The militarisation of space

Disharmony in the spheres

Modern American warfare relies on satellites. They make America powerful but also vulnerable, particularly in light of China's new celestial assertiveness

A HUSHED, dimmed hall in the nerve centre that controls America's air operations from Somalia to Afghanistan is dominated by giant video screens tracking coalition aircraft. Blue dots show the location of ground forces, with “troops in contact” highlighted for priority air support. Smaller screens show live black-and-white footage, relayed by satellite from unmanned drones which, in their turn, are remotely controlled by pilots in America.

The Combined Air Operations Centre's exact location in “southwest Asia” cannot be disclosed. But from here commanders supervise tens of thousands of sorties a year. Through aircraft surveillance pods they get a god's eye view of operations that range from old-fashioned strafing to the targeted killing of insurgent leaders with bombs guided by global positioning system (GPS) satellites, and emergency air drops to isolated soldiers using parachutes that steer themselves automatically to the chosen spot.

These days America fights not in a fog of war but, as one senior air force officer puts it, in a “huge cloud of electrons”. Large amounts of information, particularly surveillance videos, can be beamed to soldiers on the ground or leaders in America. The officer says this kind of “network-centric” warfare is “as revolutionary as when the air force went from open cockpits to jet aeroplanes.”

If Napoleon's armies marched on their stomachs, American ones march on bandwidth. Smaller Western allies struggle to keep up. Much of this electronic data is transmitted by satellites, most of them unprotected commercial systems. The revolution in military technology is, at heart, a revolution in the use of space. America's supremacy in the air is made possible by its mastery of space.

During the cold war space was largely thought of as part of the rarefied but terrifying domain of nuclear warfare. Satellites were used principally to monitor nuclear-missile facilities, provide early warning should they be fired and maintain secure communications between commanders and nuclear-strike forces. Now, by contrast, the use of space assets is ubiquitous; even the lowliest platoon makes use of satellites, if only to know its position.

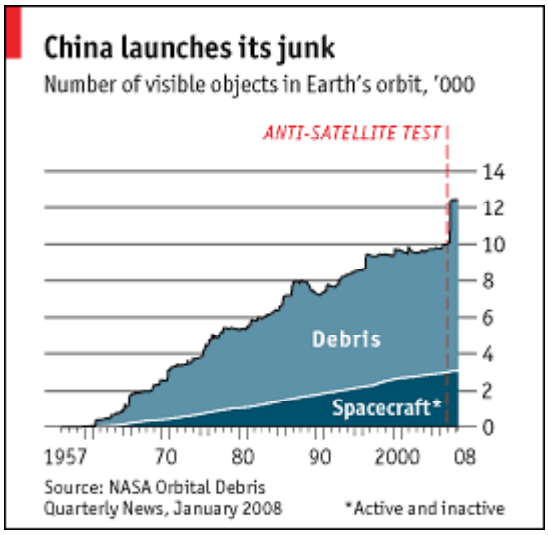
Space wizardry has made possible unprecedented accuracy. As recently as the Vietnam war, destroying a bridge or building could take dozens if not hundreds of bombing runs. These days a plane with “smart” bombs can blast several targets in a single sortie, day or night, in good weather or bad. Needless to say, precise intelligence and sound judgment are as important to military success as fancy kit.

But might this growing reliance on space and cyberspace become a dangerous dependence, a fatal weakness? Air force officers talk of space being America's Achilles heel. Satellites move in predictable orbits and anybody who can reach space can in theory destroy a satellite, even if only by releasing a cloud of “dumb” pellets in its path—using a shotgun rather than a hunter's rifle to kill the orbiting “bird”.

The Taliban or al-Qaeda can do little about America's space power except hide themselves from its intelligence-gathering satellites. But the Pentagon worries about what would happen if America came up against a major power, a “near-peer” rival (as it calls China and Russia), able to intercept space assets with missiles and “space mines”, or to disable them with lasers and electronic jammers. “There are a lot of vulnerabilities,” admits an American general, “There are backups, but our space architecture is very fragile.”

The precise nature of these weaknesses is a well-guarded secret. But wargames simulating a future conflict over Taiwan often end up with the “Red Force” (China) either defeating the “Blue Force” (America) or inflicting grievous losses on it by

launching an early attack in space, perhaps by setting off one or more nuclear explosions above the atmosphere. “I have played Red and had a wonderful time,” says the general, “It is pretty easy to disrupt Blue. We should not expect an enemy to play by established norms in space. They will play dirty pool.”



One shot China has been practising became clear a year ago, on January 11th 2007. In a nuclear-proof air force command centre, built on giant shock-absorbing springs within Cheyenne Mountain, outside Colorado Springs, officers tracked a missile fired from a mobile launcher deep inside China. It followed what one American official said was a “strange” trajectory, designed neither to land a warhead nor to put a payload into orbit. Instead it intercepted one of China's ageing weather satellites. The impact about 850km (530 miles) above Earth created a huge field of space debris, contributing about 28% of the junk now floating around in space (see chart).

Litter louts do their worst

Creating all this rubbish seems a bit irresponsible for a country seeking to be a great space-faring nation. It is true that both America and Russia carried out scores of similar anti-satellite (ASAT) tests during the cold war. Then they stopped, not least because the celestial shrapnel was endangering their hugely expensive satellites. They also accepted that spy satellites provided a degree of mutual reassurance in nuclear arms control. The last piece of American ASAT debris fell back to Earth in 2006, say Pentagon officials. China's shrapnel, created in a higher orbit, could be around for a century to come.

The missile shot put America on notice that it can be challenged in space. The Chinese routinely turn powerful lasers skywards, demonstrating their potential to dazzle or permanently blind spy satellites. “They let us see their lasers. It is as if they are trying to intimidate us,” says Gary Payton, a senior Pentagon official dealing with space

programmes. The only conclusion, he argues, is that “space is no longer a sanctuary; it is a contested domain.”

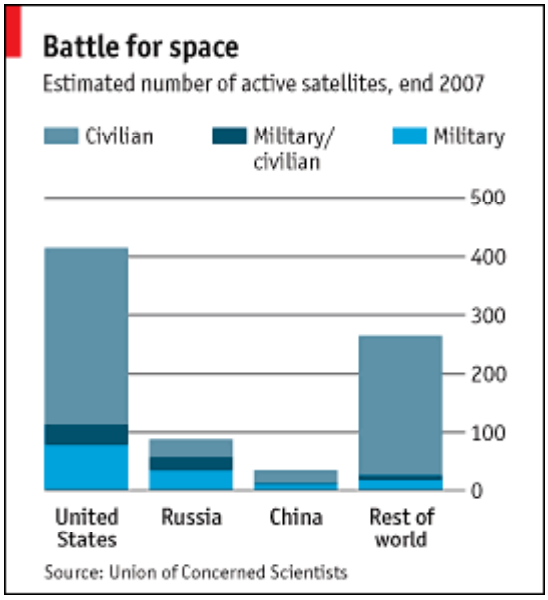
In a report to Congress in November, a commission examining America's relations with China gave warning that “the pace and success of China's military modernisation continue to exceed US government estimates.” China's principal aim, the report said, is to develop the wherewithal to delay or deter American military intervention in any war over Taiwan.

The ASAT test intensifies the concern of those who already find plenty to worry about in Chinese military literature. A study for the American Enterprise Institute, a think-tank, cites a Chinese theorist who argues that China should adopt a policy of overt deterrence in space. Other Chinese argue that their country's territorial sovereignty extends to space. This kind of thing reinforces the hawkishness of American hardliners.

Ashley Tellis, a senior associate at the Carnegie Endowment, another think-tank, believes China ultimately seeks to build a “Sinocentric order in Asia and perhaps globally.” Any attempt to negotiate arms-control agreements in space would be futile, he argues, and America “has no choice but to run the offence-defence space race, and win.”

Other experts, such as Michael Krepon, co-founder of the Henry L. Stimson Centre, a security think-tank, play down the Chinese peril. Mr Krepon says that though similarly alarming conclusions could have been drawn from American or Soviet military literature in the cold war, a space war never took place. What is more, the greater China's economic reliance on satellites, the keener it will be to protect them.

Even those who doubt that America would really go to war against China for the sake of Taiwan worry about the dangers posed by the growing number of countries that have access to outer space. Ten countries (or groups of countries) and two commercial consortia can launch satellites into orbit. A further 18 have ballistic missiles powerful enough to cross space briefly. By the end of 2006, 47 countries and other groups had placed satellites in orbit, either on their own or with help from others. In its crudest form, any object can become a space weapon if directed into the path of a satellite.



In testimony to Congress last year, General James Cartwright, a former head of America's Strategic Command, said that “intentional interference” with all types of satellites, “while not routine, now occurs with some regularity”. GPS signals are relatively weak and easy to jam. For several months in 2006 electronic jammers in Libya interfered with the Thuraya satellite telephone system, apparently because the Libyan government wanted to make life difficult for smugglers in the Sahara desert.

Satellites are not just military tools; they have also become a vital part of globalised civilian life. It is hard to disentangle military from civilian uses of space. Military GPS satellites support a myriad of civilian uses, including road directions for taxi drivers, navigation for commercial airliners, tracking goods in transit and time signals for cash dispensers. But the armed services' hunger for electronic data means that four-fifths of America's military data is transmitted through commercial satellites. A single Global Hawk unmanned surveillance aircraft flying over Afghanistan can eat up several times more satellite bandwidth than was used for the whole of the 1991 war against Iraq.

Star wars delayed

Space provides the high ground from which to watch, listen and direct military forces. But the idea that countries would fight it out in space has so far been confined to science fiction. International law treats outer space as a global common, akin to the high seas. Countries are free to use space for “peaceful purposes” but may not stake territorial claims to celestial bodies or place nuclear weapons in space. “Peaceful” has been interpreted to mean “non-aggressive” rather than non-military. Space is highly militarised but for the moment nobody has placed weapons there, not openly at least.

During the cold war, under Ronald Reagan's presidency, America worked on plans for

space-based weapons designed to shoot down ballistic missiles. But this “star wars” programme faded with the collapse of Soviet communism. Before being appointed defence secretary in 2001, Donald Rumsfeld chaired a special commission to review America's space policy. It issued a stark warning that America could suffer a crippling surprise attack on its space systems—a “space Pearl Harbour”—and argued that America “must develop the means both to deter and to defend against hostile acts in and from space.”

America then broke out of the Anti-Ballistic Missile Treaty, freeing itself to pursue a slimmed-down version of missile defence. The latest official statement on America's space policy, issued in 2006, affirms the country's freedom of action in space, the right of self-defence and the right to “deny, if necessary, its adversaries the use of space.” At the UN General Assembly, America has stood alone in voting against a resolution supporting negotiations on a treaty to prevent a space arms race, an idea pushed by China and Russia.

Yet the Bush administration has stopped short of taking the fateful step of “weaponisation” in space. Perhaps it is too preoccupied with Iraq, and certainly the downfall of Mr Rumsfeld removed a powerful champion of space weapons. A year after China's ASAT shot, the defence budget passed by the Democrat-controlled Congress did not provide any money for a missile defence “space test-bed”.

One of the big disincentives to placing weapons in space has been the technical difficulty and cost of such an enterprise. A recent study by the Centre for Strategic and Budgetary Assessments (CSBA), a defence think-tank, concluded that ground-based systems were almost always more cost effective and reliable than space-based weapons, whether used to attack missiles, enemy satellites or targets on land.

America is still hedging its bets. With some tweaking, say experts, the ground-based interceptors for shooting down ballistic missiles could be used against satellites. A host of technologies under research, such as high-powered lasers to destroy missiles rising through the air, could be applied to anti-satellite warfare.

A game of celestial dodgems

The core fear is that any conflict in space would cause the most injury to America since America has the most to lose. Damaged planes crash to the ground and destroyed ships sink to the bottom of the sea. But the weightlessness of space means that debris keeps spinning around the Earth for years, if not centuries. Each destruction of a satellite creates, in effect, thousands of missiles zipping round randomly; each subsequent impact provides yet more high-speed debris. At some point, given enough litter, there would be

a chain reaction of impacts that would render parts of low-Earth orbit—the location of about half the active satellites—unusable.

As matters stand, ground controllers periodically have to shift the position of satellites to avoid other objects. This month, NASA was tracking about 3,100 active and inactive satellites, and some 9,300 bits of junk larger than 5cm, about 2,600 of them from the Chinese ASAT test. Given their speed, even particles as small as 1cm (of which there may be hundreds of thousands) are enough to cripple a satellite.

For America, then, avoiding a space war may be a matter of self-preservation. The air force has adopted a doctrine of “counterspace operations” that envisages either destroying enemy satellites in a future war or temporarily disabling them. But for the most part, America's space security relies on passive measures: sidestepping an attacker by moving out of the way of possible strikes; protecting the vital organs of satellites by “hardening” them against laser or electromagnetic attack; replacing any damaged satellites; or finding alternative means to do the job, for example with blips or unmanned aircraft.

More esoteric space research has ideas such as sending small satellites to act as “guardian angels”, detecting possible attacks against the big birds. It also includes plans for breaking up satellites into smaller components that communicate wirelessly, or deploying “space tugs” that would repair and refuel existing satellites.

Few of these options are cost-free. More manoeuvrable satellites are heavier, as they have to carry more fuel; protective equipment makes satellites cumbrous and more expensive; placing a satellite farther away from Earth, where it is more difficult to attack, means it will broadcast a weaker signal or require more costly sensors and antennae. The promise of cheap, reuseable launch vehicles has yet to materialise. All this makes it hard for America to achieve its goal of “operationally responsive space”: the ability to place satellites in orbit quickly and inexpensively.

The essential prerequisite for better space security is to improve “situational awareness”: that is, to know what is in space, who it belongs to and whether it is acting in a threatening manner. America already has the world's most developed space monitoring system with a network of radars and telescopes. But its surveillance is patchy. Objects in orbit are catalogued periodically rather than tracked continuously. Space surveillance is not really like air-traffic control: it is more akin to trying to track ships at sea with the naked eye, watching them leave port and predicting when they will next come in sight of land. There are gaps in coverage, particularly over the southern hemisphere, and much of the antiquated surveillance system cannot fuse the data to create an overall picture.

Space surveillance would seem to be ideally suited to international co-operation. Yet the

Americans, Chinese, Russians and Europeans all seem intent on doing their own monitoring. They are frightened of giving away their space secrets to rivals. Accurate and timely information on space objects is vital for defending a satellite, but also necessary for attacking one.

Coming back down to Earth

Many strategists argue that the most vulnerable parts of the American space system are closer to home. Ground stations and control centres, particularly those of commercial operations, are exposed to conventional bombing, whether by armies or terrorists. Communication links to and from satellites are open to interference. In cyber-warfare, critical parts of the space system could be attacked from distant computers. Even without external meddling, notes Tom Ehrhard, a senior fellow at the CSBA, American forces struggle to find enough bandwidth and to prevent the myriad of electronic systems from jamming each other.

Some remedial action is being taken. Backup ground stations are being set up in case the main GPS control centre outside Colorado Springs is disabled. New satellites will have a more powerful GPS signal that is harder to block. America is experimenting with satellite-to-satellite communication by laser, which can carry more data and is less prone to interference than radio waves.

And the armed forces are starting to train for warfare with few or no data links. Simulated attacks by both space and cyberspace “aggressors” are being incorporated into events such as the regular “Red Flag” air-combat exercises over the Nevada desert. But, said an officer at one recent wargame, there are other ways of doing things. “If you really want to take us down, why go to space? You could just try to take out the control tower or bring down the electricity supply to the base.”

Pricing and the brain

Hitting the spot

People do not just say they enjoy expensive things more than cheap ones. They actually do enjoy them more

EVERYONE loves a bargain. But retailers know that people will sometimes turn their noses up at a cheap version of a more expensive item, even if the two are essentially the same. That suggests something is at work in the mind of the consumer beyond simple appreciation of a product's intrinsic qualities.

The something in question is expectation, according to research published this week in the Proceedings of the National Academy of Sciences by Antonio Rangel of the California Institute of Technology. Dr Rangel and his colleagues found that if people are told a wine is expensive while they are drinking it, they really do think it tastes nicer than a cheap one, rather than merely saying that they do.

Dr Rangel came to this conclusion by scanning the brains of 20 volunteers while giving them sips of wine. He used a trick called functional magnetic-resonance imaging, which can detect changes in the blood flow in parts of the brain that correspond to increased mental activity. He looked in particular at the activity of the medial orbitofrontal cortex. This is an area of the brain that previous experiments have shown is responsible for registering pleasant experiences.

Dr Rangel gave his volunteers sips of what he said were five different wines made from cabernet sauvignon grapes, priced at between $5 and $90 a bottle. He told each of them the price of the wine in question as he did so. Except, of course, that he was fibbing. He actually used only three wines. He served up two of them twice at different prices.

What is truth?

The scanner showed that the activity of the medial orbitofrontal cortices of the volunteers increased in line with the stated price of the wine. For example, when one of the wines was said to cost $10 a bottle it was rated less than half as good as when

people were told it cost $90 a bottle, its true retail price. Moreover, when the team carried out a follow-up blind tasting without price information they got different results. The volunteers reported differences between the three “real” wines but not between the same wines when served twice.

Nor was the effect confined to everyday drinkers. When Dr Rangel repeated the experiment on members of the Stanford University wine club he got similar results. All of which raises the question of what is going on.

There are at least two possibilities. The point of learning is to improve an individual's chances of surviving and reproducing: if the experience and opinions of others can be harnessed to that end, so much the better. Dr Rangel suspects that what he has found is a mechanism for learning quickly what has helped others in the past, and thus for allowing choices about what is nice and what is nasty to be made speedily and efficiently. In modern society, price is probably a good proxy for such collective wisdom.

However, goods can be desirable for a reason other than survival value. Many of the things for which high price is an enhancement are purchased in order to show off, as any male confronted with the wine list in a fancy restaurant knows. Indeed, conspicuous consumption and waste are an important part of social display. Deployed properly, they bring the rewards of status and better mating opportunities. For this to work, though, it helps if the displaying individual really believes that what he is buying is not only more expensive than the alternative, but better, too. Truly enjoying something simply because it is exclusive thus makes evolutionary sense.

Besides its role in giving cachet to wine, this may be the explanation for the sort of modern art that leaves the man in the street cold. Art collecting is a high-status activity par excellence. Many lowlier mortals regard it as pretentious. If Dr Rangel is right, though, pretence may not be the true explanation. The collector who has paid millions for a plain-coloured canvas or a pickled sheep probably really does think it is beautiful.

Whichever explanation is correct (and both might be), Dr Rangel's research also has implications for retailers, marketing firms and luxury-goods producers. It suggests that a successful marketing campaign can not only make people more interested in a product, but also, truly, make them enjoy it more.

Acoustic shielding

Sound reflections

How to stop echoes giving you away

IN GREEK mythology, Echo was a mountain nymph who lost her voice and was condemned to repeat only the words of others. Now science is poised to silence the sprite completely. A group of physicists, led by Steven Cummer of Duke University in North Carolina, has devised plans for a cloak that would shield objects from sound, preventing its reflection. Such a device could be used to hide submarines.

Sonar, the technique employed to detect subs, uses a transmitter to emit a pulse of sound—usually a distinctive “ping”—and a receiver to listen for its reflection. That reflection indicates the presence of an object and the time that elapses between the sound's being emitted and its being detected indicates how far away it is. A second ping allows the object's direction, speed and location to be calculated.

Dr Cummer, however, has devised a plan to surround a submarine with a shell that directs sound waves to flow around it as though the vessel were not there. The proposal relies on two properties of the material used to make the shield—its density and its “bulk modulus”, a measure of its springiness. It should be possible to tailor these so that sound waves are bent such that no echo results. The design would also avoid absorbing sound, ensuring no acoustic “shadows” were cast.

Dr Cummer's method, reported in the current issue of Physical Review Letters, is akin to an existing design for an invisibility cloak that would work for light waves, proposed by Sir John Pendry of Imperial College, London. (Sir John is also one of the authors of the new paper.) Yet the acoustic version has a distinct advantage over its optical counterpart. Making an invisibility cloak would be tricky because the device would work only at certain wavelengths. An aeroplane shrouded in such kit might be invisible to the human eye, for example, but would be picked up readily by radar, which works at radio wavelengths.

An acoustic cloak, however, would work for a wider range of wavelengths, making it far harder to spot. That is possible because light and sound are rather different sorts of waves. As Einstein observed, light in a vacuum travels at the greatest speed possible, around 300m metres a second. Even when it is slowed by air and water, its progress

usually remains close to this limit. That means light must obey the rules of Einstein's special theory of relativity. When light is bent by an invisibility cloak, certain components of the wave are allowed to stretch the laws of physics and travel faster than the nominal speed of light, but only under strict conditions. The energy and the information that the wave carries, for example, cannot exceed the speed of light. The effect is to narrow the range of wavelengths that can be bent by an optical shroud.

Sound, meanwhile, travels at a sedate 300 metres a second. Because this is a million times shy of the relativistic limit, the behaviour of sound waves is not restricted in the same way. Under non-relativistic conditions, many different wavelengths can be bent simultaneously by the same acoustic shield, making it far more effective at concealing an object.

It was unrequited love that made the Echo of Greek mythology fade away until only her voice remained. Although Dr Cummer and his colleagues are still some way from transforming their design into a working device, they reckon precisely engineered materials may soon erase her final utterances.

Syphilis

Montezuma's revenge

Uncovering the origin of syphilis

IT WAS called the “French disease” by the Italians and the “Italian disease” by the French. In the Netherlands it was assumed to be Spanish; in Russia, Polish. The Turks thought it was a Christian affliction. The Tahitians thought it came from Britain. According to Kristin Harper of Emory University in Georgia, they were all wrong. Syphilis, the illness with so many suspected origins, actually came from the New World. In other words, Columbus brought back much more than knowledge of an unsuspected continent from his travels.

For hundreds of years, people have debated whether syphilis came from the Americas or whether it, along with a number of closely related diseases, had a much longer history in Europe. Because the first undisputed outbreak was recorded in 1495, shortly after Columbus's return, circumstantial evidence suggests an origin on the western shores of the Atlantic. But now science has turned to genetics in search of a definitive answer.

Dr Harper and her colleagues wanted to find out how syphilis was related to the bacterial pathogens responsible for other so-called treponemal diseases: yaws, endemic syphilis and pinta. These three infections are not transmitted sexually, as syphilis is, but by skin-to-skin or oral contact. However, her team faced a problem: collecting samples was difficult. During the 1950s and 1960s, the World Health Organisation undertook a huge eradication campaign in which more than 300m people in Africa, South America, South East Asia, the South Pacific islands and the Middle East were examined—and tens of millions were treated with penicillin.

Reducing the burden of disease by 95% was good for patients, but not so good for paleopathologists. Instead, the team had to gather together the world's entire laboratory collection of treponematoses, and collect strains of the disease in wild baboons and rabbits. In addition, they were able to locate two specimens of yaws from the only known site of active infection in the Americas: Amerindians living far inside Guyana. In all, they managed to find 26 genetic sequences from different types of treponemal bacteria.

Comparing such data allows educated guesses to be made about which species are most

closely related and what evolved when. The first thing Dr Harper found, as she reports in the Public Library of Science, was that of all the treponematoses, yaws was most likely to resemble the ancestral pathogen. This supports a theory that yaws is an “heirloom disease”: one caused by a bacterium that infected humanity's ancestors and that has evolved with the species as people have spread around the world. Syphilis, though, emerged relatively recently in evolutionary terms.

The two Guyanese samples of yaws were a crucial component of this study, because they appeared to be the closest relatives of venereal syphilis and were genetically different from Old World species of yaws. Indeed, critics of the study reckon Dr Harper is relying too much on them, since the differences in question may be the result of local natural selection rather than the type of random mutation that this sort of analysis depends on. She, though, thinks the evidence suggests that an ancestral disease resembling yaws first arose in the Old World as a non-venereal infection. It spread to the Middle East and eastern Europe, and then on to the Americas in the form of New World yaws when humans crossed the Bering strait some 13,000 years ago. Finally, syphilis was introduced back into the Old World as a result of European exploration.

It is possible that when a bug that came from the moist, tropical New World arrived in the cooler climes of Europe it survived by adapting to the nearest thing European man (and woman) has to a tropical environment: the genitals. Thus freed from external constraint, it used the French, the Italians, the Dutch, the Spaniards, the Russians, the Poles, the Turks, the Tahitians and even the British to become the global success that it is today.

Antarctic science

Snow place like home

America's new research station at the South Pole is officially opened

MOVING house is always traumatic, and the odd tear would have been forgivable as the flag came down over America's old base at the South Pole. It was handed from person to person along a line of scientists and support staff like an egg being passed between penguins. Slowly, it made its way past the marker that represents the exact point of the Pole, and then on to its new staff outside the third incarnation of the Amundsen-Scott station that is the home of America's scientific effort at the Pole. This new station, which formally opened for business on January 12th, took almost 20 years to design and build, and cost $174m. It will house researchers from fields as diverse as neutrino astronomy, cosmology, seismology and atmospheric physics.

The first polar base was established in 1957, during the International Geophysical Year. Eventually, it succumbed to the elements and was buried under years of snowdrift. It was followed by a geodesic dome, an unheated structure filled with small shipping containers that served as buildings. That, too, is now partially buried and is scheduled for demolition over the next few years.

The latest station, though, is designed to stave off the fate of its predecessors by using the very elements against themselves. The building rests on 36 steel columns, elevating it four metres above the surface of the ice. Using detailed computer simulations, its designers have arranged its orientation and aerodynamic exterior to accelerate the

gale-force winds that blow over the pole and channel them underneath the station. The resulting gusts scour the ice surface, depositing snow on the other side instead of letting it build up against the station itself.

However, in Antarctica, the elements are relentless. Eventually, over a period of about 15 years, snowdrifts will build up. When they do, the designers have another trick up their sleeves. Using hydraulic jacks, the entire building can be raised. Extensions another four metres long can be added to the steel columns, and the scouring can begin anew. Two such extensions will add 30 years to the base's life.

Once inside, not all is so strictly utilitarian. The station has many of the comforts of home—a full-sized gym for volleyball and basketball, an exercise room, a music room, an arts-and-crafts room and a library. For those needing an escape from the 24-hour sunlight (or 24-hour darkness), there are lounges with televisions, a pool table and a good supply of beer and Scotch whisky. And for those who prefer a healthier diet there is also a hydroponic greenhouse where fresh vegetables will grow all year round.

Each of the 750 people who will pass through the base in a typical summer season will have the luxury of a private room with a phone and an internet connection. In fact, it sounds just the place for an exotic holiday. So, to remind the inhabitants that this is, indeed, Antarctica, they will be allowed to shower only twice a week.