Abstract: This report looks at nanotechnology and how it can change the way we perceive our world. The report also examines the ethical and business issue related to adopting nanotechnology.
Introduction

Nanotechnology is defined by The British Standards Institution (BSI) as the: “Design, characterisation, production and application of structures, devices and systems by controlling shape and size in the nanoscale, which covers the size range from approximately 1nm to 100nm.”\(^1\)

First introduced in 1959 by Richard Feynman at the American Physical Society in his famous talk titled “There’s Plenty of Room at the Bottom”\(^2\), the term ‘nanotechnology’ was coined in 1974, when a Japanese professor Norio Taniguchi published a research paper titled “On the basic concept of ‘Nano-technology’”\(^2\), where he defined it as consisting processes of “separation, consolidation, and deformation of materials by one atom or one molecule”\(^3\).

Nanotechnology remained mostly theoretical until the 1980’s when two scientists working in IBM’s research facility in Switzerland invented the scanning tunnelling microscope, making the ‘very small’ visible to the human eye. IBM went one step further when, on September 28 1989, an IBM Fellow, Don Eigler, became the first human in history to move, control and manipulate atoms. The picture on the left shows another accomplishment achieved by Eigler and his team on November 11 of the same year. The figure on the left shows 35 xenon atoms arranged to form the IBM logo.\(^4\)

To date, nanotechnology has become of the largest growing fields in science and technology with a wide range of applications branching into many fields, more notably the fields of Robotics, Telecommunication, Medical Electronics and Bio-Engineering.

The purpose of the report is to conduct a feasibility study into the four main areas of the nanotechnology in the attempts to better understand the application their dangers and if it’s worth entering in a specific field of nanotechnology.
**Nanotechnology in Robotics**

At the start of the year 1971, Moore’s law describes that the number of transistors that can be placed cheaply on an integrated circuit will increase by two fold every two years. To this day, the trend has continued to follow that law where it would be expected to continue until to at least the year 2015 or 2020\[1\]. During that time, we have seen technology grow exponentially dealing with ever smaller and minute scales in the past years. Because the technology is becoming ever smaller and will in the ultimately become nanotechnology, it has attracted a lot of scientist and researchers to the area to eventually, build objects from the bottom up. The final structure will have material properties that will outweigh any natural or man-made material made to date, it will be so revolutionary that in one application, the military plans to use nano-bots to develop strong and interactive armour for the army, this involves integrating the electronics into the material and will be able to stop a bullet even though the nano-bot spans a width of a thin piece of paper. \[2\]

On the contrary, nano-scale technology requires some form of nano-manipulation system to handle and manipulate nano-scale objects, so that it would give scientist the power to create and engineer complicated architectures, grasp and manipulate the features and define the material properties. \[3\]

So far to date, the theory and practical aspect of nanotechnology in robotics very much understood to a point where there are many different ways to create nanobots such as:

- **AFM-based Nanomanipulation**
- **Nanoindentation**
- **Nanolithography**

And many of these techniques have been conducted and tested creating letters on a silicon surface the width of 8µm, which would then be applied to engineer simple control circuitry\[4\]. There are many studies conducted to understand how nanotechnology reacts in areas such as Nano-toxicology, medical imaging, drug delivery and other areas which includes the risk that are involved when dealing with these areas. In the research of nano-robotics, minute robotic prototype actuators have been demonstrated which spans the length of 5 cm, furthermore, tools for nano-manipulation have been created with a size of 5µm so basic processes of creating carbon nano-tubes can be made (CNT).

**Applications**

This section aims to give the different sorts if application nanorobotics can enter into and what benefits it brings to the particular field. There are countless applications with nanobots, but the three main topics that will be discussed are medical, computers and brain augmentation.

**Medical**

Japan has a strong plan and commitment in the medical area of nanotechnology, proposing spending budgets of $250 billion, other countries are spending an immense amount also in the medical area, which shows how important medical nanotechnologies role is.

A popular application is using nanobots to identify and destroy cancer cells, these nanobots that will have grippers, syringes and cutters will enter a patient’s body searching for cancer cells, then grab onto them and makes sure it injects the right amount on concentration to cell to neutralise it or just simply destroy it. \[5\] Therefore, a large amount of nanobots are needed to destroy a number of dangerous cells, they would need to work together to coordinate and target a certain area to make sure every dangerous cell doesn’t have a chance to multiply so constant communication is needed. Another the nanobots could have are cleaning duties, they would have actuators in them which allows them to clean an artery or vein by vacuuming plaque or dirt that blocks the tunnel. This can
be most beneficial to smokers who have their lungs filled and lined with toxic chemicals, the nanobots will be able to clean out the abnormal cells the chemical produces the body can create new ones to replace them.

The nanobots other abilities is to be able to regulate any organ in the body, maintaining and looking at the performance of the organ then assisting it in any way it can. Hence for disabilities such as deaf people, dumb or even paralyzed, the muscles in the areas can be electrically stimulated for it to work and function again, they can be restored by transmitting precise electrical signals by the nanobots to the human nervous system. All the five senses of the human body and illness can be restored by inserting an army of robots that will be able to repair, build, maintain and regulate the human body.

Nanobots play a vital role in the hospital field, it will be involved in many operations where surgeons can use multiple robots to precisely control their arms to perform a medical task, as a result, no invasive surgery will be required since the robots can simply be injected [5]. Some robots can behave as a camera to the surgeon while he controls the other robots to perform the surgery, so it’s not clear whether the patient will have to undergo local anaesthetics while the surgeon performs the operation, but it’s been made possible that the patient wouldn’t have to go under the knife. As well as being guided by the surgeon, the nanobots can be guided by an MRI system for drug delivery. The Magnetic Resonance Imaging (MRI) system can be used to optimise drug delivery in the body, and show a considerable increased rate of therapeutic and diagnostic result as opposed to traditional drug delivery methods. Their role relies on producing engineering and scientific solution in enhance diagnostics, in vivo propulsion and navigation and drug delivery and release which would be discuss in the latter part of this report within nanomedicine.

Computers
As Moore’s law states how the number of transistor that can be placed on an integrated circuit will double every two years, is almost reaching its limit due to the limits of silicon. Computer processors are almost reaching their theoretical maximum limits on a single core, which is why current computers possess dual core, quad core and even up to eight cores to process data simultaneously quicker. As transistors become smaller, energy consumption increases and properties of the transistor varies. [6] Since nanotechnology became possible, carbon nanotubes can be produced which are smaller and faster components, consuming less energy than conventional transistors. Since the technology is done on a nanoscale, engineers and scientist are able fit more units into the same field, therefore more carbon nanotubes in a circuit means more computing power, storing data will become faster and analysing information will be quicker.[3] As a result, it will replace supercomputers into the size of a sugar cube in volume and use less than 2W of power. This will open up so many applications in our everyday lives, having the power of a supercomputer in the size of your hand will change the way communication is made, define the materials of clothes, create commercial products such as stay clean glass and magnetic liquids etc. The technology will be made from the bottom up defining the characteristics and properties of the product and be able to perform any task possible.

Another problems electronics face is overheating. Normally, heat sinks made of aluminium or copper are used to dissipate the heat away to avoid shortening the lifetime, since an increase of 10C in operating temperature reduces the product life time in a half [7]. But there are “microfin structures made of aligned multiwalled carbon nanotube arrays” that can dissipate heat as well as copper, but will be more robust, stronger and much lighter than any other cooling material. This allows for much more processing power without any overheating, having increased lifetimes without any degraded performance.
Brain augmentation

Considering, nanobots can enter our bodies and have the capabilities of a supercomputer, a foreseeable application that will be used in the future is the application for the brain to expand our mind through the machines intelligence. Brain augmentation can allow us to have over a trillion interneuronal connections having high speed virtual connections, humans will be able to think faster, have bigger memory and a bigger overall capacity. Human brains is a fixed design but human artificial intelligence will surpass normal human intelligence, moving beyond the basic architecture of the human brain. There will be the ability to communicate with other people with the same ability, talking to one another through the brain, in addition, humans will be able to control devices just by thinking, like turning on the TV and switching channels. The nanobots will expand the brain's memories, improving pattern recognition and sensory abilities, making the brain perform and process much more efficiently where as a result, humans will become more machine than human. A suggestion suggests that the nanobots will slowly replace the human brain one by one and would simulate all the operations of the brain. Taking a pill each day and during a six month period, the brain would be transformed into an artificial superior machine and the person would never know anything had changed. Since response time can be around 50 ns, it would seem that the way humans see the world and everyday life would slow down since their perception speeds up. Researchers in Japan are already trying to build electronic sensors that would be able to manipulate the neural pathways of the brain, powered by biological energy like glucose, the device it hoped only to monitor activity and also interact in the connections between neurons which are synapses. There has also been progress in Carlo Montemango of Cornell University where scientist have made a molecular motor less than one-fifth of a red blood cell, which uses protein from attached to a nickel spindle and a propeller and is powered by the an energy that the body itself uses to power all living activities.

One theory suggest that nanobots will become the dominant intelligence on the planet over humans. They would be to create itself to have a strong artificial intelligence where there computation will be a trillion times more powerful than a human brain, hence non-biological intelligence is thought to be considered human since it is based on parts of a human brain. It will exceed human intelligence since it can share and communicate knowledge more efficiently than humans through their thought, they are able to exchange a huge amount of interneural connections through transmission rather than language based communication.

Risks

Researchers already know how materials react on an atomic and sub-atomic scale, but they have no experience on how to apply the theory when manufacturing at that sort of level. So there are still many obstacles and roadblock to overcome, once the technology is fully understood then advancements can go forward, but currently it is still a young technology which is potentially dangerous, just like how a fire is potentially hot. Robotics does not always function 100%, there are always bugs within the system or components breaking down so there are never any guarantees nanobots will work fully, a nanobot may successfully replace a neuron in a brain, by destroying it after it’s finishes mimicking it but the robot may then malfunction and break down losing that neuron and information it possesses, then the patient will probably have some adverse side affect with his mental being.

Ethics

The main concern of society is that the application nanotechnology in robots might result a grey-goo situation. Nowadays, computers are in danger of being infected with a virus, as a virus that can delete all data from a computer or even making the computer perform in different ways. A situation...
with nanobots may be a horde of nanobots lose control when infected with a virus or bug, destroying objects everywhere it goes resulting in the area being turned into a shapeless goo. Engineers will apply a failsafe within the robot to shut it down, but due to the virus, fail-safe’s may not work, much like trying to click on the shut down button on the computers interface when it’s not there, the only way to shut it down is to pull the plug, hence will there be a plug to pull in the malfunctioning nanobots?

**Robotics in Medicine**

Imagine an army of a million robots swimming around your body, who are the ones fighting against dangerous cells rather than your immune system. Building and protecting organs from failure, repairing or even imitate it’s properties atom by atom, nanotechnology in medical electronics offers all of that. The use of nanotechnology in medical electronics involves nanobots that are injected into the body and used to destroy any disease-causing cells or just to repair the damaged one. It can also be used to create artificial organs or a part of the body atom by atom, sensing external stimuli and adapt to the environment around it.[12]

Studies and test have been made, such as in radio therapy, a nanogenerator will inject the generator of activity and target the tissue, therefore the concentration is much smaller and there won’t be any effects of radiation therapy. Ohio State University has developed a mechanism to encapsulate pancreatic cells so it’s still functional and continues to secrete insulin and the antibodies cannot get to them because they are inside the nanoparticle. So animal studies have just been started for nanoparticles that cross the blood-brain barrier to treat brain tumours[13].

The timescale is difficult to predict considering the nanobots in medicine is an evolving process, also even though the technology can be demonstrated through clinical studies, with medical products, you’ll have to go through all the regulatory process which cost time and money.

**Applications**

Currently nano-medicine is a very popular field which has generated the most interest and the most investment. The general applications that are being invested in are drugs, instruments and sensory bots.

**Drugs**

A range of pharmaceutical nanocarriers are widely used for experimental delivery of therapeutic and diagnostics agents. The carriers are often used to control their own properties so they can simultaneously perform different functions. The most important modification includes:

- Increase durability and stability in circulation
- Changed bio distribution
- Targeting effect
- Stimuli sensitivity
- Contrast properties

Nanobots injected into the body will give analytical procedures in the lab but on a much smaller scale. The drug can be targeted in a cellular basis rather than a multicellular or tissue basis, giving a more detailed examination of the cellular process, hence being a more effective in identifying the molecular target for drug development. In the drug delivery, the drug will be placed in the
nanoparticle and will bind the drug, this allows the doctor to insert the drug in a smaller dose because the nanobot will have the ability to target and deliver right to the tissue of interest.\textsuperscript{[12]}

**Smart instruments**

Surgeons will be able to insert a horde of robots which will have scalpels, grippers, cutters which can be controlled during an operation. The nanobots will provide real time information so surgeons can receive continuous data on the “force and performance of the nanobots”, therefore, the can operate on different areas of the body which requires different ways on operating on such as the bone and muscles while coping with an ever changing environment.\textsuperscript{[14]}

**Sensory bots**

With sensory bots, the nanobots can provide a more “accurate and timely medical information” to diagnose any illness or disease and respond to the situation rapidly administering the right treatment. It will send data such as “blood flow to an organ or tissue after transplant or surgery”. Furthermore, they are able to take high quality images of the area, pinpointing the exact cause of the problem, Nanoparticles that have a magnetic core can be attached to the cancer antibody and attract cancer cells, emit a dye so it can be seen by an MRI scanner.

Currently, NASA is researching in nanobots to be able to detect any radiation as the astronaut leaves the earth’s atmosphere. The nanobots will look for any radiation damaged cells then repair the cell, either by inserting antioxidants or enhancing the mechanism of the DNA, so if the cell is damaged, then the nanobot can trigger the cell to die.

**Risks**

Since nanotechnology is done on a nano-scale of 10-9m, there are problems that can be compared to that of asbestos where in the late 1800’s, where there were various reports on harmful consequences of asbestos dust since the material wasn’t fully understood. Then in the 1930’s to 1970’s, there were increasing evidence of lung cancer caused by asbestos so there were attempts to control and limit the dust but was poorly implemented, now asbestos is banned and every precaution is taken when removing the dust. Similarly, nanotechnology can be compared to the dust, the technology is young and it’ll be too late if in hundred year’s time, problems start to arise.

The nano-scale particles are very mobile and can accumulate in the environment, this can build up in the human body and can be potentially harmful since the technology is not yet thoroughly examined and fully understood. In general, scientist needs to identify, assess, approve and diversify risk in order to decrease the capital cost of taking such risk to maintain financial stability and to push the progress forward.

**Nanotechnology in Medicine**

**Medical Electronics**

Medical applications of nanotechnology is still considered to be in its infancy, but promises to revolutionise the field with advancements in areas such as patient monitoring, diagnostics and drug delivery with a wide range of applications.
Applications

Currently nano-medicine is a very popular field which has generated the most interesting and the most investment, especially in the areas of pharmaceutical drug development and sensory bots. Shown below are examples of areas in which nano-medicine can be applied to and the possibilities they provide to us.

Diagnostics

Nano-medicine has seen much advancement in attempts to better identify disease causing cells and minimizing misdiagnosis. Development of nanotechnology in such an area has been focused on developing nano-sized semiconductors known as nano-crystals that rely on the principles of quantum dots, which when made fluorescent are able to show specific areas of the body when tagged to antibodies that target, for example, cancerous cells or cells infected by diseases such as TB or HIV. These biosensors have also aided in the fight against malaria where specific proteins relating to the blood cells inner membrane have been targeted by layout the sensors in a specific network and then by monitoring the change in the layout when the sensors come in contact with the disease.

Compared to the current use of organic dyes and fluorescent proteins as markers for detecting diseases, quantum dots are made to be able to be tuned to a wide range of frequencies and not degrade as quickly in the body as the conventional methods. These benefits are achieved by the some of its unique properties such as size-tuneable light emission, superior signal brightness, and resistance to hot bleaching and simultaneous excitation of multiple fluorescence colours.

Another area under development is the area of manufacturing of nanotubes and nanowires. When attached to nucleic acid probes, they are able detect mutated RNA which is caused by diseases such as HIV and cancer.

Currently, NASA is conducting research into nanobots being able to detect any radiation as the astronaut leaves the earth’s atmosphere. The nanobots will look for any radiation damaged cells then repair the cell, either by inserting antioxidants or enhancing the mechanism of the DNA, so if the cell is damaged, then the nanobot can trigger the cell to die.

Screening

Imaging is a process that looks at the different contrasts between the healthy tissues and the diseases tissue when light is passed through. The normal method used throughout the world produces images that can be somewhat unreliable depending on the machine used and therefore misdiagnose patience. Nanoparticles can be developed as medical image enhancers which are able to produce sharper contracts between the two types of tissues producing a more accurate diagnosis due to the easiness to identify the disease.

Smart instruments

Surgeons will be able to insert groups of robots equipped with nano-sized tools such micro-scalpels, grippers and cutters, which can be controlled during an operation. As the human body is undergoing constant changes (through various changes in chemical and physical composition), the nanobots can provide feedback information in real-time enabling surgeons to receive continuous data on the
performance of the nanobots. Therefore, they can operate on different areas of the body which requires different methods of operating, such as the bone and muscle areas, and be able to adapt techniques and carry out procedures within the ever changing environment of the human body whilst reducing complications.

**Drug delivery**

Drug development has proven to be one the most feasible applications in nanotechnology as it can be based on naturally occurring biological molecules. One of the major pitfalls in modern science is the lack of complete understanding of the human body and, as well as, the technologies employed to administer drugs to a system efficiently. Through continued development, researchers have been able to tackle issues posed by modern medical sciences.

Advances in nanotechnology have allowed scientists to:

- Better regulate the release of the drug which allows targeting specific areas allow for the salvage of drugs with low bioavailability
- Increase the precision of the drug which would aid time for the drug to become effective.
- Reduce the amount of the drug that is wasted and in turn reduce the cost in manufacturing as lesser amounts would be needed to be given to a patient to have the same affects as conventional methods.

One method through which drugs can be administered through the use of nanotechnology is by using nanoscale polymer capsules which can be made to break down and release at controlled rates when a specific area of the body been reached, achieved by the specific area’s pH level. This method of drug hopes to remove the need of daily vaccines for particular illnesses.

**Risks**

When dealing with nano-scale particles, there are many dangers which scientists have to face and deal with, especially when the human body is involved. If the basic understanding of the technology and of the human body is not established, it can lead to disastrous consequences and untimely hinder the advancement of the field and potentially stop all future development.

There are no known methods to efficiently track, identify and determine the possible side effects of the nanotechnology inside a biological system. However some of the potential dangers are easy to predict. The problem arises when observed behaviour and the predicted behaviour of nano-agents do not match and this causes more concern, as observed in the toxicity of fullerenes which were, at first, believed to be non-toxic. [a1] Before any progress can truly be made the potential risks have to be addressed as to avoid questioning on the safety of such technologies are accepted and made public to avoid another incident similar to the asbestos cases in the 1800’s. Where reports revealed that harmful consequences caused by asbestos dust due to the material not being properly understood by which time the consequences where too late to reverse, by the 1930’s to the 1980’s it was revealed that there was a link to the number asbestos cases and lung cancer when the material was not properly implemented, leading to the banning of asbestos and heavier precaution methods in dealing with the dust particles. [a2] In general, scientist needs to identify, assess, approve and diversify risk in order to decrease the capital cost of taking such risk to maintain financial stability and to push the progress forward.
Bio-Engineering

Other than in the fields of Medical Electronics mentioned above, nanotechnology can also be applied to the field of biology where the nanotechnology can be used to engineer alternative to organic structures in a biological system.

Applications

There are already many uses for prosthetic limbs and devices, where they are of great help when needed, providing support for the body internally and external. By we well now look into the different areas that nanotechnology in bio-engineering can provide.

Human organs

Samuel I. Stupp, a director of the Institute for Bio-nanotechnology in Medicine suggests that nanotechnology is able to activate the body's regenerating capability to repair and heal tissues and organs. He conducted experiments using paralyzed lab mice with a damaged spinal cord by injecting some purpose-designed nanomaterials and the mice were able to walk on its legs within six weeks. The nanomaterial self-assembled into nanostructures in the spinal tissue, then was able to repair and re-grow the damaged neurons. The test was further done on mice receiving Parkinson’s disease which are recovering slowly to full health, therefore, it shows that the use of nanostructures help the body achieve recovery even when there is sufficient damaged done to the body.[17]

Scientist has already started to build functioning vascular systems which are the first building blocks of a whole organ. Even though traditional tissue engineering have grown structural tissues such as cartilage, it isn’t able to engineer a vascular system which prevents them from creating whole organs.[18]

With a wealth of nanobots that can be inserted into a body to target damaged cells, they will be able to provide a suitable environment for cell differentiation in the attempt to protect the still healthy areas of the body and prompt tissue growth to repair the damaged cells. Once the artificial organ is grown and transplanted, it will be able to provide many advantages over donor organs. The artificial organs would be able to be obtained faster with no need for waiting lists, removing the need for donor applications. The organs would be tailor made to the specific needs of the patient reducing the risks of organ rejection by the body which is frequently seen in modern medicine. Additionally, the nanobots can be grown from the patient’s own cell, it will mimic the cells behaviour and create multiple bots that will be able to accomplish the same task as the cell, there will be no need to add dangerous immunosuppressant drugs to prevent the rejection because the human cells will think the nanobot cell is just like its own.

Limbs

Robotic limbs have been used for some time; processors nowadays are advance enough for artificial limbs to be controlled accurately. I-Limb is an example of a prosthetic hand in use today with five powered digits, the individual fingers are able to move and can apply different forces of grip on an object. The problem is that the touch sense cannot be fed back to the user’s brain to feel objects, determining whether they require the right grip especially on different areas of an object or if the object is safe enough to hold. Other Limbs such as the leg requires a more sophisticated design and
processor to control its movements since the limb has to follow a heel-toe movement like a human leg.

Nanotechnology being built from the bottom up can fully mimic the limbs of the human body. It can be connected to the body with minimal invasive surgery, connecting itself to every nerve to the brain, then adapting that nerve to a movement, hence, the patient has to think and the robotic limbs will follow that instruction. It can provide the user every sort of movement possible rather than limited to a few degrees of movement a traditional limb provides, therefore, there is more flexibility on the arm, wrist and fingers, including the movements of the legs and toes of the foot. Considering nanotechnology can attach itself to the sensory nerve, the patient will be able to feel any sensory stimulus on the particular section of the body; it will be able to feel temperature and the pressure of an object just like a human hand. The sense of touch will be given back to the patient replacing the amputated limb, the nanobot can be placed anywhere to the body and find the sensory nerve, from there, the user will then feel that stimulus as if it was part of their limb.

As we know, nanotechnology offers a strong material, used in applications such as the army’s armour; it’ll be able to stop a bullet from a piece of cloth the width of a piece of paper. Accordingly, when applied to the robotic limbs, the limb can be faster and modified to use in a sport or job and become much stronger than the previous limb the patient had before. The power of the limb can be limitless, where the patient will be able to lift objects a normal human wouldn’t be able to do, increasing performance and efficiency of movements without even tiring the patient out. The robotic legs will allow the patient to run faster, jump higher and even absorb the force of strong impact when jumping off high up places, the material nanotechnology can mimic are endless, it can become as flexible or as rigid as the patient requires it to be to accomplish particular task. Therefore, in the future, there will come to a point where human become more machine than man, preferring artificial super power limbs as opposed to normal limbs, there be more use in the medical sector for treating patients, but as for other sectors such as the military, it may be altered and modified for soldiers to fight in a war.

Implants

An implant is an apparatus to replace and copy the missing biological section. The material may be made from materials such as titanium or other materials depending on which the material is suited for. Implants such as hip replacements serve as an aid to a leg, but it is usually regulated on a regulatory basis due to the invasive nature of the implant. Bones such as a crooked spinal cord may need straightening and correction, so pin or nail implants are inserted to keep the spine in a normal position, encouraging it to heal in the right way. Normally, a lot of nails and bolts are used to fasten and secure a device in the body, which requires invasive surgery and months or even years of recovery.

With the possibility of nanotechnology, implants are stronger and smarter. The nanobots can be inserted into the body and programmed to target and replace the missing biological structure, there wouldn’t be any need for nails and bolts seeing as the nanobots will connect to each other at a molecular level creating a structure which can be stronger than titanium. Bit by bit, the nanobots can trigger a cell to die and completely replace the section such as a bone; as a result, the patient will be able to have an artificial bone implanted without realising the operation is taking place. Other implants can include a new artificial eye, or even a new brain that is discussed in the robotics section of the report, every damaged part of the human body can be totally restored with a new artificial device with more capabilities, more strength and last for longer.
Risks

Every new technology always carries unknown risk. For prosthetic limbs, the devices have been assessed for over 10 years. Most of the time the devices were successful where others carry risk such as infection with require more surgery. Nanotechnology can carry such as risk if it doesn’t function properly; the body naturally tries to reject any alien component or device from the body and may not accept it leaving the wound open allowing for infection to enter. As long as the nanobots function and trigger the right cell to heal, the operation will be successful, but considering a million nanobots will be injected, what is the percentage of the million robots will work properly and will the majority of the robots be able to compensate for the broken down robots.

Future of Medicine

In figure 2, it denotes the wide range of possibilities that nanotechnology has to offer and the timescale factors to bring such technologies to commercial use from the point of discovery to clinical trials to commercial use according to the European Union’s Seventh Framework Program.[31]

Other than the applications shown above in figure 2, in the bio-engineering can become part of our everyday lives in the future, people who are able to afford a treatment will have super abilities whether it’ll be a new heart pumping more blood around the body or a new limb, lifting objects 10 times the weight of the human being. The application can be regarded as cosmetic surgery since the choice is open whether the patient wants to upgrade his body’s natural abilities, the device can be
installed easily on the person programming the robotic device to attach itself to certain parts inside the body replacing the biological components mimicking its operation.

New artificial eyes can be implanted to see further, vocal chords can be manipulated to speak louder or to sing better, hearing can be increased to amplified levels without distortion and feeling ability can become heightened sensing movements from the hairs of the skin.

Camera eyes are already a reality, replacing an eye which has lost vision, it is able to stream data from the camera eye to the internet wirelessly, but it is not connected to the optic nerve. But in the future, the artificial eyes can be connected to the nerve of the optic nerve, giving back the patients vision. The eye can be regarded as an accessory and can be upgraded which also applies to the limbs of the body, the limbs can be modified to have features such as tools and extra fingers to perform extra task.

Much work will be done by the military to turn robotic limbs into robotic limbs with an integrated weapon. The user will be able to transform its arm into a weapon such as a machine gun and controlling it through thought, connecting both robotic arms or to other human arms to create a bigger device. They will have superhuman capabilities and can be seemingly invincible due to the whole body aided by nanobots, robotic strong limbs and body can provide protection, while nanobots internally can heal damaged parts quickly.[b3] Much like today, technology is getting ever closer to the human body and will one day, be part of it.

**Ethics in Medicine**

There are some doctors and views in the public that see nanotechnology in medicine as the potential means of altering the meaning to what it means to be human, as such advancements can bring about the ability to make use smarter, stronger, rapid healing and possibly the ability to see in the dark. Would be still calling ourselves human or is it just another possibility on the man’s evolutionary path?[a4]

Nanotechnology in bio-engineering will benefit so many people, people will disabilities will be able to function again. The lame will be able to walk again, the dumb will be able to speak again, the eyes of the blind ones will be opened and the deaf people will listen with increases hearing. Although these changes bring a positive note, the public can view the operation as something inhuman. Some suggest that humans should not play the role of God, creating new limbs and replacing normal limbs alters the body’s genetic traits. Some worry the in the future, babies that are born will be more engineered than born, with features such as eye colour, facial features or even personality from parents may be gone, since the parent may have an artificial eye or limb that disturbs the genetic code even though the theory suggest nanotechnology will mimic every cell and neuron.[b2] Dolly the sheep was one example since it was fully cloned animal to show that the technology actually worked.

However not all concerns are centered on what changes the technology can bring to the meaning to be human but also the social impacts of such technology made commercial. With the pricing of current advance technology already causing a divide in the world, nanotechnology will be probably follow the trend where new technology is offered at high price where the people who can afford it are able to buy it. If this does happen it would be mean that only the rich would be able to afford nanotechnology, therefore creating two sets of human race, the rich who are modified by the technology and the poor who stay unaltered. Therefore several organizations have urged scientists and the companies developing the technology to face these issues before it becomes too late.
The future of Telecommunications

Telecommunication, where ‘Tele-’ means distant in Greek, is the process by which information (or raw data) is propagated over large distances. Earlier in human history (dating as far as 4th century BC [1]) transmitted data mainly comprised of visual indications, such as smoke signals and fire-beacons. Communication systems designed to transmit such information were very large and very primitive and limited in the amount of data that could be transmitted at any one time, as they could only transmit one bit of information due to the physical nature of the signal being emitted. Moving on to the 21st century, modern telecommunications systems have become extremely portable (being able to fit into the palm of a human hand) and are capable of sending data that contains characters, text pictures, motion pictures and graphics. They are capable of transmitting several bytes (in the order of 1000’s and 10,000’s) in less than one second and have data processing capabilities to form networks and share information. As the demand for faster and more capable devices continue to grow, we must ensure that the technology is also capable to provide sustainable solutions to keep up with growing expectations. Nanotechnology is one such solution.

Towards the end of the 20th century (and into the 21st), nanotechnology has gained enough momentum to be considered as a viable option for the next generation of electronic devices, which includes modern, portable telecommunication devices. As organisations invest large amounts of money into developing nanotechnology, the remainder of this section focuses on looking at carbon based nano-materials and structures and their application in the field of telecommunications. One particular material has recently shown great potential in drastically improving communications devices. That material is graphene.

Semiconductor devices and Graphene

One the most famous examples of a semiconductor device is the transistor. Invented and, finally, developed on December 23rd 1947[2], transistor based electronic devices went on to revolutionise the technology industry in ways not foreseen during the early 20th century. Replacing the cumbersome and inefficient vacuum tubes, transistor-based devices were able to perform similar functions whilst consuming less power and a fraction of the space and this allowed them to propel capabilities of electronic devices to new levels. In telecommunications for example, one of the main reason for the increased transmission speed in communication devices is due to the fact that transistor devices within them were able to switch at such speeds that large quantities of data were processed in less than a fraction of a second. Having switched to transistor based technology, electronic devices were smaller and faster and more capable than their vacuum-tube counterparts, which allowed. Early 21st century has seen a rise in demand for electronic devices that are capable of processing even larger sets of information. A modern mobile handset (such as a smartphone) often has to deal with large amount of data such as images and be able to process them more efficiently and quickly and as data get more complex so should the speed of the devices. According to Eric Schmidt, former CEO of Google Inc., we generate ‘as much information as we did from the dawn of civilization up until 2003’ every two days[3], which is estimated to be over five exabytes of data. The main reason behind this is due to user-generated content as people become more aware of the uses of technology in various fields (such as imaging, music and communication) and the amount of data generated is set to rise even further. So far semiconductor transistor have been improved at a steady pace to provide a steady improvement in performance over the years.
However, with increased demands for better performance, nanotechnology based platforms will offer better alternatives.

The term 'Graphene' was first used by Hanns-Peter Boehm, a German chemist, in the 1960's to describe a planar sheets made up of carbon atoms arranged in a honeycomb (hexagon) structure that is one atom thick [4]. After its discovery in 2004, Graphene is now known as the strongest material known to man. Having been described as the “miracle material of the 21st century” [5] it also has a number of valuable electrical properties that would make it an ideal replacement for current semiconductor-based field effect transistors that nearly all the integrated circuits are made of.

According to research conducted by the University of Manchester [5], graphene exhibits a high (charge) carrier mobility, compared to silicon, allowing it to be used as an ideal material for constructing ultra-thin conducting channels in field effect transistors (FETs). This means that conduction channels will be able to conduct carriers with little or no noise allowing devices to have better performance. In fact, researchers at IBM have been able to produce graphene transistors capable of switching frequencies of over 100GHz.

On February 25th, 2008, Finnish mobile phone manufacturer Nokia Corporation showcased Nokia Morph, a concept mobile communication device demonstrating future applications of nanotechnology, particularly in consumer electronics. One of the key features of this device was its ability to sense (or detect) airborne particles present in the ambient environment, achieved through nano-sized structures present on the exterior of the device. Graphene can provide the ideal nano-material for sensing such gaseous particles. Due to its simple 2D structure graphene has a very large surface area and, as such, its entire volume can be exposed to the surrounding environment when made into long, 2D structures. These graphene structures can then be ‘functionalized’ by coating it with a thin layer of polymer, which would help concentrate the particles around graphene sensors. This will cause graphene to change its electrical resistance by a minute amount depending on the type of gaseous particle being absorbed. The electrical resistance can be measured to identify the gaseous content very effectively as graphene has a very high conductivity allowing very small changes in resistance to be detected.

Graphene has the potential to improve network speeds. Earlier research into the material also uncovered another likely use of graphene, photo-electric systems. According to a BBC report [6], researchers at the University of Manchester and University of Cambridge have discovered a way to make graphene more sensitive towards light. Earlier attempts to make solar cells using graphene only yielded a very small amount of power as most of the light transmitted through the material. The material only absorbed around 3% of visible light, which was far lower than current silicon based solar cells.

Researchers have now overcome this problem through plasmonic enhancement, where graphene is combined with metallic structures known as plasmonic nanostructures. This then allowed graphene based solar cells to absorb much larger amounts of light. In fact, the light absorption reached 20% in experiments far greater than the equivalent, most efficient silicon-based solar cells of today.
Not only does this make graphene a good nano-material to make next generation of energy efficient solar cells to power houses and buildings, but then can also be used in photo detectors in high speed optical communication systems, for example as receivers in fibre optic connection. This will allow much higher transmission speeds, allowing communications networks to become even faster.

Production techniques of graphene are rapidly improving. In 2008, graphene produced through exfoliation, where graphite crystals are repeatedly split until they formed thin sheets, were one of the most expensive materials produced on earth which cost up to $100,000,000/cm². However, more cost-effective ways to produce graphene have been discovered. Obtaining graphene through heating of silicon carbide(SiC) until it decomposed will make it more cheap, at around $100/cm².

**Viable Business Model**

**Business structure**

Currently, small to medium organizations (SME) have dedicated much of their resources to nanotechnology, whereas larger companies focus more on their products and sectors seeing nanotechnology as a tool to penetrate the market or become a market leader through the use of nanotechnology.

Since there are numerous SME’s companies, all of which have different techniques and solutions to nanotechnology, a simple partnership name registration would be one of the options a SME can choose to follow, combining skills and experience together to bring a better result to a problem, there will be no limits on the liability so all the assets are at risk but there will be liability for the employees and the partners actions. Another route for SME’s is for them to turn into a corporation, they will have separate legal entity so assets are owned and shareholders and lenders can invest in the company’s limited liability. The business structure can be chosen due to a number of factors such as:

- Limited liability
- Financing
- Initial cost and continuing cost like accountants and annual returns

But firstly a basic corporate governance structure needs to be constructed, which includes the relationship among the amount of stakeholders that are investing and how the targets for which the corporation is controlled, debtholders, trade creditors, suppliers, customers and communities are also involved. Below is a basic corporate governance structure the corporation can implement.
Within partnerships and shareholders, an agreement must be set to who gets the casting votes within the organization and decides what direction it goes to, how the profits will be split among the partnerships, would it split due to the amount of contribution one company gives than the other or a fixed split amount. There are other issues such as when can one partner be moved to sell or buy the shares, since they may enter into contracts and partnerships and joint ventures with other SME’s. Furthermore, it’ll need to be decided who signs the cheques, contracts or loans, whether it’ll be one person or a group of people, a group of people will be a logical thing to do but it may take longer due to conflicting ideas everyone has. Loans and bonuses need to made, how the payments will be made and when can it be made to the people such as the shareholders or director.

**Financing**

The companies would be to raise finance, trying to receive government’s grants and tax breaks. Receiving seed capital from the investors and joint venture companies, but a strong way a company attracts investors is building their reputation, having a good track record of successful, receiving profitability from them and the IP that the company owns.

**Intellectual property (IP)**

IP’s are very important for a company, especially for nanotechnology which is the start of countless possibilities of IP the company can create and own. Trademarks and logos need to be registered for national protection, and use this tool to let themselves known when advertising their products, furthermore, copyrights need to be carried out so the works are owned by the company. IP’s are unique to each so if the company decides to expand their business abroad, they would need searches and registrations in each area. The IP allows the company to enforce rights, their rights to sue, right to file applications and prosecute other companies and other royalty rights. Currently there are strong patent wars between telecommunications companies, and since nanotechnology
can be applied into the telecommunications sector, a strong and early position has to be made so there is a strong case for the company to go into a patent war if they have to. There are already strong competitors with 34% of companies in Britain already having 10+ years experience in the nanotechnology, areas ranging from carbon based nanomaterials to biological nanomaterials.[1]

**Enhancing R&D**

Open innovation marketplaces would be beneficial for every company starting up, since this will bring researchers, scientists, developers, universities and technology companies together to find a better and creative solutions quickly, this will in effect, speed up the technological process and brings out breakthroughs, which can be applied to products launched into the marketplace quicker giving companies a competitive advantage. So the task will be set by the governments or the companies who are seeking for help to push forward their product development and solve problems, usually a large sum will be paid out to the person who solves it as a reward, where the company can receive a non-exclusive, perpetual license to use any of the ideas the person has, transferring the intellectual property.

**Commercialisation**

Companies will need to decide when is the best time and where it launches its products, they have to make sure that economy isn’t down otherwise, the launch should be delayed, the product can be launched on different regions of the globe, expanding into international markets. This depends on their capital, resources, managerial experience and operation capability, a small company should focus on cities or regions rather than a national market then slowly expand out when the time is right and the products are ready.

For licensing agreements, the company will need the ability to keep their ownership and sell the same nanotechnology multiple times for fees/royalties, so they can commercialise world-wide, then hire distributors and build a global customer base so the business will be more profitable.

**Markets**

A range of companies by a long way focuses a lot on thin films and nanocoating where 35 companies are involved, 23 companies main study is biological nanomaterial and the rest of them works on carbon based nano-materials, nano-inorganics, nanoparticulate metal and alloys and nano-ceramics.
Therefore, the figures suggest that there is a market for thin films and nanocoating, as reported about the military, research is carried out to find out whether it’ll be possible engineering a material as thin as a piece of paper that will be able to stop a bullet. This application will also benefit and allow companies to commercialise their products, such as scratch resistant and self healing glass which accommodates a big market already, super strong materials for hand held devices is becoming popular also.

A huge market nanotechnology is seen to be in the future is the medical sector. This sector has brought in the most investment which requires research for artificial limbs, organs, internal healing and so forth. A main objective is nanobots to be inserted to complete certain task within the body, but further funding is needed to make sure the technology is safe to be implemented. The military is a huge market for nanomaterials, it’ll have unlimited uses used in their products, coating self healing and super strong nanomaterials on vehicles, clothing and weapons.

Presently, the UK is a strong player in the chemical sector, applying nanomaterials into chemical formulations. Moreover the UK is increasing its potential in the electronics sector, manufacturing which needs highly specialized inks and coating, this moves on to gives an opportunity for companies to gain a competitive advantage in the ICT hardware area which depends heavily on nanotechnology, it can be done through design, developments and commercialization also.

The pharmaceutical industry in the UK produced an annual export of £17.2 billion in 2008. Therefore, they are one of the world leaders in this area and has been for a long time, on the other hand, if the industry doesn’t push forward with nanotechnology, they will be pushed back from the top. The government will need to invest and support the industry to help continue the progress, and the industry will need to find ways of attracting more investors to invest in this particular field to keep their position. Sub-field within the industry that will give potential opportunities for investors are drug delivery, drug discovery and tools and medical devices.
Conclusion
Nanotechnology is here to stay. Based on a range of application discussed in the report, we can say that nanotechnology would be the next appropriate step to sustain demands for permanent improvement in technology. It has allowed Nanotechnology and nanoscience are relatively new fields and this makes it difficult to predict where it might lead us. Looking at the report, we can say that nanotechnology will most likely have the largest impact in the medical field. Nanorobots can be programmed to carry out surgery with such precision that it would be impossible to do it using the scalpel. We can almost imagine a situation where a patient being treated for cancer would only have to drink a solution of nanobots, instead of undergoing debilitative treatments such as chemotherapy or radiography where patient can suffer from severe side-effects. Cosmetic surgeries can be carried out through these nano-scale precision through re-arranging atoms on the human face. Of course, such technology would raise a few ethical issues, but overall it would be beneficial for us to adopt the technology. Nanotechnology would continue to have a huge impact on us and we continue to discover more about the realms of the nanoscale.
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The Future of Telecommunications


Viable Business Model

Figure 4
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Figure 5