Focus

Vito Tartamella - articles translated in English

Science

In London, we visited the world's oldest biobank: it stores and despatches thousands of viruses and bacteria all over the planet, from plague to Ebola. All in aid of research.

The most dangerous bank on Earth

Photos by Christian Sinibaldi - Translation by Simon Knight

HANDLE WITH CARE. A biologist at the Culture Collections in London, where thousands of viruses, bacteria, cells and fungi are conserved.

Their website is simplicity itself: you just type in the name of the product you are looking for and the details are displayed, along with the price. But the catalogue is terrifying: for € 390 you can order the SARS coronavirus. More affordable is *Yersinia pestis*, the bacillus responsible for bubonic plague: € 348. But the real bargain is the Ebola virus (*Zaire Ebolavirus*): it comes free; you only have to pay the cost of carriage.

You might think this was a website run by bio-terrorists, but the masthead features the reassuring logo of the British NHS. The UK's public health agency provides an extraordinary service: conserving and sending by post, in unbreakable packaging, thousands of micro-organisms –including some of the most deadly – to scientists worldwide.

Culture Collections (www.phe-culturecollections.org.uk) is in fact one of many bio-banks established in different parts of the world (*see box on following page*). Rather than conserving agricultural seeds, their freezers contain dangerous infectious agents: 400 viruses and 5,000 bacterial cultures, as well as 40,000 cell lines and 4,000 strains of fungi. One of the most important international collections of its kind, and by far the oldest, it has been going for almost a century. How does it operate? What purpose does it serve? And, above all, is it safe? *Focus* magazine went to find out.

DEEP-FROZEN. Access is permitted only after a lengthy bureaucratic process. The most deadly viruses, those with a bio-security rating of 4 (fatal and infectious even when airborne), are kept at Porton Down, to the west of London, in airtight rooms, which can be entered only after strict security checks via armoured doors with combination locks. The bacteria, meanwhile, are stored by the Health Protection Agency in Colindale, north London. At these facilities, the cells, handled with long rubber gloves protruding into sealed biosafety cabinets, are carefully monitored and conserved in vials: first they are frozen in liquid nitrogen at -196°C, then kept in special freezers at -80°C.

«To keep the cultures alive and free from contamination, we need to carry out lots of tests» explains Julie Russell, the bank's director. «First we have to get them to ▸

PREPARATION. Vials of bacteria in a dryer: without water they can be stored for many years.

There is a bacterium that Fleming extracted from his nose

proliferate and, in some cases, as with the Koch bacillus, which causes tuberculosis, this may take up to six weeks. Then we perform a whole battery of bio-chemical, genomic and morphological tests. It takes three months to carry out all the checks on just one strain of micro-organism: all it takes to contaminate them is one micro-plasma (a very small bacterium - *ed.*), which is invisible using an optical microscope. We then freeze and store them, checking each year to make sure they are still alive».

BUDGET. So what is the purpose of this complex organization? Conserving this delicate biological material is only part of the work. The crucial phase is the shipping. «Our collections», explains Russell, «are used by scientists who study these pathogens to perform diagnostic tests or develop new treatments, whether antibiotics or vaccines».

One of the items most in demand this year is the Zika virus, which has raised enormous concern in Brazil because it causes malformations of the foetus. «We have three strains in our collection», continues Russell. «One was extracted in 1962 from a mosquito captured in the Zika Forest in Uganda. A second strain was isolated in the USA from a man from Puerto Rico in 2015, and a third was taken from the sperm of a patient from Guadeloupe, hospitalized in the United Kingdom: it will be available shortly, for € 298.50».

But why make people pay? Maintaining a biobank is expensive. For the first fifty years of its existence, the British institution was financed by the Ministry of Health. «But since 1970 we have been self-supporting», says Russell. «Our annual budget is £ 5 million (€ 5.83 million): 80% is derived from sales of biological material, the remainder from funding by other organizations».

How do you send a test tube containing millions of Ebola viruses or anthrax bacilli weighing just 0.15 grams? «We run a very tightly controlled operation, largely automated, in which time is the crucial factor: we cannot allow the material to be destroyed or lost. Or end up in the wrong hands», replies Ana Deheer-Graham, scientific coordinator of the Bacteria Collection.

The first step is to check the scientific credentials of those requesting micro-organisms. Recipients must be scientists working for a public or private laboratory equipped with the necessary safety structures. They must also complete a number of forms explaining why the virus or bacterium is needed, and undertake not to pass it on to others. «We do not send anything until we have checked every detail», adds Russell. «All request must be authorized by the Foreign Office. Checks can take two or three months, and not even we know what factors they take into account. Authorization may also depend on political circumstances».

PERMITS. The most critical countries? «Arab States and Iran. And less developed countries, which often do not have adequate laboratories for storing these organisms», replies Deheer-Graham. «But even shipping material to the USA or Australia is beset with bureaucratic complications: they have very rigid legislation on imports of biological material. It takes three months to obtain all the necessary permits, then you have to add the delivery time».

The bacteria are transported in vials, dehydrated, with 97% of the water removed. We then extract the air and seal the vial under intense heat. Treated in this way, bacteria can survive for up to 50 years. Viruses, on the other hand, are freeze-dried in small plastic test tubes, or in a liquid suspension, and placed in a container with dry ice, which keeps them at a temperature of –80°C. Clients can request just the RNA extracted from the virus, which is not infectious and can be used for diagnosing infections. Both types of product are transported in unbreakable packaging. A team of 20 people work exclusively on the logistics: preparing the material, packaging it and handing it over it to one of the two specialized courier firms approved by the British government. And shipments are tracked up to the moment of delivery.

Micro-organisms also travel in the opposite direction: scientists who discover new sources of infection, or mutations of al- ▸

DROP BY DROP. A biologist prepares a culture: she must take care not to contaminate it and herself avoid getting infected.

LIVING ARCHIVE. A filing cabinet full of test tubes: each contains a strain of bacteria, which are stored in refrigerated rooms.

THE 9 MOST DANGEROUS MICRO-ORGANISMS IN THE COLLECTION

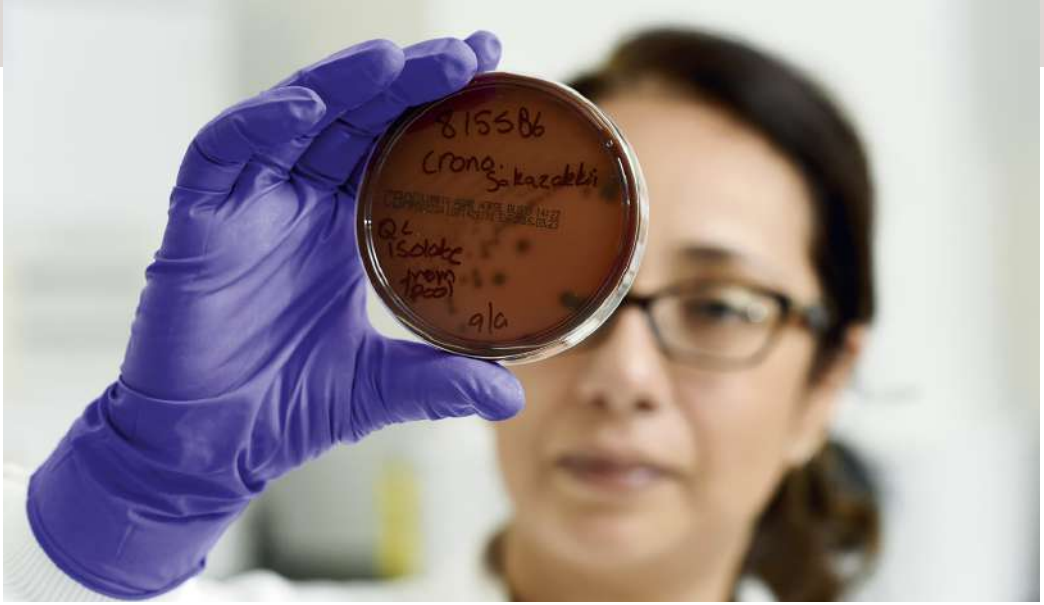
BEWARE. The British Culture Collections conserve many deadly organisms. The most high-risk bacteria are: *Bacillus anthracis* (which causes anthrax), *Francisella tularensis* (tularemia), *Yersinia pestis* (plague), *Salmonella typhi* (typhoid fever), *Mycobacterium tuberculosis* (tuberculosis), *Brucella* (brucellosis). The most dangerous viruses are: *Zaire ebolavirus* (Ebola), the yellow fever virus and the dengue virus.

BIOBANKS: 700 AROUND THE WORD (15 IN ITALY)

STRAINS. According to the World Federation for Culture Collections (WFCC), there are currently 710 biobanks in 72 different countries. Together they conserve more than 2.5 million bacteria, fungi, viruses and cell lines. The largest, in the USA, is the ATCC, which has 18,000 strains of bacteria and more than 2 million viruses. In Europe, there are biobanks in Germany, Sweden, Belgium, Spain, France and the Netherlands. And many are joining together to form pan-European institutions: France hosts the virus archive (Evag), the United Kingdom the stem-cell biobank (Ebisc).

So what about Italy? It has 15 biobanks, mostly concerned with food and agriculture. The Umcc at the University of Reggio Emilia, for example, conserves the yeasts and bacteria used in producing wines, vinegars and cheeses, especially Parmesan.

WAREHOUSE. Right, the Collection's logistics department: the cylindrical containers are liquid-nitrogen freezers, operating at temperatures as low as -196°C. Below, testing to ensure that the vials are hermetically sealed.



CATALOGUED AND CONTROLLED. A culture of *Cronobakter sakazakii*, a bacterium that infects new-born babies and may be fatal. Bacteria can be stored for up to 50 years.

ready known bacteria or viruses, can send them to the Collection, which will store them for future research. One such sender was Australian doctor Barry Marshall: in 1984 he hypothesized that ulcers and gastritis were caused by a bacterium, *Helicobacter pylori*. But the scientists of the day disagreed with him, convinced that it was killed off by the natural acidity of the stomach. To demonstrate the validity of his theory, Marshall drank a culture of the bacterium: two weeks later, he was afflicted with gastritis. Marshall won the Nobel Prize and sent his Heliobacters to London! Indeed, a number of organisms that have made history are conserved in the Collection: 16 cultures were deposited by Alexander Fleming, the discoverer of penicillin. He extracted *Haemophilus influenzae*, a bacterium that can cause meningitis, directly from his nostrils. The earliest samples in the Collection, founded in 1920 by the bacteriologist Frederick William Andrewes, are specimens of another bacterium, Shigella dysenteriae, taken from the body of Ernest Cable, the first British soldier to die of dysentery in the trenches of the First World War.

PROFILES. «Those old strains are useful for studying the evolution of micro-organisms», comments Russell. «We supplied them for an international study of 330 strains of Shigella isolated during the last century. It was discovered that dysentery, now a scourge of Asia and Africa, in fact originated in Europe. Ninety-eight per cent of its genome has remained unchanged, but in the meantime it has become resistant to antibiotics».

Since 2014, the biobank has begun studying the genome (DNA and RNA) of every micro-organism. Using cutting-edge computerized sequencers, it tales just 24 hours to trace the genetic profile of each of the items in the catalogue. The project, known as NCTC3000, was funded by a grant of £ 1 million from the Wellcome Trust Sanger Institute, and the results are published free of charge on its website for the benefit of the international scientific community.

The Collection is perfectly placed to monitor new sources of infection, reported by hospitals in the United Kingdom and through international contacts. In 2011, for example, the Collection was involved when more than 3,000 people in Germany were affected by an epidemic of *Escherichia coli*, a food-borne bacterium that eventually claimed 53 victims. Microbiologists discovered that the source was a producer of salad vegetables who was using contaminated sainfoin seeds imported from Egypt. And this particular strain had developed a gastro-resistant capsule that made it all the more virulent.

The Collection also includes the fearsome new virus that causes Middle East respiratory syndrome coronavirus infection (MERS-COV), which has a death rate higher even than SARS. «It was first isolated in 2012, in the lungs of a patient from Arabia. It may be that this disease is disseminated via camels».

Unfortunately, it is becoming more difficult to send these micro-organisms abroad: anti-terror laws, and legislation governing biological materials and GMOs, are making the biobank's work more problematic. «And», adds Deheer-Graham, «there are no international regulations on shipping bio-material. In the past, it was easier to send material abroad; nowadays, the Nagoya Protocol (2010) stipulates that any economic benefits deriving from the use of an organism must be shared between the sending and the receiving countries. It is easier to do this within Europe than elsewhere».

TISSUES. Despite these difficulties, the Culture Collections have sent 25,000 items to all parts of the world (especially Europe) over the last year. Those most in demand, however, are not bacteria or viruses, but cell lines, i.e. samples of human tissue, both sick and healthy. At Porton Down, they have over 40,000 such cell lines, covering 50 different kinds of tissue. And this section includes the biobank's most expensive item: cancer of the cervix, costing € 574.

«Cell lines are essential for testing new drugs and checking the toxicity of substances without having to use animals», explains Russell. «Many discoveries concerning breast cancer, diabetes or the effects of cosmetics on the skin have been made using such samples. But they must of course be certified».

This is something that cannot be taken for granted. In 2012, the authoritative scientific review *Nature* invited 56 laboratories to replicate their cancer experiments in the presence of an independent expert. It emerged that only 11% had used appropriate cell models. «Some biologists think they are studying cells from breast cancer tumours, when instead they are experimenting on cervical cancer cultures», says Russell. «For this reason laboratories are increasingly turning to us for genuine samples».

What will happen to the Culture Collections after Brexit? «We don't know», replies Russell. «We are worried, like all British scientists: cooperation with Europe is fundamental and continues for the time being. We were established in 1920 to supply certified resources for the progress of science. And we still believe in this mission. This is why we send the Ebola virus free of charge: to support the search for a cure».

Vito Tartamella

Artificial viruses? Possible, but...

EXPENSIVE. These biobanks are not accessible to criminals. But could a terrorist create an artificial virus or bacterium? The question is certainly not fanciful: as long ago as 2002, the University of New York was successful in creating the poliomyelitis virus – whose RNA has only 7,500 bases – in the laboratory. But would it be possible to create and more complex and powerful virus? «Nowadays various companies are synthesizing the genome for payment», replies Massimo Pizzato, virologist at the Integrated Biology Centre of the University of Trento, Italy. «Assembling the genome of a virus might cost between 2 and 3 million euro. But in some cases, such as the smallpox virus, assembling the DNA is a long process: it has 200,000 bases, and the cost would be much greater». However, adds Pizzato, simply replicating a virus or bacterium's DNA or RNA is not enough: «Bacteria have membranes, walls and cytoplasm that cannot be reconstructed artificially. So it would be necessary to transfer the DNA to an existing bacterium. This was achieved by Craig Venter in 2010, but very few laboratories have the resources and skills to do so. Viruses, meanwhile, contain enzymes and have a proteinic and often also lipoid involucre, which is what makes them infectious. To replicate them, a criminal would need to have an in-depth knowledge of molecular and cellular biology. And it would take months. Not to mention the fact that he or she would need expensive equipment to manipulate these organisms safely».

Every year they send 25,000 biological samples all over the world. Under strict conditions.

The round-the-world flight of the Swiss aircraft Solar Impulse marks the beginning of a new era. And not just for aviation.

Moving on with the Sun

MISSION ACCOMPLISHED. Bertrand Piccard, (left), aged 59, psychiatrist, and André Borschberg, aged 64, a former soldier. They took turns to pilot Solar Impulse.

Solar Impulse, Pezo.ch

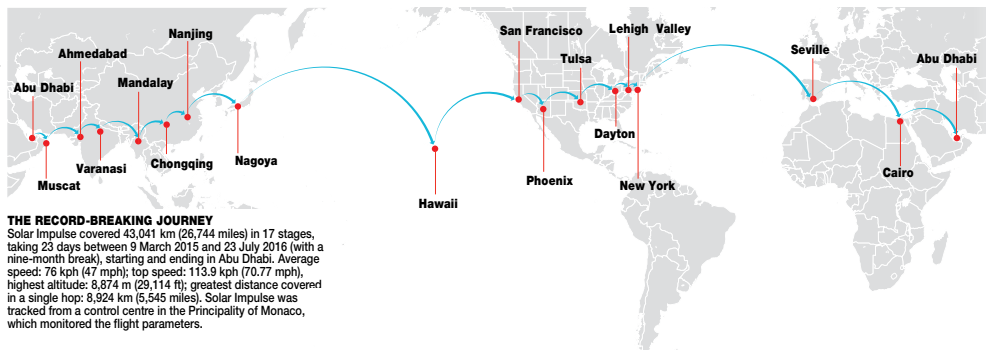
Now dismantled and stored in six sections in a hangar at the military airbase of Dübendorf near Zurich, Solar Impulse broke 12 world records in becoming part of aviation history.

Crossing four continents to complete its epic journey just a few months ago,, the first solar-powered aircraft to circle the globe was airborne for a total of 23 days. And soon it will be reassembled and put on display in a museum, most likely the National Air and Space Museum in Washington.

But it is not yet time for showboating and self-congratulation. The inspirational project undertaken by Bertrand Piccard and André Borschberg, the two Swiss who dreamed, planned and made it happen, is far from over: the technological innovations which took 13 years to develop are finding many further applications. And not only in the field of aviation. As with the moon missions of the late 1960s, this solar adventure will have many technological spin-offs.

BATTERIES. «Our experiment has shown just how efficient electric motors can be», Piccard explains to *Focus*. «They make use of 93% of the energy they produce, whereas internal-combustion engines waste 70% in the form of heat. Within 10 years, we shall have electric aeroplanes capable of transporting 50 people up to 1,000 km (620 miles) in three hours. And our countries will be monitored by solar-powered drones rather than satellites». A significant achievement, when you consider that the 100,000 planes taking to the air each day produce 3.5% of the CO_2 emissions currently polluting our planet. But it is on solid ground, in everyday life, that the developments pioneered by Solar Impulse will be having the most impact: the aircraft's batteries, capable of storing large quantities of energy to keep the plane flying at night, can be used in power grids, releasing energy when most needed. The insulating foam designed ▸

Illustration by Stefano Carrara



THE RECORD-BREAKING JOURNEY
Solar Impulse covered 43,041 km (26,744 miles) in 17 stages, taking 23 days between 9 March 2015 and 23 July 2016 (with a nine-month break), starting and ending in Abu Dhabi. Average speed: 76 kph (47 mph); top speed: 113.9 kph (70.77 mph), highest altitude: 8,874 m (29,114 ft); greatest distance covered in a single hop: 8,924 km (5,545 miles). Solar Impulse was tracked from a control centre in the Principality of Monaco, which monitored the flight parameters.

A FLYING LABORATORY

FACTS & FIGURES. Solar Impulse's real name is HB-SIB. It was preceded by a prototype known as HB-SIA. Here are its main technical characteristics:

- **length:** 25 m (82 ft)
- **wingspan:** 72 m (236 ft) (4 m - 13 ft more than a Boeing 747)
- **height:** 6.37 m (20.89 ft)
- **weight:** 2.300 kg
- **propeller diameter:** 4 m (13 ft)
- **capacity:** 13.5 kW (17.5 hp) for each of its four motors, in total 70 horsepower
- **batteries:** 4, each with a capacity of 38.5 kWh
- **take-off speed:** 36 kph (22 mph)
- **top speed:** 140 kph/h (87 mph)
- **cruising speed:** 45-55 kph (28-34 mph)
- **altitude:** 8.500 m (27,890 ft) by day (commercial airliners fly at 12,400 m / 40,700 ft), 1,500 m (4,920 ft) by night

Point your smartphone here to discover the model in 3D, the secrets and sound of Solar Impulse

DOWNLOAD THE APP (INFO ON PAGE 4)

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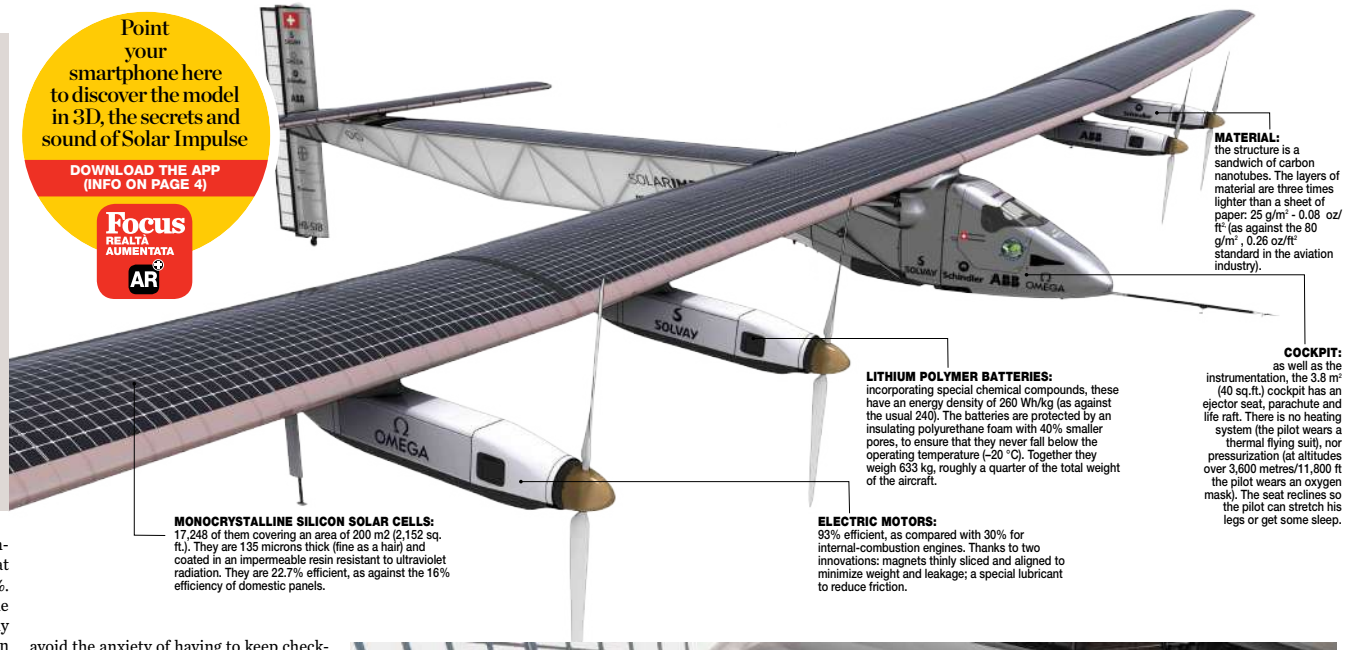


MATERIAL: the structure is a sandwich of carbon nanotubes. The layers of material are three times lighter than a sheet of paper: 25 g/m² - 0.08 oz/ft² (as against the 80 g/m², 0.26 oz/ft² standard in the aviation industry).

COCKPIT: as well as the instrumentation, the 3.8 m² (40 sq.ft.) cockpit has an ejector seat, parachute and life raft. There is no heating system (the pilot wears a thermal flying suit), nor pressurization (at altitudes over 3,600 metres/11,800 ft the pilot wears an oxygen mask). The seat reclines so the pilot can stretch his legs or get some sleep.

LITHIUM POLYMER BATTERIES: incorporating special chemical compounds, these have an energy density of 260 Wh/kg (as against the usual 240). The batteries are protected by an insulating polyurethane foam with 40% smaller pores, to ensure that they never fall below the operating temperature (–20 °C). Together they weigh 633 kg, roughly a quarter of the total weight of the aircraft.

MONOCRYSTALLINE SILICON SOLAR CELLS: 17,248 of them covering an area of 200 m2 (2,152 sq. ft.). They are 135 microns thick (fine as a hair) and coated in an impermeable resin resistant to ultraviolet radiation. They are 22.7% efficient, as against the 16% efficiency of domestic panels.

ELECTRIC MOTORS: 93% efficient, as compared with 30% for internal-combustion engines. Thanks to two innovations: magnets thinly sliced and aligned to minimize weight and leakage; a special lubricant to reduce friction.

to protect the plane against ultra-low temperatures at high altitudes can reduce heat loss through the walls of our homes by 20%. And the communication system used by the pilots to transmit flight data, weighing only 5 kg and using barely 50 watts of energy, can be fitted to boats and cars operating in extreme conditions.

But how have these results been achieved? What spurred Piccard and Borschberg, not far short of their 60th birthdays, to risk life and limb to fly 43,041 km (26,744 miles) in an aircraft with the wingspan of a Boeing 747, the weight of a commercial van and the speed of a scooter?

OUT OF GAS. The idea grew out of another exploit of Piccard's, the psychiatrist son of Jacques Piccard (the first man to plumb the Mariana Trench in a bathyscaphe): an attempt to circle the world in a hot air balloon. «That was in 1999», he recalls. «We had taken off from Switzerland with 3.7 tonnes of liquid propane gas on board. We landed three weeks later in the Egyptian desert with just 40 kg of fuel remaining, having run the risk of running out completely and being at the mercy of the winds. So I made myself a promise: my next flight around the Earth would be fuel-free, to avoid the anxiety of having to keep checking the fuel gauge». A challenging prospect: back in the 1980s, inventors were beginning to experiment with solar-powered aircraft (*see box*), but no one had ever flown for more than 6 hours, and never at night: how could the batteries be recharged without sunlight? And how could a light aircraft be made self-sufficient and safe enough for a transoceanic crossing?

The only way was to maximize the efficiency of each and every aspect of the aircraft: the aerodynamics, the airframe, the motors, the solar cells and batteries. In short, squeeze out the last ounce of energy, while cutting waste (and weight) to the bone.

To get this result, Piccard went knocking on the door of every aircraft constructor, but his idea was roundly rejected. «The experts told us it was an impossible ambition, which made us all the more determined to achieve it», he told us. Only the French aeronautics firm Dassault Aviation shared his vision, eventually joined by dozens of other partners, from the Swiss Federal Institute ▸

The plane generated enough energy to power 200 lightbulbs: like flying a Christmas tree

Solar Impulse, Rezo.ch (6)

LIGHT BUT TOUGH. Left, the cockpit: note the oxygen cylinders (green). Space is reduced to a minimum: the seat tilts backwards (photograph 1) to allow for some exercises (2). To maintain concentration, the pilots practised yoga techniques (3).

FOOD AND FLYING SUIT. Right, the provisions carried on board: 2.4 kg of food, 2.5 litres of water and 1 litre of supplements for each day in the air. Below, Piccard with his oxygen mask and thermal flying suit.

Solar Impulse, Rezo.ch (3)

AT REST. The inflatable hangar used to protect the aircraft between stages. It could be erected and dismantled in just a few hours.

The lesson from this experiment: the future of flight is electric

of Technology (Lausanne) to Omega and Google. But it took 10 years of calculations and simulations before a prototype took to the air on its maiden flight – a modest 350 metres (380 yards), one metre (3 ft) off the ground – in Switzerland in 2010. «It is not easy to replace fuel with solar energy», Piccard explains. «Exploiting the surface of the aircraft to the maximum by cladding it with highly efficient solar cells no thicker than a hair, we created 200 m² (2,152 sq.ft.) of solar panels, producing enough energy to power 200 light bulbs. As if we were taking to the air on a giant Christmas tree».

This is why the engineers had to work on two fronts: to maximize the energy generated and to reduce weight to an absolute minimum. The first limiting factor, according to Piccard, were the batteries: new ones were needed, lighter and capable of storing more energy, to power the plane at night.

A tricky problem, as they were to realize in June 2015, after flying across the Pacific from Japan to Hawaii: Solar Impulse was grounded for nine months because the batteries had been damaged by overheating. «I had to return to Switzerland and raise more money so we could make improvements», recalls Piccard.

YOGA AND HYPNOSIS. It was nothing short of a flying laboratory. Futuristic and spartan at one and the same time. The other headache for the technicians, given the very limited energy available, was how to reduce consumption to incredibly low levels.

Thanks to a carbon-fibre airframe, as used for America's Cup yachts, the aircraft weighs only 2.3 tonnes, the fuselage accounting for a mere 50 kg. Not surprisingly, the aircraft can accommodate only one pilot, in a cockpit the size of a lift cubicle, unpressurized and without a heating system (though it does have a toilet, fitted beneath the sliding seat). Whoever was flying the plane therefore had to be attached to an oxygen cylinder and wear a thermal suit on reaching an altitude of 8,000 metres (26,250 ft), where the air temperature is 40° C below zero and the portholes ice over. Moreover, while flying, the pilot could sleep for only 20 minutes at a time, having to constantly monitor the performance of the aircraft, which was highly susceptible to side winds. Piccard and Borschberg therefore taught themselves to concentrate by practising yoga and auto-hypnosis. And they carried an alarm system in their flying suits: the automatic pilot roused them by gently shaking their forearms if the plane listed by more than 5 degrees.

To make matters even worse, the aircraft could not be flown at more than 9,000 metres (29,525 ft) above ground level, because at this altitude the propellers would lose efficiency, nor fly in winds stronger than 18 kph (11 mph) without becoming unstable. They had to contend with a myriad unknown factors, with just one objective in mind: to keep flying until sunrise next day without the batteries running out of energy.

SCIENCE FICTION. After all this painstaking preparation, Solar Impulse began its great adventure on 9 March 2015, setting off from the airport of Abu Dhabi. In 17 stages taking 23 days, the aircraft touched down on four continents, landing back in the UAR at four in the morning on 26 July last year. «Flying was a magical sensation», says Piccard. «I would watch the Sun and the aircraft's propellers and think: I'm not carrying any fuel, not making any noise, not causing any pollution. I am in the future! It was like being in a science fiction film: absolutely thrilling». From his cockpit, Piccard observed the Statue of Liberty and the pyramids of Giza. But the most moving moment was a live videoconference with UN headquarters in New York, last April, during the signature of the Paris Agreement on climate change.

While flying over the Pacific towards California, Piccard commented over the radio to Secretary-General Ban Ki-moon: «If a plane can fly day and night without fuel, then the world can be a much cleaner place». Solar Impulse was not so much carrying its pilots as conveying a message: sustainable energy is within our grasp and the possibilities are almost infinite.

ON MARS. But was it worth spending 177 million dollars and risking the lives of two men? Is it true that, in the next few years, commercial aircraft will transition to solar power? Giancarlo Genta, professor of engineering design at the Polytechnic of Turin, does not think so: «Solar-powered aircraft are notoriously slow, and in bad weather downright dangerous. The Sun emits massive quantities of energy, but in diluted form: at most 1.4 kW per square metre. Even if solar cells could achieve 75% efficiency, it would take 1 m2 of them to generate 1 kW (the power of a domestic iron). But to fly a plane you need tens of megawatts (= 1,000 kW): entire football pitches covered with solar cells. Solar propulsion makes sense for space travel: a cargo ship bound for Mars could take off using conventional fuels then, once in orbit, deploy 20,000 m² (215,278 sq.ft) of solar panels. It would then travel slower, but would need far less fuel».

A HYBRID SOLUTION. But one aspect of Solar Impulse really will revolutionize air transport: the use of electric motors, which are far more efficient than internal combustion engines. «The future of flight will be hybrid», predicts Giulio Romeo, professor of aerospace engineering at the Polytechnic of Turin. «The planes of the future will have electric motors powered by a combination of hydrogen fuel cells and solar cells. This will enable them to fly at 500 kph (310 mph) and transport dozens of passengers. Another promising application are drones: powered by the Sun, as well as by hydrogen, they can remain airborne at high altitude (20-25 km / 12-15 miles) for six to eight months, without having to land. They could be used for monitoring immigration, forest fires, smuggling and agriculture. The great advantage is that, while conventional aircraft cost 9,000 euro per hour to deploy, drones cost a mere 1,500. In Turin, we have designed an aircraft of this kind, Heliplat, with a wingspan of 73 metres (240 ft). The prototype performs well and we are looking for sponsors».

In short, the quest for clean sources of energy is hotting up. Piccard is well aware of this, having founded the International Committee of Clean Technology, a 400-strong group of companies, to offer governments environmentally friendly energy solutions for everyday life. «The Committee also includes Watly, an Italian start-up that has invented a solar-powered water purifier which also generates electricity», reveals Piccard. «Within two years, we hope to be able to offer a thousand-solution package to national governments. It has been well worth the effort: we are on the right track».

Vito Tartamella

A 35-YEAR OLD DREAM

SOLE MIO. The dream of solar-powered flight is nothing new: it has been around for more than 35 years. More than 40, if you count the earliest experiments with solar-powered models (weight: 12 kg, 26.4 pounds), first flown in the USA in 1974. The first solar-powered aircraft able to carry a person dates from 1981: the Solar Challenger, a 90-kg (198 pounds) ultralight, with which its constructor, the American Paul MacCready, managed to cross the English Channel, covering 262 km (163 miles) in five hours. The stage was set. Two years later, in 1983, the German Günter Rochelt built Solair I, a machine with a wingspan of 16 metres (52 ft) that flew in Germany for five hours 41 minutes. Another record was broken in 1990: the American Eric Raymond, on board Sunseeker, flew 400 km (250 miles) across the USA in 21 stages, airborne for 121 hours, but only in the daytime. In 1996 an Italian , Antonio Bubbico, built an aircraft called "O sole mio", but was unable to test it. Meanwhile, between 1997 and 2003, NASA experimented with large solar-powered drones (wingspan 30 metres / 98 ft), which reached altitudes of 29.5 km (18 miles).

Courtesy Marina Militare

ON A MISSION
The submarine *Scirè* leaves the Gulf of Taranto, with two sailors scanning the horizon from the fin.

SUMMARY

- In August, a *Focus* journalist sailed aboard **submarine *Scirè*,** one of the eight belonging to the Italian Navy.
- Built in partnership with Germany, it is one of the most modern of its kind, with a **long range** and the ability to operate in **silence**.
- The sub patrols the Mediterranean, on the look-out for **arms**, **drugs** and **human traffickers**.

A day on board a submarine

On board an Italian Navy vessel: an amalgam of technology, spartan living and intelligence.

A a voice comes over the tannoy: "Last man aboard. Upper and lower hatch sealed. Vessel ready to dive". I am in a room full of monitors, push-buttons and piping. A dozen men in uniform are aligned before a bank of flickering consoles. In the centre, a man is looking into the eyepiece of a large metal cylinder and turning around it...

No, this is not a film set. The cylinder is a real periscope, and I am in the control room of a real submarine: the Scirè, one of the technological jewels of the Italian Navy. *Focus* wanted to see close up how a modern submarine operates, and how the submariners live on board. So this summer, with a photographer, we set sail from the Gulf of Taranto, HQ of the national submarine fleet, and participated, for a day, in a real underwater mission.

60 METRES BELOW. After sailing a few miles on the surface to reach the open sea, we slow down for a while: the time it takes to fill the ballast tanks with more than 100 tonnes of water, the weight that will take us down into the depths. And finally the long-awaited moment arrives: the commander, Raffaele Martino, has the periscope lowered into the floor-well and gives the order: "Helmsman, dive to 60 metres". In a few minutes we shall be 60 metres below the surface. My heart is racing. I watch the helmsman manoeuvring the submarine using two small black joysticks. But were it not for the slight pitching of the bow, I would have thought we were standing still.

Not the first of my illusions punctured, nor the only fascinating discovery on this voyage. Starting with the portholes through which I expected to admire some breath-taking underwater seascapes: "Submarines don't have portholes", points out 35-year-old Martino. "They would weaken the structure of the hull. To navigate under water, we have no eyes, only ears". The submarine's "eyes" are in fact functional only to a depth of 14 metres, below which it is not possible to use the periscope. Peering through it, you can see all vessels as far as the horizon, miles away, and at night too, thanks to infrared cameras. At greater depths, you have to rely on other instruments. Not radar, which works only on the surface, nor the GPS navigator, which cannot capture signals under water. Submarines therefore have to estimate their position: via GPS they log the point at which they submerge, then, using a computer connected to gyroscopic compasses and accelerometers, they estimate subsequent positions with a margin of error of a few miles (depending on underwater currents). Maybe this is why there is a red lucky charm dangling from the instruments in question...

INVISIBLE. They navigate by dead reckoning, steering in response to sounds. To measure distance from the sea bed, they use an echo-sounder, which bounces an electro-acoustic signal off the bottom. To monitor the presence of other vessels at depth, they use passive sonar: a sort of underwater microphone that can capture sounds under water, even at a distance of several miles. "By listening to its acous- ▸

Cosimo Laera (3)

CONTROL ROOM. The Scirè's war room. Centre: the captain looking through the periscope. Right: the helmsman controlling the vessel using joysticks (photograph 1); the torpedo tubes (2).

THE SUBMARINE *SCIRÈ*

Built by Fincantieri, the vessel is the result of twenty years' technical cooperation between Italy and Germany. The Germans supplied the electric motor (Siemens) and the optical components of the periscope (Zeiss). Italian suppliers contributed the stainless steel hull (AST), the torpedoes (Leonardo), and the automated steering system (Avio).

Surface displacement: 1,450 tonnes
Length: 56 m
Beam: 7 m
Height : 14 m (fin included, but excluding periscopes)
Speed: 12 knots (22 km/h) on the surface, 20 knots (37 km/h) under water
Range on the surface: 8,000 miles (14.816 km)
Range under water: 420 miles (778 km)
Crew: 27 sailors (including 6 officers)
Engines: 1 permanent magnet motor, 1 diesel generator
Armament: six 533 mm torpedo tubes

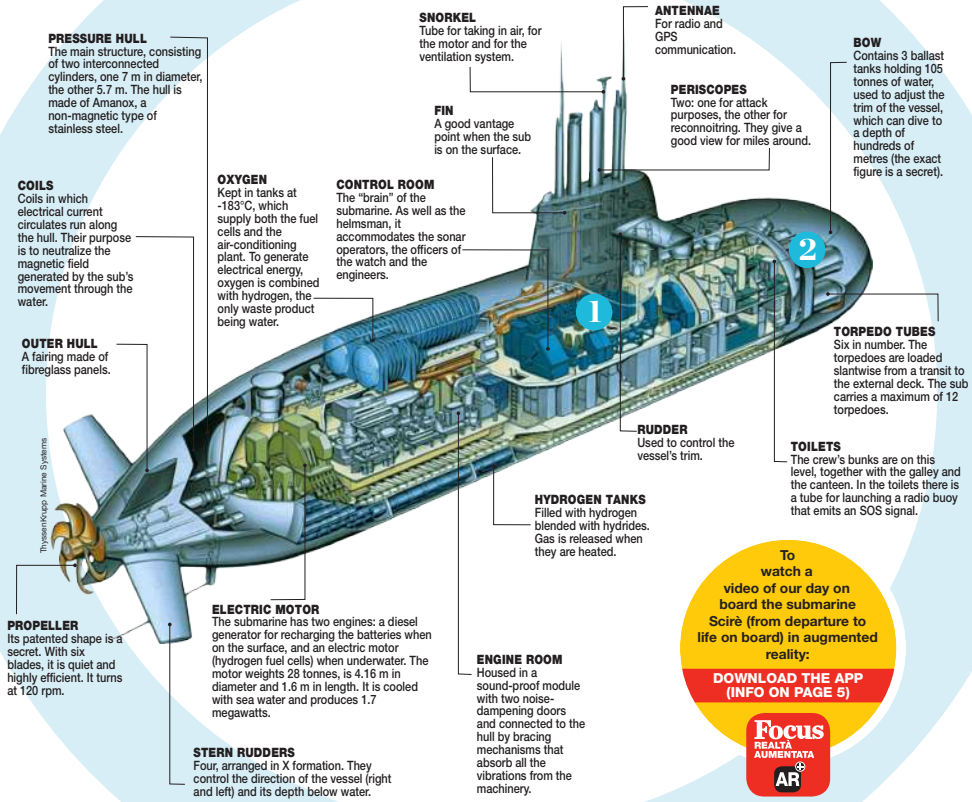
tic signature we can calculate the number of propeller shafts and blades of another craft and work out whether it is a fishing boat, a rubber dinghy or a merchant ship. Or another submarine", says Martino.
Only rarely do they use active sonar, which detects obstacles by measuring the time it takes for a signal emitted from the submarine to bounce back: "Emitting sounds would reveal our presence. Which we definitely don't want", explains the commander. The Scirè, two railway carriages in length, is powered by hydrogen (see drawing). And it must remain invisible. "A military aircraft could find us even at a depth of 40 metres, using a sensor to detect magnetic anomalies under water", explains lieutenant Carlo Faggiana. "That's why the hull is made of a special non- magnetic stainless steel".

12 TORPEDOES. There is the same obsessive control of sound emissions. Not for nothing, the British refer to their submarines as "the silent service". The propeller, for instance, has been designed to minimize noise (the patent is top secret), and the engine room with its electric motors is installed in a soundproof box suspended on springs. When the commander closes the door of the engine room, the deafening 80 decibels of noise within becomes almost imperceptible: "See how quiet it is!", Martino remarks proudly.
Thanks to this advanced technology, during a NATO exercise in the Atlantic in 2008, the Todaro, the Scirè's sister submarine, was able to escape the attentions of a whole naval squadron and come up a

> The vessel is designed to be silent. And invisible

few miles from an American aircraft carrier, the Theodore Roosevelt, taking photographs of it through its periscope. From that position, it could have hit the carrier with one of its torpedoes: all you need do is press the "Fire" icon on one of the monitors. "We have 12 torpedoes here on board", says Martino. "It would take two to send a 300-metre-long carrier to the bottom. The technique is to explode the torpedo under the enemy's keel, creating a shock wave violent enough to break a ship in two." A theoretical scenario, of course! As we shall see, the submarine's mission is something very different.
But all this "invisibility" comes at a price, above all the total isolation of the 27-man crew. "Radio waves do not penetrate under water", Faggiana points out. "Or rather, they penetrate to a depth of just a few metres and only very very slowly, using the lowest frequencies on the radio spectrum." How this system works, we were not to find out . The only area off bounds to us during our visit was in fact the radio room, the door of which bears the inscription 'Top secret SS/NATO'. "At night we come up to periscope depth, raise the antenna and communicate via satellite with our command centre", says Martino. "As well as transmitting service communications, we send messages to the crew members' families: twice a week, my colleagues give me a file of texts for their families and, before sending it, I have to check that it contains no sensitive information. In addition, we receive a compendium of news flashes from Italy and the world at large." A way of not feeling totally isolated. And for checking whether or not someone has won the football pools... Such modest activities, together with films, books and fitness training (there are exercise bikes and weights in the most unexpected corners of the sub), of passing the time between one 6-hour shift and another in this steel cylinder secretly prowling the ocean depths.
Shifts are interspersed with meals prepared in the sub's galley. Today's menu is fresh pasta with a tomato, ricotta and a spicy salami sauce, and roast chicken with savoy cabbage. "And at one o'clock in the morning, we traditionally have pizza baked in the ship's oven", adds Faggiana.

BUNK BEDS AND LOOS. There are minor comforts in this spartan way of life, despite the many myths concerning submarines: "I joined the Navy because I was fascinated by the film *The Hunt for Red October*", the commander tells us. "But then I discovered that there was nothing very realistic about it." For example, sailors smoking in shirt-sleeves, but all the crew of the Scirè wear heavy flame-proof suits, even at the height of summer. And smoking is forbidden. "The greatest ▸



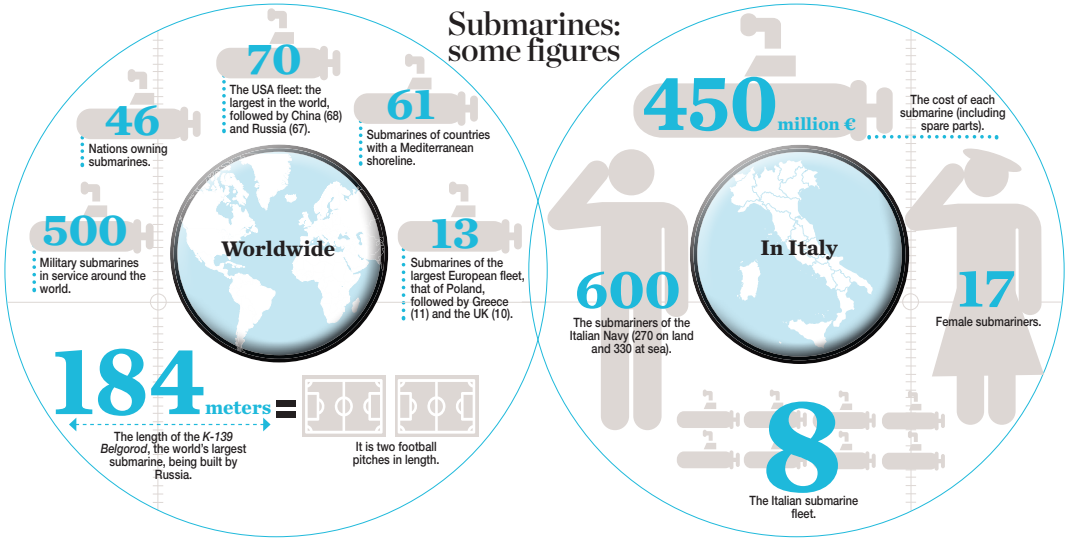
To watch a video of our day on board the submarine Scirè (from departure to life on board) in augmented reality:
DOWNLOAD THE APP (INFO ON PAGE 5)
Focus REALTÀ AUMENTATA AR

Courtesy Marina Militare

Family contact: two short text messages each week

Cosmo Laera (2)

LIKE SARDINES. Above: maintenance being carried out inside a torpedo tube. Below: the emergency steering stand. Right: the crew's couchettes, with lockers for personal items in the centre.



danger on board is not a crack in the hull, but fire", explains Faggiana.

All along the submarine (the terms "submersible" is incorrect: it refers to craft that go underwater only occasionally) runs a tube fitted with valves at half-metre intervals: "This is the Built-In Breath System (BIBS)", explains lieutenant Faggiana. "It supplies air when you plug into it with a rebreather, in the event of a fire or emergency, for instance if the sub becomes stranded on the sea bed and we have to evacuate."

In the last 19 years there have been 34 recorded accidents affecting submarines: the most recent in 2017 when the Argentinean ARA San Juan went down with 44 men on board. But these are rare occurrences in a job that is nevertheless very demanding. Nowadays, fortunately, the tradition of hot racking (two sailors sharing a bunk and changing places at the end of each shift) has died a death. Every crew member now has his own berth, but they are just cramped couchettes separated by curtains, each equipped with a 30-cm-square locker. Only the commander has his own private space, the size of a lift cabin. And there are just two toilets. One houses an ejector tube designed to launch an emergency buoy that transmits an SOS signal, the other a tube used to dispose of organic wastes (but not excrement, which is treated chemically on the submarine).

POTATOES AND ONIONS. "On board, we are careful about managing and sorting wastes. We avoid using glass, while plastics and cardboard are stored in bins and offloaded when we are in port. And to save space, we have a compactor", Martino tells us. Every square inch is precious: in the torpedo room, stowed in odd corners, are sacks of potatoes, courgettes, onions and apples. Everywhere there are stacks of mineral water bottles.

A mission lasts an average of three weeks, followed by one week of shore leave, then another three weeks on the submarine. Now I understand why their wives were hugging the submariners so ardently on the quay in Taranto before we sailed.

In three weeks' time, the crew are due to land on a Greek island, where they will find a change of clothing and other personal effects, transported there by container. Every mission requires complex logistics involving a hundred or so people. But what is the point of all these sacrifices? What are they doing in the ocean depths?

STRANGE GOINGS-ON. In recent years, the international strategic websites inform us that the Russian presence has intensified, both above and beneath the Mediterranean... But this is something commander Martino prefers not to discuss.

"Ours is an intelligence function", he tells us. "We monitor mercantile shipping and the risk of smuggling. We are on the lookout for trafficking in drugs, weapons and human beings. Also polluters and possible terrorists. If we observe suspicious movements, vessels sailing unusual routes or failing to transmit their data to the automatic identification system (a sort of automated register of maritime traffic), we keep tabs on them. Through the periscope we can film things that are happening miles away. A few years ago, one of our submarines filmed a fishing boat that was towing two craft carrying migrants, then it cut them adrift. Thanks to our video, the police were able to arrest the traffickers. A satisfying outcome, even though, in the best traditions of the service, our contribution remained secret: no one knew anything about it."

Vito Tartamella

(translated by Simon Knight)

In the new FARM

Vertical farms save land and water, do not use pesticides and are protected from bad weather. But they take a lot of **energy**.

by Vito Tartamella

Plenty

GREEN WALLS An agronomist checks the rocket, black cabbage and beetroot plants arranged on a 6 meter high wall: we are at Plenty in San Francisco, an avant-garde vertical farm.

Today is harvest day. It is 8 in the morning, when Davide turns a knob on the control panel. A door opens at the top of a wall, and from there comes out a platform filled with bright green lettuce plants that are just ripe enough. Davide presses a button, and the tray with the plants descends to the ground floor with a goods lift. David wears a white coat with shoe covers, gloves, mask and a hairnet. He observes the quality of the crop by typing in the shape and colour of lettuce heads on a tablet. Then, the tray will be loaded on trolleys and transferred to a refrigerated room, where the plants will be cut, checked and packaged. In the afternoon, the salad bags will be in the wholesalers' cold stores, ready to be sold the next morning. Davide is not working in a field. He is in an industrial warehouse on the outskirts of Melzo, east of Milan. This is the headquarters of Agricola Moderna, Italy's largest commercial vertical farm, where Davide Sosso, a 38-year-old agronomist with a postdoc at Stanford University, is Head of R&D. In the farm's growing chamber, an 8-metre high metal box—almost like a three-storey building—there are 800 m² of stacked trays filled with lettuces and brassicaceae lit by purple LED lights.

THE LARGEST FARMS IN THE WORLD

This is not a laboratory experiment: the two tonnes of salads produced each month with zero pesticides are sold by a network of hypermarkets in the area and by a farmhouse products website. Nor is this an isolated case: in April, Planet Farms, a 10,000-m² automated vertical farm, will open in Cavenago, also in Lombardy. It will be one of the largest in the world: Nordic Harvest, a 7,000-m² facility, is being built in Copenhagen. To date, the largest vertical farm is AeroFarms in Newark, USA: it extends over several floors for a surface of 6,500 m². Ikea, the Swedish furniture multinational, has also invested in this company. While Jeff Bezos (Amazon) and Eric Schmidt (Google) have invested in Plenty, a robotic vertical farm in San Francisco. Why this boom occurred? 'Covid has made people more aware of healthy food and its environmental impact', said Sosso. But the reasons go deeper.

ZERO MILE

According to its proponents, vertical farming could solve many of today's problems. Indoor fields are not subject to natural disasters, global warming or insects, therefore there is no need to treat plants with toxic fertilizers and pesticides. They allow many more harvests throughout the year, as they do not depend on the weather and the cycle of the seasons: for the same surface area, an indoor square metre is 10 times more productive than a traditional one (and some species are up to 500 times more productive). Moreover, they save a lot of soil and water thanks to hydroponic and aeroponic techniques—the roots of the plants are immersed in a water solution or sprayed with a nutrient spray mist. This means no land consumption and very low water consumption. Not to mention that, being located in cities, these farms cut down on transport emissions: they are truly zero-mile.

Urban farms make it possible to produce fruit and vegetables in small spaces: they can be "indoor farms" (set, for example, in disused warehouses), "vertical farms" (in vertically stacked layers), "plantscrapers" (cultivated skyscrapers, indoors or on the roof) and "deep farms" (set in former mines).

London-based Growing Underground produces vegetables in abandoned WWII tunnels. Local Roots, a Los Angeles-based start-up, patented Terra-Farms—12-metre containers equipped as indoor greenhouses that can be controlled remotely with a smartphone. ▶

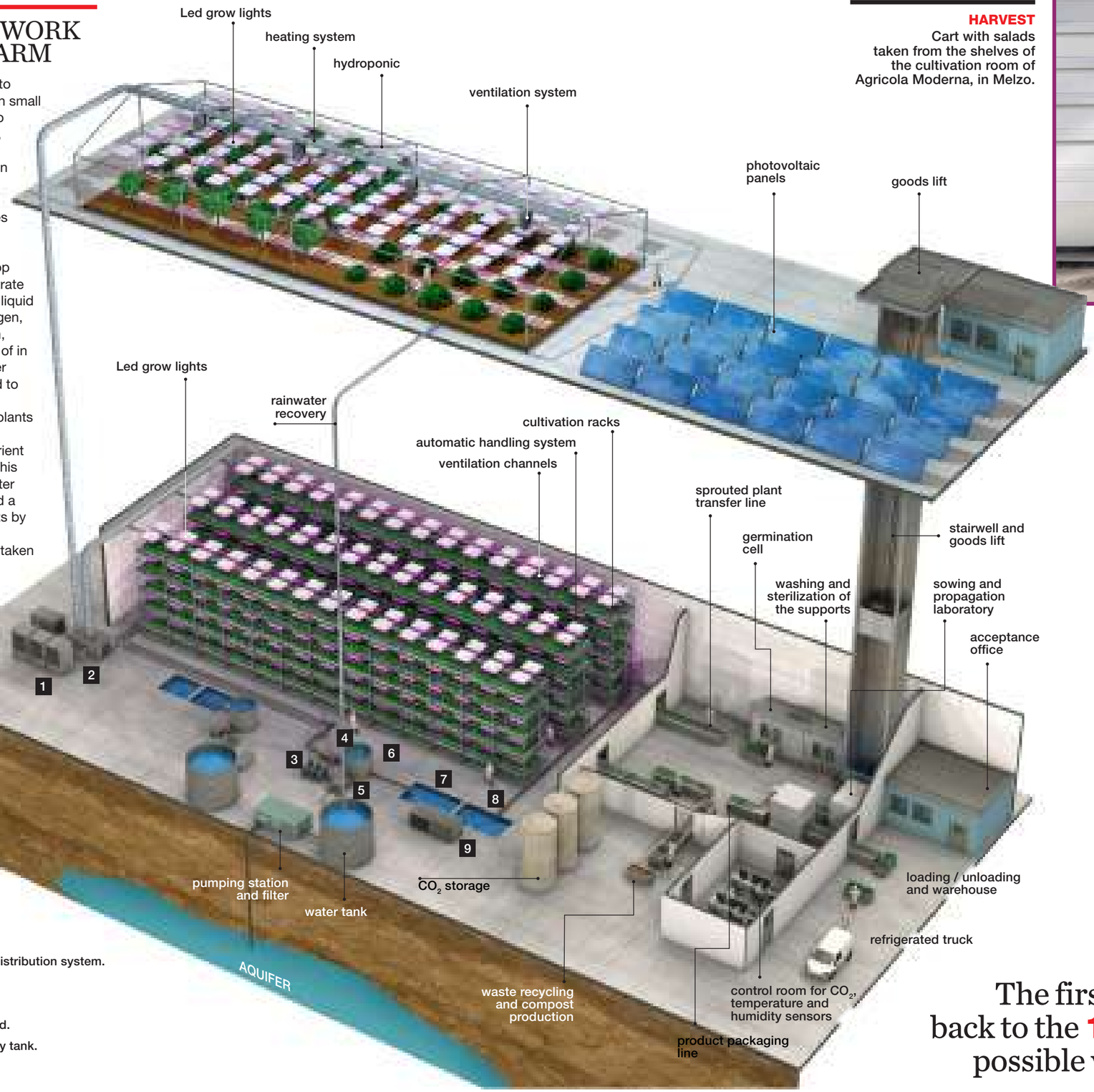
HOW DOES IT WORK A VERTICAL FARM

Urban farms make it possible to produce fruit and vegetables in small spaces and indoors. Thanks to soilless cultivation techniques, they allow less land and water consumption, faster production cycles (and more numerous during the year), zero pesticides. Indoor greenhouses use 2 soilless cultivation techniques:

1 hydroponics: plants develop their roots in an inert substrate (gravel, sand) sprinkled with a liquid solution rich in nutrients (nitrogen, phosphorus, sulfur, potassium, calcium, magnesium), instead of in the soil. This reduces the water needed by 10 times compared to traditional agriculture.

2 aeroponics: the roots of plants develop in the air inside a nebulization chamber: the nutrient solution is sprayed on them. This allows you to save 90% of water compared to hydroponics, and a greater assimilation of nutrients by plants.

In the drawing, a vertical farm taken from a project by eng. Matteo Benvenuti, founder of Vertical Farm Italia.



Stefano Carrara

1 Heat pump.
2 Air handling unit.
3 Reservoirs for nutrients.
4 Nutrient solution pumping and distribution system.
5 Bench of ferti-irrigation.
6 Nutrient solution.
7 Solution tank recovered sterilized.
8 Excess nutrient solution recovery tank.
9 Solution sterilization station.

HARVEST
Cart with salads taken from the shelves of the cultivation room of Agricola Moderna, in Melzo.

Agricola Moderna

A UNIVERSITY CHALLENGE

«With vertical farms», says Dickson Despommier, professor emeritus of Microbiology at Columbia University, «we could ensure a more sustainable future for the planet. All the land saved using this farming system could return to its natural ecological function: absorbing carbon dioxide and oxygenating the planet through forests. By 2050, the world's population is expected to increase by about 3 billion people, and almost 80% of them will live in cities. In order to feed everybody, 10 billion hectares of new land will be needed (an area 20% larger than Brazil), reducing the area of forests and producing greenhouse gases from agricultural activities». Will indoor agriculture be the solution to feed and save the world? As we shall see, the time is not yet ripe.

Despommier is the father of vertical farming, which started as a challenge in his university classroom. Back in 1999, his students, tired of dealing with pests and environmental damage, asked him to cover less depressing topics. Despommier set them a challenge: they had to calculate how many Manhattan residents could be fed a diet of 2,000 calories a day by using the rooftops of the densely populated New York City borough as arable land. The result was discouraging: with a total of 52,000 m^2 of rooftops, it was only possible to feed about a thousand people. So Despommier widened the perspective: why not use not only the roofs but also the interior spaces of the buildings, creating greenhouses lit by large windows and artificial lights? A 30-storey high farm could produce food for 50,000 people, hosting fruit and vegetable fields, chicken and fish farms fed with vegetable waste. Vertical farming was born. «Although», says Matteo Benvenuti, author of "Introduction to vertical farms" (published in Italy by Wolters Kluwer), «a similar idea was launched as early as 1984 by Canadian biologist John Todd, founder of the New Alchemy Institute. In order to make the project feasible, however, a technological breakthrough was needed—artificial lamps to irradiate indoor crops with the same wavelengths as the sun». This result has been made possible in the past decade thanks to advances in LED lamps, capable of stimulating photosynthesis of all different species, and having long life and low energy consumption. A field in which Philips invested millions in research.

HIGH INVESTMENTS, HIGH ENERGY CONSUMPTION ▸

The first ideas on vertical farms date back to the **1980s**. But they only became possible with the advent of **LED** lights

FARMERS IN COMPARISON

	OUTDOOR	INDOOR	
CONS	• 1.6 billion hectares cultivated in the world (80% of the earth's arable land)	• 30 hectares cultivated all over the world. Yeld of 1 indoor hectare = 10 traditional hectares	PROS
	• 50% of the crops are not harvested	• 90% of the crops planted are harvested	
	• Intensive use of pesticides (and only 0.1% affects insects; the rest ends up in the environment)	• 0% di pesticides	
	• Risk of parasite attacks (insects, birds, rodents)	• Very low risk of parasite attacks	
	• 70%: percentage of land freshwater used for agricultural purposes (and 50-80% of it is dispersed between evaporation and water losses)	• Less than 70-95% of water needed (using hydroponics or aeroponics)	
	• 2,400 km: average distance that a food travels to reach our table (causing pollution)	• km 0: vertical farms already arise in the city	
	• Subject to seasonal cycles and climatic weather	• Not subject to seasonal cycles or climatic weather. And different types of crops can be grown at the same time	
	• CO_2 emissions due to the use of tractors	• No use of tractors, but the high use of electricity has a very high environmental impact (if it doesn't come from renewable sources)	CONS
PROS	• Possibility of cultivating any species	• Limited number of cultivable species: small, fast-growing plants that must not be pollinated by insects	
	• Very low cost per m^2	• High cost per m^2 (even 800 times more)	
	• Energy requirement: for a greenhouse, 250 kWh of energy per year for each m^2	• High energy costs: for a vertical farm, 3,500 kWh per year for each m^2	

ROOT CONTROL
A YesHealth technician checks the roots of a hydroponic garden in Taiwan: they are immersed in a solution of water rich in nutrients.

EXTREME VEGETABLE GARDENS
Below, the "Veggie" module, in orbit on the International Space Station; below, tomatoes at the Amundsen-Scott Base at the South Pole.

According to the financial agency Bloomberg, the vertical farming market was worth $3.42 billion in 2019 and its value could more than double to $7.3 billion by 2025. Still, it remains a niche: according to estimates by Cindy van Rijswick of Rabobank Research Food in Utrecht, Netherlands, indoor farms account for 30 hectares of cultivated land worldwide, against the 1.6 billion hectares of traditional farming. There is still a long way to go, and it will not be an easy one, due to technical and, above all, economic restraints. Starting with the investment costs: starting a traditional greenhouse costs about 300 euro/m^2, while an advanced vertical farm requires between 2,000 and 2,500 euro/m^2. Not to mention the operating costs: «The highest cost», says Benvenuti, «is electricity, which can account for over 60% of the costs: the lights need to be on 12-18 hours a day, 365 days a year. Air conditioning and irrigation systems also need to be powered. A 500 m^2 farm requires more than 200 kW of instantaneous power, the amount needed to supply 100 flats».

If this energy does not come from renewable sources, the environmental impact is heavy. These costs have an impact on the type of crops that can be grown: it is necessary to choose low plants (given the limited space between growing platforms) and «with a short growth cycle, to have more harvests in a short time», points out Gabriella Funaro, an expert from ENEA (the Italian National Agency for New Technologies, Energy and Sustainable Economic Development). «Tomatoes, for instance, are unprofitable because they take 70 days to grow compared to 20 of lettuce. And rice needs large areas: the price of cereals is too low to justify indoor cultivation».

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A 27 DOLLARS LOAF

The energy imbalance between a traditional farm and an indoor one

Indoor farms are suitable for countries with **little arable land**. And to those with very **hot** or very **cold** climate

remains huge: according to the Swiss Federal Institute of Technology in Zurich, it takes 4,166 kWh of energy to grow 1 kg of lettuce in a hydroponic farm, compared with only 305 kWh in an outdoor one. According to Louis Albright, professor of Biological and Environmental Engineering at Cornell University, a loaf made with wheat grown on a vertical farm would cost $27, compared to $1.3 of one made from outdoor grown wheat.

This is why the first attempts of these growing techniques took place in an area of extreme experimentation: space. The aeroponic technique, in fact, was invented by NASA to supply astronauts on space ships with vegetables. The experiments began in the 1980s, and today the Vegetable Production System ('Veggie'), weighing 8 kg, is aboard the International Space Station: it produces lettuce, cabbage and Japanese mustard in orbit using only 90 W of power. Today, ENEA in Rome has created 'HortExtreme', a vegetable garden for a futuristic human base on Mars: 4 m^2 to grow four species of microgreens with «a high density of vitamins, mineral salts and antioxidants to reinforce the astronauts' diet», says Eugenio Benvenuto of ENEA's Biotechnologies division.

SALADS IN THE DESERT (AND AT THE POLE)

On Earth, on the other hand, vertical farms appeal to a niche market, that of consumers willing to spend more to have salads or strawberries grown without chemicals. But how much more? «An 80-g lettuce bag costs 1.6 euro, i.e. about 20 euro per kg», replies Sosso. «It is a high-end product, at the same level of organic vegetables». But making money out of it is not easy. So much that there have been epic failures in the sector. In Sweden, Plantagon wanted to build the World Food Building, a 16-storey indoor farm designed to feed 5,000 people. The construction works, which cost $40 million, started in 2018 and were due to be completed in 2020. But in 2019 Plantagon declared bankruptcy—it would not have been able to sell the products at the prices it had hoped. «A project of this size», admitted Vice-President Owe Pettersson, «was too far ahead of its time». Therefore, in order to make ends meet, vertical farming today aims to save costs or increase profit margins. «ENEA, together with Coldiretti (the main Italian organisation representing agricultural entrepreneurs) of Padua, has launched the Ri-Genera project to use warehouses or abandoned buildings for hydroponic crops», says Funaro. Others are focusing on high-income, medical or cosmetic essences: holy basil, Californian poppy, ginger, and saffron.

But the bulk of the market for vertical farms is in countries with little arable land, such as Japan, that is one of the world leaders in the sector with over 200 companies. China is a leader, too, having lost 123,000 km^2 of agricultural land to massive urbanisation, plus another 200,000 km^2 that cannot be cultivated because of pollution. Vertical farming is gaining traction in countries where the climate makes outdoor cultivation prohibitive: in Dubai, Emirates Airlines is building a 12,000 m^2 vertical farm to supply all its planes with fresh vegetables. The UAE government is investing $100 million in indoor projects: the desert climate and lack of arable land is now forcing the country to import 80% of its food. And the same goes for cold places. In addition to Nordic Harvest in Denmark, at the South Pole there is the Food Growth Chamber, a room that supplies the 65 employees of the Amundsen-Scott research station with fresh vegetables— a way to grow lettuce when outside it is 70°C below zero.

RUBBISH SPACE DUMP

There are **129 million pieces** of rocket and satellite debris above the Earth. Have we reached the limit? Not yet. But the future debris will have to be sustainable. And we'll have to remove the bigger pieces.

by Vito Tartamella

WRECK
Space debris in an artistic reconstruction: the most polluted orbits are the low ones, at an altitude of 800-1,000 km. The busiest by communications satellites.

Getty Images

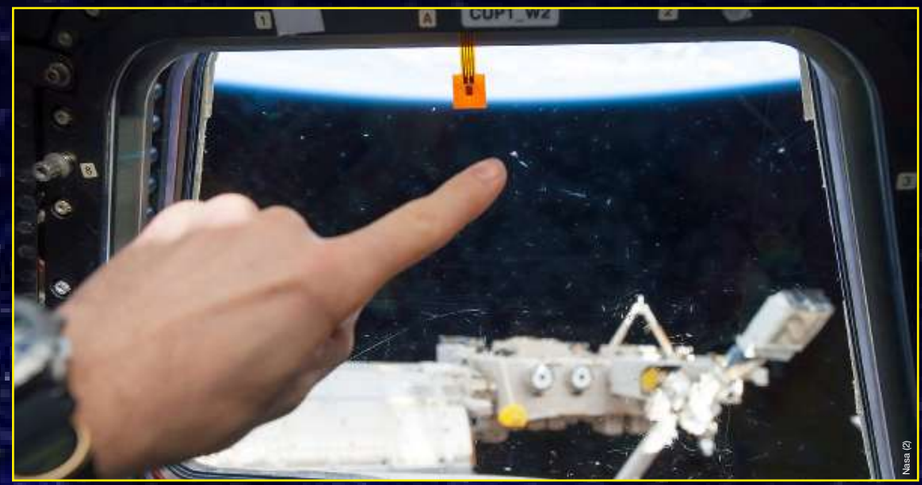
The last time it happened was on 22 September last year. At 22:21, Vandenberg Air Force Base, in California, sent the International Space Station a conjunction data message, a possible collision alert—within an hour it would be in danger of being hit by a piece of stray debris. The three astronauts on board the station, Christopher Cassidy, Anatoly Ivanishin and Ivan Vagner, got to work on the on-board computers to prepare for the emergency manoeuvre. At 22:19 they fired their thrusters for three minutes to move into a safe orbit. Then they took refuge in the Soyuz space capsule, ready to undock and return to Earth in the event of a collision.

They had a narrow escape, as the debris passed by 1,500 metres from the Station, hurtling at 52,560 km per hour over the Pacific Ocean. At that speed, a piece the size of a smartphone has the same impact force as a lorry crashing at 140 km per hour. Only at that point did the military at the Joint Space Operations Center recognize it: it was fragment 2018-084CQ, part of a Japanese rocket that had carried the satellite Gosat-2 into space in 2018. In 2019, this aluminium and carbon fibre stage, weighing more than 100 kilograms, had broken up into 74 parts.

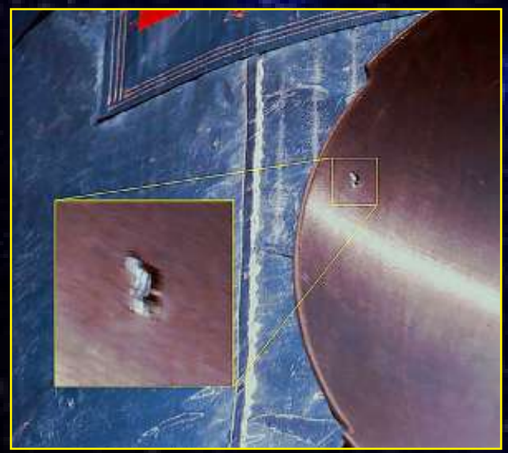
HALF-FULL?

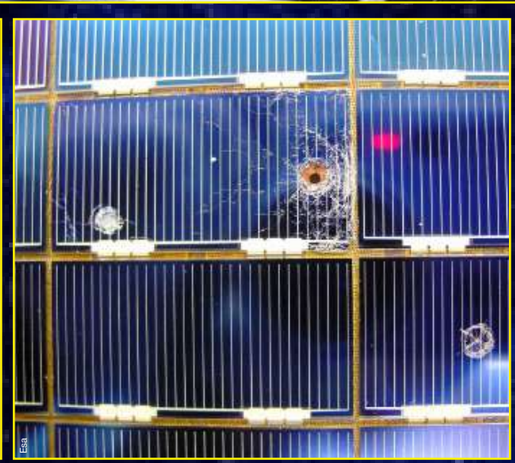
It was the 28th time in 20 years that the Station was forced into a correction manoeuvre to dodge space debris, with the previous three occurring in 2020. «The situation is getting worse», commented the then Head of NASA, Jim Brindestine. It is hard to argue with him: since the launch of the first satellite 64 years ago, the Earth's orbit has turned into a dump site. There are an estimated 129 million fragments larger than 1 mm: rocket stages, bolts, engine slag, paint flakes and retired satellites. The Envisat wreckage alone is the size of a double-decker bus. A worldwide network of orbiting telescopes, radars and sensors has so far surveyed 28,600 fragments larger than 10 cm: they have a total mass of more than 9,400 tonnes, the same as 19 train carriages.

Even if space is immense, it still has a limit. In 1978, NASA scientist Donald Kessler hypothesised a dreadful scenario: as space launches intensified, the density of objects would be so high that they would trigger chain collisions, ▸



TRACES
The sign of a micro impact on a window of the International Space Station: in recent years it has had to make several maneuvers to avoid space debris and to avoid much more serious damage.





DAMAGES
The damage caused from small space debris to the Hubble Space Telescope: here on the right, the impacts on solar panels: left, on the antenna.

Estimated objects

129 millions
1 mm-1 cm fragments (flakes of paint, residues of ignition dust from solid propellant engines, drops of coolant).

900,000
1-10 cm fragments.

34.000
fragments larger than 10 cm (including 1,950 rocket stages and 2,850 dead satellites. There are 200 critical objects of 3-9 tons).

Cataloged objects

Ground-based telescopes can detect debris from 10 cm upwards in Geo orbits. Ground radars can see debris a few millimeters in low orbit. Detectors mounted on satellites can also identify objects of a few micrometers.

To date, **28,600** fragments larger than 10 cm have been cataloged, for a total mass of over 9,400 tons, as **19** high-speed train convoys (1 locomotive and 18 carriages).

By mass, spacecraft are **55%** of the total, rocket stages **41%**, fragmentation debris **2%** and **2%** mission debris.

36000 KM/H THE AVERAGE SPEED OF IMPACT IN LOW ORBIT

A 10-cm, 300-gram object, which collides with another with an impact speed of 36,000 km / h, has the same strength as a **truck** that crashes at **94 km / h**.

State of the orbits

36.000 KM
GEOSTATIONARY ORBIT (GEO)
Satellites remain in this orbit indefinitely, even for millions of years. Objects orbit at the speed of 11,000 km per hour. Here is **5%** of the total mass of debris, and beyond this orbit another **5%**.

2.000-35.000 KM
MEDIUM EARTH ORBIT (MEO)
The time spent by the satellites is equal to that in Geo orbit. Here the objects orbit at 14,000 km per hour. In this orbit there is **15%** of the total mass of space debris.

160-2.000 KM
LOW EARTH ORBIT (LEO)
From an altitude of 1,200 km, satellites take about 2,000 years to fall to Earth; at 800 km it takes 100-150 years and at 500 km less than 25 years. Here the objects orbit at 28,000 km per hour. In this orbit (especially between 800 and 1,000 km of altitude) there is **75%** of the total mass of debris.

So far 11,670 satellites have been launched: 7,200 are still in orbit, 4,300 still functioning.
56% are from the USA, 12% from China, 5% from Russia.

Over **560 events of fragmentation** have taken place in the past 60 years
Most are **higher stage bursts**; collisions were 7.

with an exponential increase in debris and the risk of further impacts. To the point of making space exploration and the use of satellites impossible for many generations. How close are we to this scenario, known as the "Kessler syndrome"?

In a study published this year in *Acta Astronautica*, Luciano Anselmo and Carmen Pardini from the Institute of Information Science and Technology of the Italian National Research Council in Pisa, calculated that «we have already filled a third, if not half, of the capacity of low orbit, the level most crowded with satellites. We obtained this figure by considering the scenarios that would have been unacceptable 25 years ago as reference points. We have gone from 150 to 1,500 satellites launched each year, all concentrated in the same volumes of space», said Anselmo.

Kessler himself, recently interviewed, is even more drastic: «We have now reached the tipping point: debris will continue to increase even if all launches are stopped». Space waste, then, would be like carbon dioxide emissions: even if we stopped them, we could no longer stop global warming.

ANTI-SATELLITE MISSILES

What can be done about it? To answer this question, we need to take a step back: how did we get here? In recent years, there has been an assault on space, not only to observe the Planet, but above all to bring the Internet to every corner of the globe—the signal is provided by satellites in low orbit, which circle the globe in an hour and a half. But even then, an area the size of Italy would only receive this signal for 8 minutes at the most. Therefore, huge constellations are needed to guarantee a constant signal: OneWeb is going to launch 850, Kuiper 3,200 and Starlink 12,000. And the sky has also become more crowded due to the spread of CubeSats, miniature satellites. On top of this, there are military tests. In 1963, the US launched 480 million thin copper needles that created a 15-km wide, 30-km thick doughnut around the globe at an altitude of 3,700 km: they would act as radio repeaters in the event of an enemy attack on submarine telecommunications cables. It was the "West Ford" project: 36 clusters of those needles are still in orbit today.

Today, however, what is of concern are anti-satellite weapons—in 2007 alone, space debris increased by 30% after China launched a missile to destroy an old weather satellite, the FengYun-1C. The Chinese missile was used to test the ballistic capability of shooting down an enemy spy satellite. The US and Russia had carried out dozens of such tests in previous years, and in 2019 India joined them, too.

This is why space is so polluted. It is estimated that today the probability of a catastrophic collision in low orbit—i.e. one capable of destroying a spacecraft by generating thousands of pieces of debris—is one every 20 years; this probability drops to one every five years in the case of a collision between a piece of debris larger than 10 cm and a satellite.

The first such collision occurred in 2009, between the decommissioned 950-kg military satellite Kosmos 2251 and a 560-kg Iridium 33. They collided at an altitude of 789 km above Siberia at over 42,000 km per hour, producing almost 2,000 fragments. Iridium operators had ignored collision alerts because "so many were coming in that we would have to interrupt the service too often, making it commercially unviable".

In fact, the problem with space debris is first and foremost to determine its orbit. Most of them are small, irregularly-shaped objects whose orientation, size and material are unknown: companies and governments are reluctant to provide space agencies with data on their satellites, which are protected by trade or military secrets. Thus the probability of a collision between two orbiting objects is established by complex calculations and is dominated by uncertainty—the most precise estimates are only possible when impact is imminent. All these calculations result in hundreds of alerts every week, which in turn take hours of work by an analyst. However, in case of risk, only the largest satellites have propellant on board to change orbit.

Today, rules require that satellites are removed when they reach the end of their service life: those in higher orbits must be moved to higher "graveyard orbits", from which they will never fall, while the closer satellites are moved to lower altitudes, so that they disintegrate due to atmospheric drag, or are dropped into the Pacific. According to an ESA survey, however, only 50% of satellites in low orbit meet these requirements. And less than 20% of satellites with an end of life scheduled in 2017 were actually deorbited.

SUSTAINABILITY RATINGS

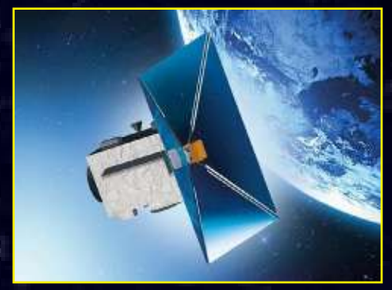
This is why last June, the World Economic Forum took the first steps towards measuring the sustainability of space missions: in 2022 the Polytechnic Lausanne Space Centre, Switzerland, will ▸

7 ways to clean up space

1 ClearSpace-1: a 100 kg probe with 4 robotic pincer arms to capture the Vespa, a part of the 112 kg Vega launcher. Esa project of 100 million euros with launch scheduled for 2025.

Esa (3)

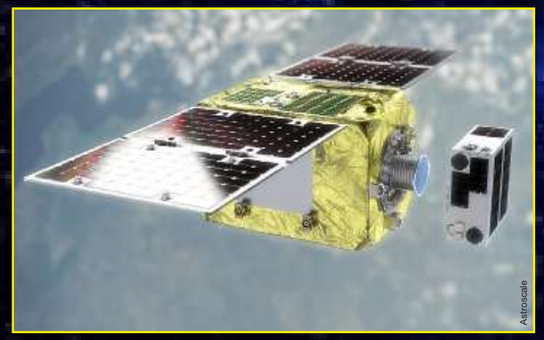
3 RemoveDebris: removing space debris by catching it with a net or harpoon. Successful in-orbit tests conducted in 2018 and 2019. University of Surrey project with a consortium of companies.



5 Adeo (Drag Augmentation Deorbiting Subsystem): sails system from 3 to 100 m² that pushes the disused satellite into a lower orbit to make it disintegrate. it is applicable to new satellites up to 1.5 tons of mass. Esa project.

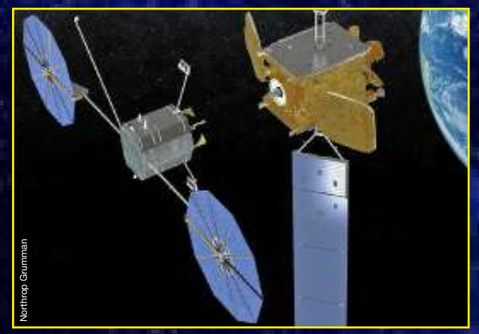
6 Electrodynamic Tether (Edt). Satellites equipped with a long conductive cable: if unrolled, it captures the earth's magnetic field generating a current that slows the satellite down to lower orbits until it reaches the atmosphere, burning itself. Under study by Nasa and Jaxa (Japanese space agency).

Jaxa



Astroscale

2 Elsa (End-of-Life Services Astroscale): mission of the Japanese space company Astroscale. It features a satellite equipped with a magnet to hook debris. A prototype was launched in March 2021.



Northrop Grumman

4 Mission Extension Vehicle (Mev): a rescue satellite hooks up to another to supply it with propellant, repair it or bring it back to a correct orbit. Northrop Grumman technology already tested.

Wikipedia

7 Direct infrared laser beams to deflect the orbit of small debris (1-10 cm in size), avoiding collisions with larger objects. It heats one side of the object so as to change its orbit and make it fall into the atmosphere first. At study in Esa.

start assessing the sustainability of space operators based on data sharing, choice of orbit, measures taken to avoid collisions, plans to deorbit satellites at the end of the mission and ease with which satellites can be identified. Spaceships will earn extra points if they have docking devices to facilitate their capture in flight.

SPACE SWEEPERS

This is not science fiction: in the next few years, the first space sweepers will enter service. The European Space Agency is leading the way in this field with ClearSpace-1. The mission has never been attempted before and consists of sending a satellite equipped with four robotic arms into orbit, capable of capturing a piece of debris in flight. Scheduled for 2025, this probe will pick up Vespa, a piece of a Vega rocket, 2-metres wide and weighing 112 kg, launched in 2013. The probe will then destroy itself and its payload by launching at full speed into the Earth's atmosphere. «Capturing space debris is no joke» warns Luisa Innocenti, Head of ESA's Clean Space Office. «The first critical aspect is to precisely frame the target, which is moving fast and can be backlit: we will have to use infrared cameras and radars on board the probe, coordinating them with ground-based instruments. Then we will have to synchronise the movement of our spacecraft with that of Vespa, approaching it gradually and surrounding it well before closing the clamp arms to capture it. It only takes one wrong move and we risk destroying the target, resulting in more debris. The exact opposite of the mission purpose». This is not the only way to tackle the problem of space junk. Last year, the US company Northrop Grumman's MEV (Mission Extension Vehicle) probe managed to dock an Intelsat satellite and return it to a service orbit, extending its operational life by another five years. «This strategy will become increasingly popular, including in-flight propellant refuelling missions», added Innocenti. «Sending a satellite into orbit and operating it costs around 100 million euro and its planning takes long. Extending its service life, on the other hand, means saving money and time, and not crowding the orbits any more. In the next decade, companies are likely to be required to pay a deposit before launching new satellites, which will be refunded if the satellites are de-orbited at the end of their service; otherwise, that amount will be used to finance the costs of removing space debris. Today, a mission like ClearSpace-1 costs 100 million—we expect to reach a removal cost of between 5 and 15 million euro to remove more than one piece of debris at a time. A sort of space sweeper».

> In the future, anyone who launches a satellite will pay a security **deposit** for cleaning costs in space

This procedure, however, concerns the military: in this way, spy satellites could be captured. In conclusion, it is a complicated, technical, political, and economic issue. And it is also a legal one: if a satellite causes damage, who pays for it? The country from which it was launched should be held accountable. Moreover, what if it does damage on Earth? Between 200 and 400 dead satellites and rocket parts fall into the atmosphere every year. Most of them disintegrate on contact with the atmosphere, but the rest reach the Earth, falling mostly into the oceans that cover 70% of its surface. The exceptions can be dramatic, such as the fall of the Cosmos 954 satellite, a Russian military satellite powered by a nuclear reactor—in 1978, due to a failure, it crashed in Canada, contaminating an area of 124,000 km². Canada asked Russia for a $6 million compensation. In the end, the Russians paid half.

CHOCOLATE AND RULES

Apart from accidents and pollution, however, prevention will continue to be the way forward. We will need to provide satellites with the propellant needed to deorbit at the end of the mission, and to build them in such a way as not to produce too much debris. «One solution», says Ettore Perozzi, Head of the Italian Space Agency's Space Situational Awareness Office, «is to assemble satellite components like chocolate bars, so that they break easily and their parts are destroyed immediately on contact with the atmosphere». At the same time, «rules of conduct in orbit will have to be set out in the same way we did with the Highway Code on Earth and all countries will have to behave responsibly», said Simonetta Di Pippo, Director of UNOOSA, the United Nations Office for Outer Space Affairs. «We have to tackle this problem on a global scale and we cannot afford to ignore it—we are at the beginning of a long road, but the start is encouraging».

According to Moriba Jah, Director of the Aerospace Engineering programme at the University of Texas, what is needed above all is a change in mentality: «Countries need to understand that the Earth's orbit is an ecosystem like the oceans and forests—it is not infinite and we need to protect it by capping the number of launches».

Will they succeed?

Between Covid, climate change and wars, **malnutrition** is again an emergency: it will not be solved by 2030. What should we do? Reduce **poverty** and change **agriculture**. To avoid death and migration.

by Vito Tartamella

STILL HUNGRY

PENDING
New Delhi (India): children queuing for a food ration after a lockdown due to Covid. The pandemic has made feeding for the poor more difficult.

Getty Images

The **UN** countries have signed 17 **goals** to be achieved by the year 2030. Focus dedicates a survey every month to one of them. Objective no. 2 intends to ensure safe, nutritious and sufficient **food** for everyone throughout the year.

Wip/Oluwaseun Oluwamuyiwa

UNDERWEIGHT
Nigeria, a World Food Program operator measures the arm of a child of 8 months: is moderately malnourished.

Wfp/Rein Skullerud

EXTREMES
Madagascar: World Food Program operators distribute food aid to populations affected by drought, which has endangered 1.3 million people. Below, overweight Californians: in the US, 16% of under-19s are overweight.

Ruth lives in a shack in Monrovia, Liberia. She is 25 years old and does not know if today she will be able to give any food to Sekou, her severely undernourished 5-year-old son. Mogubai, 16, wanders the streets of Kolkata, India, begging for a few rupees to buy at least a bowl of rice. In La Paz, Bolivia, the 45-year-old José also today is eating a plate of pork rinds and potatoes yet again—he has reached 110 kg in weight. Meanwhile in Dire Dawa, Ethiopia, 33-year-old Hermela is in despair as her crop has been destroyed by the worst locust invasion in the last 20 years.

DIE OF STARVATION. OR UNHEALTHY FOOD

These are four faces of malnutrition: a global tragedy that reflects the contradictions of our age—today we are able to produce more than twice as many calories per day than is needed by any of Earth's citizens. Yet, nearly 690 million people suffer from hunger: one and a half times the population of Europe. More than half of those live in Asia, but the problem is more widespread in Africa, where it affects one person in every five. Furthermore, if we take into account those who do not have regular access to food, that figure rises to a staggering more than 2 billion people. That's one in three people.

But that's not all. On the other end of the scale, there is the opposite problem: 2.33 billion overweight people, more than a billion of whom are obese. This does not only happen in rich countries, where there is an overabundance of food (and waste), but also in poor countries, where the only affordable food, as in the case of José, is junk food, high in calories (fats or sugars) and costing less than healthy foods such as pulses, fruit and vegetables. More than 3 billion people in the world cannot afford a healthy diet. As a result, more than half of the world's population die of either starvation or diseases caused by overeating (cancers, diabetes, strokes and heart attacks).

The situation is serious. And Covid is making it worse. So much so that the dream of ending hunger by 2030, signed in 2015 by governments representatives of 193 UN countries, is now officially over. «The world is not on track to achieve this goal», wrote the Directors of the five international agencies dealing with agriculture, childhood, food and health (FAO, UNICEF, IFAD, WFP and WHO) in their latest report The State of Food Security and Nutrition in the World 2020. To be more precise: «Africa and West Asia are completely off track. Latin America and the Caribbean are not on track, and their situation is deteriorating. Only East and Central Asia are doing well».

At this rate, the number of people suffering from hunger will exceed 840 million by 2030. Not to mention the detrimental effects caused by Covid, conflicts and climate change: «three vortexes», Maurizio Martina, FAO Deputy Director-General, told Focus, «which risk becoming a single, overwhelming cyclone».

AGGRAVATING FACTORS: COVID, WARS AND CLIMATE

Indeed, throughout the last year the pandemic has added 130 million people to the ranks of the malnourished. «Travel restrictions are preventing millions of seasonal workers from arriving from foreign countries. And unharvested food is left to rot in the fields», warns a report by Ipef Food. «Farmers and livestock breeders all over the world have kept working throughout the pandemic: they are defined as essential, but no one provides them with equipment to protect themselves from Covid or subsidies that take into account the risks they are running». The pandemic, adds IOM (the International Organization for Migration), has mainly hit undeclared work, the most widespread among migrants, with effects both on expatriates and on their families at home: in fact, three quarters of international money orders are sent to poor countries. «This scenario risks adding 33 million people to the ranks of the hungry», warns the latest report.

On top of this, there are conflicts in some countries (Syria, Afghanistan, Nigeria, and Sudan). And extreme weather events such as hurricanes and droughts, affecting South Asia and the Horn of Africa. And the invasion of desert locusts, which threatens crops in East and Southern Africa. So much so that FAO and WFP (the World Food Programme) have just launched an emergency appeal in support of the 34 million people who are at risk of dying of starvation, especially in Yemen, South Sudan and Northern Nigeria. «5.5 billion dollars are needed immediately to deal with these emergencies», says Mr Martina.

But southern Europe is not free from risks. On the contrary: «The Mediterranean will be one of the most critical areas of the world over the next 30 years», warns Marta Antonelli, researcher at CMCC (the Euro-Mediterranean Centre on Climate Change). «If greenhouse gas emissions continue at the current rate, climate change is expected to reduce freshwater resources in our area by 30-50%. This will have severe consequences for irrigation».

> G8 governments in 2008 pledged **$ 23.13 billion** in aid. They gave 13.4 billion

COMMITMENTS (AND MONEY) REMAINED ON PAPER

How did we get to this point? Does the food crisis depend on the economy? «Partly yes», replies Giacomo Branca, Professor of Environmental Economics at the University of Tuscia. «The primary cause of malnutrition is poverty. In 2008, G8 governments promised $23.13 billion in aid to the least developed countries: they delivered $13.44 billion». Just over half. «It is a pity that the human body cannot digest cellulose», Indian agronomist Mankombu Sambasivan Swaminathan commented bitterly. «Fine words on paper do not fill the belly».

«Global economic disparities have worsened over the last decade», adds Paolo Sckokai, Director of the Department of Agri-Food Economics at the Catholic University of Piacenza. «Today, agriculture provides food for all, but many people do not have sufficient income to buy it».

Getty Images

The minimum threshold to avoid starving to death is $1.25 per person per day, while the safety threshold is $1.75. FAO estimates that $145 billion will be needed over 15 years to bring the entire population up to this threshold. This is 0.17% of world GDP. An achievable target. And yet, it is becoming more and more distant: in the 1980s global aid for agriculture was 20% of the total; by 2014 it had fallen to 5%.

But the problem of hunger is not just a matter of scarce funds, warns Marc J. Cohen of Oxfam in a study published in Food Ethics. It very much depends on how these funds are used. «After the 2010 earthquake in Haiti», Cohen says, «the US gave large subsidies to its rice farmers, while Haiti reduced its duties on rice imports almost to zero. Eventually, US rice was cheaper than Haitian rice, and now it accounts for more than 80% of consumption. This way Haiti lost its food autonomy». ▶

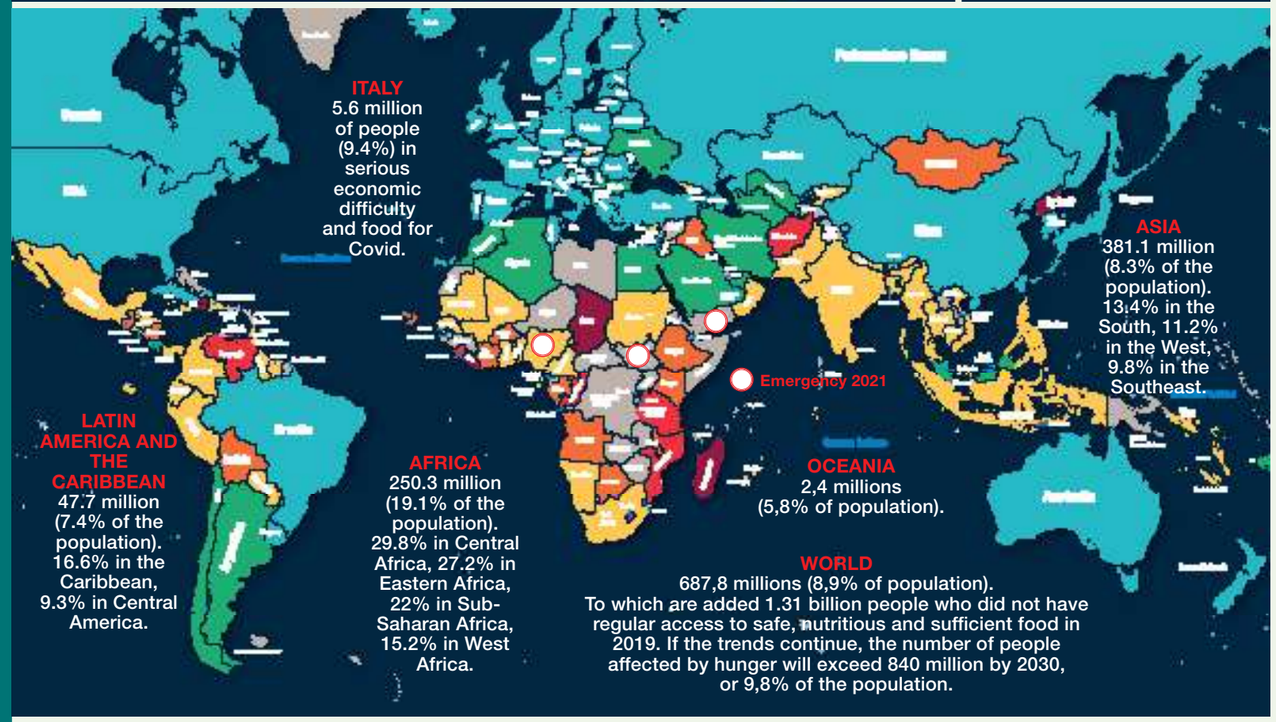
Follows on pag. 76

THE NUMBERS OF MALNUTRITION

SPREAD OF MALNUTRITION (%) OF THE TOTAL POPULATION IN 2017/19

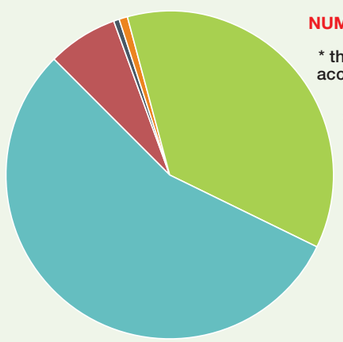
<2,5% | <5% | 5-14,9% | 15-24,9% | 25-34,9% | >35% | Data not available

MALNUTRITION: insufficient food consumption to provide the energy needed to maintain a normal, active and healthy life.



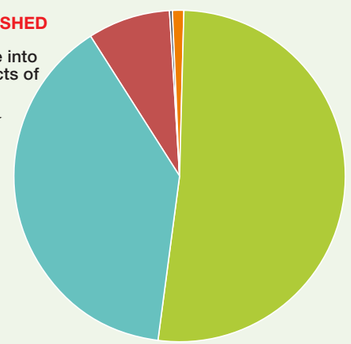
2019: 687,8 millions

ASIA 381,1 (55,4%)
AFRICA 250,3 (36,4%)
LATIN AMERICA CARIBBEAN 47,7 (6,9%)
OCEANIA 2,4 (0,4%)
NORTH AMERICA EUROPE 5,4 (0,9%)



NUMBER OF UNDERNOURISHED PEOPLE (MILLIONS)
* the forecast does not take into account the potential impacts of Covid.

2030*: 841,4 millions



ASIA 392,2 (39,1%)
AFRICA 433,2 (51,5%)
LATIN AMERICA CARIBBEAN 66,9 (7,9%)
OCEANIA 3,4 (0,4%)
NORTH AMERICA EUROPE 8,5 (1%)

FOOD AVAILABILITY

2.353 kcal
The daily calorie requirement / person for a healthy diet.

5.935 kcal
The calories / person of food produced every day in the world (plus 3,812 kcal in animal feed; total: 9,747 kcal).

Only upper-middle-income countries and Asia have enough fruit and vegetables to meet the minimum consumption of 400 g per day / person.

FOOD WASTE

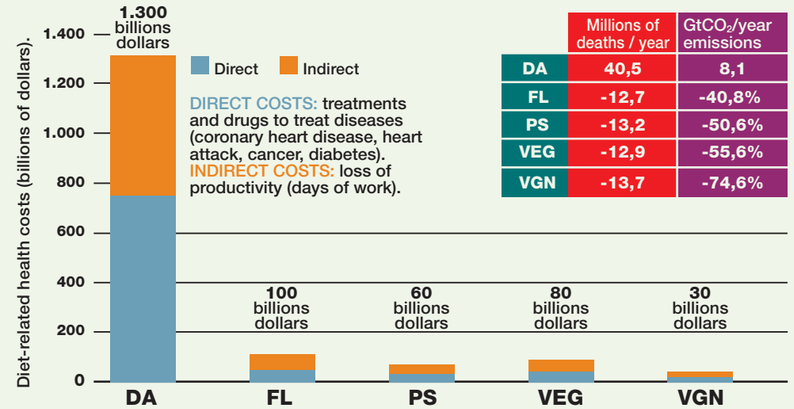
17% The percentage of food wasted on the entire production food. It is equivalent to the load of 23.3 million Tir (931 t).

121 kg/year
The average amount of food that each inhabitant of the Earth wastes.

67 kg/year
The average amount of food that every Italian wastes (a Greek 142, a Norwegian 5, European average 80 kg).

DIETS, EMISSIONS AND DISEASES

DIET-RELATED HEALTH COSTS, DEATHS AND EMISSIONS IN 2030.



	Millions of deaths / year	$GtCO_2$/year emissions
DA	40,5	8,1
FL	-12,7	-40,8%
PS	-13,2	-50,6%
VEG	-12,9	-55,6%
VGN	-13,7	-74,6%

DA: current diet; **FL:** flexible diet (moderate amounts of animal foods); **PS:** with moderate amounts of fish; **VEG:** vegetarian (also with dairy products and eggs); **VGN:** vegan.

The current dietary model involves high health costs to treat cardiovascular and metabolic diseases: by 2030 it could reach 1.3 trillion dollars (more than Canada's GDP). Adopting one of the 4 diets would cut spending below 100 billion (-92.3%), especially in high-income countries.
The current diet leads to 40.5 million annual deaths worldwide each year, 71% of deaths. Alternative diets would reduce mortality from 31.3% to 33.8% especially in upper-middle-income countries. In low-income countries, people die more from infectious diseases and malnutrition.
The current dietary model is also the cause of 21-37% of total greenhouse gas emissions, responsible for climate change. By adopting one of the 4 alternative healthy diet models, emissions can be reduced by 41 to 74%. In fact, most of the emissions depend on the consumption of meat (especially beef and lamb: 41%) and milk and dairy products (25%).

THE 2 FACES OF MALNUTRITION

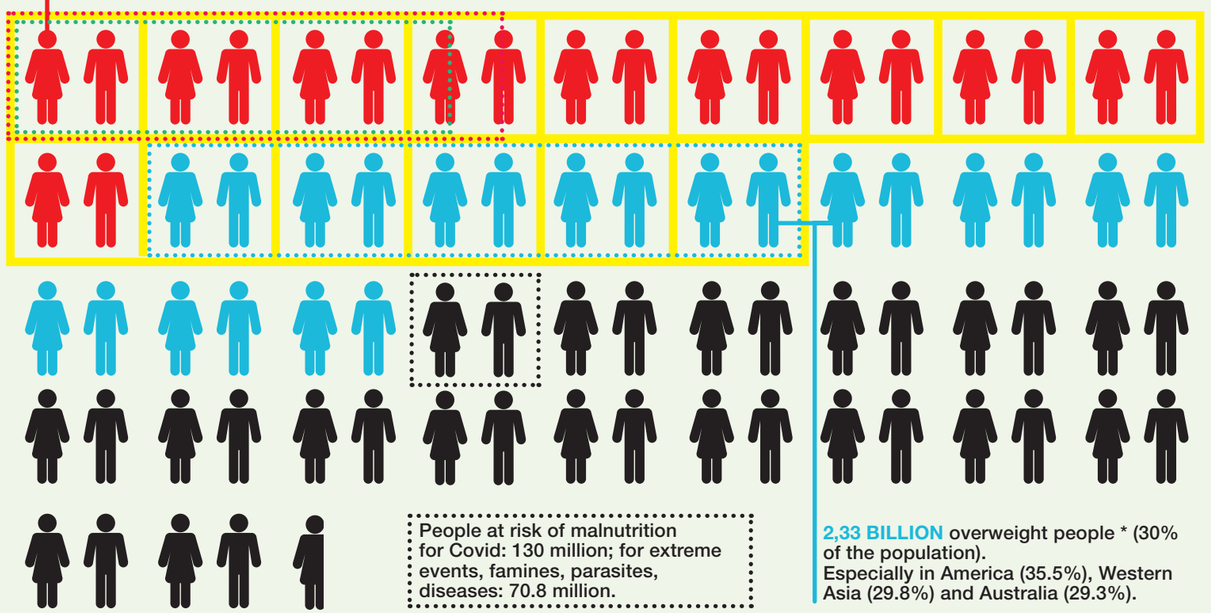
2,001 BILLIONS of people did not have regular access to food: 34.9% of the population.
IDENTIKIT: mostly women, low income, poor education, with health problems, people living in the countryside, age 25-49, separated / divorced.

People in constant food shortage: 687.8 million (8.9% of the population).

746 million people in severe food insecurity.

People who can't pay for a healthy diet: 3 billion.

Obese *: 1.04 billion people (13% of the population).



People at risk of malnutrition for Covid: 130 million; for extreme events, famines, parasites, diseases: 70.8 million.

2,33 BILLION overweight people * (30% of the population).
Especially in America (35.5%), Western Asia (29.8%) and Australia (29.3%).

LEGEND
Each little man = 100 million of people.
* = estimates

WORLD POPULATION (IN 2019)
7,7 BILLION PEOPLE

Fonti: Fao, "The state of food and nutrition in the world 2020", Oms, University of California. Food waste index report 2021.

THE EFFECTS OF DROUGHT

Right: Madagascar, people waiting for a food ration. On the ground, the signs of distancing from Covid. The drought is causing serious problems food in Africa (below, South Sudan) and also in Asia.

Wfp/Theresa Piorr

Wfp/Tsiory Andriantsoarana

Many poor countries use aid for **arms** or for the export of **land** or products. And agriculture lags behind

continued from pag. 73

The same scenario occurred with European exports of milk powder to West Africa, which tripled between 2011 and 2016: today small dairy farmers in Burkina Faso, Senegal and Nigeria are struggling to survive in their domestic markets.

Hunger, in turn, leads to conflict: «The children of herders become jihadists not out of conviction, but because there is a lack of jobs», says Adama Ibrahim Diallo, leader of the association of dairy farmers in Burkina Faso. Indeed, wars are often one of the side effects of hunger. Along with migration: according to a report by IOM, in the past 20 years the number of international migrants has increased by 56%, going from 174 to 272 million. In Sub-Saharan African countries (the area that suffers most from hunger), military spending accounts for 8% of the budget, compared with 3% for agriculture. «And four of the top five aid donors, the US, France, Germany and the UK, were among the top six arms exporters», Cohen points out.

SHORT-SIGHTED CHOICES

Then there are the short-sighted choices of governments: «Ghana has invested 58% of its budget in supporting cocoa for export, to the detriment of food crops, livestock and fisheries», Cohen says. Speaking of international relations, we cannot forget land grabbing, i.e. the leasing of large agricultural areas to foreign countries: a phenomenon that began in 2008 due to the crisis in agricultural prices. According to Land Matrix, an NGO that monitors land use, agreements have been concluded on 66.431 million hectares of land worldwide, almost as much as the entire area of France. Most of the fields are rented for wood, followed by maize, flour, palm oil (for biofuels), soya, barley and fodder. As a result, many countries are losing arable land to support their livelihoods: most of them are in Africa (39%, mainly Mozambique and the Democratic Republic of Congo), Eastern Europe (29.3%, Ukraine and Romania) and Latin America (14.6%, Brazil and Argentina). The world's largest investors are the US, China and the UK.

What should we do? In order to avoid global fallout, «the priority», says Ipef Food, «is to protect the most vulnerable: the poor, the children, the elderly, and the disabled. In order to do this, we need to promote land reform to reduce inequalities in access to land. Billions of dollars are to be allocated to save the economy during this period: we must seize the opportunity to transform it, not just to keep it afloat». Moreover, this would have beneficial effects on many fronts: wars, migration and human lives.

Another important step is to focus on biodiversity, says the WWF. «Throughout history we have used over 6,000 crops for food, while today we only use 200 of them. And nine of these account for almost 70% of the food produced. This lack of diversity makes us more vulnerable to pests, weather events and diseases».

DIVERSIFIED SOLUTIONS

Another area for urgent action is change in diet. Current eating habits, based on livestock and dairy products, produce up to 37% of greenhouse gases. And they lead to 40.5 million deaths a year, as animal fats cause cancer and cardiovascular disease. All of this also results in huge health care costs.

Switching to a flexible diet, with moderate amounts of fish, or to a vegetarian diet would reduce deaths by one third and health care costs by more than 90%, at least in upper-middle-income countries.

Finally, there is a technological aspect: «To develop agriculture, we need to introduce higher-yielding varieties such as wheat and rice. This approach has worked in Asia, so much so that countries like the Philippines and Vietnam have become exporters», Branca says. «But in Africa, this method did not take root: local producers were not ready to accept these innovations».

«The solutions cannot be the same for everyone», adds Sckokai. «They have to adapt to different realities, often consisting of remote villages with no roads to get there, no water, no electricity. We have to take one step at a time. But it is urgent to start».

Italy can play a major role in this regard, points out the FAO Deputy Director: «Our country chairs the G20 and in July is going to host the UN Food Systems Pre-Summit. We are facing three major emergencies, related to health (Covid), environment (climate change) and food (hunger). We must not neglect any of these, because each is tied to the other».

Getty Images

GRIM CATCH
Plastic waste: netted between Livorno and Grosseto during the "Clean Archipelago" ecological campaign.

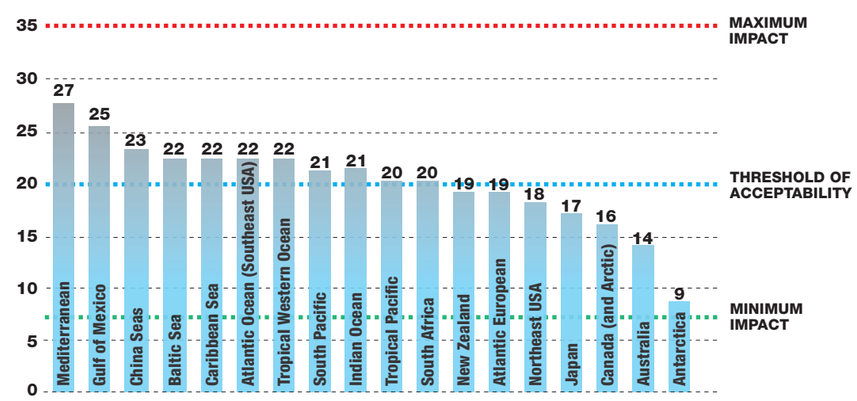
The Mediterranean malaise

Man's destructive impact on the **Mediterranean** has been greater than on any other sea. Worse than the Gulf of **Mexico** or the **China** Seas. Here's **why** and here's what we can **do** about it.

by Vito Tartamella

The ranking was merciless but unequivocal. Of all the oceans and seas on our planet, the most seriously ill is the Mediterranean. That is the assessment of the 360 scientists from around the world who took part in the impressive "Census of Marine life," a 10-year research project on Earth's marine biology. Data in hand, the scientists used a scale of 1 to 5 to evaluate the impact of human activities on the ecosystem balance. The Mare Nostrum earned the dubious distinction of last place, with a total of 27 points out of a theoretical maximum of 35 (*see table*). Worse than the Gulf of Mexico and the China Seas, both notorious for their dismal health.

Why has our sea deteriorated to such a point? We asked Roberto Danovaro, Professor of Marine Biology and Ecology at the University of Marche, and one of the authors of the ranking, published in the scientific journal *PlosOne*. "The Mediterranean is an area of major bio-geographical interest," he says. "While its waters represent only 0.32% of the volume of ▸



Source: "A Census of Marine Biodiversity Knowledge, Resources, and Future Challenges", PlosOne

WORLD RANKING
A panel of 360 scientists rated the impact of 7 parameters on the world's seas, using a scale from 1 (minimum) to 5 (maximum): overfishing, loss of habitat, pollution, presence of alien species, temperature, hypoxia (oxygen deficiency) and acidification. The maximum level of impact would score 35, the minimum 7.
The threshold of acceptability is 20, which is also the world average.

INSPECTION
Greenpeace and CNR divers study the Tyrrhenian seabed in search of plastic waste. 7% of the 8 million tons that end up in the world's oceans every year build up in the Mediterranean.

all the world's oceans, they contain 7.5% of the known marine species, and this heritage is delicate. The Mediterranean isvery much like a huge salt lake, with an average depth of 1,450 meters as compared to the oceans' average depth of 3,750 meters.

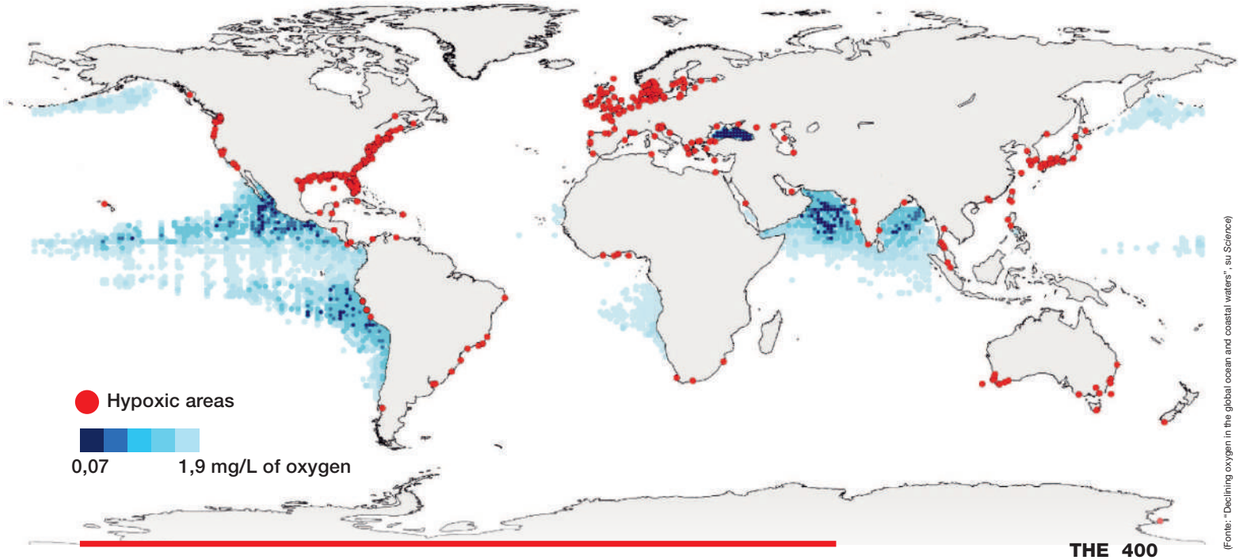
Because it is shallow, its waters warm more rapidly than any other ocean. Change, however, is very slow. It takes about 80 years for the Mediterranean to be totally renewed through new water entering via the Strait of Gibraltar. These factors make it much more vulnerable to the impact of human activity." The Mediterranean is a sort of "ocean in miniature" and can show us how other seas and oceans deteriorate due to human activity. But how exactly did the Mediterranean malaise come about? There are five causes.

1 OVERFISHING: Our sea is home to some of the fish most in demand on the market: species that live on the seabed, such as sole, turbot, cod, hake or red mullet and caught by trawling, and those whose habitat is the open sea, such as tuna or sardines. Industrial fishing techniques, however, have decimated fish populations, especially the larger species such as tuna, swordfish, grouper and shark (blue shark is often sold as swordfish). Worldwide, fishing has been in decline for over a decade. Today, 7% of marine species have become extinct, and the populations of 1 species in 3 have been drastically reduced, decreasing on a global scale by more than 90%. "A massacre that has had dramatic consequences on how ecosystems function," comments Danovaro.

2 HABITAT DESTRUCTION: Trawling, illegal fishing practices, such as date mussel harvesting, and infrastructure construction (ports, barriers, undersea pipelines and offshore platforms) have inflicted heavy damage on the seabed and its myriad life forms. In Italian waters alone, compared to 60 years ago, 25% of the Posidonia meadows and 80% of the macroalgae forests (Cystoseira) have been lost, depriving many species of their habitat, just as 60% of tropical coral reefs have been destroyed or damaged. On the global scale, it has been estimated that over 70% of marine environments have undergone significant changes since pre-industrial times.

3 POLLUTION: maritime shipping contaminates the sea through the spillage or dumping of noxious substances. The Mediterranean is one of the busiest seas in the world, with 15% of all maritime activity and 30% of all oil tankers passing through it. Most of the pollutants, however, actually come from rivers and those coastal cities that do not treat their sewage Even today, 12% of the Italian population does not have access to sewage treatment facilities, to such an extent that the European Union has opened a number of non-compliance proceedings against Sicily, Calabria, Lombardy and Campania in particular (data source: Utilitalia) with hefty fines. Effluents release quantities of heavy metals into the sea - Egypt alone discharges 5 to 14 tons of mercury and lead pharmaceuticals (which kill vital bacterial populations), as well as nitrogen ▸

30% of **oil tankers** transit through the Mediterranean and untreated effluents flow into the sea: 12% of Italy's **sewage** is untreated



(Fonte: "Declining oxygen in the global ocean and coastal waters", su *Science*)

THE 400 "HYPOXIC ZONES"
These are the marine areas across the globe where oxygen levels are below 2 mg/liter: life is at risk below this level. The blue areas indicate the "minimum oxygen zones" at a depth of 300 m. A healthy sea contains 8 mg of oxygen per liter of seawater. Below 0.2 mg/L, life is nearly absent.

AN AREA AS WIDE AS EUROPE WITH NO OXYGEN (OR LIFE)

The water has turned brown, and on the surface float rotting algae, feces and dead fish. This is a "dead zone", a stretch of ocean where the oxygen content is so low (below 0.2 mg / L) that it prevents any form of life. There are over 400 such dead zones in the world, covering a total area of over 245,000 km² - the size of the United Kingdom. The largest dead zone is located in the Arabian Sea, where it covers nearly the entire Gulf of Oman, over a surface area of 165,000 km². The second largest can be found in the Gulf of Mexico. During certain periods, dead zones have also formed in the northern Adriatic Sea. These areas form due to the warming of the sea, which decreases the solubility of oxygen in the water, combined with an excessive influx of nutrients (nitrogen and phosphorus, used in agriculture or livestock) transported by rivers.
This causes algae to proliferate unchecked, thereby further depleting oxygen. In short, dead zones expand as a direct or indirect result of human activity. Moreover, the situation is likely to get worse. In research recently published in Science, Denise Breitburg, a marine ecologist at the Smithsonian Environmental Research Center, estimates that hypoxia zones, i.e. areas where the level of oxygen is minimal (below 2 mg / L: see map), cover a total of 4.5 million km², an area the same size as the European Union.

THE LAST RESORT
Incinerator at the mouth of the Besos River near Barcelona (Spain): many industries are often not connected with purification plants.

The remedy? Turn **30%** of the seas into **protected areas**. Today it is only **2,5%**


© Suncana Tripo Vidoli/Greenpeace

and phosphorus, nutrients used in agriculture. The latter cause two types of damage: they enable algae to grow unchecked and they decrease the quantity of oxygen, which is essential to marine plant and animal life. Then there's plastic: 7% of the 8 million tons that end up in the world's oceans every year build up in the Mediterranean..

4 ALIEN SPECIES: Over the last 140 years, a thousand species from the Red Sea and other tropical waters have made their way into the Mediterranean via ballast water discharge, ship hulls and the opening of the Suez Canal. Some of the newcomers have decimated the native Mediterranean species: the Filipino clam has nearly overtaken the native Adriatic clam while the Rhopilema nomadica jellyfish, over 60 centimeters wide, has turned large stretches of the sea into expanses of jelly. Similar phenomena occur in all seas: today, over 7,000 alien species have been carried around the world by ships or by colonizing the floating islands of waste that are carried along by the currents..

5 GLOBAL CLIMATE CHANGE: Like seas everywhere, the Mediterranean has been impacted by the effects of global warming. In the Mediterranean, deep-sea temperatures do not drop below 13° C; which is 10° more than ocean temperatures at the same depth. The Mare Nostrum is warming both on the surface, where the temperature has risen by over 1.8 °C in recent decades, and in deep water, where it has risen by 0.2°C in the last 20 years. The effects have been devastating for ecosystem balance. Since 1999, there are areas where over 80% of sea fans and sponges have died in a matter of weeks due to prolonged heat waves. Extreme heat leaves organisms more vulnerable to disease and bacterial infection. In the oceans, extreme heat kills the algae that live in symbiosis with coral, thus depriving the coral of nutrients and causing it to bleach. Fortunately, at least for now, the Mediterranean has been spared two other problems caused by human activity: hypoxia (see illustration on previous page) and acidification. Acidification is triggered by our massive CO_2 emissions. Every year, in fact, about 25% of CO_2 emissions due to human activities can be successfully absorbed by our seas. But there is a price. When the CO_2 in the atmosphere interacts with water, it is converted into carbonic acid (H_2CO_3), which gradually makes the water more acidic. As a result, the shells produced by marine organisms dissolve – because they are composed of carbon and calcium -- and no longer retain the carbon element, which then accumulates on the ocean floor. "Compared to two centuries ago, oceans today are 30% more acidic. If we cannot halt this decline, by 2100 the oceans will be much more acidic than they are today. The effects will be unimaginable," emphasizes Danovaro. In short, the Mediterranean is very ill, and the other seas are not at all healthy either. So what can we do? "The first step," replies Danovaro, "is to halt our impact by seriously reducing and regulating fishing and putting an end to habitat deterioration. A great deal also depends on what we do here on land. We must reduce greenhouse gas emissions by focusing on green energy sources, decrease the consumption of plastic, increase the number of sewage treatment plants and make them more efficient. The health of the Earth is closely linked to the health of the seas." That is why, according to scientists, an effective remedy would be to safeguard at least 30% of the oceans by transforming them into protected oases. The UN is aiming for 10%. Today, however, only 2.5% of the oceans (and only 4.6% of the Mediterranean) are protected, so there is still a long way to go. But if we are to succeed in saving the Blue Planet, we must act now. Before it is too late. F


Getty Images

A MASSACRE
Fish market in Antalya (Turkey): Indiscriminate fishing has decimated many species. Above, waste on the island of Mljet (Croatia), a maritime park.

Alamy/Ipa

Eliijah J. Talamas/Ars Lleida

ENEMIES BY NATURE
The worst enemy of the Asian stink bug (on the other page) is the samurai wasp (here on the side), although it is 17 times smaller.

Wasp VS Stink bug

The **asian** stink bug has destroyed **€ 588 million worth** of italian fruit. We will fight it with its natural opponent, a wasp. An **army** of them is being bred in the lab for release this summer.

by Vito Tartamella

The bombers are deployed in hangars, ready to be launched toward enemy targets. X hour will take place just before summer, when thousands will appear in flight in the skies of the Italian countryside. They must find, target, and focus on opponents with millimetric precision. Literally. The targets,in fact, are greenish spheres 1 millimeter wide: Asian stink bug eggs. This insect, identified in Italy since 2012, is attacking our fruit production. According to estimates of the Fruit and Vegetable Service Center-of Ferrara, which rallies the largest Italian producers, in 2019 the stink bug destroyed over 300 thousand tons of fruit: above all Abate Fetel pears, Golden Delicious and Granny Smith apples, nectarine peaches and green-fleshed kiwi. They add up to more than 13,000 Tir, worth 588.36 million euros. This is without counting the damage to hazelnuts, cereals, and legumes, still not calculated. It was called "a true scourge" in the Senate resolution last April asking the government to give "highest priority" to the battle against the stink bug. Parliament allocated 80 million euro in the last budget law to compensate farmers for damages.

Yet the one responsible for this attack is a little less than 2 cm long and very similar to the common and harmless native stink bug (different in colors and other details). There is a major difference: the *Halyomorpha halys*, its scientific name, can feed on 300 different plant species. It sucks the fruit pulp, injecting saliva that dissolves its plant cells. No insecticide can eliminate it in a targeted way, and with no specific enemies to counter it, it has invaded the whole country within a few years.

Discovered in the province of Modena in 2012, today it is present in all regions. This is a true invasion. It is very prolific: each female may lay 280 eggs; up to 215 young can hatch from each. Given that half of them are females, one pair alone would be enough to generate more than 30 thousand descendants in one year.

BREEDING BOMBERS

One remedy exists, however, and it was created by nature. In China, Asian stink bug populations are kept under control by a natural antagonist, the samurai wasp (*Trissolcus japonicus*). This tiny insect, which looks like a flying ant, is the size of a midge (1 mm), is harmless to humans and other insects, but has the habit of laying eggs inside those of the stink bug. It "parasitizes" them, exterminating its generations before they are born. They are the "bombers" cited at the beginning of the article. The "hangars" that host them are in the Florence countryside, in the laboratories of the Council for Research in Agriculture and ▸

VIDEO

IN THE FLORENCE LABORATORY THAT BREEDS THE SAMURAI WASP


Crea Firenze

OUR ALLY
Magnification of a samurai wasp (it is 1 mm long): it lays its eggs in those of the Asian stink bug, exterminating its population. On the left, test tubes with hundreds of specimens bred at the Crea of Florence.


Warren H. L. Wong

The **samurai wasp** lays its eggs in those of the bed bug, **exterminating them**

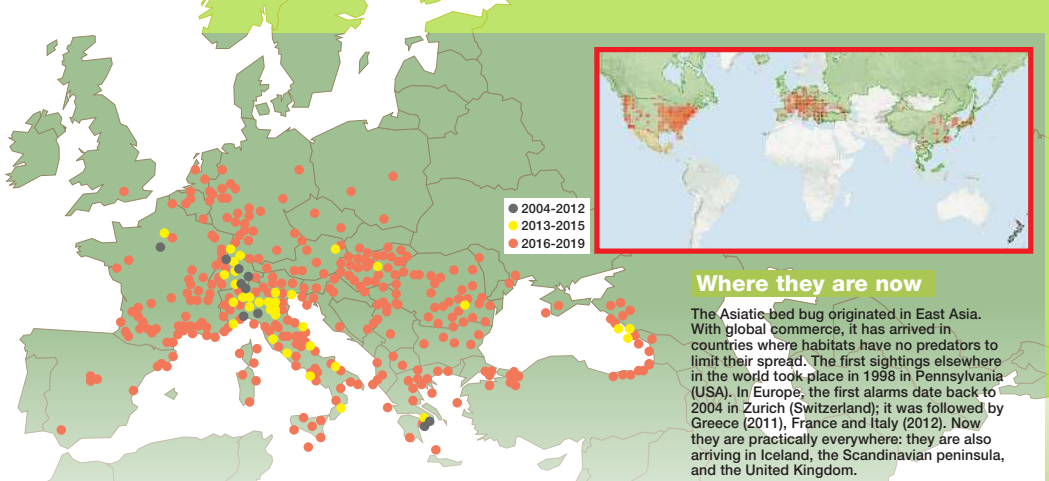
Analysis of the Agricultural Economy (Crea), the main agency dedicated to agri-food chains. These wasps are bred with leaves soaked in honey inside small glass tubes stored in climate-controlled cells at 26 °C. Crea will provide thousands of specimens to the regions' plant protection services in June. Ready to target the stink bug eggs.

IT ALL STARTED WITH A COLLEGE EXAM...

But how did we get to this point? The first specimen was found 8 years ago by a university student, Simone Berselli, who was preparing for an entomology and plant pathology exam with Professor Lara Maistrello of the University of Modena and Reggio Emilia. "It was September 13, 2012, my birthday. And it marked my life," the entomologist recalls. "I had asked my students to bring a box with at least 30 different insects to the exam. Among them was also a *Halyomorpha halys*. And I reported it immediately to the Regional Phytosanitary Service. The stink bug had been found in Magreta, in the province of Modena, but we did not know if it was an isolated case. So we started a citizen science investigation: we asked citizens to report stink bugs by sending a photo via the Internet to me and to the regional plant health authorities. In just a few months 377 reports came in: 200 were positive. The invasion had begun. Something had to be done."
But how did an insect native to China and Korea get to Italy? "It's one of the side effects of globalization," the entomologist replies. "The stink bug takes refuge anywhere for winter shelter. If it enters a warehouse that ships goods around the world, it can slip into a container or box and travel across continents. It is an invasive hitchhiker. The first specimen in Europe was found in Zurich (Switzerland) in 2004. To celebrate their Chinese sister city, the Swiss had imported several pagodas for an exhibition; with them had also come stink bugs. But they did not cause serious problems: the mountain climate does not promote their proliferation and their agriculture is undeveloped."
On the other hand, stink bugs have found their Eldorado: the climate is mild, and Emilia-Romagna is the orchard of Italy. From the north, they spread everywhere: reports exceeded 1,900 thanks to a phone app, "BugMap," created by the Mach Foundation of San Michele all'Adige (Trento).
"In Palermo, a person found one in a kitchen cabinet made in Friuli. In Naples, it was found in a used car that arrived from Lombardy. And so on," Professor Maistrello recounts. "With genetic analyses, then, we realized that these stink bugs were of 13 different haplotypes (variants): in Italy we have the world's greatest biodiversity of stink bugs after Asia.
The specimens found in the North-East (Friuli, Veneto, Trentino) are different from those in the North-West (Lombardy and Piedmont): this means that these two areas trade with different areas of Asia. However, this also means that eradicating the stink bug becomes more complicated: variants have different biological characteristics and can give rise to previously unknown genetic combinations."

INSECTICIDES AND EUROPE

It is not the only complication of this invader, which manages to resist different insecticides. Only those with a wide spectrum can be used, "which risk also killing beneficial insects such as bees and ladybugs. A few days after the treatment, they become ineffective," the entomologist states. "Not to mention that some pesticides have problems of toxicity to humans: they had been severely reduced in our fruit, and now, by reintroducing them, we are in danger of going back 10 years."
Last December, among other things, Europe banned the use of two insecticides, chlorpyrifos and chlorpyrifos-methyl, which had been demonstrated as effective against the Asian stink bug: they would present neurotoxic risks to children.
"These products have been used for decades," counters Davide Vernocchi, president of Apo Conerpo in Bologna, the largest organization of fruit and vegetable producers. "
Their toxicity, as with all chemicals, depends on the dose used. In fact, we fear that there are large trade interests behind this ▸



Where they are now

The Asiatic bed bug originated in East Asia. With global commerce, it has arrived in countries where habitats have no predators to limit their spread. The first sightings elsewhere in the world took place in 1998 in Pennsylvania (USA). In Europe, the first alarms date back to 2004 in Zurich (Switzerland); it was followed by Greece (2011), France and Italy (2012). Now they are practically everywhere: they are also arriving in Iceland, the Scandinavian peninsula, and the United Kingdom.

A global and hungry guest

Profile

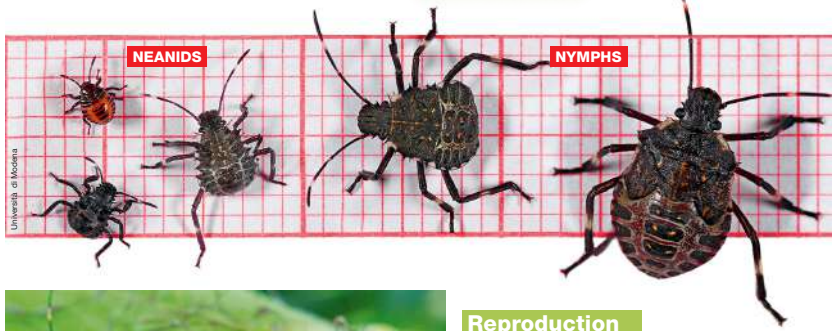

Marco Uliana/Alamy/Ipa

The Asiatic stink bug (brown marmorated stink bug, *Halyomorpha halys*) is an insect originating from China, Korea, Japan and Taiwan. The adults are 1.7cm long and 1 cm wide (the males are smaller and narrower). They have the typical shield shape of other stink bugs and are differentiated by their marbled brown and gray color and the presence of two white bands on their antennae.


Gerry Bishop/Alamy/Ipa

Life cycle

From the egg clusters, usually consisting of 28 eggs, hatch juveniles called "neanids:" they remain on the open eggs to feed on the bacteria released by the mother during laying. Within 5 days after hatching, they are ready to attack the fruit.
After 3 neanid stages (15 days), the stink bug passes to the "nymph" stage characterized by the presence of hints of wings.
A mere 30-40 days from hatching, the stink bug becomes an adult: it can fly and reproduce.
The stink bug lives from 3 to 12 months (those born in late summer). In autumn, adults look for a dry, sheltered place to spend the winter, often choosing our houses). Their hibernation will end in spring, and reproduction begins at about the end of May.



Università di Modena

Over a life time, a stink bug can generate more than **thousand descendants**

Reproduction

The male causes a vibration in the branches or leaves on which it perches, issuing special signal, to which the female responds to indicate her own presence. On reaching the female, he does a little dance and then brings the point of his abdomen closer to that of the female, latching onto her with a sort of pincer. Then, his aedeagus (penis) releases the sperm that will fertilize the eggs. Every female lays 28 eggs at once, as seen on the bottom of the page, mating several times with different partners. Over a lifetime, a hibernating stink bug can generate 280 descendants, which in turn can generate up to 215. Within a lifespan, a single pair of stink bugs can generate more than 30 thousand descendants unless affected by predators or an adverse climate.

Università di Modena

INEDIBLE
"Corked" pears: they shrink this way after the sting of Asian stink bugs. Their saliva dissolves the fruit's plant tissues. Once it is pierced, the fruit must be thrown away.

ban: these substances have been prohibited by Belgium, the Netherlands, Poland and Germany; that is, our main export rivals for pears and apples. As long as we have the stink bug emergency, we will ask for a waiver to use one of those products, in compliance with the limits imposed by Community rules."

Another strategy that was rather ineffective was to lure stink bugs into mechanical traps primed with pheromones, biochemicals that usually signal sexual availability. Stink bugs, on the other hand, arrived in the area without entering the traps, because pheromones are used generally used by these insects to indicate an area rich in food or suitable for wintering. They are aggregation signals and not sexual.

VIBRATING TRAPS, LAWS AND ENEMIES

Researchers at the Mach Foundation have come up with another way of attracting stink bugs by exploiting their specific sexual signals. They found that these insects woo each other by emitting low-frequency sounds: they produce them to signal their position by vibrating the branches and leaves on which they rest. So scientists invented traps capable of reproducing these sounds: with these vibrating traps, the amount of males caught rose 2 to 5 times. To work, however, these traps need electricity, and photovoltaic panels are too heavy and cumbersome. Researchers count on succeeding in producing a marketable model for 2021. Meanwhile, other avenues have been attempted. It turned out that the *Anastatus bifasciatus*, a hymenopteran already present in our countryside, manages to parasitize stink bug eggs.

So in 2018/2019, the University of Modena and Reggio Emilia tried to raise them and release them en masse in orchards. But it only attacked 9% of Asian stink bug eggs. "It is a generalist parasite: it would be an ineffective weapon," says Maistrello. The samurai wasp, however, is more precise: it manages to eliminate up to 90% of Asian stink bug eggs. It is not possible to use it, however because a law of 2003 prohibited the use of exotic organisms for biological control. Last year a new law was launched (Dpr 102/2019) which authorized the release of a new species as antagonists of harmful organisms only for "reasoned reasons of relevant public interest," and as long as they do not harm local flora and fauna.

Thus, after 18 months of study, the Crea of Florence confirmed that the wasp would not cause damage to the environment. And now there are technical tables to put them in action this summer. "We hope that the Ministry of the Environment will sign the decree with the regulation and that the release will then be authorized," says Pio Roversi, director of the Crea Defense Research and Certification Center. "In a month and a half, starting from 600 females, we could obtain a first nucleus of 360 thousand wasps to be distributed to plant health services in the regions, which in turn will multiply them to obtain a important mass. The whole operation will cost at most a million euros. To restore the ecological balance in the fruit, it is plausible that it will take from 2 to 6 years."

Will it work? Farmers hold their breath.

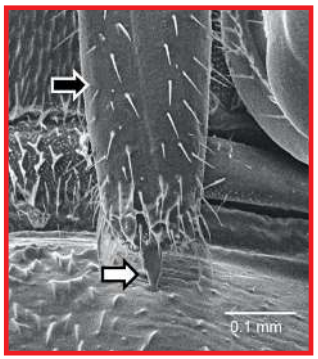
In the United States, the stink bug arrived earlier than it did here, in 1998, and no one has yet managed to stop it. It is now widespread in 44 of the 50 states, especially on the east coast. "Federal laws prohibit releases of exotic species on a national scale," says Tracy Leskey, entomologist director of the U.S. Department of Agriculture research service. "So each state used different methods. Some released the samurai wasp; others relied on insecticides. But without a unique strategy, the stink bug has continued to spread. If it finds an unfavorable environment, it moves and invades others. It can travel from 2 to 100 km in a day."

THAT INVASION IN THE EARLY 1900S...

That is why the eyes of the world are on Italy. Past history, however, bodes well.

"At the beginning of 1900, another exotic insect, the San Jose cochineal insect (*Pseudaulacaspis pentagona*) arrived in Italy. It sucked the sap of mulberry trees, killing them. A million families that raised silkworms with the leaves of this plant found themselves out on the street," recalls Roversi del Crea. "So in 1906, the entomologist Antonio Berlese imported a hymenopteran, a relative of the samurai wasp, which was its natural antagonist. In 3 years, it managed to control the cochineal, which in his honor was named *Prospaltella berlesei*. We hope to see this feat succeed."

> They are a **scourge:** they travel with goods from the East. They resist insecticides and destroy every **fruit**



Vito Baranella

CLOSE UP VIEW
On the side, Lara Maistrello, entomologist from the University of Modena and Reggio Emilia. It was she who discover the Asian stink bug's arrival in Italy.
Further to the left, a magnification of the stiletto-like proboscis with which the stink bug stings the fruit and injects them with its destructive saliva.

ITS WEAPON OF MASS DESTRUCTION: A THIN NEEDLE

Defenses: The stink bug emits a pungent smell from its chest, to keep away vertebrate predators (lizards and mammals). This is its only weapon of defense: to humans it is harmless.
Foods: It is polyphagous; that is, it eats everything. It feeds on over 300 species of plants, including many agricultural crops: peach and apple trees, green beans, soy, cherries, raspberries, hazelnuts and pears.
Damages: to feed, the stink bug stings vegetable tissues with its stiletto, a needle 5 mm long and 0.01 mm wide (see photo above left) and injects it with saliva rich in enzymes that kill the plant cells. In this way, the fruit releases its own liquids, from which the bug feeds. But after this puncture, the plant cells turn into cork, making the fruit inedible.

EUROPE INVADED BY 66 SPECIES OF HARMFUL ALIENS

The Asian stink bug is not the only enemy. In Europe, invasive exotic species, in a degree to threaten ecological balances, cause damage of over 12 billion euros every year.
The blacklist includes 66 organisms, from mammals (nutria), to reptiles (turtle American marsh), from invertebrates (American crayfish), to plants (American yarrow).
And, of course, also insects: in addition to the Asian stink bug, recalls Piero Genovesi, coordinator of Wildlife in Ispra, " in the past, Italy has seen the arrival of the red palm weevil and the Asian woodworm, which digs into the trunk of trees. And recently, they were joined by two insects that threatened the production of pine nuts, since they attack the pine trees: the maritime pine bark cochineal (from Morocco) and the American pine stink bug (from Canada)."

Stephan Ausmus

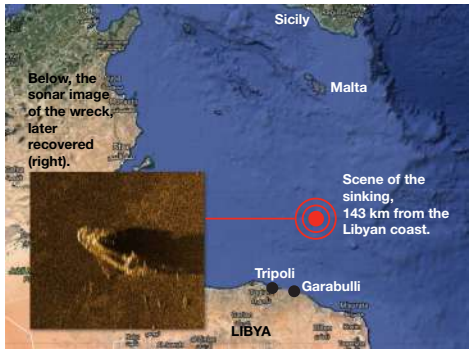
ON THE ATTACK
Stink bug with a nymph on an apple: note the stiletto penetrating the fruit. Through this proboscis it injects saliva that dissolves plant tissues, ruining the fruit.

READY TO DIVE.
One of the divers of Comsubin, the specialised unit of the Italian Navy that took part in the recovery of the fishing boat and the victims.

Marina Militare (3)

ANATOMY OF A SHIPWRECK

The recovery of the boat that went down in the Strait of Sicily with 800 migrants on board: a humanitarian and scientific challenge.



THE STORY: A TRAGEDY OF OUR TIMES

NAVIGATION. The traffickers first sailed from Egypt in a fishing boat. On 18 April 2015, they reached the Libyan coastline and waited offshore while the migrants were ferried across on rubber dinghies from the beach at Garabulli. Their passengers, numbering roughly 800, mostly young men, were from Syria, Ethiopia, Somalia, Senegal, Mali, Gambia, Côte d'Ivoire and Bangladesh. Each had paid at least $US 1,500 for the trip. Those who had paid more were accommodated on deck; the others were packed into the hold and the engine room. After several hours' sailing, one of the two traffickers on board (a Tunisian and a Syrian) telephoned the Italian Coast Guard requesting assistance. The nearest vessel, the Portuguese container ship King Jacob, was diverted to the area. But one of the traffickers miscalculated and steered the fishing boat into the larger vessel, causing it to sink. Only 28 of the occupants (including the two traffickers, who were subsequently arrested and given custodial sentences) escaped alive.

A reconstruction of how the fishing boat was raised from the seabed: watch the video in enhanced reality.

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Focus REALTÀ AUMENTATA AR

Marina Melissari (2)

DELICATE MANOUEVRES. Right, a naval rating monitors the recovery of the wreck, which is hitched to a crane (below). The boat will go on show at Milan's Museum of Human Rights.

The jacket had a strange feel to it . In the lining was in fact concealed a plastic bag. It contained a sheet of paper covered in writing, rubber stamps and figures. They were marks: an eighth-grade report card issued by a school in Mali. It belonged to Ibrahim, a 16-year-old. He had carried it with him throughout his dangerous 5,000-kilometre journey. He wanted to prove he had completed his secondary studies, so he could continue his education or find a job. Ibrahim's story – we have changed his name as a matter of respect – could have remained buried for ever on the seabed. The fact that we now know his identity, and that his parents will be able to grieve over his tragic loss, is thanks to a historic achievement in maritime technology. And the operation to recover a boat packed with migrants that sank on 19 April 2015 off the coast of Libya is also revolutionising the science of identifying disaster victims.

This was the most tragic shipwreck in the recent history of the Mediterranean, claiming at least 800 lives. And it was also the most complex recovery operation ever attempted: the fishing boat transporting the young people, aged between 10 and 30, from the poorest countries in sub-Saharan Africa, lay in open water at a depth of 370 metres. Hundreds of people – naval personnel, forensics experts, firefighters and volunteers – have been involved for almost three years in this arduous mission. And now we are beginning to see some results: after circulating requests for information via the consulates and International Red Cross offices of dozens of countries, the Office of the Commissioner for Missing Persons – the Italian authority that coordinates investigations concerning nameless victims – has received the details of 156 missing migrants, supplied by families living in Africa, Asia and Europe.

After almost three years of hard work, it may be possible to identify 80 of the victims.

THE CHALLENGE. «There is a good chance that we shall be able to identify 80 of them», the outgoing Commissioner, Vittorio Piscitelli told *Focus*. «And in the case of six of them – five young people from Mali and one from Côte d'Ivoire – we have an almost perfect match».

How has this been achieved? The operation has been an unprecedented challenge, from a technical/scientific and human point of view. According to Rear-Admiral Paolo Pezzuti, commander of Comsubin, the Navy diver and special forces unit that has coordinated the operation: «The wreck had settled on the seabed in the Strait of Sicily, 143 km from the Libyan coast, at a depth of 370 metres. No one had ever undertaken a recovery operation of this kind». In 1997, it is true, an Albanian launch was raised from a depth of 800 metres in the Strait of Otranto: «But on this occasion we had to recover a wreck in open water, where the weather conditions are often hostile. And rather than transport it 74 km to the nearest harbour (Brindisi), we had to make for Augusta (Siracusa): a distance of 365 km».

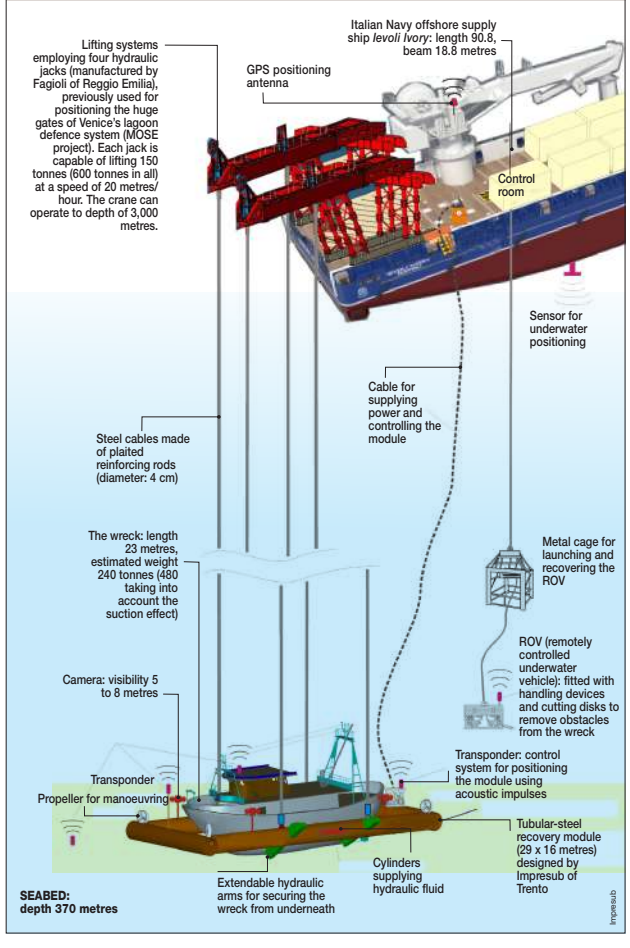
To further complicate matters, the wreck weighed 240 tonnes, as compared with 35 for the Albanian launch. Moreover, the fishing boat was embedded in the mud, so the load to be raised was in fact 480 tonnes because of the suction effect drawing it to the seabed. It was like lifting a 12-coach railway train to the height of the Empire State Building. «We entrusted this mission» Pezzuti told us «to Impresub, the same company as had recovered the Albanian launch».

DUMBSTRUCK. While a remote-controlled vehicle belonging to the Italian Navy was beginning to recover the migrants' bodies, Impresub produced a digital reconstruction of the wreck, using an underwater robot (ROV) equipped with laser sensors to carry out a 3D survey. They then designed a made-to-measure recovery module to support and lift the wreck (see drawing on left): a steel rectangle a third the size of a football pitch, fitted with propellers for manoeuvring, sensors and cameras: the largest ROV ever created. And to lower it to the seabed and secure the fishing boat, they used one of the cranes deployed to lay the huge underwater gates of Venice's lagoon defences (MOSE project).

The recovery mission began on 19 April 2016, one year after the sinking: «We had to work within tight limits», explains Captain Giampaolo Trucco. «We could only operate in grade 2 conditions or less (waves up to 50 cm), and we needed five consecutive days of good weather to complete ▸

AN OPERATION THAT TOOK MORE THAN A YEAR

THREE PHASES. The recovery of the sunken fishing boat was a 3-phase operation:
1) May 2015: an Italian Navy minesweeper, using an autonomous underwater vehicle (AUV), finds the wreck.
2) October - December 2015: A naval Remotely Operated Underwater Vehicle (ROV), using its mechanical arms, recovers 169 bodies from the seabed. The company responsible for the operation, Impresub, designs a module for raising the wreck.
3) April - June 2016: the recovery operation begins. The offshore supply ship Ievoli Ivory sets sail from Ravenna, escorted by a flotilla of naval vessels: the salvage ship *Anteo*, carrying the specialised divers; the *San Giorgio*, to ensure security in the area; the *Tremiti*, fitted with refrigeration units for the bodies; and the support ship *Alghero*. 200 people in all. On 27 June, the wreck is raised to the surface and on 30 June is brought in to the port of Augusta after a 365-km journey. Here, at the NATO base of Melilli, a team of forensics experts performs autopsies on the bodies. The operation has cost EUR 9.5 million.



ONGOING INVESTIGATIONS. Remains of the victims being examined in a tent erected at the Melilli NATO base. Below and in the larger photograph: forensics expert Cristina Cattaneo examines some of the artefacts recovered from the seabed: clothing and personal effects.

Ap Anga (2)

Roberto Cacciapaglia/Contrasto (3)

Tattoos, teeth, birthmarks: all useful in reconstructing a person's identity.

the operation. This was because it took the ROV 20 hours to reach the seabed, and another 20 to return to the surface. But in that area conditions change very quickly: twice we hooked on to the wreck but had to lower it back to the bottom because of sudden rough seas».
They had to wait more than two months for favourable conditions. Then, on the evening of 27 June, at 22.28, the wreck broke surface. «In the stern and on deck were an undefinable number of skeletons. It was a sight that affected us profoundly: we were all struck dumb».

A LAST EMBRACE. On 30 June, the wreck arrived at the NATO base of Melilli (Siracusa), where the second and no less difficult part of the operation began: the autopsies to identify the victims. The fire brigade removed from the boat, refrigerated with liquid nitrogen, hundreds of corpses in pitiful condition: saponified bodies, with the parts not covered by clothing (faces and hands) gnawed to the bone by fish . Many of those trapped in the hold were holding each other in their arms.
How could their identities possibly be established? The currents had scattered the bodies over an area of 2 km², often mixing their remains, which filled 450 body bags. All were examined by a team of volunteer forensics experts, coordinated by Cristina Cattaneo of the Milan-based University Laboratory of Forensic Anthropology and Dentistry (Labanof). «Those nights», Cattaneo tells us, «I dreamed of walking along a path and finding other bones on the ground; I was afraid I had lost some».
But why so much effort to be able to name these victims? The recovery operation was decided on by the then prime minister, Matteo Renzi, as a wake-up call to the EU authorities to take political measures to stem the flow of migrants. But the operation also had an important humanitarian purpose: to provide answers for the living. «Many people think that no one is searching for those unfortunates, but they are wrong", explains Cattaneo in her book *I diritti annegati* (*Drowned rights*, pub. Angeli). «A nameless body is unfinished business . The loss of a family member leaves their relatives in a kind of limbo, their suffering unresolved. And it leaves people unable to get on with their lives: widows who cannot remarry or inherit their spouse's property, or children who cannot be adopted by other relatives. So, identifying migrants who die trying to reach Europe is an act of respect for their dignity. After all, no one is scandalised when people and resources are mobilised to identify the victims of a plane crash or an earthquake».
Identifying the victims of this particular shipwreck, though, was very difficult. Only 70 identity documents were found on the seabed: many migrants travel without them, so they are not obliged to apply for asylum in the first country they come to. Then there was the terrible state of the bodies after twelve months under water. And the remoteness of the family members from whom confirmation was needed.

UNIQUE SMILES. «To identify a victim, you have to compare the post-mortem data (the person's physical appearance, DNA, fingerprints, teeth) with ante-mortem information: photographs, genetic samples, dental records», explains Cattaneo. «But in the case of migrants, no such data exists: their relatives are too far away to provide DNA, their fingerprints are not kept in European databases, and they don't have dental records. So we have to focus on secondary data: we photograph the bodies in search of distinguishing features, such as birthmarks, tattoos or scars. Their configuration, when compared with an ante-mortem photo of the deceased is a sure means of recognition». This method was used for the first 169 bodies recovered from the wreck, those in best condition.
For the others, mere skeletons or totally unrecognisable , the Lab adopted a different approach: they performed 3D scans of the skulls, which could be superimposed, using computer technology, on the photographs of possible victims sent by relatives.
«If the two images match, we get the relatives to send us a sample of DNA (e.g. on a toothbrush) to compare with the DNA of the victim, to see if they correspond. But when the smile of a deceased person is visible in a photograph, and the profile of his teeth matches that of a skull we have scanned, the identification is unambiguous: dental profiles are unique».

20,000
The number of migrants lost in the Mediterranean since 2000. At least 65% of them have not yet been identified. (IMO estimate).

A POCKETFUL OF EARTH. This is why the medical experts have not only taken samples of DNA, photographed the bodies and taken fingerprints, but have also catalogued the personal items recovered: wallets, T-shirts, USB pen drives . Some of the victims had concealed in their clothing a plastic bag containing a handful of their native soil: a souvenir of a one-way journey. "You can't perform these investigations without feeling compassion", says Cattaneo.
The experts are now keen to extend this methodology to all persons lost in the Mediterranean. «We are faced here with a tragedy that defines our day and age», says former Commissioner Piscitelli. «And identifying the victims is an act of respect for their dignity and for their surviving relatives. Existing legislation, however, does not prescribe autopsies and DNA sampling of all dead migrants: the magistrates generally focus on the people-traffickers and how the survivors should be dealt with. I have therefore officially asked the Italian judiciary to ensure that DNA samples of shipwreck victims are taken in all cases and entered in the Italian Lost Persons database, which is managed by the police. But this is just a first step: the database is available only to the security forces and only general parameters are included. Meanwhile our office, with a staff of seven, has to manage 15,000 cases every year. More resources are needed for this operation: data on victims needs to be gathered by the Mediterranean countries and managed by an international authority. But the EU has turned a deaf ear».
In the meanwhile, the Mediterranean continues to swallow up victims each and every day. Many will remain nameless and their families will never know what became of them. As may well happen in the case of young Ibrahim. F

Vito Tartamella
(translated by Simon Knight)

LIVES DESTROYED. Below, some of the items found on migrants: comb, USB pen drive, dental hygiene stick, medicines, money, sim card. All catalogued with the letters "PM" for post mortem.

The Stradivarius mystery

Science investigates the secrets of the luthier from Cremona, creator of the world's most highly prized violins

Roberto Caccuri/Contrasto

SUPREME ELEGANCE. The "Bazzini", a Stradivarius dating from 1715. It is named after its first owner, Antonio Bazzini, director of the Milan Conservatoire.

UNDER THE MICROSCOPE. Magnification of the surface layer of varnish (0.03mm) of a cello made by Pieter Rombouts, a contemporary of Antonio Stradivari.

Gerrit. conc.: C.Y. Barlow e J. Woodhouse, Cambridge University.

The maestro would wander round the Val di Fiemme woods with a torch, when the moon was full. One by one, he would scrutinise the spruces (Picea excelsa). Finding a majestic specimen, he would remove a piece of bark, strike the tree with a hammer and listen. If he liked the sound, the tree would be felled and transported to Cremona...

We do not know if this is how Antonio Stradivari really selected the wood for his violins. What we do know is that, four centuries later, they are still world renowned for their limpid, luminous and richly nuanced sound. The most celebrated violinists, such as Uto Ughi, compare them with Raphael paintings "for their balance and purity".

But how exactly did Stradivari impart a soul to the wood? Did he use special materials, adopt a secret process? Countless stringed-instrument makers have tried in vain to replicate his violins. And, over the last 80 years, physicists and chemists in different parts of the world have tried to discover his secrets, studying the instruments using X-rays, CT scans and spectroscopic techniques. These have yielded some interesting results, but many uncertainties remain.

MISSION IMPOSSIBILE. It is, in any case, an almost impossible challenge: Stradivari did not leave any documents describing his methods, knowledge of which was lost for ever in 1743, when his sons Francesco and Omobono, his only apprentices, died just six years after the master himself. Futhermore – and this is a serious limitation for a researcher – it is not possible to scrape so much as a molecule from one of these instruments, given their historical, musical and financial value: in 2011, the 'Lady Blunt', a Stradivarius dating from 1721, sold for 11.1 million € (over 12 million $).

Their legendary sound? A combination of painstaking design, the very best materials and special processes

AN INIMITABLE SHAPE. The 'Bazzini' in profile and (right) its scroll: it was made during Stradivari's golden period. The kinds of wood used and the inlay decoration depended on how much the customer was prepared to pay.

Roberto Cacour/Contrasto (2)

"For balance and sound purity, they are like Raphael's paintings"
Uto Ughi, violinist

'Strads' have in fact become an investment: the prices they sell for have increased 200-fold over the last 20 years, 10 times more than gold. This is why many of the surviving violins belong to Russian, American and Japanese millionaires, not to mention financial institutions. Matteo Fedeli, the violinist who has played the largest number of these instruments - 25 in the last 11 years – goes around with armed bodyguards and expensive insurance policies when he performs with the 'Bazzini' (1715), owned by a Swiss collector. "Many of the owners of these legendary violins are not able to play them", he says, "so they contact me to keep them alive by playing them in a concert setting."

GOLDEN PERIOD. Stradivarius violins, together with the Gutenberg Bible and Leonardo's Mona Lisa, are icons of Western culture. This is why, in the last century, Lenin and Hitler were so quick to confiscate them. But they were already a legend during the lifetime of their maker, who died in Cremona in 1737, at the age of 93. His instruments – harps, lutes and mandolins, as well as violins and violas – were sought after by popes and rulers from all over Europe.
Stradivari had succeeded in perfecting the violin, an instrument developed in the workshop of his fellow townsman Andrea Amati at the end of the 16th century. Until 1679, the young man had served as an apprentice in the workshop of Amati's nephew, Niccolò. In 1680, he set up on his own account and in the next 57 years built no fewer than 1,116 musical instruments - a rate of around 20 a year. Just over half have survived, 650, of which 500 are violins. The most highly valued are those of his 'golden period', produced between 1700 and 1720.

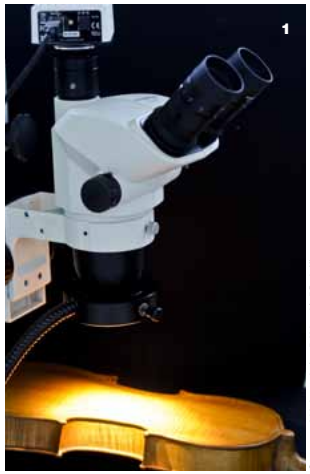
GOLDEN FLAME. According to Fedeli, "Their distinguishing features are their golden, flame-like varnish; the carefully cut-out "f"-holes in the sound box, their curvature and scrolls. In some cases, the label glued to the inside of the instrument: Antonius Stradivarius cremonensis faciebat. And, obviously, their unmistakeable sound. Each has its own personality, which is why they bear a name, the name of their original owner."
But to what can their unique sound be ascribed? Research has pointed to three factors: painstaking design, the timber used, and the way in which the timber was treated. "Stradivari", according to Fausto Cacciatori, curator of the Cremona Violin Museum, "would make careful drawings of his violins on paper, before cutting out the wooden shapes. He drew on his wealth of experience and a long tradition, but he was also in close touch with contemporary violinists. He was successful because the violins he built were not only beautiful and harmonious, but also had a powerful 'voice', which was increasingly important in the making of late-Baroque music." And the same is true today: "When I do half a day's practice", explains Fedeli, "I have to use ear-plugs, or I am bound to end up with headache". The sound of a strad is a force to be reckoned with.

ICE AGE. A violin is made up of 70 different parts. For the body of the violin, which acts as a sound box, Stradivari used two kinds of wood: Balkan maple (Acer hyrcanum), lighter and more rigid than its Italian counterpart, for the back; Alpine spruce for the belly, or top. We do not know where he got his supplies: studies of the timber he used suggest that he purchased whole tree-trunks, probably from the woods of the Trentino region. Once felled, they were shipped along the River Po to Cremona. He then left them to season on the *secadùur*, the covered terrace of his workshop. According to Lloyd Burckle, a geochemist at Columbia University, Stradivari was favoured in his selection of timbers by a chance climatic factor: the trees he used were survivors of the Little Ice Age, a period of severe winters which affected Europe in the years 1645 to 1715 and slowed the trees' rate of growth, producing a compact, elastic timber with evenly proportioned rings.

11,1
million € (over 12 million $): the highest figure ever paid for a Stradivarius (the 'Lady Blunt', 1721), in 2011.

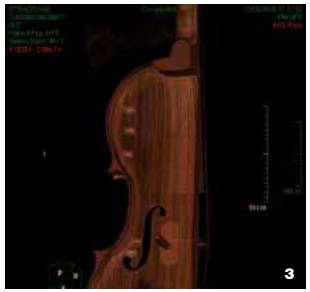
VARNISHES. Finally, there are the varnishes Stradivari used to embellish and protect his violins. Rivers of ink have flowed on this subject. Without these 50 microns (thousandths of a millimetre) of varnish, strads would make a much poorer sound. So what exactly did the maestro use? The only documentary evidence we have is a letter in which he apologises for late delivery of an instrument, due to the time required for the varnish to dry: "You will bear with me if the violin is delayed because of the varnish, so that the sun does not open up any big cracks". In the 1970, Simone Sacconi, a luthier who in the course of his career restored 350 strads, suggested that the varnish was used to improve the sound quality of the wood: "Stradivari prepared a vitreous substance which made the wood harden and become more homogeneous as it penetrated into the pores in the timber. Thin though the wood was, this increased its capacity to vibrate and produce a more powerful sound." According to Sac- ▸

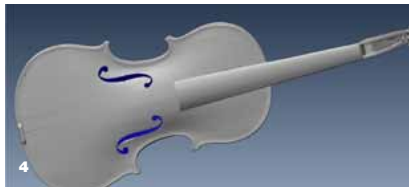
SCIENTIFIC RESEARCH. Gli studi non invasivi sugli Non-invasive studies of Stradivarius violins
1. An old instrument under the stereomicroscope: showing small scratches.
2. A violin lit by an ultra-violet fluorescent lamp: the darkest areas are those where the varnish is thickest.



Gentl. concessione Matteo Fedeli (2)

Gentl. conc. del Laboratorio Arvedi, Università di Pavia (2)





INITIAL RESULTS. Results of the investigations
3. A TC scan: the small rectangles on the body show where the wood has been repaired (with filler).
4. Three-dimensional model of a Stradivarius, used for replicating the various shapes.

OF 650 INSTRUMENTS, ONLY ONE IS ALMOST 100% ORIGINAL

ALTERATIONS. Over four centuries, Stradivarius violins have inevitably undergone alterations. The wooden parts have been filled and revarnished, and various components have been replaced without undue reverence. The important thing was that they could be played. In the 19th century, for example, all violin fingerboards were replaced with longer, more angled versions so they could play higher notes.
Of ther 650 instruments that have come down to us, the only Stradivarius still in original condition (including varnish), is the 'tenore mediceo', a 1690 viola on display at the Galleria dell'Accademia in Florence. Because of its large size, it has been little played over the years. And yet, nobody, according to the Florentine luthier Fabio Chiar, has really studied it, though some X-rays and UV photographs have been taken. More searching investigations could reveal the secrets of Stradivari's varnishes.

After Stradivari's death, his 'recipe' was lost. Luthiers adopted 'Chinese' varnishes, easier to use for producing more violins.

"To the refinement of his instruments, Stradivari adds nobility, embellishing them with graceful purfling"

Desiderio Arisi, friend of Stradivari.

Gent. conc. Laboratorio di Acustica Musicale, Politecnico di Milano (2).

RECORDINGS. Violinist Anastasiya Petrishak playing the 'Vesuvius' in order to record its acoustic properties; above, a bow fitted with a movement-monitoring system for studying the interaction between musician and instrument.

An unmistakeable sound? Not according to scientific testing...

A SURPRISING RESULT. Not so unmistakeable after all. A French researcher studying acoustics, Claudia Fritz (Institut Jean Le Rond D'Alembert, Paris), has put the Stradivarius legend to the test. In 2012, she invited ten famous soloists to a concert hall in Paris, blindfolded them and presented them with 12 violins, 6 ancient (including five strads) and 6 modern. They each played for two 75-minute sessions, solo and accompanied by an orchestra. Result: six out of ten preferred a modern instrument. The one that got the most votes overall was a modern instrument, while a Stradivarius from the golden period came only third.

Can one generalise from the judgement of 10 musicians? "Probably not", replies Fedeli. "A couple of hours is not enough to form a relationship with an antique instrument. Especially since the sound of a violin needs to be judged from a distance. The performer himself is too close to the source to assess it effectively." Indeed, Claudia Fritz also asked 50 experts present in the concert hall to say which of the 12 violins sounded best.

The jury is still out: the results will be published in 2015. The mystery remains unresolved.

FULL IMMERSION. The Milanese violinist Matteo Fedeli – the musician who has played the greatest number of strads: 25 in the last 11 years.

Roberto Cascur/Contrasto (2)

coni, Stradivari used silica, carbon and potash, the ash produced by burning the dregs from the grape press. These ingredients were reduced to a powder, dissolved in water, boiled again and then decanted. Spread on the wood, the varnish took weeks, if not months, to dry. Some researchers from Cambridge University, have hypothesised that he used volcanic ash.

X-RAY ANALYSIS. To get a better understanding, researchers at the University of Pavia's Arvedi Laboratory, inaugurated in 2013 at the Cremona Violin Museum, have been using scene-of-crime techniques. They first shone an ultra-violet fluorescent lamp on the Museum's violins to identify the areas with the thickest covering of varnish. Using radiography, they pinpointed the least restored areas, then investigated them with spectroscopic techniques to identify the molecules contained in the wood, based on how they absorb light.

The result? "We have found calcium and potassium", reveals Marco Malagodi, lecturer in restoration chemistry at the University of Pavia. "It is probable that Stradivari treated his violins with a mixture of casein (a milk protein) and slaked lime (calcium hydroxide). After a week, this yields calcium caseinate, a glue. This substance has been found in other instruments by Austrian researchers". Stradivari followed this up with two further layers: "an insulator, made of linseed or walnut oil and pine resin (rosin); and a layer of coloured varnish consisting of oil, rosin and, in some cases, cinnabar, a mineral rich in sulphur and mercury that Leonardo da Vinci had previously used as a red pigment. These varnishes took many weeks to dry." This also explains why Stradivari produced fewer than two instruments a month.

SHARP EYES, SKILLED HANDS. No alchemist's magic, then? "The techniques and materials employed by Stradivari were the same as those used by his contemporaries", comments Bruce Tai, a chemist at the California Institute of Technology. "He obtained his supplies from vendecolori, pharmacists who sold pigments for painters and furniture-makers. But the processes he adopted were complex, with many variable parameters (dosage of the mineral particles, type and quantity of rosins and pigments, heating and drying times). Using the same ingredients, luthiers could obtain very different results.

Stardivari's success depended on a combination of sharp eyesight, acute hearing, manual dexterity, attention to detail, creativity through constant tweaking, and, most of all, artistic inclination. Augusto Sarti, director of the Musical Acoustics Laboratory at the Polytechnic of Milan, is trying to identify the physical parameters typical of the Stradivarius sound, whatever they may have been. "Our objective", he says, "it to replicate them in modern instruments."

650

The number of Strads that have survived. Stradivari is reckoned to have made 1,116 instruments in 57 years.

CHINESE VARNISHES. The processes used by the luthier from Cremona were lost for ever after his workshop closed. At the end of the 18th century, oil-based varnishes were replaced by alcohol and essential oils. These were 'Chinese' varnishes, based on sandarac resin (obtained from a North-African tree) and shellac, a polymer derived from an Asiatic insect, the lac bug (Kerria lacca). Strong and shiny, cheap and easy to apply, they were ideally suited to the growing demand for violins in Europe.

Maybe the secret of Stradivarius violins was simply a question of slowness – like the heart-rending slowness of Oblivion, a piece by Astor Piazzola that Fedeli performed for this Focus reporter on the instrument dating from 1715. It brings tears to one's eyes. Whether this should be ascribed to the violinist or the elusive luthier is also a mystery. And maybe it is better it remain so.

Vito Tartamella