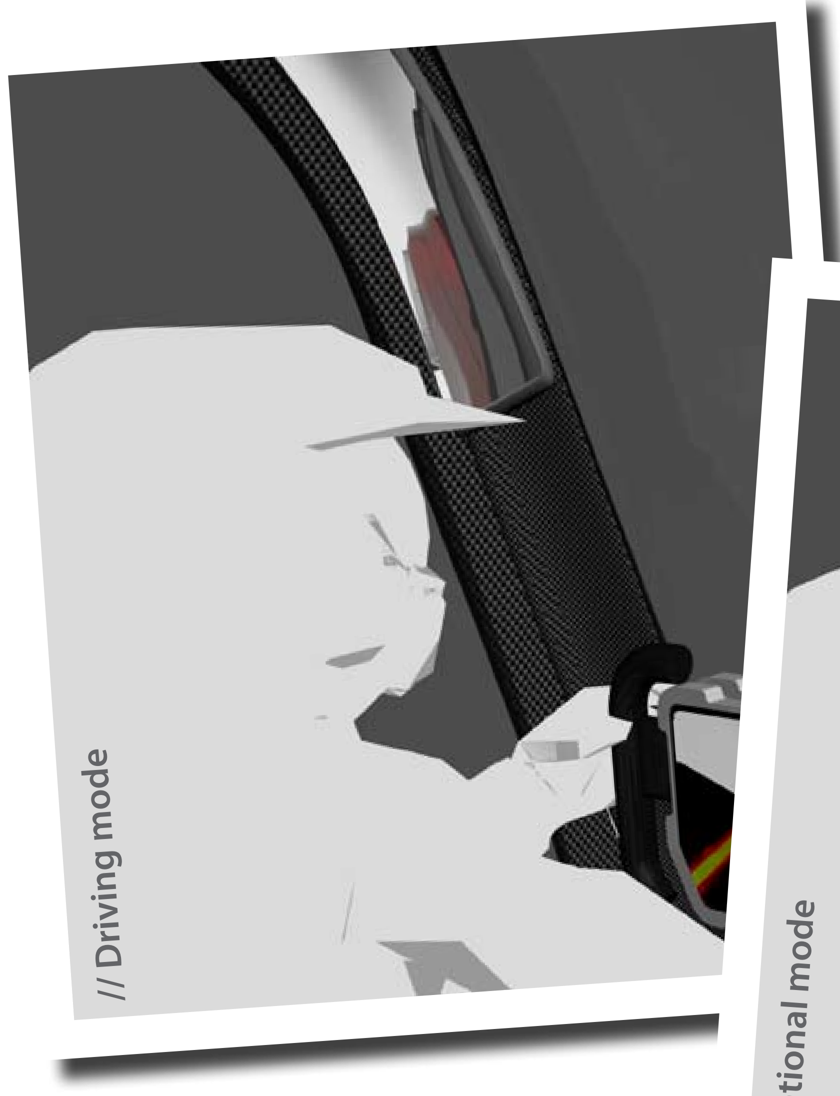
// AUGMENTED REALITY

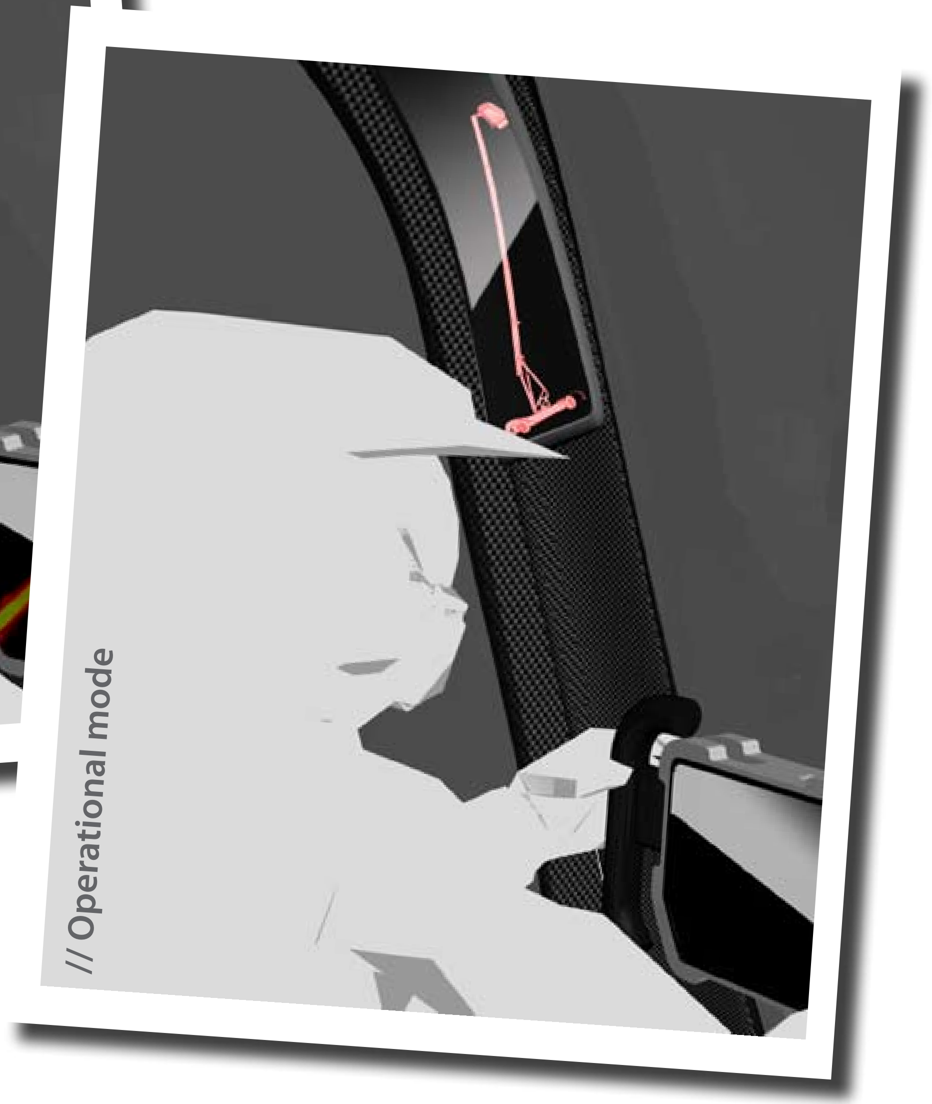


Significant information, gathered by on-board sensors or collected remotely, is displayed on the wind-screen HUD. The heads-up-display (HUD) display superimposes this information as a layer top of the real world.

This augmented reality not only substitutes sensory information (heat, smell, sound) but gives the firefighter access to extrasensory information. This is information which he could not have obtained by himself. The solution gives the operator the information he needs without having to move focus away form the task at hand .

// INFORMATION





// MIRRORS

Mirrors are normally a very important piece of a vehicle. But with the multi modal role of the cockpit, acting both as a transportation cabin in addition to providing an operational space when it is in the elevated state, normal mirrors would not depict information of relevant character.

This concept utilizes active screens instead of passive mirrors to provide information about what is happening behind the vehicle while driving. Two small cameras situated on each side of the vehicle capture the images that appear on the screens. In order to maintain the operator's normal convention regarding the placement of the mirrors, they are situated at the same position as normal mirrors.

By utilizing screens instead of mirrors, it is also possible to transmit other relevant information when in the operational mode. Such information may include information regarding the position of the vehicle, the strain on the lift due to torque or just situational pictures of the base itself.

Robotic exoskeletons, like the one depicted, are currently under development for both civilian and military applications. By using powered joints it is possible to achieve super-human power and stamina. These systems are worn rather than operated.

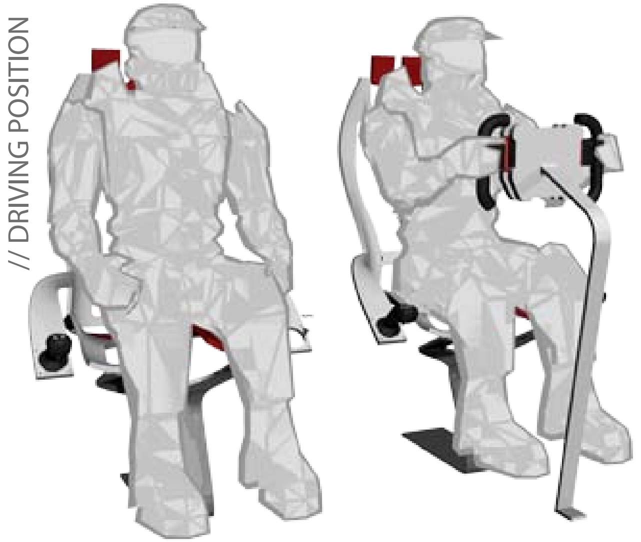
Sensors placed on the limbs detect pressure, and direction and adjusts the robotic arms/ legs accordingly. Operating the unit becomes second nature for the user, as there are no issues concerning mental mapping.

Modern fighter jets and some commercial jets have adapted the HOTAS control philosophy. HOTAS is an abbreviation for “Hands on Throttle and Stick”. In other words, the hands are placed where they are most likely to be needed. The pilot rarely has to move his hands to operate auxiliary functions. This dogma has been designed to ensure maximum readiness and minimize strain.

// USER INTERFACE

// USABILITY

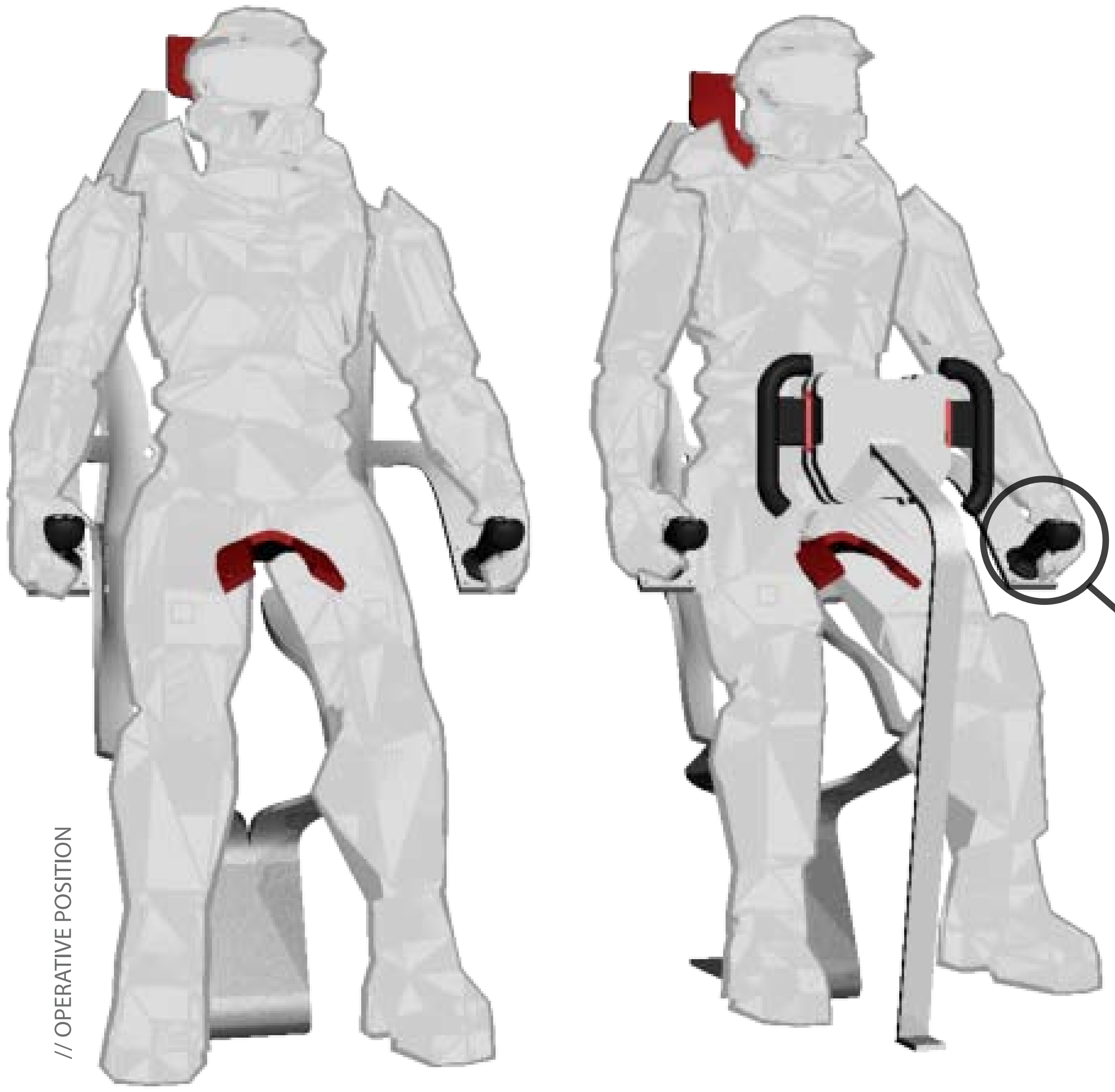
// DRIVING POSITION



To help fire fighters perform to the best of their abilities, this vehicle allows them to work in a more-or-less upright posture. In addition to giving the user better overview, the upright position also makes it easier to commit to the situation as adrenalin levels are heightened naturally. The firefighter is put face-to-face with the fire, so to speak.

To ensure a flexible and stable working posture when in the upright position, the seat is constructed to emulate a motorbike saddle. This feature improves lateral stability by working as a support to the upper thighs and reduces strain.

// OPERATIVE POSITION

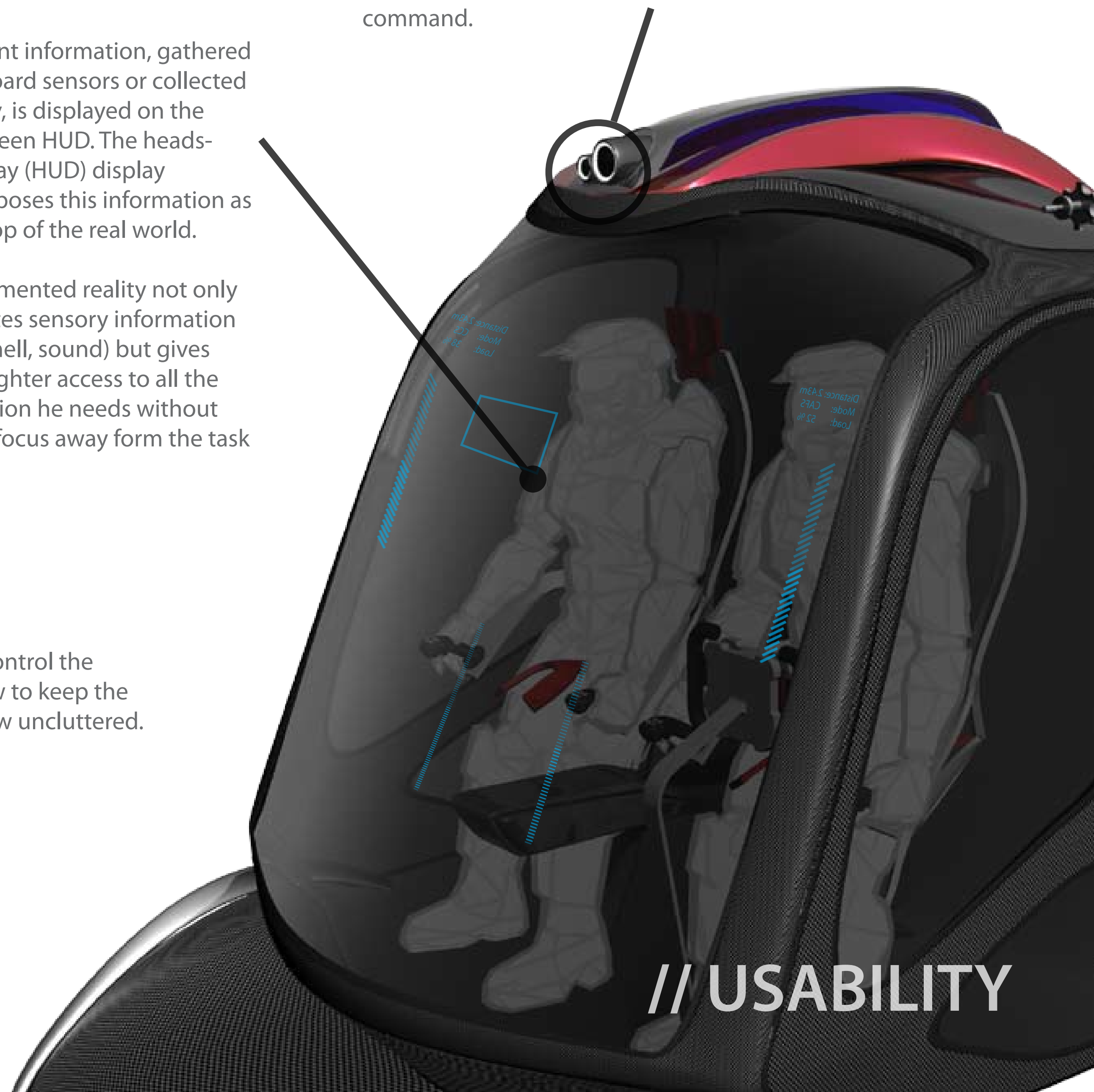


The interfaces that control the FireArms are kept low to keep the operators field of view uncluttered.

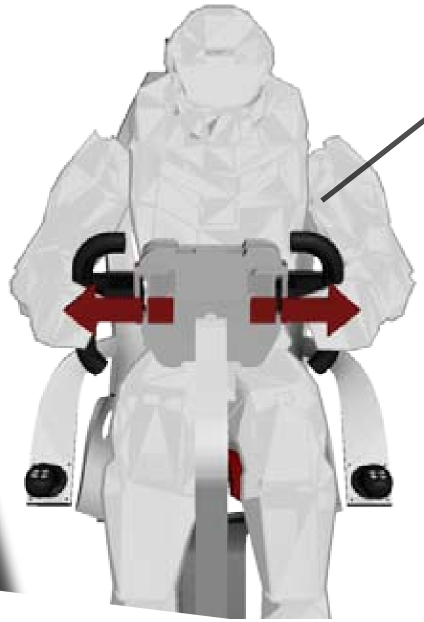
In addition to housing the emergency lights, the "mohawk" also contains a high-definition video camera and IR-sensors. This information is used to increase situational awareness. Sensor-information and video-feed is shared between the vehicles and on-site command.

Significant information, gathered by on-board sensors or collected remotely, is displayed on the wind-screen HUD. The heads-up-display (HUD) display superimposes this information as a layer top of the real world.

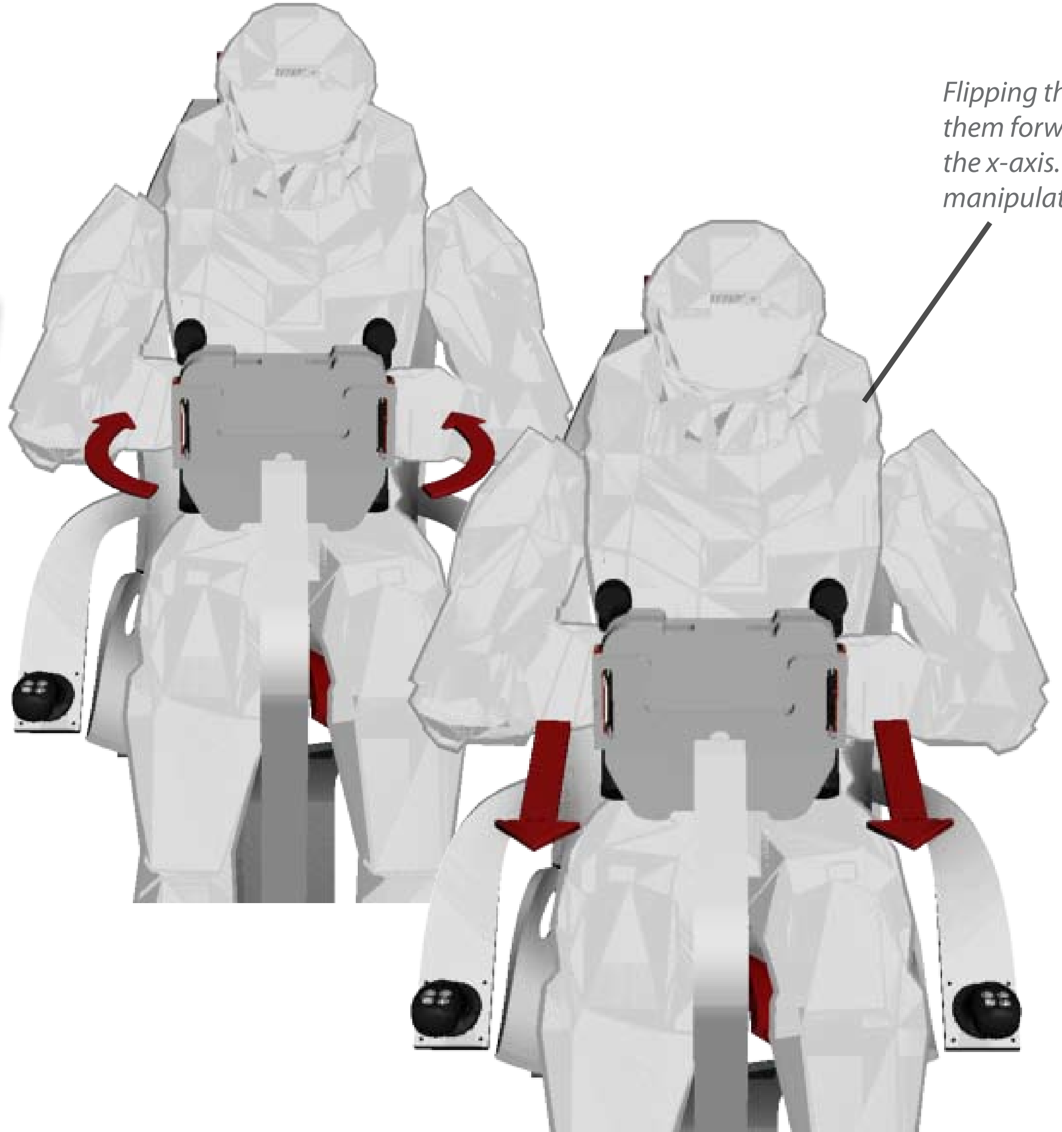
This augmented reality not only substitutes sensory information (heat, smell, sound) but gives the firefighter access to all the information he needs without moving focus away form the task at hand .



// USABILITY



Simultaneously pulling the two handlebars outwards, alternates the interaction of the vehicle. This mode allows the operator to position the spread.



Flipping the handlebars inwards and pushing them forward locks the rotation around the x-axis. This also activates the vertical manipulation mode for of the cabin.

// VERTICAL MANIPULATION MODE

To communicate the multi modal purpose of this vehicle, the most direct link between the machine and its operator has also been given a multi modal interface. The main operator of the vehicle has to manage two very distinct tasks, namely to drive the vehicle itself in transit, as well as operating the boom on-site. In addition the main operator may also be obligated to control the left FireArm. It is therefore critical to physically separate the controls to ensure that the operator has to take deliberate actions in order to ensure that only the intended action is carried out.

A rear compartment houses the auxiliary equipment needed for the operation of the vehicle. Pumps and fittings are placed here. This allows for easy operation, maintenance and disassembly for repair or upgrades.

As the vehicle generally is placed nose-in at the scene, the boom will be extended forward. This leaves the rear of the vehicle to be considered a safe zone except in very rare occasions.

// REAR COMPARTMENT

6 FINAL CONCEPT

// COMPONENTS


FireArm
Boom
Pivot point of the boom
Rear compartment
Steps
Emergency lights
Camera
IR Camera
Evacuation platform
egenes

// OPERATION

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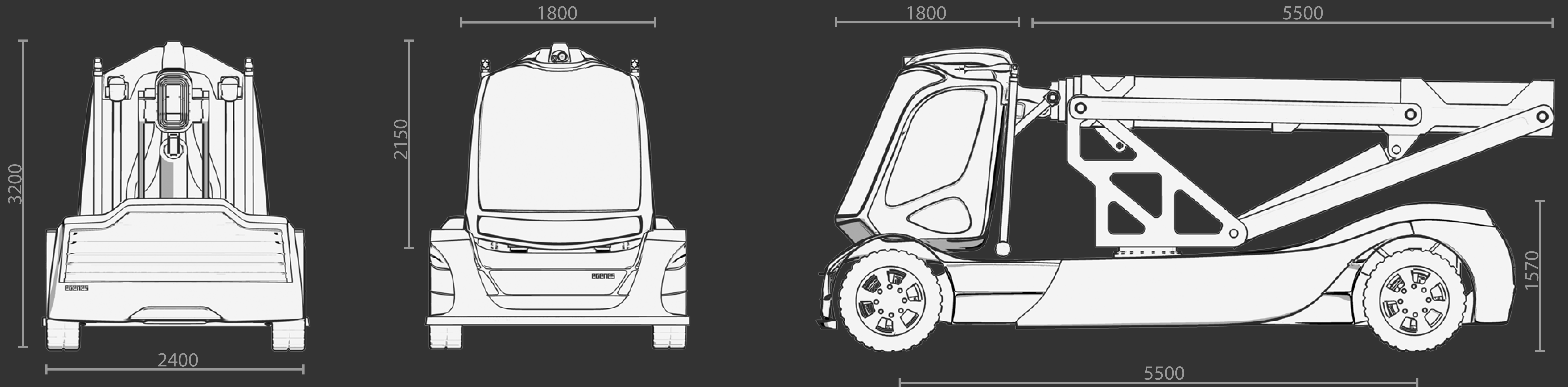
APPENDIX



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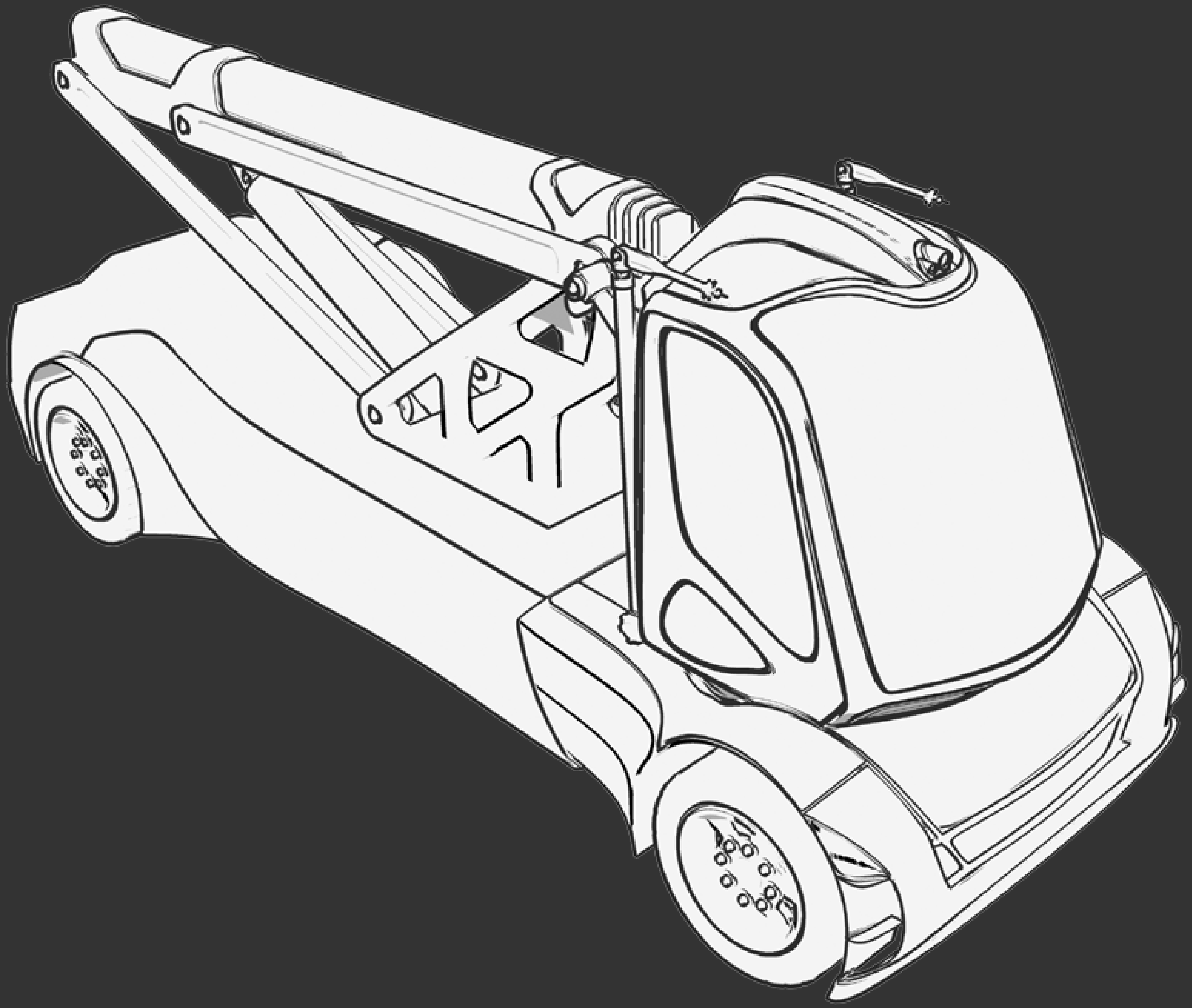

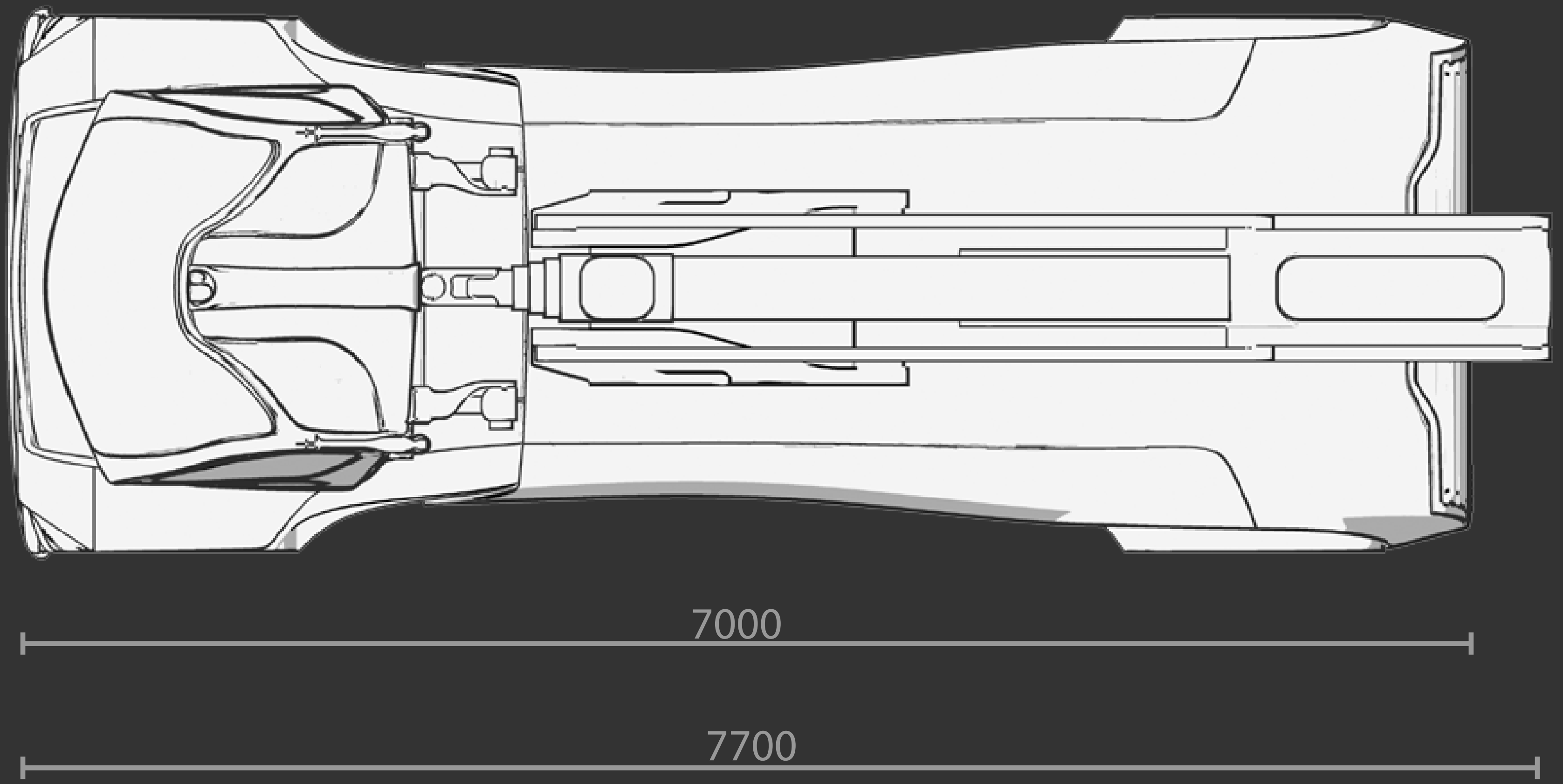

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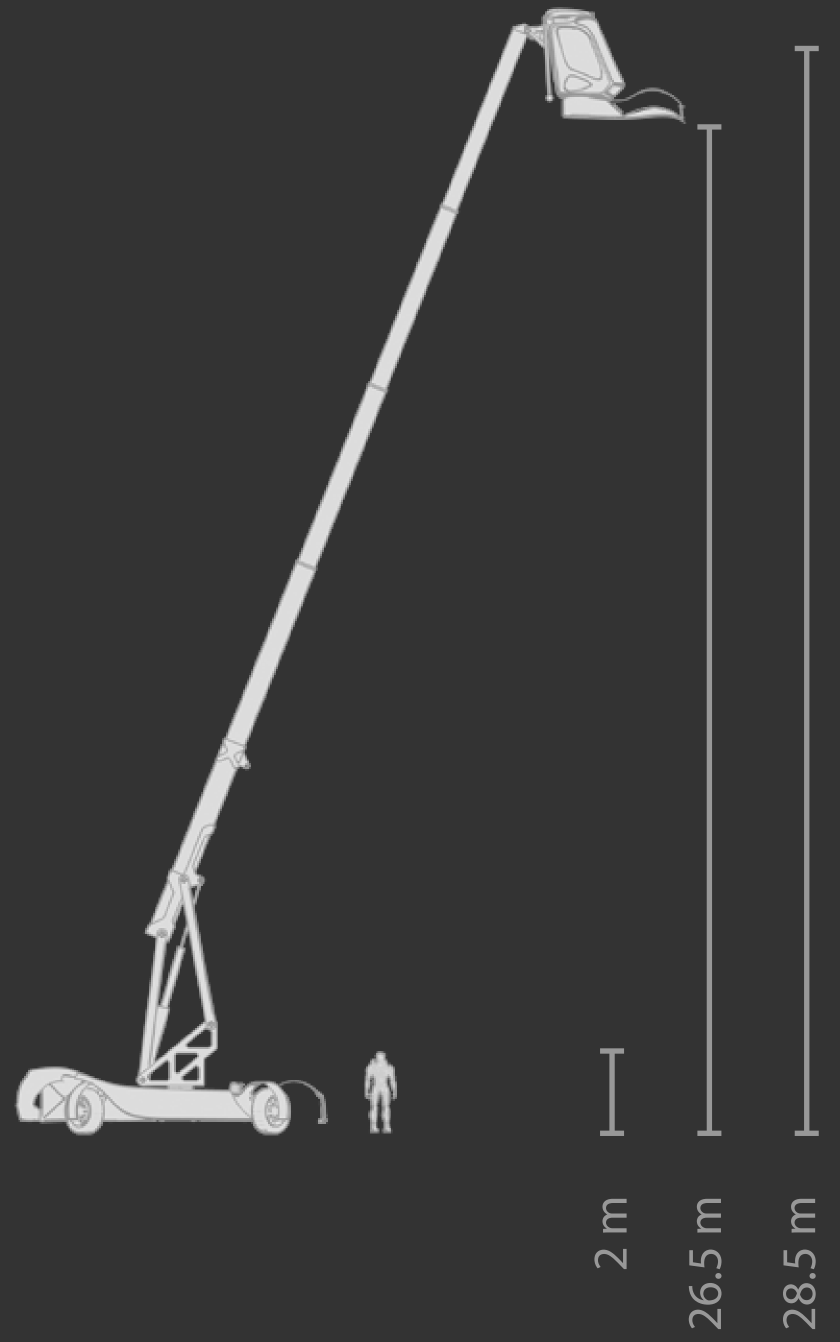

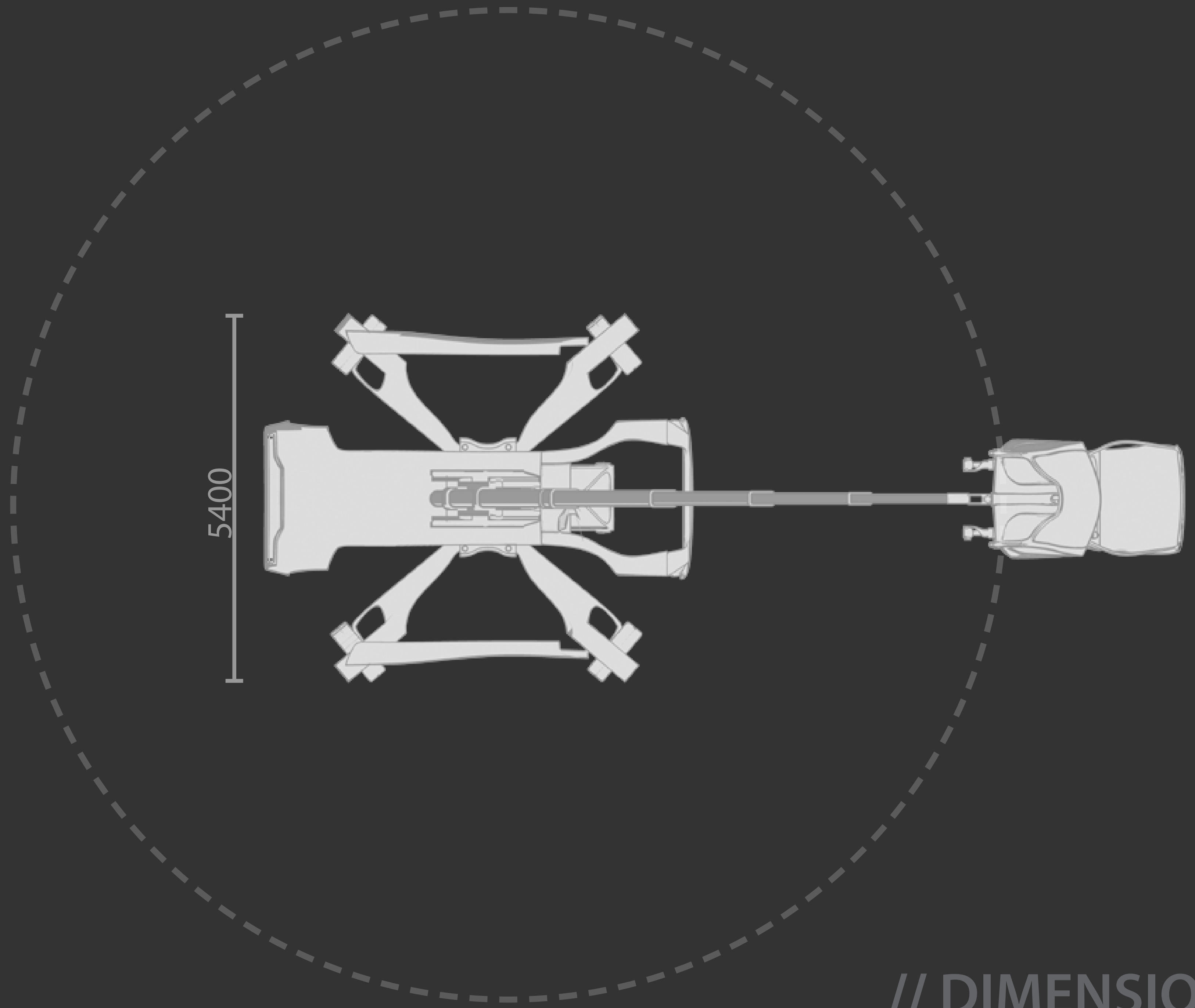

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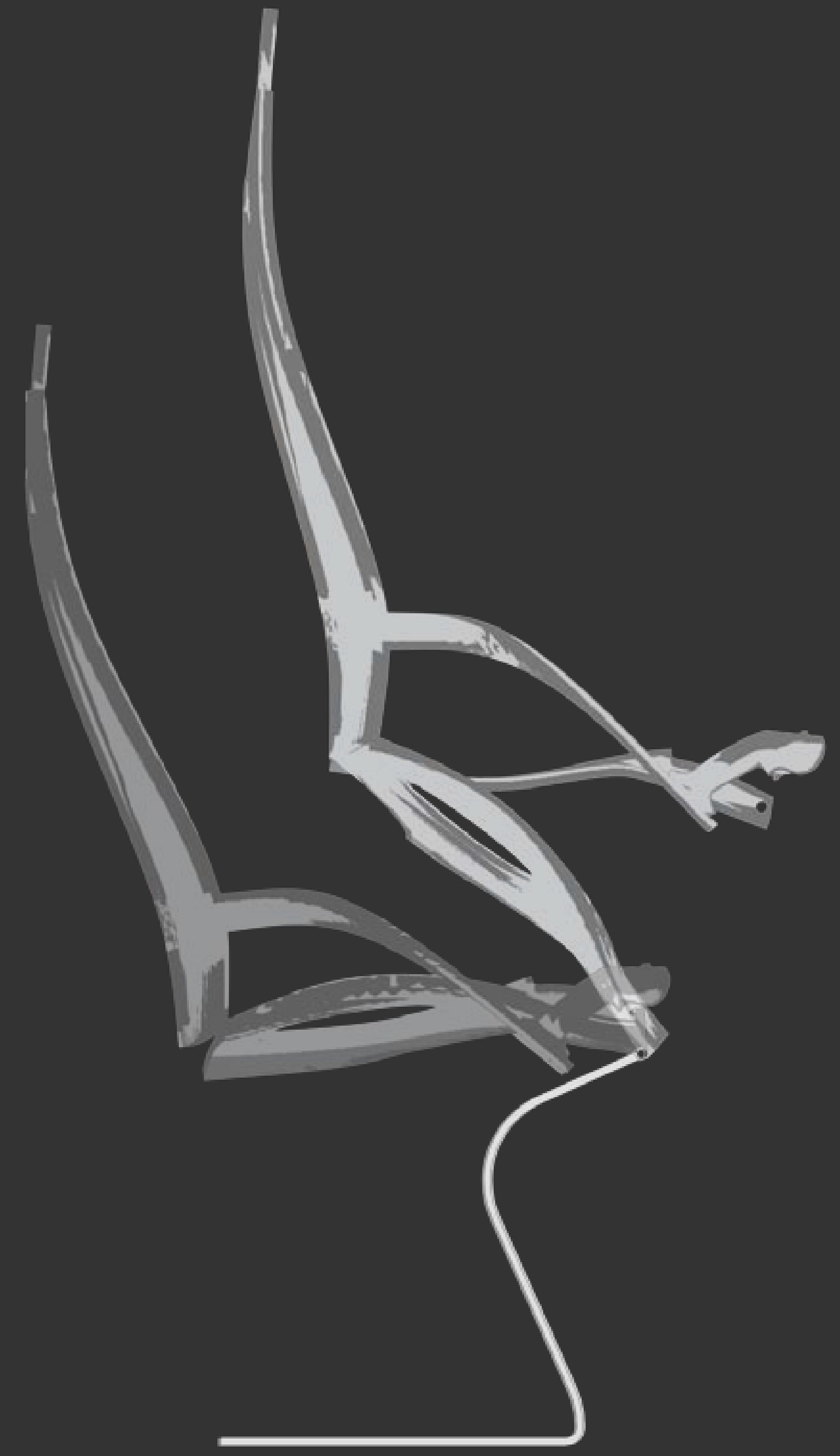

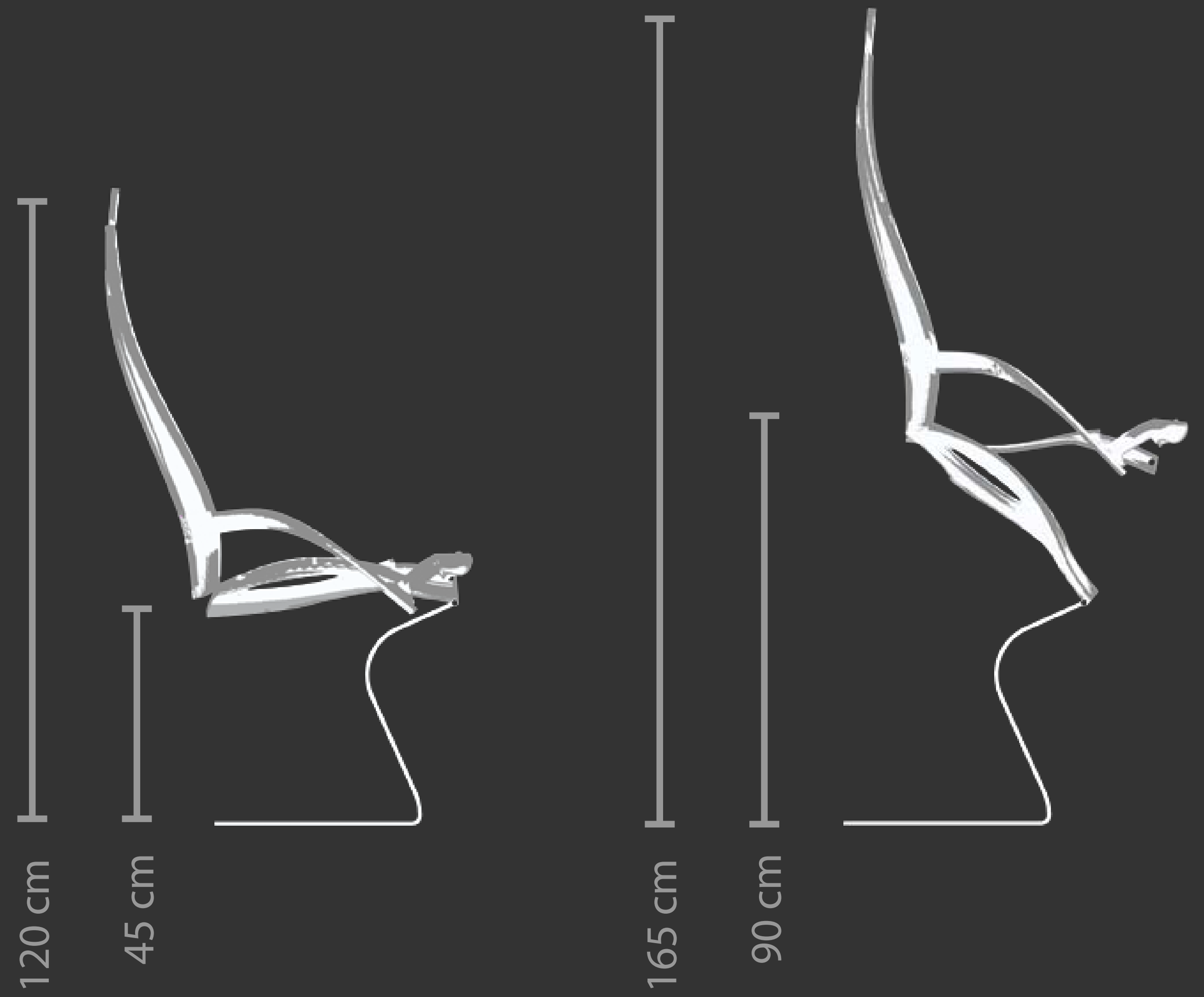

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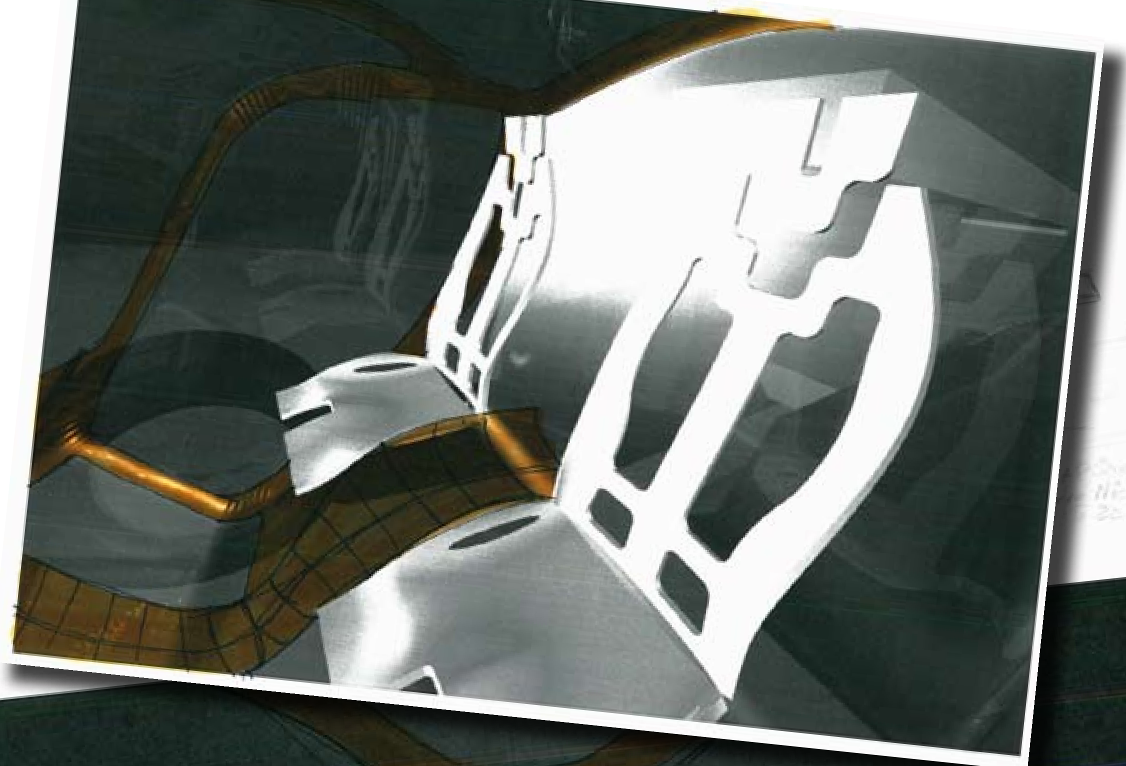

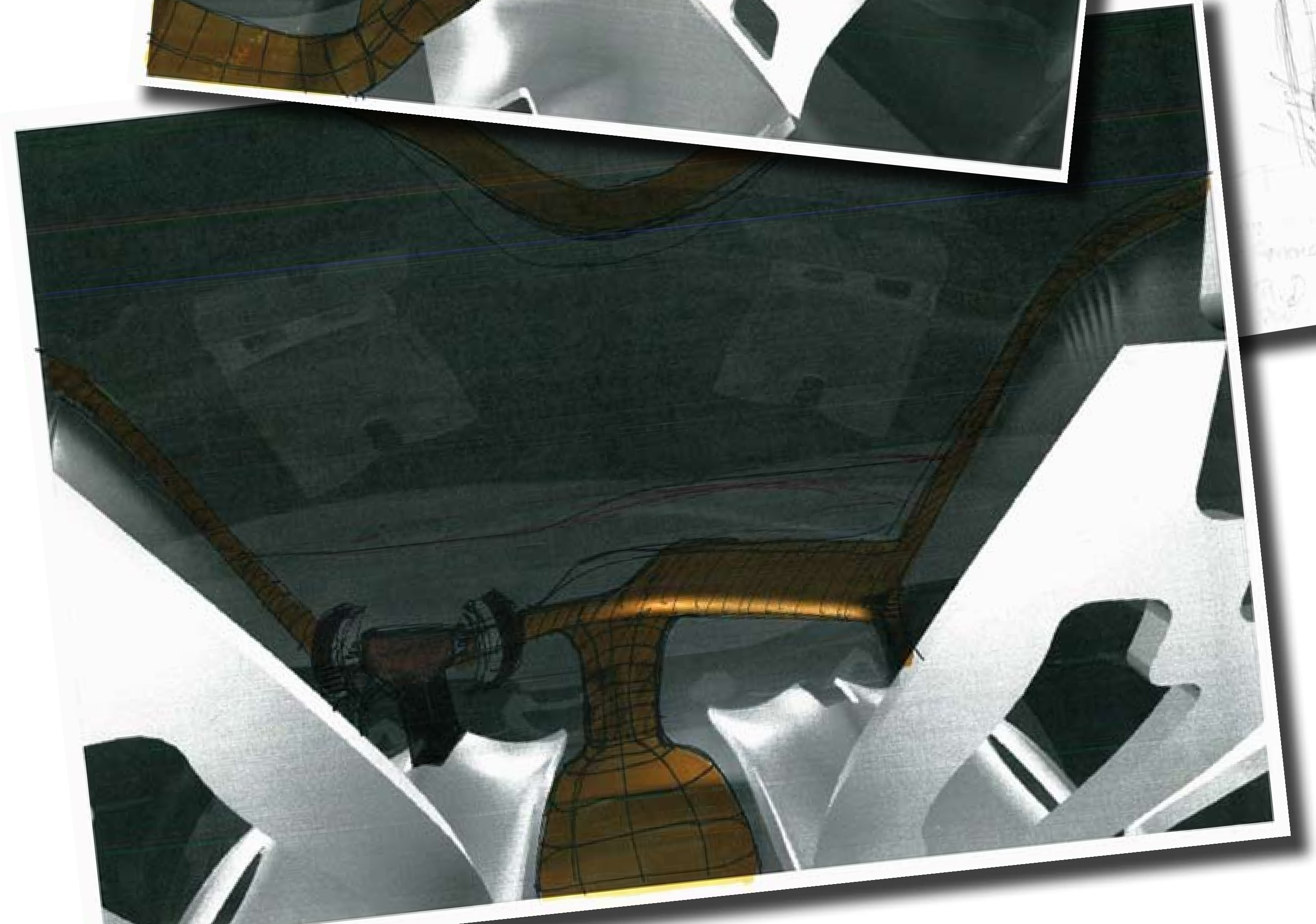

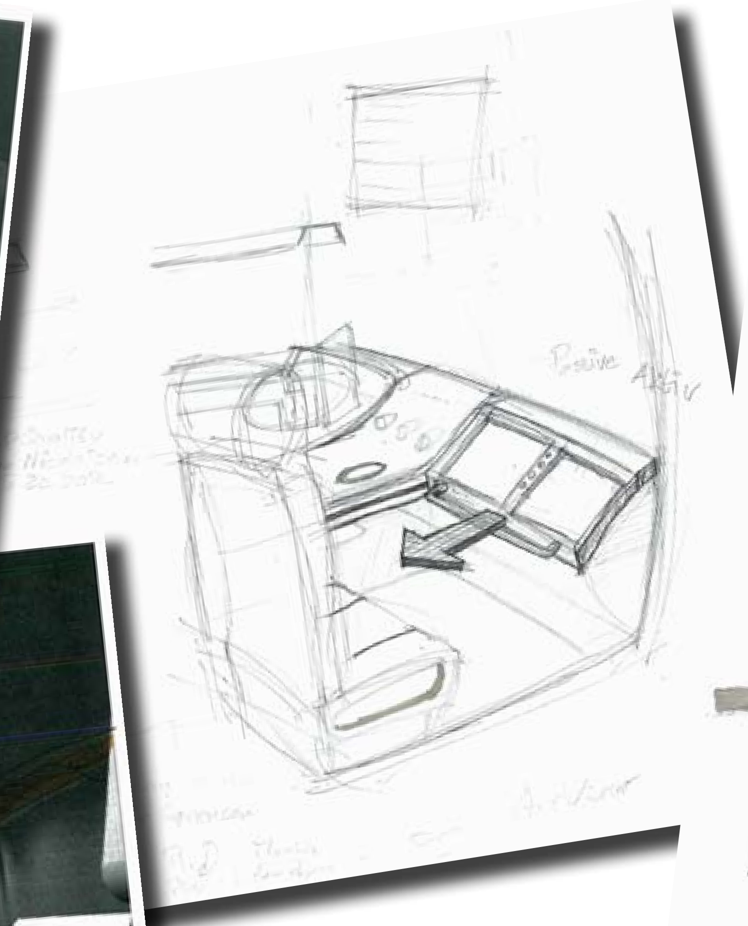

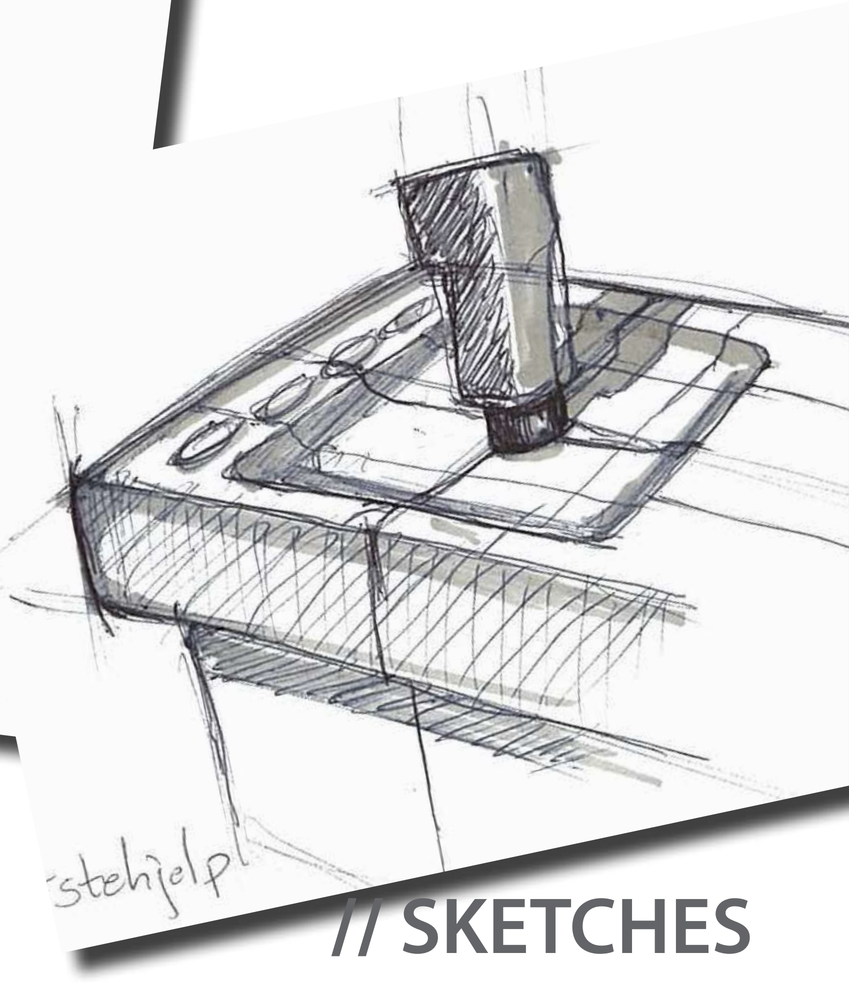

// SKETCHES

// TESTING

//TOM ANDRE TARLEBØ //OLE TERJE ØSTREM //2008