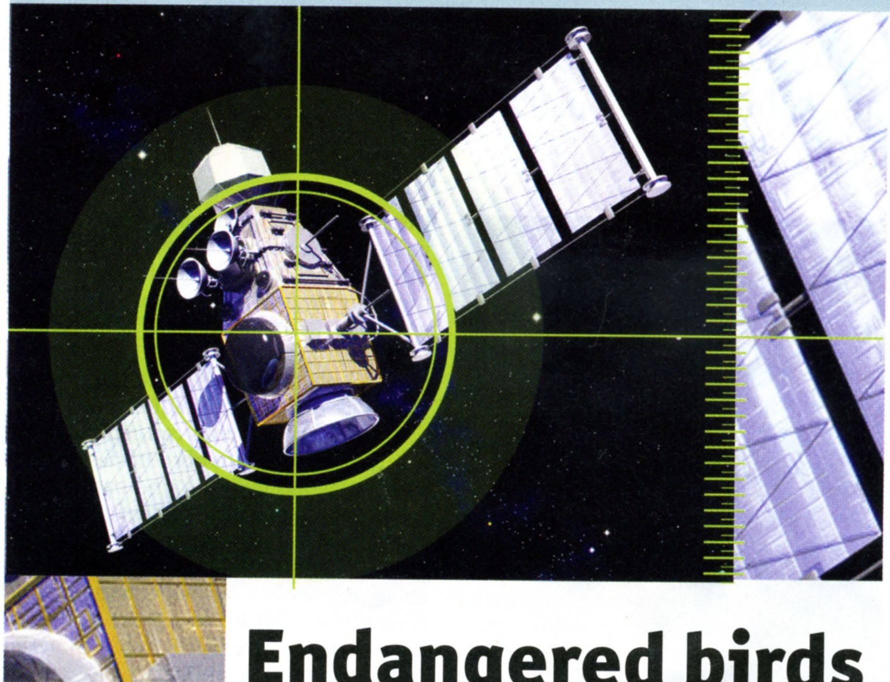

Endangered birds

Space technology: Concern over anti-satellite weapons is changing the way satellites are designed, built and launched

IN JUNE the US Strategic Command, an arm of America's Department of Defence, began operating a spy satellite called TacSat-3. It can see objects on the ground as small as four metres across, and its "hyperspectral" imaging system (which combines visible with infra-red light) can distinguish between various types of metal, rock and other materials. The results can then be beamed directly to soldiers on the ground, providing detailed information about the terrain and nearby targets. Being able to get precise, timely information from a satellite (or "bird") in this way is of great military value, and not just to ground troops. America's forthcoming "Prompt Global Strike" non-nuclear hypersonic missiles will be able to hit almost any spot on earth in less than an hour—provided excellent satellite data is available.

Even as satellites become more capable, however, they are also increasingly vulnerable to attack, says Lieut-Colonel Ryan Pendleton, who is in charge of TacSat-3 at the US Air Force Space Command. China and the United States have both shot down satellites using missiles in recent years, and the old Soviet Union tested several anti-satellite weapons. The other handful of countries able to place spacecraft in orbit, including India and Iran, will probably be able to shoot down a satellite soon, reckons Uzi Rubin, a former head of Israel's Arrow missile-defence programme. This has led to what Colonel Pendleton calls a "revolutionary transition", as concern over anti-satellite weapons is changing the way satellites are designed, built and launched.

One way to protect a satellite would be to equip it with sensors and rockets to enable it to dodge an incoming missile. But this would not protect it against a sufficiently large detonation nearby, or a cloud of pellets shot into its path. A simpler approach is to build smaller satellites that can be assembled quickly and cheaply. These are harder to track and hit, and quicker and less expensive to replace. Today's biggest satellites, larger than a bus and nearly a decade in the making, can cost $10 billion. TacSat-3, roughly the size of two fridges, was built in about 15 months for $65m. Its offspring will cost even less and get into orbit even more quickly.

In 2007 America's Congress ordered the Department of Defence to establish a body to lead the shift toward quick-build, quick-launch replacements. Later that year the Operationally Responsive Space Office (ORSO) opened at Kirtland Air Force Base in New Mexico, staffed with experts from America's air force, army, marines and navy, a handful of intelligence agencies, and NASA, the space agency. The result, says the office's director, Peter Wegner, has been an "explosion in innovation".

For starters, ORSO is standardising satellite components so they can be quickly combined and assembled to meet the requirements for a particular military campaign. When possible, parts are linked with standard USB plugs like those found on personal computers. Shunning made-to-order satellite frames, ORSO's technologists use time-saving pegboard boxes perforated with screw-holes five centimetres apart. In one trial a satellite was assembled in less than four hours. ORSO also trains technologists in allied countries and then challenges them to beat its record. An air force satellite engineer calls the method "Eli Whitney meets spacecraft", referring to the American inventor who promoted the use of interchangeable parts to speed up the manufacturing of muskets.

Software is also being simplified. In the past entirely new software was developed for each satellite. But a team led by James Lyke, a senior satellite engineer at the Kirtland base, together with Sweden's ministry of defence, is developing a "universal, standard, plug-and-play" operating system so that satellites, like personal computers, can easily recognise and accommodate new hardware as it is plugged in. The software will be distributed to America's allies in Europe and elsewhere.

As satellites shrink, launch costs can drop dramatically too, because new launch methods become feasible. Launching a payload to low-earth orbit can cost $20,000 or more per kilogram. But small satellites, including shoebox-sized "cubesats", are often used in place of the ballast carried by rockets to improve their weight distribution. This "almost free ride to orbit" is fuelling entrepreneurship and innovation, says Aaron Rogers, a designer of intelligence and military satellites at John Hopkins University's Applied Physics Lab in Maryland. Worldwide, more than 120 organisations, many of them student groups, are now designing cubesats, he reckons.

Fire when ready

Although TacSat-3 and its successors are still too large to take advantage of this approach, there is plenty of scope for other innovations in launching military satellites. Integrating a satellite with a launch rocket can take six months or more, but the US Air Force hopes to reduce this to days or even hours. Its new software will help; another improvement involves designing satellites to fit, alone or with others, inside a standardised "dispenser" that can be fastened to more than one rocket model.

Being able to build satellites quickly in a conflict is no good if your launch pads have been destroyed, however. Several countries have developed alternative ways to launch satellites. The Pegasus launcher operated by Orbital Sciences ▸▸

"Roving garbage robots might be a good way to clean up space debris, but they could also be used to knock enemy satellites out of orbit."

Corporation, an American firm, is a rocket that attaches to the underbelly of a modified jumbo jet and is capable of placing small payloads into orbit. China appears to be designing a spacecraft-launcher that attaches to the undercarriage of a large warplane. And France is going one step further. In 2013 its space agency, CNES, together with Dassault Aviation, a French firm, and German and Spanish partners, will test a satellite-launching rocket that attaches to the Rafale fighter jet. Unlike the American and Chinese planes, the Rafale, built by Dassault, can fly from aircraft carriers. This would allow naval fleets, which depend heavily on satellites for communications and intelligence, to launch their own satellites if needed.

With this launcher, called Aldebaran, France is pushing technological limits "perhaps more aggressively" than the United States, says a US Air Force space official and former defence attaché to Paris. He and others note that the Aldebaran rocket could be used to destroy satellites as well as launch them. But French officials deny such intentions: blowing up a satellite can litter orbits for decades with shrapnel that endangers all spacecraft, so "kinetic" anti-satellite weaponry is greatly stigmatised. Mr Rubin, a former head of Israel's Arrow missile-defence programme, reckons that the project gives France an edge in developing anti-satellite missiles, however, while avoiding the international criticism that would accompany an explicit anti-satellite programme.

Shooting at birds

In 2007 China was criticised when it used a missile to destroy an old Chinese weather satellite, spreading debris into other orbits. (A defence adviser to a west European head of state, requesting anonymity, says his government is still upset.) The following year America blew up a malfunctioning spy satellite, USA-193, using a ship-launched missile (pictured). The satellite was in a low orbit, which ensured that the resulting debris fell into the atmosphere within a few days. America said the satellite's hydrazine fuel might have caused injury if USA-193 had fallen to earth intact. But it was accused by Russia and China of using this as an excuse to demonstrate that it, too, could carry out a successful anti-satellite strike.

Yet there are other ways to disable or destroy a satellite. Dennis Göge of the German Aerospace Centre in Cologne, a government space-robotics lab, suggests that a spacecraft could spray a nearby enemy satellite with paint or goo to ruin its lenses, sensors, moving parts and solar panels. In an exercise earlier this year, China appeared to demonstrate robotic technology for a "non-co-operative rendezvous" in orbit. A new Chinese satellite slowly approached, and possibly bumped into, an old Chinese satellite, which changed trajectory. The ability to nudge satellites has both peaceful and military uses. Roving "garbage man" robots might be a good way to clean up space debris, suggests Jeffrey Caton, a professor at the US Army War College, but they could also be used to knock enemy satellites out of orbit. As a result, concern over the militarisation of space threatens to hamper efforts to develop clean-up technology.


We can do it too, says America

Satellites can be temporarily blinded with lasers fired from earth. Several countries, including America, Britain, China, France, Israel, Japan and Russia, are thought to possess the necessary technology. (A US Air Force official would "neither confirm nor deny" America's development of anti-satellite lasers.) In the past few years French satellites have been hit several times with "dazzle" strikes from lasers in China, says Erwin Duhamel, head of security at the European Space Agency (ESA). An American general has complained of similar dazzle harassment from China's military. None of the satellites appeared to be permanently damaged, says Mr Duhamel. But a powerful laser could probably burn sensitive optical sensors on a satellite, doing permanent damage. Protective countermeasures are under development, including lens shutters and filters that block certain laser frequencies.

Only a few countries can carry out dazzle attacks, but dozens of countries can jam satellite signals using ground-based transmitters to overwhelm their signals. This does not damage satellites, but it worries governments because the technology is cheap, relatively easy to operate and widely available, says Rickard Nordenberg, an adviser at the Swedish Defence Materiel Administration, a military-procurement agency in Stockholm. The Hizbullah militia in Lebanon pulled off such an attack during its 2006 war with Israel, "significantly" scrambling signals for days from a big French military satellite uninvolved in the conflict, according to an ESA official.

With increasingly sophisticated technologies designed to "blind and deafen" satellites, to use a phrase from a Pentagon report this year, space powers will step up research into countermeasures. Clouds of radar-reflective foil known as "chaff", ejected from a satellite, might fool an incoming missile's homing sensors. Satellite cases are being hardened to prevent circuitry from being fried by microwaves or other electronic weaponry. Systems being designed by the US Air Force simultaneously perform identical "backup" calculations in five parts of the satellite. The Royal Dutch Defence Academy is working out how a "constellation" of small satellites can operate more safely than a big satellite, distributing operations to protect against the loss of some individual units, says Roy Lindelauf, one of the researchers.

With the emphasis on defence rather than attack, it is not an arms race yet. But nine countries can launch spacecraft and more than a dozen others can launch rockets (and therefore weapons) to altitudes close to orbit, according to the Space Security Index, a report funded by Canada's foreign ministry. Big space powers, including America, China and Russia, have not categorically ruled out the use of anti-satellite weapons. Bans on anti-satellite research have been proposed at the United Nations, but verifying compliance with such a ban would be almost impossible, as America has pointed out. Short of a big political turnaround, it seems likely that space will be increasingly contested—with satellites on the front-line. ■