Hypersonic missiles

Gliding missiles that fly faster than Mach 5 are coming

They combine the speed of intercontinental ballistic missiles with the accuracy of cruise missiles

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"'Once the rockets are up, who cares where they come down?/ That's not my department!' says Wernher von Braun."

Tom Lehrer's satirical ditty on the Nazi-turned-American rocketeer was faithful to the essence of early missile development, whose principal challenge was hoisting the weapons into the sky. Gravity did most of the rest. The first warheads capable of steering on descent did not arrive until the 1980s. Even they were limited in how much they could move around, making it pretty easy to predict their target area.

A new generation of hypersonic missiles is changing all that. Some might be capable of gliding across continents at great speed, their target unpredictable until seconds before impact. Russia claims to have a hypersonic glider on the cusp of deployment; others are redoubling their efforts. Many are likely to start entering service in the 2020s. All this opens up new military possibilities—and problems.

Missiles that travel at speeds greater than Mach 5 (five times the speed of sound, or about 1.5km per second), have existed for some time. Intercontinental ballistic missiles (ICBMs) re-enter the atmosphere at up to 8km per second. What is different about the hypersonic weapons in the pipeline is that they are designed to sustain such speeds over long distances, manoeuvre as they do so and, in some cases, hit targets with pinpoint accuracy.

"Manoeuvrable missiles travelling at many times the speed of sound barely leave time for considered human responses," warned Heiko Maas, Germany's foreign minister, in March. Such weapons may also elude today's arms-control agreements, which were written for an earlier generation of weapons.

There are two basic designs: cruise missiles and gliders. Hypersonic cruise missiles are essentially faster versions of existing ones but powered by very different jet engines. Gliders are pricier and harder to build, but can travel faster and farther, and so are receiving more attention. Like ICBMs and von Braun's V-2s, they are lofted into space and fall to earth unpowered. But unlike the old-fashioned projectiles, they do not follow a predictable, parabolic arc through the sky. Instead, a hypersonic glide vehicle (HGV) detaches from the rocket while it is still ascending and either skips along the upper atmosphere or, having re-entered, glides through it for hundreds or thousands of kilometres.

Such gliders have several advantages. Ballistic missiles are less agile and tend not to be very accurate. A Minuteman III ICBM, the backbone of America's nuclear arsenal, has a "circular error probable" of roughly 120m, meaning only half the missiles fired are expected to land within 120m of the impact point. That is fine for nuclear bombs but useless for hitting a ship or runway. Today's cruise missiles, on the other hand, are very accurate—one could be sent through a window—but much slower. HGVs combine the speed of ballistic missiles with the manoeuvrability and accuracy of cruise missiles. "You can fly, you can shape your trajectory, you can turn," says Will Roper, the US Air Force acquisitions chief.

The key is their trajectory. An unpowered ICBM warhead spends most of its time in the vacuum of space where it cannot duck or dive, but HGVsspend 80% of their time below 100km, allowing them to manoeuvre for most of their flight. They can also dodge ground-based radar for longer by hiding behind the curvature of the Earth. Whereas American ICBMs must fly over Russia to hit China—which could lead to dangerous misunderstandings—gliders could take more circuitous routes, avoiding missile defences and leaving adversaries uncertain of the target.

Hypersonic gliders are almost a century in the making. The first rocket-boosted glider flew in Germany in 1928. During the second world war, German engineers tried to extend the range of von Braun's V-2 by having it glide. After the war, America and the Soviet Union pilfered German rocketry, leading to a series of technological leaps. Alpha Draco, an American HGV,

was tested to hypersonic speeds in the 1950s and hypersonic gliding was refined by the space race: the space shuttle was a

hypersonic glider, in its way.

War at Mach 5

Why, then, have hypersonic missiles taken so long to arrive? Extended hypersonic flight presents fiendish scientific and engineering challenges. The lift-to-drag ratio of the space shuttle at hypersonic speeds is around one, notes James Acton of the Carnegie Endowment, a think-tank; an advanced glider would require over twice that. Higher lift-to-drag ratios require sharp leading edges, which, combined with extreme velocities, can generate surface temperatures up to 2,000ºC. That can erode a glider's protective coating, fry its electronics and bend it out of shape. America's test of one prototype in 2011 failed when the skin blistered and peeled off. The resulting shockwaves overwhelmed control systems in less than two seconds.

The only thing that seems to work, says an expert at an arms company that is developing gliders, is to cover the vehicle in cork. But that is vaporised in minutes or less, so does not work for long-range missiles. Dissipating heat as quickly as it is built up is "daunting" and "perhaps impossible" above Mach 10, he says.

Great speeds also break up molecules in the atmosphere, creating a field of charged particles (or "plasma") around the glider, which disrupts GPS and other signals required for guiding the missile to its target. Researchers "still don't completely understand the physics of hypersonic flight", wrote Ivett Leyva of America's Air Force Office of Scientific Research in a 2017 paper.

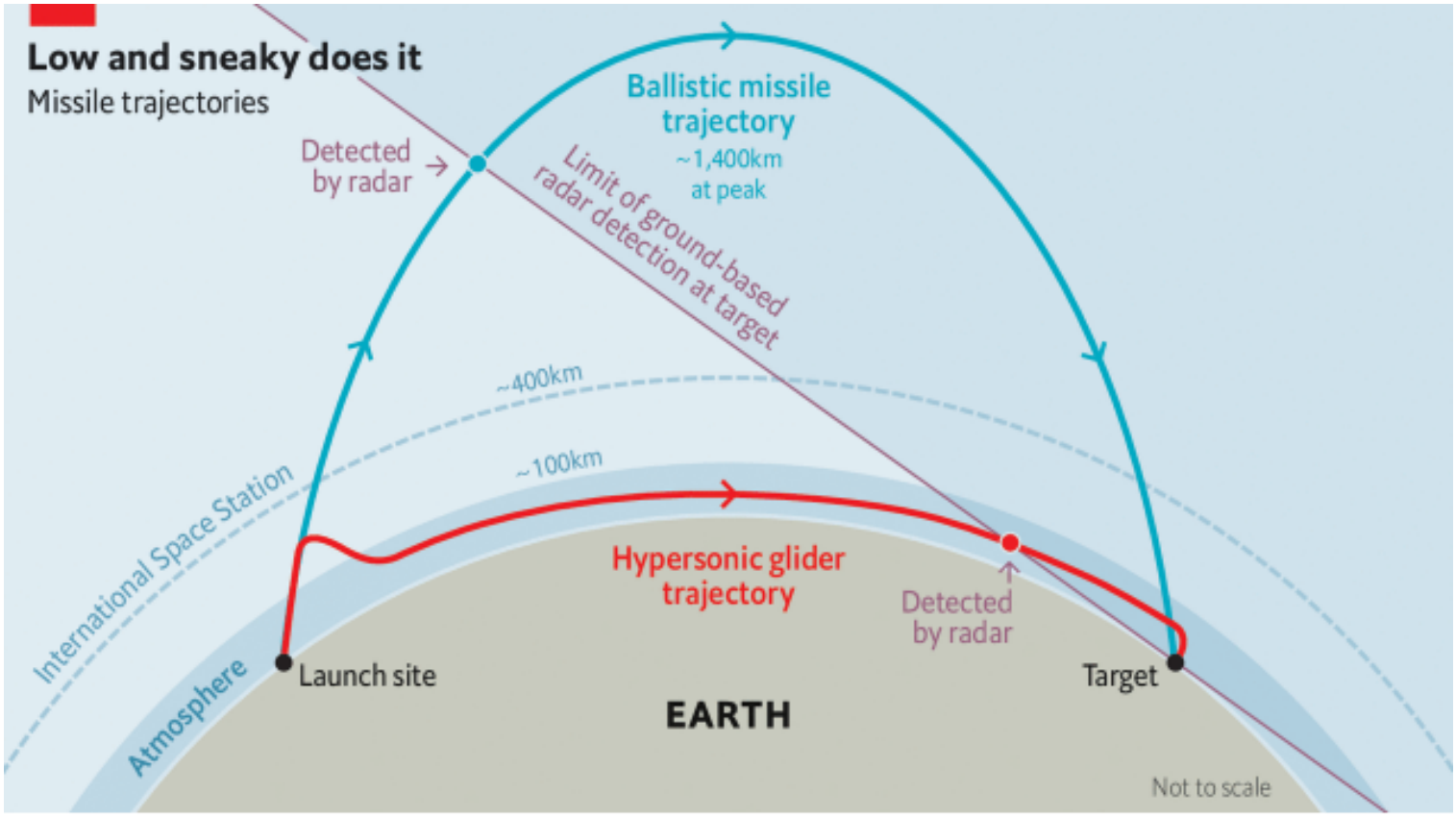
The big powers have all made some progress in surmounting these challenges. Thomas Bussing, who heads missile development for Raytheon, an arms company, says there has been a "step change" over the past decade, thanks to advances in computational fluid dynamics, new materials and electronic and guidance systems. America, which set aside $2.6bn for hypersonic weapons in the Pentagon's 2020 budget, is probably farthest ahead. It tested a wedge-shaped glider in 2010 and 2011, a more successful cone-shaped design in 2011, 2014 and 2017 (the Alternate Re-entry System) and is working on tactical systems that use smaller, cheaper rockets and could be launched from ships and aircraft.

Russia has been working on hypersonics for decades, haltingly. Its flagship Avangard glider was flaunted publicly by President Vladimir Putin in March 2018 and tested to great fanfare in December, after which it was declared ready for service this year—somewhat implausibly, say experts. Pavel Podvig of the United Nations Institute for Disarmament Research points out that very few of the glider's tests were successful and that the programme was nearly shut down four years ago.

China has tested its own DF-ZF HGV at least nine times since 2014. Almost nothing is publicly known about its nimbleness or accuracy. Australia, India, France and Japan are all chasing the pack. "We have lost our technical advantage in hypersonics," warned General Paul Selva, America's highest-ranking air-force officer in January. China has built two to three times as many hypersonics-related facilities as America, including the world's fastest wind tunnel for testing, and pumped out the most public research on the technology (716 publications in 2017, compared with 207 from America and 76 from Russia).

Even so, Mr Acton suggests that the Chinese programme is probably less advanced than America's. For one thing, America is testing its gliders over significantly longer ranges than China is. It is also solving a different, harder, problem. America wants the ability to deliver conventional warheads over continental distances. It is because ICBMs are not accurate enough for this that it wants HGVs. Russia and China are keener on nuclear-tipped ones, partly because they fear their existing nukes might one day be stopped by improvements in America's missile-defence shield. Their own gliders need not be so precise.

Douglas Barrie, an expert at the International Institute for Strategic Studies, a think-tank, forecasts that hypersonic gliders are likely to start entering service in the early 2020s. The result might be twitchier decision-makers and a more frenzied battlefield.



The Economist

Area defences, which guard broad swathes of territory like continental America, rely on shooting down missiles midcourse and on a straightforward trajectory. Gliders do not go as high and are less predictable, hence Mr Putin's boast that the Avangard is "invulnerable to interception" (some reckon that interceptors placed in space might have a shot as super-hot gliders should stand out to infra-red sensors).

Point defences, which guard individual sites against shorter-range missiles, might have more luck. Gliders must slow down as they approach their targets. Systems like America's THAAD have a proven ability to shoot down ballistic missiles, which close in more quickly.

"The world has changed dramatically," says Mr Bussing. "These systems are very, very difficult to counter and fundamentally give the holder a tremendous advantage over the states that don't have them. The sense of urgency to develop ways to counter them is an imperative."

One American military official suggests that humans will have to hand ever more control to defences that are already semi-autonomous: "There will be no time at all for a man in the loop." The uncertain payload of gliders is another problem. If targets could not tell the difference between conventional and nuclear gliders, or feared that conventional ones, through accuracy and kinetic energy alone, could threaten important targets, they might choose to launch their own nuclear forces to avoid losing them.

There are also wider implications for arms control. The impending collapse of the Intermediate-Range Nuclear Forces (INF) Treaty, which barred America and Russia from possessing land-based missiles of 500km-5,500km ranges, clears the way for both countries to develop and deploy new ground-launched hypersonic missiles. A separate treaty, New START, caps the number of longer-range weapons, but is up for renewal in 2021 and looking shaky. When it was negotiated in 2010, America and Russia implicitly agreed that gliders would not be covered. Former officials say that was a mistake.

Germany convened an arms-control conference in Berlin on March 15th to kick-start a discussion on taming the risks posed by futuristic weapons, including hypersonic missiles, through diplomacy. Mr Maas called for an "international missiles dialogue" to discuss the challenge.

The UN's disarmament office has proposed that rivals could swap information on test flights and take other confidence-building measures. Corentin Brustlein of IFRI, a French think-tank, suggests capping glider numbers. Yet America and Russia are enmeshed in worsening disputes over today's weapons, let alone tomorrow's, and China shows little interest in tying its hands. Gliders are likely to enjoy a fair geopolitical wind.

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