These include agriculture and food science and technology, the ocean economy, climate, data science, energy, health and medicine, polar research, quantum technologies and water.

This would be in addition to existing ties in nuclear energy and space. Russia has supplied India with nuclear reactors and fuel, and the countries' space cooperation dates back to the 1970s. In 1984, Rakesh Sharma, an Indian air-force pilot, joined the Soviet Union's Soyuz T-11 expedition, becoming the first person from India to travel to space.

The new Modi–Putin science plan will not be affected by the invasion of Ukraine, says Jagannath Panda, head of the Stockholm Centre for South Asian and Indo-Pacific Affairs in Sweden. "New Delhi has a vested interest in ensuring such cooperation with the long-standing partner [Russia] continues despite disruptions."

The last time the two countries scaled up their joint projects was 1987–90, when they established eight collaborative centres, including some in materials science, advanced computing and ayurvedic medicine.

India's largest research partners (as measured by joint publications) are in Europe and the United States. Researchers with knowledge of how the Indian government organizes science told *Nature* that they do not anticipate these research relationships changing.

However, D. Raghunandan, president of the Delhi Science Forum, a non-profit science-policy organization, predicts that international sanctions will eventually have a more serious impact on India's research collaborations across the board. Trade sanctions against Russia, he says, mean researchers in India and Russia might be unable to transfer research material between the countries. Moreover, banking sanctions are likely to prevent funds being transferred using international banks.

To get around this, India and Russia are reported to be discussing trading with each other using the rupee and the rouble instead of US dollars. However, Raghunandan warns there's a risk that sanctions might extend to a ban on technologies that can be used for both military and civilian purposes.

"Monetary sanctions can be taken care of," Raghunandan says, but he predicts trouble for India's scientists if Europe and the United States decide to extend sanctions to apply to countries that have relations with Russia. "International collaborations in science will depend on how far the US and Europe are willing to take the sanctions. We do not know how the future will unfold."

'Serious consequences' in Brazil

Unlike China and India, Brazil is expected to experience serious consequences for its joint projects as a result of international economic sanctions against Russia, some of Brazil's researchers have told *Nature*. At the same time, scientists and funding agencies are organizing to support colleagues who need to flee either Ukraine or Russia.

Before the invasion, Ricardo Galvão, a fusion-energy physicist at the University of São Paulo, was expecting to start a collaboration with two of Russia's largest physics institutes, the Ioffe Institute in St Petersburg and the Kurchatov Institute in Moscow. The project aimed to measure energy and rotation in the plasma inside tokamaks — doughnut-shaped fusion reactors with powerful magnets.

"Those plans were also destroyed by the missiles of this war," Galvão says. At the very least, there will be delays and increased costs, he adds. In the first weeks after the war started on 24 February, the rouble lost 20% of its value against the Brazilian real.

Brazil's research leaders are "obviously against war", says Jerson Silva, a biochemist at the Federal University of Rio de Janeiro and director of the state's science funding agency, FAPERJ. FAPERJ has launched a funding call for researchers in Rio de Janeiro who wish to host scientists fleeing Ukraine, Russia and other conflict zones.

The US$2-million programme, which started on 24 March, will provide aeroplane tickets to Rio, travel insurance and a monthly stipend of 9,000 reais (around US$1,900) for up to a year. Some of Brazil's 25 other science funding agencies, including FAPESP in São Paulo, are launching similar calls.

The goal, says biochemist Vânia Paschoalin, FAPERJ's coordinator of international relations, is to allow Ukrainian and Russian researchers to continue their work. "The conflict ends," she says. "Science doesn't. Science is always alive."

Some also disagree with the pressure to cut scientific links with Russia. Paulo Artaxo, an atmospheric physicist at the University of São Paulo, says: "You cannot exclude Israeli, South African or Russian scientists, because they are not responsible for [their] government's actions."

Brazilian Physics Society president Débora Peres Menezes also opposes a boycott. Peres Menezes, a nuclear physicist at the Federal University of Santa Catarina in Florianópolis, says physics is a collaborative science and some of her students have benefited from visiting research institutions in Russia. "Scientists should not individually pay the price of war."

CHEMICAL WEAPONS IN UKRAINE? RESEARCHERS EVALUATE THE RISKS

Analysts explain fears that the Russian military will use these weapons — and how to know if it did.

By Davide Castelvecchi

As Russia's invasion of Ukraine enters its eighth week, Western governments and independent observers continue to warn that Russian military attacks could escalate from indiscriminately bombing cities to using non-conventional warfare, in particular chemical weapons.

The Kremlin has denied any intention to use chemical weapons. But the Russian government has been linked over the past two decades with this type of attack. And concern over President Vladimir Putin's intentions spiked on 28 March, when *The Wall Street Journal* reported that envoys and mediators in Russia–Ukraine peace talks earlier in the month had been poisoned — although at least one Ukrainian government source has reportedly denied the story. Reports this week of a chemical attack in the city of Mariupol have reignited fears.

Nature spoke to several analysts to explore the chances of chemical weapons being deployed in the war.

Why do Western leaders think Russia might use chemical weapons?

Even though the world has outlawed the use of chemical weapons, the Russian government has been linked to them on several occasions, some recent.

In 2018, the UK government accused Russia of using a Novichok chemical — a nerve agent developed by the Soviet Union decades ago — to poison Sergei Skripal, a Russian former double agent living in the United Kingdom. In another high-profile incident, Russian opposition leader Alexei Navalny was poisoned with a different type of Novichok agent in 2020. The Kremlin denied involvement in either event.

"These two incidents raise question marks on whether elements of the former Soviet programme have not been eliminated," says Ralf Trapp, a disarmament consultant based in Chessenaz, France.

Furthermore, Russian troops have fought alongside the regular Syrian army during that country's civil war, which began in 2011. The Organisation for the Prohibition of Chemical Weapons (OPCW), based in The Hague, the Netherlands, confirmed that the Syrian army deployed chemical weapons against its own people. The Russian government denied involvement in any of these attacks.

When it comes to Ukraine, the Russian government has accused the country of preparing to use chemical weapons. But Western governments say this could be a 'false flag' tactic, which the Kremlin has used in the past. "Russia has a long track record of accusing others of what they are either already doing or about to do," said US President Joe Biden on 22 March, according to news outlet CNBC.

Trapp, who is a former OPCW officer and was involved in verifying adherence to the 1997 Chemical Weapons Convention (CWC) in several countries, including Ukraine, says there is no evidence that Ukraine has chemical weapons. "It doesn't make any sense for the Ukrainians to think of using them," he adds.

Russia and Ukraine are signatories to the CWC, which outlaws the use of chemicals in warfare. This includes substances with legitimate applications such as chlorine, which is used, for instance, to sanitize water. The OPCW, which monitors compliance to the treaty, verified in 2017 that Russia had destroyed all of its declared stockpiles of chemical weapons.

If Russia or any other signatory uses chemical weapons, it's a breach of the convention, says Leiv Sydnes, a chemist at the University of Bergen in Norway, who has chaired a task group for the OPCW and helped to draft previous reviews of the treaty.

The Russian foreign ministry has called accusations that the country's military plans to use chemical weapons in Ukraine a "smear campaign" by Western nations.

Why would Russia use chemical weapons?

Analysts say that chemical weapons have limited usefulness on the battleground, especially against armies, such as Ukraine's, that are equipped with protective gear. "If you are using them against a military target, it is relatively straightforward for the defenders to have CBW [chemical- and biological-weapon] protection kits," says Paul Rogers, a peace-studies researcher at the University of Bradford, UK.

Instead, chemical weapons are mainly a tool for terrorizing populations and breaking their will to resist, Rogers and other researchers say. "The main purpose to use chemical weapons is to terrify people and to generate panic," Sydnes says.

Observers fear that the Russian military could launch chemical attacks on Ukrainian cities to cause panic among civilians. Chlorine gas, in particular, is denser than air and could settle into the underground shelters used by city dwellers during bombardments, causing people to suffocate.

ALEXANDER ERMOCHENKO/REUTERS

Ukrainians pass a building in Mariupol that was destroyed during the Russian invasion.

The Russian military could also use nerve agents such as sarin, which is extremely deadly but dissipates quickly, enabling the attacking army to subsequently occupy the targeted site. Chemicals such as Novichok agents, however, would be less practical for Russian troops to use, because these substances are persistent and would require extensive decontamination before the army could occupy the site.

Recent developments on the ground, with the Russian military refocusing its efforts on eastern regions of Ukraine, could make a chemical attack less likely, Rogers says. "I think the risk is less than two or three weeks ago."

Is there any way to prevent the use of chemical weapons in Ukraine?

If the Kremlin is serious about its accusation that Ukraine is preparing to use chemical weapons, it could pursue its allegations through the proper channels. "They can demand from the OPCW what is called a challenge inspection," Sydnes says. "If this is a real issue for Putin, and he doesn't want to use chemical weapons, that is what he should do."

But if the Russian government is claiming that Ukraine has chemical weapons as a pretext to use such weapons itself, then any country — even Ukraine — could trigger OPCW inspections of Ukraine to challenge the assertion. "The Ukrainians could say, 'Come and have a look, we have nothing to hide'," says Alastair Hay, an environmental toxicologist at the University of Leeds, UK. "That would clearly wrong-foot the Russians."

In either scenario, international inspectors would need guarantees for their safety, such as a ceasefire in the areas they are visiting.

The OPCW told *Nature* that it has not received any requests for a challenge inspection.

Can science help to verify a suspected attack?

The OPCW would be called on to verify any allegations of a chemical weapons attack. Even without direct access to the war zone, the organization can gather evidence, in particular from satellite imagery and medical reports, Trapp says. "If there are victims, you will see victims being treated in medical facilities." And their symptoms and medical records would give clues.

Chemical weapons vary greatly in how they work and the types of evidence they leave behind. If inspectors have direct access in the immediate aftermath of an attack, they could collect samples — such as the by-products that nerve agents leave in the blood, or trace residues in the environment. In some situations, evidence collection could be more difficult; for instance, a chlorine attack might be hard to prove, because the gas can dissipate without leaving any trace.

There is precedent for this type of inspection, Trapp says: during the Syrian civil war, OPCW inspectors collected evidence in a war zone for the first time and reported that both chlorine and nerve agents had been used — something the Syrian government has denied. The inspectors did so at considerable risk, and came under gunfire in at least one incident.

More recently, the organization has tested methods for remotely gathering evidence from the site of a chemical attack. Researchers are exploring the use of a land or aerial drone to collect samples or even analyse them on site.