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IN FUTURE: A GLIMPSE OF SCIENCE & SOCIETY IN 2020

An Interactive Qualifying Project Report,
completed at the National Museum of Science and Industry,
Mr. Owain Davies, liaison,
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WORCESTER POLYTECHNIC INSTITUTE
in partial fulfilment of the requirements for the
Degree of Bachelor of Science
by

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Abstract

This IQP team created six interactive games for the In Future gallery at the Science Museum in London. The games demonstrate how technology may affect daily life in 2020. Topics are Android Servants, Cloning Extinct Species, Flying Cars, Genetic Enhancement, Nanorobots, and Weather Modification. We created topic proposals, surveyed visitor interest, generated text, and evaluated it with visitors. Our results were story boards detailing the introduction, game, and conclusion for each topic for software engineers to implement into the exhibit.

Executive Summary

What will the future bring? No one can say for sure, but our project team had a chance to predict the future of science and technology at the National Museum of Science and Industry (NMSI) in London. Working in conjunction with Mr. Owain Davies, member of the NMSI Welcome Wing Exhibition Team, we contributed to an exhibit called In Future. In Future provides a glimpse of the possibilities of science and technology in the year 2020 and of how selected scientific developments might affect everyday life. Through interactive games and stimulating questions, In Future asks visitors to decide how they feel about certain technologies that may be available in twenty years time.

Each game explores a controversial topic in current scientific development and gives the visitor the opportunity to decide, by weighing its possible advantages and disadvantages on society, whether or not this technology should be made available. The games that had already been created before our arrival include Male Pregnancy, Sex Selection, Holidays in Space, Computer-Driven Cars, and Tracking Children by Implanted Devices. Wellcome Wing Exhibition Team members were still developing two topics during our time working at the museum, Lab Grown Meat and 'Smart' Toilets that Diagnose Illness.

Our team contributed the main ideas, research, text and story boards (often referred to as 'development') for six games that software engineers will later implement. The timetable for the development of each game is generally several months. Our team's goal was the development of six games in fourteen weeks. We began our work in Worcester, brainstorming and researching possible topics. We focused our ideas using

four criteria: feasibility of the technology by 2020, interest to the public, impact on the average person's daily life in 2020, and comprehension by our target audience of eight to sixteen year old children and non-specialist adults. We began our work at the NMSI with fourteen topic proposals: Cloning Extinct Species, Flying Cars, Supersonic Submarines, Controlling the Weather, Nanomedicine, Tissue Engineering, Enhanced Genetic Expression, Artificial Intelligence, Android Servants, Underwater Oceanic Colonisation, Virtual Reality, Wearable Computers, Smart Clothes, and Renewable Energy: Flywheels.

In London, our first major task was to decide which of the topics we would further pursue. We narrowed down our list by surveying visitors in the museum about their awareness and interest in each of the topics, and asked them to scale each topic based on their interest in learning more about the concept. Our criteria for narrowing down the list were based mostly on the ratings, but we also considered the amount of information available on the subject. After careful examination of our data, the six games we chose to develop were Android Servants, Cloning Extinct Species, Controlling the Weather, Nanorobots, Flying Cars, and Gene Enhancement.

With these six topics, we then generated the text that would accompany each game. With a young and non-specialised target audience, we needed to combine technical accuracy with simple language. Our goal was to portray each technology along with its possible advantages and disadvantages to society in a non-biased, interesting, and educational manner. To be certain that we had achieved these objectives, we tested the script for each game with museum visitors. We asked visitors to read the text and to answer questions related to their understanding. These data helped us determine the effectiveness of the script in portraying the game's message, and we made changes as

necessary. The final step in the completion of our work at the museum was to insert the text for each game into storyboards, which are layouts of the look and sequence of the game. These storyboards illustrate how each frame of the game should appear. They consist of graphics and notes that explain the action in each segment of the game and how transitions between frames should look as the game progresses.

Throughout our time at the NMSI, we used our technical knowledge, creative abilities, and communication skills to achieve our goals. We completed the development of six games for the In Future exhibit and prepared detailed layouts for later implementation by software engineers. In Future urges awareness of scientific developments that may be a part of daily life in the future and of the possible societal implications of these technologies. At WPI, we are pursuing specialised fields that may pioneer these technologies. Thus, this project provided a perspective of how our careers could impact people, not just impact the advancement of science.

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1.0 Introduction

Imagine a future where cars drive themselves. Imagine a future where androids cook and serve dinner. Imagine a future where dinosaurs roam the earth once again. At the National Museum of Science and Industry (NMSI), the newly created and vast Wellcome Wing poses such possibilities. Specifically, an exhibition unveiled in June 2000, In Future, invites guests to "glimpse the future and say what you think about technology that may well be common in twenty years' time." While the general public may not be aware, the topics mentioned above are possible, even probable, in twenty years. The purpose of this exhibit is to examine the directions science and technology may take by the year 2020 and their effect on everyday life. Currently, five of thirteen "games" in the exhibit have been completed and two are close to implementation. However, topics and implementation of the final six games are yet to be completed. The NMSI sponsored our group of four Worcester Polytechnic Institute (WPI) students to determine appropriate topics for the remaining six games and to develop them as part of the exhibit.

The In Future exhibit strives to create a link between the present and the future. Museum visitors are able to think about and discuss coming innovations before they are realised. The NMSI wants to inform its visitors so they are capable of making decisions about topics that may evolve in their future, such as human control of the weather. Once the visitors have made their decisions they are encouraged either to help bring about these new innovations, or to attempt to change the directions that science and technology are taking. By selecting controversial topics, In Future aims to force visitors to think about the future and their place in it. The topics already incorporated into the exhibit before our

arrival include holidays in space, driverless cars, the tracking of children through small microchip implants, male pregnancy, and sex selection of children prior to birth.

The goal of our project was the development of the six remaining game topics to complete the exhibit. Before travelling to London, we researched the current state of technology and the directions it is likely to take in the next twenty years. From this information we proposed a number of possible topics for consideration. In order to meet our specific objectives, we first conducted extensive research. Collaborating with the NMSI staff, we proposed numerous possible topics for consideration. It was imperative that we create proposals based on diverse, interesting, and feasible topics. Relying on feedback from our liaison, Owain Davies, and the NMSI staff and our technical knowledge, we chose fourteen topics and developed then into preliminary two-page proposals. These proposals provide an introduction to the topic, as well as background information, advantages and disadvantages of the technology in 2020, possible voting questions, and some "quirky" facts relating the future technology to what has already been accomplished today. Upon arrival in London, we worked with the staff at the NMSI to survey visitors to learn which topics they are knowledgeable about and which topics they are interested in. Based on these results, we narrowed our research and created text for each of the games. We then asked visitors to evaluate this text using the museum's established method of evaluating exhibits in progress. Finally, we created a basic layout, called a story board, for each of the six topics.

Once in London, we found the exhibit setup to be similar to the written descriptions provided by our liaison. The exhibit takes the form of three large circular tables, each designed to accommodate up to eight people. Visitors to the museum

interact with the exhibit through the use of a wheel and a single button (see p. 90, Appendix A). Graphics are projected onto the table by a projector in the ceiling. The interface for the games is intentionally simple, and the target audience is families with children eight and up as well as non-specialist adults. Each game begins with a short piece of text that introduces the visitors to the subject. This is followed by a two to three minute game involving all visitors at the table. Upon conclusion of the game, visitors are asked to vote and give their opinions on the topic. These votes are tallied throughout the day. Finally, each game concludes with a flourish: an interesting fact about the topic to link the possibilities of the future with the reality of today.

Our team followed the same linear progression during our development of new topics for the exhibit, and the staff of the NMSI was immediately interested in our findings. Together, the Wellcome Wing staff of In Future and our project team used iterative feedback and visitor evaluations to determine and develop the final six games of the exhibit. After the games are completed and opened as part of the exhibit, the museum visitors will be interested in our results. Ideally, the visitors will be excited to visit the exhibit and will leave with a strong "take-away message" concerning each controversial topic. The NMSI can then use the topics and information we have provided, as well as our visitor evaluation data and recommendations to improve all aspects of the exhibit and present it as complete.

An Interactive Qualifying Project (IQP) allows WPI students to take a step back from their concentration in science and technology and examine its impact on society and the world around us. In our project we looked at the possible repercussions of the technologies we will be developing in our professional careers. These repercussions are a

perspective that one may not normally confront if one is deeply involved in working on the technology itself. When we are closely involved in a project, it is easy to ignore its effects on the world around us in favour of seeing it as simple research that needs to be completed. Scientists often pursue science for the sake of science, without examining ethical concerns or the opinions of the actual user of the technology. Since the results of our IQP work were focused towards the myriad of museum visitors that will visit the exhibit each year, many of whom are not in technical fields, we have been encouraged to view science and technology from the perspective of the more general population.

2.0 Literature Review

2.1 London

London, the largest city in Europe and the driving force of the British economy, is located in the southeast corner of England on the River Thames. It holds more of the headquarters of Europe's five hundred largest companies and more of the world's top five hundred companies, after Tokyo, than any other city (Williams, 1999, pp. 16-17). Great Britain has profound roots in historic science and technology and numerous accomplishments originated there (Leventhal, 1995, p. 324-325, 523-524, 620-622). These include: development of x-ray crystallography which helped discover the double-helix structure of DNA, discovery of the structure of penicillin and vitamin B12, contributions to high-energy physics and nuclear fusion, and major contributions to the study of genetics including an active role in the Human Genome Project. Due to Great Britain's many contributions to the fields of science and technology, it seems appropriate that its capital holds a museum for visitors to explore this world.

2.2 The National Museum of Science and Industry

Originally established in 1857 as The South Kensington Museum and a part of the Victoria and Albert Museum, the National Museum of Science and Industry became an independent entity in 1909 (Freecampus, 2000).

The museum's visitor base is primarily comprised of three groups: Families (with children under 12), independent adults, and school groups. 40% of daily visitors are

families, 40% are independent adults, while the remaining 20% of visitors are school groups. The museum's busiest time periods are during the half-term breaks of the London school system in mid-February and mid-October (Gammon 2000).

Currently the museum hosts over forty galleries totalling over 10,000 exhibits (Science Museum London, 2000; LondonNet, 2000). Yet, only 10% of the objects owned by the museum are currently on display. The active exhibits and galleries find their homes among one of several wings of the museum.

2.3 The Wellcome Wing

One of the major sponsors, and the namesake, of the NMSI's Wellcome Wing is the Wellcome Trust ("About the Wellcome Trust" Accessed 9/2/01). The Wellcome trust draws its name from its original benefactor, Sir Henry Wellcome. The initial funds for the Wellcome Trust found their origins in the merger of Glaxo and Wellcome plc. As technology advances, "the Wellcome Trust is committed to promoting wide informed debate on the use of new knowledge" so as to allow the general public make their own decisions on how the technology should, or should not be used ("About the Wellcome Trust" Accessed 9/2/01).

The Wellcome Wing at the NMSI is dedicated to the promotion of current scientific topics and issues in society (Science Museum, London, 2000). The wing is designed to promote awareness among museum visitors. Specifically, it aims to discuss science and its eventual impact on the daily lives of all people.

Physically, the wing consists of four floors (NMSI Official Website, 2000). The ground floor contains exhibits focusing on current advancements in science and technology. The Talking Points exhibit accomplishes this using a series of small scientific and art displays including genetically modified pig hearts or mechanical hearts as replacements for human hearts, and the visible human. Antenna is an exhibit comprised of a continuously updated stream of current science events similar to a stock ticker (NMSI Official Website, 2000). Example headlines include robotic aquariums and genetically engineered babies (NMSI, London, 2000, November 12).

One floor above, on the first floor, the Wellcome Wing houses the exhibition "Who am I?" (NMSI Official Website, 2000). This exhibition is structured entirely around the science of human identity. It has many smaller exhibits within it that are designed to further knowledge of science and technology's contributions to the exploration of ourselves and our surroundings. Part of this exhibition also discusses the history of the human species. Small exhibits on this floor have been subjects of previous Worcester Polytechnic Institute (WPI) IQPs.

Next, travelling one level upstairs, museum visitors enter the world of "Digitopolis". This floor studies the uses of high technology in today's world. The entire floor relates digital technology and information transportation. It deals with the potential uses of digital technology in everyday life in the future as well as the major uses present in today's world.

The last remaining floor, the third floor, contains the In Future exhibit with interactive games to promote speculative ideas on how technology and science currently being developed may likely affect our daily lives in twenty years.

2.4 In Future

As stated by the NMSI (Official Website, 2000), the exhibit "invite(s) you to glimpse a series of imaginary futures created out of decisions that you make about uses of new discoveries and innovations." The goal of the exhibit is to investigate how future innovations in science and technology may impact daily life in the year 2020. It should force people to begin thinking about the topics, whether their opinions are positive or negative, hopeful or cautious.

The exhibit, opened on June 27th, 2000, by the Queen Elizabeth II, will, upon completion, house thirteen interactive games. Circular tables provide the interface to support up to eight users for each self-contained exhibit (see Appendix A for photographs). Currently there are five games in active use. Their topics are as follows:

- Should men have babies?
- Will we take holidays in space?
- Should parents tag and track their children with implanted electronic chips?
- Will computers without any human aid drive future "smart cars"?
- Should parents be allowed to select the sex of their child?

Two more interactive games are currently in development with these topics:

- Can a toilet diagnose illness and disease?
- Can meat be made of man-made cells instead of by killing animals?

Each "In Future" exhibit game has four phases, each developed by software engineers in consultation with researchers (Davies, 2000, November 17). Our project team served as consultants to develop new topics and formats for the exhibit. First, the user is greeted with a brief introductory text. This text serves to provide the scene for the game and necessary information about the topic in order to continue. Next, the users interactively play the actual "game" for approximately two to three minutes. Creative scenarios are designed for each topic that allow the users to explore the topic in an engaging, yet informative manner. Immediately following, the users are polled based on a specific question concerning the topic. The questions are always opinion-based and should begin encouraging users to think about the scenario occurring in their daily life. Generally, the questions have some ethical dilemma. Examples of these questions are included above as the topic sentences provided for the existing games. After each user has voted, tabulated daily results are shown on the table. Finally, the game concludes by giving the user a "take-home message," otherwise called a "flourish". This should be a hard-hitting factoid and relate the future to today's research and development. It is hoped that the users will leave each game with a better understanding of future technology, be prepared to encounter it on a daily basis, and begin deciding whether this technology is something they would want in their lives.

The "In Future" exhibit deals with speculative future innovations and their relation to daily life. The layout of the exhibit reflects this (L. Menides and R. Thompson, personal communication, November 7, 2000). Bright, neon colours and black lights fill the entire area.

2.5 Topical Fields

While researching potential topics for the remaining six games for the "In Future" exhibit, it became obvious that virtually every potential topic would fall into one of six major categories.

- Biological Manipulation
- Space Travel
- Renewable Energy Sources
- Robotics and Artificial Intelligence
- Information Technology
- Environment
- Transportation

Based on this observation the following brief overviews of those topical areas are discussed below.

2.5.1 Biological Manipulation

A major avenue of technological advance is biological studies (Martini & Bartholomew, 1999, p. 64, 143, 178, 382). This area encompasses the popular topics of tissue engineering, cloning, genetic research, ageing and health, and a myriad of other subtopics. New developments in these fields circulate speculation of future advances on a regular basis.

First, in the field of tissue engineering, scientists are currently harvesting a patient's own cells to generate new body parts for the patient (Regalado, 1999, January/February, p. 422). Engineered skin is the only United States Food and Drug Administration (FDA) approved organ to be utilised currently, but cartilage is also in clinical trials. Dr. Andrea Nicklason in collaboration with Dr. Robert Langer (1999, April 16) has produced working arteries that survived after implantation for more than three weeks. Leading scientists in this field believe that the replication of every human organ is not out of reach.

The concept of tissue engineering is derived from taking the patient's stem cells (undifferentiated cells usually found in the earliest stages of embryonic development) and proliferating them in the laboratory to produce whole organs (Ferber 1999, April 16, p. 423-5). Then, the organs, made of entirely human cells, are transplanted back into the patient. Major difficulties currently include provision of nutrients and oxygen to the growing cells of the engineered organ, providing the correct growth factors in the correct amounts so that the cells, actually grown in a laboratory, believe they are growing in the human body, co-ordination of the engineered organ with the vasculature of the patient, and rejection of the engineered organ after implantation.

Similarly, the popular topic of cloning has advanced rapidly in the past few years (Hawks 2000, November 8, Health Section). Entire animals have been cloned and the ethical debate continues on this subject. The process of cloning is very similar to that of tissue engineering, with the distinction that cloning refers to the replication of an entire being. The first animal cloned (to survive) was Dolly the sheep in Scotland. Scientists began by sampling embryonic cells and proliferating them in the laboratory. These cells

were then implanted in a uterus for gestation. However, the mother is not necessarily of the same species (The London Times 2000, October 8). An Asian ox was born from a barn cow! An Asian guar embryo, an endangered species, was implanted into a barnyard cow's uterus and the guar was born on 8 January 2001. Unfortunately, the guar died a few days later.

Another large area of biological technology is genetic research and testing (Sillery 1999). Scientists published the first report on the Human Genome Project in February 2001, detailing their near completion of mapping the human genome. Studies are currently being conducted to alter genetic code, create babies with desirable traits, and eliminate the gene for certain diseases. Clinicians, engineers, and physicians must proceed in this field with caution as it brings about great debate. The power of such technology is obvious, but field technicians question the morality and safety of widespread use of such power. In a study done by E. Mountcastle-Shah and N.A. Holtzman (2000 October, p. 411-416) at the Johns Hopkins Medical Institution in Baltimore, Maryland, physicians were surveyed as to their perceived barriers and concerns towards genetic research and testing. Only 30% said they were willing to participate in genetic research. The majority of the comments noted "uncertainty as to the clinical utility and clinical validity of predictive genetic testing" as a major concern.

Next, another key area of technological advance is micromachine insertion for biological healing and drug delivery (Desai, Hansford & Ferrari, 2000 October). At present scientists have developed machines on the order of a few microns, that carry the genetic code of the patient. The micromachines are programmed with a specific task and use the genome of the patient to correct defects, illness, or a malfunctioning body part.

The machines are made of a material that automatically degrades after a given amount of time, and the disabled micromachine is then flushed out of the system as a waste product. Ethical issues arise from giving a machine the entire genetic makeup of a human. If successful, this technology could be used to reverse cancer or possibly just cure the common cold.

Overall, biological technology topics are extremely promising, and extremely controversial. To what extent should humans control the quality of life? Is it better to let one's life run its natural course or to improve it artificially? These questions may never be fully answered, and debate remains heated.

2.5.2 Space Exploration

One of the most popular topics among science fiction writers is that of space travel. High levels of feasibility that the stories represent may cause this. We send objects and people into orbit many times each year. We have already visited our closest celestial body in person and have sent robotic observers to several others.

One aspect that makes this topic so interesting is the feasibility and exoticness of space. The possibility is currently on the horizon for the average person to take a once-in-a-lifetime holiday in an orbiting hotel. This planet is rapidly becoming overpopulated and one avenue for relieving the tension that this causes on our resources is a permanent move into space, whether it is to the moon or to Mars or simply into an orbiting permanent dwelling matters little. It is the idea of people living permanently in space that fascinates people, not the specifics.

This fascination is becoming more plausible as more information is discovered. The *Clementine* mission brought the discovery of an abundance of frozen water on the moon, quite possibly enough to last a human colony for decades without worry. Discoveries like this prove not only how little we know, but also how much easier it may be to explore celestial bodies other than Earth than we had previously believed.

2.5.3 Renewable Energy Sources

What happens when the world's ability to find more oil stops? What happens when the remaining oil is gone? These are questions that are weighing heavily on many nations on this planet. OPEC is currently receiving more money for its oil than it has in the past because it realises that its oil reserves are finite. Other countries are wondering about the answers to these questions because of the resulting price increases in oil-based products. The reality is that the world is far too dependent upon non-renewable energy sources and is rapidly using the stores that exist. The time has come for the world to fully investigate the alternatives that are available. There is substantial research being done to determine the efficiency and stability of energy fuel cells as well as the idea of recharging vehicles by using flywheels as an energy storage device.

2.5.4 Robotics and Artificial Intelligence

"Can machine's think?" was a question proposed by A.M. Turing, and later discussed in the publication Mind: A quarterly review of Psychology and Philosophy (Clark & Toribio, 1998, p. 1-20). This concept has spawned many fictional stories, but

also many realistic research avenues. Since the original publication a standardised test has been developed to test systems for artificial intelligence. This test has been entitled the Turing Test. The test involves two humans and the subject of the test, the computer. It involves one human becoming an interviewer, asking questions to both the computer and the second human. Their job is to determine which respondent is the other human and which is the computer. The test is performed via a text interface to remove any voice bias.

Expert systems are a kind of artificial intelligence (Arnold & Bowie, 1986, p.82-109). Instead of trying to create a system that is capable of taking in and analysing data in a general sense, expert systems restrict the potential topics to a specific area. An example of an expert system is the autopilot system in an aeroplane. The system knows the course it is supposed to be flying, and has been programmed with the information needed to control the aeroplane, and how to respond to different controls. Based on this information, the expert system determines what the proper course of action is to keep the aeroplane on course.

One area of robotics in which a large amount of research is currently being done is learning robots. These robots are given very little specific information about how their systems interact with one another and with the world. Through repeated use of their systems, these robots learn about these interactions and establish ways of using the interactions to perform various tasks.

The Massachusetts Institute of Technology (MIT) humanoid robotics group, a division of the MIT Artificial Intelligence Lab, does some of the most advanced research in learning robots (MIT Humanoid Robotics Group, 2000). Cog is one of the humanoid

robotics group's advanced learning machines, resembling the upper body of a human. Although Cog does not think or learn in the same sense that most adult humans would envision, it does actually learn. Initially, Cog is given control of its physical body, but no knowledge of how to use that control. Through performing basic tasks such as picking up an object, Cog learns how to interact with the world. Through its machine vision system, Cog first learns how to identify objects, then by moving its arms about, Cog learns how to spatialise and link what it is seeing to the location of its arms.

The realm of robotics is not restricted simply to robots that are learning how to interact with the world. Many robots currently in use have a very small set of potential tasks, and are programmed specifically to perform those tasks. These robots are generally controlled by expert systems intended to deal with the task assigned to the robot. Robots are currently used extensively in industry to perform repetitive tasks, or tasks that are too difficult or dangerous for humans to perform

2.5.5 Information Technology

Currently one of the most marketable industries in the world is the selling of information, specifically people's names, telephone numbers, addresses, email addresses, etc. This process primarily involves the collection of the information. This information can be collected in many forms, from discount cards at local grocery stores to input gathered from a website. Likewise, the information can be used for many different purposes, most of which are currently marketing purposes. The controversial issue this industry presents is proliferation of personal information. This is found in the selling of mailing lists and consumer information. Another more complex example involves the

possibility of tracking people wherever they may be by the use of cell phones, personal organisers, or even tracking devices that can be implanted below the skin.

2.5.6 Environment

Each year more of the natural habitat of this planet is destroyed (RainForestSite 2000). As this occurs the ability of the planet's ecosystem to regenerate itself is also damaged. Part of this problem is caused by the extent of overpopulation found in the world today.

This overpopulation is causing immense strain on our ability to produce enough food from the land that we have currently "tamed," thus causing more and more depletion of natural habitat by expansion into it. Many areas of research are conducted each year by organisations such as Greenpeace, into the impact such encroachment has on the natural surroundings of the planet and into ways that we can better use the land we have already taken. Some avenues of research that have been explored deal with moving people to new regions, while others deal with reusing materials we have already harvested from the planet and yet more still deal with the idea of how to reduce the amount of materials that we consume as a whole. One area of overuse (in the United States of America) is energy. Energy, as is commonly known, cannot be created, nor destroyed, but rather only converted from one form to another. This conversion process requires the use of materials and releases some of the resulting energy into a non-usable form. This means the more energy that is consumed, the more resources that are used for generating the energy that could be used elsewhere. Other current topics in the

environmental field are how to create and use renewable energy sources rather than being so thoroughly dependent on non-renewable sources such as oil.

2.5.7 Transportation

With the world's economy growing as fast, if not faster than the world's population, one of the major concerns we, as a species, face is moving products and people from place to place both efficiently and rapidly (Population Reference Bureau, 2000). Many countries do this with large mass transit systems, others do it with large highway systems, and some use both (Germany, for example with its Autobahn Highway and Euro rail systems). As more technologies become available, they may be used for creating efficient transportation systems. Examples of past applications of new technology to the transportation field range from the invention of the wheel in pre-history through to the current use of the Concorde supersonic jet. Currently technologies are being developed and investigated by many manufacturers to create a "Space Plane" which will be able to travel faster than the Concorde by attaining a low orbit for a short period of time, thus taking advantage of the Earth's natural rotation (Popular Science June 2000). Other industries are attempting to make trains that operate in a friction free environment by creating a magnetic levitation field that will suspend the train above the tracks. By doing this friction between track and train is eliminated. If the train is then placed in a tube, which has the air evacuated out of it the air resistance is also eliminated. Currently there are researchers debating how to create a propulsion method for this type of train. Other methods involve submarine transportation techniques. A submarine is immune to the weather on the surface of the planet once it is deep enough, creating the

ideal environment to avoid delays and cancellations due to external conditions. The current problem of submarine transportation is speed.

2.6 Museum Techniques and Protocol

The Visitor Research Unit of the NMSI devotes its time to studying visitors' behaviour (Gammon, 2001, 22 January, Visitor Awareness Training). The results of this department's research are used to aid exhibit designers. Designers must mould their exhibits towards the visitors' wants and interests for the exhibit to be popular. Throughout the course of our project team's Visitor Awareness training, we learned various aspects of creating "visitor-friendly" exhibits, creating effective evaluations for exhibits, and interacting with visitors in the museum. The NMSI has established methods of achieving the preceding objectives, which are discussed below.

First, when designing an exhibit, one must consider several factors (Gammon, Visitor Awareness Training, 22/1/01). Visitors, who will be viewing the exhibit, have various styles of learning. The main four learning styles are imaginative, dynamic, problem solving, and analytical. Imaginative learners are mostly concerned with human interactions. Dynamic learners are apt to seek out hidden possibilities. Problem solving learners find solutions, and analytic learners have a concrete, logical style. A good exhibit caters to visitors of all learning styles. Exhibit developers may incorporate stories of how people interact with the object in a glass case (imaginative), riddles about the object (dynamic), puzzles to solve (problem solving), and numerical details (analytical) into the exhibit.

Next, the NMSI has a standard protocol for developing evaluations for exhibits (Gammon, Visitor Awareness Training, 24/1/01). First, the type of evaluation must be decided. Three types of evaluations are customary. Front-end evaluations are often used to collect information concerning visitors' knowledge about a potential exhibit topic, and their interests with respect to the topic. Next, formative evaluations are conducted during the development of the exhibit mainly to ensure that the project is headed in the right direction. Summative evaluations are conducted at the end of a project, typically a prototyped exhibit, to evaluate its success with visitors. Throughout this project, we mainly focused on face-to-face questionnaires that we individually, personally conducted. During questionnaire construction, it is crucial that the questions do not intimidate the visitors or make them feel incompetent. It is also crucial that many of the questions are open-ended to allow the visitors to add details to their comments. Finally, important questions should be repeated in several ways throughout the survey so as to ensure the information is gathered. Once a script has been written for a questionnaire, the staff member cannot diverge from it during the interview.

Finally, museum staff must be able to interact with visitors, especially when conducting surveys and interviews (Gammon, Visitor Awareness Training, 24/1/01). It is pertinent that the interview creates a relaxed and inviting atmosphere. This atmosphere allows the interviewee to concentrate on the questions and provide honest, accurate answers. The interviewer should always inform the interviewee of the time commitment involved, and should never attempt to coerce a visitor to being interviewed. Importantly, the interviewer must not diverge from the script created for the interview. Each question should be phrased in several ways as they are written on the questionnaire. This

rephrasing of questions aids the interviewer in staying true to the script even if the interviewee does not understand the question initially. "Adlibbing" from the script of the questionnaire can create a bias where one interviewee is presented with information in a different way than another. This also tests the interviewer's knowledge of the subject.

2.7 Target Audience

The NMSI has determined that the target audience for the "In Future" gallery is people who are old enough to understand the concepts presented, but who do not have any substantial specialisation in a particular science-orientated field. Ideally, according to Owain Davies, (2000, November 14, personal communication) this sets the stage for children between ages 8 and 16 as well as non-specialist adults.

One method of ensuring that the museum meets the needs of this target audience is developing material that is interesting enough to keep all parties (especially children) involved with the gallery and also be easy enough for them to understand. The material must also be presented so that independent adult museum patrons will also enjoy the gallery. Both of these aims can be accomplished by creating a scenario in which all individuals viewing the gallery can comprehend the ramifications of the technology presented.

3.0 Methodology

The objective of this project was to aid in the completion of the In Future exhibit, located in the Wellcome Wing of the National Museum of Science and Industry in London. Our project team's work, when implemented by software engineers, will nearly double the size of the exhibit. Currently, the In Future exhibit consists of seven interactive games, described in the Literature Review section of this report. The museum staff felt that was an insufficient number. Our team was asked to complete at least ten proposals for additions to the exhibit. We exceeded these expectations by proposing fourteen topics to the NMSI staff. These proposals were then reduced to the six that we developed into full story boards. These story boards will be implemented into games and incorporated into the In Future exhibit.

3.1 General Research

Our first step in this project was to research various general fields in science and technology. We located the current state of technology, and cutting-edge advancements. The general categories we investigated included the biomedical field, space travel, renewable energy sources, robotics and artificial intelligence, informational technology, environmental concerns, and transportation. Detailed research on these topics is discussed in the Literature Review section of this report. To find the most recent technological advances in each of these categories, we researched periodicals and websites such as *Nature, Popular Science*, and www.foresight.com. Journals and magazines are good resources as the articles are aimed at the public, and therefore the topics are new and

interesting, sometimes even devoted to predicting the impact of future technology on society. Magazines focus on topics in which the public is interested and when discussing technological advances, they explain the science and technology involved in terms that the general public understands. This level of explanation is crucial when creating museum exhibitions.

After gaining an overall idea of the directions in which technology is heading, we brainstormed a list of preliminary ideas to discuss with our liaison, Owain Davies, of the Wellcome Wing Exhibition Team. His feedback focused our efforts and included a chart that contained our ideas and the evaluation criteria used to determine whether the ideas were acceptable.

3.2 Topic Criteria

The topic selection criteria include, primarily, accessibility of the topic by the general public. Some ideas may be too complex and obscure for the target audience at the museum and therefore are not an ideal addition to the exhibit. The second criterion is topic relevancy. Relevancy is determined by how important these topics would be to the everyday life of the average person in the year 2020. If the topic will impact very few people, or will not be a prominent part of the public's daily life, the topic is not acceptable. A tertiary concern is the appeal that the topic will generate. The topic must be interesting. If the visitors are bored by the topic, it is a waste of the museum's time and resources as well as the time of the visitors. The final criterion is the topic's ability to be implemented as an appealing and engaging interactive activity. Many topics that

would generate interest and enthusiasm by the visitors are discarded due to the impracticality of creating a game that would be entertaining and engaging. The best topics overall are those that are controversial enough to perk public interest and create opinions among most members of the general public. Mr. Davies and his colleagues applied these criteria to our list, and together he and our project team decided on several ideas that were worth further investigation. We then created proposals for these topics. This iterative cycle of proposed ideas and feedback continued until a specific number of topics had been developed for presentation to the NMSI staff. These proposals were used in conjunction with other criteria to be discussed later to select the six final topics to be implemented as additions to the In Future exhibit.

3.3 Proposal Format

After our team developed this working list of ideas, we wrote proposals for each topic. Each proposal followed the same format and, to achieve consistency, included the same categories of material. The proposals evaluated the topics in more depth using the above criteria. The first section of the proposal is the activity message, which is a very brief (preferably one-line) description of the basic idea. Next, the proposal details a more extensive description of the idea, including full background information, the current state of the technology involved, and the probable cost of such a technology. Once the description is complete, the following section explains the possible advantages and disadvantages this technology would have for society in the year 2020. Since the exhibit strive to make a lasting impression on visitors, each topic must have an engaging

question associated with it for them to ponder. A possible question that could be asked with each topic idea is presented in the proposal. The museum refers to the next section as a *flourish.* A *flourish* is described as an interesting, hard-hitting fact that is meant to show the visitors that while the exhibit is based on predictions, these predictions are based on scientific facts. The current state of technological development shows that these predictions could likely evolve into reality within twenty years. The last section of the proposal is the "take-away message", which is what the visitors should learn from the activity. These final proposals comprised the preliminary part of the project completed before arrival in London.

3.4 Proposed Topics

The fourteen topics derived using the above methodology involved diverse fields of science and technology, including computer development, overpopulation, biological manipulation, and transportation. Each topic idea is introduced below. The complete proposal for each idea can be found in Appendix C.

- Will an android cook dinner in 2020 (see p. 99)?
- Will computers soon become smarter than humans (see p. 104)?
- Will Jurassic Park become reality through cloning (see p. 108)?
- Will flying cars take to the skies (see p. 111)?
- Will children be created with perfect physical traits through genetic enhancement (see p. 114)?

- Will magnetic levitating trains, faster than the speed of sound, travel from London to New York in under an hour (see p. 118)?
- Will patients ingest microscopic robots in order to speed healing (see p121)?
- Will humans become permanent residents of the ocean (see p. 125)?
- Will flywheels make batteries obsolete (see p. 129)?
- Will "smart" clothes, which adapt to internal and external environments, present a health hazard (see p. 133)?
- Will human organs be grown in a laboratory as spare parts (see p. 137)?
- Will VR systems become so real that they could become a viable substitute for real life experiences (see p. 142)?
- Will your computer travel with you comfortably all the time (see p. 146)?
- Will weather modification save lives and money that are now lost from storms (see p.150)?

3.5 First Tasks in London

The initial step we took toward the completion of the In Future exhibit during our first days in London was to explore what existed of the exhibit so far, as well as other exhibits in the Wellcome Wing. This step was important as it provided us with first hand observations as to which techniques work well in scientific exhibits in general, and what the games of In Future actually entail. We spent a considerable amount of time at the In Future exhibit playing each of the existing games and observing such things as the amount of text used, the language used in the text, the graphics used, and how the games

expressed the topics that they represented. At the end of the first week, we wrote a critique of the exhibit, pointing out good points, such hard-hitting flourishes, and bad points, such as the lengthy gap between the interactive phase and the voting phase, in each of the games. We also critiqued the appearance of the floor as a whole. This critique was useful both for us, as we eventually created the additional games, and to the museum, as it served as an evaluation of the exhibit and provided suggestions for improvement.

Also during the first week at the museum, we read through the documentation reports for each of the completed games, as well as those for games that are still in development. These reports consisted of folders containing the initial proposals, such as those that we created before our arrival to the museum; all the research completed on the topic; communications with experts on the topic; ideas for game designs and storyboards; and evaluations. This step provided us with an understanding of the process the museum follows to carry an idea all the way through to completion. By reading through these reports, we learned how much research was necessary for each of the topics, as well as how to contact experts in the field who have varying views in order to get many different perspectives for each idea. We also looked through various ideas for games and storyboards to go along with each topic. Later, these references helped us to develop games and storyboards for our topics that are both entertaining and educational for the visitors. Lastly, the folders provided us with important examples of evaluation reports so that we would be familiar with the museum's style of evaluation and gain an understanding of problems typically encountered when designing the games.

3.6 Visitor Awareness Training

The second week was mainly devoted to visitor awareness training. A two-day course, given by museum staff, involved a discussion about the museum's visitors, a lecture on learning in museums, and a lesson on evaluating. We were trained by Dr. Ben Gammon, a member of a team of audience advocates who act as guardians and who provide advice about following the museum's visitor-centred approach. Our training included visitor observation while being stationed in a particular area and watching all the visitors who came by, and tracking visitors' patterns of movement throughout the museum. This training was valuable because it provided us with a better comprehension of our audience, which is necessary in game design and storyboard development.

3.7 Verifying Technical Accuracy

Throughout the visitor awareness training and testing of topic suitability, we also completed in-depth research for each of the topics. While the In Future exhibit is speculative, it is imperative that we base our predictions entirely on facts from present research. To verify our predictions, we contacted various experts in each of the fields to hear their opinions on the subjects and to get help in obtaining the most recent research. These experts included Robert Freitas, author of *Nanomedicine*, in the field of nanotechnology; Phillip Kennedy, developer of the neurotrophic electrode, in the field of virtual reality; and Robert Langer, Massachusetts Institute of Technology (MIT) Professor, in the field of tissue engineering. Most experts provided general responses that aided our understanding of the topics. We began running dialogues with certain

experts, such as those mentioned above, who were willing to offer more detailed information. Conversation topics included their educated guesses as to the state of the technology by the year 2020, their opinion on the most probable applications of the technology, and their knowledge of obstacles that need to be overcome before the technology can advance. Later in our development of the games, we sent copies of our proposed text to these experts and asked them to verify its technical accuracy. We made subsequent changes to the text based on their responses. A complete log of our email contacts is included in this report as Appendix E, beginning on page 206.

Through the process of research and speaking with experts we found that some of the topics were closely related and were better suited to the goal of the project when they were combined. The research indicated that two topics, Smart Clothing and Wearable Computers, are truly one topic. Experiments at MIT have begun to merge the two areas, and specialists are planning to build computerised devices into fabrics. Also, research points towards the combination of the two topics of Artificial Intelligence and Android Servants. Studies have shown that in order to make an android servant the machine would need a level of intelligence to perform the required tasks, thus incorporating artificial intelligence into the android servant topic. Research also indicated a change in direction of two other topics. The topic of Mag-Lev trains was changed to Super-Sonic Submarines. We elected to make this change because experts believe that the construction of a super-cavitation submarine will most likely occur before the construction of a sealed, vacuum filled, tunnel for a magnetic levitation train.

3.8 Front-End Visitor Evaluation

During the third week, we also created a questionnaire and interviewed visitors about our topic ideas. This is considered a front-end evaluation because it was conducted before the generation of the exhibit so that we could focus our efforts. We now had twelve topics to be considered for the exhibit, and our project group's main focus for narrowing down the number of ideas was visitor evaluation. The data received from these interviews provided an insight as to which topics appealed to visitors, which topics they'd be interested in learning more about, as well as which topics they didn't understand or wouldn't be interested in. On Thursday, 1 February and Friday, 2 February, all four team members spent time on the museum gallery floor interviewing visitors. Interviewees were selected as a part of a random sample. Every tenth person to pass the interviewer was asked to participate. The interviews were conducted verbally in front of the visitor. For each topic, 20 visitors were interviewed on their knowledge and interest in learning about the topic. During each interview, each visitor was asked about three separate topics. A copy of our questionnaire can be found on page 153, Appendix D. A summary of the data received and the results of these interviews can be found in the next section of this report (Data and Analysis).

Once we finished interviewing the museum visitors and had a suitable amount of research done for each of the ideas, we were able to spend the end of the third week writing summary documents of the interviews termed "evaluation reports". This was the last step in deciding which topics we wished to develop further. The evaluation reports are customary for museum protocol, and these were given to our liaison and other Wellcome Wing staff before the final reduced topic list was decided.

We made several conclusions about the visitors' interest in our 12 proposed topics, and analysis can be found in the next section of the report. After analysing our data, we conferred with Owain Davies and decided to narrow down the topics to six. We also considered similarity to existing exhibits, ease of ideas for game generation, and our depth of research on each topic before final selection. Our six topics selected for implementation are:

- Controlling the Weather
- Cloning Extinct Species
- Nanorobots
- Android Servants
- Flying Cars
- Genetic Enhancement

3.9 Game Development

With this refined list, we spent the fourth week generating text for the games' story boards. In accordance with the standards put in place for the In Future games, we were limited to 70-80 words of text for each game introduction and the same amount for each game ending. This limit is imposed so that the games move quickly and accommodate the shorter attention of our target audience,. 8-16 year olds. The text also needed to be concise. Technological terms such as "genetics" and "electronic impulse" needed to be simplified.

After we evaluated text with visitors (methods discussed in the next paragraph), we generated, for each of the games, graphics that matched the text. All of the In Future games need to follow the same general format to maintain a coherent exhibit, so we used past games as templates for the basic design and style. We used the software Adobe PhotoShop 5.5 to create a graphical story board to which the text was attached. The complete story boards are included in this report as our Results (Section 5.0, pp. 41-73).

3.10 Formative Visitor Evaluation

When we had generated text for all of the games, we began our fifth week evaluating the text with visitors. This was considered a formative evaluation because the exhibit was still in development and changes were made based on the results of this evaluation. Over a three day period, we interviewed, face-to-face, 60 museum visitors. We interviewed 10 visitors per topic. Our liaison felt that this number was sufficient because comments from the visitors were all similar and positive towards the text.

Each interview began by asking the visitor to read the text. The text was printed on numerous sheets with a layout similar to the one that would appear during the game. We imposed a 15 second time limit per page because that is the longest amount of time that the text would appear on the screen at one time in the game. After the visitor finished reading, we asked topic-specific questions. Copies of the questionnaires and data can be found in Appendix D, pp153 , while a summary of the data is discussed in the next section, Data and Analysis, of this report. Based on the qualitative data received, we revised the text according to visitor comments concerning comprehension, interest,

and confusing wording of text. We also made changes to the graphics towards the end of week six in order to meet our objectives for the games. They should be entertaining and make appropriate use of the interface. They should successfully display the topics. The votes, a standard part of each game, should generate discussion. Lastly, the flourishes, the conclusion screens of each game, should intrigue the visitors and leave them with the message of the game.

We completed our work for the museum by presenting our completed story boards and full text on Monday 26 February. At that time, we gave a copy of this document, our Interactive Qualifying Project report, to the museum to keep on file as further documentation of our development of the six newest In Future games.

4.0 Data & Analysis

4.1 Front-End Evaluation

We collected our first set of data by interviewing 80 museum visitors as to their interests and knowledge about our proposed topics. This is what in the museum is known as a front-end evaluation because it was conducted before we began generating the games. We used these data to narrow down our topic list to those ideas that we would develop fully. The demographic composition of visitors interviewed was as follows:

Of the 80 visitors interviewed, 53 were male and 27 were female. Our target audience is 8 to 16 year olds, and non-specialist adults. We interviewed 27 visitors from the age group of 8 to 16 years, 23 between 17 and 25, 22 from 26 to 40, and 8 who were more than 40 years old.

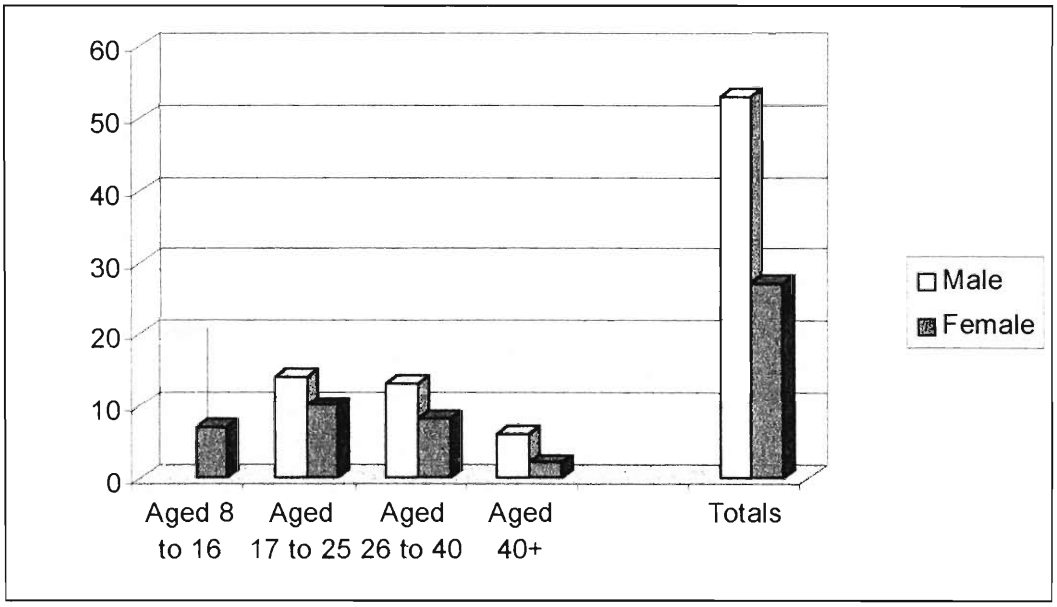

Table 1 - Age/Gender Distribution of Front End Evaluation

As the first part of the interview, we noted the level of awareness of the visitors concerning the proposed topics. The topics that the visitors had the most knowledge of were artificial intelligence and cloning with 90% and 80%, respectively, of interviewees acknowledging their familiarity with these subjects. Conversely, only 15% of visitors interviewed claimed any knowledge of super-sonic submarines, and 20% of the topic wearable computers.

Topic	Yes	No	Percentage % yes
Android Servants	18	2	90
Cloning Extinct Species	16	4	80
Virtual Reality	14	6	70
Tissue Engineering	13	7	65
Genetic Enhancement	11	9	55
Nanomedicine	9	11	45
Alternate Energy	9	11	45
Weather Modification	8	12	40
Flying Cars	7	13	35
Ocean Floor Colonisation	6	13	30
Wearable Computers	4	16	20
Super-Sonic Submarines	3	17	15

Table 2 - Visitor's Prior Knowledge of Topics In Decreasing Order

Next, we asked visitors to describe any information they could recall about the topic. If the visitor responded that they were unaware the topic existed, we did not record data for this question. The comments from visitors who were aware of the topic mainly centred on newspaper or magazine articles they had read about advancements in the field. Examples of these types of comments follow. In response to the question, "Can you tell me anything you've heard about Genetic Enhancement?" a female aged 17 to 25 years said "Human genome project, glowing monkey." We also received visitor comments about their viewpoints on the advantages and disadvantages of the technology. One boy between the ages of 8 and 16, when

asked "Please tell me anything you've heard about cloning extinct species," replied, "Only heard of it from *Jurassic Park*..., sounds good unless they kill us!" The comment portion of the interview was open-ended and therefore we received a wide variety of responses. A complete listing of the comments acquired from the interviews can be found beginning on page 155, Appendix D of this report.

Finally, we asked interviewees to rate their interest in each topic discussed, and we also asked that they not compare one topic to any other. The rating scale ranged from 1 (not interested at all) to 5 (very interested). We received the following rating results from the interviews: all of our proposed 12 topics earned an average score of above 3 (3.2 for the least interesting topic and 4.15 for the most interesting topic). We also recorded a cumulative score for each topic ranging from 0-100.

Topic	Cumulative Score	Average	Ranking	# Interviews
Controlling the Weather	83	4.15	1	20
Cloning Extinct Species	82.5	4.13	2	20
Artificial Intelligence/Androids	81	4.05	3	20
Nanomedicine	81	4.05	3	20
Flying Cars	80.5	4.03	5	20
Super-Sonic Submarines	79	3.95	6	20
Colonising the Ocean Floor	78	3.90	7	20
Enhanced Genetic Expression	78	3.90	7	20
Virtual Reality	77	3.85	9	20
Tissue Engineering	73.5	3.68	10	20
Wearable Computers	67	3.35	11	20
Alternative Energy	64	3.20	12	20
			Total	240

Table 3 - Cumulative Topic Scores

A complete listing of the individual interview data can be found on pages 155 -208, Appendix D.

After reviewing the data, we realised that nine of the proposed topics were so close in score for visitor interest (only 0.3 difference in average score) that they were likely statistically equivalent. With a goal of six topics for game development, we still needed to narrow the list. Two of our topics, Super-Sonic Submarines and Ocean Floor Colonisation, had little research available to us. Experts in these fields could not provide concrete examples of technology heading in these directions and much of the research was designated as classified by the military. For these reasons we decided not to pursue these topics any further. Another popular topic, Virtual Reality, was abandoned due to its familiarity with visitors. 70% of visitors were knowledgeable about virtual reality. Experts contacted could not predict any applications of virtual reality that were not similar to those of which visitors were already aware. We decided that it would better suit the futuristic atmosphere of In Future if the topic of virtual reality was dismissed. This left our team with six suitable topics, which are as follows:

- Controlling the Weather
- Cloning Extinct Species
- Nanorobots
- Android Servants
- Flying Cars
- Genetic Enhancement

4.2 Formative Text Evaluation

We collected our second set of data by interviewing 60 visitors as to their understanding of and interest in the text we generated for each game topic. Based on data received from these interviews, we were able to adjust the text and make changes as necessary. The demographic composition of visitors was the following:

35 visitors interviewed were male, while 25 were female. 25 visitors were between the ages of 8 and 16, 14 between 17 and 25, 12 between 26 and 40 years old, and 9 over the age of 40.

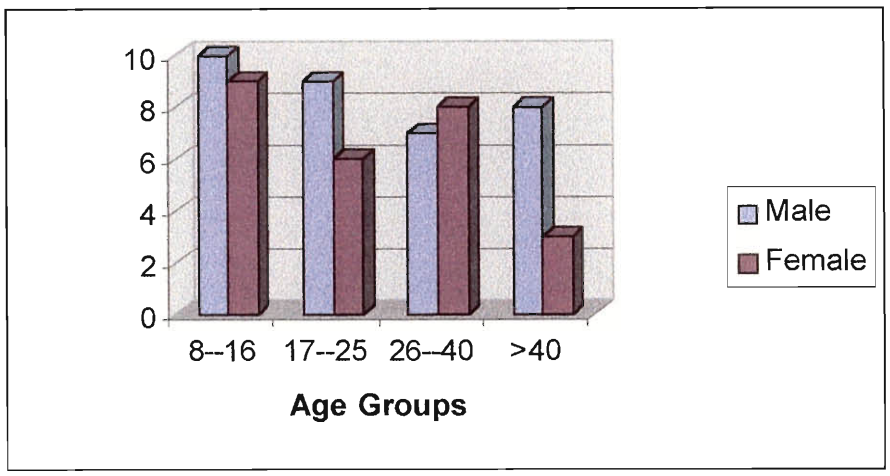

Table 4 - Age/Gender Distribution of Formative Text Evaluation

All data were verbal answers to questions we asked. The questions were topic-specific and therefore could not be compared quantitatively. We therefore analysed the data qualitatively. Our team and liaison openly discussion trends among visitors. To uncover trends, we grouped visitor comments by each topic.

First, analysis of the subject of android servants revealed that the text was clear and easily understood by the visitors. While many of the visitors did not know the difference between a robot and an android, all understood the concept of android servants and could follow the text progression. This distinction was not essential to visitors' understanding or interest so we did not change the text to clarify.

Next, we analysed the comments received concerning cloning extinct species. All 10 visitors identified the text as discussing cloning animals that are extinct. The terms DNA, cloning, and human interference were understood by all 10 visitors. However, suggestions from experts urged us to make several minor changes in the text for technical accuracy. The text line "DNA can be found in any preserved body part of the animal, such as its bones." Now is displayed as "DNA can be found in almost any preserved body part of the animal, such as its bones." Second, the term "DNA-free egg" seemed convoluted by experts and thus we changed the line of text containing that term. The final text reads, "Removing the DNA from the egg of a similar creature and inserting the preserved DNA creates the extinct animal embryo." Another change made to the cloning extinct species text was the addition of more positive effects of the technology. The following text now lists a reason we might want to develop the technology. "We could soon have the technology to bring these animals back, repair the damage caused in the past, and possibly make new scientific discoveries." Finally, we elected to change wording in the flourish statement based on technical feedback from experts at the Australian Museum. We replaced the word "using" with "starting" to create the following: "The Australian Museum is planning on cloning an extinct Tasmanian tiger starting with the DNA of a pup that has been preserved in alcohol since 1866!"

Analysis of the interviews about flying cars revealed that we needed to make changes in the text. The interviewees all understood the concept and terminology used, but repeatedly commented that they were interested in aspects of the flying cars that were not presented in the text. Visitors remarked that the details of how the cars operate was not as interesting as how fast or how high they could fly. We decided to change the text to include these details. The line of text that reads "Flying cars could go much faster than those on the ground" will now read "Flying cars could go much faster than those on the ground, as much as 350 mph!"

Next, we made slight changes to the weather modification text after interviewing visitors. All of the interviewees understood the process of weather modification and the terminology used in the text. However, visitors commented that the text does not clearly state that this technology is currently developing. Knowing that scientists are developing the technology is important to the overall message of the game so we decided to add this point to a line of text. This text now reads, "This "laser" idea is currently being researched in the USA and if successful could prevent the thousands of lives lost each year due to violent storms."

Our next interview results showed that the topic of nanorobots was, while not familiar to visitors, understood by them. All visitors identified the term "nanorobot" to mean a small machine that one swallows for medical purposes. However, visitors did not understand how the nanorobots worked since it is not discussed in the text. The most common comment from visitors when asked, "How do you understand the nanorobots to work?" was "I don't know. They just work." After discussion, we decided not to add text explaining how the nanorobots work since it is a fairly complicated process. Places where visitors can find such detailed information can be found in the Recommendation and Conclusions section of this report.

Finally, the data received from asking visitors about the genetic enhancement text was positive, but an expert in the topic, Dr. Marcy Darnovsky, raised several concerns. Our text pointed to editing isolated genes as the method of changing a unborn child's appearance. Dr. Darnovsky commented that this is much too narrow a path to present to museum visitors. Our text must reflect a vagueness to avoid technical inaccuracies and assumptions because the genetic engineering field is still in its infancy. Terms such as "scientists will" were changed to "scientists may". The topic of genetic enhancement is extremely controversial and we felt that we should not make bold predictions about the technology for this reason. After consultation with our liaison, we reworked the entire text for this topic. The final text can be found along side the story board for Genetic Enhancement in the Results section of this report and the original text can be found on page 196. Our original text was successfully evaluated by visitors but new evaluations will be conducted with the substantially different text once the game has been prototyped. This will occur after we have finished working at the museum and the software engineers implement our game ideas.

The results from these interviews helped us to edit the text for each game so that it will be clearly understood and interesting to visitors. We incorporated these changes into the story boards to achieve our final results, provided in the next section.

5.0 Results

The final outcome of our work provided the museum with the explicit plans for the completion of the In Future exhibit. These plans include our initial topic proposals, all the research completed for each idea, documented contacts with experts in each area, text and storyboards, and evaluations performed with the visitors.

Our major results consist of the detailed story boards for each topic. The story boards progress linearly through the game. Each story board has text accompanying the images. These images are not the final images that will be incorporated into the games.[1] They serve as representative symbols of what type of image should be present on each screen. To avoid copyright infringement, the actual images used must be original works of the software developers. Since the images on the story boards are utilised for internal and private use only, the use of copyrighted images is allowed. During frames where animation occurs, the animation is described along side a still image of the screen. This section of the report is devoted to the presentation of these story boards. For clarification, some explanation is provided along side frames of the story boards.

The final step needed to complete the In Future exhibit involves giving our game designs to the software developers who will add the games to those that currently exist on the third floor of the Wellcome Wing. The Science Museum's software engineers will implement our story boards into the final game prototypes.

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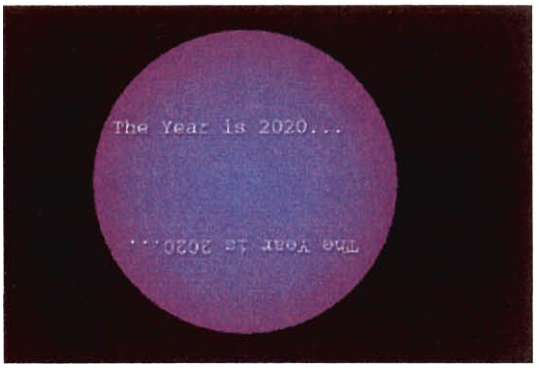
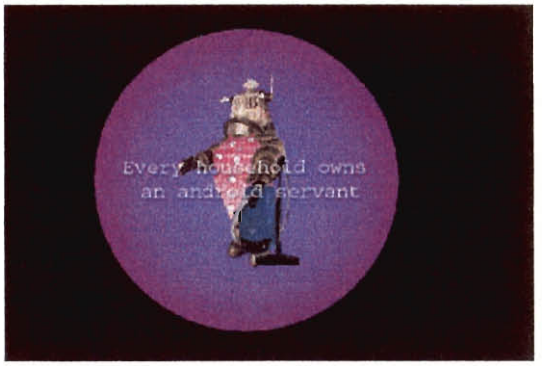
[1] All images used in the story boards were not created by our project team. They have been taken from internet sites. Many of the images used are not copyrighted, such as clip art, but those that are copyrighted have been acknowledged in the Bibliography section of this report. Project team members have altered some images from their original form.

5.1 Android Servants Storyboard

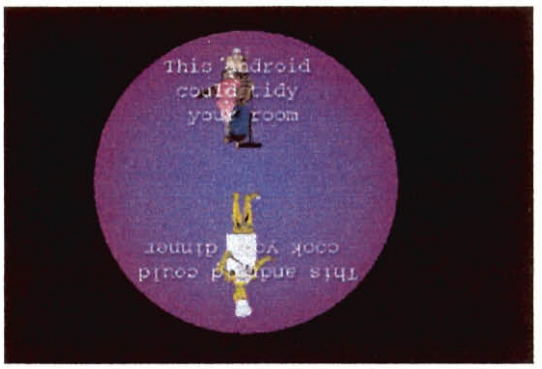


The Year is 2020….



Every household owns an android servant.

The image is of a generic robot that is prepared to clean.



The android could tidy your room. The android could cook your dinner.

The images reflect the statements.

It could even wash your smelly socks

The image is the android covered in socks, perhaps with visible odours rising.

Game Description:

The game play for this interactive is simple. The user has the ability to manipulate the environment of several rooms in a house with an android. Initially the user has only the view of a map of a generic house (this should be as if the roof were removed, all other aspects of the house are intact). Once the user selects a room to go to a first person point of view of that room appears in front of them, supplementing the map in the center of the table.

The user navigates to one of the rooms by moving a coloured icon representing their station at the table (either an android or simply highlighting the rooms in a color). The icons move on a predetermined path in either a clockwise or anticlockwise direction. The movement is controlled by the user turning the wheel on the table. To choose a particular room the user places their icon in that room and pushes the button.

Each room is a stereotypical room of that sort. The map should provide the ability to go to a child's bedroom, a master bedroom, a bathroom, a den, and a kitchen. Each room will provide several activities for the user to do. Each activity must have a potential bad effect as well as a good one, which effect the user gets is randomly decided. The navigation around the room to select an activity is the same as the navigation around the house map. The user turns the wheel to scroll a 'halo' from object to object around the room. This halo moves in a pre-determined course, either clockwise or counterclockwise and skips items which have already been tried. The user returns to the house map by selecting an arrow (or some other marker) at the bottom of the screen. As the halo rests on an item a quick test blurb lists what the task will be, for example an unmade bed would produce the text of 'Make the bed.'

In the master bedroom the user finds a clean room. There should be a dirty laundry container, the bed needs to be made, a vacuum cleaner lies in the corner and the return to map

icon. Choosing the laundry container (causing the android to wash the clothes) results in either a animation of the android doing the laundry in a laundry machine (the good result) or the android doing the laundry in the dishwasher (the bad result). Clicking on bed (causing the android to make the bed) results in either an animation of the android building a bed in the bedroom (bad result) or the android making the bed the proper way (good result). Clicking the vacuum cleaner (vacuum the floor) results in the android vacuuming the floor and sucking up anything other than furniture that is on the floor, an example would be sucking a blanket up into the vacuum cleaner (bad result) or the android vacuums the floor the proper way, avoiding anything that shouldn't be vacuumed up into the machine. Clicking the last remaining item returns to the house map.

The child's bedroom has a container of dirty laundry, which is overflowing onto the floor, a desk which is cluttered with papers, a messy floor, an unmade bed, a vacuum cleaner in the corner and an icon to return to the house. Clicking the dirty laundry produces the same animation as in the master bedroom, with the same results. Clicking the desk (tidy the desk) results in either an animation in which the android stacks all the books on the desk neatly and throws all of the loose papers in the rubbish bin, even homework (bad result) or it stacks all of the loose papers neatly on the desk next to the neatly stacked pile of books (good result). Clicking on the messy floor results in the android picking up all of the items on the floor and putting them in the rubbish bin (bad result) or the android picking up all of the items and putting them where they belong (good result). Clicking the bed provides the same result as clicking the bed in the master bedroom, as does clicking the vacuum cleaner.

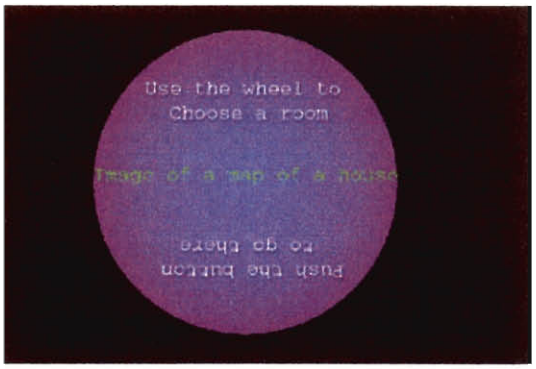
The bathroom provides a toilet, a sink, and a bathtub/shower. Clicking the toilet (clean the toilet) results in either the android removing the toilet (leaving leaking pipes in the floor)

and takes it outside to clean it with a hose and sponge (bad result) or it cleans the toilet in the proper manner (good result). The sink (un-clog the drain) results in the android removing the drain piping from the sink to clean it out (bad result) or the android using chemicals and a sink plunger to empty the drain pipe (good result). Clicking the shower/bathtub (clean the shower) results in the android cleaning the shower and removing the shower curtain to wash it in the laundry machine (bad result) or cleaning the shower and the shower curtain where they are.

The living room has a sofa covered with cat hair (the cat is on it), a fireplace, a china cabinet in the corner, and a vacuum cleaner in a different corner. Clicking the sofa (clean up the cat hair) shows the android removing the cat hair from the sofa and then the android shaving all the hair off the cat (bad result) or the android simply moves the cat and cleans the couch (good result). Clicking the fireplace (clean the fireplace) results in the android blowing all of the ash out of the fireplace, all around the rest of the room (bad result) or the android removing all the ash by placing it into some container (good result). Clicking the china cabinet (dust the room) causes the android to go around the room dusting everything, but it accidentally knocks over the china cabinet or the android dusts everything without breaking anything. Clicking the vacuum cleaner produces the same results as the vacuum cleaner in the bedrooms.

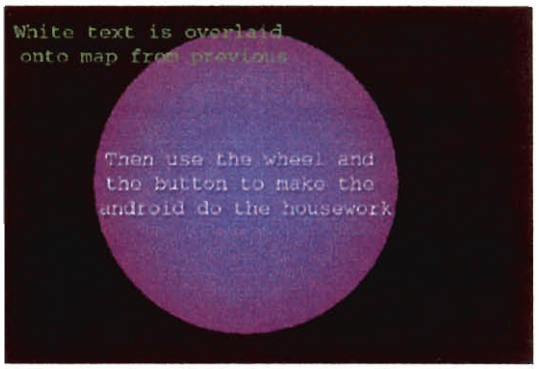
The kitchen has a stove/oven, a dishwasher, a toaster, a rubbish bin and a refrigerator. Clicking the oven/stove (cook dinner) results in the android lighting the kitchen on fire (bad result) or a marvelous dinner for the entire family (good result). Clicking the dishwasher (clean the dishes) results in the android placing the dishes into the laundry machine (bad result) or the android placing the dishes into the dishwasher (good result). Clicking the toaster (clean out the toaster) results in the android filling the nearby sink with soapy water and placing the toaster

into it while it is still plugged in (bad result) or the android unplugs it and empties the crumbs into the rubbish bin (good result). Clicking the rubbish bin (put the rubbish out) results in the android hanging the rubbish on a clothes line in the backyard, with other bags of older rubbish (bad result) or the android takes the rubbish to the street for it to be picked up (good result). Clicking the refrigerator (Go get more groceries) results in the android going to the grocery store and taking the groceries on the list, without paying for them and getting caught (bad result) or the android goes to the store and buys the groceries and brings them home and puts them away neatly.



Use the wheel to choose a room. Push the button to go there.

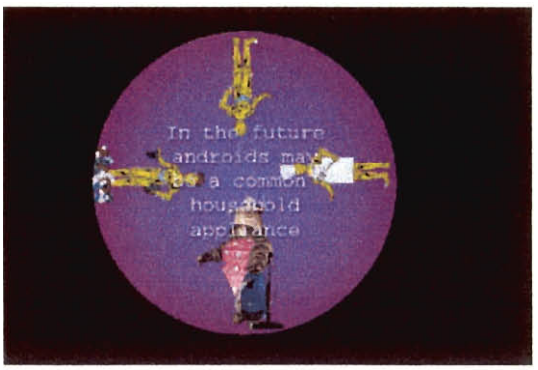
The image is a map of a house. In the map are little robots, in eight different colours.



Then use the wheel and the button to make the android do the housework.

The background image is a messy room.

The game consists of the ability to choose one of several rooms. Once in the room one of several activities can be performed.
The kitchen could have cooking and cleaning as two activities, among others described on the previous page.

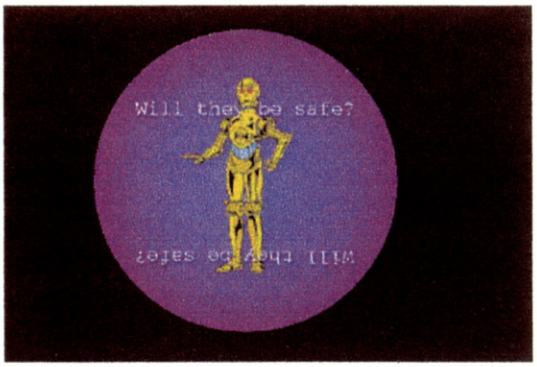


In the future androids may be a common household appliance.

Four images: three of the android cleaning (as in the game), and one of the android by itself.

But what happens when they make a mistake?

Two identical images facing opposite directions. The image shows an android that has just made a significant mistake (ex. Vacuuming the cat!)

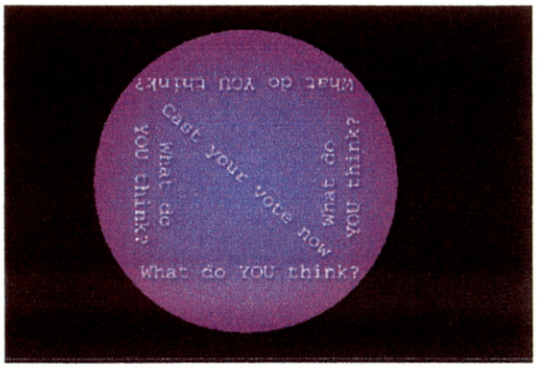


Will they be safe?

The text is on the table twice. The image should be the android, shrugging.

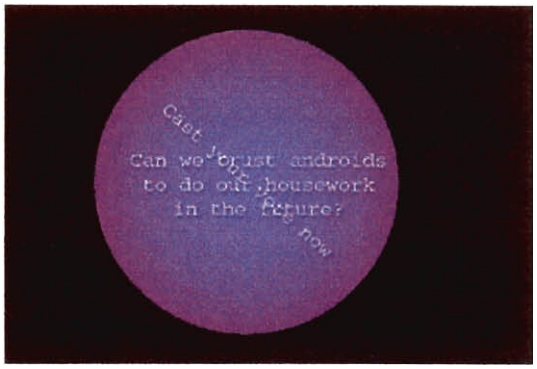
Will they make us lazy?

The image is the epitome of human laziness. It appears twice.



What do **YOU** think? Cast your vote now.

Line one appears suddenly, rotates 90 degrees and starts to fade out as line two fades in.

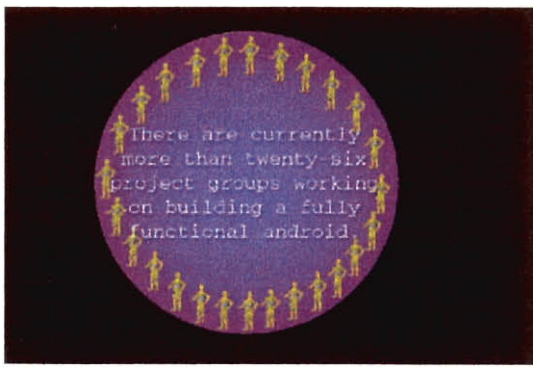


Cast your vote now. Can we trust androids to do our housework in the future?

Line one spins off into the distance as line two fades in with the vote buttons.

This is for real....

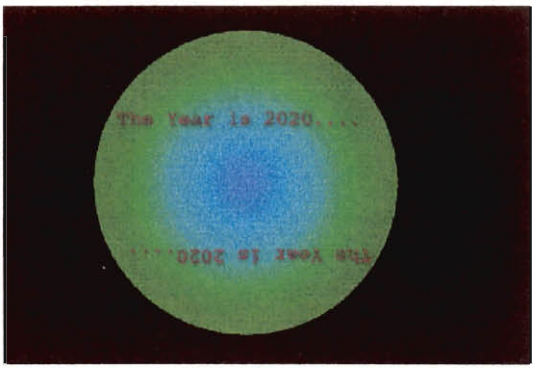
The line of text should disappear as the next screen dissolves in.

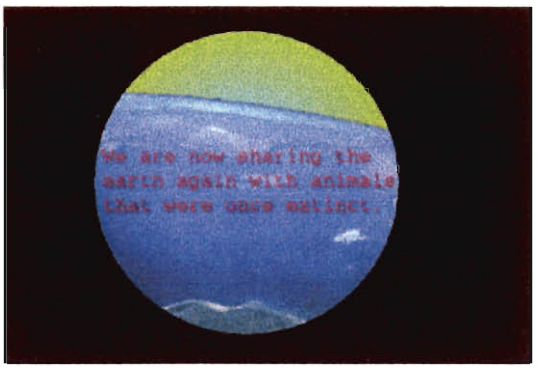


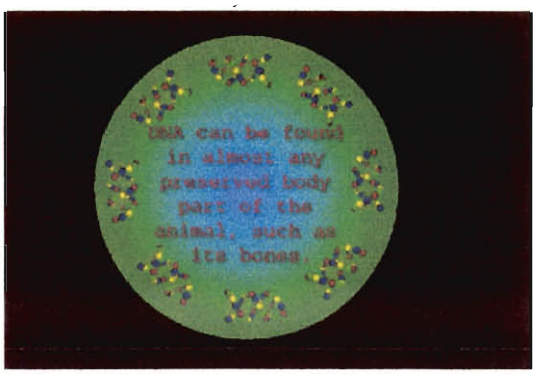
There are currently more than twenty-six project groups working on building a fully functional android

The accompanying image should be 26 little androids circling the table.

5.2 Cloning Extinct Species Storyboard







The Year is 2020…

All text for the entire game changes in the form of molecules of DNA breaking apart and re-forming into the new words.

We are now sharing the earth again with animals that were once extinct.

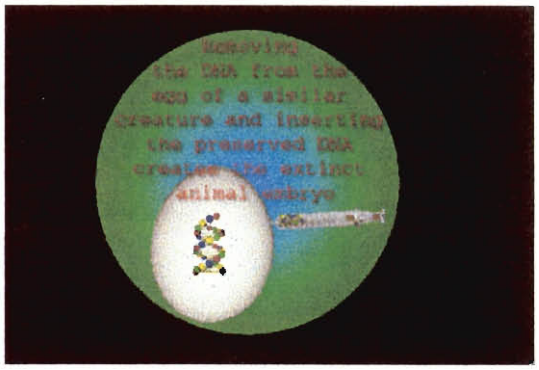
Graphic is of a horizon of earth.

Extinct species can be reborn as long as we have a sample of their DNA.

Four images. Two are of DNA, Two are of two different extinct animals, perhaps dinosaur and woolly mammoth.

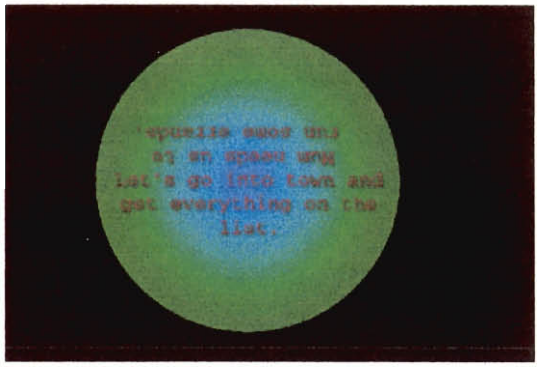
DNA can be found in almost any preserved body part of the animal, such as its bones.

Eight small DNA models are around the table.

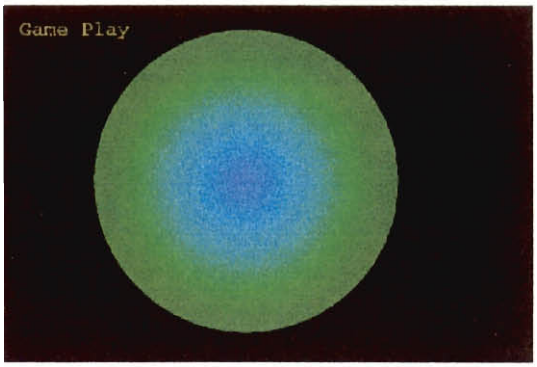


Removing the DNA from the egg of a similar creature and inserting the preserved DNA creates the extinct animal embryo.

An egg with DNA in it. A syringe is injecting the DNA.



Mum needs us to run some errands. Let's go into town and get everything on the list.



This is the game intro screen.

Many species were driven to extinction because of human interference.

Two or more images of animals that
humans have become extinct appear, perhaps a gaur and a dodo bird.

Game Description:

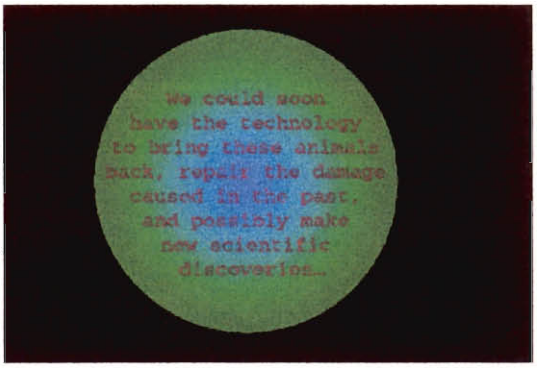
At the start of the game, a shopping list appears next to each wheel, on the table are various clearly labelled stores and a child on a bicycle represents each player. The bicycle begins to move and is steered by the player with the wheel. The object of the game is to go to each store in order to get everything on the list. The player completes this task by steering the bicycle towards a store and pushing the button to stop when at a store to obtain an item on the list. The things on the list would be cheese, bread, meat, fruit, etc. The stores would include the bakery, the butcher, the fruit stand, etc. As the player rides his bike around town, there are many exotic animals roaming about peacefully, showing how nature and society can exist peacefully at times.

But then there are also problems being created due to these animals roaming about. The obstacles pop up randomly, so can't be avoided by the player. As the player is riding around on his bicycle, something will pop up in his path and his bike will stop. A text blurb will appear explaining the situation and why the player must wait before continuing on his way. Some of the obstacles will include:

- A Brachiosaurus bathing in the river has created a flood! – You must wait until the water drains.
- A herd of Quaggas is heading your way! – You must pull over to the side of the road before being trampled.
- There's a rather large pile of Woolly Mammoth dung in the road! – You must wait while it is being cleared.
- You suddenly get dumped on by a flock of Great Auks flying overhead! – You must find a toilet to clean up.

- Traffic is stopped while a family of Dodo birds crosses the street! – You'll have to wait until they're safely on the other side.
- You've been knocked over by a child whose pet Tasmanian Tiger chases a Wallaby through the park! – It takes you a few seconds to get back up onto your bike.
- A shopkeeper and a customer are creating a scene over an argument about the price of a Sabre-Tooth Tiger fur coat! – You'll have to wait until the road crowd clears away before you can pass.

The game ends when one of the players gets everything on the list. (There will be a set amount of time and if the end of that time comes before any of the players finish their list, the game will just end.) The game shows that while it could be fun and exciting to see such a variety of animals around, some of which not seen for many years, if at all. But on the other hand, having these animals around that we know little about could create more problems than they're worth!



We could soon have the technology to bring these animals back, repair the damage caused in the past, and possibly make new scientific discoveries…

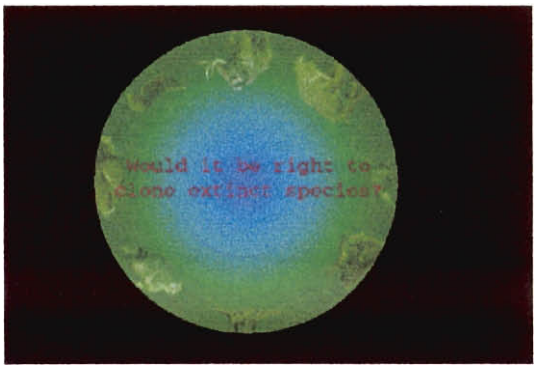
The images from the previous screen fade.

But is this right, or would we be making more mistakes?

This screen should have some graphic indicating one of the potential bad effects of bringing these creatures back.

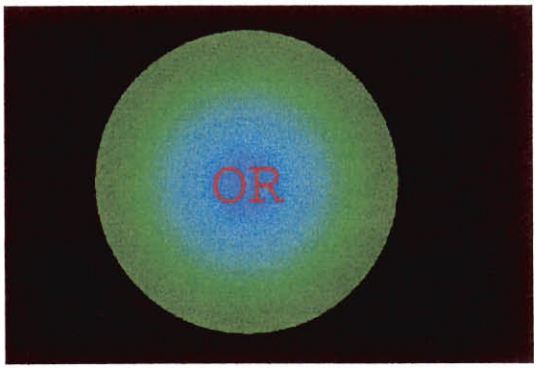
What do you think?

Any graphic from the previous screen fades away.



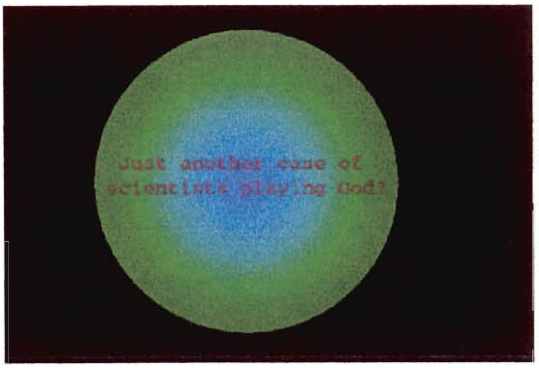
Would it be right to clone extinct species?

A chaser of translucent images circulates the perimeter of the table. The images are of extinct species.



OR

The images fade. In this instance the central text changes into the 'or' and grows by consuming the surrounding text.



Just another case of scientists playing God?

The text does exactly the reverse of the process used to build the 'or.'

Cast your vote now
Should we clone extinct species?

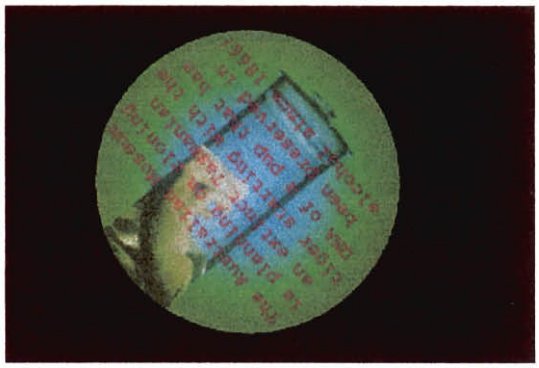
No graphic other than the standard voting sequence of animations.

An endangered gaur, which is similar to an ox, was successfully cloned in the USA, although it died a couple of days after birth.

Two images of the gaur, named Noah.

But the effort isn't extinct...

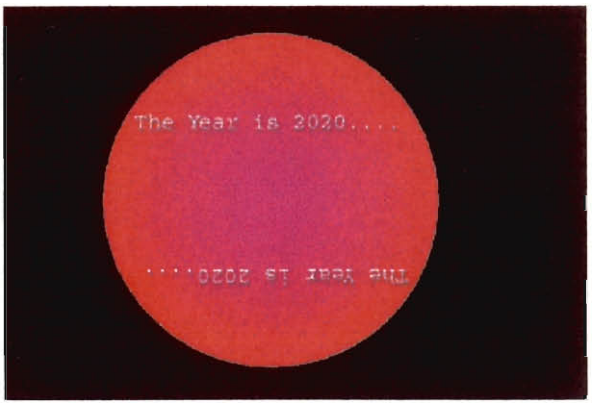
Graphics fade out as text changes.



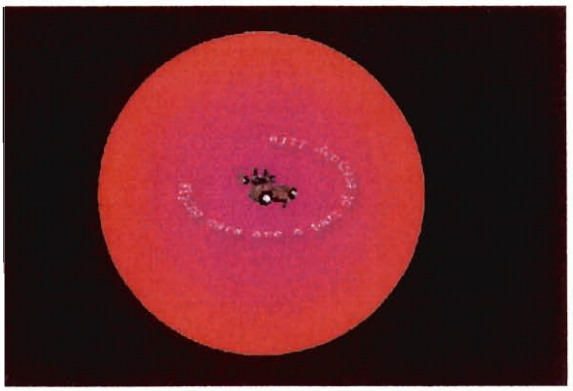
The Australian Museum is planning on cloning an extinct Tasmanian tiger starting with the DNA of a pup that has been preserved in alcohol since 1866!

An image is of the Tasmanian tiger pup as it is now, in a jar.

5.3 Flying Cars Storyboard

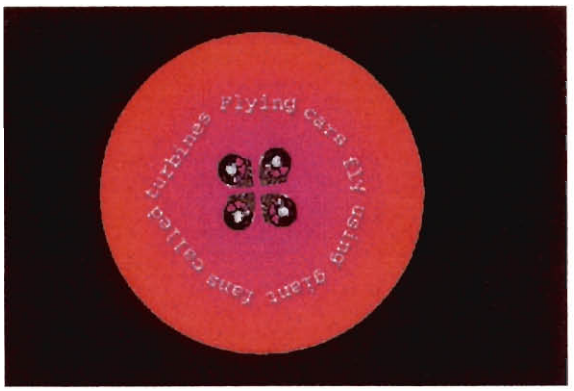


The year is 2020….



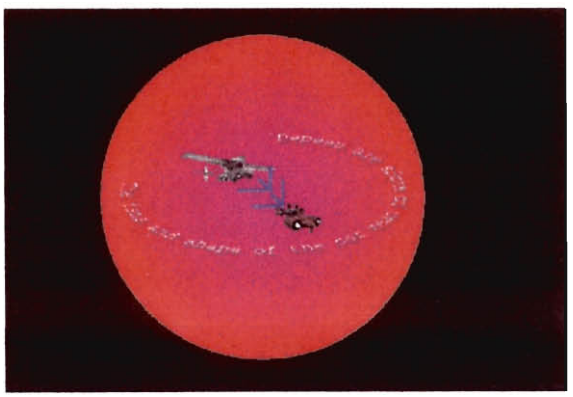
Flying cars are a part of everyday life.

Text appears on one side of the table and then rotates to other sections of the table so all can read. The image is a basic polygon flying car.



The cars fly using giant fans, called turbines

The images are all turbines.



The fans and shape of the car mean no wings are needed

The graphic depicts one of the older car/airplane combos with arrows into a wingless car.

Why don't we try it out?

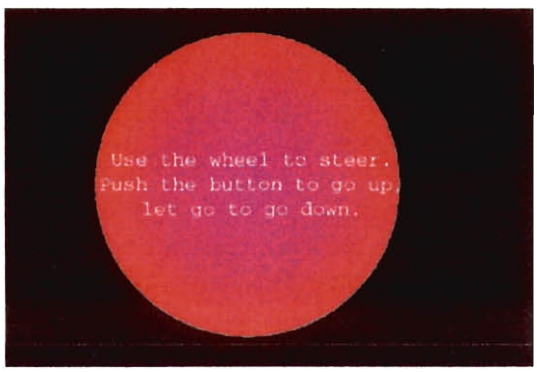
An image of a driver's view out through the windscreen appears in the middle of the table.

Get ready to fly!

An image of a driver's view out through the windscreen remains in the middle of the table.

The first one to the cinema gets the last ticket!

The image in the centre sheds a copy to each user, then the original fades into one cinema ticket.



Use the wheel to steer. Push the button to go up, let go to go down.

The text is in the middle of the table. The 'cockpit' view in front of each play remains, while an overhead map appears in the centre.

Game Description:

The game portion of this interactive takes the form of a race. The user interface allows the user to go up or down and to steer. Due to a lack of controlling interfaces there is no option for speed control, therefore all the cars go the same speed. The winning car is the one that crashes the least often.

The game starts as a race to get to the cinema to get the last ticket to the film. Each user gets a colour coded car. They can steer this car using the wheel as well as making the car go up and down by pushing and releasing the button.

The game takes the form of an eight player, multiple viewpoint game, meaning each user has their own view of the race. This view is through he cockpit of their car. The course is a set of normal city streets through which the users must navigate to get to the cinema. As the user approaches a point at which they must change their direction an arrow flashes showing them which way to go. They could be forced to turn left or right or they could be forced to go up or down to avoid obstacles and buildings. Each car can see all the other cars as they pass them or are passed by them. As passing a car can only occur when it has crashes there will be limited numbers of graphics needed to represent the passing sequence.

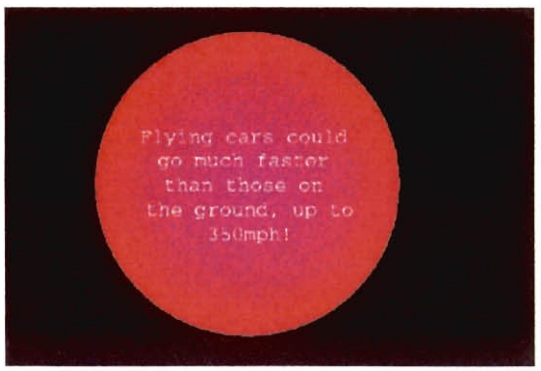
When the first person gets to the cinema their cockpit converts into a car and flies out into the middle of the screen to get a cinema ticket (which has morphed from the map). All the other car cockpits fade into the background.

Ready, Set, Go!

Text is in the middle of the table. The 'cockpit' view remains as does the map. Proceed to game play.

No Text. Game play. The game is a multiplayer, multiview racing game. The map shows the positions of all the racers, while the view in front of each user is individual.

No Text. End of game. The winner's view morphs back into a car and flies to the centre of the table. The map has morphed into two tickets to the cinema.



Flying cars could go much faster that those on the ground, up to 350 mph!

No Image.

But will they be more dangerous?

Possibly an image of a car crash morphing into a flying car crash.

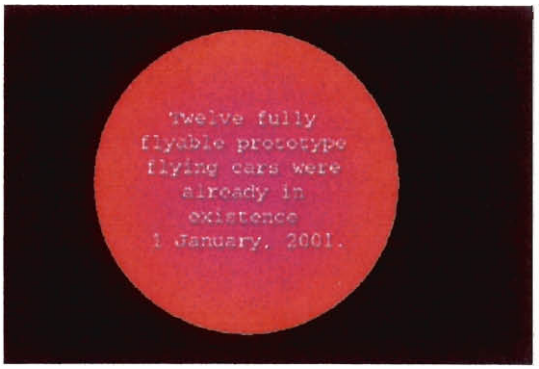
What do YOU think?

Text is in middle of table, spinning slowly. The graphic is a giant question mark. If not too nauseating the question mark might spin counter to the text.

Cast your vote now. Should we replace today's cars with ones that fly?

Line 1 in the centre, line two at edge. Line one appears first, then line 2.

This is for real…



Twelve functioning flyable prototype flying cars were already in existence 1 January, 2001.

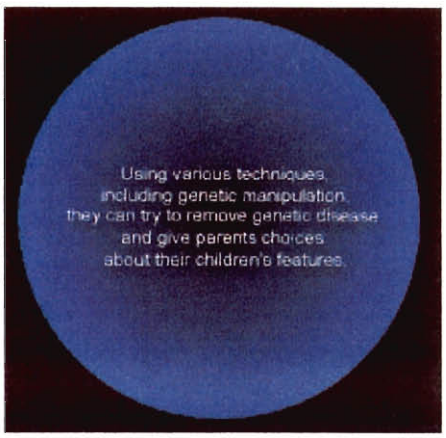
Text in centre of table.
Perhaps some images of different types of cars in the background.

5.4 Genetic Enhancement Story Board

The Year is 2020

Scientists can help you design your children

Background: Image of DNA



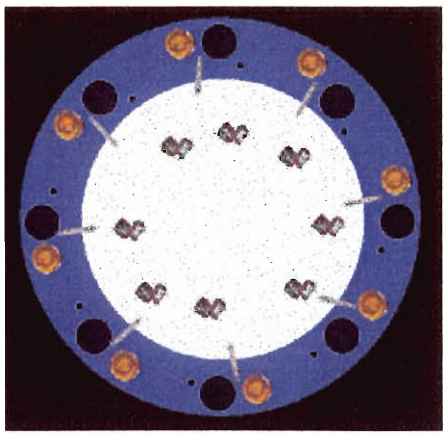
Using various techniques, including genetic manipulation, they can try to remove genetic diseases and give parents choices about their children's features.

They can try to change children's height, hair colour, and even shoe size.

Background: World's Tallest Man (or similar image)

Let's design a child!

Game: Each player has a syringe with which to grab different genetic traits. These traits are swimming around the middle of the board. As each player grabs traits, they are deposited in a petri dish next to the player. After a set amount of time play is stopped, and each petri dish is shown growing into a person. The person will graphically show the various traits that the player selected.

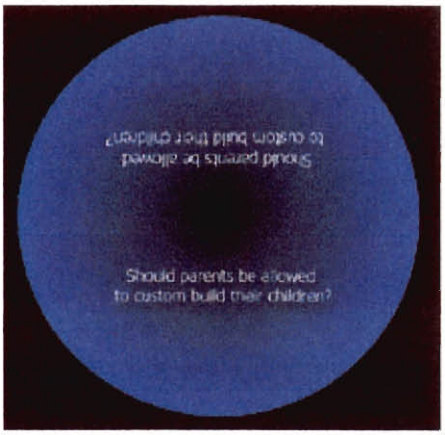


Game Description:

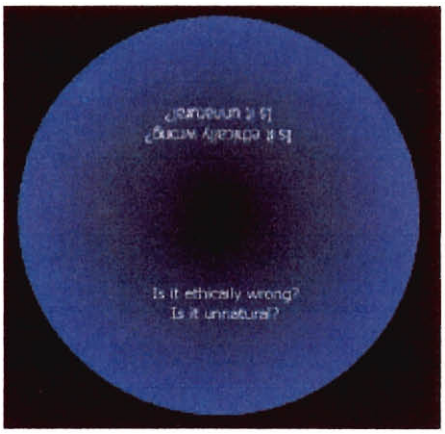
The goal for the players is to create a person. Each player has a collector, controlled by the wheel and button, and a petri dish next to their station. As the player turns the wheel, the collector moves into or out from the center of the table. Pressing the button will operate the collector, and attempt to collect a strand of DNA from the table.

Moving randomly about the table are strands of DNA, each of which is labelled with a specific physical trait. These traits should include things such as height, eye and hair color, as well as more humorous traits such as shoe size, and different ears and noses. The players will spend several minutes collecting these traits to build their person from.

Once a set amount of time has passed, the game will stop and change into an animation. This animation will have the petri dishes migrate in front of their respective players. At this point, each dish will be shown growing into a foetus, then a child, and finally an adult human. The final adult should be cartoonish and display the traits that the player collected from the board. There should also be some possibility of error, which would result in the person displaying traits that weren't selected, to show that the process of gene selection is not %100 accurate. Possible erroneous gene selections include asthma, cystic fibrosis, multiple sclerosis, down's syndrome, sickle cell anemia, arthritis and others.



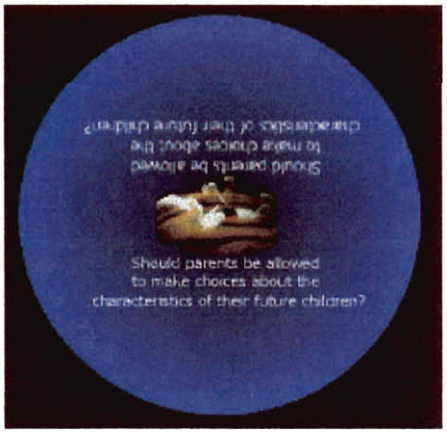
Should Parents be allowed to custom build their children?



Is it ethically wrong? Is it unnatural?

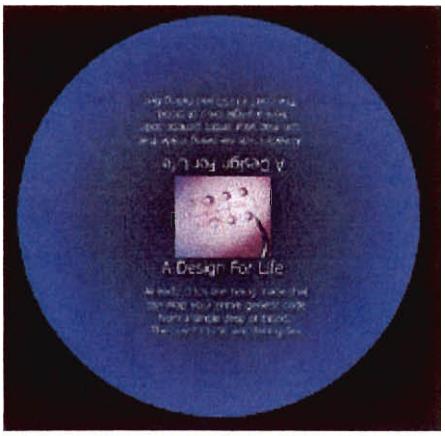
Or will it lead to happier parents and children?

Cast your vote!



Should parents be allowed to make choices about the appearance of their future children?

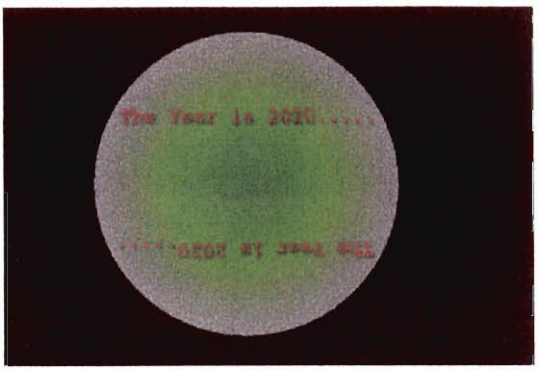
Background: Image of foetus.



A Design For Life: Already chips are being made that can map your entire genetic code from a single drop of blood. The cost? £1250 and falling fast.

Background: Image of lab-on-a-chip.

5.5 Nanorobots Storyboard



The Year is 2020….

Injuries can now be healed by swallowing tiny machines.

The graphic, if there is one, should be of someone swallowing a pill

These machines are called "nanorobots." They're invisible to the human eye.

Four images, each of someone looking at a robot through a magnifying glass.

You swallow them, millions at a time. As they travel through your body, they repair injuries.

The graphic is a different graphic of a person swallowing or the nanorobots.

After healing an injury the nanorobots are dumped out when you go to the toilet.

A graphic of a toilet should appear in the centre with text around it.

Ride along with the nanorobots!

A graphic of a nanorobot inside the body

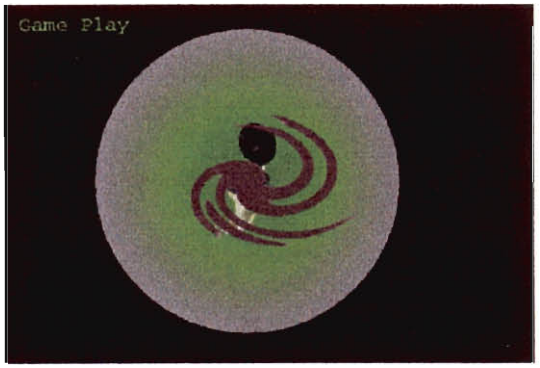
Go to the injury, heal the patient and get out as fast as you can!

The previous image splits into two smaller versions which separate. In the centre appears an outline of a body (the "patient")

The game consists of an injury for each player to heal. The game is a race to heal the injury and vacate the body as fast as possible.

Game Description:

The interactive game portion of the nanorobots game begins by challenging each player to ride along with the nanorobots inside a patient that has an injury (i.e. a broken leg). The players are each in command of a group of nanorobots that are competing to get the injury healed as fast as possible. The centre of the table is a view of the patient, with only an outline of the body so that it is able to show the progress of the nanorobots and each player. Each player is denoted by a specific colour and their progress is tracked on the body in the centre of the table. When play begins, each player has a "cockpit" view as his or her interface. The players use the wheel to steer their personal nanorobots towards the site of injury. This site is shown by a blinking red light on the body outline in the centre of the table. Once the players get to the site, they can heal the broken leg by pushing the button as fast as possible. This simulates the nanorobots performing the bone-healing procedures. As each player pushes the button, the progress of the healing is shown as a meter in front of each player. A figure that continually morphs from a completely broken bone to a healed bone appears in the centre of the table. One player wins the game by finishing his or her repairs on the bone. At that point, control returns to the main computer. The centre of the table becomes a "cockpit" view of the nanorobots in the bloodstream. They travel through the body until they get to the digestive track and ready for excretion. Then, the centre of the table becomes a toilet. The patient walks to the toilet and the next image shows the toilet flushing, carrying all the nanorobots with it. Everything swirls down the drain and all images disappear. The next line of text appears.



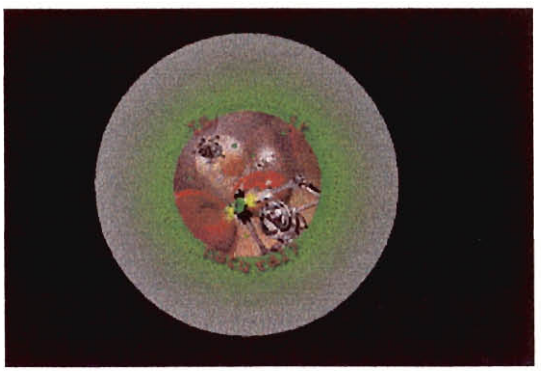
End of game play. When the first player finishes, the screen morphs into a toilet as all the players are flushed down the toilet.

Nanorobots could speed healing.

A graphic of a nanorobot in the blood comes back. It may be the same as the one before.

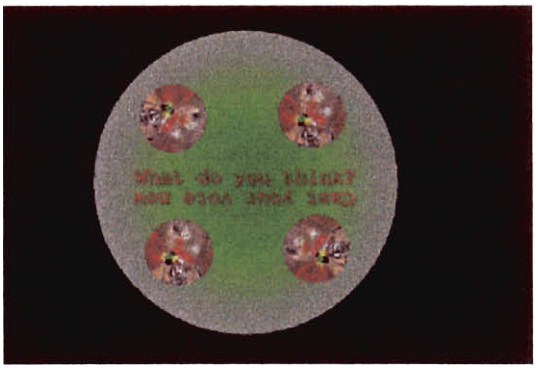
But are these machines safe to put inside your body?

The graphic does not change, the text morphs and moves to the new positions.



Is it natural?

Again, a transition in text only.



What do you think?
Cast your vote now.

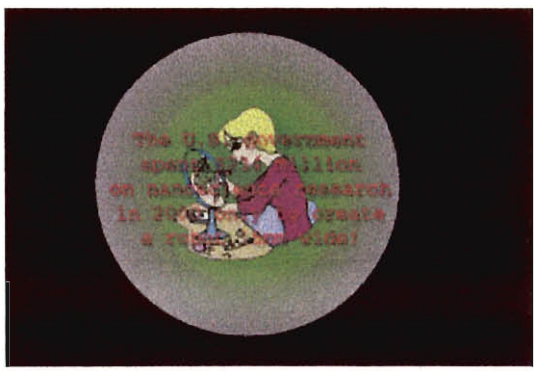
The actual image stays the same, but splits into four and each goes to a "corner" of the table. The text morphs from previous.

Would you swallow nanorobots to speed healing?

Image remains unchanged. Text morphs from previous.

It's a small world...and getting smaller all the time.

The smaller images start to migrate to the centre and fade into one larger, translucent image.



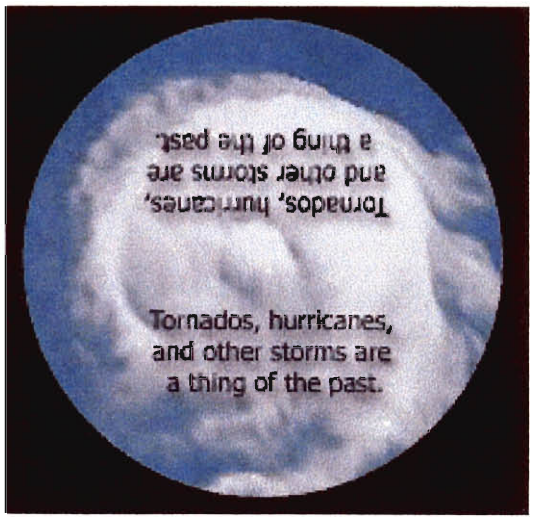
The U.S. government spent $234 Million on nanoscience research in 2000 only to create a robot 15mm wide!

The image morphs into someone examining/building tiny, tiny robots.

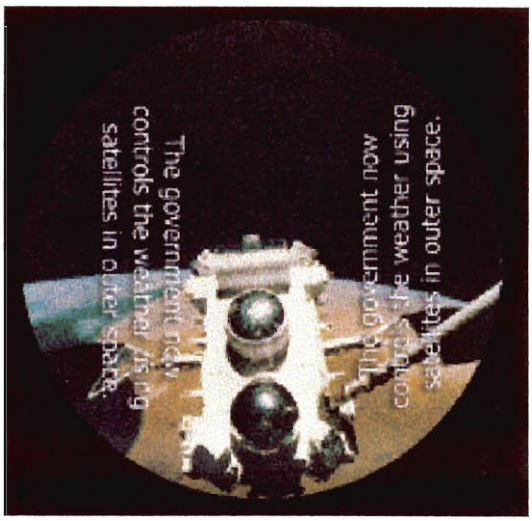
5.6 Weather Modification Story Board

The year is 2020.

Background: Hurricane satellite image.



Tornadoes, hurricanes, and other storms are a thing of the past.



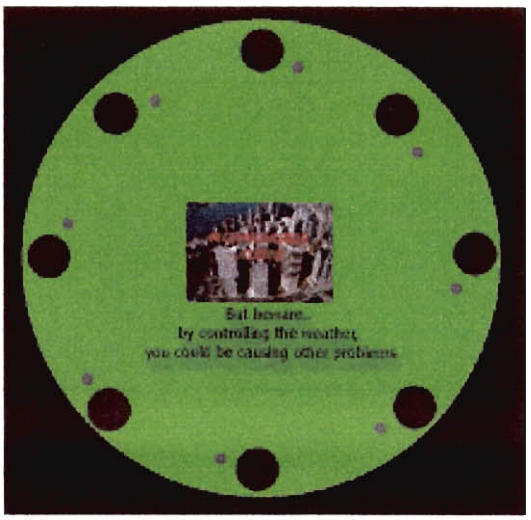
The government controls the weather using satellites in outer space.

Background: Satellite with earth in view.

The satellites calm the storms by zapping them with laser beams and cutting off their energy supply.

Let's play with the weather controls. You're operating a weather satellite.

Background: Change to game background, city image in the centre.



But beware… by controlling the weather you could be causing other problems.

Game Description:

At the start of the game, a laser-firing satellite appears in front of each player. The wheel is used to aim the laser and the button is used to fire. In the middle of the table is a city and storms appear around the city (swirling clouds) throughout the game. The object of the game is to shoot the storms before they hit the city and create destruction. At the beginning of the game, only a couple of storms appear, and as the game continues more and more storms will be on the table at one time. The storms are rated according to their level of intensity, a 1 being a less threatening storm and a 5 being a very violent storm. When the storms first appear on the table, they are weak and will display that they are level 1. As time progresses, the storms increase in intensity.

There is a flashing target on each storm (this might be a flashing circle in the middle of the storm that also displays the number representing the level of intensity of the storm). Hitting this target with the laser decreases the intensity by one level per shot. Hitting a level 1 storm in its target destroys it and it disappears. The level increases with time and also if a player hits the storm in any spot other than the target. The level will increase one level for each shot that hits the storm anywhere other than the target.

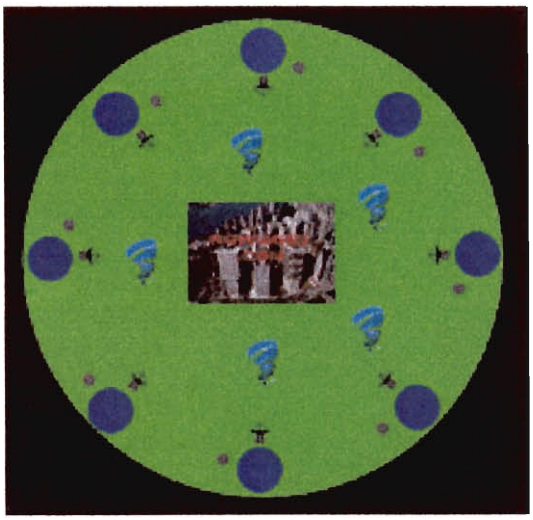
Each level storm causes a different amount of damage to the city, 1 being the least and 5 being the most. At the end of the game, which is determined by a set amount of time, the players are informed of how much damage was done to the city compared to how much damage would have occurred if they had let the storms run their natural course without interfering. Each player is also informed of his of her individual performance, specifically whether they helped or hurt the city.

This game shows that controlling the weather could be a very beneficial if used correctly, but if used incorrectly could make the weather even more dangerous than it is naturally.

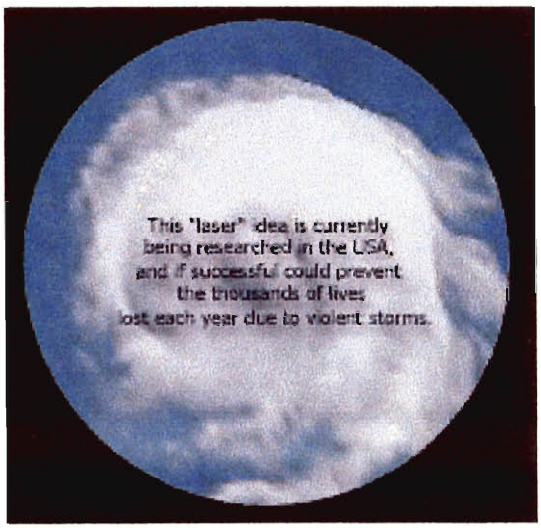
Turn the wheel to aim your laser beam.
Click the button to fire the lasers at the storms before they destroy the city

Turn the wheel to aim your laser beam. Click the buttons to fire the lasers at the storms before they destroy the city.

Final intro to game.



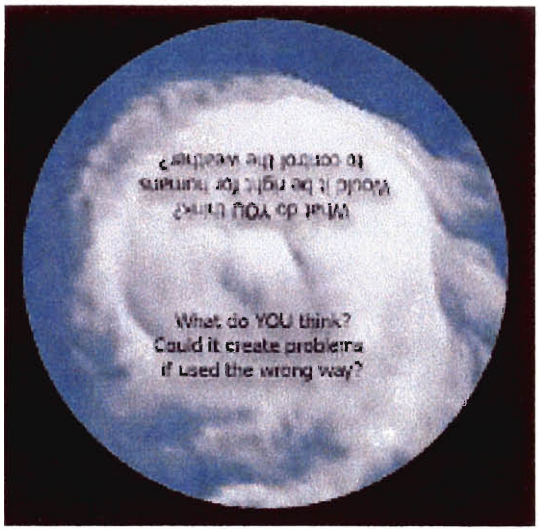
Game: Each player has a satellite in front of them as tornadoes approach the city. Firing at the tornado stops it. Firing and missing the tornado by only a small margin can change tornado or alter its path.



This "laser" idea is currently being researched in the USA, and if successful could prevent the thousands of lives lost each year due to violent storms.

This "laser" idea is currently being researched in the USA and if successful could prevent the thousands of lives lost each year due to violent storms.

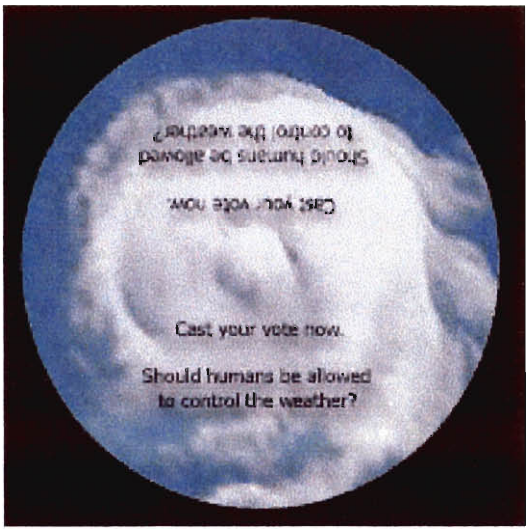
Text rotates 180 degrees



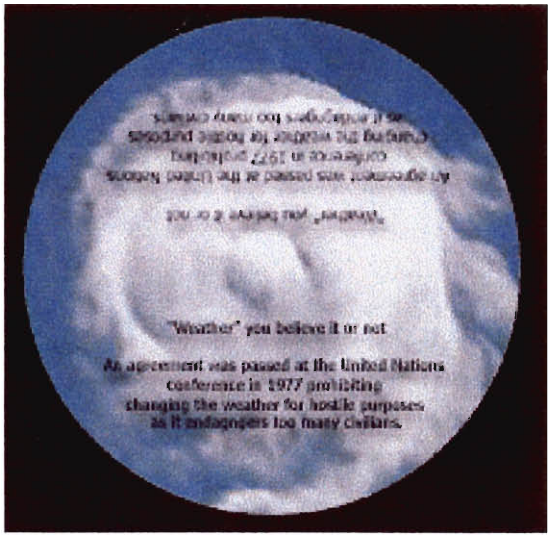
What do YOU think? Would it be right for humans to control the weather? Could it create problems if used the wrong way?

Would we be interfering with nature? And what if the wrong people get their hands on the controls?

Text rotates 180 degrees



Cast your vote now. Should humans be allowed to control the weather?



"Weather" you believe it or not. An agreement was passed at the United Nations conference in 1977 prohibiting changing the weather for hostile purposes as it endangers too many citizens.

6.0 Recommendations & Conclusions

In conjunction with our final storyboards, we also recommended several ways to improve the In Future exhibit. We noticed several areas that, if updated, could increase In Future's success and popularity. These areas include ways to encourage visitors to go to the exhibit, ways to improve activity and lighting, and ways to make In Future more interactive. We noticed that the floor is isolated from the rest of the museum, as it is not obviously connected to the museum from any floor other than the ground floor. There are currently three tables on the floor and two benches with feedback stations. This arrangement leaves a large expanse for more tables, features, or other suggestions that are described below.

First, we suggest projecting the images from one of the games in play on the far wall of the room as well as on the table. This wall projection would allow visitors as they first walk into In Future to see the games in play and encourage them to try playing the games themselves. The wall projection would also create movement in the room and it might even be seen from the ground floor, depending on its placement.

Next, a projection of the daily tally of votes from all the tables somewhere in the room might stimulate interest among visitors to supply their opinion with a vote, and encourage them to stay at the table after the interactive portion is over. The projection displays already on the wall in the room may be ideal for this purpose. Currently, only the In Future logo is projected on these screens. As of our departure from the museum, the Wellcome Wing staff was beginning to look into implementing this idea.

Feedback stations, which are computer terminals found throughout the museum, currently allow In Future visitors to read more detailed information about the topics.

However, they do not have any direct link to the presentation of the topics on the tables. We suggest allowing the feedback stations to have a link to the daily tallies. The tallies could be updated periodically throughout the day by technical staff. We also think it would be wise to incorporate the tallies and detailed information into the Wellcome Wing's website, which contains a section that is devoted entirely to the In Future exhibit.

Another recommendation we had involving the feedback stations was the opportunity for visitor's to take home more information on the topics introduced by In Future. The visitor could request information by leaving his or her email address to receive an email from the museum with a list of links to useful, informative websites about the issue.

A second alternative for visitors to access more information on the In Future topics could be to make the educational packets more accessible to every visitor. Currently, these packets are available upon request to school groups, but we believe that all visitors should have the availability to request this information. Although it may not be possible to have copies on gallery for visitors at all times, there could be a place where a visitor could leave his or her name and address to have an information packet sent home. We feel that In Future is such a unique exhibit that successfully sparks interest in the topics it introduces, and many visitors would probably enjoy learning more about these issues. Allowing visitors to access further information would make the exhibit more informative and educational.

Next, to draw visitors to the exhibit, we decided that creative signs could be placed in the hallway of the third floor and in sequence leading to the exhibit. Signs that match the text for each game are our suggestion. The first sign (at the staircase landing) might

say "The year is 2020". Further down, the next sign might say "In Future: Vote for what *you* want to happen". Other signs, all similar in nature, either in the hallway or throughout the floor, could incorporate each of the individual topics. Examples could be: "Imagine... Cars that drive themselves"; "Imagine... You can now buy laboratory-grown meat"; "Imagine... Dad can be Mum", etc.

Finally, we suggest that more movement around the floor would increase the energy in the room. Projections that move across the floor would add brightness and life to the floor, similar to those on the second floor of the Wellcome Wing at the entrance to Who Am I?. Also, movement around the floor may catch the attention of visitors elsewhere in the Wellcome Wing and entice them to visit the third floor.

Other recommendations to the museum involve the many topics that we investigated. We filed the topics that we decided not to pursue for the In Future exhibit for possible use by the museum at a later time. In these files, we included the original topic proposal, any research we had completed on the subject, the names and email correspondences of experts we contacted, and data from the initial visitor evaluation. Although we did not pursue these ideas, our research is still valuable, as the topic may be suitable for a different future exhibition. It is important for the museum to know whom we contacted in the various fields, should they desire to contact them further for a future project.

In conclusion, our IQP project team worked for a total of fourteen weeks to develop six topics for the In Future exhibit at the London Science Museum. The first half of the project was devoted to the generation of ideas for topics that we proposed to our liaison and museum staff. Once in London, we worked to evaluate our proposed topic

ideas by collecting visitors' viewpoints and by brainstorming about how our ideas might be implemented. After narrowing down our topics based on visitor evaluations and existing criteria, we developed the ideas into storyboards including full text. After our team finished its work at the Science Museum, our designs were given to software engineers for implementation. The museum's software engineers will be able to transform our storyboards into the final game prototypes.

Over the past fourteen weeks we have learned valuable social science skills. We expanded our interviewing and data analysis skills. We increased our writing abilities. Our team has also developed many useful skills beyond these academic skills. We learned about group dynamics, the roles that we each play, and the communication necessary to achieve our goals. We interacted with visitors to the Science Museum, and gained a valuable perspective on how the public views cutting edge science and technology.

We hope that the Wellcome Wing staff and also visitors to the Science Museum will benefit from our work. The museum's goal for the In Future exhibit is to educate the public about the future of science and urge them to leave the exhibit still thinking about the impact of these directions on their futures. Our project achieves this through accurate and detailed research, clear and concise storyboards, and the impact of each flourish. Our focus remained unbroken through iterative feedback from both professional museum staff and visitors. Our project team is proud of the work we have done at the Science Museum. We have nearly doubled the content of the exhibit in 14 weeks when it normally takes the museum staff 5-6 months per interactive (Davies, personal

communication, 8/2/01)! The results of our work will be seen by thousands of people every day.

As we begin our careers in highly specialised engineering fields, we may likely face decisions like those proposed in the In Future scenarios. Our IQP has taught us to be aware that our pursuit of scientific research could affect individuals and communities across the globe. After this experience, we will certainly be responsible with that power.

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8.0 Appendices

8.1 Appendix A: Museum Information

The National Museum of Science and Industry (NMSI) was originally created as a section of the South Kensington Museum in 1857 (NMSI 2000). It became a separate entity in 1909, and a new building to house the NMSI was built in 1928. The NMSI is actually a compilation of three separate museums: the Science Museum, London, the National Museum of Photography, Film and Television, Bradford, and the National Railway Museum, York. A Board of Trustees that is appointed by the Prime Minister governs the NMSI. The museum's funding comes mainly from Grants-in-Aid from the Department of Culture, Media, and Sport.

The NMSI mission statement is the following:

> "The Museum exists to promote the public's understanding of the history and contemporary practice of science, medicine, technology and industry." (http://www.nmsi.co.uk/review/mission.html)

Our liaison, Mr. Owain Davies, is new to the WPI project group experience. He is currently a member of the Wellcome Wing Exhibition Development Team.

8.1.1 Photograph of In Future Table

The above image is a picture taken of one of the In Future tables currently in place in the Wellcome Wing.

8.2 Appendix B: Idea List

The concepts below are all ideas our project group considered developing into proposals for the museum. We brainstormed these ideas and they served as a base of material from which we drew during the preparatory phase of our project: the Pre-Qualifying Project (PQP).

Oceanic Farming

Using the ocean's resources as a place and way to grow more food

Global Warming and Its Impact

After every ice age the planet resumes its normally tropical state. How will the current emergence from the last ice age alter our lives in 2020?

Wearable Computers

Moore's law states that roughly every eighteen months computer processors will halve in size and double in power. We may very well be wearing our laptops in 2020.

Flying Cars

Could the car of tomorrow take to the skies instead of crossing the ground?

Anti-Gravity

The potential uses for this technology are limitless. Can it come about before the year 2020?

Under Oceanic Magnetic-Levitation Trains (Trans Atlantic or Trans Pacific)

Trains that can cross under the ocean faster than the speed of sound in a vacuum tunnel riding a cushion of magnetic energy.

1984

As governments grow they create more laws to restrict their citizens. As each new restriction takes place ones that follow are easier to accept. When is enough enough? Where might this control by the government bring us in the year 2020?

Computer-Simulated People

As computers become more powerful their ability to simulate real things does as well. When do simulations and the real world merge? At what point do we fail to tell the difference between the two?

Electronic Drugs

Currently drugs affect the brain by altering the chemicals present in the brain. These chemical changes alter the electrical impulses that the brain generates and recieves. Perhaps in the year 2020 the ability to change those electric impulses directly will be readily available.

Alternative Prisons

Penal moon colony. Antarctic colony. Volunteers needed. Survival expectation low. Promise of freedom while there. Return to civilisation not permitted.

Genetically Engineered Worker Classes

The human genome project aims to map out what each gene in our DNA does. With this comes the knowledge (and power) to alter the makeup of individual

people. We could create a class of sub-humans that do all the grunt work for everyone else, or a class of people to rule, or a class of people to perform sports, or a class or people....

Asteroid Impact or Some Other Geo-Catastrophic Incident

As we emerge from this ice age we could be forced into another one. This would destroy civilisation and could happen at any moment.

Population Explosion

We already have too many people. We are reproducing rapidly. How do we stop it? What if we don't?

Regenerating the Rain Forests

The rainforests are being destroyed at an alarming rate. They provide a substantial source of natural cleansing to our air. Replanting may reduce our pollution problems

Virtual Romances

When does an online relationship become a real one?

What if We Discover Life Elsewhere in the Universe

Any life form from the smallest bacterium to the most intelligent race imaginable)? How will people react?

Mass Brainwashing Via Television

Subliminal messages are banned from movie theatres. What if they were not actually removed? What if television uses them?

What if We Find a New Ancient Civilization

Who knows what it could tell us

Super Encryption and Super Encryption Breaking

Imagine if no matter how hard you tried to stop it, someone could break into your computer. It can be done now. What about in 20 years?

ESP Studies and Potential Proof

What would irrefutable proof of ESP or psycic abilites bring to our lives?

"Lost" Species Resurfacing (the selacanth, Bessie? ogopongo, etc).

What if All Rainforests Are Destroyed?

The sheer lack of biodiversity may be a problem, but then again it might not.

How will it effect the climate? Our O2 supply?

What if We Run Out of Oil?

We currently depend on oil for about everything. We will run out. What happens when we do?

What if Medical Treatments for a Disease Stop Working?

Diseases mutate. Treatments for diseases kill off the weak versions, leaving only the strong. What happens when the treatments no longer work?

Flywheel Power Sources for Vehicles

Alternative to oil. Very efficient when used, but lots of loss when not being used.

High powered laser in space (against ICBM's against people, etc).

Lasers are used in many ways. What if a high powered laser were placed in space.

How could it change the way we feel about our personal security?

Robot Soldiers

Wars kills people. But if we developed the right robot maybe this would change.

What repercussions would this bring? When does it become wrong?

Personal and Military "Cloaking Devices" (light bending technology)

Light can be redirected. People could use this technology to insure privacy.

Geo-Thermal Energy Sources

Alternative energy source. We sit on a gigantic generator. Why not use it?

Thumb Print Financial Transactions and Security (or retinal scan)

Never worry about forgetting your password again. Just use your thumb.

Radioactive Power Sources (using the raw radiation as a source of power)

Some highly radioactive materials are just wasted biproducts of fission. Could their radiation itself be harnessed as a power source?

"Smart" Clothes

Sensors imbedded in clothing which constantly monitor the wearer to insure the optimum comfort levels.

Waste Reclamation (heavy duty recycling of trash, waste materials etc).

Why throw anything away? Everything is recyclable in one form or another.

Clear-Cutting Impact

Clear-cutting happens. It damages the soil. What happens when the damage will not allow further growth?

EMP (electro magnetic pulse)

An Electro Magnetic Pulse would destroy all magnetically stored data in the affected area. How likely is this destruction to happen? What would the results be?

Stock Market Crash Collapsing US Economy.

It would cascade through the entire world's economy, leading to a great depression that would be world wide.

Optical Computers (all transmissions at the speed of light)

Invulnerable to EMP. Would not generate heat. How would a processor work?

Floating Cities (either nautical of aerial)

Just like colonizing the ocean floor, only on top of it. Or maybe even floating in the air (see anti-gravity)

High Speed Oceanic Transport (vs. airplanes)

Hydroplaning boats. They reach incredible speeds. Is it plausible to think they may replace airplanes (see also sub-oceanic mag-lev trains)

Depopulation of Whales

Whales are killed every day. What impact will their total loss have on the ocean's ecosystem? How will that affect us?

Hormone treatments in food stock, milk cows.

Hormones are used to make various farm animals grow faster and bigger. They are also used to cause dairy cows to produce more milk. Any excess hormones make their way out of the cows body, some into the milk. How will this porcess change people over time?

Grain Plague (hits breadbasket of USA)

What if all of the grain produced in the US were to be killed by some disease (for as little as one year)?

Ultrasonic Weapons

A way to stun an attacker without causing permanent harm. The user would need earplugs or else, they too would be affected.

Light (LASER) Weapons (hand held)

See orbiting laser, adapted to handheld version.

Magnetic "Force" Fields

High tesla fields can crush a rat, why not stop a person? High magnetic fields have many applications. For corporate as well as individual use.

A Required Application Process for Having Children

All potential parents must apply, those accepted can have children, those that are not, cannot. See population explosion.

Portable Medical Scanners (handheld, a Tricorder (Star Trek)).

A potentially useful tool for making diagnosis more efficient and more accurate. How feasible are they at the moment?

Space Junk Leading to a Catastrophe

There are literally millions of pieces of tiny debris in orbit and the number grows with every space mission. What happens when a ship hits one?

The End of Broadcast TV and Radio

More and more of our communication occurs through the web. What happens when all of it does?

We Develop a Way to "Reinstall" Life Into a Deceased Body Part

(Or whole body).

8.3 Appendix C: Proposals to Museum

We generated the following proposals during the PQP portion of this project. Each was given to our liaison, Owain Davies, for consideration as a potential topic for further development. For each proposal, we researched the topic in more detail than simply the ideas mentioned in the preceding idea list. The proposals became our working topics for visitor evaluation upon our arrival in London. It was from these topics that the six for full development were chosen.

8.3.1 Android Servants

Activity Message:

Robotics and home automation are advancing at a very rapid rate. With sufficient advances, it would be possible for everyone to have a robotic servant to perform everyday household tasks.

Background Information:

As robot technology and computer power both become more and more advanced the world is combining them to create ever more independent machines. The day will come when we start making robots that are fully mobile and also fully able to make basic decisions about pre-programmed tasks. This day will come sooner than many believe.

The concept of android servants is not a new one, however the feasibility of making functional android servants in the near future has never been a realistic one.

Currently some companies in Japan have been able to make a self contained robot that can walk. This was a big step in the development of a working android. Other developments are being made in the Artificial Intelligence (AI) field which, when coupled with the robotic developments, will help develop this walking prototype into a robot that will do much more than simply walk.

Advantages of Technology in 2020:

The advantages of this technology are obvious. A robotic servant which can do the menial chores around the household will free up a significant amount of time for the people to use elsewhere, whether it is spending time with their families or working, or going to an exercise facility.

Disadvantages of Technology in 2020:

The major disadvantage this technology could create would be a lack of responsibility because all of the menial tasks (dusting, vacuuming, walking the dog, etc) would be taken care of. This also leads the dependence upon such robots to do these tasks for those that own the robots. Another disadvantage is not to individuals, but a potential disadvantage to society in that the robots could replace people that perform the same task. These people would then have a lack of jobs.

Current State of the Technology:

Currently there are robots that can be programmed to do repetitive tasks (such as assembly line work). There are also toy robot kits that can be programmed to do specific

tasks (Lego Mindstorm). If toy kits can be programmed to do complex specific tasks then logic would dictate that it should not be difficult to adapt the same process to more permanent robots. This leads to the current state of the technology needed to build the hardware. At least one Japanese company has built a robot that can walk on its own. This having been accomplished other advancements are sure to follow allowing integration of more features than a simple guidance system into such a robot. Other possibilities would be to make the robot a wheel or tread based machine, thus reducing the computer power needed for mobility and guidance. In any of these cases the technology exists currently to make a simple household servant robot today. The future will only bring better, more complex ones.

Probable Cost of the Technology in 2020

In 2020 the idea of a robotic servant will most likely be widespread. It will, therefore, be safe to assume that the machines will be a highly manufactured item, making the cost to acquire one less than it would be today. This leads on to believe that to purchase a robotic servant the cost would be similar to a very expensive appliance (or maybe that of a lesser expensive automobile today).

Visitors' Reactions:

Most will find the idea fascinating and believable. Many will walk away wanting to have a robot of their own tomorrow, others will find the idea disgusting. Some will

find the idea intriguing but will decide that they will decline to have a robot in their home.

Visitors' Prior Knowledge:

Most of the visitors know very little about robots. Most of the general public hear the word "robot" and think of C-3PO from Star Wars or some other man-shaped robotic being. In this case this is exactly what is desired because the robotic servants would most likely be androids, or robots that resembled people. This will have several benefits, one of which is familiarity. The Public will probably be unaware of the walking robots that have been built in Japan as well as any other technological improvements that have occurred in this field.

Take Away Message:

"Now you too can own an ANDY for your home!" Imagine the idea of having an android there at all times to watch your kids, to help clean to help cook, to take care of the pets and just generally be helpful. Will it be as good as a live person? Will it be trustworthy? Will it be competent? What if it breaks when you need it most?

Quotes:

There are currently no quotes for this topic. More research is currently in progress.

Other Points:

This topic is another topic that appears regularly in science fiction. Notable appearances are in any of the Isaac Asimov Robots Series, Lost in Space, and the movie Forbidden Planet.

References:

Day, R. (2000, September). ROBOTS. Popular Mechanics, 90-93.

Menzel, P., & D'Aluisio, F. (2000, September). BIOBOTS. Discover, 86-93.

MIT Humanoid Robotics Group. Retrieved November 12, 2000, from the World Wide Web: http://www.ai.mit.edu/humanoid-robotics-group/

Robot lab lessens astronauts' work. (2000, August). Popular Mechanics, 20.

Wardell, C. (2000, September). Home of the future. Popular Science, 68-77.

8.3.2 Artificial Intelligence

Activity Message:

What happens when machines achieve a level of intelligence equal to or great than that of humans?

Background Information:

Artificial intelligence (AI) is a concept that has been around since the early days of computing. Unfortunately, since intelligence is a poorly defined concept, the study of AI has been forced to be divided into two groups: Strong and Weak AI. Strong AI is the idea that a computer can be programmed to think at or above the level humans are capable of. Weak AI strives to give to machines only parts of the human capability to think.

Since creating a full artificial intelligence is such a complex task, AI research is generally done in one of many subcategories, each working to resolve a particular part of the overall problem. Speech recognition, machine vision, machine learning (using new data to self-modify existing programs), and natural language processing (enabling the computer to process linguistic information) are several important areas of AI research.

Another way to divide the study of AI is into classical and statistical AI. Statistical AI programs take in some form of stimulus, match to an existing pattern, and produce the appropriate output. Examples of these would be robotic control systems that learn how they interact with the environment through repeated action. Classical AI programs, on the other hand, attempt to deduce a conclusion based on a collection of data.

Advantages of Technology in 2020:

- AI could aide in complex design and analysis tasks, drastically reducing the time required to perform them.
- Personal computers could work as personal assistants.
- Wide ranging applications for weak AI:
  - Driverless Cars
  - Robotic Controls
  - Any application where computer control of a physical system is needed.

Disadvantages of Technology in 2020:

- Possibility of a "machine revolt" exists given sufficiently advanced AI. (i.e.- Terminator 2, The Matrix)
- Will people accept machines that can think? How would AI be any less alien than extraterrestrial life forms?
- What happens if the AI doesn't want to do what it's asked?

Current State of the Technology:

As of yet, no functioning strong AI has been created. However, many advanced weak AIs are currently in use. For example, the computer Deep Blue, created by IBM, has succeeded in defeating chess grandmaster Gary Kasparov. In recent years, speech recognition software has become more and more advanced, and is now economical enough for home use. Robots such as Cog, at the MIT Artificial Intelligence lab, are

capable of learning to use their bodies to interact with the surrounding world, based on nothing more than a knowledge of what systems the have control over. Another robot at the MIT lab, Kismet, is capable of displaying facial expressions in reaction to visual stimulus. Although Kismet's reactions are very predictable and follow an understood program, it is a showcase for how varying types and levels of visual stimulus can be interpreted by a computer and used to create "emotions".

Currently, AI is more of a concept than a reality. Many different types of weak AI are being developed successfully, but they have yet to be integrated into a singular program capable of human level thought.

Visitors' Prior Knowledge:

Visitors are unlikely to have any knowledge of AI beyond what is presented in popular media. They probably don't realise that there is much more to AI than just sentient computer programs.

Possible Vote:

- Where is the line between being just a computer program and being life? Would AIs deserve the same rights/privileges as humans?
- How would people react to a machine capable of human-like thought?

Take-Away Message:

While a full AI may be far off, machines around us every day are already "thinking".

Popular Media References:

The Matrix – 1999 movie where AIs have enslaved their human creators.

Terminator 2 – movie where an AI global defence system attempted to destroy humanity in an act of self preservation.

References:

Arnold, W., & Bowie, J. (1986). Artificial intelligence: A personal, common-sense journey. Englewood Cliffs, N.J.: Prentice-Hall.

Clark, A., & Toribio, J. (Ed.). (1998). Cognitive architectures in artificial intelligence. New York: Garland Publishing.

Clark, A., & Toribio, J. (Ed.). (1998). Machine intelligence: Perspectives on the computational model. New York: Garland Publishing.

Fetzer, J. (Ed.). (1988). Aspects of artificial intelligence. Boston: Kluwer Academic Publishers.

Garfinkel, S. (2000, September). The measure of a man. Discover, 28, 31.

Graubard, S. (Ed.). (1988). The artificial intelligence debate: False starts, real foundations. Cambridge, MA: MIT Press.

8.3.3 Cloning Extinct Species

Activity Message:

Cloning technology is continuously advancing. It is now possible to clone your pet if you want it to live forever, and if we discover preserved DNA of an extinct species, such as the dinosaur, we have the technology to bring that species back to life.

Background Information:

Now that scientists have mastered cloning, developments are being made to take the technology to the next level. Cloning technology is currently being used to preserve endangered species, by keeping DNA samples available of endangered species so that when the numbers get too low, more animals can be created. The San Diego Zoo has a Centre for the Reproduction of Endangered Species (CRES), which consists of a huge collection of cyropreserved cells, or as they call it a "frozen zoo". The purpose of this collection is for scientific study and opportunities for genetic management of endangered species.

A technique recently developed for cloning endangered species, is currently being tested and it looks as though it will be successful. This technique, developed by ACT in Worcester, Massachusetts, USA, involves the combination of cloning with implanting an embryo holding the DNA of the endangered species in a similar species for birth. Currently, there is a cow in Iowa pregnant with a rare Asian guar, through the use of this technique, which is described as follows:

1. The DNA was removed from the cow's egg.

2. This egg was then fused with a skin cell from the rare ox, producing an egg with the endangered ox's DNA that would be accepted by the cow's immune system.
3. Before implanting the egg, it was artificially induced to begin dividing without fertilisation.

The cow now has a fully developed foetus, and as long as there are no complications with the birth, the technique will be successful.

Advantages of technology in 2020:

One advantage of this technology would be the ability to clone your pets in order for it to live forever. Another advantage would be the ability to bring back extinct species that once roamed the earth. Bringing these species back to life could help scientists make discoveries about the Earth's history to gain a better understanding of what the Earth was like long ago. This technology will also make the preservation of endangered species possible that will prevent further extinction. The Earth will become more diverse and this may possibly help the restoration of the planet.

Disadvantages of technology in 2020:

There is the possibility that the public will prefer this cloning technology for preservation to the current efforts in breeding and habitat protection, due to cheaper expenses. If this occurs, then the funding now provided for breeding and habitat conservation will diminish. This would be a problem because efforts to save the planet

could disappear and the animal kingdom could become yet another "human controlled" domain.

A possible problem with the technology is that herds of a species would be created with each animal having an identical DNA makeup. This is a problem because genetic diversity is crucial to survival, and there is no reason to create herds of animals if they cannot survive on their own.

A second survival issue is that the natural habitat of many extinct species is gone; therefore if these animals are created, they could only survive in a zoo, which is a human controlled environment. Again it seems pointless to bring back a species, if it could only survive under human control.

Current State of the Technology:

Currently, the technique presented to birth the Asian Guar only works for DNA from a living animal, one that has been dead for less than five days, or one that has been preserved (frozen) since death. It is believed that this technique would not work for the woolly mammoth because, although a frozen animal was found, the DNA is fragmented. A similar technique may be used to clone a Tasmanian Tiger, extinct since 1936. This may be possible due to a pup that has been preserved in alcohol since 1866. The only difference in the technique is that the egg will be incubated rather than implanted into the donor. This technology depends on living or preserved tissue, so if preserved DNA is found for species that have been extinct for hundreds of years, such as the dinosaur, the technology will be ready to clone that species, and we could have a real case of Jurassic Park.

8.3.4 Flying Cars

Activity Message:

The technology for flying cars has been developed and is currently available. A prototype already exists of an actual flying car called the Moller Skycar or M400. But many steps must be taken before flying cars can be introduced to society as an everyday household transportation means.

Background Information:

Moller International has created, built, and flown the M400 prototype, and the technology incorporated allows vertical take off and landing, or VTOL. The vehicle holds ducted fans, each of which houses two rotary engines to provide thrust. The conventional pistons, cylinders, and connecting rods used in engines were replaced with a triangular rotor housed in a trochoidal-shaped chamber. As the rotor turns around, compression and expansion are created. A patented thrust deflection vane system redirects thrust and enables the aircraft to hover, or take off and land vertically from practically any surface. They can launch into the sky faster than a mile a minute and fly comfortably at 350 mph at 15 miles per gallon.

Advantages of Technology in 2020:

The advantages of this technology would be a reduction in traffic congestion issues on the land, faster personal transportation means, and an increase in the personal safety of people on land. Concentrating transportation in the air will open up an

enormous amount of space on land currently used for roads, to be available for other purposes.

Some of the technical advantages include a low fan noise, and little pollutants. The engine produces little nitrogen oxide, which is the hardest pollutant to eliminate. There are also little unburned hydrocarbons and hydrogen monoxide.

Some of the safety precautions that have been taken include emergency parachutes and the ability to land practically anywhere should an emergency situation arise. The skycar can also be driven on land for short distances, should flying being unsafe.

Disadvantages of Technology in 2020:

The disadvantages with flying cars involve safety and control. People would need to learn how to operate the machines safely and get used to a completely new set of rules concerning travel. Another disadvantage is creating and enforcing these new "traffic" laws. It will be very challenging to come up with rules for driving in the sky! There will be no roads, or intersections, or signs, so how will it be controlled? Also, the prototype can fly at speeds up to 350 mph, and it would be unsafe if every driver had the ability to travel this fast.

Other disadvantages include the fact that no boundaries exist in the sky; therefore crossing over boundaries would be much easier. There would be no way to monitor who is crossing the boundaries and what they are transporting. Traffic policing would be more challenging (how do you pull someone over in the air?).

Possible Vote:

If this technology were possible in the year 2020, would you want one? Would you feel safe flying one? Would you feel safe in the sky with other people flying them? Are the advantages of freed up space on land worth the disadvantages that are incorporated with flying cars?

Take-Away Message:

The take-away message would be that flying cars are a very possible aspect of the future whether everyone has them or only an elite group, but no matter whom has them, there are safety issues for everyone that must be considered.

References:

McCosh, D. (2000, March). Dream machine. Popular Science. 68-71.

http://www.moller.com/skycar/m400

8.3.5 Genetically Engineered People

Activity Message:

Just as cells of the body differentiate to perform a specific function for the good of the body, humans may soon be able engineer themselves based on specific desired traits such as physical strength, intelligence, creativity, and artistic ability.

Background Information:

The technology of genetic engineering is already researched and developed under the "sex choice of children" game, but is taken a step further in this scenario. Researchers have created genetically altered cattle with excessive muscle mass (*Nature* 377 (1995), 381). Genes have also been isolated in various animals for such properties as protein production, cell self-lysis (suicide of the cell), and vaccination from disease (referenced from *Nature* and *Biotechnology*). If these genes were engineered in specific combinations in humans, various "classes" of people could be created. One such class could be the worker class. This group of people's entire existence would be to perform remedial tasks that are still necessary to society. These people would not know that their profession is undesirable because they would lack the intelligence. Also, people could be engineered to perform certain occupations including immune-enhanced doctors who work with infectious patients and super-athletes. This issue raises EXTREME ethical questions.

Genetically engineering a desired trait first begins in the somatic cells. Somatic cells make up most of the body's cells. However, these cells will not pass their information to the next cell generation. Therefore, there is no chance of the trait being passed into the sperm or egg cells and into offspring. Scientists can inject an extra copy

of a gene into the somatic cells (i.e. the gene for growth hormone to increase height). The cells will then go through mitosis and spread the gene to other cells.

Advantages of Technology in 2020

- Specialised individuals would perform their occupation very well
- Would eliminate job dissatisfaction
- May advance fields (science, sports, medicine) more rapidly

Disadvantages of Technology in 2020

- Unethical???
- This technology may backfire and not work as expected
- It would add to the over-population problem that is significant already
- Will humans still be able to have children naturally? If so, they may be far inferior to genetically engineered people.

Progress of Technology to Date

Genes have been isolated in various animals as well as certain genes in humans. Scientists have been successful in expressing the gene through birth, and certain genetic disorders have been removed successfully from experimental foetuses.

Cost of Technology in 2020

The technology will not be overly expensive by the year 2020. Major costs come in research techniques and facilities. If supported by the government, the cost to the parents would not be impossible to raise.

Take-Away Message

Mainly ethical concerns - the technology is available, but it is up to the people to decide how to use and control it. Imagine the level of civilisation we could achieve with differentiated persons.

How Visitors Will Feel

Surprised, shocked, amazed, excited, wonder what they would like to have specialised

Visitors' Prior Knowledge

Most people are aware of gene isolation and animal genetic testing. Also, most people have either read (in high school for US students) or have general knowledge of the novel Brave New World. This may be a negative aspect, as the novel portrays a harsh and cruel view of genetic engineering.

Other Points

If this technology advances far enough, humans may be able to rival their favourite comic book super-hero. Features such as super speed, strength, or flexibility are all inherent human traits that could be enhanced through genetic engineering.

Experts and Sources

The scholarly journals Nature and Biotechnology have abundant publications concerning advances in genetic engineering. Most information was found there.

http://www.greepeace.org/~comms/97/geneng/getoogoo.html

- This site is a lengthy listing of issues concerning genetic engineering. Points include the unpredictability of genetic engineered products, case studies of when genetically altered items have gone wrong, and the close relationship between scientific research and industry.

Genzyme Transgenics is a cutting-edge genetic engineering (and tissue engineering) company in Massachusetts. Many students from WPI actually intern there. Expert sources would be found in the scientists and researchers at the company.

8.3.6 Magnetic Levitation trains

Activity Message:

There are technologies currently being developed that would allow an underwater passenger vessel to travel faster than the speed of sound. If this becomes a popular travel means, aeroplanes may become obsolete.

Background Information:

The technology involved in the possibility of under-oceanic transportation is basically the same technology used for torpedoes and is also being used in the development of guns to destroy underwater mines, just applied to a much larger vessel. This technology uses the phenomena of *cavitation*. Cavitation occurs due to pressure drops, which cause liquid molecules to vaporise and form cavities or bubbles. This is usually an unwanted occurrence, but in the case of high-speed underwater vessels, supercavitation occurs. Under the specific conditions needed to create supercavitation, a single bubble or supercavity forms around the entire object, so that only the nose is in contact with the water. The main condition needed to create supercavitation is the object must be moving very fast (about 180 km/hr or 50m/s). Another condition is, unlike aeroplanes where the nose needs to be pointed to create high velocities, the nose of the underwater vessel should be flat. This is necessary to create the supercavity around the object, although the nose should also be slightly curved to reduce drag. Because the underwater vessel is in a bubble and surrounded by water vapour rather than water, there is virtually no skin friction, therefore the vessel will not be slowed down.

The aspects that still need to be developed before high-speed under oceanic transportation is possible are a propulsion system, a power source, and steering system. For long distance travel, a nuclear reactor would probably be the only power source compact enough for the vessel, although an aluminium-burning rocket could use the water as an oxidiser and wouldn't need to carry oxygen. The steering problem is currently being developed through the use of fins, which leaves the major problem being: how will the vessel reach these high speeds in the first place?

Advantages of Technology in 2020:

The advantages of this technology would be that travelling would become even faster. One of these underwater vessels could travel from New York to London in well under an hour! Humans could basically travel anywhere in the world in dramatically less time than current transportation technology allows.

Disadvantages of Technology in 2020:

The major disadvantages with this technology involve safety. Since these underwater vessels would be primarily used for passenger transportation, there are many safety concerns. One problem already stated is how will these vessels obtain supersonic speed in the first place? And will it be safe to have passengers on board when accelerating to such high speeds? Another problem is the possibility of the vessel slowing down to subsonic speeds while underwater and supercavitation will fail to be possible.

Possible Vote:

If this technology were possible in the year 2020, would you prefer it as a transportation means, or would you feel safer in an aeroplane? (not taking expenses into account)

Flourish:

Describe the technology behind underwater high-speed vessels (a diagram would work well here). Also, give some facts about how fast travel would be at such speeds, (NY to London in under an hour).

Take-Away Message:

The take-away message would be that travel technology is getting very advanced and very fast, but safety needs to be the number one concern. Before implementing the idea of under-oceanic transportation, everything that could possibly go wrong should be thought of and emergency evacuation means available.

References: Graham-Rowe, D. (2000, July 23). Faster than a speeding bullet. New Scientist. 26-29.

8.3.7 Nanomedicine

Activity Message:

Nanotechnology is going to be one of the most important technologies to emerge in the 21st century. Microscopic devices will have an incredible array of potential uses, including many in the field of medicine.

Background information:

Currently robotics technology is a field where rapid advancements are being made. The current progress is to not only make the robots more versatile but also to make them smaller. Robots currently range from large automated machines that assist in assembly lines to smaller assisting robots in laboratories. Current research is leading toward smaller robots which could, in time, lead to microscopic robots designed to assist in healing people by supplementing the immune system or assisting in repairing damaged parts of the body (bones, muscles, possibly even nerves). Current technology has already built robots that can pick up and set down microscopic beads of glass using small arms made of a metal that responds to electric charge. The charge causes a contraction in the metal that causes the arm to close on the bead, picking it up. As technology and research in this field progresses further the small robots will only become smaller and more agile.

Advantages of Technology in 2020:

The major advantage this provides is the ability to enter the body and perform directed repair procedures without causing major damage to the outer layers. If the technology progresses far enough doctors could perform much more complex surgical

procedures than they do now using no surgical cuts on the outside. This will assist in the recovery periods needed after surgery by making them shorter as well as making the surgeries more accurate. It also will make the preparation period before an operation more accurate by knowing exactly what will be faced during the surgical procedure before attempting to procedure.

Disadvantages of Technology in 2020:

While also being used for major advancements in helping people this technology has the ability to be misused as well. The misuse could come in the form of altering a person without their knowledge, or to kill them by inducing medical malfunctions using the robots. Other disadvantages are the possibility of administering the robots to the wrong patient (much like administering the wrong medication to a patient today).

Current State of the Technology:

The current state of the technology is that robots are being made and research is being done to further the microscopic features as well as the ability to make the robots do more. The current size of the smallest robots is borderline microscopic, with limited ability in manipulating microscopic beads of glass (online articles through MSN news, summer 2000).

Probable Cost of the Technology in 2020:

The probable cost of this technology will likely be in comparison with many of the more costly medical procedures available today. The savings in the other medical

procedures will offset the cost of the robots. Many of these procedures will likely be supported and covered by medical insurance due to the smaller likelihood of errors once the technology is perfected.

Visitors' Reactions:

Many of the visitors will have trouble believing the technology is as close as it is. Most will readily believe that the technology could happen someday, but will have trouble with the idea that it could happen in roughly 20 years. The visitors will also feel shocked and surprised that the technology could be used in this manner. They will also likely be terrified of the potential repercussions of misuse.

Visitors' Prior Knowledge:

Most people in the general public are very ignorant about robots. Most people, when the word "robot" is used picture C-3PO or some other robot that looks very much like a person. The reality is that robots can be in any shape or form and that they are just machines that do a task without direct instruction at every step ot the way by a human user. This is the first misinformation that will have to be fixed before the people will understand the concept. The visitor's will also likely have no knowledge of the idea behind (and the current technology of) microscopic robots for medical purposes.

Take-away message:

Robotic implants in the body to assist with healing. "Can you imagine having thousands, maybe millions, or microscopic robots in your blood to help fix problems or injuries?"

Quotations:

There are currently no valid quotations to list here.

Other Points:

This topic has been focused on in episodes of Star Trek: The Next Generation as well as a few other science fiction stories.

References:

Desai, T., Hansford, D., & Ferrari, M. (2000, October). Micromachined interfaces: New approaches in cell immunoisolation and biomolecular separation.

Weed, W. S. (2000, September). Downloading your body. Discover, 82-85.

8.3.8 Ocean Floor Colonisation

Activity Message:

With world population growing at a rapid rate, we are going to need new places for people to live. Sub-oceanic habitats are one potential possibility.

Background information:

Currently it is possible to spend short periods of time living in artificial environments on the bottom of the ocean. Scientists in structures referred to as "Habitats" do this. Unfortunately the habitats have a depth limitation (currently believed to be 60 ft, but research is under way to verify. J.C.).

A habitat has the ability to be sealed off from the ocean outside, so that it can only be accessed via a central airlock in the floor. Once the habitat is placed on the location that it be anchored its air supply is pressurised to match that of the water pressure outside. Once this has taken place both airlock doors can be opened so that the floor is exposed to the ocean. Due to the pressurisation the water will not enter. This creates a small "bubble" of air under the ocean for the scientists to live in.

The pressurisation process is completed via an umbilical cord to the surface where a support platform exists. This platform keeps the habitat's air supply fresh as well as at the proper pressure. The umbilical cord also supplies fresh water for drinking and electricity (and communication lines) from (and to) the surface.

Currently we have the technology to build structures that can easily withstand the depths of the ocean with an un-pressurized air supply. Along with this technology is the ability to clean and recycle the air. With these two technologies an undersea colony

could be built in such a manner that it would need to receive food supplies to keep it maintained, but not need external sources of fresh water, energy or air. These technologies can currently be found in military submarines which can be submersed for months at a time if the need were to occur (a more precise duration can be found during the research phase).

Advantages of Technology in 2020:

If this course of action were to be taken by the general population of this planet the advantages would be the potential of alleviating the population stress of those living on the land surface of the planet by moving a portion of the population to the floor of the ocean. Other advantages would be the vast amount of knowledge that could be gained by having a permanent residence in a prime research location as well as the potential of harvesting some of the ocean's resources.

Disadvantages of Technology in 2020:

Which nations would regulate these colonies, and what would determine the "ownership" of the surrounding landscape of the ocean floor. Who would be responsible for maintaining the required food supply. Other disadvantages would be how to deal with a disaster or social problems within the colony and how to maintain communication with the rest of the planet (water provides a barrier to all forms of radiation, even radio). The majority of the disadvantages lie in the social dynamics of how to manage people who take up permanent residence in a region currently considered internationally owned.

Current State of the Technology:

The technology to create these colonies exists at the moment. Most of it is in use in military submarines everyday. The basics needed to build and maintain such a colony are air recycling, water recycling, energy efficiency, and pressure manipulation. Currently these technologies are all fully developed. The need is to redirect their use into one, permanent, stationary structure which may or may not be fully self sufficient. The BioDome experiments have been successful is demonstrating that we have the knowledge to make a partially self sustaining colony that is isolated from the outside world. This technology, combined with the ability to block out the vast pressures of oceanic depths could easily lead to permanent ocean floor colonies.

Probable Cost of the Technology in 2020

Given that all of the technology needed to develop these under water colonies, the cost to develop it would be insignificant. The adaptation of the technology will require marginal research and development cost, but nothing exorbitant.

Visitors' Reactions:

The visitors will most likely find themselves intrigued by the possibilities. This concept will also make them ponder the possibility. That the technology is currently available will likely surprise most visitors.

Visitors' Prior Knowledge:

Most visitors will have no knowledge of the ability to currently spend short periods of time in temporary residence on the ocean floor. Most of the visitors' knowledge about undersea habitation will be limited to the general public's knowledge of military submarines. This topic is not in the media much because it is not speculated to have much interest and few organisations (if any) have done serious research into creating permanent habitation facilities on the ocean floor.

Take-Away Message:

The return of "Atlantis." We can move to permanent residence on the ocean floor. This will help alleviate the current population stress of the land surface area.

Quotations:

There are currently no valid quotations to list here.

Other Points:

The topic of undersea colonisation has been the subject of several science fiction stories, ranging from SeaQuest DSV to The Abyss.

8.3.9 Renewable Energy Sources

Activity Message:

The Earth's natural resources are being used very rapidly and will continue to diminish as the population continues to increase, so new energy technologies using renewable sources need to be developed. One such technology is flywheels, which could eventually replace batteries if developed further.

Background Information:

There are many renewable energy sources being developed and used currently. They include:

Wind Energy

Modern wind turbines take energy from the wind to generate electricity, charge batteries, and pump water. These modern turbines are either horizontal axis turbines or vertical axis turbines.

Tidal Energy

Tidal energy makes use of ocean waves, tides, or the thermal energy stored in the ocean. Energy can be generated from waves crashing on the shoreline or through the use of current hydropower technology through the rise and fall of the tides. This is possible by building a dam across the opening to a tidal basin; the dam contains a sluice that is opened during the rising of the tide to allow water to flow in. When the tide is high, the sluice is closed, and as the sea level drops, the elevated water is used to generate electricity through hydropower technologies. Researchers are currently developing ways

to extract energy directly from tidal flow streams. Lastly, the ocean absorbs much of the sun's heat, which can be converted into electricity also.

Geothermal Energy

Geothermal energy uses the heat of the Earth for direct use applications, such as geothermal heat pumps and electrical power production. Drilling technologies are under development and make use of improved drill bits, slimhole drilling, and advanced instruments. Geothermal hot water at the Earth's surface can be used directly for heating buildings and as a heat supply for a variety of commercial and industrial uses. Finally, underground reservoirs of hot water or steam can be tapped for electrical power production.

Solar Energy

Solar energy is categorised either in the form of heat (thermal energy) or light (photovoltaics). Solar thermal technology is used as heat for such applications as space heating, pool heating, and water heating for homes and businesses. Photovoltaics (PV) is a semiconductor – based technology that converts light into an electric current, which can be used immediately or stored.

Flywheels

A flywheel is a rapidly spinning cylinder or disc suspended in a vacuum-sealed container that stores kinetic energy, which can be converted into electrical energy. Solar-powered flywheels use photovoltaic panels to generate electricity to spin the flywheel.

Fusion

Fusion, the conversion of matter into energy, is the power source of the sun and stars, and could soon be an energy source on Earth. It involves heating hydrogen to very high temperatures forming plasma. In plasma, hydrogen atoms combine or "fuse" to form helium, while some of the remaining hydrogen is converted directly into energy.

Fuel Cells

Fuel cells use hydrogen to produce energy in the way a battery works, but they never run down and don't require recharging. This technique involves an electrolyte sandwiched between two electrodes, a positive (cathode), fed with oxygen, and a negative (anode), fed with hydrogen. The hydrogen atom separates, the electron going through an external circuit, creating a flow of electricity, and the proton migrating through the electrolyte to the cathode where it is reunited with the oxygen and the electron producing water and heat.

Advantages of Technology in 2020:

There are many advantages associated with the development and implementation of renewable energy sources. First is the obvious one, they are renewable, meaning that the source of the energy will never run out. Most of these energy technologies are also environmentally safe, and will help decrease pollution and global warming problems (no more smog or acid rain). These forms of energy are also cheaper than the current prices we pay for oil, gas, and electricity, and could replace the lead acid batteries which are not only environmentally unsafe, but are affected by temperature extremes. Another advantage is that the plants that would be created to utilise these technologies would

create more jobs, meaning that not only would those who are employed by current energy companies not lose their jobs, but also more people could be employed. Lastly, many of these renewable energy technologies can be used in conjunction with one another, to create more efficient means of generating energy than one alone.

Disadvantages of Technology in 2020:

People aren't receptive to change. It would be difficult to persuade the public to buy new cars, install new systems into their homes, etc., even if it could be proven that this change would be beneficial in the future.

Possible Vote:

A possible question could be:

Do you think we should make people use renewable energy in the future to preserve what we have left of the world's natural resources, even though it would require drastic changes in lifestyle?

(Note: to reduce the size of this topic and stray from "car" technology, a possible angle to take would be the replacement of batteries with flywheels for a portable energy source.)

Flourish:

Provide facts and statistics about some of these technologies already in place.

For example: Utilising only 1% of the earth's deserts to produce clean solar electric energy would provide more electricity than is currently being produced on the entire planet by fossil fuels. (Status Report on Solar Thermal Power Plants. Pilkington Solar International GmbH: Cologne, Germany, 1996.)

Take-Away Message:

The take-out message would be to inform the museum visitors that the Earth's natural resources are depleting and the situation will continue to worsen until we do something about it. A very possible and reasonable solution to the problem is to begin utilising the renewable energy sources that are becoming available now.

8.3.10 Smart Clothes

Activity Message:

Sensors and environmental control systems have become advanced enough and small enough that they could be integrated into clothing. The result would be clothes that would monitor the wearer's environment an make adjustments to keep the wearer optimally comfortable.

Background information:

As technology increases more and more products are being imbedded with self-monitoring sensors. These sensors range from everyday devices that people use directly, such as thermostats, to devices that most people are unaware of, such as sensors in automobiles to determine fuel flow rates, among other things.

Such sensors could easily be adapted to clothing. Once installed into clothes these sensors could easily monitor all environmental conditions to insure the ideal comfort levels as determined by that wearer.

Advantages of Technology in 2020:

The obvious advantage is that the wearer of such clothing will always be at the highest comfort level possible. Heaters can counter the cold weather, while fans and air vents can combat warmer weather. In high humidity levels or even rain the usage of both sets of sensors can remove the excess water from the clothing.

Disadvantages of Technology in 2020:

The disadvantages are also obvious. Currently portable power supplies have either long life or compactness. To get both one must contribute large sums of money to the manufacturer. Other disadvantages lie in wearer complex electronic circuitry. In the event that the waterproof lining were to fail short circuits could occur, causing damage to the clothing, the wearer or both. Other disadvantages lie in the possibility of the technology malfunctioning. This could cause adverse effects in the interior environment (and potentially hazardous health conditions. Also malfunctioning equipment would be extremely expensive to repair, therefore making replacement cheaper than repair. The final disadvantage lies in the economic and social repercussions of such an advancement in technology. It is not unheard for situations to arise (more common in highly populated areas, such as cities, than relatively low populated areas) for crimes to revolve around the clothing of the victim. This can, and does, occur because of the desirability of the victim's clothing or the inference that the victim has money because they are wearing expensive clothing. With the advent of smart clothing the types of clothing theft would widen the amounts and types of clothing that people find desirable and profitable.

Current State of the Technology:

The technology to make these clothes exists already. Refrigerators, central heating and air conditioning all have thermostats. Portable regulating heaters are currently available in winter socks (available at various skiing stores and such websites as http://www.surprise.com) and are powered by batteries. Portable fans can be purchased at

such stores as RadioShack. Venting technology is simply opening small flaps and closing them as needed.

Probable Cost of Technology in 2020:

The probably cost of the technology in the year 2020 is low. The technology is readily available and awaiting some entrepreneur to adapt it to clothing. Heating units will be highly desirable in clothing worn by people that spend a significant amount of time outside during the winter months (and in harsh regions), while cooling units will be very popular among those that spend a substantial portion of their time outside in extremely warm climates. Moist climates and climates that have extreme temperature ranges will bring potential demand for types of clothing that can dry the wearer out, as well as heat them in the cold and cool them in the hot temperatures. Basically the cost will be slightly higher than expensive jackets and other forms of clothing are now.

Visitors' Reactions:

Most visitors will carry the response that this idea is an incredibly useful one. Many will desire such articles of clothing based on the idea that they could always be comfortable. The downside of malfunctions will likely be forgotten in the same manner that people forget the potential for malfunction in all of their normal, everyday appliances and pieces of machinery.

Visitors' Prior Knowledge:

Most visitors will not realise that the technology is currently available, but not yet converted for this purpose. Most, however, will be aware of all the concepts in the smart clothing and therefore see the possibilities of this technology being adapted to this type of use.

Take-Away Message:

How useful and desirable would electronic, smart clothing be? Would you want to wear it? What happens when it fails?

Quotations:

Other Points:

No other points at this point in the research.

References:

8.3.11 Tissue Engineering

Activity Message:

Tissue engineering is the process of taking a patient's own cells and creating "spare parts" (organs, arteries, joints, etc.) in a laboratory and then implanting them into the patient.

Background Information

The process of tissue engineering begins with the selection of the cells to begin proliferating into the organ. Most commonly and successfully, human stem cells are chosen for this purpose. Stem cells are human cells that have not yet differentiated into a specialised type of cell. These are most often found in the earliest stages of an embryo. The cells are considered controversial because there is some ethical debate over whether the harvesting of these cells is considered abortion.

Once the cells have been selected and a sample has been taken from the patient, the cells need a place to grow. The scaffolding for the organ is made of a degradable, porous polymer, usually PGA-PLA. The scaffolding must be porous so that the cells can attach themselves securely and in the innermost regions of the organ. Also, it must be porous so that nutrients such and oxygen can reach all the cells and the so that the cells can excrete waste products.

The cells, once attached to the scaffolding, are allowed to proliferate into the final organ. Special consideration is given to assuring the cells nutrients and hormones that simulate human growth hormones. The cells must grow in an environment to that in

which the internal organ lives so that it develops the necessary characteristics for adapting to such an environment. For instance, and artificial artery must simulate the cyclic pressures and shear stresses as in a human artery so that it can withstand those conditions once implanted. For this purpose, bioreactors have been successful. Bioreactors simulate various internal conditions so as to "trick" the cells into thinking they are actually growing inside the body.

Once the cells have grown into a complete or almost complete organ, it can be implanted into the patient. By this time, the scaffold should have degraded completely as the cells filled in the area. Rejection is eliminated by using the patient's own cells, so the main concern is infection and the maintenance of the organ once implanted. In past studies, artificial organs have self-destructed due to cells that realised the change in environment from the laboratory to the body. Another implantation concern is the connection of the implant to the vasculature of the patient. The most successful method of combating this is to create the vasculature connections within the implant and then surgically connect these to the human vasculature. This reduces the chances that the human vasculature will refuse to fuse to the implant and reduces the amount of time the implant goes without a fresh, circulating blood supply.

Advantages of Technology in 2020

- Organs of patient's own cells eliminates the possibility of rejection
- Gives hope to patients with terminal diseases (i.e. kidney failure) for whom "it's only a matter of time"
- Has the potential to save hundreds of thousands of lives every year

Disadvantages of Technology in 2020

- People won't die! Over population could become an increasing concern.
- Proliferation time is lengthy, so this would not benefit accident victims (anything sudden)

Progress of Technology to Date

Currently have artificial skin grafts on market. Cartilage is in clinical trials. Supposedly, organs such as liver and heart could be made in 10 years

Cost of Technology in 2020

Expensive! At present, skin grafts cost approximately 1-10,000 U.S. dollars (including surgical costs). In the next twenty years, expected costs will decline greatly for skin and cartilage but will remain in the 10-100 thousand U.S. dollar range for larger organs.

Take-Away Message

Tissue engineering of organs holds great promise for the immediate future. However, the time has come for scientists and the public to consider the implications of this technology. Will the good of saving millions of lives overcome the bad of an unnatural and possibly overpopulating (the earth by renewing the life span of humans) procedure?

How Visitors Will Feel

Surprised, hopeful

Visitors Prior Knowledge

Most know of skin grafts but don't think it is possible for major organs to be done.

Other Points

Possible angles: You're a diabetic but the thought of taking a shot and medicine every day for the rest of your life seems unbearable. Not to worry! At the local hospital, doctors can just grow you a new pancreas!

Your father needs a triple bypass surgery but his arteries are blocked beyond repair. Stents and grafts do not look promising. Again, not to worry! New arteries can be grown to replace the clogged ones, and miraculously saving your father's life.

Differentiating this topic from two other existing games – lab-grown meat and bionic limbs -- should not pose a problem. Bionic limbs are electrically based. Stimulation from the brain translates into electrical impulses that are able to move artificial limbs. Tissue engineering is an overall process with mainly chemical and biological foci. Lab grown meat is similar in the overall concept, but many more factors must be taken into consideration with tissue engineering. Rejection plagues organ transplants. If it was not a concern, organ transplants would be a much more acceptable procedure. Tissue engineering solves that problem. Also, engineered tissue will forever become a living part of you. Lab grown meat is digested and broken down into the fundamental nutrients that

natural meat also contains. Yet, engineered tissue remains artificial, but alive and working, for the rest of the person's life.

Experts and Sources

www.tissueengineering.gov (US site)

www.tissue-engineering.de (Denmark site)

(This will bring you to a slide show providing the process of tissue engineering of skin)

(There are many sources, not only websites! I included these as a quick reference)

Dr. Robert Langer – Massachusetts Institute of Technology (MIT)

Professor Satya Shivkumar – Professor of Biomaterials/Tissue Engineering at WPI

8.3.12 Virtual Reality

Activity Message:

As video games become more realistic, the feasibility of virtual reality games becomes greater. Virtual reality systems are already in use, although not widely popular. Their potential in the fields of medicine, general education and even leisure activities is increasing.

Background Information:

Virtual reality systems range from simple to complex. Three-dimensional video games, flight simulators and immersion helmets are all considered virtual reality systems. The systems that will likely become technology developed by the year 2020 are the immersion methods. Virtual reality utilises all the senses to create an artificial environment that appears extremely lifelike. These systems usually force the user to wear various suits of sensors that at the present are often bulky, heavy and uncomfortable. The user has a helmet, which houses numerous computers. Often, the helmet includes various screens, one for each eye's front view, and one for each eye's periphery view. Often, the screens' projections are slightly different to simulate stereoscopic vision. The user may also wear sensor gloves to be able to "touch" objects in the artificial environment. Recently, smell and taste have been used in conjunction with sight, hearing and touch to create a more realistic experience. Recent advances with virtual reality systems have allowed the user to completely immerse, interact, and alter the artificial environment. Virtual reality can allow people to experience events or places that they never normally would for reasons of expense, danger, or others.

Advantages of Technology in 2020:

- Practice of dangerous procedures (surgery, space exploration)
- Excellent learning tool (frog dissection could become obsolete as students "travel inside a VR frog"

Disadvantages of Technology in 2020:

- Costs may well still be relatively high
- Technical expertise required for use (more than simple computer literacy)

Current State of the Technology:

Virtual reality systems are currently available for special applications, but cost and accessibility have limited their widespread production. The University of North Carolina Medical Centre uses virtual reality equipment to practice radiation treatments. NASA uses virtual reality systems to "fly" onto the surface of Mars. Other applications include the fields of medicine, chemistry, architecture, interior design, military, and robotics.

Cost of the Technology in 2020:

Expensive! At present, one type of VRL computer for use with virtual reality costs a quarter of a million (US) dollars. (See web references at end of proposal.) Prices will decline as technology is updated and hopefully, by the year 2020, prices will allow

most companies to own them. As of today's technology, it does not seem feasible (due to expense) for the average consumer to be able to purchase virtual reality equipment.

Visitors' Reactions:

Not too surprised, anxious, excited

Visitors' Prior Knowledge:

The general public has knowledge of virtual reality systems. Most, however, have never used one.

Take-Away Message:

Virtual reality systems will become widespread in the future if technology advances on this path. People must decide how integral a part of their life they will become however. Will virtual reality vacations and activities take the place of the actual activities?

Other Points:

Possible angles: using virtual reality as a learning tool in all schools; video game replacement with virtual reality games; the limiting of certain activities to virtual reality (i.e. *population control – only allowed to procreate in virtual reality)

Experts and Sources:

www.csun.edu cod 93virt AVRSE~1.html - This site states the progress to date of educational applications and provides advantages

and disadvantages to virtual reality systems.

www.vrs.org.uk - This is the site for the Virtual Reality Society, an international organisation based in England.

Professor John A. Vince, Bournemouth University; Dr. Robert D. Macredie, Brunel University; Professor Rae A. Earnshaw, University of Bradford – these are the managing editors of the Virtual Reality Society (VRS) and the VRS Journal.

8.3.13 Wearable Computers

Activity Message:

Computers are constantly becoming smaller and more powerful. Eventually people will be able to carry more power than today's desktop computers in a less conspicuous and more easily used package than today's laptops.

Background Information:

As technology becomes more advanced each year computers become not only more powerful, but also smaller. Every day more and more people start using a mobile phone or a personal digital assistant (PDA). These, too, become more and more powerful with each new product line that finds its way onto the consumer market. At what point do these technologies all become replaced by wearable computers that have mobile up-links the all the information the internet can provide?

Advantages of Technology in 2020:

This concept provides a wealth of potential benefits to both mankind in general and to individual persons who take advantage of the abilities it generates (http://mevard.www.media.mit.edu/projects/wearables/). Authors such as Neil Stephenson has speculated this technology in their current works of fiction and the rudimentary workings of these fictional abilities are becoming apparent in experimental stages at such engineering institutions as MIT. The obvious advantages are the ability to access any information at any time. This can be as simple as a definition to a word or as

complex as a doctorate thesis on quantum mechanics. Essentially the wearing of the computer would have full access to the entire world wide web at al times via the computer's up-link and the visual interface. Professional advantages would be the ability to always be aware of the financial market, or to be aware, instantaneously, of any changes in a project definition. The public could, theoretically, take advantage of the technology by equipping law enforcement agents allowing them real time information updates from satellite transmissions or via secure links to headquarters regarding any situation that they may find themselves in at any point.

With technology such as this the potential advantages are innumerable, mainly because, as computers advance, the limitations on what functions they can assist us in become smaller and smaller.

Disadvantages of Technology in 2020:

The major disadvantage of this technology would be the continuing distancing from reality that people are starting to experience today. It is widely speculated by the media that incidents such as the Columbine High School incident (several students entering with firearms and shooting colleagues and teachers) are spawned by a detachment from reality by virtual reality and violence in the popular mass media (movies and television). If the ability to go online for any purpose were to be present at al times this detachment could continue to grow. The questions becomes "when does society as we know it cease to exist?"

Current State of the Technology:

Currently the technology exists to build these machines (http://wearcam.org/computing). For the most part, the machines are more bulky than most would desire, but the main reason for this is because the parts must be built. The technology exists to make computers that are easily small enough to be built into cases which can be worn, however the technology is limited to portable computers referred to as "laptops" and "notebook computers" (the Sony Vaio, for example).

Probable Cost of the Technology in 2020:

In the year 2020 this technology should be priced the same as a laptop computer is today. Desktop computers will likely be things of the past, replaced by laptop computers. Most likely homes will have a central server, which will be roughly the size of a desktop computer today.

Visitor Reactions:

Most visitors will most likely not thought about the subject. The idea behind the subject is that it could happen now, and therefore has an extremely high probability of occurring within the next twenty years. The visitor response should vary widely on this topic ranging from those that love the idea to those that think it is an technological abomination of society.

Visitor's Prior Knowledge:

As stated above, most visitors will not be aware that there are currently groups making these machines. They will, for the most part, be aware of laptops and notebook computers, so the cognitive leap to understanding wearable machines should be an easy one for everyone who comes to visit.

Take-Away Message:

Technology is advancing. Computers are becoming more portable at all times. With mobile phones being as large a nuisance as they are in public at the moment do we wish to have people who are not only on the phone at all times, but also on the internet at all times as well. At what point does this ability become a safety hazard to all those surrounding the individual with the wearable computer?

Other Points:

See the two major references for more in depth information.

http://wearcam.org/computing

http://mevard.www.media.mit.edu/projects/wearables

Other References:

Kirschner, S. K. (2000, September). Get wired. Popular Science, 78-81.

Komando, K. (2000, September). Policing your PC. Popular Mechanics,

32,34.

Komando, K. (2000, September). Road warriors. Popular Mechanics, 80-83, 136.

Miller, C. (2000, October). Calling all wrist phones. Popular Science, 64, 65.

O'Malley, C. (2000, November). E-Life. Popular Science, 8, 10.

8.3.14 Weather Modification

Activity Message:

Although thoughts of weather control haven't been taken seriously by the scientific community in the past, new technologies are being developed that could prove weather modification possible.

Background Information:

Ben Eastlund, an expert on electromagnetism, has been studying weather modification for years and has finally developed a theory that could work to stop tornadoes from forming. Extreme weather kills thousands every year, and this number has been predicted to increase due to global warming. Eastlund's idea involves blasting a tornado with powerful beams of microwave radiation generated by huge solar powered satellites. According to his research, tornadoes form from cold rainy downdrafts in a storm that represent a crucial flow of energy. By hitting this cold downdraft with a beam of microwaves, the energy flow that allows a tornado to form could essentially be cut off. It has also been predicted that hurricanes could be prevented from forming by a slight change in the energy cycle from which they form. Hurricanes start with an energy cycle spawned from the hot, humid air over the tropics; therefore a small change in this energy cycle could make the hurricane unstable.

There are many other weather modification ideas that have been developed, and if tested successfully could allow humans to have control over virtually every aspect of the weather. It could be possible, for instance, to heat the edge of the jet stream of high

winds and alter its direction, essentially "controlling the wind". Another example involves "controlling the rain", which is actually an idea developed in the mid 1900's that worked, but there was too much suspicion that the treatment and the rain were merely coincidence. This technique, called "cloud seeding", involves sprinkling clouds with dry ice (solid carbon dioxide) or particles of silver iodide. Water then forms around these particles and falls to the ground in droplets as big as normal rain droplets.

Advantages of Technology in 2020:

The advantages of this technology would be the prevention of natural disasters and storms that kill thousands every year. Weather threatens every part of the world in some form, therefore people everywhere would live more comfortably and safely if weather wasn't a threat.

Disadvantages of Technology in 2020:

Some of the techniques being developed to make weather modification possible could be hazardous to the environment and the population if not developed correctly. For instance, Eastlund's idea of blasting tornadoes with microwaves may not be safe for the environment and people if they are subject to the radiation.

Possible Vote:

Would you feel safer without the threat of extreme weather, or would you feel just as threatened by the techniques being used to prevent the extreme weather?

Flourish:

Facts to go along with this game could be the techniques being developed and the ideas that make weather modification a future possibility.

Take-Away Message:

The message that we would want the visitors to take away is that weather modification would have many advantages and people would feel safer without the threat of extreme weather. At the same time, there could be dangers associated with some of the techniques that are currently being developed.

References:

Matthews, R. (2000, August 12). The weather man. New Scientist, 24-29.

8.4 Appendix D: Evaluation Data

8.4.1 Front-End Topic Evaluation

8.4.1.1 Questionnaires

These are the questionnaires used to interview visitors and evaluate the twelve topics for previous knowledge and interest.
(Note: Each interview consisted of only three topics.)

Hello, my name is _____, and I work here at the Science Museum. We are currently researching themes for an exhibit looking at the future of science. Would you mind answering a few questions? It should only take about 5 minutes.

I'll be asking you to rate your interest in different topics. Please try to look at each topic separately and not compare your interest in one as more or less than your interest in another.

(Prompt: For instance, if you really like all 3 of the topics, you can give them all the highest score. If you do not like any of them, you can give them all the lowest score.)

Weather Modification

1. Have you ever heard of the possibility of humans controlling the weather?

No – Skip to question 2.

Yes – Can you tell me some of the things you've heard?

2. On a scale of 1 to 5 where 1 is not interested at all and 5 is very interested, how interested would you be in finding out how controlling the weather could be a real possibility in 20 years?

1 2 3 4 5

Sex: M F

Age: <8 8-16 17-25 26-40 >40

Flying Cars

1. Have you ever heard of an actual flying car?

   No – Skip to question 2.
   Yes – What have you heard?

2. On a scale of 1 to 5 where 1 is not interested at all and 5 is very interested, how interested would you be in finding out about cars that can fly and when we can expect to see them?

   1 2 3 4 5

Sex: M F

Age: <8 8-16 17-25 26-40 >40

Cloning Extinct Species

1. Is the term cloning familiar to you?

   No – Cloning is a way to make an exact copy of a living thing. Skip to question 2.
   Yes – Have you ever heard of cloning extinct species, such as dinosaurs?

      No – Skip to question 2.
      Yes – What kinds of things have you heard?

2. On the same scale of 1 to 5, how interested would you be in learning about a way to bring back extinct species, such as dinosaurs, by the year 2020?

   1 2 3 4 5

Sex: M F

Age: <8 8-16 17-25 26-40 >40

Artificial Intelligence

1. Have you ever heard of artificial intelligence or androids?

   No – Artificial intelligence the ability of computers to think like humans, and androids are robots that use this intelligence. Skip to question 2
   Yes – Can you tell me some of the things you've heard?

2. On a scale of 1 to 5 where 1 is not interested at all and 5 is very interested, how interested would you be in finding out how very advanced computers could make robot servants a possibility in 20 years?

1 2 3 4 5

Sex: M F

Age: <8 8-16 17-25 26-40 >40

Wearable Computers

1. Have you ever heard of computerised clothing?

   No – Computerised clothing is clothing with a computer built in which would make it possible for you to have your computer with you at all times. Skip to question 2
   Yes – What have you heard?

2. On a scale of 1 to 5 where 1 is not interested at all and 5 is very interested, how interested would you be in finding out about computers that you can wear as part of your clothing?

		1	2	3	4	5
Sex:	M	F				
Age:		<8	8-16	17-25	26-40	>40

Ocean Floor Colonisation

1. Have you ever heard of the possibility of people colonising the ocean floor?

   No – Research is currently being done to find a way to build a habitat on the ocean floor suitable for humans. Skip to question 2

   Yes – What kinds of things have you heard?

   (If mentions submarines: Have you ever heard about or thought about a permanent structure under the surface of the ocean in which people could live?)

2. On a scale of 1 to 5 where 1 is not interested at all and 5 is very interested, how interested would you be in learning about the possibility of living for an extended period of time on the ocean floor?

1 2 3 4 5

Sex: M F

Age: <8 8-16 17-25 26-40 >40

Renewable Energy

1. Are you familiar with the concept of flywheels?

No – A flywheel is a rapidly spinning cylinder that stores energy, which can be

used like a battery. Skip to question 2.
Yes - Could you tell me a little of what you know?

2. On a scale of 1 to 5, 1 being not interested at all and 5 being very interested, how interested would you be in learning about an energy storage technology that would take the place of batteries?

1 2 3 4 5

Sex: M F

Age: <8 8-16 17-25 26-40 >40

Virtual Reality

Have you ever heard of virtual reality?

No – Virtual reality is a developing technology that may allow you to control computers with your brain. Skip to question 2.
Yes – Have you ever heard of virtual reality being used to control computers with your brain?

No – Developments are being made that will allow this to be possible. Skip to question 2.
Yes –Can you tell me what you've heard?

2. On a scale of 1 to 5, how interested would you be in learning about the brain being used to control computers.

1 2 3 4 5

Sex: M F

Age: <8 8-16 17-25 26-40 >40

Supersonic Submarines

1. Are you aware that research is being done that would allow submarines to travel faster than the speed of sound?

   No – Research is being done to make it possible in 20 years for a submarine to travel underwater faster than an aeroplane in the sky. Skip to question 2.
   Yes -Could you tell me a little of what you've heard?

2. On a scale of 1 to 5, how interested would you be in learning about supersonic submarines that could travel from London to New York in less than an hour?

   1 2 3 4 5

Sex: M F

Age: <8 8-16 17-25 26-40 >40

Nanotechnology

1. Have you ever heard of machines invisible to the human eye used in medicine?

   No – These are tiny machines that can travel through the body to help repair injuries faster. Skip to question 2
   Yes – Could you please tell me some of the things you've heard?

2. On a scale of 1 to 5, where 5 is very interested and 1 is not interested at all, how interested would you be in learning about microscopic machines in medicine?

1 2 3 4 5

Sex: M F

Age: <8 8-16 17-25 26-40 >40

Genetic Enhancement

1. Is the topic of enhancing genetic traits familiar to you?

   No – Enhancing genetic traits involves changing around the blueprint of your body to make you stronger, faster, smarter, etc. Skip to question 2
   Yes - Could you tell me what you have heard about this topic?

2. On a scale of 1 to 5, how interested would you be in learning about enhancing genetics?

1	2	3	4	5	
Sex: M	F				
Age:	<8	8-16	17-25	26-40	>40

Tissue Engineering

1. Have you heard of growing human organs in a laboratory?

   No – Advances are being made that would make it possible to grow an entire organ, such as a heart or lung, from a few cells. Skip to question 2
   Yes - What are some of things that you have heard?

2. On the scale of 1 to 5, how interested would you be in finding out more about growing human organs in a laboratory?

1 2 3 4 5

Sex: M F

Age: <8 8-16 17-25 26-40 >40

8.4.1.2 Quantitative Topic Evaluation Data

Topic	Cumulative Score	Average	Ranking	Number of Interviews
Controlling the Weather	83	4.15	1	20
Cloning Extinct Species	82.5	4.13	2	20
Artificial Intelligence	81	4.05	3	20
Nanorobots	81	4.05	3	20
Flying Cars	80.5	4.03	5	20
Super-Sonic Submarines	79	3.95	6	20
Colonising the Ocean Floor	78	3.90	7	20
Enhanced Genetic Expression	78	3.90	7	20
Virtual Reality	77	3.85	9	20
Tissue Engineering	73.5	3.68	10	20
Wearable Computers	67	3.35	11	20
Alternative Energy	64	3.20	12	20
	Scale: 0-100	Scale: 1-5		Total: 240

Table 3: Summary of Visitors' Interest in Topics

Topic	Yes	No	Percentage % yes
Android Servants	18	2	90
Cloning Extinct	16	4	80
Virtual Reality	14	6	70
Tissue Engineering	13	7	65
Gene Enhancement	11	9	55
Nanomedicine	9	11	45
Alt. Energy	9	11	45
Weather Control	8	12	40
Flying Cars	7	13	35
Ocean Colonisation	6	13	30
Wearable Computers	4	16	20
SuperSonic Subs	3	17	15

Table 2: Visitors' Awareness of Topics in Decreasing Order

Topic	Yes	No	Percentage % yes
Weather Control	8	12	40
Cloning Extinct	16	4	80
Android Servants	18	2	90
Nanomedicine	9	11	45
Flying Cars	7	13	35
SuperSonic Subs	3	17	15
Ocean Colonisation	6	13	30
Gene Enhancement	11	9	55
Virtual Reality	14	6	70
Tissue Engineering	13	7	65
Wearable Computers	4	16	20
Alt. Energy	9	11	45

Table 5: Visitor's Awareness of Topics in Decreasing Order of Interest

Individual Interview Data

Topic	Gender	Age	Numerical Rating	Asked with	Heard of it?
Alternative Energy	M	8 to 16	3	Nano, Subs	yes
	M	8 to 16	3	Ocean, Subs	yes
	M	8 to 16	3	Cars, Weather	yes
	M	8 to 16	4	Nano, Computers	yes
	M	17-25	3	Tissue, Cars	no
	M	17-25	3	Tissue, Cars	no
	M	26-40	5	Nano, Ocean	no
	M	26-40	3	Wearable, AI	no
	M	26-40	3	weather, subs	yes
	F	8 to 16	4	Tissue, Cars	no
	F	8 to 16	3	Wearable, Tissue	no
	F	17-25	3	VR, Cloning	no
	F	17-25	2	ocean, virtual	no
	F	17-25	2	tissue,genes	yes
	F	17-25	4	Nano, Weather	yes
	F	17-25	3	cars, tissue	yes
	F	17-25	3	Ocean, Genes	no
	F	17-25	3	Tissue, Cars	no
	F	26-40	3	Weather, Genes	yes
	F	26-40	4	Tissue, Cars	no

Table 6: Front-End Individual Evaluation Data: Alternative Energy

Topic	Gender	Age	Numerical Rating	Asked with	Heard of it?
Artificial Intelligence/ Android Servants	M	8 to 16	4	Weather, Cars	yes
	M	8 to 16	5	Tissue, Weather	yes
	M	8 to 16	5	Cars, Genes	yes
	M	8 to 16	5	Genes, Wearable	yes
	M	8 to 16	5	Ocean, Genes	yes
	M	8 to 16	5	Ocean, Genes	yes
	M	17-25	3	WM, OFC	yes
	M	17-25	5	tissue, ocean	yes
	M	26-40	5	Computers, Tissue	yes
	M	26-40	4	Nano, Genes	yes
	M	26-40	5	cloning, wearable	yes
	M	26-40	2	wearable, energy	yes
	M	>40	2	SS, TE	no
	F	8 to 16	5	Ocean, Cloning	yes
	F	26-40	4	Ocean, Genes	no
	F	26-40	5	Ocean, Genes	yes
	F	26-40	5	Cloning, Computers	yes
	F	26-40	3	Genes, Ocean	yes
	F	26-40	2	Weather, Cars	yes
	F	>40	2	Ocean, Genes	yes

Table 7: Front-End Individual Evaluation Data: Artificial Intelligence/Android Servants

Topic	Gender	Age	Numerical Rating	Asked with	Heard of it?
Cloning Extinct Species	M	8 to 16	5	Subs, VR	yes
	M	8 to 16	5	subs, weather	yes
	M	17-25	4	Weather, Wear	yes
	M	17-25	4.5	Cars, Genes	yes
	M	17-25	4	wearable, nano	yes
	M	26-40	4	Cars, Tissue	yes
	M	26-40	5	Weather, Wear	yes
	M	26-40	3	wearable, nano	yes
	M	26-40	3	AI, wearable	yes
	M	26-40	4	weather, wearable	yes
	M	>40	4	nano, cars	yes
	M	>40	5	Weather, Wear	yes
	F	8 to 16	5	Weather, Wear	yes
	F	8 to 16	4	Weather, Wear	no
	F	8 to 16	4	Ocean, AI	no
	F	17-25	5	VR, Energy	yes
	F	17-25	4	tissue, virtual	no
	F	26-40	3	cars, tissue	yes
	F	26-40	5	AI, Computers	yes
	F	>40	2	VR, Genes	yes

Table 8: Front-End Individual Evaluation Data: Cloning Extinct Species

Topic	Gender	Age	Numerical Rating	Asked with	Heard of it?
Colonising the Ocean Floor	M	8 to 16	5	Genes, Tissue	no
	M	8 to 16	3	Subs, Energy	yes
	M	8 to 16	5	AI, genes	no
	M	8 to 16	4	AI, genes	yes
	M	17-25	3	AI, WM	yes
	M	17-25	4	Nano, Weather	no
	M	17-25	4	subs, virtual	yes
	M	17-25	3	AI, tissue	no
	M	26-40	5	Nano, Energy	no
	M	26-40	3	weather, genes	no
	M	26-40	3	subs, nano	yes
	M	>40	3	cars, VR	no
	F	8 to 16	4	Nano, Virtual	no
	F	8 to 16	5	AI, Cloning	no
	F	17-25	3	energy, virtual	yes
	F	17-25	4	energy, genes	no
	F	26-40	4	AI, genes	no
	F	26-40	5	AI, genes	no
	F	26-40	4	AI, genes	no
	F	>40	4	AI, genes	no

Table 9: Front-End Individual Evaluation Data: Colonising the Ocean Floor

Topic	Gender	Age	Numerical Rating	Asked with	Heard of it?
Controlling the Weather	M	8 to 16	4	AI, Cars	no
	M	8 to 16	5	Cars, Energy	no
	M	8 to 16	4	Cars, Virtual	no
	M	8 to 16	5	subs, cloning	no
	M	8 to 16	4	Tissue, AI	yes
	M	17-25	5	AI, OFC	yes
	M	17-25	3	cars, tissue	no
	M	17-25	3	Nano, Ocean	yes
	M	17-25	5	Cloning, Wear	yes
	M	26-40	5	Cloning, Wear	yes
	M	26-40	4	genes, ocean	no
	M	26-40	3	cloning, wearable	yes
	M	26-40	3	energy, subs	yes
	M	>40	5	Cloning, Wear	yes
	F	8 to 16	4	Cloning, Wear	no
	F	8 to 16	5	Cloning, Wear	no
	F	17-25	5	energy, nano	no
	F	17-25	5	Tissue, Subs	no
	F	26-40	5	AI, cars	no
	F	26-40	1	Computers, Genes	no

Table 10: Front-End Individual Evaluation Data: Controlling the Weather

Topic	Gender	Age	Numerical Rating	Asked with	Heard of it?
Enhanced Genetic Expression	M	8 to 16	4	Tissue, Ocean	yes
	M	8 to 16	4	AI, ocean	yes
	M	8 to 16	4	nano, subs	no
	M	8 to 16	5	cars, AI	no
	M	8 to 16	5	AI, wearable	no
	M	8 to 16	4	AI, ocean	yes
	M	8 to 16	3	VR, Cars	yes
	M	17-25	5	Cloning, Cars	yes
	M	17-25	4	nano, VR	no
	M	26-40	4	weather, ocean	no
	M	26-40	2	AI, Nano	no
	F	17-25	4	energy, ocean	no
	F	17-25	5	energy, tissue	yes
	F	26-40	2	AI, ocean	yes
	F	26-40	2	AI, ocean	yes
	F	26-40	5	AI, ocean	yes
	F	26-40	4	Computers, Weather	yes
	F	26-40	5	Weather, Energy	no
	F	>40	3	VR, Cloning	no
	F	>40	4	AI, ocean	yes

Table 11: Front-End Individual Evaluation Data: Enhanced Genetic Expression

Topic	Gender	Age	Numerical Rating	Asked with	Heard of it?
Flying Cars	M	8 to 16	4	VR, Genes	no
	M	8 to 16	4	Weather, AI	no
	M	8 to 16	4	Energy, Weather	yes
	M	8 to 16	4	Weather, Virtual	no
	M	8 to 16	5	genes, Ai	yes
	M	17-25	3.5	Cloning, Genes	yes
	M	17-25	5	Energy, Tissue	yes
	M	17-25	4	tissue, weather	yes
	M	17-25	5	Energy, Tissue	no
	M	26-40	3	Tissue, Cloning	no
	M	>40	4	VR, Ocean	no
	M	>40	5	nano, cloning	yes
	M	>40	2	Subs, Computers,	no
	F	8 to 16	4	Energy, Tissue	no
	F	8 to 16	5	Subs, Nano	no
	F	17-25	5	Energy, Tissue	no
	F	17-25	3	energy, tissue	no
	F	26-40	5	Energy, Tissue	no
	F	26-40	2	cloning, tissue	yes
	F	26-40	4	weather, AI	no

Table 12: Front-End Individual Evaluation Data: Flying Cars

Topic	Gender	Age	Numerical Rating	Asked with	Heard of it?
Nanomedicine	M	8 to 16	4	Energy, Subs	no
	M	8 to 16	3	VR, Subs	no
	M	8 to 16	3	VR, Subs	yes
	M	8 to 16	4	subs, genes.	no
	M	8 to 16	5	Computers, Energy	no
	M	17-25	5	VR, subs	yes
	M	17-25	3	cloning, wearable	yes
	M	17-25	5	Weather, Ocean	yes
	M	17-25	5	VR, genes	no
	M	17-25	5	VR, Subs	no
	M	26-40	5	Energy, Ocean	no
	M	26-40	3	VR, Subs	yes
	M	26-40	3	subs, ocean	yes
	M	26-40	4	AI, Genes	yes
	M	26-40	3	wearable, cloning	no
	M	>40	4	cars, cloning	yes
	M	>40	5	VR, Subs	yes
	F	8 to 16	3	Ocean, Virtual	no
	F	8 to 16	4	Cars, Subs	no
	F	17-25	5	energy, weather	no

Table 13: Front-End Individual Evaluation Data: Nanomedicine

Topic	Gender	Age	Numerical Rating	Asked with	Heard of it?
Super-Sonic Submarines	M	8 to 16	4	Cloning, VR	no
	M	8 to 16	4	Nano, Energy	yes
	M	8 to 16	5	Energy, Ocean	no
	M	8 to 16	4	VR, Nano	no
	M	8 to 16	3	VR, Nano	no
	M	8 to 16	5	Virtual, Tissue	yes
	M	8 to 16	5	weather, clones	no
	M	8 to 16	3	nano, genes	no
	M	17-25	4	nano, virtual	yes
	M	17-25	3	VR, wearable	no
	M	17-25	5	VR, Nano	no
	M	17-25	3	VR, ocean	no
	M	26-40	2	VR, Nano	no
	M	26-40	4	weather, energy	no
	M	26-40	5	nano, ocean	no
	M	>40	5	AI, TE	no
	M	>40	5	VR, Nano	no
	M	>40	2	Computers, Cars	no
	F	8 to 16	5	Cars, Nano	no
	F	17-25	3	Tissue, Weather	no

Table 14: Front-End Individual Evaluation Data: Super-Sonic Submarines

Topic	Gender	Age	Numerical Rating	Asked with	Heard of it?
Tissue Engineering	M	8 to 16	3.5	AI, Weather	no
	M	8 to 16	3	virtual, wearable	no
	M	8 to 16	5	Virtual, Subs	yes
	M	8 to 16	4	Ocean, Genes	yes
	M	17-25	2	Energy, Cars	no
	M	17-25	4	AI., ocean	yes
	M	17-25	4	weather, cars	no
	M	17-25	4	Energy, Cars	yes
	M	26-40	4	Computers, AI	yes
	M	26-40	4	Cars, Cloning	yes
	M	>40	3	AI, SS	no
	F	8 to 16	4	Energy, Cars	yes
	F	8 to 16	2	wearable, energy	yes
	F	17-25	3	virtual, cloning	yes
	F	17-25	4	Energy, Cars	yes
	F	17-25	5	Subs, Weather	yes
	F	17-25	5	energy, genes	yes
	F	17-25	4	energy, cars	no
	F	26-40	3	Energy, Cars	yes
	F	26-40	3	cars, cloning	no

Table 15: Front-End Individual Evaluation Data: Tissue Engineering

Topic	Gender	Age	Numerical Rating	Asked with	Heard of it?
Virtual Reality	M	8 to 16	4	cars, genes	yes
	M	8 to 16	5	Cloning, Subs	yes
	M	8 to 16	5	Subs, Nano	yes
	M	8 to 16	4	Subs, Nano	yes
	M	8 to 16	3	Cars, Weather	no
	M	8 to 16	4.5	Tissue, Subs	yes
	M	8 to 16	3.5	tissue, wearable	yes
	M	17-25	4	nano, subs	yes
	M	17-25	5	nano, genes	no
	M	17-25	4	subs, wearable	no
	M	17-25	4	ocean, subs	no
	M	17-25	4	Subs, Nano	yes
	M	26-40	3	Subs, Nano	yes
	M	>40	4	Cars, Ocean	yes
	M	>40	1	Subs, Nano	yes
	F	8 to 16	5	Ocean, Nano	yes
	F	17-25	4	tissue, cloning	no
	F	17-25	4	Energy, Cloning	yes
	F	17-25	3	Ocean, Energy	no
	F	>40	3	Cloning, Genes	yes

Table 16: Front-End Individual Evaluation Data: Virtual Reality

Topic	Gender	Age	Numerical Rating	Asked with	Heard of it?
Wearable Computers	M	8 to 16	5	virtual, tissue	no
	M	8 to 16	5	Nano, Energy	no
	M	8 to 16	4	AI, genes	no
	M	17-25	3	cloning, nano	no
	M	17-25	4	Cloning, Weather	no
	M	17-25	4	subs, virtual	yes
	M	26-40	4	Tissue, AI	no
	M	26-40	3	Cloning, Weather	yes
	M	26-40	4	cloning, AI	no
	M	26-40	4	weather, cloning	yes
	M	26-40	2	cloning, nano	no
	M	26-40	1	AI, energy	no
	M	>40	1	Subs, Cars	no
	M	>40	5	Cloning, Weather	no
	F	8 to 16	5	Cloning, Weather	no
	F	8 to 16	2	Cloning, Weather	no
	F	8 to 16	3	Tissue, energy	no
	F	26-40	1	Energy, Genes	no
	F	26-40	4	Cloning, AI	no
	F	26-40	3	Weather, Genes	yes

Table 17: Front-End Individual Evaluation Data: Wearable Computers

8.4.1.3 Qualitative Topic Evaluation Data

Visitor Responses after being asked what they know about each of the topics.

Renewable Energy

- It can be used in a car (*M 8-16*)
- It's a wheel, knows a lot, studied last year (M 8-16)
- He knew a lot! (M 8-16)
- He doesn't remember much, covered it in school (*M 8-16*)
- Wheel that spins to store energy (*M 26-40*)
- Non-renewable energy is running out, so we need to start using renewable energy (*F 17-25*)
- Used on a car engine (*F 17-25*)
- It's a spinning wheel (*F 17-25*)
- I heard of it a long time ago (*F 26-40*)

Artificial Intelligence

- Robots like people, brains and stuff (*M 8-16*)
- They can change your DNA, take cells and make people (*M 8-16*)
- Heard of it but couldn't remember anything about it (*M 8-16*)
- Create super-humans, immune to illness, they have a brain (*M 8-16*)
- Misnomer (AI is) because no one has found out yet how to deal with unexpected impulses. They're still working on it. Not accomplished yet. If you're researching it, don't included Kevin Warrick! There's so much more above that! (*M 8-16*)
- Robots like humans (*M 8-16*)
- UFO's?, (prompt): it's not possible, a person programs the computer and the person is in control, these computers will destroy us! (*M 17-25*)
- HAL-2001, MIT, Turing Test, Deep Blue (*M 17-25*)
- Some sort of experiments, saw some display on smart algorithms and machines that can learn (*M 26-40*)
- HAL-2001, MIT (*M 26-40*)
- Robots taking over earth (*M 26-40*)
- Not much, just obvious, make decisions (*M 26-40*)
- Not real, like aliens (*F 8-16*)
- Heard of it in films (*F 26-40*)
- Saw it on TV and in films (*F 26-40*)
- Sent androids to space, AI – thinks of computers (*F 26-40*)
- Heard of it but doesn't remember much (*F 26-40*)

- Androids are only seen in science-fiction, seen scientific documentaries on AI (*F >40*)

Cloning Extinct Species

- Only heard of it from *Jurassic Park,* sounds good unless they kill us! (*M 8-16*)
- They clone living things, trying to do people (*M 8-16*)
- Heard of it from *Jurassic Park* (*M 17-25*)
- Saw a documentation on cloning dinosaurs (*M 17-25*)
- Cloned a sheep, people say it's possible to clone all beings, used a lot in science fiction (*M 17-25*)
- *Jurassic Park*, found mosquitoes (*M 26-40*)
- Dolly the sheep in Scotland, cloning artificial limbs for transplants, bodies? cloned found in Brazil (*M 26-40*)
- Dolly, cloned Guar (*M 26-40*)
- Science Fiction, *Jurassic Park*, cloned Guar, Dolly (*M 26-40*)
- Nothing outside science fiction (*M 26-40*)
- Definition: splitting of cells so that it makes an identical copy, cloned Dolly the sheep (*M >40*)
- Saw it on TV, recover the species we've (humans) made extinct, doesn't want to encourage cloning, but there are good uses for it such as cloning human organs and such (*M >40*)
- Recognised the concept but didn't have anything to add (*F 8-16*)
- Scientists can take one human being and clone another (*F 8-16*)
- Make a replica of you as animals (*F 17-25*)
- From DNA (*F 26-40*)
- Cloned some endangered species, Dolly (*F 26-40*)
- Same thing as original (*F >40*)

Ocean Floor Colonisation

- Diving belts used for ocean diving near bottom, big problem would be letting people in and out because of huge water pressure outside. Read a lot of sci-fi (anti star trek) though predicting OFC (*M 8-16*)
- Big domes with O_2 (*M 8-16*)
- Similar to a lunar colony, could be possible, might be too much pressure (*M 17-25*)
- Science fiction (*M 26-40*)
- Heard of possibility (*F 17-25*)

Weather Modification

- Minds control, people can change weather with the power of their minds (*M 17-25*)
- Can't control only predict, it's nature, you can't control nature (*M 17-25*)
- Just that it is really not all that feasible (*M 17-25*)
- Cloud seeding, not very effective (*M 26-40*)
- Military experiments done recently (*M 26-40*)
- Cloud seeding (*M 26-40*)
- Science fiction readings, (pause), in parts of the US they seed clouds with ice to make it rain (*M >40*)

Genetic Enhancement

- Cloned sheep and stuff, might be humans soon (*M 8-16*)
- It's misunderstood because people think they can directly find a gene that codes for a behaviour, but at it's best it is 40% environment, 60% genetics. Everyone thinks it's either "genetic or learned" behaviour, but what about pre-natal influences? (*M 8-16*)
- They can change your DNA to make it more powerful or immune to diseases (Note: when this topic came up he realised that this is what he meant when he commented on AI) (*M 8-16*)
- Certain traits from 2 animals together to make better ones (*M 8-16*)
- Modern technology, might be dangerous, don't know if it's right (*M 17-25*)
- Science teacher, teaches this subject, knows it thoroughly (*M >40*)
- Human genome project, glowing monkey (*F 17-25*)
- Heard of genetic selection (*F 26-40*)
- Heard about genetically modified plants, cloning (*F 26-40*)
- A-level genetics, learned about it here involves DNA – "interfering" (*F 26-40*)
- Intelligence, gene, diabetes (*F 26-40*)

Flying Cars

- Read in the paper about vehicles that fly and swim (*M 8-16*)
- Seen it in films (*M 8-16*)
- Saw it on television, saw a model in a museum in Berlin (*M 17-25*)
- Read about one in a newspaper (*M 17-25*)
- They are working on it (*M 17-25*)
- Science fiction (M <40)
- Tried but failed (*F 26-40*)

Nanotechnology

- Know that it exists (*M 8-16*)
- Heard of it but doesn't remember anything (*M 17-25*)
- Vague stuff, knows it exists (*M 17-25*)
- Nanotech – building things atom by atom (*M 17-25*)
- Molecularly sized probe body (*M 26-40*)
- Not in medicine but heard of microscopic machines (*M 26-40*)
- Heard of it on the news, "nanomachines" (*M 26-40*)
- Reconnaissance machines (tiny) but not in medicine (*M >40*)
- Science fiction (*M >40*)

Supersonic Submarines

- Looked surprised (*M 8-16*)
- "Cool" (*M 8-16*)
- Knows about research (*M 8-16*)
- Saw it on television, submarine vanishes very fast, but not like teleporting on star trek (*M 8-16*)
- Supercavitation torpedo, Russian, sunken Russian sub? (*M 17-25*)
- Surprised (*M 17-25*)
- Surprised, interesting but not to him (*M 26-40*)

Tissue Engineering

- Genes into test tubes (*M 8-16*)
- Saw it on television, growing organs (*M 8-16*)
- Involves cloning stuff (*M 17-25*)
- Ear on mouse, "scary stuff" (*M 17-25*)
- Highly controversial, based on animal (*M 26-40*)
- Projection of current experiments (*M 26-40*)
- Heard it on TV probably, doesn't remember (*F 8-16*)
- Heard they were working on a liver, and that they hope to make a heart and brain (*F 8-16*)
- Heard it at school (*F 17-25*)
- Embryonic stem cells (*F 17-25*)
- Yes, cloning and taking genes (*F 17-25*)
- Hoping to grow hearts because they're aren't enough, currently growing skin (*F 17-25*)
- Couldn't tell about it but read bits and pieces, something to do with genetics (*F 26-40*)

Virtual Reality

- Headsets, thoughts to compute (*M 8-16*)
- Saw something about it on the television and in a museum (*M 8-16*)
- Learned it in class, used for games (*M 8-16*)
- People being able to move small bits, like disabled people, also used in surgery (*M 17-25*)
- Paraplegics, move cursor and click (*M 17-25*)
- Very vague material from reading, nothing stands out, aware that it exists (*M >40*)
- Move finger and something happens (*F 8-16*)
- Direct brain energy toward computer (*F 17-25*)

Wearable Computers

- Beltpacks, ugly, bulky (*M 17-25*)
- Eyeglass monitors, belt mounted (*M 26-40*)
- Heard of wearable (*M 26-40*)
- Read about it in magazines, "really only that", heard that they can take away your sweat and adapt to weather and body conditions (*M 26-40*)
- Supposed it's inevitable, television on watch soon he thinks (*M >40*)
- Smart appliances (*F 26-40*)

8.4.2 Formative Text Evaluation Data

The formative text evaluation was used to allow visitors to read the text and answer questions afterwards to test their understanding of the technology being described.

Sample Questionnaire

(Note: Each interview consisted of only one topic and the text presented to the visitor was displayed as one line per page. In the interest of saving space we have condensed the text onto one sheet.)

Hello, my name is ____ and I work here at the Science Museum. We are testing out some writing for a new exhibit on the future of science. I was hoping that you could help us by testing it out. It should only take about 5-10 minutes, but it would involve you reading the text and answering some questions at the end.

8.4.2.1 Android Servants

The Year is 2020

Every household owns an android servant.

This android could tidy your room.

This android could cook you dinner.

It could even wash your smelly socks.

In the future, androids may be a common household appliance, but what happens when they make a mistake?

Will they be safe?

Will they make us lazy?

What do YOU think?

Cast your vote now

Should we rely on androids to do our housework in the future?

This is for real.

There are currently more than 26 project groups

working on building a fully functional android.

1. What do you think this text was about?

M 8-16: Robots in your house.
M 8-16: Androids, housework robots.
M 17-25: Android servants.
M >40: Androids, robots basically.
M >40: Androids, robots of the future.
M >40: Robots in the house.
F 8-16: Having android servants in 2020.
F 17-25: It's about human ultimate laziness resulting in androids taking over the world.
F 17-25: Robots (Visitor did not fully understand how survey worked. She read English very well but did not comprehend the questions as well.)
F >40: Androids.

2. What do you know about the term "android"?

M 8-16: It's a robot.
M 8-16: Cook dinner, wash socks, etc. (Stated back all the items mentioned in the text.)
M 17-25: It's a type of robot.
M >40: Robotic, basically, basic computer. We make mistakes, only as good as programming in them.
M >40: In science books, robot looks life like, like people.
M >40: Half robot, half human?
F 8-16: Well, I kind of figure the term "android" means kind of a mechanical and robotic.
F 17-25: Machines that resemble humans.
F 17-25: Yes (she did not understand the question very well)
F >40: Nothing

3. What do you know about the different between a "robot" and an "android"?

M 8-16: An android is a robot, right?
M 8-16: Androids do housework (stated back all the items again mentioned in the text), stuff for you.
M 17-25: An android is a human-like robot.
M >40: Very little
M >40: A robot is a robot for a specific purpose.
M >40: A robot is a robot, and android is half-robot half-human.
F 8-16: Not much

F 17-25: An android resembles a human and tries to be humanlike. A robot can be any shape or design.
F 17-25: Yes (again, didn't understand)
F >40: No idea, robot probably more controlled than an android.

4. Is there any question regarding this issue that you would like to know more about?

M 8-16: Not really
M 8-16: What would happen if it made a mistake?
M 17-25: Not really.
M >40: No
M >40: No
M >40: Don't know if feasible for them to do everything.
F 8-16: No
F 17-25: I don't know.
F 17-25: No
F >40: Not really.

5. Do you have any other comments or suggestions relating to the text?

M 8-16: No
M 8-16: Good idea
M 17-25: No
M >40: No
M >40: No, very straight-forward
M >40: Great if they could do it
F 8-16: No
F 17-25: I think it would be a shame if androids were developed to the extent of the text. People would become too lazy and their brains would turn to mush if they didn't do things for themselves.
F 17-25: Not safe, bad idea because humans need something to do other than control machines.
F >40: Jobs they can't do, wouldn't trust, they will make us lazy. Can't possibly make one, but then again, that is what we said about large plans to going to space and the moon, etc.

8.4.2.2 Cloning Extinct Species

The Year is 2020

We now share the earth again with animals that were once extinct.

Extinct species can be reborn as long as we have a sample of their DNA.

DNA can be found in any preserved body part of the animal, such as its bones.

Putting this DNA into a DNA-free egg of a similar creature creates the extinct animal embryo.

Many species were driven to extinction because of human interference.

We could soon have the technology to bring these animals back and repair the damage caused in the past.

But is this right, or would we be making more mistakes?

What do YOU think?
Would it be right to clone extinct species?

Is it just another case of scientists playing God?

Cast your vote now.
Should we clone extinct species?

An endangered gaur, which is similar to an ox, was successfully cloned in the USA, although it died a couple days after birth.

But the effort isn't extinct...

The Australian Museum is planning on cloning an extinct Tasmanian tiger using the DNA of a pup that has been preserved in alcohol since 1866!

1. What do you think this text is about?

M 8-16: Cloning animals.
M 8-16: Cloning, making extinct species.
M 17-25: Genetic, cloning animals that have been extinct, Jurassic Park.
M 26-40: Like Jurassic Park
M >40: Bringing back extinct animals. You know, like Jurassic Park.
F 8-16: Bring extinct creatures back to life.
F 17-25: Reproducing extinct creatures.
F 17-25: Cloning extinct animals
F 26-40: Cloning, Jurassic Park
F >40: Cloning and the future of extinct animals. Try to regenerate extinct animals.

2. What comes to mind when you hear the term DNA?

M 8-16: Genetic code.
M 8-16: Chemical stuff that makes life.
M 17-25: Blueprint of the body, double helix.
M 26-40: All components in a living thing.
M >40: Building blocks of life.
F 8-16: Blood inside you.
F 17-25: Genetics
F 17-25: Basic science
F 26-40: Genes
F >40: Human map, personality and everything.

3. Do you recall what is done with the DNA once it is obtained?

M 8-16: Bring back extinct, create. Tampering with nature.
M 8-16: Embryos, back to life.
M 17-25: Put into an egg of a similar species with no DNA in it.
M 26-40: Injected
M >40: Inserted into a DNA-free egg of a similar animal.
F 8-16: no
F 17-25: Put into an egg of a similar creature.
F 17-25: Used to clone animals, inserted into DNA-free embryo
F 26-40: Injected into egg
F >40: Try to reproduce it.

4. What do you understand by "human interference"?

M 8-16: Tampering with nature.
M 8-16: Us interfering with nature.

M 17-25: Where humans have taken to playing God, messing with nature.
M 26-40: Mess around with nature
M >40: When humans change things in nature.
F 8-16: We've interfered with nature, pollution.
F 17-25: Changing natural selection to nature.
F 17-25: Humans basically interfering in the way the planet is going naturally.
F 26-40: Messing with nature
F >40: Interfering with natural process.

5. Is there anything else you think should be included in this text?

M 8-16: no
M 8-16: no
M 17-25: not off hand
M 26-40: no
M >40: no
F 8-16: no
F 17-25: No, except maybe why they are doing it.
F 17-25: No, seemed quite clear.
F 26-40: Seemed as though it was promoting concept.
F >40: Trouble with page 5, awkward wording. Unsure how to. What is "DNA-free egg"? Didn't realise DNA-free eggs existed.

Observations:

M 8-16: none
M 8-16: none
M 17-25: A couple of pages were long, but he had no idea how to shorten them.
M 26-40: Why would you want to bring them back?
M >40: no
F 8-16: Kind of like Jurassic Park.
F 17-25: none
F 17-25: Very fast reader.
F 26-40: none
F >40: none

8.4.2.3 Controlling the Weather

The Year is 2020

Tornadoes, hurricanes, and other storms are now things of the past.

The government now controls the weather using satellites in outer space.

The satellites calm the storms by zapping them with laser beams and cutting off their energy supply.

Controlling the weather could prevent the thousands of lives lost each year due to violent storms. But could it create problems if used the wrong way?

What do YOU think?
Would it be right for humans to control the weather?

Would we be interfering with nature? And what if the wrong people get their hands on the controls?

Cast your vote now
Should humans be allowed to control the weather?

"Weather" You Believe it or Not

An agreement was passed at a United Nations conference in 1977 prohibiting changing

the weather for hostile purposes as it endangers too many civilians.

1. What do you think this text is about?

M 8-16: Controlling the weather.
M 17-25: Controlling the weather, but it sounds like fiction. Surprised by the UN thing. (He asked if it was true!)
M 17-25: We'll control the weather eventually.
M 26-40: Weather control.
M 26-40: Controlling the weather, could be dangerous.
F 8-16: Controlling the weather.
F 8-16: The weather controlled by humans.
F 17-25: People controlling the weather and what it would cause.
F 26-40: Controlling the weather. Could be dangerous if in the wrong hands. Could be useful too. Things like preventing floods and stopping the polar caps from melting.
F 26-40: Changing the weather, ethics and science.

2. Do you remember how the tornadoes are stopped?

M 8-16: laser
M 17-25: lasers
M 17-25: satellite firing lasers
M 26-40: laser
M 26-40: lasers
F 8-16: lasers
F 8-16: ?
F 17-25: satellites in space, laser beams
F 26-40: laser
F 26-40: laser

3. If they only mention the lasers, ask them where the lasers come from.

M 8-16: satellites in space
M 17-25: space, satellites
M 17-25: (answered above)
M 26-40: satellites
M 26-40: satellites
F 8-16: from space
F 8-16: ?
F 17-25: (answered above)
F 26-40: satellite
F 26-40: from satellite

4. What did you think about the last line discussing the UN agreement?

M 8-16: surprised
M 17-25: surprised, didn't believe any of it until he got to that part
M 17-25: 1977 – too dangerous to civilians
M 26-40: didn't know about it
M 26-40: interesting, surprising
F 8-16: long time ago, surprising
F 8-16: ?
F 17-25: She said she wouldn't agree with controlling the weather. (She might have thought I was asking if she agreed when I asked about the agreement.)
F 26-40: Didn't know about it. Surprised that it was passed so long ago.
F 26-40: Can understand why they did it. Surprised that they thought it would be possible someday.

5. Is there anything else you think should be included in the text?

M 8-16: no
M 17-25: It just seems far-fetched. Imagination.
M 17-25: no
M 26-40: how it works
M 26-40: no
F 8-16: no
F 8-16: no
F 17-25: no
F 26-40: Include more pros, along with the cons. Things like how it would help with growing fruits and vegetables, and harvesting. Got the impression that it was all bad. We would need to be very careful, controlling nature is a very tricky thing. How would it effect thi ıgs like volcanoes?
F 26-40: She thought it was very good. She's glad we mentioned who would be in charge, although she's not sure if she would trust the government with that power!

Observations:

M 8-16: He looked surprised by the whole thing, especially the flourish.
M 17-25: He was surprised by the flourish but still not convinced that it would ever be possible. He figured there must have been plans at some point that would cause this agreement to be passed. (I think he read "United Nations", but thought "United States")
M 17-25: none
M 26-40: He seemed surprised at the beginning when he first realised what it was about, then surprised at the end when he read the flourish.
M 26-40: Looked interested as he read, surprised at the end.
F 8-16: Seemed disinterested at first, looking around for classmates. Then as she read, she seemed to be more interested and stopped looking around.

F 8-16: She wasn't English, but said she could still do it. She either didn't remember anything, or couldn't understand what I was asking for.
F 17-25: She was French, but read English well and was explaining each page to her friends. She looked surprised towards the end.
F 26-40: Read it with her husband. Looked surprised as she read; especially the flourish where she commented that she didn't know that. She seemed very interested and had a lot to say during the questions. She realised how dangerous it could be, but thought that there should be more about all the good things that would come from it. *F 26-40*: She was reading it with her boyfriend. When she read about the government controlling the weather, she said, "I would hope it would be the government and not some madman!" Then she was pleased with herself when she read the line about the weather getting into the wrong hands. She looked shocked at the end when she read the flourish.

8.4.2.4 Genetic Enhancement

The Year Is 2020

Scientists can now edit the genes of unborn children.

Genetic diseases can be cured, but parents can make other choices about their children's features.

Children's height, weight – even hair colour and shoe size can be planned before birth.

What do YOU think?

Should parents be allowed to custom build their children?

Is it right? Is it unnatural?

Or will it lead to happier parents and children?

Cast your vote.

Should parents be allowed to make choices about the appearance of their future children?

A design for life.

Already chips are being made that can map your entire genetic code from a single drop of blood. The cost? £1250 and falling fast.

1. What do you think this text is about?

M 8-16: Choosing child's looks.
M 8-16: Changing people's looks, children's.
M 17-25: Picking children's looks.
M 17-25: Creating children; appearance, etc.
M 17-25: Changing children's DNA.
M 17-25: Picking kid's looks.
M 26-40: Changing children's features, looks.
F 8-16: Changing looks.
F 8-16: Designing children's looks.
F 26-40: Designing children.

2. What do you understand the word "gene" to mean?

M 8-16: DNA
M 8-16: Makes you who you are.
M 17-25: Parents to children, makes you who you are.
M 17-25: Person to person; looks and like.
M 17-25: DNA
M 17-25: DNA – makes you who you are
M 26-40: DNA – codes for who you are.
F 8-16: Code for life.
F 8-16: Makes you who you are and how you act.
F 26-40: Passed from parent to child. Codes for traits.

3. What do you understand the phrase "edit the genes of unborn children" to mean?

M 8-16: Changing looks.
M 8-16: Changing genes.
M 17-25: Change what they're like.
M 17-25: Make appearance, attitude.
M 17-25: Change while mother is still pregnant.
M 17-25: Changing their genes, picking traits.
M 26-40: Pick their looks, personality.
F 8-16: Changing who they'll be.
F 8-16: Choose looks, personality.
F 26-40: Changing their traits.

4. What do you understand the question "Should parents be allowed to make choices about the appearance of their future children" to mean?

M 8-16: Should they choose how they look.
M 8-16: Choose how they look.
M 17-25: Choosing looks.
M 17-25: Should they be able to select their appearance.
M 17-25: Should they be able to pick their looks.
M 17-25: Picking kids' looks.
M 26-40: Changing looks.
F 8-16: Should they change looks.
F 8-16: Choosing what they look like.
F 26-40: Changing looks.

5. Do you feel the text is for or against this technology?

Everyone said against.

Observations:

8.4.2.5 Flying Cars

The Year is 2020

Flying cars are a part of everyday life.

The cars fly using giant fans, called turbines.

The fans and shape of the car mean no wings are needed.

Flying cars could go much faster than those on the ground.

But will they be more dangerous?

What do YOU think?

Cast your vote now.

Should we replace today's cars with ones that fly?

This is for real.

12 functioning prototype flying cars were already in existence

1 January, 2001.

1. What do you think this text is about

M 8-16: Flying cars.
M 8-16: Cars that fly.
M 17-25: Flying Cars.
M 26-40: Development of antigravity cars, flying cars.
M >40: Cars in the future, isn't it?
F 8-16: Flying Cars
F 8-16: Flying Cars
F 17-25: Interesting theory.
F 26-40: Flying Cars
F >40: Taxis in the sky.

2. Do you remember how the term "turbine" was defined?

M 8-16: No
M 8-16: A fan.
M 17-25: No
M 26-40: Giant fan
M >40: Vaguely, as I said, I'm not a technical guy. (see comments)
F 8-16: No
F 8-16: No
F 17-25: Fan
F 26-40: Some sort of big fan.
F >40: I don't remember, (she asked her grandson if he did!)

3. Is there anything else about flying cars that you think should be added?

M 8-16: The effects of the weight.
M 8-16: How fast do they go?
M 17-25: No, not really.
M 26-40: Interesting that there are 12 of them. How fast? How high?
M >40: I would be happy if I had one just for myself, but produced on a mass scale, they could cause a lot of problems.
F 8-16: How much?
F 8-16: How fast do they go?
F 17-25: How would it be controlled, guidance, so they don't all crash into each other, like air traffic control.
F 26-40: No
F >40: It would be quite fun, interesting.

Observations

M 8-16: Read quickly.
M 8-16: Read fast, seemed interested.
M 17-25: Read fast.
M 26-40: Read with partner, smiled towards the end. "No way!" at flourish.
M >40: "I'm not quite technical, I'll tell you that" when I asked, "Will I be here then?" as he read, "That so, interesting" at the flourish.
F 8-16: She like the idea.
F 8-16: Read with friends, they all seemed interested.
F 17-25: Looked interested as she read.
F 26-40: Looked surprised at flourish.
F >40: Read with kids (grandchildren probably). Reminded her of a film, Star Wars she thought it might be. She was really excited at the end!

8.4.2.6 Nanorobots

The Year is 2020

Injuries can now be healed by swallowing tiny machines.

These machines are called "nanorobots". They're invisible to the human eye.

You swallow them, millions at a time. As they travel through your body, they repair injuries.

After healing an injury, the nanorobots are dumped out when you go to the toilet.

Nanorobots could speed healing
But are these machines safe to put inside your body?
Is it natural?

What do YOU think?
Cast your vote now

Would you swallow nanorobots to speed healing?

It's a Small World
The US government spent $234 million on nanoscience research in 2000, only to create a robot only 15mm wide!

1. What do you think this game is all about?

M 8-16: How science in the future will be more advanced. If you think about it right now, it doesn't seem possible, but later it will.
M 26-40: Oh, I've heard about it on the news before, so it really just told me what I already knew. They enter your bloodstream and work on your body.
M >40: Nanorobots! Healing my body.
M >40: Tissue repair by cleansing the body of bad injuries with these machines.
F 8-16: New imaginary thing they're expecting to make by 2020. Heal injuries.
F 8-16: How in the future little tiny machines will go inside of you and do stuff.
F 26-40: Little machines that speed up healing and go through your body.
F 26-40: When you would normally have surgery, you don't have to open up the body. You just swallow this thing, "strange really", but "supposed it is possible". (positive tone)
F 26-40: Never heard of it before! But it's about really small machines that you swallow. She understood it though "clear".
F >40: Cleaning the body to prolong life.

2. What do you understand by the term "nanorobot"?

M 8-16: It's kind of like a tablet that you take that cures... well, just about anything.
M 26-40: Well nano is a small exponential of 10. So it's pretty small! It's a machine that gets absorbed through your blood.
M >40: Very small, small enough to swallow them.
M >40: Tiny micro-organism that can go inside you.
F 8-16: (took a while to answer, she couldn't quite describe it) Futuristic robot that you take like a drug.
F 8-16: Really little robot.
F 26-40: Never heard of it before (asked how to pronounce it), but it's a little machine that speeds up healing and you can excrete them (laughed). (Asked if they were indestructible.)
F 26-40: Nano is very tiny. Robot is, well, a robot. So it's a very small machine that goes inside you but is controlled by someone outside supposed.
F 26-40: Very small machines.
F >40: Tiny little machine

3. How do you understand nanorobots to work?

M 8-16: Umm...just get inside you to do their thing and fix what's wrong with you and get out.
M 26-40: Does something, exactly how? You swallow them, they go into your bloodstream, work on tissues, and get out.
M >40: Don't really, you just swallow them.
M >40: Probably replace the cells – good ones for the bad ones that they replace.
F 8-16: You just swallow them. They're little guys that work on your body.

F 8-16: Don't know really, they just go in and fix you, but I don't know how. How? (she asked me.)
F 26-40: Don't really know how it works, just that you swallow them, they work, and then you flush them out. Speeds healing.
F 26-40: Basically what I said before, (laughed), someone outside the person controls the machines while they're inside you.
F 26-40: Don't know really, they do something, but exactly how? Not sure, doesn't really matter I guess.
F >40: I don't know really, they just heal you.

4. What was your reaction to the fact about the USA at the end of the text?

M 8-16: Seems silly to spend so much if other countries aren't.
M 26-40: Not too bad, that seems reasonable for the USA. (He was American)
M >40: Bit shocked and surprised.
M >40: I would think that the US would be the leader of research in high-tech things.
F 8-16: Shocked. Didn't think they would spend that much money on that type of thing.
F 8-16: That's a LOT of money!
F 26-40: Typical! A lot of money.
F 26-40: Well, the US always spends a lot of money on everything. But I think in this case, it would be worth it. Sometimes it is, sometimes not, but I would think so here.
F 26-40: A little scary that they do so much research that the citizens don't know about. (She was American). Surprising that is wasn't a pharmaceutical company doing it.
F >40: Figured it is the US that would be doing that.

Observations:

M 8-16: Read quickly, answered right away, not much pausing or thinking. (Described nanorobots to his friend after he walked away and did a good job!)
M 26-40: Even though he already knew about it, he said it was interesting, just the text.
M >40: none
M >40: Saw him thinking about the vote question in his head (rolled eyes up), but said, "I'd have to have a think about it".
F 8-16: Seemed interested. Really understood the "futuristic" part of the game.
F 8-16: Interested in learning more. Asked me to explain how they work!
F 26-40: Seemed to get the point across without getting technical. Said "right" after several of the statements. Good impression overall. Thought it was "interesting". Answered the vote with, "Not sure really".
F 26-40: Thought it was a "strange topic". Thinking during reading, "trying to picture it". She was saying that someone would control it from outside. "I suppose someone would have to!" (I think she was thinking of lasocropic surgery.)
F 26-40: She said she felt like she was on Jay Leno!
F >40: Talked out loud during the reading of the text. Couldn't decide whether she'd swallow them or not. "Don't fancy having machines in me, but if it prolonged life...?"

8.5 Appendix E: Email Log

(Note: We received no expert responses for Supersonic Submarines, Virtual Reality, and Renewable Energy.)

8.5.1 Android Servants

Date: Tue, 23 Jan 2001 07:53:37 -0500 (EST)
From: ShadowHeart <shadohrt@sidehack.sat.gweep.net>
To: info@irobot.com
Subject: Science Museum Research

To Whom it May Concern:

I am currently a full-time university student at Worcester Polytechnic Institute in Massachusetts, USA. In collaboration with the Science Museum in London, I am researching and working on a new gallery called IN FUTURE. This gallery focuses on the future of science and technology in 2020 and asks visitors to consider this technology and its use through a series of interactive games.

Currently, I am researching the possibility of artificial intelligence and android servants by the year 2020.

I have sent this email to you in an attempt to reach any of the designers in your organisation for some feedback on whether they believe either android servants or an intelligent computer will be reasonable expectations for the year 2020.

I would greatly appreciate any expert opinions or pointers toward other people that may also be willing to give assistance with this research.

I can be contacted at the number below or via a return email.

011 44 207 942 4835

I look forward to hearing from you.

With many thanks.

Yours sincerely,
Justin T. Cole

Date: Fri, 26 Jan 2001 12:22:18 -0500
From: Sharon Campbell <scampbell@irobot.com>
To: ShadowHeart <shadohrt@sidehack.sat.gweep.net>
Subject: Re: [Info] Science Museum Research
Parts/Attachments:

Dear Justin:

Thank you for your inquiry and your interest in irobot.

I have spoken to Colin Angle, our CEO, and he will have some time available either Wednesday (January 31) or Thursday (February 1) in the morning to answer any your e-mail inquiry. It might be helpful if you could provide me with some questions that you have formulated. We can either respond to your questions or set up an interview. Which do you prefer?

Regards,
Sharon Campbell

Date: Tue, 30 Jan 2001 07:49:23 -0500 (EST)
From: ShadowHeart <shadohrt@sidehack.sat.gweep.net>
To: Sharon Campbell <scampbell@irobot.com>
Subject: Re: [Info] Science Museum Research

Dear Sharon,

First of all, I thank you for your prompt reply. In regards to your request, I do have several more specific questions that I think will provide the most helpful answers to my work, but before I ask them I would like to give you a quick background on the exhibit I am working on (in the event that the exhibit provides insight in a form I had not considered).

The exhibit, entitled 'In Future,' is an interactive gallery in which he visitors play short (two to three minutes each) computer games relating to a current topic in science and technological research. After the game the users are provided with a brief, but substantial fact regarding the topic and are then asked to vote on their views of the topic (each question is narrowed down to a 'yes' or 'no' answer). The goal of the exhibit is to stimulate the interest of the public in how technology might affect their lives in the year 2020 (either to benefit their life, or place restrictions upon it).

My major questions regarding both artificial intelligence and household android servants are fairly basic.

The first is: "how likely are either a truly artificially intelligent machine or an affordable household android servant by the year

2020?"

The second question is: "Would both topics we symbiotic in nature, would they be able to be totally independent or would one likely lead to the other?"

The last major question I have is as follows: "To your knowledge, how close is the nearest researcher to creating one (or both) of these items (an android servant or a truly artificially intelligent machine)?"

Lastly, if you have any spectacular facts that would be a great way to reinforce this topic when the visitors have played a game I would find that most helpful as well.

Again, many thanks for your assistance,

Sincerely,
Justin T. Cole

8.5.2 Cloning Extinct Species

Date: Tue, 23 Jan 2001 06:38:19 -0500 (EST)
From: Kerri Anne Hufnagle <khufnagl@wpi.edu>
To: mcgee@mail.med.upenn.edu
Subject: Science Museum Research

Dear Dr. McGee,

I am currently a full-time university student at Worcester Polytechnic Institute in Massachusetts, USA. In collaboration with the Science Museum in London, I am researching and working on a new gallery called IN FUTURE. This gallery focuses on the future of science and technology in 2020 and asks visitors to consider this technology and its use through a series of interactive games.

Currently, I am researching the topic of cloning extinct species and looking at the possibility of this practice becoming a common one in 20 years time. I would greatly appreciate hearing your views on this issue and obtaining more information on the problems that would be associated with this practice.

If you could provide any information on this area or any contacts with whom I could get in touch, I would be very grateful to hear from you.

I can be contacted by email at khufnagl@wpi.edu or at the number below.
001-44-207-942-4836

I look forward to hearing from you.

With thanks.

Yours sincerely,

Kerri Hufnagle

Date: Tue, 23 Jan 2001 21:58:36 -0500
From: Glenn McGee <mcgee@mail.med.upenn.edu>
To: Kerri Anne Hufnagle <khufnagl@WPI.EDU>
Subject: Re: Science Museum Research

Dear Kerri,

I would be happy to help. We need to get dates straight because if

you want me to come over I will need to schedule the time somewhat in advance, though I am in London so frequently that there is no inconvenience involved at all. I would be happy to meet with you and help you in this worthy effort.

Glenn

Glenn McGee PhD
Center for Bioethics
University of Pennsylvania
3401 Market St. Suite 320
Phila PA 19104-3308

http://bioethics.org

Date: Tue, 30 Jan 2001 05:46:51 -0500 (EST)
From: Kerri Anne Hufnagle <khufnagl@wpi.edu>
To: Glenn McGee <mcgee@mail.med.upenn.edu>
Subject: Re: Science Museum Research

Dear Dr. McGee,

Thank you so much for your quick response and willingness to help out with this project. We're actually still in the preliminary research stage, so I don't think that a meeting would be necessary at this point. What we are looking for is any information or research that has been done on the issues related specifically to cloning extinct species, such as a real Jurassic Park situation!

If you could help us obtain any research or articles on this topic, it would be greatly appreciated. Thank you again for your willingness to help and I will be sure to contact you again if needed as the project continues.

Yours Sincerely,

Kerri Hufnagle

Date: Tue, 30 Jan 2001 11:58:05 -0500
From: Glenn McGee <mcgee@mail.med.upenn.edu>
To: Kerri Anne Hufnagle <khufnagl@WPI.EDU>
Cc: MichaelH@LEIGHBUREAU.com, thomasd@mail.med.upenn.edu
Subject: Re: Science Museum Research

There is a great deal of discussion about attempts to bring back extinct species, and at least one successful attempt to initiate cloning to bring back an extinct Hawaiian holy bird. All of this however is simple journalism; you don't need me for that. The best source I suppose is the U.S. Yahoo! full coverage of cloning, accessed through a search of the Yahoo! news pages.

I believe it will be very helpful for you to have a bioethics scholar on your research team. I am not sure whether or not your budget includes funding for a bioethics scholar, but if you want to help in that way I do all personal consulting for libraries and museums through the Leigh Bureau (I've copied them above; http://leighbureau.com) but of course I am happy to help with occasional questions. Leigh also books my talks if that is where you think we are headed. I am in London frequently and keep an apartment there so let me know well in advance if you can so that I can clear some time.
Thanks,
Glenn

Glenn McGee PhD
Center for Bioethics
University of Pennsylvania
3401 Market St. Suite 320
Phila PA 19104-3308

http://bioethics.org

Date: Wed, 14 Feb 2001 14:26:40 +1100
From: Don Colgan <donc@austmus.gov.au>
To: Kerri Anne Hufnagle <khufnagl@WPI.EDU>
Subject: Re: E-mail address
Parts/Attachments:

1	Shown	9 lines Text
2		24 KB Application
3		26 KB Application

Dear Kerri,

I have atatched two files that should be of assistance - at least in giving direction to your further queries.

Regards,

Don Colgan

Date: Tue, 20 Feb 2001 05:49:45 -0500 (EST)
From: Kerri Anne Hufnagle <khufnagl@wpi.edu>
To: Don Colgan <donc@austmus.gov.au>
Subject: Re: E-mail address

Dear Don,

Thank you for the articles. They were most helpful. We have developed some text for the Cloning Extinct Species game and I was hoping that you could take a minute and read through it. The text is written in a very simplified manner as it is to be read by science museum visitors of all ages. If you could read through it and let us know if their are any inaccuracies, it would be greatly appreciated. Thank you so much for your help.

Sincerely,
Kerri Hufnagle

The Year is 2020

We now share the earth again with animals that were once extinct.

Extinct species can be reborn as long as we have a sample of their DNA.

DNA can be found in any preserved body part of the animal, such as its bones.

Putting this DNA into a DNA-free egg of a similar creature creates the extinct animal embryo.

(Here there will be an interactive game)

Many species were driven to extinction because of human interference.

We could soon have the technology to bring these animals back and repair the damage caused in the past.

But is this right, or would we be making more mistakes?

What do YOU think?

Would it be right to clone extinct species?

Is it just another case of scientists playing God?

Cast your vote now.
Should we clone extinct species?

An endangered gaur, which is similar to an ox, was successfully cloned in the USA, although it died a couple days after birth.

But the effort isn't extinct

The Australian Museum is planning on cloning an extinct Tasmanian tiger using the DNA of a pup that has been preserved in alcohol since 1866!

Date: Tue, 20 Feb 2001 22:51:14 +0000
From: Don Colgan <donc@austmus.gov.au>
To: Kerri Anne Hufnagle <khufnagl@WPI.EDU>
Subject: Re: E-mail address

Dear Kerri,

Thanks for letting me see this text. I have made a few comments (enclosed in # marks) on the text - though none of these apart from the first could be regarded strictly as "inaccuracies".

Regards,

Don

The Year is 2020

We now share the earth again with animals that were once extinct.

Extinct species can be reborn as long as we have a sample of their DNA. #might be revived - I'd still put the chances as only about 8 - 10%#

DNA can be found in any #almost any# preserved body part of the animal, such as its bones.

Putting this DNA into a DNA-free egg of a similar creature creates the

extinct animal embryo.

(Here there will be an interactive game)

Many species were driven to extinction because of human interference.

We could soon have the technology to bring these animals back and repair the damage caused in the past.

But is this right, or would we be making more mistakes?

What do YOU think?

Would it be right to clone extinct species?
#What sorts of extinct species should we clone - all, recently extinct animals or only those that were eliminated by humans?#

Is it just another case of scientists playing God?
#I don't know exactly what this means, but I am personally religious enough to be highly disturbed by the thought that I could be arrogating God's will - the best answer that I can come up with is that I doubt that it was God's will that the thylacine went extinct#

Cast your vote now.
Should we clone extinct species?

An endangered gaur, which is similar to an ox, was successfully cloned in the USA, although it died a couple days after birth.

But the effort isn't extinct

The Australian Museum is planning on cloning an extinct Tasmanian tiger using #starting with (as we will be using other specimens, too)# the DNA of a pup that has been preserved in alcohol since 1866!

8.5.3 Genetic Enhancement

Date: Tue, 23 Jan 2001 06:28:09 -0500 (EST)
From: Lani Warner <ewarner@wpi.edu>
To: teel@adax.com
Subject: London Science Museum Inquiry

Dear Dr. Darnovsky,

I am currently a full-time university student at Worcester Polytechnic Institute in Massachusetts, USA. In collaboration with the Science Museum in London, I am researching and working on a new gallery called IN FUTURE. This gallery focuses on the future of science and technology in 2020 and asks visitors to consider this technology and its use through a series of interactive games.

Currently, I am researching the topic of selecting genetic traits before birth. More specifically, I am looking for information regarding the possibility if enhancing gene expression to abnormal levels. One angle for the interactive is "creating superheroes through biotechnology". Since reading through your newsletter, the Techno-Eugenics Email Newsletter, I have become very interested in you knowledge about this topic.
Our goal in this gallery is to explore all sides of an issue and let the visitors decide for themselves whether they would like this technology in their lives.

If you have any information on this area or any contacts with whom I could get in touch, I would be very grateful to hear from you.

I can be contacted at any of the numbers below.

I look forward to hearing from you.

With thanks.

Yours sincerely,

Elaine Warner
In Future Gallery
National Museum of Science and Industry
011-44-207-942-4836
ewarner@WPI.edu

Date: Tue, 23 Jan 2001 16:08 PST
From: md@adax.com
To: ewarner@WPI.EDU
Subject: human genetic technologies

Dear Elaine Warner,

Thanks for your interest in our work. We'd appreciate the opportunity to talk with you and others at the Science Museum who are working on the "In Future" exhibit, and to find out what you're planning.

Our organisation, the Exploratory Initiative on the New Human Genetic Technologies, consists of a network of concerned leaders of environmental, religious, women's, and other civil society organisations; scientists, health professionals, and ethicists; and others.

We are working to alert the public and civil society to the need for effective societal regulation of the new genetic technologies. We're particularly concerned about "germline" genetic engineering--altering the genes we pass on to our children--and about human reproductive cloning.

I'd like to hear more about the idea of an interactive exhibit on "creating superheroes through biotechnology." I'm afraid that my initial response is concern that such a display would serve to confuse playful fantasies about superheroes with an endorsement of the actual creation of "alpha humans." Since there is currently a resurgence of such eugenic projects, including among prestigious scientists and professionals, this would be a very serious confusion to foster.

Below I've pasted a blurb on the Exploratory Initiative. I hope we can talk in the near future. I'd be glad to give you names and contact information of colleagues in North American and/or in the UK.

Thanks and looking forward to talking with you,
Marcy Darnovsky

Marcy Darnovsky, Ph.D.
Exploratory Initiative on the New Human Genetic Technologies
466 Green Street
San Francisco, CA 94133
415-434-1403
510-444-8360

md@adax.com

Date: Wed, 31 Jan 2001 06:14:32 -0500 (EST)
From: Lani Warner <ewarner@wpi.edu>
To: md@adax.com
Subject: Re: human genetic technologies

Dear Dr. Darnovsky,

Thank you for your timely response. The information you sent provided an interesting and important perspective, and one that we have definitely not overlooked in our research for the exhibit. Currently, we are talking to visitors about their knowledge and interest in our proposed subject areas (genetic enhancement being one of these) to find out their misconceptions, degree of knowledge and begin gathering data of their viewpoints on the matter.

I would greatly appreciate any information that either yourself or a colleague could provide more specifically concerning legislation, acts, demonstrations, etc. that have occurred in this area. One segment of the exhibit provides a 'flourish' - which we define as a hard hitting factoid that will perhaps shock people and make them think. Perhaps a statistic about an implication of this technology would be appropriate?

Also, later in the development of the exhibit, we will be constructing story boards of text and images. Would it be possible to run these by you and ask for any feedback?

Thank you again for your help. It is much appreciated.

Sincerely,

Elaine Warner

Date: Tue, 23 Jan 2001 06:32:38 -0500 (EST)
From: Lani Warner <ewarner@wpi.edu>
To: genome@science.doe.gov
Subject: London Science Museum Inquiry

Dear Human Genome Project Staff,

I am currently a full-time university student at Worcester Polytechnic Institute in Massachusetts, USA. In collaboration with the Science Museum in London, I am researching and working on a new gallery called IN FUTURE. This gallery focuses on the future of science and technology in 2020 and asks visitors to consider this technology and its use through a series of

interactive games.

Currently, I am researching the topic of selecting genetic traits before birth. More specifically, I am looking for information regarding the possibility of enhancing gene expression to abnormal levels. One angle for the interactive is "creating superheroes through biotechnology". I am interested in your expert knowledge of genomic mapping and tracking as this would make our topic feasible.

If you have any information on this area or any contacts with whom I could get in touch, I would be very grateful to hear from you.

I can be contacted at any of the numbers below.

I look forward to hearing from you.

With thanks.

Yours sincerely,

Elaine Warner
In Future Gallery
National Museum of Science and Industry
011-44-207-942-4836
ewarner@WPI.edu

Date: Mon, 05 Feb 2001 09:59:53 -0500
From: Marissa Mills <millsmd@ornl.gov>
To: ewarner@WPI.EDU
Subject: London Science Museum Inquiry

Dear Lani,

Try contacting the experts listed below. I heard them speak as panelists on this very topic at a meeting last month.

(1) Eric Juengst, PhD, at Case Western Reserve University (etj2@po.cwru.edu, tel 216/368-6196, fax: -8713).

(2) David Resnik, PhD, at East Carolina University (resnikd@mail.edu.edu, tel 252-816-2492, fax: -2319).

(3) David Rothman, Ph.D. Columbia University (djr5@columbia.edu, tel 212-305-4096, fax: -6416).

(4) Sheila Rothman, Ph.D. Columbia University (smr4@columbia.edu, tel 212-305-5497, fax: -6416)

Also, you might be interested in a San Francisco organisation that puts on these conferences called, THE NEXT TWENTY YEARS SERIES. Their conferences focus on different topics including technology and medicine. See their website at http://www.next20years.com/.

Sincerely,
Marissa

8.5.4 Flying Cars

Date: Tue, 23 Jan 2001 06:20:35 -0500 (EST)
From: Kerri Anne Hufnagle <khufnagl@wpi.edu>
To: library-enquiries@srg.caa.co.uk
Subject: Science Museum Research

Dear associate of the Safety Regulation Group,

I am currently a full-time university student at Worcester Polytechnic Institute in Massachusetts, USA. In collaboration with the Science Museum in London, I am researching and working on a new gallery called IN FUTURE. This gallery focuses on the future of science and technology in 2020 and asks visitors to consider this technology and its use through a series of interactive games.

Currently, I am researching the possibility of flying cars being a part of everyday life in 20 years time and I am looking into the considerations that must be taken before this technology could be introduced to society.

If you have any information on this area or any contacts with whom I could get in touch, I would be very grateful to hear from you.

I can be contacted by email at khufnagl@wpi.edu or at the number below.

44-0207-942-4836

I look forward to hearing from you.

With thanks.

Yours sincerely,

Kerri Hufnagle

Date: Wed, 24 Jan 2001 10:25:02 -0000
From: Cairns Carol <carol.cairns@srg.caa.co.uk>
To: 'Kerri Anne Hufnagle' <khufnagl@WPI.EDU>
Subject: Flying Cars

Kerri

Thank you for your email. The only information we have in the Library

consists of two articles taken from journals. I would be happy to post these to you if you send me your address. I suggest you also contact Cranfield University who may be able to help with your research. A colleague has also mentioned trying some of the automobile journals (Autocar?) as he thinks they may have featured this subject.

Cranfield University
Cranfield
Bedfordshire
MK43 OAZ

Tel: 01234 75011
www.cranfiled.ac.uk

Regards

Carol Cairns
Librarian

Thanks

Date: Tue, 30 Jan 2001 05:50:46 -0500 (EST)
From: Kerri Anne Hufnagle <khufnagl@wpi.edu>
To: Cairns Carol <carol.cairns@srg.caa.co.uk>
Subject: Re: Flying Cars

Dear Carol,

Thank you so much for your help. If you could mail me those articles, it would be greatly appreciated. You can send them to:

Kerri Hufnagle
Wellcome Wing
Science Museum
Exhibition Road
LONDON
SW7 2DD

Thank you for the additional contact also, I appreciate the time you have taken to help with this project.

Yours Sincerely,

Kerri Hufnagle

8.5.5 Nanorobots

Date: Tue, 23 Jan 2001 06:44:02 -0500 (EST)
From: Lani Warner <ewarner@wpi.edu>
To: rfreitas@zyvex.com
Subject: London Science Museum Inquiry

Dear Dr. Freitas,

I am currently a full-time university student at Worcester Polytechnic Institute in Massachusetts, USA. In collaboration with the Science Museum in London, I am researching and working on a new gallery called IN FUTURE. This gallery focuses on the future of science and technology in 2020 and asks visitors to consider this technology and its use through a series of interactive games.

Currently, I am researching the topic of nanomedicine. Possible angles we are considering include nanomedical applications in space and nanomedicine in conjunction with genomic coding. After looking over your work, Nanomedicine Volume I, I am very interested in more detailed information regarding the possibilities of this technology.

If you have any information on this area or any contacts with whom I could get in touch, I would be very grateful to hear from you.

I can be contacted at any of the numbers below.

I look forward to hearing from you.

With thanks.

Yours sincerely,

Elaine Warner
In Future Gallery
National Museum of Science and Industry
011-44-207-942-4836
ewarner@WPI.edu

Date: Tue, 23 Jan 2001 17:17:44 -0800 (PST)
From: Robert Freitas <rfreitas@calweb.com>
To: Elaine Warner <ewarner@WPI.EDU>
Subject: Re: London Science Museum Inquiry

Dear Dr. Freitas,

I am currently a full-time university student at Worcester Polytechnic Institute in Massachusetts, USA. In collaboration with the Science Museum in London, I am researching and working on a new gallery called IN FUTURE. This gallery focuses on the future of science and technology in 2020 and asks visitors to consider this technology and its use through a series of interactive games.

Currently, I am researching the topic of nanomedicine. Possible angles we are considering include nanomedical applications in space and nanomedicine in conjunction with genomic coding. After looking over your work, Nanomedicine Volume I, I am very interested in more detailed information regarding the possibilities of this technology.

I'm very pleased to learn of your interest.

If you have any information on this area or any contacts with whom I could get in touch, I would be very grateful to hear from you.

If you've already read my book, then there are two other major sources that you can look at for further information relevant to nanorobotic nanomedicine.

First, my Nanomedicine Page <http://www.foresight.org/Nanomedicine>, hosted for me by the Foresight Institute, has hundreds of links to nanomedicine-related articles, papers, sites etc. I update it with new information every month or two. Regarding genetic nanomedicine, My popular article "Say Ah" briefly describes my concept of chromosome replacement therapy, which I'll be discussing more extensively in the next volume in my trilogy, Nanomedicine, Volume II (to be published ca. 2003; sorry about that!). Regarding space nanomedicine, I'll have a lot to say on this in the future as well, but right now the best thing I have online for you is my respirocyte design -- the artificial mechanical red cells. There are several papers about the respirocytes available on my Nanomedicine Page.

Second, my Nanomedicine Art Gallery <http://www.foresight.org/Nanomedicine/Gallery/index.html> is the first and only online collection of original and previously published nanomedicine-related graphics, artwork, and animations of medical nanorobots, and other related links. If you decide to use any of these, and if you seek scientific accuracy, ask me which of the images are grounded in reality and which are not -- most of them are fanciful "artist's concepts" and nothing more. The most technically accurate are the respirocytes and endotheliocytes. Best wishes on your very interesting project!

Robert A. Freitas Jr.
Research Scientist
Zyvex Corp.

Date: Tue, 6 Feb 2001 08:14:30 -0500 (EST)
From: Lani Warner <ewarner@wpi.edu>
To: Robert Freitas <rfreitas@calweb.com>
Subject: Re: London Science Museum Inquiry
Parts/Attachments:
1 Shown 78 lines Text
2 25 KB Application, "In Future Introduction"

Dear Dr. Freitas,

I have been looking actively at the sources you provided and they have proved very useful. The topic of Nanomedicine has been chosen by our project team as one of the six to be developed fully. We are developing the angle of nanorobots within the body (not in space applications that I had mentioned in my previous email.) I have a few specific questions that I was hoping you could answer in regards to future development of certain aspects of nanomedicine. I have also attached a brief introduction to this project if you are interested.

1. In section 4.8 of Nanomedicine, you briefly discuss in vivo sensing techniques. How advanced, in your expert opinion, will these techniques be by the year 2020? What are the largest pitfalls that must be overcome to perfect these processes?

2. In chapter 16, you are to discuss methods of getting sensors into and out of the body. I have the same questions in regards to this process. How advanced will doing this be by the year 2020? and can you list some of the major obstacles in perfecting it?

3. My last question deals with legal approval. Would the FDA be responsible for approving nanorobots? If not, then who would? What types of procedures must companies, researchers go through in order for nanorobots to become commercial applications. Is there a timeline for this?

Thank you for all your help. I hope to hear from you soon.

Sincerely,

Elaine

Date: Sun, 11 Feb 2001 01:35:13 -0800 (PST)
From: Robert Freitas <rfreitas@calweb.com>
To: Lani Warner <ewarner@WPI.EDU>
Subject: Re: London Science Museum Inquiry

> I have been looking actively at the sources you provided and they have proved very useful. The topic of Nanomedicine has been chosen by our project team as one of the six to be developed fully. We are developing the angle of nanorobots within the body (not in space applications that I had mentioned in my previous email.)

That's wonderful. Glad to hear it!

> I have a few specific questions that
I was hoping you could answer in regards to future development of certain aspects of nanomedicine. I have also attached a brief introduction to this project if you are interested.

Thanks, I looked it over.

> 1. In section 4.8 of Nanomedicine, you briefly discuss in vivo sensing techniques. How advanced, in your expert opinion, will these techniques be by the year 2020? What are the largest pitfalls that must be overcome to perfect these processes?

Section 4.8 refers specifically to cellular bioscanning. I would say that most of the applications envisioned here should be at least in laboratory prototype stage by 2020. Some of the more intrusive techniques, such as direct neural monitoring (4.8.6), may take a little longer to get out of the lab than the other items, mainly because the higher consequences of device failure will require more extensive testing prior to any kind of clinical application.

Aside from the neural monitoring, I actually thought the material on macrosensing (4.9) would be of even greater interest to a general audience....

The single greatest challenge in perfecting these processes is the same challenge faced in all of nanorobotic medicine -- that is, the ability to cheaply and precisely manufacture molecular machine systems, in large quantities, and reliably. This is going to take 10-20 years; there's just no way around it. Until then, we must rely on relatively less-efficacious biotech-related solutions and very limited bio-MEMS devices in therapeutic medicine.

> 2. In chapter 16, you are to discuss methods of getting sensors into and out of the body. I have the same questions in regards to this process. How advanced will doing this be by the year 2020? and can you list some of the major obstacles in perfecting it?

I'm going to be writing this chapter in the Spring, so you're a little ahead of me here!

The major obstacles are probably: fabrication issues (see above); biocompatibility issues (numerous, and so far largely unexplored in the context of medical nanorobotics); navigation (how do you know where you are in the body, and that you're measuring the right thing?); and communications (how do you get the data signals out of the body?). The latter two issues are dealt with at length in my book (Vol. I), and both can be solved by installing an active "wireless" (e.g. acoustic) communications network inside the body, with one relay nanorobot stationed at every node, with the nodes perhaps 100 microns apart in a Cartesian grid pattern (NMI Section 7.3.2).

The ability to fabricate early versions of these devices should be available by 2020. However, entire systems of such sophisticated devices, such as the in vivo personal communications net mentioned above, may take another decade or so.

> 3. My last question deals with legal approval. Would the FDA be responsible for approving nanorobots? If not, then who would? What types of procedures must companies, researchers go through in order for nanorobots to become commercial applications. Is there a timeline for this?

Almost certainly some regulatory agency will be involved. In the U.S., the best bet appears to be the FDA. There are a lot of legal issues which are just now beginning to be thought about. The first legal paper on nanomedical regulation was by Fiedler and Reynolds; you can view their paper online by going to my website (i.e., the Nanomedicine Page, at www.foresight.org/Nanomedicine), clicking on the Recent Articles section, and then looking for their entry in 1994.

Nanotech products in general, and their manufacturing facilities, will be subject to a number of government regulations. In addition to these regulations, nanomedical devices also will be subject to other sets of regulations designed to ensure medical safety. Until we can build devices, this is all theoretical, of course. But once we *can* build devices, perhaps in 10-20 years, the pace of regulatory development is going to accelerate dramatically -- especially since the promise for human health is so great.

Robert A. Freitas Jr.
Research Scientist

Zyvex Corp.

Date: Sat, 17 Feb 2001 17:02:48 -0800 (PST)
From: Robert Freitas <rfreitas@calweb.com>
To: Lani Warner <ewarner@WPI.EDU>
Subject: Re: London Science Museum Inquiry

Looks good.
Only suggestion, you might add, just before the question "is it natural", the question:
"What if they have been FDA approved" for U.S. audience, or maybe "What if they have been doctor-approved?", or something like that. My thinking is that it would be nice to give the kids an opportunity to come to (what I regard as) the "right" answer!

Good luck on your project.

Robert A. Freitas Jr.

Date: Thu, 25 Jan 2001 11:06:27 -0500 (EST)
From: Lani Warner <ewarner@wpi.edu>
To: zhuxm@eecs.berkeley.edu
Subject: London Science Museum Inquiry

Dear Mr. Zhu,

I am currently a full-time university student at Worcester Polytechnic Institute in Massachusetts. In collaboration with the Science Museum in London, I am researching and working on a new gallery called IN FUTURE. This gallery focuses on the future of science and technology in 2020 and asks visitors to consider this technology and its use through a series of interactive games.

Currently, I am researching the topic of nanomedicine. Possible angles we are considering include nanomedical applications in space and nanomedicine in conjunction with genomic coding. I received your name from Professor Pister and after looking at your work, I am very interested in more detailed information concerning the possibilities and applications of this technology.

If you have any information on this area or any contacts with whom I could get in touch, I would be very grateful to hear from you.

I can be contacted at any of the numbers below.

I look forward to hearing from you.

With thanks.

Yours sincerely,

Elaine Warner
In Future Gallery
National Museum of Science and Industry
011-44-207-942-4836
ewarner@WPI.edu

Date: Thu, 25 Jan 2001 22:13:46 -0800
From: Xiaoming Zhu <zhuxm@eecs.berkeley.edu>
To: Lani Warner <ewarner@WPI.EDU>
Subject: Re: London Science Museum Inquiry

Dear Elaine:

Thanks for your interests. I am mostly working on the communication technology which can be employed to interrogate those small-scale sensors and devices. Currently my work is mostly free-space optical communication and wireless communication techniques. Prof. Pister is the PI of this project and is in charge of the system design and device fabrications. My work is somewhat in a more general theoretical way which relates to this Smart-Dust project. Hope that explains my work. If you would like to know more detail about my work, feel free to contact me.

BTW, I am quite interested of your IN-FUTURE gallery project. So if you could let me know something about that, I would be appreciated..:)

yours,
Xiaoming

Date: Wed, 31 Jan 2001 05:43:43 -0500 (EST)
From: Lani Warner <ewarner@wpi.edu>
To: Xiaoming Zhu <zhuxm@eecs.berkeley.edu>
Subject: Re: London Science Museum Inquiry
Parts/Attachments:
1 Shown 112 lines Text
2 25 KB Application, "In Future Project Overview"

Dear Xiaoming,

Thank you for your prompt reply. From your response I have generated some more specific questions below. Many are theoretical "in your expert opinion" type questions, and educated guesses are fine. Also below is a more detailed description of the In Future exhibit and my project team's involvement with it.

1. The communication techniques of the sensors and devices: What types of data are you researching? Are there any available statistcs? Do you think, in your opinion, that the communication could progress to communicate between the devices and signals from the body? (i.e. the sensors monitor body signals and communicate back to the researcher).

2. Are any of the materials used toxic or have any other aspect which would render their association with living systems impossible? or even difficult?

3. Popular media, such as the film Innerspace and the Body Wars theme park attraction: If you are familiar with these, do you think their communication techniques (both within the machines and to the outside world) are feasible? If so, how long do you believe will this take to develop?

4. Our exhibit is based on predictions of life in the year 2020. Where do you believe the state of your research will be by that time? How fast is progress being made now?

Thank you again for your help. I look forward to hearing from you.

Sincerely,
Elaine

Date: Wed, 31 Jan 2001 18:12:28 -0800
From: Xiaoming Zhu <zhuxm@eecs.berkeley.edu>
To: Lani Warner <ewarner@WPI.EDU>
Subject: Re: London Science Museum Inquiry

Dear Elaine:

Below is some of my comments on your questions, hope they will help...:)

> Dear Xiaoming,
>
> Thank you for your prompt reply. From your response I have

> generated some more specific questions below. Many are theoretical "in
> your expert opinion" type questions, and educated guesses are fine. Also
> below is a more detailed description of the In Future exhibit and my
> project team's involvement with it.
>
> 1. The communication techniques of the sensors and devices: What types of
> data are you researching? Are there any available statistics? Do you think,
> in your opinion, that the communication could progress to communicate
> between the devices and signals from the body? (i.e. the sensors monitor
> body signals and communicate back to the researcher).
For our specific project of Smartdust, we are considering the case where the number of information sources is large while for each source the information flow is only about a few kb/s which is quite small. This is set-up for sensor networks where distributed lots of sensors will try to transmit their info back to the base station. I think the statistics of those data can be treated as fixed information flow with some random fluctuations or packet lost ratio. However our communication techniques can be extended to much wider range of applications. For medical usage, I think wireless optical communication might be impossible for the line of sight communication, however we can use wireless RF communication and the sensor network idea in the project to help collect signals from body to some communication device.
>
> 2. Are any of the materials used toxic or have any other aspect which
> would render their association with living systems impossible? or even
> difficult?
The smartdust are mainly MEMS devices, I am not an expert on fabrications, but I think the devices are mainly Si, SiO2 and those normal semiconductor materials which is definitely not harmful. But during the processing there might be some toxic chemicals which needs to be cleared after the fabrication procedure, which has been done successfully in each semiconductor labs.
>
> 3. Popular media, such as the film Innerspace and the Body Wars
> theme park attraction: If you are familiar with these, do you think their
> communication techniques (both within the machines and to the outside
> world) are feasible? If so, how long do you believe will this take to
> develop?
I am not sure about the techniques you meant. But I think the communications will be restricted by the fundamental theories of electromagnetism and wouldn't go without any loss of information. I think current technology can only go for wider bandwidth and higher efficiency in spectrum and power usage but not a revolutionary innovation. One thing missing in our existing communication while is researched by Bio-engineering is how biologically transmit the information, I do not know much about this, there might be a miracle out there in that field.
>

> 4. Our exhibit is based on predictions of life in the year 2020. Where do
> you believe the state of your research will be by that time? How fast is
> progress being made now?
I think as the world are becoming connected, by internet currently. The depth and coverage of that intercommunication will more and more dependent on communications, I think it would be the hottest area and much new schemes of new communication techniques will be proposed and utilised in the future.

Xiaoming

Date: Tue, 30 Jan 2001 11:44:42 -0500
From: Nadrian C Seeman <ncs1@SCIRES.ACF.NYU.EDU>
To: Lani Warner <ewarner@WPI.EDU>
Subject: Re: London Science Museum Inquiry

Hi Elaine:

You can start with my web site, below. That will explain what we have already done. If you want more, I can tell you a few things about what I believe to be possible in the next 20 years.

Best,
Ned

Nadrian C. Seeman
Department of Chemistry
New York University
New York, NY 10003, USA
phone: 212-998-8395
fax: 212-260-7905
email: ned.seeman@nyu.edu
url: http://seemanlab4.chem.nyu.edu

Date: Tue, 30 Jan 2001 12:30:26 -0500
From: Nadrian C Seeman <ncs1@SCIRES.ACF.nyu.edu>
To: Lani Warner <ewarner@WPI.EDU>
Subject: Re: London Science Museum Inquiry

Hi Elaine:

> Thank you for a rapid response. I looked over the website and
> found valuable information concerning the details of how the process was
> established. I do have some more specific questions concerning future

> developments that I have stated below:
>
> 1. What are the current applications of this technology? (i.e. How are you
> using it today?)

Everything is still at the basic development stage. No applications outside my lab yet. We are using some of the systems to answer some questions about scientific issues in the molecular biophysics part of my lab.

> 2. Along those lines, ideally, how would you like to apply this technology
> in the future? (and if this is projected past the year 2020, what stage,
> in your expert opinion, do you believe you will have reached by the year
> 2020?)

The key goal is to solve the macromolecular crystallisation problem. This will render the 3D structures of cellular components tractable to structural analysis. Many are available now, but there are still issues of crystallisation, which we hope to solve. The idea is to produce 3D DNA lattices and use them to scaffold the organisation of these molecules into crystals.

We hope to organise nanoelectronic components in the same way, leading to a true 3D integration of information storage, and possibly processing systems.

We hope to produce nanodevices that can function as parts of nanorobots, nanofactories and multiplexed nano-scale biosensors. I expect all of this development to be in place by 2020.

> 3. Are the type of nanodevices you are developing compatible with human
> tissues? (i.e. do you think it feasible to place nanomachines inside the
> human body to run tests, attack virus, etc.?)

The devices we are developing may be susceptible to various nucleases. It might be necessary to use modified forms of the basic building blocks. There are plenty around.

> 4.Are you looking into any applications where these devices work in
> conjunction with other technologies? If so, how so?

Nanoelectronics, mentioned above and gene therapy are technologies with which we are likely to interact. We also are involved in the DNA-based computation community, which is another outlet for the systems we have devised.

> 5. Even more specifically, could every individual's DNA be used to make

nanostructures of some benefit to them?

Realistically, that is happening now. The DNA codes, as you know for proteins that are nanodevices functioning in structural and catalytic roles in the cell. In addition, we expect that we could get cells to produce RNA devices or modified RNA devices that might function if they were not degraded. The question is what we want the devices to do. With a specific goal, it is a lot easier to come up with an answer.

> Thank you again for your help. I look forward to hearing from you
> again and will continue to look into the research you have already done
> in the field.

Good luck!

Ned Seeman

8.5.6 Ocean Floor Colonisation

Date: Wed, 24 Jan 2001 09:10:47 -0500
From: "Nord, Daniel" <dnord@dan.duke.edu>
To: "'shadohrt@sidehack.sat.gweep.net'" <shadohrt@sidehack.sat.gweep.net>
Cc: "Evesque, Celia" <cevesque@dan.duke.edu>
Subject: RE: Science Museum Research

Justin - thank you for your inquiry and know we wish you luck with your project! I'm not certain to whom you might address your questions. However, you might try and locate a copy of the book, Project Sealab, which describes the U.S. Navy's ambitious effort to demonstrate man's capability to live on and explore the continental shelves of the world. This project was developed in the early 1960's and paved the way for other similar efforts by, I believe, the U.S. National Oceanic and Atmospheric Administration < http://www.noaa.gov > Visit their website and see if you can locate and network with someone who has background knowledge on this Administration < http://www.noaa.gov > Visit their website and see if you can locate and network with someone who has background knowledge on this subject. If nothing else, this may at least turn up other leads.

Divers Alert Network

Daniel A. Nord, EMT-P, CHT
Director, DAN Medical Services
Department of Anaesthesiology
Duke University Medical Center
(919) 684-2948 ext. 232 Office
(919) 493-3040 Facsimile
E-mail: dnord@dan.duke.edu

-----Original Message-----
From: Evesque, Celia
Sent: Wednesday, January 24, 2001 08:50
To: Nord, Daniel
Subject: FW: Science Museum Research

Not sure who to send this one to
C

-----Original Message-----
From: Winkler, Peter
Sent: Tuesday, January 23, 2001 4:22 PM
To: Evesque, Celia

Subject: FW: Science Museum Research

-----Original Message-----
From: ShadowHeart [mailto:shadohrt@sidehack.sat.gweep.net]
Sent: **Tuesday, January 23, 2001** 7:25 AM
To: dan@diversalertnetwork.org
Subject: Science Museum Research

To Whom it May Concern:

I am currently a full-time university student at Worcester Polytechnic Institute in Massachusetts, USA. In collaboration with the Science Museum in London, I am researching and working on a new gallery called IN FUTURE. This gallery focuses on the future of science and technology in 2020 and asks visitors to consider this technology and its use through a series of interactive games.

Currently, I am researching the possibility of creating an underwater colony by, or in the year 2020. One of the major areas of concern are medical issues relating to this type of habitat. I was wondering if I could receive a small list of potential contacts regarding the medical repurcussions that living in a colony such as this might create. I would also appreciate an other contacts of people that may have expert opinions and ideas regarding other aspects of this research.

I can be contacted at any of the numbers below or via a return email.

011 44 207 942 4835

I look forward to hearing from you.

With thanks.

Yours sincerely,
Justin T. Cole

Date: Tue, 23 Jan 2001 07:26:23 -0500 (EST)
From: ShadowHeart <shadohrt@sidehack.sat.gweep.net>
To: ussubs@ussubs.com
Subject: Science Museum Research

To Whom it May Concern:

I am currently a full-time university student at Worcester Polytechnic Institute in Massachusetts, USA. In collaboration with the Science Museum in London, I am researching and working on a new gallery called IN FUTURE. This gallery focuses on the future of science and technology in 2020 and asks visitors to consider this technology and its use through a series of interactive games.

Currently, I am researching the potential for creating a permanent dwelling on the ocean floor either for residential use or for marine research purposes.

If you have any ideas on this subject or know of someone I could contact that would have ideas I would love to hear them.

I can be contacted at the number below or via a return email.
011 44 207 942 4835

I look forward to hearing from you.

With thanks.
Yours sincerely,
Justin T. Cole

Date: Mon, 5 Feb 2001 13:37:55 -0500
From: L. Bruce Jones <ussubs@ussubs.com>
To: ShadowHeart <shadohrt@sidehack.sat.gweep.net>
Subject: Re: Science Museum Research

I'm happy to discuss the subject with you.

I can be reached at the number below.

Kind regards,

L. Bruce Jones
>>quoted message

==========

L. Bruce Jones, President U.S. SUBMARINES, INC.
936 N.W. First St. Fort Lauderdale, FL 33311
Tel: 954/467-9028 Fax: 954/467-9584
E-mail: bruce@ussubs.com http://ussubs.com

"Design, engineering and construction of submarines and submersibles"
"Submarine related consulting, sales and operations."

==========

8.5.7 Smart Clothes/Wearable Computers

Date: Tue, 30 Jan 2001 09:01:32 -0500 (EST)
From: ShadowHeart <shadohrt@sidehack.sat.gweep.net>
To: rehmi@media.mit.edu, morth@media.mit.edu
Subject: Science Museum research

Dear Professors Post and Orth,

I read your article on 'Smart Fabric, or Washable Computing' on the world wide web.

I am currently a full time student at Worcester Polytechnic Institute and I am working on a project in conjunction with the national Museum of Science and Industry in London, UK.

The goal of the project is to complete an exhibit entitled 'In Future.' The exhibit is designed to foster public awareness on current technological and scientific progress through a series of interactive games. My project is to research several more potential topics for this exhibit. Two of the topics I cam up with were the possibility of laptops evolving into wearable computers and clothing that would be smart enough to always maintain an environment in which the wearer was comfortable. In my research, including your article, I discovered that it may be possible to skip that phase of both technologies and jump to a point in which the two converge to make computers that are built into clothing.

I was hoping that one, or both, of you would be able to assist me in my research by giving me a professional, expert opinion of what the current state of the technology is for either one of the fields (or both) as well as an expert guess as to where the technology will be in the year 2020.

I also would appreciate any input regarding other possible sources for similar information that you may be aware of.

Many thanks and I hope to hear from you soon.

Sincerely,
Justin T. Cole

Date: Tue, 30 Jan 2001 09:14:03 -0500 (EST)
From: Margaret Orth <morth@media.mit.edu>
To: ShadowHeart <shadohrt@sidehack.sat.gweep.net>
Cc: rehmi@media.mit.edu
Subject: Re: Science Museum research

I would be happy to chat with you. Would you like to make a phone appointment?

maggie orth

Date: Wed, 31 Jan 2001 07:46:33 -0500 (EST)
From: ShadowHeart <shadohrt@sidehack.sat.gweep.net>
To: Margaret Orth <morth@media.mit.edu>
Cc: rehmi@media.mit.edu
Subject: Re: Science Museum research

A phone appointment would be great. The best times for such an appointment (given the time zone change) would be in the morning for you (anytime before 12 noon). If you would like to supply me with a date and phone number at which I can reach you I would be happy to call you at that time if it is possible for me to do so.

Thank you,
Justin T. Cole

Date: Wed, 31 Jan 2001 09:12:04 -0500 (EST)
From: Margaret Orth <morth@media.mit.edu>
To: ShadowHeart <shadohrt@sidehack.sat.gweep.net>
Cc: rehmi@media.mit.edu
Subject: Re: Science Museum research

How about this Friday AM

the number is 617 252-0804

9:30 -12 I will be there.

maggie

8.5.8 Tissue Engineering

(Note: This topic was previously pursued by NMSI staff for an exhibit and kept a running dialogue with experts. Our liaison advised that contacting more was unnecessary.)

Date: Thu, 25 Jan 2001 10:13:54 -0500 (EST)
From: Lani Warner <ewarner@wpi.edu>
To: rlanger@MIT.edu
Subject: London Science Museum Inquiry

Dear Dr. Langer,

I am currently a full-time Biomedical Engineering student at Worcester Polytechnic Institute. In collaboration with the Science Museum in London, I am researching and working on a new gallery called IN FUTURE. This gallery focuses on the future of science and technology in 2020 and asks visitors to consider this technology and its use through a series of interactive games.

Currently, I am researching the topic of tissue engineering. Possible angles we are considering include the hazards involved in the proliferation stages and the possibility of "stem cell banks" in the future. We are currently shying away from the cloning aspects of tissue engineering. After researching your work, I am very interested in more detailed information that you may be able to provide. We hope to introduce the topic to museum visitors in an engaging and creative manner.

If you have any information on this area or any contacts with whom I could get in touch, I would be very grateful to hear from you.

I can be contacted at any of the numbers below.

I look forward to hearing from you.
With thanks.

Yours sincerely,
Elaine Warner
In Future Gallery
National Museum of Science and Industry
011-44-207-942-4836
ewarner@WPI.edu

Date: Tue, 30 Jan 2001 11:37:15 -0500
From: Robert Langer <rlanger@MIT.EDU>

To: Lani Warner <ewarner@WPI.EDU>
Subject: Re: London Science Museum Inquiry

Hello,
I have some information that I can send you. Please email me with your mailing address (please cc my assistant at ifmoura@mit).
Regards,
Bob Langer

Date: Tue, 30 Jan 2001 11:50:10 -0500 (EST)
From: Lani Warner <ewarner@wpi.edu>
To: Robert Langer <rlanger@MIT.EDU>
Cc: ifmoura@mit.edu
Subject: Re: London Science Museum Inquiry

Dear Dr. Langer,
Thank you for your help. Out mailing address is:

Elaine Warner
Wellcome Wing Project
Science Museum
Exhibition Road
London SW7 2DD
UK

Any information you have would be appreciated. Specifically, any information regarding pitfalls/obstacles that need to be overcome during the proliferation of cells to form the tissue would be of use. We are currently developing an interactive, aimed at children, that puts them in the position of inside the tissue during the growth. Thank you again for your help.

Yours,
Elaine

8.5.9 Weather Modification

Date: Tue, 23 Jan 2001 06:52:04 -0500 (EST)
From: Kerri Anne Hufnagle <khufnagl@wpi.edu>
To: eastlund@eastlundscience.com
Subject: Science Museum Research

Dear Dr. Eastlund,

I am currently a full-time university student at Worcester Polytechnic Institute in Massachusetts, USA. In collaboration with the Science Museum in London, I am researching and working on a new gallery called IN FUTURE. This gallery focuses on the future of science and technology in 2020 and asks visitors to consider this technology and its use through a series of interactive games.

Currently, I am researching the topic of weather modification and the possibility that humans may be controlling the weather in 20 years time. I would greatly appreciate hearing your views on this possibility, as well as any information concerning your theories and developments that you could provide.

If you could provide any information on this area or any contacts with whom I could get in touch, I would be very grateful to hear from you.

I can be contacted by email at khufnagl@wpi.edu or at the number below.

001-44-207-942-4836

I look forward to hearing from you.

With thanks.

Yours sincerely,

Kerri Hufnagle

Date: Tue, 23 Jan 2001 11:35:10 EST
From: ESEC@aol.com
To: khufnagl@WPI.EDU
Subject: Re: Science Museum Research

Dear Kerri,

Congratulations on your ambitious project. You might want to start with the two technical papers available on my web site. The first is the paper I presented at the Explospace Conference in Sardinia regarding the "Thunderstorm Solar Power Satellite". This paper reviews other weather modification projects, such as "StormFury". The second paper develops guidelines for doing such research.
(I adopted some of the guidelines from an NRC report on ground rules for mitigation of global warming research.)

Go to my website at www.eastlundscience.com and click on current projects. The weather papers can be found in that section.

If I can be of any further help, please let me know.

Best Regards,
Ben Eastlund

Date: Tue, 20 Feb 2001 06:02:07 -0500 (EST)
From: Kerri Anne Hufnagle <khufnagl@wpi.edu>
To: ESEC@aol.com
Subject: Re: Science Museum Research

Dear Dr. Eastlund,

Thank you for your help with our project on weather modification. We have developed the text for the "Controlling the Weather" game and were hoping that you could take a minute and read through it to check for accuracy. We realize that the level of the text is very simplified as it needs to be understood by science museum visitors of all ages. If you could read through the text and let us know if there are any inaccuracies, it would be greatly appreciated.

Thanks again for all you help.
Sincerely,
Kerri Hufnagle

The Year is 2020

Tornadoes, hurricanes, and other storms are now things of the past.

The government now controls the weather using satellites in outer space.

The satellites calm the storms by zapping them with laser beams and cutting off their energy supply.

(there will be an interactive game here)

Controlling the weather could prevent the thousands of lives lost each year due to violent storms. But could it create problems if used the wrong way?

What do YOU think?
Would it be right for humans to control the weather?
Would we be interfering with nature? And what if the wrong people get their hands on the controls?

Cast your vote now
Should humans be allowed to control the weather?

"Weather" You Believe it or Not
An agreement was passed at a United Nations conference in 1977 prohibiting changing the weather for hostile purposes as it endangers too many civilians.

Date: Tue, 20 Feb 2001 14:26:27 EST
From: ESEC@aol.com
To: khufnagl@WPI.EDU
Subject: Re: Science Museum Research

Thanks for the update. I would use both microwaves and lasers in the description.
(Lasers can't penetrate deep enough into some of the storms.)

Cheers,

Ben Eastlund

Date: Tue, 23 Jan 2001 06:57:06 -0500 (EST)
From: Kerri Anne Hufnagle <khufnagl@wpi.edu>
To: emanuel@texmex.mit.edu
Subject: Science Museum Research

Dear Professor Emanuel,

I am currently a full-time university student at Worcester Polytechnic Institute in Massachusetts, USA. In collaboration with the Science Museum in London, I am researching and working on a new gallery called IN FUTURE. This gallery focuses on the future of science and technology in 2020 and asks visitors to consider this technology and its use through a series of interactive games.

Currently, I am researching the topic of weather modification and the possibility that humans may be controlling the weather in 20 years time. I would greatly appreciate hearing your views on this possibility, as well as any information concerning your studies on this subject.

If you could provide any information on this area or any contacts with whom I could get in touch, I would be very grateful to hear from you.

I can be contacted by email at khufnagl@wpi.edu or at the number below.
001-44-207-942-4836

I look forward to hearing from you.

With thanks.
Yours sincerely,
Kerri Hufnagle

Date: Wed, 24 Jan 2001 08:29:48 -0500
From: Kerry Emanuel <emanuel@texmex.mit.edu>
To: Kerri Anne Hufnagle <khufnagl@WPI.EDU>
Subject: Re: Science Museum Research
Parts/Attachments:

Dear Ms. Hufnagle: Thanks for your note. I am by no means an expert in weather modification, though recently we have begun some laboratory experiments to determine whether hurricane intensity might be modified by artificially inhibiting evaporation from the sea surface. I attach a proposal we wrote about a year ago to build an apparatus to do this; that proposal was funded and the apparatus has been built. We are just now doing experiments with it. If you would like to come to MIT some day to have a look, do let me know.

Yours, Kerry Emanuel

Date: Fri, 9 Feb 2001 05:36:31 -0500 (EST)
From: Kerri Anne Hufnagle <khufnagl@wpi.edu>
To: rasm@ucar.edu
Subject: Science Museum Research

Dear Erik Rasmussen,

I am currently a full-time university student at Worcester Polytechnic Institute in Massachusetts. In collaboration with the Science Museum

in London, I am researching and working on a new gallery called IN FUTURE. This gallery focuses on the future of science and technology in 2020 and asks visitors to consider this technology and its use through a series of interactive games.

Currently, I am researching the topic of weather modification and the possibility that humans may be controlling the weather in 20 years time. I have contacted Dr. Bernard Eastlund about his ideas on tornado suppression, and I have also been in contact with Bruce Boe of Weather Modification Inc, who suggested I contact you. I would greatly appreciate hearing your views on the possibility of controlling the weather in the year 2020, and specifically any thoughts you might have on Dr. Eastlund's ideas that tornadoes could possibly be overcome by directing lasers at their energy source to prevent them from forming.

Any thoughts, ideas, or further contacts you could provide would be most useful.

I can be contacted by email at khufnagl@wpi.edu or at the telephone number below.
001-44-207-942-4836

I look forward to hearing from you.

With thanks.
Yours sincerely,
Kerri Hufnagle

Date: Fri, 9 Feb 2001 09:15:25 -0700
From: Erik Rasmussen <rasm@ucar.edu>
To: Kerri Anne Hufnagle <khufnagl@WPI.EDU>
Cc: rasm@ucar.edu, Chuck Doswell <doswell@nssl.noaa.gov>
Subject: Re: Science Museum Research

Kerri,

I am cc'ing my response to Dr. Charles Doswell because he has given a lot of thought to the issues of weather modification that you might find helpful.

Personally, I think Dr. Eastlund's idea is dangerous, and I wish he would stop promoting it through the popular media. Our most recent research indicates that warm downdrafts increase tornado probability, and increase the probability of strong tornadoes. The last thing I would _ever_ want to do to a supercell thunderstorm is warm its downdraft. This is an idea that could end up killing people (assuming that you haven't already killed them

with the microwave radiation!).

Regards,
Erik

Date: Fri, 9 Feb 2001 12:13:43 -0600
From: Chuck Doswell <cdoswell@hoth.gcn.ou.edu>
To: Kerri Anne Hufnagle <khufnagl@WPI.EDU>
Cc: Erik Rasmussen <rasm@ucar.edu>
Subject: Re: Science Museum Research

Ms. Hufnagle,

Dr. Erik Rasmussen sent:

>I am cc'ing my response to Dr. Charles Doswell because he has given a lot of
>thought to the issues of weather modification that you might find helpful.
>
>Personally, I think Dr. Eastlund's idea is dangerous, and I wish he would
>stop promoting it through the popular media. Our most recent research
>indicates that warm downdrafts increase tornado probability, and increase
>the probability of strong tornadoes. The last thing I would _ever_ want to
>do to a supercell thunderstorm is warm its downdraft. This is an idea that
>could end up killing people (assuming that you haven't already killed them
>with the microwave radiation!).

You should go to:

<http://webchat.chatsystems.com/~doswell/wxmod/wxmod.html>

for my thoughts on the subject.

Regards ... Chuck Doswell

Dr. Charles A. Doswell III CIMMS
The University of Oklahoma
phone: (405) 325-6093 Sarkeys Energy Center
e-mail <cdoswell@hoth.gcn.ou.edu> 100 East Boyd Street, Room 1110
Norman, OK 73019-1011
WWW home page: <http://www.nssl.noaa.gov/~doswell>
Standard disclaimer ... my views are my own, so don't blame my employer.

He who breaks a thing to find out what it is, has left the path of wisdom.
- J.R.R. Tolkien, Lord of the Rings

Date: Tue, 23 Jan 2001 07:04:38 -0500 (EST)
From: Kerri Anne Hufnagle <khufnagl@wpi.edu>
To: info@weathermod.com
Subject: Science Museum Research

Dear member of Weather Modification Inc.,

I am currently a full-time university student at Worcester Polytechnic Institute in Massachusetts, USA. In collaboration with the Science Museum in London, I am researching and working on a new gallery called IN FUTURE. This gallery focuses on the future of science and technology in 2020 and asks visitors to consider this technology and its use through a series of interactive games.

Currently, I am researching the topic of weather modification and the possibility that humans may be controlling the weather in 20 years time. I would greatly appreciate hearing your views on this possibility, as well as any information concerning your studies on this subject.

If you could provide any information on this area or any contacts with whom I could get in touch, I would be very grateful to hear from you.

I can be contacted by email at khufnagl@wpi.edu or at the number below.

001-44-207-942-4836
I look forward to hearing from you.

With thanks.
Yours sincerely,
Kerri Hufnagle

Date: Thu, 01 Feb 2001 11:07:31 -0600
From: Bruce & Peg Boe <bboe@tic.bisman.com>
To: khufnagl@WPI.EDU
Cc: jim@weathermod.com
Subject: future of weather mod
Parts/Attachments:

Dear Kerri--

My name is Bruce Boe; I work for Weather Modification, Inc., as an atmospheric scientist. To provide you some perspective of my background, until late last year I served as Director of the North

Dakota Atmospheric Resource Board (ARB), a division of the State Water Commission. The ARB is the entity here in North Dakota responsible for the regulation and oversight of cloud seeding activities, which up here are seasonal, conducted during spring and summer to increase rainfall and decrease hail damage. While serving in that capacity, I co-ordinated two fairly intensive research field programs, one in 1989, the other in 1993. I have attached a bibliography (NDTP_BIB.wpd) summarising the results of these programs, in the event you are truly brave and wish to explore further.

In November 2000, the National Academy of Sciences convened a national panel on the subject of weather modification, because the NAS Board on Atmospheric Sciences and Climate (BASC) felt a national review of the technology was overdue, especially considering the technological advances since 1978, when the issue was last addressed. That meeting (of which I was fortunate to be a part) went well, and it is my understanding that the NOAA has agreed to fund a more in-depth follow-on study. An initial report has been issued by the BASC; you might obtain a copy by contacting Mr. Vaughn Turekian at vturekia@nas.edu.

As to my personal feelings as to where the technology is headed, I offer the following comments.

Precipitation Enhancement
Future: Very bright. Advances in nucleation technology, both for glaciogenic (ice-forming) and hygroscopic (drop-forming) agents have created new opportunities here. Projects are showing increasingly positive results; recent successful efforts with hygroscopic seeding have been replicated elsewhere on at least two other projects, so this is encouraging indeed. I'm confident the NAS will place special emphasis in this area. Will humankind be able to make it rain whenever we want by the year 2020? I doubt it very much. However, the precipitation increases realized from the technology are already well into the double-digits (percentage-wise), and will probably continue to increase. One of the so-called "down sides" to seeding for precipitation increase has in the past been the perception that doing so simply moves the water around, that is, if one gets more water in one location, it is decreased someplace else. This perception too is changing, as we've come to realize that the hydrologic cycle is just that, a cycle, and additional water that falls as precipitation because of cloud seeding is most often quickly returned to the atmosphere via evaporation and transpiration, to feed future cloud development. Put another way, If you need rain, would you rather be downwind of a desert or an oasis?

Hail Suppression

Future: Bright. Advances are helping here, too. However, one must deal with a more energetic and complex phenomenon. Results from existing operational programs continue to be positive (e.g. 45% decrease in crop-hail damage in North Dakota), but a great deal is not known about the physics and dynamics of hailstorms. Technology now offers the tools to tackle these questions, and I believe we'll see some answers in the next ten years. By 2020, this emerging technology should be on a very sound scientific basis (right now, much remains speculative), but I suspect there'll remain some storms so severe that they'll still produce hail.

Fog Suppression
Future: Extremely bright for supercooled fogs, good to bright for warm fogs. Supercooled fogs can routinely be dissipated by treatment with glaciogenic agents. This is routinely done during winter months at some fog-prone airports (Salt Lake City, for example). Warm fogs are more difficult because one can't make ice in them, and the energy required to dissipate them (with lasers, say) is prohibitively expensive. New hygroscopic treatments offer some hope here though, as this approach works through the warm cloud (coalescence) process. Right now, we already can "control" cold fogs; we'll see about the warm ones.

Tornado and Hurricane Suppression
These are real long shots, but not inconceivable. As our knowledge base grows, we may learn things that will make this possible, at least in some cases. There is some interest in exploring this-- Erik Rasmussen (I believe at the National Severe Storm Laboratory, Norman, OK, but maybe with the U of OK) has communicated an interest in this to me within the last year. You might explore his feelings about this subject.

Well, I've already go on quite long enough, so I'll cease. Hope this helps.

Best Regards,

Bruce Boe
bboe@weathermod.com
bboe@tic.bisman.com

Date: Mon, 5 Feb 2001 11:22:50 -0500 (EST)
From: Kerri Anne Hufnagle <khufnagl@wpi.edu>
To: vturekia@nas.edu
Subject: Science Museum Research

Dear Mr. Vaughn Turekian,

I am currently a full-time university student at Worcester Polytechnic Institute in Massachusetts, USA. In collaboration with the Science Museum in London, I am researching and working on a new gallery called IN FUTURE. This gallery focuses on the future of science and technology in 2020 and asks visitors to consider this technology and its use through a series of interactive games.

Currently, I am researching the topic of weather modification and the possibility that humans may be controlling the weather in 20 years time. I contacted Mr. Bruce Boe, an atmospheric scientist for Weather Modification Inc. He mentioned that he attended a meeting of the National Academy of Sciences on the subject of weather modification in November 2000, and said I might obtain a copy of the initial report from you.

If you could provide this report, any information on this area, or any contacts with whom I could get in touch, it would be greatly appreciated.

I look forward to hearing from you.

With thanks.
Yours sincerely,
Kerri Hufnagle

khufnagl@wpi.edu
Wellcome Wing
Science Museum
Exhibition Road
London
SW7 2DD

Date: Mon, 5 Feb 2001 11:27:19 -0500
From: Vaughan Turekian <vturekia@nas.edu>
To: Kerri Anne Hufnagle <khufnagl@WPI.EDU>
Subject: Re: Science Museum Research

Kerri,
I will send you a copy of the National Research Council's report on Weather Modification.

If you have any questions, please contact me. should I send it to the London address?

Vaughan

Vaughan Turekian Ph.D.
Program Officer
Board on Atmospheric Sciences and Climate
The National Academies
202-334-2547
vturekia@nas.edu

Date: Mon, 5 Feb 2001 11:36:34 -0500 (EST)
From: Kerri Anne Hufnagle <khufnagl@wpi.edu>
To: Vaughan Turekian <vturekia@nas.edu>
Subject: Re: Science Museum Research

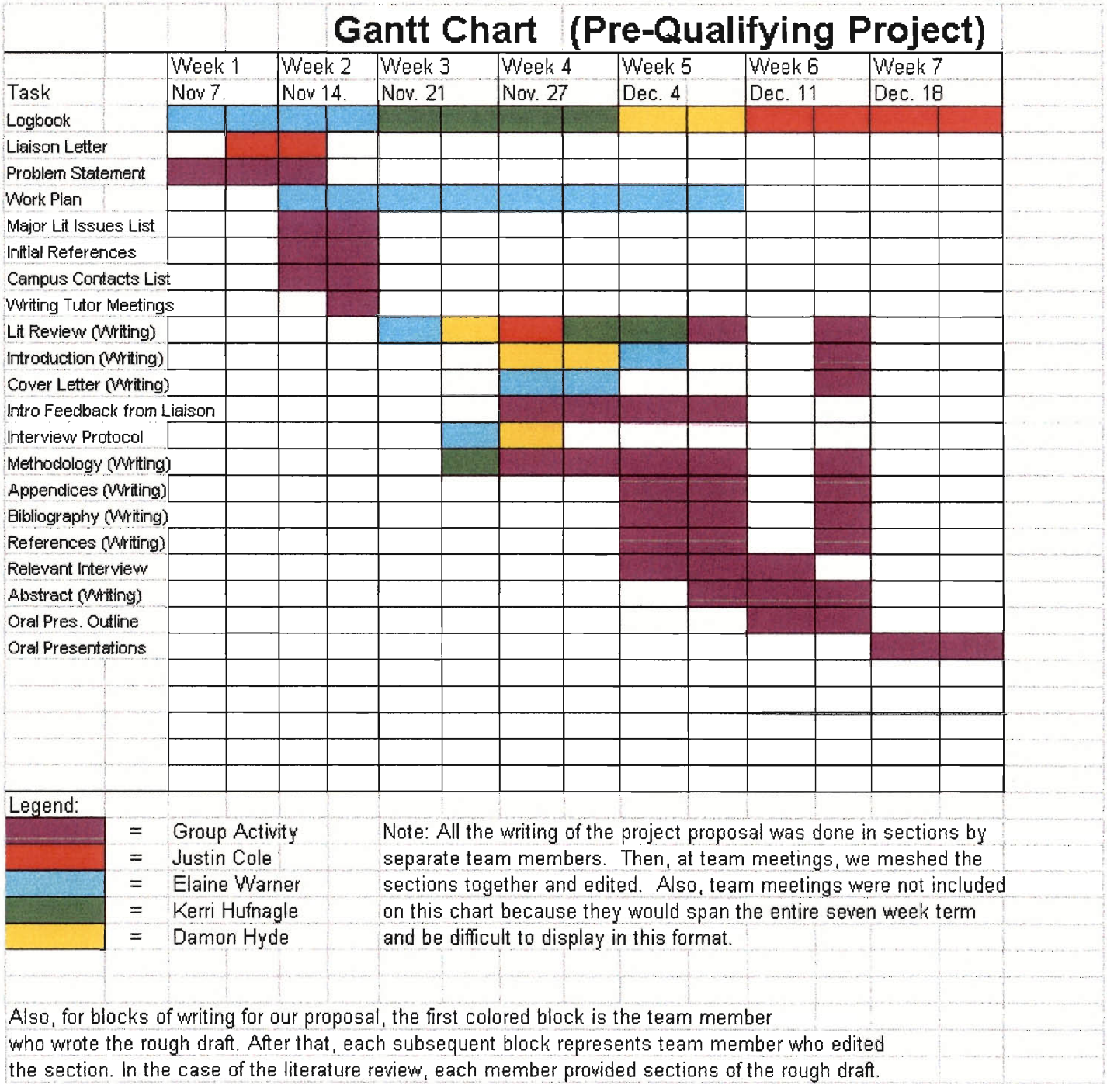
Dear Vaughan,

Thank you for your quick response. Yes, please send it to the London address. I appreciate your help as this report will be most useful for our research.

Thanks again,
Kerri

8.6 Appendix F: Task Charts for PQP and IQP

8.6.1 B Term 2000 (Pre-Qualifying Project)



8.6.2 C Term 2001 (Interactive Qualifying Project)