Commercial space flight

Starship enterprise: the next generation

A fleet of privately financed spaceships is emerging. It heralds a new business in space travel

THE way Will Whitehorn tells it, the story began in 2003 in Mojave, California, on a visit to Scaled Composites, a company with a reputation for designing and building futuristic and sometimes wacky-looking aircraft. Mr Whitehorn is one of the top brass in Sir Richard Branson's Virgin Group; and Virgin Atlantic, Sir Richard's airline, was sponsoring Global Flyer, a Scaled Composites creation, on a non-stop voyage around the world. On his way out of the factory Mr Whitehorn saw something unusual and asked what it was. Burt Rutan, head of Scaled Composites, told him it was a spaceship. He was building it for another customer, but he couldn't say any more.

Mr Rutan's customer turned out to be Paul Allen, one of the founders of Microsoft. When SpaceShipOne, as the craft was called, reached space for the second time, on October 4th 2004, it won the $10m Ansari X Prize. The craft was taken to high altitude by White Knight, a more-or-less conventional aircraft, and then dropped, whereupon its engines ignited to shoot it 100km (60 miles) above the planet, and thus officially into space. After a short flight it re-entered the Earth's atmosphere and glided down to land on a conventional

runway. Manned space travel thus moved from the realm of governments to private enterprise.

However, Mr Allen was interested only in proving that the spaceship technology would work, not in exploiting it commercially himself. That left Mr Rutan with a very cool spaceship on his hands, but no way of making money from it. Mr Whitehorn and Sir Richard were intrigued. Virgin Galactic, a company in the Virgin stable and which was headed by Mr Whitehorn, decided to license the technology for SpaceShipOne and White Knight. Virgin Galactic said it wanted to offer commercial sub-orbital flights to paying passengers by the end of the decade.

Virgin Galactic has since accumulated a number of commercial rivals in the space-tourism market. One of them is Jeff Bezos, the founder of Amazon.com, who is building a competing sub-orbital spaceship at a ranch in Texas. His space company, Blue Origin, is so secretive that it will not even answer questions about its logo.

But Virgin Galactic has passed an important milestone. At an event held at the American Museum of Natural History in New York, on January 23rd, the company unveiled the design of its new generation of vehicles, and said that the first examples had almost been finished at Mr Rutan's factory. White Knight Two is due to begin test flights towards the middle of 2008, but may roll out of the hangar in the next few weeks. Test flights of SpaceShipTwo itself could start towards the end of the year.

Fly me to the moon

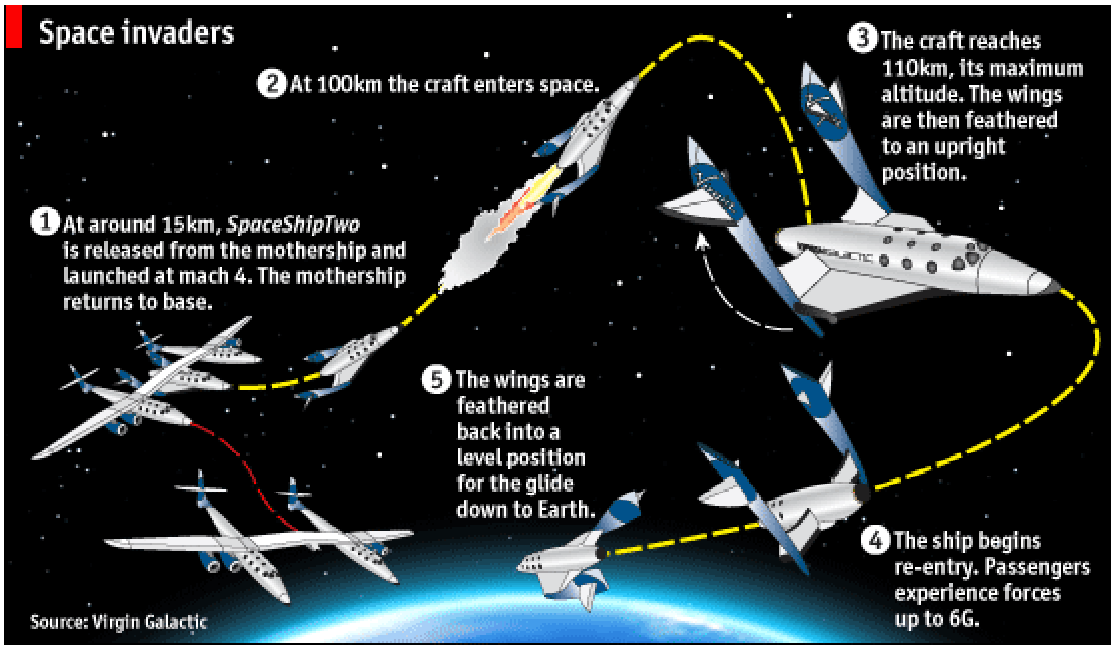
The combination of a carrier aircraft and a spaceship to get into space is akin to building a two-stage rocket. Air-launched rockets have a long history. SpaceShipOne and White Knight were, in essence, vastly improved and much cheaper versions of the X-15 rocket plane that set speed and altitude records in the early 1960s and the B-52 bomber that carried the rocket plane under its wing. But pure rockets, such as the ones that lift the space shuttle, won out because the Space Race between America and Russia emphasised speed over cost, and rockets were proven technology, having already been developed as intercontinental ballistic missiles. However, they consume a huge amount of power as they claw their way up through the Earth's thick atmosphere. By contrast a rocket lifted by a plane with wings before being launched can be made much smaller and lighter. The plane itself is light because its engines breathe air. It thus needs to carry less fuel than a rocket, and no chemical

oxidant to burn that fuel, as a rocket would. Each craft—plane and rocket—can therefore be optimised for its own job, which is easier than designing a single vehicle that has to make lots of compromises to do both.

Lifting more

Virgin Galactic's second generation of craft are based on SpaceShipOne and White Knight, but with plenty of differences. White Knight Two has been redesigned wholesale to lift a much larger spaceship with eight people on board instead of three. It has a wingspan equivalent to that of a Boeing 757, is three times larger than its predecessor and is the largest aircraft made entirely from composite materials like carbon fibre. It is powered by four Pratt & Whitney engines. With its twin boom and long wing, it looks more like the Global Flyer than its predecessor. It has also been engineered to be able to treat any passengers it carries to zero-gravity swoops on the way down after they have watched the spaceship being released for its trip into space.

SpaceShipTwo itself will accommodate two pilots at the front and also six passengers, who will have room enough to bounce around in zero gravity. It has more of a dolphin-like nose than its prototype and more windows. It will also go a little higher than its predecessor, so that its passengers will experience five minutes or so of weightlessness before flying back to receive their astronauts' wings. But, crucially, it has the same flip-up wings. These are used when the craft reconfigures itself for re-entry into the Earth's atmosphere. The wings rotate through 90° to give it extremely high drag, which allows it to begin its slow deceleration through the atmosphere earlier and at higher altitudes than previous spaceflight re-entries.



The spaceship will be fuelled by a “hybrid rocket”—so-called because it contains both liquid and solid propellants. These rockets can be cheaper to develop and operate, and the fuel is safer to store than in purely liquid-fuelled ones. SpaceShipOne used rubber and laughing gas. Scaled Composites is studying alternatives to rubber that may offer better performance.

Another change in the design of the spaceship is the insertion of a flexible glass-fibre section into its composite structure. This will allow the rocket's oxidiser tank to expand when it is full. All these changes mean that when SpaceShipTwo does begin flight tests, the programme will last at least a year before paying customers can take to the skies.

Work will also begin soon on fitting out another factory to start making more of these craft. Virgin Galactic has ordered five spaceships and two carrier aircraft. The spaceships will take longer to refuel for their next flight than the carrier aircraft do, so—thinking just as an airline would—the firm has concluded it needs more spaceships than carriers. Each spaceship should eventually be capable of making two trips into space every day, and the launch aircraft three or four flights. Mr Rutan says they could operate from a number of airports and spaceports around the world.

Virgin Galactic believes the fleet it has ordered should be large enough to furnish its space-tourism business in the early years. Trips are expected to cost some $200,000 each to start with. Hundreds of people have put down a total of $30m in deposits. However, as the firm also made clear at the announcement in New York, the new craft may one day do a lot more than ferry day-trippers to the edge of space and back. Stephen Attenborough,

Virgin Galactic's commercial director, says the spaceship is revolutionary because it is able to take not just people into space, but other payloads too.

Up, up and away

What those other things will be is still unclear, but satellites are a possibility. Virgin Galactic says it thinks it could launch small satellites in the range of 50-100kg into low-Earth orbit using an unmanned rocket hung from White Knight Two for less than $2.5m. The market for launching small satellites is presently only partly served by the Pegasus rocket, which is launched at high altitude by a commercial jet aircraft. But a launch using Pegasus would cost many times the price that Virgin is talking about. If costs are brought low enough it could make even tiny satellites financially viable. These could be sent up by all sorts of organisations, including universities for research projects.

An air launch is constrained by the weight the carrier aircraft can lift, so big rockets blasting off from the ground will, for the time being, remain the only way to get the heaviest payloads into space. It is possible for small satellites to hitch a ride along with big payloads, but that can be difficult to arrange and is much more restrictive than having a dedicated low-cost launch vehicle like White Knight Two. Virgin Galactic is already having discussions with a company interested in creating a rocket that would launch satellites from White Knight Two.

Launching at high altitude has many advantages for space tourists and commercial loads alike. Using an aircraft to take up a rocket can avoid the numerous weather-induced delays—and costs—that get in the way of rockets fired from the ground. Aircraft can climb above bad weather to a more suitable launch position. Nor do they need specially built, reinforced launch pads. Any suitable runway will do.

In addition, an air launch promises a lot more scope to find a good “launch window” to get the spacecraft into orbit. Launching from the ground can mean waiting for the Earth to rotate until the launch window is accessible. But an aeroplane carrying a rocket can fly to the window instead.

Air launches are also a greener way of getting into space, because they avoid igniting rockets in the lower atmosphere. Earlier this month Virgin Atlantic said it would fly one of its Boeing 747s using biofuel during a demonstration flight in February. Mr Attenborough says this has “implications” for White Knight Two, which indicates that the company is also looking at greener fuels for the carrier

aircraft.

Who knows if the moon's a balloon?

In the longer term Virgin Galactic's system could also be used to launch hypersonic vehicles, which could dash from one side of the world to the other in a few hours. In 2005 and 2006 White Knight test-launched the American government's experimental X-37 hypersonic plane. America's space agency, NASA, has signed an agreement with Virgin that covers co-operation on the planes. The company is also said to be discussing a third, more powerful generation of spaceships, designed to make longer sub-orbital journeys rather than just poking their noses into space in the way that White Knight Two will.

Mr Whitehorn and Mr Rutan have made no secret of their desire to see later generations of carrier aircraft and rocketry that can put people into orbit. Some within the industry are sceptical that Mr Rutan can develop such vehicles, which will have to travel many times faster than a sub-orbital plane and must have tougher heat-shielding in order to survive harsher re-entry. Nevertheless, business is taking an increasing interest in the possibilities and last year Northrop Grumman, a big aerospace and defence contractor, increased its 40% stake in Scaled Composites to 100%. Mr Rutan expects Scaled Composites to build 40-50 launch aircraft. He thinks that at least 15 will be used for space tourism, with the rest used for satellites and other payloads.

As the new generation of craft emerges, so will new ideas about their capabilities and potential. With some $70m already spent and another $130m still to come, Mr Attenborough says that Virgin Galactic expects to break even in 2014. Reducing the price of a trip into space to attract more customers is also part of the plan, as is exploiting every possible form of additional income, such as selling media rights.

Finding new markets for its carrier ship will help Virgin Galactic make money faster. Mr Whitehorn believes that wider use of the vehicle will ultimately come with lifting payloads and satellites into space. Although the customers for such launches are not yet putting down their deposits, the progress to commercial space flight—complete with a business plan and a profit goal—is nonetheless remarkable. There are surely easier and safer ways for businessmen like Sir Richard, Mr Bezos and others to make money. Then again, commercialising space is a venture for the unconventional.

Spaceflight medicals

Suited for space

Can humans cope with the final frontier?

PEOPLE did not evolve for space flight, so how will they cope when the tickets go on sale? It will be a wild ride, but one that a surprisingly large number may enjoy. Many of Virgin Galactic's early customers have been put through a human centrifuge to find out. This tests their reactions and tolerance to the forces that they would experience on a sub-orbital trip. That includes dealing with G-forces 6.5 times that of Earth's gravity and mostly they coped very well.

Human centrifuges featured in both “Moonraker” and “The Right Stuff”. The machines in those films were basic: a seat on the end of a metal beam. Known as “iron maidens”, they are medieval compared with the kit at the National Aerospace Training and Research Centre (NASTAR) in Southampton, Pennsylvania, which opened last year at a cost of $25m. The centre can simulate gravitational forces in any direction in its “dynamically positioned gondola”—a fancy way of describing a cabin that can face in any direction and is attached to an arm spinning around a central point.

The victims—sorry, customers—are strapped in as they watch a wide screen simulating the view into space. To the rear is another screen showing the receding Earth. With this, NASTAR is able to recreate any kind of space launch. Glenn King, of NASTAR, says the company usually trains fighter pilots, but it has also trained a few people who have paid to visit the international space station.

The simulation of forces likely to be experienced on the new Virgin Galactic spaceship suggests more people than had previously been imagined would be able to endure the trip. The accepted view was that only the fittest could withstand six Gs through the chest and 3.5Gs from head to toe. The second, smaller force, is tougher, because it pushes blood downwards and away from the head, sometimes leading to unconsciousness. Nevertheless, the passengers who tested well at NASTAR included a 77-year-old woman and James Lovelock, a scientist and author, who is 88.

Some people did need a trip to the doctor before going for a spin. In these

cases doctors looked for abnormalities, like an unusual heart rhythm. Unknown health problems are more of a threat than known ones. But even some who had health problems were able to go ahead, says Mr King. Of the 80 potential passengers, two were advised by their doctors not to take part and three were asked to come back after more training.

NASTAR reckons that more than 90% of the population could handle a sub-orbital flight. Nor does Mr King see any reason why children as young as five or six could not go too. Air sickness should not be a problem. Virgin Galactic's Will Whitehorn says that one operator of zero-gravity aeroplane rides has virtually eliminated the vomiting, thanks to a combination of “diet, drugs, training and methodology”. No reason then, short of a few hundred thousand dollars, not to book a flight right now.

Artificial life

Nearly there

The penultimate step towards the creation of artificial life has just been announced

LIKE a striptease artist in front of an eager audience, Craig Venter has been dropping veils over the past few years without ever quite revealing what people are hoping to see: the world's first artificial organism. He has been discussing making one since 1995, when he worked out the first complete genetic sequence of a natural living organism. And, after a lot of hard graft and blind alleys, he and his team have almost got there. As they report in this week's Science, they have replicated the genome of Mycoplasma genitalium, the species that was the subject of that original sequencing effort. It is not actual life, but it is surely the tease before the last veil finally falls away.

Though Dr Venter (pictured above at the helm of his yacht, Sorcerer II) is the public face of the effort, and the 17-strong team that did the work are all employed by the J. Craig Venter Institute in Rockville, Maryland, the synthetic genome project is equally the brainchild of his collaborator, Hamilton Smith. Indeed, it is in Dr Smith's name that the paper announcing the synthesis is published—along, of course, with the 16 others including Dr Venter himself.

It is a formidable effort. But what is, perhaps, most noteworthy is that the starting point for the project was not the raw nucleotides (the chemical letters of which DNA is composed), but a set of pre-assembled “cassettes” of DNA that the team had ordered from commercial suppliers. The point where any Tom, Dick or Harriet with a reasonably well equipped genetics laboratory could do likewise is not, therefore, that far off.

All you create

M. genitalium's genome is a single, circular chromosome that is 580,076 letters long, and contains 485 protein-coding genes. The team divided it on paper into 101 units (the cassettes), each containing four or five genes. They also took the precaution of editing one gene in particular, so that it would not

work. The gene in question is crucial to M. genitalium's ability to stick to mammalian cells, and thus become infective (it lives naturally in the urinary tract and is thought to cause urethritis). Disrupting it thus forestalled the risk of creating anything nasty.

The team placed orders for the cassettes with three firms that turn such things out routinely. They then used a variety of techniques, some old and some specially invented, to link the cassettes together into larger and larger units until they had two half chromosomes which, with the aid of some yeast cells, they turned into a whole one. All that remains to create what most researchers in the field would be willing to recognise as an artificial organism is to insert such a chromosome into a bacterial cell that has had its own chromosome removed. At the moment, no one is clever enough to make all of the cellular machinery that translates genes into the stuff of life. Hence the need for this shortcut. But if the newly reconstituted cell were able to grow and reproduce, the nature of its progeny would be dictated by the implanted chromosome. That, not the nature of the host “shell”, would define the species of the progeny.

Dr Venter's purpose in synthesising artificial genomes is twofold. Scientifically, he wants to understand how life works. One way to do this is to discover what he refers to as the minimal genome. This is a Platonic ideal of life, which would contain only the genes absolutely necessary for survival and reproduction, and might shed light on the nature of Luca, the last universal common ancestor of life on Earth. In practice, that ideal is difficult to realise, since many genes cover for each other. He knows that 100 of M. genitalium's genes can be eliminated individually without killing it, but eliminate all of these and it dies. Assembling mix-and-match genomes with lots of different combinations of cassettes that each contain but a handful of genes should shed light on the question.

But Dr Venter is also a practical man, who wants to turn genomics into technology. Indeed, one of his other enterprises is a firm called Synthetic Genomics and he is one of the leading lights of the emerging field of synthetic biology. This seeks, among other things, to create a parts list of biological components such as DNA cassettes that could be ordered from catalogues in the way that electronic components can be.

Synthetic Genomics itself is a bit cagey about exactly which molecular products it is working on, but one of Dr Venter's interests is in using modified bacteria to make fuels. Natural bugs can turn out both hydrogen and methane. There is talk of modifying them to produce high-value liquid fuels, for jets, say.

He is not alone in this idea. Several Californian firms are also seeking to make advanced biofuels using modified bacteria. But if Dr Venter can take the final step of kicking the new, wholly synthetic genome into reproductive life, he will not only have made a great technological leap forward, he will also have erased one of the last mythic distinctions in science—that between living and non-living matter. Watching that veil drop will have been worth the wait.

Microelectronics

Eyeing up a new technology

A “bionic” eye lens points to a new way of building microelectronic circuits

CONVENTIONAL contact lenses are good at correcting vision. That, however, is not enough for Babak Parviz. Dr Parviz, who works at the University of Washington, in Seattle, wants to get them to provide information, too. His model is the “head-up” displays of useful information on the windscreens of aircraft. Putting such displays into lenses might be valuable for both soldiers and civilians, but shrinking the technology to the point where it could be done has proved hard. Last week, however, at a conference in Tucson, Arizona, organised by the Institute of Electrical and Electronics Engineers, Dr Parviz revealed that he was getting close.

The lenses are made of polyethylene terephthalate (PET), the stuff used in overhead projection sheets. Dr Parviz uses PET because his research has shown that metal circuits can be safely attached to it. The trick is building that circuitry in the first place, because the components—most notably, light-emitting diodes, or LEDs—have to be made at high temperatures using corrosive gases.

The usual way of doing this—on a piece of silicon that also serves as the circuit board—would not work on PET, which would be almost instantly destroyed. Instead, Dr Parviz uses a technique he developed the year before last, and for which this is the first application.

It works by etching small, precisely shaped holes in the PET. The shapes of the holes match the components. Those components are made elsewhere, using conventional, plastic-hostile techniques. They are then mixed together to create a grey powder that floats in alcohol over the surface of the lens.

When a component is over an appropriately shaped hole in the PET, it slips into position. In this way, not only can LEDs be laid down, but also tiny solar panels and antennae that convert radio waves into electrical energy. Everything is

thus in place for a display unit that can both extract power from the outside world and also receive signals from it. All that need then be done is to encapsulate the result in Perspex—the material from which hard contact lenses are routinely made—to protect the circuitry without harming the wearer's eye. Lastly, the whole assembly is heated on an aluminium mould, so that it fits the eyeball of the wearer.

At the moment, Dr Parviz's prototype does not produce a useful image. That would require much more complicated circuitry than he has built so far. But he can make the LEDs flash on and off, so the principle seems to work.

The next stage is to get someone to try one of the lenses on. That, in today's risk-averse world, requires regulatory approval. But even by getting his self-assembled screen of LEDs to flash, Dr Parviz has shown that circuits can be built at room temperature this way. And that, rather than the details of this bionic-eye lens, is the real point of the exercise.

Organ transplants

A successful mixture

Transplanting immune-system stem cells along with kidneys stops rejection

WOE to the patient waiting for someone to offer up a spare organ for transplantation. Demand so far exceeds supply these days that in America alone around 17 people die every day while languishing in the queue. Nor do problems end there. Even the lucky ones, who do get their desired replacement part, face a lifetime on immunosuppressant drugs, to stop the alien tissue being rejected by their own immune systems.

David Sachs and Benedict Cosimi, of Harvard Medical School, have been working for some time to find a way around these problems. Their goal has been to trick the body into thinking that a foreign organ is really a native one, so that its immune system refrains from rejecting the foreigner. In this week's New England Journal of Medicine they report a small but promising study that, if confirmed on a grander scale, may deal with the issue once and for all and usher in a world in which immunosuppressant drugs are unnecessary and organs no longer need be matched to patients. That would make the lives of transplant patients easier and longer, and might also increase the useful supply of organs available for transplant.

Dr Sachs and Dr Cosimi tricked the body by transplanting a part of the donor's bone marrow along with the organ. Since the cells of the immune system are derived from stem cells in the bone marrow, these patients go on to develop what is known as chimeric immunity, which blends elements from the immune systems of both the donor and the recipient.

The process begins with the partial destruction of the recipient's own bone marrow using a drug called cyclophosphamide, followed by treatment with an antibody that depletes his supply of T cells, the part of the immune system that is most implicated in organ rejection. Once that is done, the organ (in this case a kidney) and the bone marrow are transplanted and the patient is confined for a fortnight in a sterile environment to protect him from infection while his new, mixed immune system boots up.

Dr Sachs and Dr Cosimi tried their new procedure on five people and it worked for four of them (though they did modify the process slightly after the third patient, by including antibodies against B cells, a second part of the immune system). On each occasion they transplanted a kidney that was, immunologically speaking, a poor match for the recipient. And in each of the four successful cases they were able take the patient off immunosuppressant drugs within 8-14 months, with no sign of rejection. All four of these patients are still alive; indeed, the first has now survived for more than five years. (The one failure later received a standard transplant, followed by a permanent regimen of immunosuppressant drugs, and is also still alive.)

Although the technique looks promising, it is a mystery why it should work. You would think that a chimeric immune system would be more active, not less, and would therefore attack the recipient's other organs, since they look foreign to the transplanted immune cells. Not so. Nor is it clear how the transplanted immune cells stop the existing ones from attacking the new organ. And, the immune system does not stay chimeric forever. Eventually, the original one predominates and the transplanted one vanishes (or, at least, becomes undetectable). Yet the transplant's protective effect persists with no sign, as yet, of diminishing—and there is every reason to believe, based on the results of experiments on monkeys, that it will not diminish in the future.

Four successes are not, of course, proof of a reliable technique. And even if the approach works for kidneys, it has yet to be tested for other organs. Neither does eliminating rejection increase the supply of organs for transplant, even though it means that fewer will be wasted. But Dr Sachs and Dr Cosimi have a suggestion here, too. They hope their discovery may allow organs to be transplanted from other species, such as pigs, and have filed a patent based on the idea.

Xenotransplantation, as this idea is known, really would increase the supply of organs, but it is a controversial idea. The “yuck” factor that cross-species transplants would probably provoke would surely fade if lives were saved. However, xenotransplantation brings the risk of transplanting animal viruses and thus creating new human diseases. It would be an irony if something intended to preserve lives ended up destroying them.

Physiognomy and success

Face value

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From The Economist print edition

What the boss looks like determines how he performs

A COUPLE of years ago a group of management scholars from Yale and the University of Pittsburgh tried to discover if there was a link between a company's success and the personality of its boss. To work out what that personality was, they asked senior managers to score their bosses for such traits as an ability to communicate an exciting vision of the future or to stand as a good model for others to follow. When the data were analysed, the researchers found no evidence of a connection between how well a firm was doing and what its boss was like. As far as they could tell, a company could not be judged by its chief executive any better than a book could be judged by its cover.

A few years before this, however, a team of psychologists from Tufts University, led by Nalini Ambady, discovered that when people watched two-second-long film-clips of professors lecturing, they were pretty good at determining how able a teacher each professor actually was. At the end of the study, the perceptions generated by those who had watched only the clips were found to match those of students taught by those self-same professors for a full semester.

Now, Dr Ambady and her colleague, Nicholas Rule, have taken things a step further. They have shown that even a still photograph can convey a lot of information about competence—and that it can do so in a way which suggests the assessments of all those senior managers were poppycock.

Dr Ambady and Mr Rule showed 100 undergraduates the faces of the chief executives of the top 25 and the bottom 25 companies in the Fortune 1,000 list. Half the students were asked how good they thought the person they were looking at would be at leading a company and half were asked to rate five personality traits on the basis of the photograph. These traits were

competence, dominance, likeability, facial maturity (in other words, did the individual have an adult-looking face or a baby-face) and trustworthiness.

By a useful (though hardly unexpected) coincidence, all the businessmen were male and all were white, so there were no confounding variables of race or sex. The study even controlled for age, the emotional expression in the photos and the physical attractiveness of the individuals by obtaining separate ratings of these from other students and using statistical techniques to remove their effects.

This may sound like voodoo. Psychologists spent much of the 20th century denigrating the work of 19th-century physiognomists and phrenologists who thought the shapes of faces and skulls carry information about personality. However, recent work has shown that such traits can, indeed, be assessed from photographs of faces with a reasonable accuracy.

And Dr Ambady and Mr Rule were surprised by just how accurate the students' observations were. The results of their study, which are about to be published in Psychological Science, show that both the students' assessments of the leadership potential of the bosses and their ratings for the traits of competence, dominance and facial maturity were significantly related to a company's profits. Moreover, the researchers discovered that these two connections were independent of each other. When they controlled for the “power” traits, they still found the link between perceived leadership and profit, and when they controlled for leadership they still found the link between profit and power.

These findings suggest that instant judgments by the ignorant (nobody even recognised Warren Buffett) are more accurate than assessments made by well-informed professionals. It looks as if knowing a chief executive disrupts the ability to judge his performance.

Sadly, the characteristics of likeability and trustworthiness appear to have no link to company profits, suggesting that when it comes to business success, being warm and fuzzy does not matter much (though these traits are not harmful). But this result also suggests yet another thing that stockmarket analysts might care to take into account when preparing their reports: the physog of the chief executive.