

# Pesquisa

## FAPESP

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# SRIUS

*The 4<sup>th</sup> generation synchrotron light source will be the largest facility of its kind in Brazil and will improve the quality of research conducted in physics, biology, and materials science*

The new Embraer aircraft has performed better than expected in flight tests

Algorithms are developed to address problems of different natures and of varying scales

Thirty-four times as many immigrants have sought refuge in Brazil compared to 10 years ago

Compositional analyses have revealed Heitor Villa-Lobos's complex creative process

Reefs at the mouth of the Amazon River may be larger and deeper than expected

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## LETTER FROM THE EDITOR

# Lighting the way

Alexandra Ozorio de Almeida | EDITOR IN CHIEF

In certain fields, innovative scientific discoveries are increasingly reliant on large and often multinational facilities. These projects are frequently the subject of controversy within (and outside) the scientific community due to the high costs involved, particularly in developing countries, but supporters argue that such investments are needed to stimulate qualitative advances in science.

In December 2018, Brazil inaugurated its largest, most complex and versatile research instrument: a fourth generation source of synchrotron radiation, a type of light that allows scientists to study materials on an atomic scale. The Sirius project is located at the Brazilian Centre for Research into Energy and Materials (CNPEM) near Campinas, São Paulo State. Tests on the accelerator are scheduled for the second semester of 2019. By the end of the year, six of the thirteen beamlines foreseen in the project should be open to researchers based in Brazil and abroad.

The CNPEM is also home to UVX, the first synchrotron light source in the Southern Hemisphere. The knowledge acquired during the development of the UVX and the experience gained by the researchers that used it were essential to the Sirius project, which has a budget of R\$1.8 billion. The cover article of this edition, originally published in Portuguese in July 2018, tells the story of the new synchrotron facility in Brazil (*page 4*).

\*

Algorithms are behind programs that help us face daily challenges. By applying sequences of rules and logical procedures to a data set, algorithms find the route home with the least traffic, recommend music and films, and suggest which shares to buy or sell and how

to stock control or carry out warehouse maintenance, among many other uses. A feature in this issue, the cover of our April 2018 edition, explains how these algorithms are created and describes some of their current and future applications. Their omnipresence stems directly from the ease with which large amounts of information (known as big data) are now collected, stored and processed by increasingly powerful computers (*page 58*).

\*

The political sociologist Elisa Reis is dedicated to studying the Brazilian elites. Institutional position is key to how Reis defines the elite: people who control material and symbolic resources and occupy high positions with the capacity to influence or make important decisions. Reis discussed in an interview the main objective of her research, which is to understand, often using comparative studies with other countries, how the Brazilian elite relates to poverty and inequality (*page 12*). Based at the Federal University of Rio de Janeiro, Reis has a PhD from MIT, studying there at a time when there were few women and foreigners at the institution. She advocates the production of knowledge as a collective effort. While recognizing the desire for originality, Reis argues that this inclination contributes to a high level of fragmentation, making it difficult to consolidate and generalize results: “Teamwork is essential in academic research.”

This international edition of *Pesquisa FAPESP* brings other interesting features from our Portuguese editions published between March and August 2018. They range from the performance of Embraer’s new aircraft in flight tests (*page 70*) to the depth and size of the reefs in the Amazon river (*page 40*).

COVER

LEAPING TOWARDS  
BRILLIANCE



Detail of an wiggler, a series of magnets that make the electrons snake inside the storage ring and release energy in the form of synchrotron light

## In its final stage of construction, the latest-generation synchrotron light source could elevate the quality of Brazilian research

TEXT **Ricardo Zorzetto**

PHOTOS **Léo Ramos Chaves**, from Campinas, SP

It was almost six o'clock in the early evening of Thursday, May 17, when electrical engineer Sergio Marques took the opportunity to stretch his legs and look for more energy in yet another cup of coffee. Then, he would resume taking the measurements his team had been working on since the beginning of the week, together with Brazilian physicist Liu Lin's research group, sometimes for 24 hours at a stretch. Marques and Lin, both researchers at the Brazilian Synchrotron Light Laboratory (LNLS) in Campinas, in central São Paulo State, had been testing the components of a linear electron accelerator purchased for US\$6 million from the Institute of Applied Physics in Shanghai, China. Installed during the previous weeks in a 32-meter tunnel with concrete walls, every half a second the device propels microscopic packets of trillions of negatively charged particles at close to the speed of light. The accelerator will feed the largest, most complex and versatile research instrument ever built in the country: Sirius, a state-of-the-art source of synchrotron radiation, which is a special type of light that allows researchers to investigate the structure of matter at the scale of atoms and molecules.

Sirius has been under construction since 2014 at the Brazilian Center for Research in Energy and Materials (CNPEM), 15 kilometers from Campinas. It should be ready for an initial test by the end of this year, if the requested funds approved by the federal government months ago are released soon. The new synchrotron light source is a particle accelerator comprising three parts. It is installed in a 68,000 square-foot building that must remain as isolated as possible from temperature changes and external vibrations, especially those generated by truck traffic on the highway connecting Campinas to Mogi-Mirim, which is two kilometers away.

Designed by the LNLS teams, Sirius will replace the UVX, the first source of synchrotron light in the Southern hemisphere. Built in the 1990s, today the UVX is no longer competitive. Approximately 90% of Sirius's components were developed at the LNLS workshops or designed there and produced by Brazilian high-tech companies. The linear accelerator is an exception. "Due to time concerns, we commissioned a machine with

# A special kind of light

When it goes into operation, possibly in 2019, Sirius will be one of the most brilliant sources of synchrotron radiation in the world

SOURCES HARRY WESTFAHL JR / LNLS / CNPEM AND THE SIRIUS PROJECT

## FROM ELECTRONS TO RADIATION

1

### LINEAR ACCELERATOR

Electrons released by a heated metal filament are propelled in a 32-meter-long linear accelerator to nearly the speed of light, with 0.15 giga-electron volts (GeV) of energy and injected into the booster

2 BOOSTER

Inside a smaller, inner ring, the electrons gain energy by passing through a radio-frequency chamber and attain 3 GeV of energy

3 STORAGE RING

Now at their maximum energy, the electrons are kept in a stable trajectory in the larger ring, 518 meters in circumference, by sets of special magnets

4 MAGNETIC LATTICE

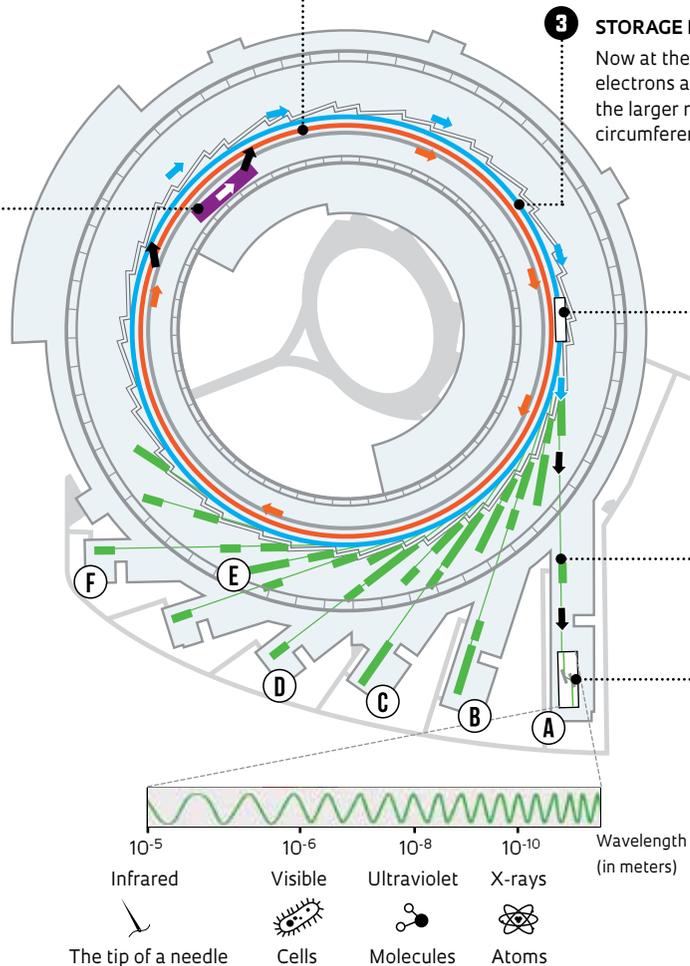
By passing between dipole magnets and undulators, electrons undergo trajectory deviations and lose a fraction of their energy in the form of light: it is this light, or synchrotron radiation, that spans a wide range of energy (from infrared to X-rays)

5 SYNCHROTRON LIGHT

The synchrotron light leaves the ring tangentially and is sent to the experimental stations

6 EXPERIMENTAL STATIONS

Optical setups equivalent to prisms installed at these stations allow selection of the range of radiation that will be used to analyze samples. Each range of radiation is appropriate for observing structures at different scales, ranging from fractions of a millimeter down to the nanometer



Sirius is located approximately 15 kilometers north of the city of Campinas

## THE FIRST BEAMLINES

Of the 13 beamlines planned to complete Sirius, all named after Brazilian trees, the six identified below will be the first to go into operation

### A CARNAÚBA

This will be the longest beamline, at 145 meters in length. Its beam of X-rays will resolve objects down to 30 nanometers (a resolution 1,000 times higher than that of Brazil's current light source, the UVX). It will enable two- and three-dimensional analysis of catalyst materials, semiconductors, and biologicals with nanometer resolution

### B CATERETÊ

An X-ray beamline that will enable the acquisition of three-dimensional images of living cells and can register dynamic phenomena on the order of fractions of a second, such as alterations in molecules of DNA. It will allow researchers to observe the interaction between chemical elements in different materials, as well as the nanoscale structures of oils and polymers

### C EMA

Its ultrabright X-ray beam will produce nanometer-scale images of materials under extreme conditions (temperature, pressure, and strong magnetic fields), which are important for the research of superconducting materials. It will feed equipment at two experimental stations

### D MANACÁ

This will be the first beamline assembled at Sirius, with completion scheduled for April 2019. Its X-ray beam will be used to analyze protein crystals, enabling scientists to obtain three-dimensional images of their molecules that show the precise location of each atom

### E MOGNO

One of Sirius's most energetic X-ray beamlines, Mogno, is expected to generate 3D images of nanometer-scale structures of dense materials in just seconds. It will be capable of penetrating centimeters into rocks taken from oil reservoirs. The current light source can analyze samples with only fractions of millimeters of thickness. Mogno will also enable the study of live animals

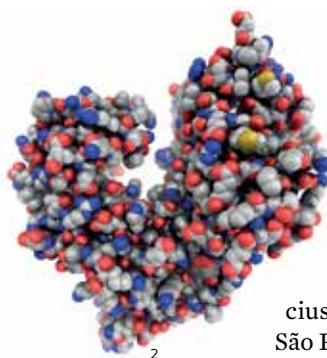
### F IPÊ

This light source will work with low energy X-rays and will enable the mapping of electrons responsible for the physical properties of matter, such as magnetism and electrical conductivity. It will make it possible to observe the formation of chemical bonds between atoms of matter in solid, liquid, and gaseous states

high-level specifications from researchers who had completed a third-generation synchrotron light source in Shanghai, one generation prior to Sirius, and they provided us data on almost every part of the accelerator,” Marques explains. He began working at the UVX in 1997 at the age of 16 and now leads the LNLS diagnostic group, which monitors the electron beam and the quality of synchrotron light that arrives at its experimental stations.

When it goes into full operation, Sirius will be—for a limited time—the most advanced source of synchrotron light in the world, in addition to being the brightest X-ray spectral source in its energy class (see article on page 10). Put simply, this means that the accelerator will allow researchers to extract very concentrated beams of light from electron streams traveling at almost 300,000 kilometers per second. These beams that can penetrate deep into dense materials such as rock and will produce clear images of objects only a few nanometers (millionths of a millimeter) apart. The intense brightness of the beams will reduce the image acquisition time from samples from hours to seconds, which is crucial in the study of biological materials, which degrade rapidly. The reduction in the time needed to produce each image will allow a greater number of images to be obtained per second and enable scientists to reconstruct the movement of very fast phenomena at the level of atoms and molecules, such as interactions between two compounds, or the movement of ions in charging and discharging batteries.

Sirius’s resolving power will outpace third-generation synchrotron light sources such as the current technology at the European Synchrotron Radiation Facility (ESRF) in France. Israeli researcher Ada Yonath performed some of the experiments that defined the three-dimensional structure of the ribosome—the protein-producing organelle in cells—at the ESRF, which earned her the 2009 Nobel Prize in Chemistry. Images from Sirius are also expected to achieve a resolution up to 1,000 times better than that of the UVX, which is a second-generation light source.



The three-dimensional structure of the NS5 protein of the Zika virus, defined atom by atom

Even though it is out of date, the UVX allowed physicist and professor Glaucius Oliva and his team at the University of São Paulo (USP) in São Carlos to identify the three-dimensional structure of the NS5 protein, which is essential to Zika virus reproduction (see Pesquisa FAPESP issue no. 254).

With the new synchrotron in Campinas, researchers expect to go even further and identify the three-dimensional structures of larger, more complex proteins of interest in biology and pharmaceuticals and study materials of interest to industry (see infographic on following page). “Sirius is very close to the limit of what engineering can currently build, and will be able to produce internationally competitive science for at least a decade,” says physicist Antônio José Roque da Silva, director of the LNLS and the Sirius project. A professor at USP and a specialist in the mathematical modeling of materials at the atomic scale, Silva arrived at the LNLS in 2009 with two missions: first, to improve the UVX, which as an aging technology was beginning to lose users and researchers to institutions abroad, and second, to carry out the project of building its replacement. The name Sirius would come later, borrowed from the brightest star in the night sky.

From the beginning, Silva sought the help of two former LNLS collaborators: civil engineer Antonio Ricardo Droher Rodrigues, one of the three Brazilians who led the construction of the UVX from 1987 to 1997, and French physicist Yves Petroff, who directed synchrotron light labs in France and participated in the first Brazilian light source project. “The UVX no longer had the ability to compete, so we opted to improve in niches where we could produce relevant research using infrared and ultraviolet radiation,” Silva says. At the same time, the trio perfected a third-generation light source project developed by the team led by physicist José Antônio Brum, who directed the Brazilian Association of Synchrotron Light Technology (ABTLuS), now CNPEM, from 2001 to 2009. Three years later, with a mature project in hand, Silva and his team submitted their project to an international scientific committee.

In their final report, the committee members said the design of the new light source was excellent according to the current standards, but they recommended that the team strive for a level of brightness that would remain competitive into

Aerial image of the Sirius building, taken in mid-June in 2018



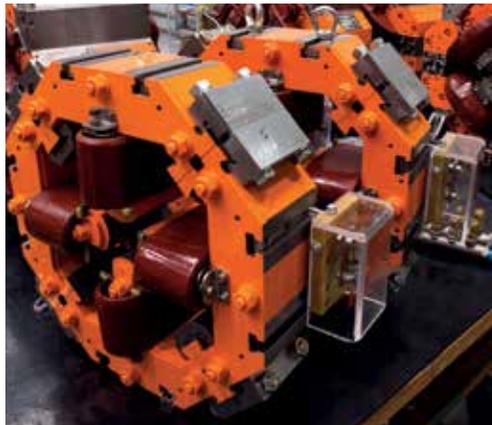
the future. “There wasn’t a machine with the characteristics they were suggesting in operation anywhere in the world,” recalled Silva on the morning of May 17, in his office at the LNLS. “It was our chance to get out in front of the United States, Japan, and the European countries, and stay there for a while.”

The LNLS teams returned to the design table and resumed equipment testing. Responsible for accelerator physics at the LNLS, Liu Lin and her group redesigned Sirius’s magnetic lattice so that its brightness would surpass that of the existing machines. Six months later, the committee approved the new project, budgeted at US\$585 million (R\$1.3 billion at the time). Obtaining stable financing was critical but only one part of the problem. “We had to acquire a location for construction and define the building’s characteristics while at the same time we were redesigning the machine and looking for a way around technological challenges,” Silva recalls. “There were times when we were juggling 20 plates in the air.”

**T**he first R\$9 million for the preproject were disbursed in 2009 and 2010 by the then Brazilian Ministry of Science and Technology (MCT), under the management (2005–2010) of physicist Sergio Rezende, who had first encountered Brum’s project in 2008. However, a definitive source of funding was missing, which would initially be provided by the MCT (now MCTIC, after incorporating Innovations and Telecommunications), together with the Brazilian Development Bank (BNDES) and other development agencies. Two other underwriters succeeded the ministry to lead the funding and contributed R\$77 million to the project. Finally, in 2014, engineer Clélio Campolina Diniz was able to give the green light to begin construction with a proposed 2015 budget of R\$240 million. The following year, Sirius was included in the second edition of the Growth Acceleration Program (PAC), which today is a Programa Avançar project.

Fluctuations in the dollar, inflation, and improvements to the light source and structural design elevated Sirius’s cost to R\$1.8 billion. “It’s the only Brazilian project on this scale going forward without major delays,” says electronics engineer and physicist Rogério Cezar de Cerqueira Leite, chairman of the CNPEM board of directors, an NGO linked to MCTIC, the managing agency of the LNLS.

Pedro Wongtschowski, a chemical engineer who chaired the CNPEM board from 2010 to 2015, attributes the project’s adherence to its schedule and its low number of budget changes to the adoption of a governance model used by the private sector on large-scale projects. “Project execution only began once a detailed imple-



Engineer Rafael Seraphim tests the vacuum system of the chambers that will propel the electrons. Left, quadrupole magnets, one of the components of the storage ring

mentation plan was completed; the contracting of work was done through a careful bidding process, and the equipment that required longer delivery times was acquired first,” he recalls. “We also took advantage of the deployment of Sirius to develop components through Brazilian suppliers, a move that received support from FAPESP,” says Wongtschowski, current chair of the board of directors at Ultra (Ultrapar Participações) and a member of FAPESP’s governing council.

Of the total estimated cost, R\$1.16 billion has already been delivered by the MCTIC, of which R\$760 million was spent under the management of Gilberto Kassab, as noted by Cerqueira Leite, who played a fundamental role in the implementation of the UVX during the 1980s. In Leite’s view, Sirius only survived the recent economic slowdown because the project managed to gradually interest “authorities and politicians in Brasília,” in addition to its creators and the scientific community.

A similar conclusion was reached years ago by two researchers who analyzed the process of creation and implementation of the UVX. Léa Velho, a professor at the Department of Science and Technology Policy at the University of Campinas (UNICAMP), and Osvaldo Frota Pessoa Junior, a professor at the Department of Philosophy at USP, evaluated the reasoning that motivated the construction of the first Brazilian synchrotron and the negotiations that took it from design to real-



The hall where some of Sirius's experimental stations will be installed

ity. In a 1998 article in the journal *Social Studies of Science*, they stated that support for the project came more from science policy sectors than from researchers and potential users. They added that the political skills of the few scientists involved were crucial to the project's implementation.

"Sirius represents an attempt to leap to a new level of quality in Brazilian science," observes Argentine physicist Aldo Craievich. At the age of 79, retired from USP, he's still doing research using the UVX. Together with physicist Cylon Gonçalves da Silva and Ricardo Rodrigues, Craievich was the third member of the trio who coordinated the construction of the first Brazilian synchrotron.

**T**he first large-scale research equipment project in Brazil—i.e., "Big Science," such as that which began in the United States during World War II with the nuclear bomb project—was initiated at the Brazilian Center for Physics Research (CBPF) in Rio de Janeiro in the early 1980s by physicist Roberto Leal Lobo and Silva Filho. With support from Lynaldo Cavalcanti de Albuquerque, then president of the National Council for Scientific and Technological Development (CNPq), Lobo guided the project until the beginning of the democratic government in 1985. With the creation of the MCT, he was replaced by Cylon, who had the support of the new agency's minister, Renato Archer.

"When we decided to build Brazil's first synchrotron light source, the only operational model that made sense was that of a national lab along the lines of US facilities, open to users from research institutions and companies in Brazil and abroad," Cylon notes. "The construction of the machine was merely an excuse to educate people who would be qualified to generate technology in Brazil, and capable of producing science at the frontiers of knowledge. We opted on designing and building as much as we could here nation-

ally, which gave us the expertise used to create Sirius."

Building equipment to do science on a large scale demands a continuous flow of funds and technical and scientific expertise, and it almost always generates controversy. This was the case with the UVX project, and on a smaller scale, with Sirius. Soon after Brazil's first synchrotron light source project was approved, the directors of the Brazilian Society of Physics published a manifesto condemning the effort. It stated that there was not enough technical competence within the country to build it, that there would not be any users for it and that the

UVX would drain resources from other

areas of science and technology. "None of these predictions came true," says Rodrigues, coordinator of the Sirius accelerators. "We built the machine, the researchers came—today there are 6,200 registered users—and the level of funding has increased in every area."

"Large facilities like Sirius are expensive anywhere in the world, but they pay for themselves over time," says Fernanda De Negri, an economist at the Institute for Applied Economic Research (IPEA). Its cost represents 0.05% of the overall Brazilian national budget (government revenue), approximately R\$3.5 trillion. "In many areas, infrastructure like this is necessary to producing quality science capable of generating innovation and making the country more economically competitive," the researcher says. In Negri's book *Novos caminhos para a inovação no Brasil* (New pathways to innovation in Brazil; Editora Wilson Center), she mentions Sirius as a rare example of long-term scientific planning in Brazil, launched in June.

"Since the atomic bomb project and the Apollo mission, science is no longer done only on small investments and short-term vision," says Glauco Arbix, a professor in the Department of Sociology at USP. Arbix is a former president (2011–2015) of the federal innovation promotion agency FINEP (Brazilian Funding Authority for Studies and Projects). He states that "It's necessary to have medium- and long-term vision, and to irrigate the system in such a way as to nourish smaller labs and create research projects with scientific, economic, and social relevance that are capable of raising the level of Brazilian science and increasing its impact. Without this, the country will continue to slip behind." ■

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#### Scientific article

VELHO, L. and PESSOA JR., O. The decision-making process in the construction of the Synchrotron Light National Laboratory in Brazil. *Social Studies of Science*. v. 28, i. 2, p. 195–219. April, 1998.

# The race for the best light

Sirius will compete with a fourth-generation facility inaugurated in 2016 in Sweden and another planned to begin operating in 2020 in France

There is a rush to complete Sirius, Brazil's new synchrotron light source, which will be one of the most advanced sources in the world. The goal is to keep delays on completion of its construction and assembly to a minimum. It is currently a modest six months behind schedule, which is acceptable in a project of this magnitude and technical complexity. It's competition is just in sight. The facilities are designed to create a similar or even higher brightness than that of the Brazilian synchrotron, which will certainly attract the attention of academic researchers and companies interested in conducting experiments that require increasingly greater spatial and temporal resolutions.

This is why last May, while physicists and engineers from the National Synchrotron Light Laboratory (LNLS) completed the installation and performed the initial testing of the linear accelerator, workers and civil engineers were working on Sirius around the clock, from Monday through Saturday. They are working to finish the building by August so that other parts of the accelerator and the experimental stations can be assembled as soon as possible. Even if the

facilities are ready in the near future, the new light source will not work without the connection between the high-voltage electrical grid and the substation that will feed Sirius and the rest of the campus at the National Center for Research in Energy and Materials (CNPEM), and this link has yet to be provided by Campinas-region utility CPFL Energia. Sirius and the campus together will consume the energy of a city of 40,000 inhabitants. "We need to hurry if we want to have the brightest light source in the world for even a short time," says physicist Antônio José Roque da Silva, director of the LNLS and manager of Sirius's construction.

Today, there are almost 50 synchrotron light sources operating in just over 20 countries. Almost half of them are concentrated in three countries: Japan has nine (many smaller sources), the United States has seven, and Germany has six. Just over 20 are third-generation sources, one generation earlier than the most modern equipment, which is now reaching the limit of what can be built. As a fourth-generation facility, Sirius will have two direct competitors: one light source that is already in operation in Sweden and another going into opera-

tion soon in France. There are also another 13 fourth-generation light sources being designed.

Located 500 kilometers south of Stockholm in Lund, Sweden, a city of 120,000 people, the MAX IV light source is the first in the world to be regarded as fourth generation. These devices are given this classification due to their innovative distribution of magnets around the electron storage ring, first proposed in 1993 by German physicist Dieter Einfeld and Slovenian physicist Mark Plesko in an article in the journal *Proceedings of SPIE*. This new magnetic lattice design was first adopted in MAX IV and allows smaller storage rings to be used to obtain more concentrated, brighter synchrotron light beams.

Built with components designed and manufactured in Sweden and other countries, MAX IV was inaugurated in June 2016 at a ceremony attended by the King of Sweden, Carl XVI Gustaf. The synchrotron consists of two storage rings: one containing electrons with 1.5 giga-electron volts (GeV), which feed two experimental stations currently in the commissioning phase, and a second with 3 GeV electrons, which provide synchrotron light for five stations, of





The European Synchrotron Radiation Facility in France, which will be upgraded in 2019 (*left*), and MAX IV in Sweden, the world's 1<sup>st</sup> fourth-generation synchrotron light source (*below*)

which three are active and two are in testing. “Since the start of operations, we’ve already had 318 users,” says Brazilian-Swedish physicist Pedro Fernandes Tavares, MAX IV’s director of accelerators. According to Tavares, the higher-energy ring should provide sufficient synchrotron light this year for the experimental stations connected to it to operate for approximately 4,000 hours, the equivalent of 167 days.

If everything goes as planned, Sirius and MAX IV will soon face a strong competitor: the extrabright source (EBS) of the European Synchrotron Radiation Facility (ESRF), located in Grenoble, a city of 160,000 people in the southeast of France, at the foot of the Alps. The EBS will be an enhanced version of their current synchrotron light source, which was the world’s premier third-generation light source to go into operation, in the 1990s. The ESRF is operated by a consortium of 22 countries and, for the last three years, its technicians and engineers have been preparing for an upgrade, which will cost €150 million.

The current facility will be shut down in December of this year. Over the following 18 months, its storage ring will be dismantled and replaced by a new



version with a circumference of 844 meters, which will provide electrons circling at 6 GeV of energy—double that of both Sirius and MAX IV. According to the ESRF communications office, the project is on schedule. It is expected that the new synchrotron, which will emit a brightness 100 times more intense than the current machine, will be reopened to users in 2020 and will provide beamlines to 44 experimental stations.

In the opinion of physicist Aldo Craievich, a retired professor from the University of São Paulo (USP) and one of the leaders in the construction of the first Brazilian synchrotron light source,

the UVX, Sirius will compete on equal terms with MAX IV and the ESRF-EBS and attract international collaborators. “I am convinced that even researchers from the more developed countries of the Northern Hemisphere will come, because a good number of advanced experiments can only be done here,” he states. “It will be a strong stimulus for international cooperation, which should exceed what the UVX did.” The current Brazilian light source, which is to be shut down at the end of 2019, has an average of 1,200 users per year, with approximately twenty percent coming from other Latin American countries. ■ Ricardo Zorzetto

# A pioneering look at **social inequality**

A researcher of the ruling elite advocates for the continued development of comparative studies to gain a better understanding of social phenomena

**Christina Queiroz**

PORTRAIT Léo Ramos Chaves | Published in April 2018

**A**t a time when the issue of poverty was mobilizing other researchers in her field, the political sociologist Elisa Pereira Reis was developing innovative studies on social inequality. Based on comparative analyses of conditions in a range of different nations, her work has influenced thinking about the imbalance of the distribution of resources not only in Brazil but also around the world. By focusing on the ruling elites' perspectives on the problem, Reis advanced the development of a new understanding of social disparities. In her conception, the elite is composed of people who occupy high-status positions in certain institutions, controlling both symbolic and material resources; in other words, they not only have money but also the ability to influence the decisions that reinforce their own power base.

A descendant of landowners from Araxá, Minas Gerais, Reis has been married to economist Eustáquio José Reis, a researcher at the Department of Macroeconomic Policies and Studies at the Institute of Applied Economic Research (DIMAC/IPEA), for over four decades. At the age of 20, she obtained a degree in sociology and politics from the School of Economic Sciences at the Federal University of Minas Gerais (FCE-UFMG) in Belo Horizonte. She defended her doctoral thesis at the Massachusetts Institute of Technology (MIT) in 1979.

**AGE** 72

**SPECIALTY**

Political sociology

**INSTITUTION**

Federal University of Rio de Janeiro (UFRJ)

**EDUCATION**

Undergraduate degree in sociology and politics from the School of Economic Sciences at UFMG (1967); doctorate in political science from MIT (1979)

**SCIENTIFIC**

**PRODUCTION**

Approximately 50 scientific articles and 11 books authored or edited



Now a tenured professor at the Federal University of Rio de Janeiro (UFRJ), Reis currently divides her time between political science activities, teaching, and two global research projects. “The time I spend teaching is what keeps me feeling consistently challenged. My first teaching experience was during my last year as an undergrad, when I taught an introduction to sociology for a social science class that had just passed the 1967 college entrance exams at the UFMG School of Philosophy,” she says. “I’m retiring from UFRJ, but I want to continue teaching, including undergraduate classes.” In the following interview, the researcher speaks about her studies on inequality and her current projects.

***Your path in academia could be considered a hybrid since your work covers both politics and sociology. Where does your interest in the social sciences come from?***

I left my parents’ house at the age of 14 for high school in Uberaba in preparation for studying engineering. In the first months of the course, however, I got caught up with social justice issues and became involved in high school politics. This motivated me to opt for the social sciences. Like many others of my generation, I was motivated by the idea of changing the world. I received my undergraduate degree at the School of Economic Sciences at UFMG, in Belo Horizonte. At the time, I thought political science, economics, and sociology were the same field of study. Today I define myself as belonging to the field of political sociology, but I will never lose the stamp of political science in my education.

***How did you get to MIT?***

I took the college entrance exam in 1964. I have always enjoyed studying the people who control material resources and their relations with the state. My Master’s thesis attempted to show how, in 1930, the state subordinated the coffee-growing elite to support the industrial elite. I received an education that approximated a political economics degree since I was in the last class to receive an undergraduate degree in sociology and politics at FCE. I had classes in international law, constitutional law, economics, and the history of economic thought, but not in the fields dealing with social



I work with the concept of the elite, which comprises people who control both symbolic and material resources

thought, for example. The degree was harder compared to social science degrees. The economics courses I took then were far more politicized than they are today. The university’s environment at the time could be considered legendary for—among other reasons—pioneering the introduction of the competitive scholarship system for undergraduates, investing in books and periodicals, and fostering intense activity in its reading rooms and library. I lived away from my family, in the city, and I considered school my home. I graduated in 1967, at the age of 20. The following year, while obtaining my degree in development sociology at the Latin American Institute of Doctrine and Social Studies [ILADES] in Chile, I lived with people from all over the world and with many exiles from Latin American dictatorships. The idea of producing comparative studies, which I find so interesting, began with my experience in Chile. When I arrived at MIT in 1972 for my doctorate, the institute had very few women and foreigners in the political science field. Soon I began taking classes from teachers who had been my bibliographical references, such as Samuel Huntington, Hayward

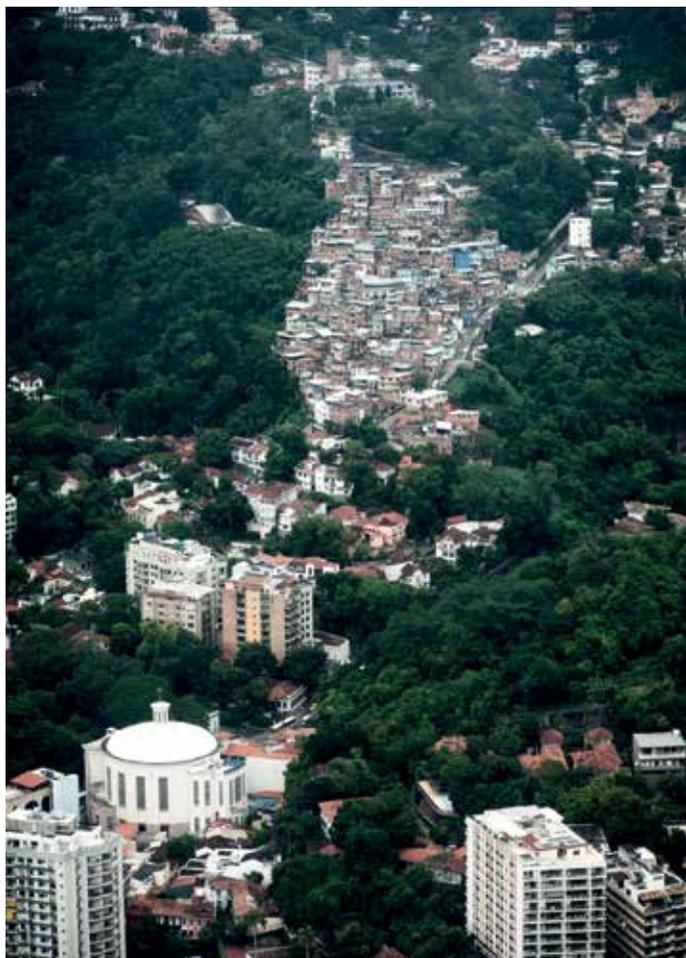
Alker, Daniel Lerner, and Barrington Moore. Being a “bibliography” student is good because you demystify the person and come to believe that it is possible to go far yourself.

***What did you study for your doctorate?***

With my doctorate, I endeavored to answer the question of why Brazil had so much difficulty in consolidating its democracy. To do this, I developed a macro-historical study that examined the time period from the abolition of slavery through the Revolution of 1930. I tried to show with empirical data how the conditions were created that led to Getúlio Vargas [1882–1954] carrying out his authoritarian revolution. In my thesis, I argue that the 1930 Revolution was not bourgeois but was cultivated by the agrarian elites during the Old Republic, creating the conditions for Vargas to install a modernizing dictatorship. At the time I was pursuing my doctorate, many social science researchers were concerned with explaining why Brazil was authoritarian. Many of us, such as Simon Schwartzman, Otávio Velho, and Luiz Werneck Viana, developed macro-historical theses to understand the dictatorship. That was the question of the era. I never published my thesis, but I wrote several articles that derived from it. One of the most widely read, “O Estado nacional como ideologia: O caso brasileiro” (The nation state as ideology: The Brazilian case) (Estudos Históricos, 1988), I consider an early-stage writing. In it, I worked with an unprecedented concept of “nation” that had already been approached by Benedict Anderson [1936–2015] in his 1985 book *Nation and National Identity*, which I had not been aware of.

***When did you first become interested in studies on inequality?***

I continued to work on the relationship between government and the market, keen to understand how economic interests were part of the construction of the state in Brazil. Because of my growing concern, my focus gradually shifted to studying inequality. My concern has always been very theoretical and macro-historical, unlike the tradition in Rio de Janeiro and São Paulo. I eventually joined the sociological theory committee of the International Sociological Associ-



Researcher seeks to understand how people who are not poor coexist with misery

ation. At that time, I converted from political science to sociology, but I continued to focus on the relations among the state, society, and the market. In another study, I created a database to map the relationships of nongovernmental organizations (NGOs) with the government. I submitted questionnaires to 300 NGOs involved in social policy in five Brazilian states as well as to a group of beneficiaries of these organizations' programs. My goal was to assess how leaders of these institutions relate to the state and the market and how their beneficiaries viewed these organizations.

#### **What are you researching today?**

I am working on two fronts. One study is my personal project of investigating the ruling elites' perception of poverty and inequality. The first phase of this initiative was developed between 1993 and 1995 by a group from the former University Research Institute of Rio de Janeiro [IUPERJ], which is now the Institute of Social and Political Studies (IESP/UERJ),

as part of the study "Strategic Elites and Democratic Consolidation," which focused on the process of redemocratization in Brazil. I joined this team to ask the elites questions about their perceptions of inequality. We conducted a survey with politicians, bureaucrats, and business and union leaders from all over the country. I then continued this research in a study developed in partnership with European colleagues, including the Dutch sociologist Abram de Swaan, a professor emeritus at the University of Amsterdam. We set up a group to investigate the perceptions people had of poverty in Brazil, South Africa, the Philippines, Bangladesh, and Haiti. We prepared a questionnaire to interview 80 representatives of the elites in each of these countries. The results were published in 2005 in the book *Elite Perceptions of Poverty and Inequality*, which I edited with Mick Moore, a professor at the Institute of Development Studies at the University of Sussex in the United Kingdom. The work was well received

by other specialists but has only recently gained visibility. At that time, inequality was not the main concern of my partners, who were more focused on poverty issues. I had trouble persuading them to include the word "inequality" in the title of the work. Today, what draws the most attention to the book is precisely the fact that it deals with the idea of inequality. I just returned from a doctoral panel at the London School of Economics and Political Science in which the doctoral candidate analyzed the views held on inequality and poverty by the wealthiest 1% of London's population. She had developed her thesis based on the book that Mick Moore and I edited. Between 2013 and 2014, I further developed the same study with another team of researchers to evaluate the perceptions of elites in Brazil, South Africa, and Uruguay. Questionnaires were completed by 180 people in each of these countries. The idea was to assess whether there were changes over time and what they were. We have not published the results of this project yet. I am behind on it because I got involved in another big project to which I have currently been concentrating most of my energy.

#### **How did your interest in elites develop into an object of research?**

The concept of "elite" has many definitions. Instead of adopting, for example, a concept based on income or wealth or notoriety and celebrity, I adopt a positional criterion; in other words, one based on an institutional position. By doing this, I presume that those at the top of certain institutions control material and symbolic resources. By the 1990s, after the dictatorship, the Brazilian political scene was optimistic. There was, however, the perception that inequality was widespread and nothing was being done to change the landscape. I began to feel concerned about the reality of living under these conditions. How do we organize our thinking in a society with so much disparity in terms of perspectives on life? At that time, various studies had already been performed on poverty and survival strategies under precarious conditions. However, I did not want to approach the subject from that point of view. I wanted to understand how people who are not poor live with, and justify, the existence of poverty.

### ***And did you?***

Most people who study poverty and inequality argue that to reduce disparities in society, it is necessary to rely on the goodwill of the elites, focusing on philanthropy to achieve this goal. I agree that philanthropy can be one path. However, with this study, I wanted to identify motives that could stimulate the elites' interest in investing in reducing inequalities. In the first stage of our research, the results of which were published in 2005, we identified that, in general, the elites of Brazil, South Africa, the Philippines, Bangladesh, and Haiti understood poverty and inequality as being problems that affected them. According to our questionnaires, they preferred to protect their property individually, investing in security, walls, and alarms without allying with the state. In an effort to understand how the Brazilian elite mobilizes to do something for the most needy, I have based my research on the Swaan model. He argues that the welfare state was built in Europe because elites thought they should involve the government in the protection of their interests. For Swaan, elites act reactively and supported the creation of this welfare state because they felt threatened. During our research, I observed that this motivation can be based on fears of violence or threats to material assets. This has allowed me to state that the stimulus for reducing inequality can be both philanthropic and defensive. In the quest to secure their position in political, intellectual, corporate, or bureaucratic spheres, the elite needs to consider that inequality and poverty also pose risks to it.

### ***What was your finding regarding Brazil?***

During one stage of research performed in 2013 and 2014, I observed a different attitude in Brazil. The country was experiencing a period of economic and social prosperity and the elites realized that if there were a redistribution of income, they would also benefit because the consumer market would become more dynamic and the workforce more qualified. As a result, they began to bet on social progress as something that would also generate benefits for themselves. Comparing Brazilian data with data from South Africa, we noticed significant differences. In the original study,

the elites of the two countries thought similarly. Later, in Brazil, the people who occupied these positions still considered economic growth to be the most important factor for the nation, but they recognized that if there was social progress for the poorest, the possibility of economic advancement for all groups increased. Here, the elites positioned themselves in favor of progressive economic measures such as the Bolsa Família [the federal Family Allowance] program. In South Africa, elites continued to argue that it was necessary to grow the economy first and then redistribute income.

### ***What is the other project that you're involved with?***

Along with other researchers, I am coordinating the development of a global panel to assess social progress in various countries, especially over the last 50 or 60 years, and map out the problems currently affecting us and any serious threats to continuous progress. The preservation of the environment, the issue of chemical and biological weapons, and the imperative of sustainable growth are a few of the enormous challenges we are faced with. I am part of the scientific committee, and I coordinate one of the chapters together with the Dutch historian Marcel

van der Linden. The panel involves approximately 300 researchers and is being drafted without government financial assistance because we wanted to maintain our autonomy as regards possible political pressures. Three books containing the results of this project will be published in July by Cambridge University Press. In addition, six of us who are coordinating the project have written a short work presenting the panel's results for a nonacademic audience, which will also be published by Cambridge University Press later this year. My research on the elite and the panel on social progress are the two intellectual activities that occupy me most these days.

### ***Has the panel identified any social progress?***

Of course, there is no denying that mankind has experienced immense material progress, among them improvements in the areas of health and life expectancy. However, these gains are not distributed equally, and miserable conditions are the reality for millions of people. It is also necessary to take into account issues concerning equality and the recognition of diversity. There is no doubt, for example, that patriarchal domination has declined significantly in many contexts, but much remains to be done. Thousands of women around the world still have to fight for the right to merely attend school, as seen in places such as Pakistan and Afghanistan. Religious freedom is brutally denied to many minorities, such as Christians in Nigeria. Homosexuals are punished by imprisonment and, according to recent reports, even capital punishment in countries such as Sudan, Iran, Saudi Arabia, and Yemen. Moreover, we have recently witnessed the rise of authoritarian tendencies that threaten the democratic achievements we have been accustomed to thinking of as enduring and continuously expanding. The emerging crisis of democracy indicates that we urgently need to find new institutional formats to ensure political representation and participation. The growing worldwide wave of populism feeds on the dissatisfaction of significant portions of the population with a political establishment that ignores their concerns. In this context, many people are seduced by false salvationist promises of opportunist leaders.



Incentives to reduce inequality can be both philanthropic and defensive

### **Where is Brazil in this scenario?**

In the case of Brazilian society, the schism between official politics and the demands of citizens is remarkable. The climate of frustration is spreading and resentment and intolerance are growing, making dialogue impossible and helping set back various social achievements. The situation in Brazil can be seen almost as a parable of what is happening in the rest of the world. It seems that we have difficulty understanding something very simple: if the rights that some enjoy are not generalized to include everyone, we are talking about privileges and not rights. The liberal-democratic agenda, by definition, must be universal. The resistance to including new sectors of society fosters not only the dissatisfaction of the excluded but also the irrational defense of the status quo and often retrogression itself. The consequence for everyone is the loss of democratic coexistence. The magnitude of the inequality on the one hand and the denial of respect for so many on the other have led to a serious crisis of sociability among us. We all lose when social solidarity shrinks. However, it should not be inferred from the present crisis that we are condemned to face decline and barbarism. What motivates our panel's project is exactly the conviction that, as agents given rationality and volition, we have the moral challenge of thinking about alternatives to ensure that science, technology, and innovation are effective partners in the advancement of social achievements.

### **You have also been very involved in political science activities. What are they?**

Since 2013, I have been vice-president of the International Social Science Council (ISSC). There were two councils until recently: the ISSC, for the social sciences, and the International Council of Sciences (ICSU), made up of the so-called hard sciences. These two organizations are coming together to form a single council, the International Science Council (ISC). In June, we will have the first assembly of the new organization, which now includes all the sciences. The idea of unifying the organizations occurred because there is a growing awareness that we must think about social problems together, rather than separately or by discipline. We discussed this merger for two years. In late 2017, we concluded



**Brazil originated as an authoritarian state, but I do not think it is fated to continue as such**

the discussion on unifying the two councils into a new organization. That was a subject that kept me very busy in recent years.

### **With such a long and intense research history, what do you still need to accomplish?**

I coordinate the Interdisciplinary Network for Studies on Inequality, (NIED), which has been around for 20 years. We performed a great deal of research, and it bothered me that I had never studied color-based inequality in Brazil. Then, in 2004, the sociologist Michèle Lamont, a professor at Harvard, invited me to participate in a comparative study in this area. The idea was to understand how black people in the United States and Brazil and minorities in Israel deal with inequality, prejudice, and stigma. In Brazil, research on this subject usually focuses on the study of individual cases and life histories. When I received the invitation, I felt uncertain about it because I am not an expert on race. Michèle proposed that I work with Graziela Moraes Silva, currently a professor at the Graduate Institute of International and Development Studies in Geneva, Switzerland, who developed a thesis at

Harvard comparing black liberal professionals in Brazil and South Africa. It took us ten years to complete this study, and at the end of 2016, we published a book presenting our results, titled *Getting Respect: Dealing with Stigmatization and Discrimination in the United States, Brazil, and Israel* (Princeton University Press, 2016). I want to publish this book in Brazil, but for now it is only a concept.

### **In the article "The National State as Ideology: The Brazilian Case," you call attention to the fact that authoritarianism is in the genesis of the Brazilian state. Even so, is it possible to build a new national project?**

This is a subject that really energizes me. I have one foot in macro-historical sociology, but I do not consider the genesis of a society to be an "original sin." If I thought that because we originated as an authoritarian state we were fated to continue as such, I would not have studied social sciences. We choose this career when we believe that it is possible to change things. Sometimes historical works are read as if they were concrete evidence that we have a manifest destiny of authoritarianism. We do not. We choose things. It is common to hear that, in Brazil, there is color-based inequality today because we had slavery in the past. I agree that this is the origin of the problem, but inequality and the discriminatory and elitist aspects of our society are constantly being recreated and reactivated. These conditions do not automatically remain unchanged. We need to know how to explain why they do not change.

### **How do you view current production in the social sciences in Brazil?**

When I was a student, I learned that I should work with the research subject held at an objective distance and that we had to choose topics that we were not emotionally close to. However, that idea has changed, and I gave it up. Choosing a topic because it moves us is not a problem. It is also necessary to recognize that we all want to be original in choosing our subjects, but I think that this tendency is exaggerated at times and contributes to an excess of fragmentation, which makes it difficult to consolidate and generalize results. Teamwork is critical to academic research. ■



# One eye on science, the other on industry

An engineer provides insight into how artificial intelligence will help develop novel types of glass and explains his new definition of the material

**Neldson Marcolin**

PORTRAIT Eduardo Cesar | Published in July 2018

**AGE** 64

**SPECIALTY**

Materials science / Glass

**INSTITUTION**

Federal University of São Carlos (UFSCar)

**EDUCATION**

Bachelor's degree in Materials Engineering from UFSCar (1976), MSc in Physics from IFSC-USP (1978), PhD in Glass Science and Technology from Sheffield University, UK (1981)

**SCIENTIFIC**

**PRODUCTION**

3 books, 20 book chapters, 250 articles, and 20 patents

The engineer Edgar Dutra Zanotto likes to cite one of his favorite science articles to show how glass is important to science. “Glass is the eye of science,” he says, alluding to the title of a paper (“Glass: The eye of science”) by Marvin Bolt, curator of science and technology at the Corning Museum of Glass in New York. In his paper, published in February 2017 in the *International Journal of Applied Glass Science*, Bolt argues that the most important tools in the scientific revolution of the seventeenth century were the microscope and the telescope—both of which have glass lenses as primary components.

When he took an interest in the field in the mid-1970s, Zanotto had not yet come to this realization, but found the subject to be both interesting and under-researched in Brazil. Zanotto earned a degree in materials engineering from the Federal University of São Carlos (UFSCar) in 1976, but it was at the São Carlos Institute of Physics at the University of São Paulo (USP) and at the University of Sheffield in the UK—where he pursued his Master's degree and PhD, respectively – that the then young researcher was exposed to the field that would define his career.

One thing that has marked Zanotto's career is his concurrent interest in both basic and applied science. “I've always worked with one foot in each,” he says. His training in both physics and engineering enables him to formulate and test scientific hypoth-

eses and develop special types of glass for use in industry and that has special functionality for use in the human body, such as bioactive glass.

Zanotto was born in Botucatu, São Paulo and was a professor at UFSCar for 42 years. The engineer previously served as a visiting professor at universities in Europe and the US and as a science consultant for companies in Brazil and abroad. He also served as an assistant coordinator of the Scientific Directorate at FAPESP. Since 2013, Zanotto has headed the Center for Research, Education, and Innovation in Vitreous Materials (CeRTEV), one of the 17 Research, Innovation, and Dissemination Centers (RIDC) funded by FAPESP that brings together researchers from UFSCar, USP, and São Paulo State University (UNESP). He is also chairman of the Scientific Advisory Board at Serrapilheira, in Rio de Janeiro. His experience at these organizations has equipped him to actively engage in science outreach.

In the following interview, Zanotto, who is married and is the father of two daughters, discusses his most recent work and a bold proposition published in 2017 describing a new state of matter—the glassy state.

***Could you describe your latest research on the development of artificial intelligence for time savings in the laboratory?***

Our focus is on prediction. Science is almost 100% about understanding and describing natural phenomena. Whenever we understand and describe something new, we can publish a paper about it. Making predictions beforehand would be ideal, but is very difficult. If we can accurately predict a phenomenon or trend, we will not have to devote enormous amounts of time, financial resources, and energy to a large number of experiments. We are currently working with students and postdocs—professors Pedro Rino and André Moura from UFSCar and André Ponce de Leon from CeMEAI [Center for Research in Mathematical Sciences Applied to Industry, an RIDC based at USP in São Carlos]—on a computational model to predict phenomena related to the structure, dynamic processes, and properties of glass. If successful, we will be able to create novel types of glass in a significantly reduced length of time. The first two papers are now being drafted and are in the adjust-



**If our strategy works, we will be able to create novel types of glass in much less time**

ment phase. A postdoc from our group, Daniel Cassar, compiled approximately 55,000 glass transition temperature data points to begin this study.

***What is the research about?***

Glass is a rigid material made of multiple reactants that are typically melted and rapidly cooled to prevent crystallization. As a result, the atoms get trapped in a state of disorder, forming a temporarily frozen liquid that we call glass. In a crystalline structure, the atoms are perfectly organized, forming a solid. Crystallization is a naturally occurring process in all glasses but can take from seconds to millennia to occur depending on temperature. When heated, all types of glass undergo a phenomenon called the glass transition at  $T_g$ —the temperature at which a transformation from rigidity to a high-viscosity liquid occurs—that is dependent on the chemical composition. To develop a glass with a new functionality without spending large amounts of time and energy on experimental tests, it is helpful to know the value of  $T_g$  and other properties beforehand. With this idea in mind, Cassar scanned the literature from the last 50 years for papers describing the chemical composition and the relevant  $T_g$  of different glasses. Cassar

compiled 55,000 different compositions of oxide glasses—there are currently more than 400,000 cataloged glasses. With the help of the artificial intelligence expert André Ponce de Leon, Cassar created an algorithm that was “trained” to correlate  $T_g$  with the chemical compositions of 45,000 of these glasses. We used the data for the 10,000 glasses omitted from the training stage to test the ability of the new algorithm to predict  $T_g$  values, and we compared them with the reported values to see if they were accurate. There is still room to optimize the resulting neural network, but currently, the maximum error is 6% in 90% of tests, which is good and consistent with the typical errors for the experimental data. With this software, we will be able to predict the  $T_g$  of any putative oxide glass. The same logic can be applied to predicting other physicochemical properties of glass.

***How will this program save time?***

In 2004, I published an article with Chico Coutinho [physicist Francisco Bezerra Coutinho from the USP School of Medicine] in which we calculated how many glass compositions would be possible using 80 “friendly” chemical elements. We used 1% composition increments to combine those elements in different ways. In this prediction exercise, we found that it would be possible to obtain  $10^{52}$  types of glass—an astronomical figure. The 400,000—or  $4 \times 10^5$ —inorganic glasses known today represent only a tiny fraction of that number. We would require an infinite amount of time and resources to produce  $10^{52}$  different types of glass, which is simply impractical. The solution is to perform computational simulations until we find interesting formulas that could have unusual properties. Then, we can go to the lab to test each composition and see if it really delivers the properties that the software predicted.

***Last year you proposed a new state of matter—the glassy state—something that is neither a solid nor a liquid. If it is neither of these, what is it then?***

I will begin by answering another question: what is the difference between information and knowledge? We begin with one piece of information, then find another, then another; information accumulates over time. By joining and connecting the different pieces of information, we



The physicists Robert Weeks, Phillippe Bray, and Nevil Mott (a 1977 Nobel Prize winner) with Zanotto, who had just been handed a Zachariasen Award from JNCS, and engineer David Pye in 1990 (left to right)

gain knowledge. It has taken 40 years of studies and research to gather insight, reflect on it, and then write the article on the glassy state, published in the *Journal of Non-Crystalline Solids* [JNCS].

#### **What are the pieces in the information puzzle?**

The first is the atomic structure of glass, which is the same as that of the liquid from which it derives. Glass is a frozen liquid that is temporarily in a noncrystalline state. Next comes the concept of structural relaxation—a spontaneous and partial rearrangement of the molecules in the material—and finally crystallization, when all the atoms and molecules are aligned in a well-defined, three-dimensional structure. This transition happens with all glasses, which will all eventually crystallize over longer or shorter lengths of time. How long? At relatively high temperatures, the change takes just a few hours. At room temperature, the amount of time is very difficult to precisely determine, and we need to perform calculations and simulations. The new definition of glass proposed in our 2017 paper states that the molecular structure of glass is the same as that of the mother liquid, with the atoms frozen in the same position, and is very different from that of a crystal. Over time, glass spontaneously relaxes until it crystallizes. At a temperature close to  $T_g$ , glass crystallizes in a matter of minutes or hours; at low temperatures, glass takes much longer to crystallize.

#### **Were these concepts already known?**

Researchers in the field have long been considering these concepts, but no one

had put it all together like John Mauro [of Pennsylvania State University] and I did. I wrote the first draft of the article, and Mauro joined me later. We combined different information and clarified the nature of glass.

#### **How did this collaboration develop?**

I presented these ideas during the Society of Glass Technology (SGT) Centenary Conference in Sheffield in September 2016. The Indian-American professor Arun Varshneya from Alfred University, a well-known “glass guru” and a long-time friend of mine, said straight away: “I do not agree with this package; we need to discuss it.” We had a lengthy discussion in Sheffield, and when I returned to Brazil, I decided to write a draft. I sent it to Varshneya, who invited a cousin of his, Prabhat Gupta, a very good theorist from Ohio State University, into the discussion. Varshneya also invited John Mauro, who had been his brightest doctoral student; Mauro was one of the inventors of Gorilla Glass, a special glass for smartphones. After exchanging a dozen emails with these researchers, I invited them to participate as coauthors, but they never responded. I thought the lack of response meant they disagreed with my proposition. That was in October 2016. In December, I was touching up the manuscript when John Mauro sent me a Christmas message and asked me what had become of the article. I replied that it was almost finished, but that I was the sole author as they had not shown interest in joining me. He immediately replied that he was still interested. Between Christmas and New Year, we each took turns spending a day working on the

paper until it was finished and submitted for publication. As of a few weeks ago, the paper had already received more than 7,000 views. That is many views for a paper in a small subfield of materials science. To give a quantitative idea of how large that number really is, the JNCS website has 26,000 articles, and all are available to download. From publication to date [6/24/2018], our paper has out-ranked all these articles in downloads.

#### **How large is the glass research community?**

Estimates indicate that there are approximately 3,000 glass researchers globally and only 100 to 120 in Brazil who publish regularly in this field. Of these, 14 professors and 60 students and postdocs are at CeRTEV. Outside Brazil, there are companies with many more researchers, but in an academic setting, there are few large groups. I know of only one that is bigger than ours—a very large group in Rennes, France. In China, there are possibly larger groups because they publish even more prolifically than US researchers in this field. In Japan, the US, and Europe there are typically one to three professors in each group. For these reasons, I believe our team is among the global top five. When Hellmut Eckert [a German chemist, deputy coordinator at CeRTEV, and professor at USP São Carlos] and I formed the RIDC group, the center gained greater visibility on the international scene.

#### **Has visibility increased across both science and technology?**

Yes, for both. In fundamental scientific research, we have a group that uses different techniques to characterize the structural features of glass. Structure and chemical composition are what determine the optical, mechanical, thermal, magnetic, chemical, and biological properties of glass. This group also does research on dynamic processes, the mechanisms at play when glass is heated—the atoms begin to move, relax, melt, or crystallize. Crystallization is the area in which I am most actively involved. We study both structure and dynamic processes, and the two subjects combined determine a given glass’s properties and potential applications, which are divided into five categories at RIDC: mechanical properties, which we research to develop



Bioactive glass ceramics: an eye implant (*left*) and middle-ear ossicles

stronger and more resistant glasses and glass ceramics, a type of material that is currently high in demand in global industry; electrical properties, such as for ionic conducting glasses, with potential applications in new and more efficient batteries; bioactive properties, for glasses made of bioactive materials for use in living organisms; optical properties, for which glass is best known and that we modulate by adding impurities to modify color, absorption, etc.; and last, materials for catalytic processes.

#### ***How is research on bioactive glass progressing?***

These materials are very promising. Bioactive glass was first invented in the early 1970s with a chemical composition comprising sodium, silicon, calcium, and phosphorus. This composition gives the glass high bioactivity when in contact with body fluids. This type of glass can be used in applications that include bone regeneration, such as prostheses, dental problems, skin wounds and degeneration of nerves and cartilage. As a powder, bioactive glass functions as a kind of glue. Some of these potential applications are already in use. For example, an artificial iliac bone made of bioactive glass ceramics has been developed by Tadashi Kokubo of Chubu University, Japan, for implantation in the hip. According to Kokubo, this glass has already been used in thousands of patients. Here at UFSCar, with the help of two former students who are now professors, Oscar Peitl and Murilo Crovace; several post-docs, notably Marina Trevellin; and students, we have created a bioactive glass ceramic material similar to the middle ear ossicles that is used as a replacement when the ossicles have been damaged as a result of a severe infection. We conducted successful clinical trials at the USP School of Medicine in Ribeirão Pre-

to led by the physician Eduardo Tanaka Massuda, but further testing is needed to receive approval from Anvisa [Brazilian Health Regulatory Agency]. This [Zanotto shows a specimen] is another example: it is an artificial eye made of a patented bioactive material. Once implanted, the eye attaches to the nerves in the ocular cavity, so it moves naturally in tandem with the good eye. We conducted successful clinical trials at the Botucatu campus of the UNESP School of Medicine led by Silvana Schellini and Simoni Milani Brandão. But again, we need to continue testing.

#### ***You publish in the Journal of Non-Crystalline Solids, of which you are also an editor. Doesn't this create a conflict of interest?***

I began working as an editor in 2010, but I had already published approximately 70 articles in the journal before then. This journal is my favorite journal because it was established 50 years ago, because it is highly rigorous—it rejects 2/3 of submissions, with an average response time of only six weeks—and especially because it is read and highly respected by the global glass research community. When I was invited, I replied to the Elsevier publisher Karine Van Wetering that I would agree to be an editor only if I could continue to publish in the paper. She replied that there would not be a problem as there would be three editors. My papers would be submitted to ad hoc peer reviewers without my knowing who they were. She wanted me and the other editors to continue publishing there because that would send a message to readers that the editors value the journal they edit.

#### ***What made you first take an interest in glass?***

I graduated from the third materials engineering class at UFSCar, which created

the program—the first in its field in Latin America—in 1970. At the time, there were few professors available in the field, so UFSCar invited visiting professors. The visiting professors came from USP and UNICAMP, and many came from abroad. One of these professors, Osgood James Whittemore [1919–2010] from the University of Washington, invited me to work on a scientific initiation project. The project was an experimental study on the chemical durability of candidate glasses for the encapsulation of radioactive waste. The purpose of the project was to collect waste from nuclear power plants, add reagents, melt everything, and cool it down quickly, forming a large block of glass. The resulting monolith is compact and impermeable and is intended to be buried in an abandoned coal mine many meters underground, encapsulated and separated well from the surface environment, without contaminating the air and groundwater. This method is still in use today. I then began to do research on glass. I picked up books from the library and started reading papers. I was keenly interested. It was also an opportunity to practice my English. These interests landed me a job as an assistant lecturer in the Department of Materials Engineering [DEMa] at UFSCar.

#### ***Was that the only reason you were hired at the age of 22?***

I was a dedicated student, spoke English, and was performing research on glass. DEMa needed professors in this field, and there were no specialists available. Because I only had an undergraduate degree, I was given an ultimatum from the head of the department, Dyonísio Garcia Pinatti [1946–1986]: “You have two years to get a Master’s degree in any subject related to glass, then study abroad for a PhD, then return to head our glass research group.” Fortunately, the only researcher doing glass research in Brazil at the time was Aldo Craievich from the Physics department at USP in São Carlos. I owe much of my scientific training to having completed my Master’s degree in physics under him. Craievich then recommended me to an acquaintance of his, the famous physicist Peter James [1940–2005] of the University of Sheffield. I was awarded a grant from CAPES [Brazilian Federal Agency for Support and Evaluation of Graduate Education] and went to do my doctorate

under Peter from 1979 to 1982. Sheffield had the largest glass research team in the world at that time. The experience was extremely valuable for my training.

***In what way does your group collaborate with companies?***

At all levels. We might make an interesting discovery and then prospect for companies potentially interested in conducting pilot-scale trials and licensing the invention. Companies might approach us instead. For example, we helped to perfect this material [Zanotto produces a 1 cm<sup>2</sup> piece of glass and illuminates it with a laser], which diffracts light. This material has nanometer-sized crystals inside that are spaced one visible-light wavelength apart or approximately 400 nanometers from each other. This is the only material in the world that can be used for high-power laser diffraction gratings. There is a crystal hologram in here. Any high-power system, such as an industrial laser machine, requires several parts like this inside. There are only three companies in the world that produce this material. This tiny part costs US\$5,000. The product was already available in the market, and I helped to optimize it. The material was invented at Corning and was then improved and produced by Optigrate at a facility in Orlando, Florida. I spent 10 months there in 2005, on invitation, while taking a sabbatical at the University of Central Florida. Their material performed very poorly; the material was unfit to market because it scattered too much light. Optigrate agreed to allow me to publish certain articles during the course of the collaboration, which is not customary, as companies typically require us to sign a nondisclosure agreement.

***You have recorded many of your lectures about glass. Why?***

I produce two types of videos: formal lectures and science outreach videos. I record all of my lectures and publish them on the internet. The results have been fantastic. If a student misses a class, the student can just watch the video. If students need to study for a test, the lectures are readily available. We also produce 1- to 5-minute educational videos explaining concepts and experiments with glass, and we have science-themed manga in print and on the CeRTEV webpage. We began to do science outreach



I record all of my classes and publish them on the internet. If a student misses a class, they can just watch the video

due to requirements placed on RIDC. It has been pleasurable as well as a learning experience.

***Serrapilheira, of which you are a member, shares the same interests, doesn't it?***

The institute's founders and sponsors, Branca and João Moreira Salles; the Board of Trustees; and the Science and Administration boards all expect researchers and grant holders to engage in science outreach if they have the desire and the skills to do so. This year the institute launched a public call for proposals for its first science outreach support program, called Camp Serrapilheira, to train facilitators and to identify and select outreach projects to be funded.

***Do you think the institute can make a difference in funding science?***

Yes. Serrapilheira is currently working to organize research groups led by promising young researchers who demonstrate potential for high-level research in relevant fields at the cutting edge of knowledge. An estimated R\$16–18 million will be invested annually. The grant model is a dream for researchers as it is much

more flexible than that at any public research institution. The project selection system is rigorous, but successful candidates can use their grant money toward any research-related costs, such as hiring other researchers, buying equipment and materials, engaging services, and traveling on research-related business. These researchers can do so without having to resubmit resumes, subproject proposals, cost estimates, or price quotes for review. Moreover, the laborious stage of project accounting is handled by a foundation, not by researchers. We provide full flexibility because we trust researchers and want them to devote most of their time to research, not to project management. This model is in contrast to public agencies, which typically demonstrate mistrust of researchers. For example, I have 42 years of research experience, I am head of a RIDC, and I am a member of the ABC [Brazilian Academy of Science], but when I apply for a scientific initiation grant from any government agency, I have to write a project proposal, submit an updated resume, and submit resumes for my students. There is a large painstaking bureaucracy. At Serrapilheira, we trust our researchers and give them greater freedom.

***You like to say you “believe in old-school researchers.” Why?***

“Old-school” researchers would dedicate 20, 30, 40 or even 50 years not only to collecting data but also—and especially—to connecting all the data to create knowledge. Of course, there are bright young scientists who can make the necessary connections in less time. I have discussed this several times with Fernando Reinach, a biologist and fellow member of the Board of Trustees at Serrapilheira. Reinach is among those who think that only young researchers have a future. I disagree. I believe that senior researchers who are active and remain motivated in tackling the day-to-day challenges of doing research, designing and conducting experiments, testing hypotheses, creating theoretical models, attending conferences, mentoring, publishing, teaching and learning—and receiving criticism—can continually improve. The quality of my current research is better than that of my earlier research 10 and 15 years ago. I hope to continue making progress in the coming decades. ■



# A strategy for research data



Researchers are being encouraged to better manage and share the data they produce

**Bruno de Pierro**

PUBLISHED IN MAY 2018

**M**anaging and storing large volumes of research data are challenges faced by scientists in every field. In the last decade, research funding agencies such as the National Science Foundation (NSF) in the US and the Economic and Social Research Council in the UK have increasingly required grant applicants to submit data management plans outlining how research data will be managed, preserved, and made available through public repositories. Their aim is to ensure that information is shared, that research data is reusable, and that experiments are reproducible, facilitating further scientific discoveries and optimizing returns on funding investment.



# A five-step guide to datamanagement plans

1. Specify the types of data that will be produced during the project. For example: specimen collection records, experimental results, charts, maps, video footage, spreadsheets, audio recordings, or images.



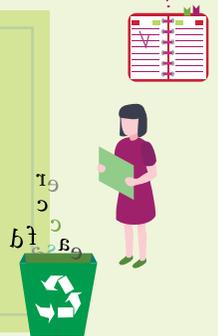
2. Communicate any ethical or legal restrictions on sharing the data as well as precautions for protecting data privacy, confidentiality, security, and intellectual property.



3. Provide instructions on preserving and sharing data (for example, whether the data will be made available immediately or only after publishing a paper).



4. Describe the methods that will be used to store and provide access to the data. Include metadata (data that describes datasets) so that users can reuse files that have been archived in repositories.



5. Update the plan as necessary to describe any change of course or new methodologies.

SOURCE: CLAUDIA BAUZER MEDEIROS

Although data management planning is not currently mandatory in Brazil, last October FAPESP took a step in this direction and announced that grants for “thematic projects”—projects lasting five years and characterized by ambitious objectives—would be required to include a data management plan as a supplement. The requirement would be gradually extended to other grant mechanisms later in the year. “This is among the first initiatives in Brazil to establish policies and guidelines for managing scientific data,” says Claudia Bauzer Medeiros, a professor at the Computing Department at the University of Campinas (UNICAMP) and head of FAPESP’s eScience program.

The Foundation’s *Code of Good Practice* launched in 2011 already required researchers to submit records from their research. “They will now be required to specify how their data will be managed—from collection to storage—and how and when the data will be made available,” she says. UNICAMP was

ILLUSTRATION: JÚLIA CHEREM RODRIGUES WITH IMAGES FROM FREEPICK



## Researchers are being required to specify how their data will be managed, from collection to preservation

the first university in Brazil to post a data management plan template on the DMPTool website ([dmptool.org](http://dmptool.org)). The initiative, led by Benilton de Sá Carvalho of the Institute of Mathematics, Statistics, and Scientific Computing (IMECC), allows researchers from his university to easily create their plans online and make them available worldwide. More than 200 research institutions in different countries have officially adopted DMPTool to create and share data-management plans. Currently, only three Brazilian universities are on the platform: UNICAMP, the University of São Paulo (USP) and the Federal University of ABC (UFABC).

**M**aking experiment or field data widely available can lead to collaborations and accelerate scientific breakthroughs by increasing the visibility of research outputs. In 2016, an international consortium involving more than 30 organizations including the Oswaldo Cruz Foundation, the Chinese Academy of Sciences, and the National Institutes of Health (NIH) in the US encouraged researchers to share the data that they had collected during the recent Zika virus outbreak. As a result, in a matter of months they were able to publish research showing the link between Zika and microcephaly. In the field of biodiversity, storing research data in public repositories makes millions of records on plant and animal species widely accessible, facilitating further research. The speciesLink network, a digital biodiversity database developed in Brazil, allows researchers to find information on the occurrence and distribution of species of microorganisms, algae, fungi, plants, and ani-

mals. The platform has compiled records from 470 collections in Brazil and other countries. These collections contain roughly 9 million records on 125,000 species, including records on 2,756 threatened species.

However, data management planning involves more than simply listing data on an online database. According to the Digital Curation Centre, a UK center specializing in digital curation, a data management plan should include information on how and why data have been created and stored. This means that information must be provided on how metadata—or data describing other data—will be organized. “Metadata are descriptions of datasets, detailing how, when, and where they were produced, how they can be reused, and who created them,” explains information scientist Márcia Teixeira Cavalcanti, a professor at Universidade Santa Úrsula, Rio de Janeiro and a member of the Information, Heritage, and Society research group at the Brazilian Institute of Information in Science and Technology (IBICT). “It’s about identifying and standardizing scientific data so they can be easily accessed in repository searches and reused in other research,” she says.

In 2016, Cavalcanti was involved in curating data on the CarpeDIEN platform ([carpedien.ien.gov.br](http://carpedien.ien.gov.br)) of Brazil’s Nuclear Energy Institute (IEN), which performs research in fields such as radiopharmaceuticals and artificial intelligence. “It took time to develop the right metadata models for the kind of information we were dealing with,” she says. According to Cavalcanti, the curation process should begin before any data is produced. “In a data





management plan, it may also be important to specify the software or equipment that will be used to generate information such as images or algorithms.” Claudia Medeiros agrees that this type of information can be essential. “Often having access to the data is not enough to reproduce an experiment. You also need to have the same computer programs or operating system to recreate the same conditions as in the original study,” she says.

**D**uring her time at IEN, Márcia Cavalcanti conducted a survey on data repositories in Europe, which she published last year in a journal of the Institute for Humanities and Information Sciences of the Federal University of Rio Grande (FURG) in Rio Grande do Sul. The survey covered 33 countries and found that only nine supported open-access research repositories in 2016. Her findings show that data-sharing is still incipient in many European countries. Horizon 2020, the largest research funding scheme in the European Union established in 2007, issued a step-by-step guide on data-management plans in 2016 before making them mandatory for all grant applications in 2017. One important aspect of the guide lies in the attention it draws to conditions under which sharing raw data can create ethical issues such as clinical trials that use personal data and must protect patient privacy.

Barring these exceptions, there are really no arguments to justify publicly funded researchers in refusing to furnish their data,” says Gilberto Câmara, a researcher at the Brazilian National Institute for Space Research (INPE) and a coordinator of the FAPESP Research Program on Global Climate Change. According to Câmara, many researchers will hold off archiving experiment data until

## Publicly funded researchers cannot omit themselves from sharing information, says Câmara



their research has been published in a journal on the argument that their data could be appropriated by others and published without them receiving credit for them. “That’s a poor excuse,” he says. Câmara explains that information can be safely archived before publishing a paper, as all data are assigned an identification code known as a Digital Object Identifier (DOI), so they are traceable. “The fact is that, unfortunately, many researchers don’t want others to publish research before they, who collected the data, have published their work,” says Câmara.



“All the data from my research are archived in open databases as they are collected,” says the researcher, who publishes data from satellite-image analyses on Pangaea, a platform for georeferenced data. Recently, information he stored in this digital repository was used by researchers from Restore+, an international consortium for land-use research based in Germany. Câmara welcomes FAPESP’s initiative to require researchers to develop data-management plans. “This can help to address bad habits in the scientific community by promoting good practices in data management,” he says. “There are researchers who feel they own the data and will only share it with their colleagues if they get something in return, such as co-authorship of the paper. This, unfortunately, is all too frequent,” he says. ■



# Precocious entrepreneurs

OECD study places Brazil among the countries with the largest number of startups founded by students or recent graduates

PUBLISHED IN JUNE 2018

A report by the Organisation for Economic Co-operation and Development (OECD) shows that entrepreneurship among university students and recent graduates is highest in countries such as Canada, Australia, India, and Brazil. In these nations, students account for more than 10% of all entrepreneurs starting new technology companies—a rate higher than those of countries such as the United States, Israel, the United Kingdom, and France. The OECD evaluated the profiles of startups registered on Crunchbase, a database with information on approximately 447,000 innovative companies based in 199 countries. Only 290 startups were identified in Brazil, but 12% were founded by undergraduate students or recent graduates. Although they have a significant failure rate, these startups act as a gauge of how important innovation is to young people and of often they draw the attention of large companies interested in new business models.

In the countries analyzed, the gaming, transport, education, and e-commerce sectors were the most popular for student entrepreneurs. It is no coincidence that innovation in these areas is usually tied to software applications and low-investment ideas. Startups in sectors such as bio-





Alex Matioli (*left*) and Vinícius Freitas (*right*) founded their startups before completing their undergraduate degrees

technology, health, energy, and food are usually created by more experienced people who are studying or have already studied at the graduate level.

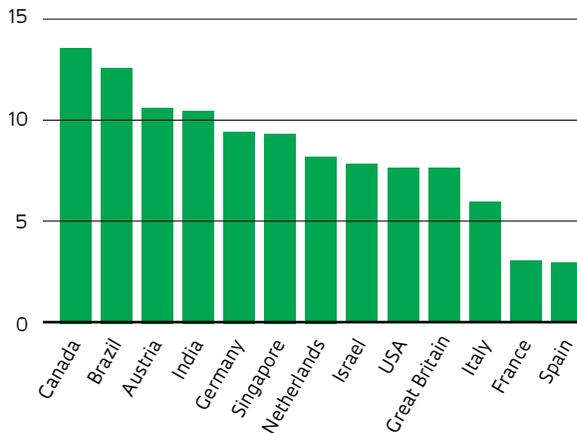
Rafael Ribeiro, director of the Brazilian Startup Association (ABStartups), believes that a number of interconnected factors explain the entrepreneurship of students and recent graduates in Brazil. “Young people tend to be more risk-tolerant and are often motivated by failure,” he says. “In addition, the current economic crisis makes entrepreneurship and potential financial independence an attractive prospect.” According to the OECD report, student entrepreneurship has increased thanks to the success of startups that have grown into global giants such as Facebook, Microsoft, and Apple. Despite being exceptional cases, all three companies were started when their founders—Mark Zuckerberg, Bill Gates, and Steve Jobs, respectively—were undergraduates, and none of them completed their studies.

Computer scientist João Machini, 29, helped found three companies at the end of his undergraduate degree at the Institute of Mathematics and Statistics of the University of São Paulo (IME-USP). The most recent started four years ago is WorldPackers, a company that advertises volunteer work opportunities from around the world. “It is a collaborative system involving hostels, homestays, and NGOs [nongovernmental organizations], where travelers exchange skills for accommodation,” he explains. The platform has more than one million users who each pay an annual fee of US\$49 to use the service. Machini, whose parents are both university professors, considered an academic career himself, but decided against the idea while working on his undergraduate research project. “Entrepreneurship is very dynamic. To understand how a new idea is being received, you really need to be close to your customer, and startups are better for this than big companies, which involve more bureaucratic internal processes.”

There is a growing trend of large companies such as Microsoft, Google, Telefónica, and Bradesco establishing programs that aim to accelerate technological development through startups (see Pesquisa FAPESP *issue no. 226*). “Big companies want to learn and absorb the new business models created by startups, many of which—such as Uber, Airbnb, and Brazilian company Nubank—have grown so rapidly that they are threatening traditional markets,” explains Jaercio Barbosa, coordinator of the School of Entrepreneurship (ESE) of the Brazilian Micro and Small Business Support Service (SEBRAE) in São Paulo. “Startup accelerators encourage young people to create new companies,” says Barbosa. Business incubators based in universities also play an important role. “These environments

# Young business leaders

Startups founded by undergraduate students and recent graduates in select countries (%)



SOURCE OECD, BASED ON STARTUPS REGISTERED ON THE CRUNCHBASE PLATFORM

provide students with institutional support and expert guidance in the form of technological consulting, business administration, and commercial structuring,” explains Guilherme Ary Plonski, scientific coordinator of the Technology Policy and Management Center at USP.

Founding a startup while still studying, however, can sometimes be a poorly timed and risky decision, says Mariana Zanatta Inglez, manager of the Business Incubator at the University of Campinas (UNICAMP). “Some students are not able to reconcile their studies with the life of an entrepreneur,” she says. “This can undermine their education, while they are not yet ready to run a company.” Alex Matioli, 27, studies business administration at UNICAMP and divides his time between classes, his job at a board game bar, and Rubian, the startup he founded in 2015. “The objective is to develop bioactive extracts for application in cosmetics and nutraceuticals (a type of food supplement).” The company is studying achiote and passionfruit features in partnership with UNICAMP and supported by FAPESP’s PIPE program. One obstacle that Matioli had to overcome was a lack of financial resources to get his company off the ground. “I did not want to rely solely on financial help from my parents, so I started working at a bar and saving

money. The help of a business mentor, who later became a Rubian partner and investor, was also essential.”

A 2017 survey by SEBRAE found that only 28.4% of student entrepreneurs were studying a business-related subject at university, and at the institutions that offer such courses, just over half focused more on “finding inspiration” than on practical knowledge. “There are very few schools in Brazil that aim to train entrepreneurs,” says Jaercio Barbosa of SEBRAE. Another study conducted in 2016 by the universities of Bern and St. Gallen in Switzerland surveyed more than 122,000 students from universities in 50 countries. It found that 80.3% of the students intended to work as employees immediately after graduation. Only 8.8% said they wanted to start their own company after completing their studies. However, 38.2% said they would open a business five years after graduating—a period they deemed as enough time to take a graduate course or gain valuable work experience.

## MATURITY

Vinicius Freitas, a business administration student at the Institute of Education and Research (INSPER), took a two-year internship in the financial sector before starting his business. “I worked with

experienced colleagues and this accelerated my learning. If I had started the company before taking the internship, the chance of it failing would have been higher.” Freitas, 24, is one of the founders of LiveHere, a Campinas-based startup that acts as a mediator between property owners and students. “Our platform simplifies the rental process for students, with no need for a guarantor or security deposit,” he explains.

The OECD survey shows that the proportion of startups founded by people with a doctorate is much higher in more developed countries such as Switzerland, Denmark, Germany, and the United States than in Brazil. In the United States, companies founded by individuals around the age of 40 tend to do better than those started by students in their twenties according to a study published on the National Bureau of Economic Research (NBER) repository in April by researchers from MIT and Northwestern University. “Older entrepreneurs often have a more specialized perspective, which is fundamental to developing more robust innovations,” says Lucimar Dantas, manager of the Business Incubator at the Alberto Luiz Coimbra Institute for Engineering Graduate Studies and Research at the Federal University of Rio de Janeiro (COPPE-UFRJ).

In Brazil, most student entrepreneurs are undergraduates or only have a bachelor’s degree as shown by the OECD survey. “This negatively influences the level of technological innovation at a company,” explains Fabio Kon, a professor of digital entrepreneurship at IME-USP and a member of FAPESP’s adjunct panel for innovation research. While Kon does not wish to discourage younger students from creating startups, he argues that we should openly discuss the limitations of student entrepreneurship due to the high failure rate of these companies and negative impacts on academic performance. Rafael Ribeiro of ABStartups notes that young entrepreneurs face a long and arduous journey. “Many tend to fail when they do not receive proper mentoring and help,” says Ribeiro. “Every student needs to learn how to build relationships with the startup community to help shorten their learning curve and enable them to validate their product or service with the consumer market.” ■ Bruno de Piero

# Closer links with industry

UNICAMP is Brazil's highest ranked university for patent applications, and USP is highest ranked for licensing royalties

PUBLISHED IN JULY 2018

The University of Campinas (UNICAMP) was the top filer of patent applications at the Brazilian Intellectual Property Institute (INPI) in 2017, filing a total of 77 patent applications, according to a June INPI report titled "Industrial Property Indicators 2018". UNICAMP's patent prowess is long-standing, the result of a decades-long policy of protecting intellectual property. Data from the university show that it currently has a total of 1,121 patents, of which 13% are currently being monetized. In 2015, UNICAMP executed 15 license agreements with companies. That number increased to 22 in 2017. These agreements provided more than R\$1.34 million in royalties

to UNICAMP in 2017, which is twice as much as the R\$660,000 earned in 2016 but less than the record of R\$1.93 million set in 2015.

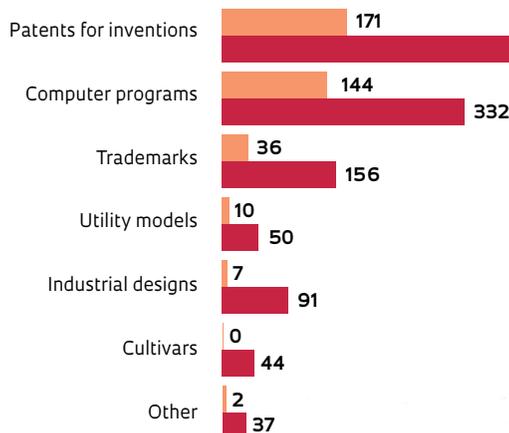
While its patent performance is on the rise, UNICAMP is surpassed by the University of São Paulo (USP), which pulled in R\$2.49 million in license revenues in 2017. USP currently has 1,299 patents in Brazil. However, USP's license agreements have remained flat in recent years: five in 2015 and four in 2017. "We're working toward playing a more active role in seeking out companies and attracting partners, instead of waiting for companies to come to us," says biologist Antonio Carlos Marques, a coordinator at the USP agency for in-

novation. "Our strategy is now to collect information about available patents and approach potential users directly," he says. "We're hoping to see more cases like Vonau Flash, a new formulation of Vonau, a medication used to prevent nausea and vomiting." The formulation was developed by the Laboratory for Medicine Development and Innovation (DEINFAR) at the USP School of Pharmaceutical Science, in collaboration with Biolab Sanus. The license agreement was executed in 2005 and is currently the University's largest source of royalties.

The INPI data show that universities were again the dominant patent filers in Brazil in 2017 (see chart on page 33). The only company in the top 10 is CNH In-

## Patent applications

Top categories in 2016 and applicant institutions



Private Public

SOURCE FORMICT/MCTIC

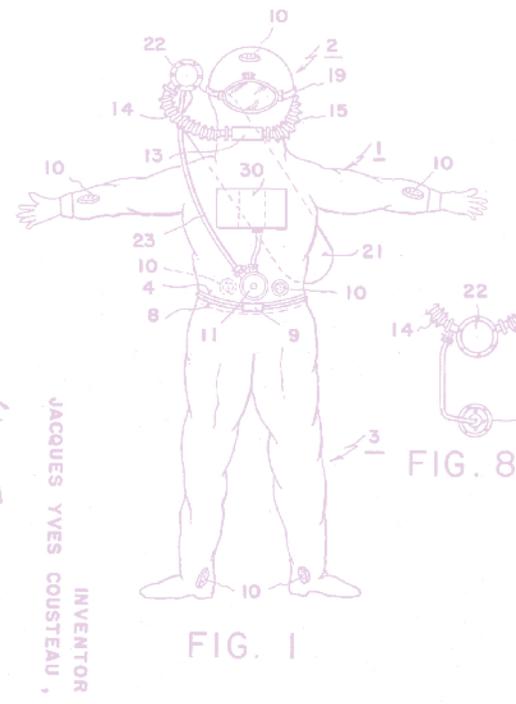
dustrial, an agricultural machinery and light truck manufacturer. In this aspect, Brazil's science, technology, and innovation ecosystem differs greatly from developed countries, where companies are the most vested in protecting and monetizing intellectual property (see Pesquisa FAPESP issue no. 123). Revenues from technology transfer agreements executed by science and technology institutions have grown in recent years and was R\$437.8 million in 2016, according to a report on Science, Technology, and Innovation Institution Policy Information Filings (FORMICT) prepared by the Brazilian Ministry of Science, Technology, Innovation, and Communications (MCTIC). Of total revenues, R\$34.4 million are from licenses for intellectual property rights.

In 2016, 278 institutions, 193 public and 85 private, submitted policy information filings. In total, the filings reported 823 license agreements for intellectual property rights across patents, software or cultivars. Southeastern Brazil has the highest volume of reported revenues, with 59 license agreements generating R\$21.5 million in revenues (see table opposite). "We are likely to see a boost in new patents and license arrangements with the recently introduced regulations on science, technology, and innovation," says MCTIC analyst and FORMICT coordinator Antenor Corrêa, referring to Act 13.243/2016, introduced by the federal government in February (see Pesquisa FAPESP issue no. 265). The new regulations permit Technological Innovation Centers (NITs), such as the innovation agencies run by USP and UNICAMP, to operate not as university departments but as private, not-for-profit organizations with their own legal personality.

One of UNICAMP's largest technology license agreements was executed with Cargill Agrícola, which uses a technique developed by researchers at the School of Food Engineering to produce fat that is low in saturated fatty acids. The process was licensed in 2014 and is used to produce food products such as cookies. The UNICAMP innovation agency, Inova, has implemented a range of strategies in recent years to boost technology transfer to industry. "More than just filing patent applications, our mission is

to develop license arrangements so that academic knowledge ultimately benefits society," says Inova director Newton Frateschi. The agency has worked to build closer relations with industry by helping companies access the innovation developed at the university. Inova has recently subscribed to the 100 Open Techs initiative, an online platform created by not-for-profit organization Wenovate to connect companies to solutions created in an academic setting. Last year, the institution listed 192 university-developed technologies on the platform, leading to 85 business meetings with companies.

Inova has also invested in building a platform to facilitate interaction between researchers and UNICAMP's



## Revenues

From technology transfer agreements executed by research institutions in 2016, by region\*

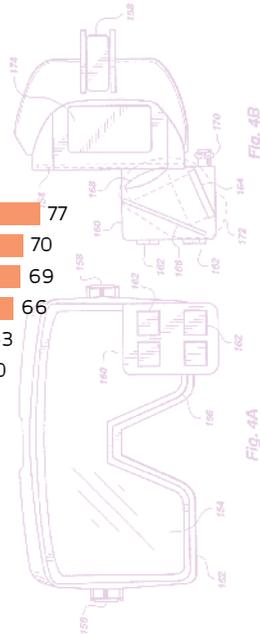
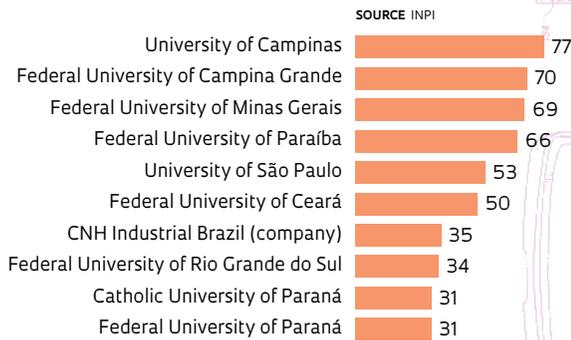
Type of agreement	Amounts in R\$			
	SOUTH	SOUTHEAST	MIDWEST	NORTHEAST
Licenses for intellectual property (patents, industrial designs, software, cultivars, scientific or artistic works, and other)	1,641,875.11	21,523,996.59	10,903,005.91	350,000.00
Partnership agreements for research, development, and innovation (RD&I) involving technologies, products or processes	119,627,461.11	95,770,467.90	6,036,270.00	301,559.00
Know-how, technical assistance, training, and other services	36,579,787.36	71,458,743.06	0	0
Co-ownership agreements	2,352,031.44	270,000.00	0	0
Permission for the use of laboratories, instruments, and equipment by Brazilian companies and nonprofit organizations	2,114,104.02	0	0	0
Shared use of laboratories, instruments, and equipment by small firms under incubation	149,850.00	117,600.00	6,690,165.31	0
Use of intellectual property in RD&I projects	21,838,303.14	341,778.68	35,837,327.54	0
Other	1,450,226.14	500,000.00	2,007,062.28	0
<b>TOTAL</b>	<b>185,753,638.32</b>	<b>189,982,586.23</b>	<b>61,473,831.04</b>	<b>651,559.00</b>

\*There were no revenue-earning agreements in the north

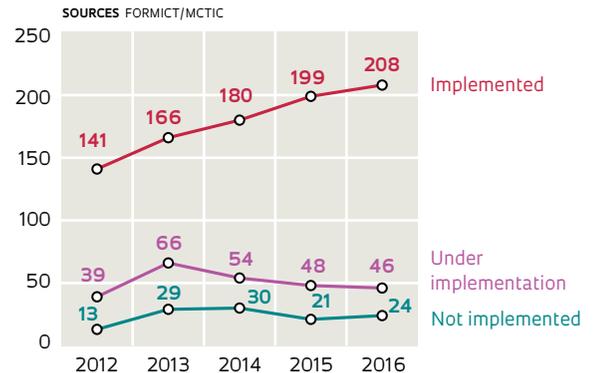
SOURCES FORMICT/MCTIC

IMAGES: GOOGLE PATENTS (PATENT NO. 2,593,988); DIVING APARATUS, J. Y. COUSTEAU, 1952

## TOP BRAZILIAN PATENT FILERS IN 2017



## CURRENT STATUS OF TECHNOLOGICAL INNOVATION CENTERS



daughter companies, including companies created by students, alumni, persons with an employment relationship with the university, startups established at the UNICAMP Technology-Based Company Incubator (INCAMP), and companies whose primary business derives from technology licensed by the institution. “It will operate as a large forum,” says Frateschi. “Companies can provide information about their requirements and establish communications directly with other UNICAMP firms or laboratories. It will create a way to accelerate technology transfer.”

The Department for Technology Transfer & Innovation at the Federal University of Minas Gerais (CTIT-UFGM), which also has a long history of protecting intellectual property, initiated a reorganization process this year to build stronger relations with industry. “We’re setting the department up to operate as a brokerage firm,” says lawyer Juliana Crepalde, an executive coordinator at CTIT-UFGM. The changes, she says, will help to generate new license and codevelopment opportunities. “With the new legal framework supporting new ways of interacting with industry, including universities holding equity interests in companies, our center can be more dedicated to managing technology assets in a structured and strategic way,” she says. “We will also be able to generate technology transfer opportunities through codevelopment agreements involving research teams from both UFGM and partner firms, instead of just operating as a patent filing

## We develop license arrangements so that academic knowledge benefits society, says Newton Frateschi of UNICAMP

department,” explains Crepalde. In 2017, license agreements mediated by CTIT-UFGM generated more than R\$650,000 in royalties. License revenues peaked in 2015 at R\$956,000. One of the technologies that CTIT-UFGM licensed in the previous year is being used to identify fraud in products of animal origin through DNA testing.

NITs have explored different methods of technology transfer. “Part of the role of a university is to produce and transfer knowledge. This can be achieved in different ways and will not necessarily generate royalties,” says Wagner Cotroni Valenti, director of the São Paulo State University (UNESP) innovation agency. According to Valenti, while the university has earned royalties from technology transfer agreements, consolidated

information on the amount of revenue is unavailable. The agency has also initiated a reorganization this year. UNESP’s focus will now be not only on patents but also on cultivars and social technologies, or technologies that create (often simple and low-cost) techniques and methods for addressing problems and needs in society. One example is a technology to help waste pickers pull their carts without injuring their spine. The technology was developed by the UNESP Cooperative Incubator (INCOP-UNESP) in Assis and donated to waste picker cooperatives.

One of the best-ranked education and research institutions for patents filed at INPI is the Federal University of Campina Grande, with 70 applications filed in 2017. Another well-placed institution is the Federal University of Paraíba (UFPB), with 66 applications. The two institutions together filed a total of 136 applications, which is more than that of UNICAMP and USP combined (*see the chart above*). “Although patent filing has increased each year, demand for licensed technologies and processes is still very low,” laments Petrônio Filgueiras de Athayde Filho, CEO of the UFPB Innovation Agency (Inova-UFPB). Created in 2013, the agency has filed a total of 225 patents to date, but none have produced royalties. One of the largest roadblocks, according to Athayde, is the state of Paraíba’s lack of a strong technology park with companies hungry for innovation. “We’re now beginning to incubate startups of our own, and prospecting for partners and companies interested in our portfolio in other Brazilian states,” he says. ■ Bruno de Piero

# On the frontiers of ethanol made from sugarcane

Project outlines scenarios to increase biofuel production in Africa and Latin America

**Fabício Marques**

PUBLISHED IN APRIL 2018



Sugarcane cutter in South Africa: bioenergy has stagnated on the continent due to a lack of investment and land ownership problems

**M**ore than 100 countries utilize sugarcane, but Brazil's performance in this area of agribusiness is unique. The country is the largest sugarcane producer in the world, harvesting 646 million tons in the 2017/2018 season, and its mills produce high yields, manufacturing sugar and ethanol on a large scale and burning sugarcane waste to generate electricity. A group of researchers from the Interdisciplinary Center for Energy Planning at the University of Campinas (NIPE-UNICAMP) has spent the past five years studying why the model used in Brazil has not been equally successful in other countries with tropical climates, as well as studying the conditions needed for Latin America and Africa to increase their production of bioenergy. "Creating a robust network of countries that produce

ethanol from sugarcane is important to solidify the biofuel market," explains agricultural engineer Luis Cortez, a professor at UNICAMP. "The objective of our project is to produce knowledge to guide strategies in these countries."

Cortez directs LACAF (Bioenergy Contribution of Latin America & Caribbean and Africa to the GSB Project), a thematic project begun in 2013 and linked to the Global Sustainable Bioenergy initiative (GSB), which discusses the viability of large-scale biofuel production on a global level (see Pesquisa FAPESP *issue nos. 162 and 163*). LACAF was established to answer three questions. First, why should a Latin American or African country take interest in producing ethanol? "The experience in Brazil, which has created a bioethanol industry and uses this fuel as a gasoline

additive, partly answers this question," says engineer Luiz Horta Nogueira, a researcher at the Federal University of Itajubá and at NIPE. "But there is a background, namely, unbalanced development. Latin America and Africa are moving farther away from industrialized societies in Asia. Bioenergy would help these regions to gain momentum."

The second question is how can ethanol be produced sustainably? The researchers tested conservative scenarios. In an article published in January in the journal *Renewable Energy*, the group noted that countries like Guatemala, Nicaragua, and Cuba could use ethanol to replace 10% of the gasoline and between 2% and 3% of the diesel they consume just through productivity gains in mills and distilleries, without having to expand the area planted with sugarcane.



Sugarcane plantation in the Cauca Valley in Colombia: the country has high productivity and follows a model similar to that of Brazil

In addition, by slightly expanding cane fields into areas of pastureland, Bolivia could replace 20% of its gasoline and diesel and still export excess ethanol. Electricity produced by bagasse (the fiber remaining after sugarcane is pressed) could meet the needs of one-third of the 11% of Bolivians who do not have access to electricity.

In Africa, the impacts would be even more extensive. A 2016 paper published by the group in *Frontiers in Energy Research* showed that a 1% expansion of sugarcane into pasture areas of Angola, Mozambique, and Zambia would generate a volume of fuel that could replace 70% of the wood used in stoves that fill kitchens with smoke and cause health problems. Furthermore, burning sugarcane waste could boost electricity generation by 10% in Mozambique, Malawi, and Zambia, and by 20% in Angola.

Third, how can production be expanded? To answer this question, the researchers found that no single path exists, even though the Brazilian model can serve as inspiration. Colombia, Argentina, Guatemala, and Paraguay have adopted a system similar to Brazil's, with large plants producing ethanol, sugar, and energy. "To some extent, this is proof that the model is sustainable," says engineer Manoel Régis Leal, a researcher at NIPE-UNICAMP. It is true that the scale of production is not comparable: Brazil is estimated to account for three-quarters of the sugarcane production in the Americas, while the other countries split the remaining 25%. "But regions like the Cauca Valley in Colombia,

which have irrigated sugarcane fields, have high productivity," says Leal.

Different forms of land use exist where this raw material is produced. In Brazil, an average of one-third of the sugarcane is planted on land belonging to refineries, another one-third on leased land, and the final one-third is purchased from independent producers. "But not all plants work this way, and there are places like India and Thailand where 100% of the sugarcane is supplied by small producers," says Leal.

#### ASSISTANCE AND INPUTS

The researchers visited several countries but concentrated their analysis on just two: Mozambique and Colombia. "Colombia is much more advanced, and even has research centers to improve production," says Luis Cortez. Mozambique, however, has an environment of stagnation. An exception is Xinavane, a sugar producer in Maputo Province. "The company was established by the Portuguese, halted production during the civil war [1977–1992], and was later renovated by a South African group. The plant implemented a system in which small producers provide part of the sugarcane and receive assistance and inputs

in return," explains Leal. The difficulties in Mozambique, he notes, have to do with a complex structure of land ownership. "The land belongs to the government, and land grants are brokered by tribal chiefs." Nevertheless, economic indicators tend to improve when a plant is built. "The people have access to more jobs, and there are gains in infrastructure, including power lines, hospitals, and schools," says Leal.

The case studies suggest that the economic viability of bioethanol is related to large-scale production. "A model based on family farming does not work. Plants of a certain size ensure adequate productivity," says Luiz Horta Nogueira. He explains that bioethanol has not become well established in other countries for several reasons. "One is limited resources for large projects. But there is still a significant amount of misinformation," he says. "For decades, we have used ethanol in automobile engines, but in some countries, this fuel is still believed to cause corrosion." The most recurrent concerns revolve around the idea that, if land is used to produce energy, space to produce food will be insufficient. "This doesn't make sense. In Mozambique, we ran simulations expanding 1% into pastureland," he says. "Since the post-war period, food availability per person has greatly increased. There are localized problems associated with income, but not with a lack of food."

To share the knowledge, the group has held workshops in the United States and in South Africa and invited researchers and authorities from several countries. "We presented maps and modeling studies. The impact was positive. The Colombians invited our staff to return," says Cortez. The results of the project will be published in a book to be released by the British publisher Taylor & Francis. ■

#### Project

Contribution of bioenergy production in Latin America, the Caribbean, and Africa to the GSB-LACAF-Cana-I project (no. 12/00282-3); **Grant Mechanism** Thematic Project; **Principal Investigator** Luis Augusto Barbosa Cortez (UNICAMP); **Investment** R\$1,418,993.89.

#### Scientific articles

SOUZA, S. P. *et al.* Sugarcane can afford a cleaner energy profile in Latin America & Caribbean. **Renewable Energy**, v. 121, p. 164–72. June 2018.

SOUZA, S. P. *et al.* Potential of sugarcane in modern energy development in Southern Africa. **Frontiers in Energy Research**, v. 4, Dec. 2016.



A colony of *Leishmania*,  
the protozoa  
that causes visceral  
leishmaniasis

# A parasite reaches the

# BIG CITY

Difficult diagnosis and a warmer climate facilitate the advance of visceral leishmaniasis toward large urban centers

**Carlos Fioravanti**

PUBLISHED IN JUNE 2018

**V**isceral leishmaniasis, which has been thought of as a rural disease restricted to Brazil's northeastern region up to the 1980s, is moving toward increasingly larger urban centers. Caused by the protozoan *Leishmania infantum chagasi* and transmitted by bites from the female insects that transmit it, mainly the phlebotomine sandfly species *Lutzomyia longipalpis* (known locally as the *birigui*), the disease is currently present in all major regions, with almost half of the cases (47%) concentrated in the northeast of the country, according to the Brazilian Ministry of Health (MS). In 2016, the MS registered 3,626 cases in humans and 275 deaths across the country. In 2017, the states of Rondônia and Amapá recorded the first cases of domestic dogs with leishmaniasis, and the cities of Florianópolis and Porto Alegre saw their first cases in humans.

Since São Paulo registered its first human cases in 1999 in the municipalities of Araçatuba and Birigui in the northwest of that state, visceral leishmaniasis has been spreading toward the coast. Of the 645 municipalities in the state of

São Paulo, 177 have already had cases of dogs or people with visceral leishmaniasis. According to a study published in February 2017 in the journal *PLOS Neglected Tropical Diseases*, by 2020, the number of infected dogs is expected to increase in Balbinos, Sabino, and Guaimbê in the central region of the state as a result of its proximity to the Marechal Rondon highway, high temperatures, and the presence of the insects that transmit the disease; dogs act as reservoirs for the protozoa. The number of infected persons is also expected to increase in Luiziana, Alto Alegre, and Santópolis do Aguapeí, in the west of the state, because of increased humidity and the combined presence of insects and infected dogs (*see the maps in the online version of this report*).

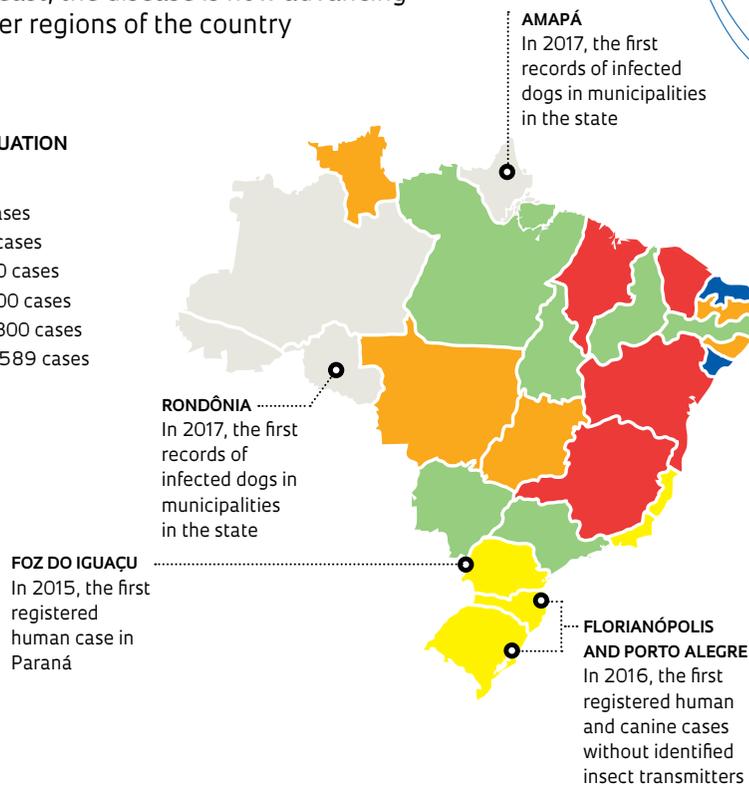
“Visceral leishmaniasis is advancing because of the lack of information which would permit early diagnosis,” commented parasitologist Mauro Célio de Almeida Marzochi, a researcher at the Oswaldo Cruz Foundation (FIOCRUZ) in Rio de Janeiro, at a scientific meeting held by the São Paulo State Department of Health in late April at the University of São Paulo Medical School (FM-

# Visceral leishmaniasis in Brazil

While still concentrated in the Northeast, the disease is now advancing to other regions of the country

## THE SITUATION IN 2016

- No cases
- 1–10 cases
- 10–50 cases
- 50–100 cases
- 100–300 cases
- 300–589 cases



SOURCE: MINISTRY OF HEALTH

for the possible origin of cases of canine leishmaniasis, which have been registered in the region since 2003. *Lutzomyia longipalpis* was not present, but he found many examples of *Pintomyia fischeri*, a species cited as a potential transmitter of *Leishmania infantum chagasi*. “Even if confirmed, *P. fischeri* has a lower transmission potential than *L. longipalpis*, which could explain the lack of human cases in these municipalities.” According to the World Health Organization (WHO), the parasite that causes the disease can be transmitted by approximately 30 species of biting flies around the world.

Visceral leishmaniasis is a problem typical of countries with precarious hygiene conditions, since the insects that transmit the illness reproduce in decomposing organic matter and garbage dumps. Of the 82 countries where it has already been identified, seven concentrated 90% of cases of the disease: India (6,249 cases in 2016), South Sudan (4,175), Sudan (3,810), Brazil (3,336), Ethiopia (1,593), Somalia (781), and Kenya (692). In 2015, the WHO registered 23,084 cases of people infected with visceral leishmaniasis worldwide.

## REASSESSED STRATEGIES

The identification of infected mosquitoes, dogs, or humans in large cities has led to a reassessment of ways to combat the disease. “The strategies for prevention and control should focus on reducing populations of *Lutzomyia* and blocking contact between them and the hosts in areas with high risk of transmission,” emphasizes veterinarian Anaiá da Paixão Sevá, a researcher at the USP School of Veterinary Medicine and Animal Science (FMVZ-USP) and lead author of the article predicting expansion into areas where infected insects, dogs, and humans are present. Marzochi of FIOCRUZ emphasizes how important it is to look for human and canine cases as a way to reduce the deaths caused by this disease.

USP). In August and November of 2016, respectively, a 19-month-old boy and his four-year-old brother died from this disease when it was diagnosed late in Guarujá, on the coast of São Paulo. In 2017, Guarujá reported another case, along with Votorantim, a city in São Paulo State near Sorocaba; no deaths occurred.

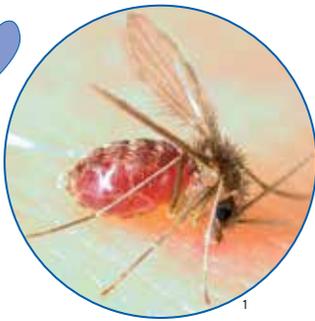
“*Lutzomyia longipalpis* is well adapted to hot areas with more open vegetation, such as the Cerrado scrublands,” observes biologist Eunice Galati, a professor at the University of São Paulo School of Public Health (FSP-USP). “Deforestation and replacing native vegetation with monocultures can create unfavorable environments for this species, which finds an environment in the cities that allows it to survive.”

Visceral leishmaniasis initially manifests in humans as pallor, continuous fever, weight loss, cough, diarrhea, and swelling of the liver and spleen. It can be fatal in humans if left untreated because of the damage to the liver, spleen, and bone marrow caused by *Leishmania*. The mortality rate is considered high, 7.8% on average, and few medicines are

available that are effective against this disease. The most common treatment is pentavalent antimony, which involves daily intramuscular injections for at least a month. Although it effectively eliminates the parasite, the side effects are intense: the medication can cause muscle aches, nausea, vomiting, kidney inflammation, and gastrointestinal, cardiovascular, and respiratory problems.

In areas where visceral leishmaniasis is transmitted, the full disease transmission cycle is not always recognized and includes insects that transmit the disease, dogs, and infected humans. Sometimes only infected dogs and insects are found; other times, only human cases appear, such as in Guarujá. Another situation that can occur is that only dogs and people with leishmaniasis are identified and not any of the known insect vectors. This was the case in Florianópolis, which recorded three cases in humans and 125 infected dogs in 2017.

From 2010 to 2012, biologist Fredy Galvis-Ovallos, a researcher at the FSP-USP, visited the municipalities of Embu das Artes and Cotia in São Paulo to look



1  
Stray and domestic dogs are reservoirs for *Leishmania*, a parasite transmitted by the biting fly *Lutzomyia longipalpis*, above



2

## “The insecticide collar protects healthy dogs and prevents transmission from infected animals,” says Tolezano

Euthanasia of infected dogs, a practice recommended by the government as a way to control visceral leishmaniasis, “is being considered less and less,” says veterinarian Francisco Edilson Ferreira de Lima Júnior of the MS. Euthanasia has proven ineffective because of the high replacement rate for infected dogs, especially puppies, which are more susceptible to the parasite. Furthermore, dog owners can begin treatment with miltefosine, a drug approved for veterinary use in 2017. However, this medication has an initial cost of approximately R\$2,000 per month and does not totally eliminate the parasites.

As an additional strategy to control leishmaniasis, the federal government is considering the possibility of distributing collars impregnated with a 4% insecticide solution (if all goes well, starting in 2019) to control visceral leishmaniasis in areas with the greatest risk of trans-

mission. “The use of collars has a greater impact than euthanasia in reducing transmission of visceral leishmaniasis,” says physician and epidemiologist Guilherme Werneck, a professor at the Federal University of Rio de Janeiro (UFRJ). Each collar costs an average of R\$100, and they act for four to six months.

The use of these collars on dogs resulted in a 60% reduction in the population of biting flies that transmit the parasite in parts of Fortaleza, Ceará, and a 15% drop in an area of Montes Claros, Minas Gerais, in comparison with control areas in the same cities over 30 months, according to a study published in March 2018 in *Memórias do Instituto Oswaldo Cruz* (Memoirs of the Oswaldo Cruz Institute), which featured participation by UFRJ and FIOCRUZ. According to Werneck, the Montes Claros study also revealed the limitations of this technique, indicating that the collars need to

be applied to more than 75% of the dogs in a region and that up to 40% of collars may be lost in six months.

“The collar protects healthy dogs and prevents transmission in infected ones,” says biologist José Eduardo Tolezano, director of the Center for Parasitology at the Adolfo Lutz Institute (IAL). He headed an assessment of collar use in approximately 10,000 dogs (both infected and uninfected) in Votuporanga, in the northwest region of São Paulo State. The infection rate in the dogs fell from 12% in 2014 to 1.5% at the end of 2015, when the study ended. “There was a clear association between the drop in leishmaniasis cases in dogs and the reduction of cases in humans,” observed Tolezano.

The biologist Osias Rangel, a researcher at the Endemic Diseases Oversight Office (SUCEN), emphasizes: “Actions to control transmitting insects cannot be interrupted. If they are, the disease comes back.” Werneck stresses: “We have to change the pillars which were established many years ago, without scientific evidence, on prevention and control, because today visceral leishmaniasis is an urban disease.” ■

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The scientific articles mentioned are listed in the online version of this report: [bit.ly/enInternac](http://bit.ly/enInternac)

# Underwater Forest

Coral reefs at the mouth of  
the Amazon River may  
be larger, deeper, and more  
complex than expected

PUBLISHED IN JULY 2018



Underwater surveys indicate that reefs on the continental shelf in front of the mouth of the Amazon River may be much larger, deeper, and richer in species of aquatic organisms than indicated by initial measurements, which were carried out in 2012 and 2014 using sonar and dredges that sweep the seabed bottom. The reefs are 110 kilometers (km) from the coast and extend from Amapá to Maranhão. There, the muddy waters of the Amazon meet the Atlantic Ocean, and the tide rises from 6 to 8 meters (m) per day. Like the Amazon itself, the world's largest river spanning 50 km wide in some areas and spilling approximately 200 tons of water and 14 tons of sediment per second into the sea, the reefs are proving to be monumental.

The reef area may be six times greater than the initially estimated 9,500 square

kilometers (km<sup>2</sup>) and may reach 56,000 km<sup>2</sup>, according to expeditions conducted in January and February 2017 and April and May 2018 aboard the *Esperanza*, a ship belonging to the nongovernmental organization Greenpeace, by researchers from universities in Paraíba, Pará, Rio de Janeiro, and São Paulo. If confirmed, the area may be larger than the state of Espírito Santo (46,000 km<sup>2</sup>).

In September 2017, a group of researchers from the Abrolhos Network ([abrolhos.org](http://abrolhos.org)) aboard the *Alucia* of the Woods Hole Oceanographic Institute in the United States toured the region and found that the reefs extend to 350 m in depth, almost three times deeper than originally estimated. "We confirmed that the landscape is very fragmented and discontinuous, like other reefs on the edges of the continental shelf," says biologist Rodrigo Moura, a professor at

the Federal University of Rio de Janeiro (UFRJ) and coordinator of the trip with the *Alucia* and Abrolhos Network.

The two teams recognize that this is a rich and complex area. "The diversity of environments is equivalent to forests, with a large number of species in a wide area," notes biologist Ronaldo Francini Filho, a professor at the Federal University of Paraíba (UFPB) and lead author of a paper published in April 2018 in the scientific journal *Frontiers in Marine Science* presenting the results from the *Esperanza* trips. He adds, "Each area is at a different stage of development," with some younger and some more mature reefs, forming or occupying clearings.

The formations differ in a north-south direction. According to Moura, the reefs on the coastline of Amapá are older (approximately 14,000 years), have stopped growing, and are composed mainly of

Sea sponges and algae at 90 meters deep in the northern area of the Amazon reefs



mollusks and other aquatic invertebrates but not corals. The reefs in Maranhão are younger, still growing, and comprised of corals and calcareous algae. The biologist Gilberto Amado, a researcher at the Jardim Botânico Research Institute in Rio de Janeiro participated in the *Alucia* voyage with other specialists from the Abrolhos Network and verified that the structure and composition of the banks of calcareous algae called rhodoliths become more complex moving from north to south, as described in a July 2018 article in the *Journal of South American Earth Sciences*.

"Most coral reefs are in warm, shallow, and clean waters, with lots of light and few nutrients," says oceanographer Nils Asp, a professor at the Federal University of Pará (UFPA) who participated in one of the trips on the *Esperanza*. "There, at the mouth of the Amazon, it's the opposite. The sediment carried by the river makes the water cloudy but brings along many nutrients, making up for the lack of light." Another peculiarity is the variation in acidity, salinity, and turbidity in the water that results when the river meets the ocean.

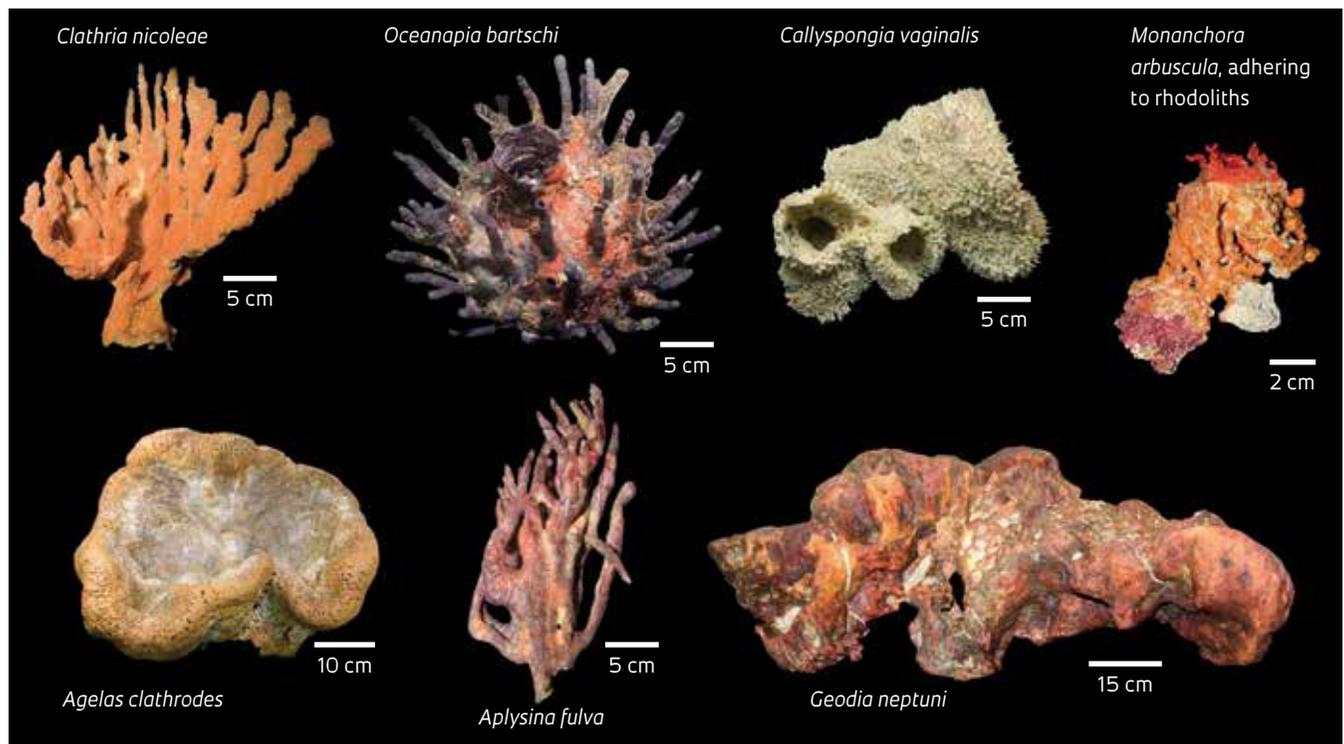
## The volume of nutrients from the mouth of the Amazon creates an ideal environment for the colorful sponges that dominate the landscape

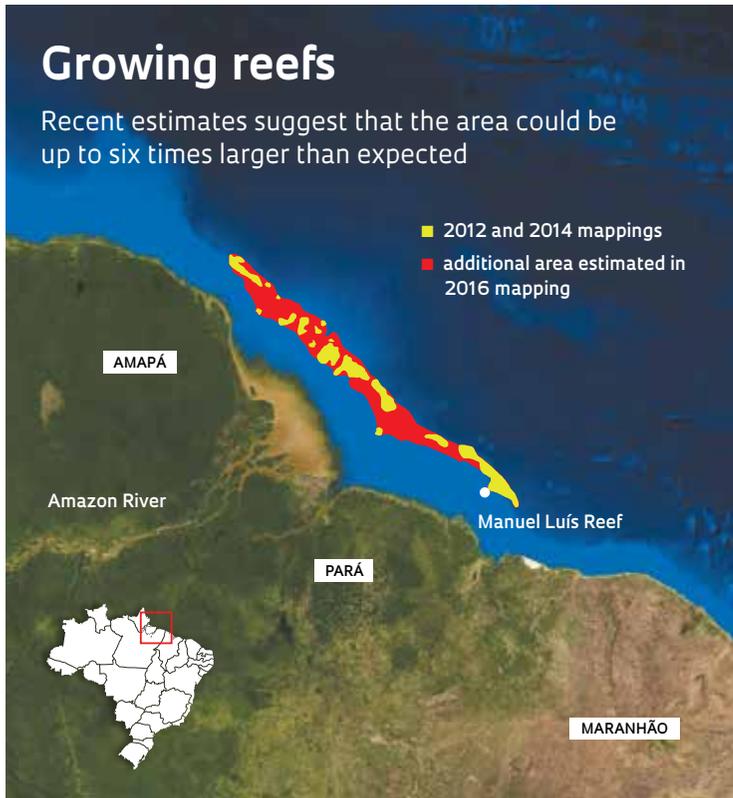
At the bottom of the continental shelf in front of the mouth of the longest river in the world, reefs and rhodoliths extend for hundreds of kilometers. On this surface, large yellow, red, black, and white sponges dominate the landscape. "Because of the volume of nutrients, it's an ideal environment for sponges, which are filtering organisms," says Moura. Meanwhile, the researchers identified approximately 70 species of fish, including some which are rare on the Brazilian coast, such as the northern red snapper, which reaches up to 1 m in length, and the Atlantic goliath grouper, which can reach 3 m long. So far, the expeditions have also recorded approximately 80 species of sponges and 40 coral species, many of which are similar to those found in the reefs of the Fernando de Noronha and Abrolhos Archipelagos.

A team from the Federal University of Pernambuco (UFPE), led by fisheries engineer Sigrid Neumann Leitão, identified complex communities of organisms that float in the water called zooplankton. The researchers counted 197 species of zooplankton, predominantly millimeter-long crustaceans similar to insects known as

## Amazon varieties

Sponges collected along the river mouth by the Abrolhos Network teams





SOURCE: FRANCINI FILHO, R. ET AL. *FRONTIERS IN MARINE SCIENCE*, 2018

copepods, with 92 species. As detailed in a March 2018 article in *Frontiers in Microbiology* by the Pernambuco researchers, the density ranged from 2.6 million individuals per cubic meter ( $m^3$ ) in the areas closest to the mouth of the river to 107 individuals per  $m^3$  in more distant regions because of the sediment volumes.

On the reefs live two species of bluish fish known as damselfish (*Chromis* spp.), which are common in the Caribbean Sea approximately 2,000 miles away. This and other indications reinforce the hypothesis that the reefs could act as a corridor (and not as a barrier, which has also been considered) between the sea in northern South America and the coast south of Maranhão. "Since the 1970s, it was thought that fish and other organisms could pass little by little along the bottom of the river mouth and that there could be genetic mixing between organisms from the Caribbean and from the coast to the area south of the Amazon mouth," says biologist Sergio Floeter, professor at the Federal University of Santa Catarina (UFSC) and coordinator of the National Research Network for Marine Biodiversity (SISBIOTA-MAR). "Now we have more evidence of this connection." On the sea floor, cliff-like escarpments

extend for kilometers and up to 70 m in height. "It is believed that in this part of the continental shelf, the sand and mud accumulated over 10 million years had already covered the entire ocean floor," says Asp. According to him, these step-like levels may be a consequence of the erosion caused by seawater 18,000 years ago, when the sea level was approximately 120 m lower than it is today. These escarpments consequently mark the level of the Atlantic Ocean during the last ice age, when large areas of the planet were covered by ice, or show changes in the course of the Amazon River, which could have excavated the rocks with its waters. There is even a third hypothesis that suggests these slopes resulted from sediment weight. In this case, there would have been a seesaw effect: some stretches of the river mouth would have gone down, raising other areas up, such as the eastern part of Marajó Island.

#### UNIQUE ENVIRONMENT

"The reefs of the Amazon River are a unique environment, which is still being discovered. Nobody imagined it could be so large," says biologist Helena Spiritus from Greenpeace. This huge, rich area is only being studied now, because up until

the mid-1970s, scientists were certain that the volumes of sand and mud the river spilled into the sea would block light from penetrating and the formation of any type of environment. The evidence has gradually worn away this theory.

There has only been limited information on the mouth of the Amazon since the 1950s. During the 1960s, oceanographer John Milliman of Woods Hole and geologist Henyo Barreto of Petrobras identified a rocky structure rich in carbonates in this region. In 1977, two biologists from the National Museum of Natural History in the United States, Bruce Collette and Klaus Rützler, presented a list of 45 species of fish and 35 species of sponges typical of reefs, which they collected along the river mouth.

In July 1998, Moura, Francini, and the biologist Ivan Sazima from the University of Campinas (UNICAMP) went beyond Manuel Luís Reef in Maranhão, which until that point had been the northernmost coral reef in Brazil; they entered the waters further north along the Brazilian coast and found six coral species that had not been reported in this part of the shoreline. "The fishermen said that there were a lot of reefs to the north of this area," recalls Francini. Fishing for red snapper and lobster in the region also indicated that the bottom was solid and not only mud, but logistical and financial difficulties hindered the organization of expeditions. That is, until 2012, when a team coordinated by Moura of UFRJ traveled to the area on Woods Hole's *Atlantis*.

Along with the fascination of these discoveries comes concern, since the mouth of the Amazon has been targeted for oil and natural gas exploration. In 2013, the federal government offered 125 areas in an international bidding process, 39 of which were acquired by Brazilian and multinational companies. At the end of May, after returning from the second expedition to the mouth of the Amazon, Francini sent a letter to the Brazilian Attorney General containing underwater photos of the coral reefs and calling for a halt to applications for environmental licensing from an oil company interested in exploring an area within the region. ■

Carlos Fioravanti

The scientific articles mentioned are listed in the online version of this report.

River-dwellers in houses built on stilts on the banks of Lake Tucuruí in the state of Pará: excessive exposure to mercury



# Contamination beyond the mines

Areas of the Amazon flooded by dams may lead to an increase of the mercury levels in fish consumed by local residents

Rodrigo de Oliveira Andrade

**R**iver-dwelling and indigenous communities residing in areas close to hydroelectric plants in the Amazon may be exposed to high levels of mercury. This suspicion comes from a group of Brazilian and Spanish researchers coordinated by the biochemist María Elena López of the Institute of Biological Sciences at the Federal University of Pará (UFPA). The team analyzed hair strand samples taken from 37 people living on islands located in Lake Tucuruí of the Caraipe region of Pará surrounding the Tucuruí hydroelectric plant, the second largest in Brazil. They found that over half of the residents had levels of contamination of up to seven times higher than the limit of 10 micrograms of mercury per gram of hair set by the World Health Organization (WHO).

“More than 80% of the metal identified was in its organic form, the so-called methylmercury,” stated López. This is the most toxic form of mercury, which is able to circumvent the body’s defenses and reach the brain. In these cases, it may cause a severe neurodegenerative syndrome known as Minamata disease, characterized by tremors, coordination problems, sensory disturbances, vision and hearing impairment, and in extreme cases, death. Although they had high levels of methylmercury in their bodies, none of the river-dwellers were diagnosed with any health

problems, which was not surprising to the researchers; clinical signs associated with contamination by this metal take years to appear.

In their paper, published in January in the journal *Ecotoxicology and Environmental Safety*, the researchers argue that the Tucuuruí residents are being contaminated by the fish they eat. They first suspected that the poisoning was the result of gold mining because cases of mercury contamination in the Amazon are almost always associated with gold extraction. Miners typically pour liquid mercury into a mixture of sand and gravel extracted from rivers to attract the precious metal. This practice releases large quantities of mercury into the environment.

When they analyzed the history of the region, the researchers found multiple mining ventures, but none extracting gold. They then suggested that the main source of mercury contamination could be indirectly traced to the operation of the Tucuuruí hydroelectric plant, which was built between 1974 and 1985.

#### DAM EFFECTS

López explains that the construction of the dam created closed ecosystems that flood periodically. “In some areas of the reservoir, the water is retained up to 130 days per year,” she says. As a result, every year during the rainy season, when the river overflows and invades the forest, water rich in decomposing organic matter mixes with large volumes of young organic matter. Over time, sunlight causes these compounds to produce hydrogen peroxide, which helps release the inorganic mercury stored in the soil. Anaerobic bacteria then convert the substance into methylmercury, which enters the aquatic food chain.

The possibility that this dynamic would become a problem in the region was raised almost 20 years ago by the American biologist Philip Fearnside, who today works for the National Institute for Amazonian Research (INPA), in articles published in the journal *Environmental Management*. In August of last year, a study published in *PLOS ONE* also highlighted risks of methylmercury contamination resulting from dam construction in the Amazon.

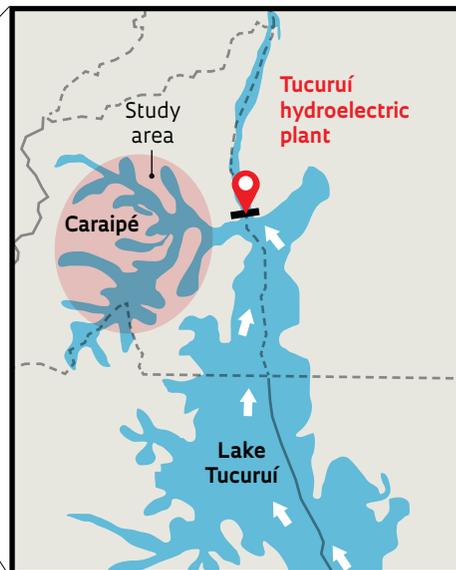
“The Amazonian soil is naturally rich in mercury, in its less aggressive inor-

## Silent pollution

Dam construction has created closed ecosystems, which may release mercury into water bodies when they are flooded



In some areas of the hydroelectric plant reservoir, water is held for up to 130 days per year



## Levels of contamination in inhabitants of the Caraipé region are up to seven times higher than the WHO limit

ganic form,” says López. In some regions, the characteristics of the soil and water lead to high concentrations of this metal. This is the case for the Rio Negro basin, where each kilogram of soil contains an average of 172 micrograms of mercury, almost four times higher than levels considered normal for soils

in other regions (see Pesquisa FAPESP, issue no. 143). “The problem is that any environmental changes may cause inorganic mercury to be released and converted into methylmercury,” adds López.

When released into the environment, the metal is absorbed by algae; small fish eat the algae and in turn are eaten by larger fish. “The fish that are at the top of the food chain have a greater risk of accumulating mercury by feeding on smaller contaminated organisms,” explains López. This is the case for peacock bass (*Cichla sp.*), a species that is one of the most commonly consumed in the region and widely sold in Belém. “The samples of peacock bass we evaluated showed mercury levels similar to those found in fish in the Tapajós River basin, which is the largest area of active gold mining sites in Brazil.” A 1995 study published in the journal *Science of the Total Environment* had already identified the presence of methylmercury in another fish species from the region where the Tucuuruí hydroelectric plant is located, the South American silver croaker (*Plagioscion squamosissimus*).

Eletrobras Eletronorte, which administers the Tucuuruí plant, recognizes the complexity and importance of this is-



Tucuruí is just one of more than 400 plants operating or currently under construction in the Amazon region

sue. In a note the company says that it “promotes and supports studies that contribute to a better understanding of the origins of mercury in natural and anthropized [human-altered] environments in the Amazon region, as well as the biological, geological, and chemical mechanisms that contribute to their mobilization, accumulation, and transfer between different environmental compartments.” The company also notes that it is currently conducting a study on the role of microorganisms in mobilizing and accumulating mercury in the plant reservoir in partnership with the UFPA.

Mercury contamination is also occurring in other parts of the Amazon such as in indigenous tribes in the state of Roraima, in Northern Brazil. In 2016, researchers from the Brazilian School of Public Health at the Oswaldo Cruz Foundation (FIOCRUZ) analyzed hair samples from 239 Yanomami and Ye’kuana Indians from 19 villages and found that in some areas up to 92% of indigenous peoples had mercury contamination. In this case, however, the metal was released into the environment through mining activity. “Children and women of reproductive age were the most af-

ected,” explained Paulo Cesar Basta, a physician and coordinator of the FIOCRUZ study.

Basta believes that it is important to establish an environmental monitoring plan to identify possible sources of mercury exposure in the Amazon, which seem to stem from gold prospecting. More than 400 hydroelectric power plants are operating or under construction in the region, especially in the Tapajós River basin. “Another strategy would be to conduct a more profound analysis of water bodies in the region and assemble a map of contamination risk that could be used to guide the local population,” he suggests. “We are talking about poor and isolated communities that depend on fishing to survive,” says María Elena López. “Many don’t even know they are contaminating themselves,” stated the biochemist of the UFPA. ■



Fish such as peacock bass accumulate methylmercury by ingesting other contaminated organisms

#### Scientific articles

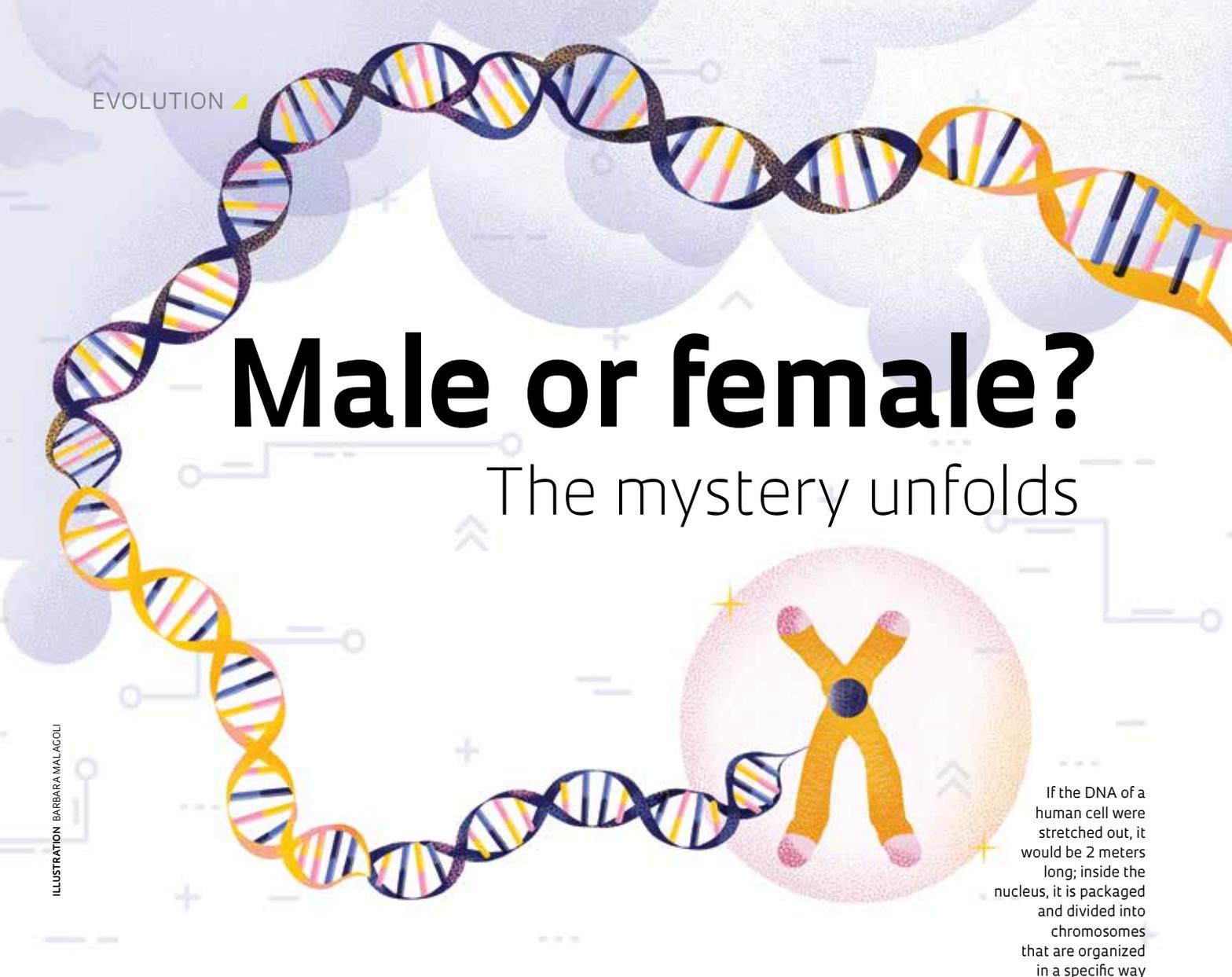
ARRIFANO, G. P. F. *et al.* Large-scale projects in the Amazon and human exposure to mercury: The case-study of the Tucuruí Dam. **Ecotoxicology and Environmental Safety**. vol. 147, p. 299-305. Jan. 2018.

FORSBERG, B. R. *et al.* The potential impact of new Andean dams on Amazon fluvial ecosystems. **PLOS ONE**. vol. 12, i. 8, p. 1-35. Aug. 2017.

# Male or female?

## The mystery unfolds

ILLUSTRATION BARBARA MALAGOLI



If the DNA of a human cell were stretched out, it would be 2 meters long; inside the nucleus, it is packaged and divided into chromosomes that are organized in a specific way during replication

Amazonian frog species has more sex chromosomes than any other vertebrate

**Maria Guimarães**

PUBLISHED IN MARCH 2018

When biologist Thiago Gazoni first examined the chromosomes of the smoky jungle frog (*Lepidactylus pentadactylus*) for his Master's thesis at São Paulo State University (UNESP), he did not expect to discover the species with the largest number of sex chromosomes ever seen in a vertebrate, as described in an article published on the website of the scientific journal *Chromosoma* in January. The species has 12 of these DNA packages which form a ring during cell division as if circle dancing. It is nothing like the X and Y system that determines whether a human is male or female. The previous record holder was the platypus, which has 10 sex chromosomes.

"Less than 5% of the amphibians the chromosomes of which have been described so far have easily identifiable sex chromosomes," says Gazoni, who continued the study while obtaining his PhD, which he completed in 2015. This means that when making the karyotype—a way of organizing and studying a set of chromosomes—it is usually impossible to visually distinguish which chromosomes are related to the determination of sex. In fact, little is known about the specific genes that make amphibians male or female, a function performed in mammals by the SRY gene.

Even more curious is that the 13 frogs studied (six females and seven males) had more sex chromosomes than non-sex chromosomes (autosomes); 12 of

the total set of 22 chromosomes are related to the determination of sex. "Sex chromosomes are defined by the visual differences between male and female karyotypes," explains Gazoni. The chromosomes unique to a sex are responsible for defining it. During evolution, autosomes undergo alterations that may give rise to chromosomes with genes specific to one of the sexes. Other genes near the sex chromosomes are gradually inactivated, creating specialized chromosomes. The inactivated parts become more condensed and can be identified by certain staining methods.

In 2014, Gazoni spent three months at the University of Cambridge, UK, at the laboratory of geneticist Malcolm Ferguson-Smith, developing a probe capable of marking the chromosomes of the frogs and mapping the exchanges that occur between different chromosomes. In the future, he hopes to identify and locate the genes related to sex determination in these amphibians.

"We still do not know why some species have multiple sex chromosomes," says biologist Patricia Parise-Maltempi from UNESP, who was Gazoni's cosupervisor during his doctorate, together with zoologist Célio Haddad from the same institution. Parise-Maltempi did a postdoctoral fellowship with Ferguson-Smith approximately ten years ago, learning about techniques such as chromosome painting, which allows scientists to identify specific parts of the chromosome and compare karyotypes. She specializes mainly in fish, which also have multiple sex chromosomes, but she says that knowledge about sex determination is still very limited. In fish and the *L. pentadactylus* frog, surplus sex chromosomes are not inactivated, as is the case in mammals, in which one of the two X chromosomes in females is silenced to maintain a level of genetic activity equal to that in males, who only have one X chromosome (see Pesquisa FAPESP, issue no. 260).

#### EVOLUTIONARY MYSTERY

There are equally no inactivated chromosomes in previous record holder, the platypus: although it sports a beak and webbed feet, this strange Australian egg-layer is a mammal, not a duck. Members of the monotreme order of egg-laying mammals along with the

## A variety of blueprints

In different groups of animals, the sex determination system may depend on specific chromosomes... or not

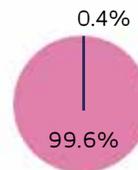
● XX, XY and variations ● ZZ, ZW ● Temperature ● Hermaphrodite ● Undetermined

### MAMMALS



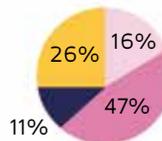
The XX (female) and XY (male) system, with some variations, applies to all mammals

### BIRDS



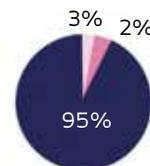
The sex of almost all birds is defined by ZZ (male) and ZW (female) chromosomes

### REPTILES



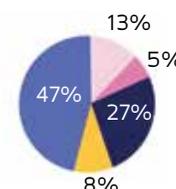
The sex chromosomes are not always distinct from the autosomes, and for some species, sex is determined by the temperature of the eggs during development

### AMPHIBIANS



In most species, the genes that determine sex have yet to be identified

### FISH



Almost half of all species are hermaphrodites (with the reproductive organs of both sexes), and the rest have varying sex determination systems.

SOURCE JUDITH MANK/TREE OF SEX CONSORTIUM

# Vertebrate record holders

The smoky jungle frog and the platypus have the largest numbers of sex chromosomes ever found; the examples below are of males because the females only have X chromosomes

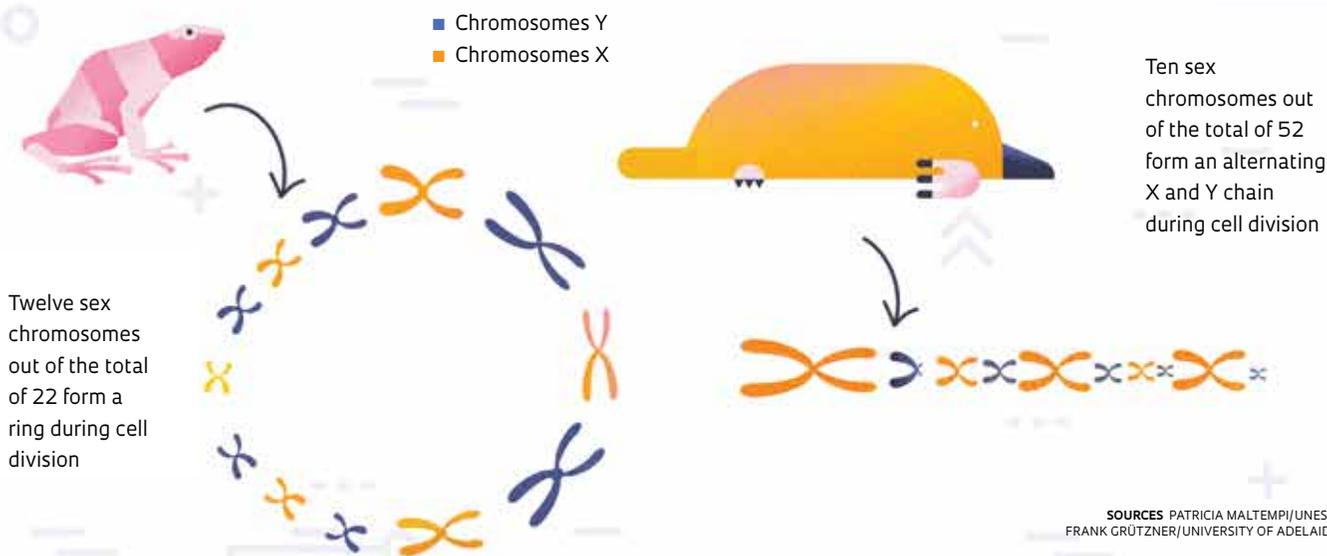


ILLUSTRATION BARBARA MALAGOLI

spiny eel, the platypus feeds milk to its young, even though it does not have teats. Since the 1970s, we have known that these curious underwater hunters have 52 chromosomes, of which 10 are related to sex determination and form a chain during cell division. It was another 30 years until the tools needed to study this system became available, according to German geneticist Frank Grützner, from the University of Adelaide, Australia, who has been studying this mystery since 2002. "I had learned a technique called fluorescent in situ hybridization, which makes it possible to mark chromosomes with different colors," he says. "It was clear that it would allow us to solve this complex system, but it took several years of hard work to show that there were five pairs of XX or XY chromosomes that form an alternating chain during the meiosis phase of cell division" (see infographic above).

Particularly relevant to our understanding of the evolution of sex-determination systems was the discovery that this chain of chromosomes in the platypus contains genes typical of the X chromosomes found in mammals and in the Z chromosomes of birds, according to an article by Grützner published in *Natu-*

*re* in 2004. The discovery suggests that these systems, which were previously believed to have arisen independently, may share a common origin. Even so, it is still unclear which gene determines sex in this species. Attempts to sequence the full genome are ongoing, with further difficulties regarding the Y chromosome. "Recently, while working with Henrik Kaessmann [from Heidelberg University, Germany], we discovered a potential candidate—an AMH gene linked to the Y chromosome," he says. "This gene is traditionally linked to the development of the reproductive organs, so it will be interesting to see how it may be involved in sex determination in this species."

## FINGERPRINTS

In addition to the profound evolutionary implications of the genetic sex-determination system, chromosome configuration is widely used to help characterize a species, sort of like a fingerprint. This was one of the objectives of Gazoni's Master's research, which was supervised by UNESP cytogeneticist Sanae Kasahara, who died in January of this year. "There were poorly resolved taxonomic issues relating to the genus, so Olivia Araujo and Felipe Toledo, who were researchers in Haddad's lab at the time,

brought us an *L. pentadactylus* male collected in Paranaíta, Mato Grosso," he says. "We soon identified several chromosomal rearrangements."

The study progressed in other directions, but attempts to classify the species continue. "Our recent research shows that there are actually two species currently referred to as *L. pentadactylus*, and we need to figure out which is the real one," says Gazoni. He plans to name the new species after his first supervisor, who dedicated her career to researching cytogenetics in vertebrates. ■

## Projects

1. Contributions to our understanding of the origin and evolution of sex chromosomes in vertebrates, based on the study of repetitive DNA (No. 17/00195-7); **Grant Mechanism** Regular Research Grant; **Principal Investigator** Patricia Pasquali Parise-Maltempi (UNESP); **Investment** R\$106,795.21.
2. Diversity and conservation of Brazilian amphibians (No. 13/50741-7); **Grant Mechanism** Thematic Project; **Program** Biota; **Principal Investigator** Célio Fernando Baptista Haddad (UNESP); **Investment** R\$4,386,814.61.

## Scientific articles

- GAZONI, T. *et al.* More sex chromosomes than autosomes in the Amazonian frog *Leptodactylus pantadactylus*. **Chromosoma**. Online. Jan. 26, 2018.
- GRÜTZNER, F. *et al.* In the platypus a meiotic chain of ten sex chromosomes shares genes with the bird Z and mammal X chromosomes. **Nature**. v. 432, i. 7019, p. 913-17. Oct. 24, 2004.

# Partnership between giants

President of the GMT telescope explains why he joined with competitor TMT to secure funding from the National Science Foundation

Marcos Pivetta | PUBLISHED IN AUGUST 2018

After almost two decades of intense competition, two international megaconsortiums comprising universities and research institutions decided to join forces in pursuit of a common goal: to persuade the National Science Foundation (NSF), the leading research funding agency in the USA, to invest in their astronomy projects. With no money to complete their super telescopes, which are scheduled to begin operating in the next decade, the Giant Magellan Telescope (GMT) and the Thirty Meter Telescope (TMT)—whose headquarters are situated just eight kilometers apart in the California city of Pasadena—are aligning their scientific goals to jointly seek funding from the United States government. At an estimated cost of US\$1 billion, the GMT is building a 24.5-meter telescope in Chile. The TMT, at US\$1.4 billion, is further behind schedule. The northern hemisphere location where the telescope will be built has yet to be determined. The initial plan called for a location in Hawaii, but those behind the project are now also considering the Canary Islands.

In 2017, American physicist Robert Shelton was appointed president of the

GMT consortium, which is coordinated by Carnegie Observatories, and he has played a key role in forging a partnership between the two projects. Having previously worked with the University of California and the California Institute of Technology (Caltech), the two institutions managing the TMT, Shelton has dedicated himself to strengthening the scientific and administrative ties between the two projects. He regularly visits GMT partners to discuss the progress of the project and more recently, the new relationship with TMT. Shelton was in São Paulo in early August to visit FAPESP, one of the GMT partner institutions, and to meet the São Paulo astrophysicist community, which will be given 4% of the telescope's observation time. He later met with researchers in Porto Alegre and Rio de Janeiro. "I want to understand the perspective of Brazilian researchers," said the physicist, interviewed days before landing in Brazil for the first time.

### ***How did the GMT and TMT collaboration begin?***

The two projects have been working in parallel for many years, and both are based in Pasadena, California. TMT is

located at Caltech and GMT at Carnegie. These two organizations have a history of collaborating and competing, both of which can be positive. My background initially was more connected to the University of California [he studied for his PhD at the UC San Diego campus], which is partnered with TMT. I specialize in condensed matter, but I first got involved with astronomy when I served on the governing board of the Keck Observatory in Hawaii, which is linked to Caltech and the University of California. So, I am familiar with the key players from TMT. Later, I was on the boards of other telescopes, including that of Hubble. Since I came to GMT, my interest has been in making sure the two projects are supportive of each other. For the US astronomy community, having access to super telescopes in both the northern and southern hemispheres is a very powerful incentive. The leaders of both boards have been talking about the two projects for over a year. Now, there is a new ingredient: the possibility of federal US funding for the two telescopes.

### ***This possibility already existed in the past...***

Yes, but in the past, the two projects were



We have raised US\$520 million so far, approximately half of the initial budget target for the GMT



not as compatible. At the time, the projects each approached the federal government in their own way. There is nothing wrong with that, but it can put the government in the difficult position of having to choose between one proposal or the other. Now, we agree that we must work together for the benefit of astronomy at large.

***Was the lack of money available to complete both projects a determining factor in establishing this collaboration?***

Yes, although money has always been a factor. I cannot speak for TMT, but both projects have always been looking for a way to complete their telescopes. What has changed is that now they see themselves as more complementary than competitive.

***Was it a mistake to start two different super telescope projects at the same time?***

I do not know how to answer that question. At the time, there was every reason to think that there would be sufficient funds from the USA and partner countries to sustain both projects, which use very different observation technologies.

***The two telescopes are at different stages of development. Will each project ask for the same amount of money from the NSF?***

We have not written the joint proposal yet. There is sequence of events that has to happen before we can do so. The first task is to identify key science projects that require both telescopes. We need to formulate a strong scientific proposal to be presented to the National Academy of Sciences decadal survey [a report that identifies priority research areas to be supported by funding agencies over the next decade]. We set up a steering group with people from GMT, TMT, and the National Optical Astronomy Observatory [NOAO] that represents the NSF. We hold meetings every three weeks, either at our office or the TMT office.

***How much time do you have to submit the proposal for the decadal survey?***

We are aiming to provide our documentation in the first half of 2019. Then, the proposal will go through about a year's worth of work, and we hope that the recommendations based on the decadal survey will be released in January 2021. If we are able to secure federal govern-

ment funding, the money will probably be available in 2023. It is a long process. But, of course, things can change along the way. In parallel with demonstrating the scientific need for these telescopes, we have to submit a financial proposal, which means we have to decide: how much money should we ask for? Honestly, we do not have a set figure right now. But, the request will be in the hundreds of millions of dollars. In principle, each project should ask for the same amount of money but will probably use the money in different ways. Our needs and the TMT's needs may differ. Throughout this process of discussing and formulating a joint scientific proposal, we have made sure to include representation of our international partners, such as FAPESP. We need this international perspective to make the GMT a success.

***If the NSF does not finance the telescopes, is there a plan B?***

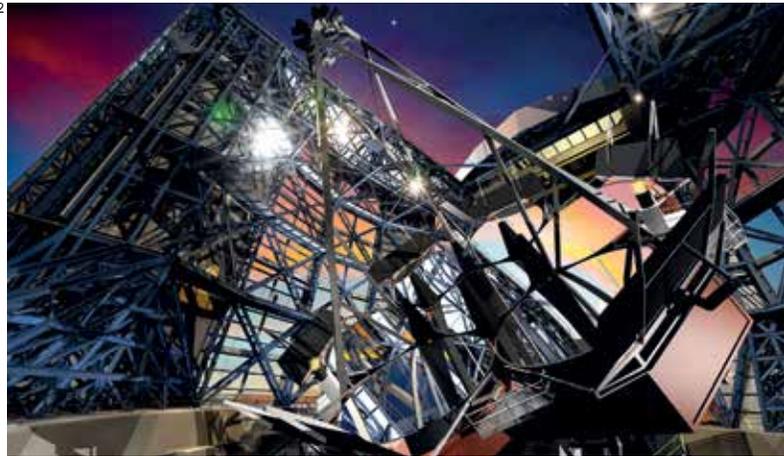
Raise more money, probably from private sources. Either way, we will have to get to the first light stage almost on our own before the NSF money comes through. We want to partner with NSF not just because they have the money—of course that is important—but also because it would allow other astronomers who are not currently part of our consortium to use the telescope. That will give intelligent people with excellent ideas the chance to use the GMT in ways that might not have been thought of otherwise.

***Will the collaboration with TMT change the relationship between GMT and its international partners in any way?***

We are being very careful to ensure that the role of our international partners is respected—not just because of the money our partners have invested but also for the scientific contributions they bring to the project. If the NSF gives us significant funding, our partners will want control over some of the time on the telescope. So, for example, if they give 25% of the total cost, they will ask for 25% of the time, which will not be a problem for us, because we have not assigned all of the observation time yet. What could have an impact on every partner, though, is if the total cost increases. The US\$40 million that FAPESP has invested in the project, which today equates to 4% of the observation time, could turn into 3% if the cost



1 The location of the TMT project, budgeted at US\$1.4 billion, has not yet been confirmed



2 Artist's representation of the seven GMT telescope mirrors under construction in Chile

of the telescope rises to US\$1.2 billion. However, there is another issue to be considered. Those who entered the project early are more protected than those who entered later. Most international partners invested money into the project at a time when the risk was higher. We cannot adopt the simple cost proportion rule for those who supported the project from the start. That will not change. A change to that principle would have to be approved by all the founding partners, and I cannot imagine anyone would want to do that, which is why the founding partners of the GMT play such an important role. The astronomers from São Paulo will be granted observation time due to the partnership with FAPESP. Those in the US who are not associated with the founding institutions will have to ask the NSF for time, and they may or may not get it.

#### ***How much money has GMT raised so far?***

Approximately US\$520 million, which is roughly half of the initial budget target. One thing I have learned from being on the boards of various telescopes is that astronomers can always spend more. I say that as a compliment. Astronomers will always be able to think of new instruments, new data analysis software. So, we know we need to raise more money.

#### ***What is the telescope development schedule?***

We are experiencing a period of strong technical progress. The first of the seven GMT mirrors has been completed. The second is almost complete and has taken much less time than the first mirror. We

are learning all the time. We have all the glass we need, 40 tons of it, to cast the sixth and seventh mirrors, which reduces risk. We are currently finalizing the design of the mount [the structure that supports and moves the telescope], which will cost approximately US\$100 million. At the GMT site in Chile, we already have electricity, water, roads, and the internet. If we continue at this pace, we hope the telescope will begin operating—with the first four mirrors—in 2024. Even with just four mirrors, GMT will be the largest telescope in the world. The remaining mirrors will then be added as they are completed. Right now, our schedule is for all seven mirrors to be operating by 2027.

#### ***What are the first scientific targets of the GMT?***

One of the first will be the study of exoplanets. Many of these Earth-like planets have been discovered in recent years, a number of which are located in the habitable zone of their systems. Currently, we know that these planets exist, but we are not able to collect enough light to actually analyze their atmospheres. We have no way of knowing if these planets contain oxygen, water vapor, or methane, all the chemical elements that we think of as signatures of life. Even with four mirrors operating in 2024, we believe the GMT will be able to do this, though obviously not as efficiently as when we have seven mirrors. The TMT and the E-ELT [European project planning the construction of a 390-meter telescope in Chile within the next decade] will also study these exoplanets.

#### ***What other topics will be a priority?***

There are many questions about the growth of galaxies and black holes that are very important to what is known as multimessenger astronomy. Our location in Chile is highly valuable. We are right next to the largest synoptic telescope in the world [LSST], which will begin operating in 2023 or 2024. The LSST will survey the entire sky every night, and when the LSST detects significant changes, we will be right by their side to look at those changes in detail with the GMT. When all of our instruments are installed, we will be able to look back in time to the beginning of the universe. The GMT will function for 50 years or more. Over time, new instruments and software will be added and the telescope will improve more and more.

#### ***How do you expect the São Paulo astronomy community to contribute to the project?***

We expect brilliant ideas on how to use the GMT to produce the best science possible. We are grateful to FAPESP for the financial support—we know that such support is not simple for any institution. We hope astronomers from São Paulo will collaborate with colleagues from other GMT partners. We value different perspectives in our decision-making processes. When I started working on this project, I promised to visit all the partners. I think it is important to meet the Brazilian astronomers, understand their viewpoints and priorities, and share the latest information about the telescope. I like to do this personally, face to face. ■

# Creative Turbulence

Stimulating random fluctuations may increase energy production in nuclear fusion reactors

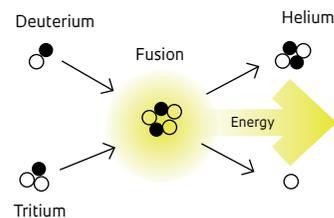
**Victória Florio**

PUBLISHED IN MAY 2018

**T**urbulent systems with random fluctuations can be unpredictable, making it difficult to formulate models to explain natural phenomena. However, stimulating a certain level of turbulence could actually be positive in tokamaks, the experimental nuclear fusion reactors where the nuclei of two different hydrogen isotopes join to form the nucleus of a helium atom while simultaneously producing energy. This seemingly paradoxical idea was proposed by Brazilian physicist Vinícius Njaim Duarte, a postdoctoral fellow at Princeton University, USA, as a way of reducing the amount of energy that these superheated plasma reactors lose via a phenomenon known as chirping. What started as a theoretical proposal was then simulated by computers and later successfully tested in three tokamaks. "The greater the turbulence, the lower the chance that chirping will occur," explains Duarte, who published the results of the experiments in the American Institute of Physics journal *Physics of Plasma* last December.

Inaudible to human ears, chirping in this context refers to a high-pitched trill emitted by frequency waves that propagate through the plasma in fusion reactors, so called because of the technical similarities it shares with bird song. It is caused by interactions between plasma oscillations and highly energetic particles. The phenomenon expels particles from the reactor, cooling the environment and compromising the continuity of nuclear fusion reactions. Every tokamak produces a particu-

## HOW DOES NUCLEAR FUSION OCCUR?



Strong magnetic fields confine a plasma inside a reactor. At extremely high temperatures, two forms of the hydrogen atom, deuterium (whose nucleus has one proton and one neutron) and tritium (which has one proton and two neutrons), merge. The process creates a heavier element—helium, whose nucleus has two protons and two neutrons—and releases one neutron and a large amount of energy

○ neutron ● proton



A photo taken in March 2018 shows the construction of the ITER in southern France, which will be the world's largest nuclear fusion reactor

## No current nuclear fusion reactors are capable of producing more energy than they consume, a problem still to be overcome

lar amount of chirping, creating its own identity: some chirp a lot, others not so much. The effect also commonly occurs in astronomical objects, such as in the plasma of the Sun's magnetosphere—the outer area of the star's atmosphere that is filled with electrically charged particles. Turbulence is actually an inherent characteristic of fluids. In general, it does not need to be induced and occurs naturally due to the movement of plasma particles. "Turbulence is usually undesirable in any system, but in tokamaks, it can potentially help to increase energy production in the plasma," explains physicist Ricardo Galvão, director of the Brazilian National Institute for Space Research (INPE) and supervisor of Duarte's doctoral thesis on the subject, which he defended last year at the University of São Paulo Institute of Physics (IF-USP).

Galvão accepted him as a student at the request of Italian physicist Roberto Antonio Clemente, from the Gleb Wataghin Institute of Physics at the Uni-

versity of Campinas (IFGW-UNICAMP). Clemente fell ill while supervising Duarte during his master's degree, and before he died in 2011, he asked Galvão to supervise the student during his PhD. The USP physicist saw Duarte's research potential and sent him to Princeton to work with one of his colleagues, Russian physicist Nikolai Gorelenkov. The original theme of his doctoral research was related to plasma physics but not the issue of chirping specifically. "While working on his original topic, Duarte attended seminars and realized that chirping had never been explained," says Galvão. "He decided to investigate the matter on his own and his results were excellent: his fellowship was extended for another year, funded by Princeton, so that he could study chirping." It was during this period that he had the idea of controlling chirping in reactors by stimulating turbulence in a plasma.

To test Duarte's proposed model, specific experiments were carried out on

the DIII-D tokamak, operated by the United States Department of Energy in the General Atomics laboratories in San Diego, California, by imposing a particular geometry that is known to mitigate turbulence. Chirping is usually a rare occurrence in the DIII-D, but during the tests, the chirping increased. In tokamaks where there is normally a lot of chirping, such as Princeton's NSTX, Duarte and his colleagues at Princeton adopted a geometry that favors turbulence and successfully reduced the problem. Before confirming the key role played by turbulence, the researchers tested other hypotheses, such as collisions between particles and their resonant velocities, but no other factor seemed to control the chirping. "What we have learned about plasma in a laboratory setting could also be useful in explaining and controlling chirping in nature," comments Gorelenkov, coauthor of the paper.

The results were so encouraging that Duarte's method will be used in other tokamaks, such as the ITER, which is under construction in southern France and when completed will be the world's largest fusion reactor. Its objective is to demonstrate the economic and scientific viability of energy produced by nuclear fusion. Scheduled to begin operations in 2025, the megaproject involves 35 countries and an investment



The NSTX, at Princeton University, was one of the tokamaks used to test the energy-loss reduction method

of €20 billion. It is hoped that the ITER will be able to generate 10 times more energy than it spends, producing 500 megawatts (MW) for every 50 MW of input power. Those behind the project say that because it is so large, the reactor will produce energy more efficiently than its smaller counterparts. Nuclear fusion is safer and generates less radioactive waste than nuclear fission, which involves splitting the nuclei of atoms and is currently used to produce energy in atomic power plants. The problem is that current tokamaks, unlike nuclear power plants, consume more energy than they

produce. The world's largest nuclear fusion experiment, JET, located in Culham, England, has achieved a maximum efficiency of 67%, generating 16 MW for every 24 MW it invests.

#### ENERGY OF THE STARS

In laboratories, the physics of plasmas tries to imitate nature. The nuclear fusion process created in tokamaks produces energy in the same way as in the stars. The immense gravitational attraction in these celestial objects pulls hydrogen atoms toward each other so strongly that fusion is inevitable. In theory, coupling two hydrogen isotopes to form a helium nucleus is relatively simple, but in practice, the task is not so trivial. To simulate the conditions of stars in a tokamak, physicists have to make the atoms move a lot. The minimum temperature for triggering fusion in a tokamak is approximately 150 million degrees Celsius, 10 times hotter than in the center of the Sun.

The tokamak is toroidal in shape, like a donut. Inside, strong magnetic fields confine a mixture of hydrogen plasma—a state of matter in which gases are heated until the electrons escape from the atoms—and fast particles, also known as alpha particles, including the nuclei of helium atoms. "To make fusion an efficient and self-sustaining process, we have to stop the fast particles escaping from the reactor so that they can transfer their energy to the rest of the plasma," explains Duarte. ■

#### Project

Geodesic and continuous acoustic Alfvén modes in rotating plasma columns (no. 12/22830-2); **Grant Mechanism** PhD Fellowship; **Principal Investigator** Ricardo Galvão (USP); **Fellowship Beneficiary** Vinícius Njaim Duarte; **Investment** R\$86,783.64 and R\$78,445.84 (Overseas Research Fellowship Grant, no. 14/03289-4).

#### Scientific article

DUARTE, V. *et al.* Theory and observation of the onset of nonlinear structures due to eigenmode destabilization by fast ions in tokamaks. **Physics of Plasmas**, vol. 24, i. 12, Dec. 2017.



# Frozen light

Theoretical study  
proposes a new way  
of stopping light

PUBLISHED IN APRIL 2018

Light moves faster than anything else in the universe, but it can be brought to a complete stop as it travels through space, according to a theoretical method proposed by three researchers, one of whom is based in Brazil. Based on numerical simulations, the three scientists demonstrated that it is possible to stop pulses of light as long as their trajectory is confined by waveguides—physical structures that direct light (such as optical fibers or channels)—arranged in such a way as to create singularities. The mathematical concept relies on what is known as the exceptional points of a system (in this case, light passing through waveguides), at which unusual or undefined properties arise. When passing through these points, the speed of a light pulse is

reduced to zero, according to mathematician Alexei Mailybaev, from the Institute of Pure and Applied Mathematics (IMPA), Rio de Janeiro, and physicists Nimrod Moiseyev, from the Israel Institute of Technology (Technion), and Tamar Goldzak, a postdoctoral fellow at the Massachusetts Institute of Technology (MIT), USA.

The new method differs from other approaches pursuing the same objective, because the light decelerates completely without losing its original intensity, according to the article published in the scientific journal *Physical Review Letters* on January 3. In other theoretical techniques, the light intensity weakens before it comes to a stop. At exceptional points, the various waves that make up a pulse of light behave as one, which is essential to maintaining its intensity when it stops. However, Mailybaev points out that there are technical limitations to putting the idea into practice. "It would be difficult to record whether the light actually stopped," explains the Russian mathematician, who now lives in Brazil. He has been working with Nimrod Moiseyev's research group for eight years. "Recording where the signal is in the waveguide at any given time, which is necessary to calculate any changes of speed, is a complex process. But these technical difficulties can be overcome."

Light is created by the vibrations of electric and magnetic fields. Physicists use mathematical equations to represent the properties of these waves, such as their frequency, amplitude, energy, and speed. Mailybaev says that the idea of studying how to stop light resulted from a discussion between the three researchers regarding physical phenomena that emerge from singularities in mathematical calculations. "Out of curiosity, we wondered what would happen to light in these unusual situations," recalls the IMPA researcher. They did the math and realized that when passing through these exceptional points, the speed of light would be zero. They then began to investigate ways of creating exceptional points in structures that direct light—waveguides—and formulated a

proposal. By placing two waveguides adjacent to each other and adjusting their parameters so that the intensity of a light beam increases in one waveguide while decreasing in the other, an exceptional point is created where the beam of light stops moving. This is because one waveguide gains energy at exactly the same rate as the other one loses it. "The advantage of our proposal is that it covers a large number of parameters in a modifiable structure," says Tamar Goldzak.

#### SLOWER LIGHT

In a vacuum, light travels at a constant speed of approximately 300,000 kilometers per second (km/s), but when light moves through other media, such as air or water, it naturally decelerates. The formation of a rainbow, for example, would not occur if light traveled at the same speed in water (where it moves at approximately 225,000 km/s) and air (where it is just slightly slower than in a vacuum). Over the last two decades, physicists have been trying to control light and have obtained surprising results. In 1999, a group led by Danish mathematician and physicist Lene Hau at Harvard University, USA, experimentally reduced the speed of light to 17 meters per second by firing a laser beam through an ultracold atomic gas known as a Bose-Einstein condensate. In 2001, the team took a step further and stopped light for 1 second within a similar system.

## THE NEW METHOD SLOWS LIGHT PULSES TO A STOP WITHOUT LOSING THEIR INTENSITY OR FORM

Hau's method has since enabled scientists to turn light upside down, decelerate it, accelerate it, and store it. However, before it can reach a speed of zero with this method, the light dies out and almost its entire form is imprinted on the structure of the atoms, like a kind of digital light. "Reducing the speed of light in ultracold gases is great for basic research, but it is unlikely to result in any real-world applications," says physicist Thomas Krauss, from York University, UK. Mailybaev, Moiseyev, and Goldzak believe their proposal has greater potential for applications because the exceptional points could be used to control waves of any type (including light, sound, and others) regardless of the medium through which they are travelling. Even waves moving through water could be controlled by this method, according to the researchers. "Slower light interacts more with matter," says Emiliano Martins, an expert in guided waves from the São Carlos School of Engineering at the University of São Paulo (EESC-USP). "This characteristic is essential to the development of telecommunications and optical data processing." ■ **Victória Flório**

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#### Scientific article

GOLDZAK, T., MAILYBAEV A. A. and MOISEYEV, N. Light stops at exceptional points. *Physical Review Letters*, v. 120, i. 1, Jan. 3, 2018.

# { A world that is controlled by algorithms }

Logical computer systems have a growing impact on everyday life



**Bruno de Pierro**

PUBLISHED IN APRIL 2018

**A**lgorithms are everywhere. When share prices rise and fall, algorithms are typically involved. According to data that were released in 2016 by the Institute for Applied Economic Research (IPEA), investment robots that are programmed to instantly react to specified scenarios account for more than 40% of stock market transactions in Brazil. In the United States, this figure is 70%. The success of a simple Google search depends on these computer programming procedures, which can filter billions of web pages in mere seconds; the importance of a website, as defined by an algorithm, is based on the quantity and quality of other pages that link to it. At the frontier of automotive engineering research, sets of algorithms are used by autonomous cars to process information that has been captured by cameras and sensors to instantly make decisions at the wheel without human intervention.



## What is an algorithm?

An algorithm is a logical sequence of steps that are used to solve a problem and are written in a computer programming language



## How to build an algorithm

1

### Identify the problem

The objective of the algorithm must be defined. If the objective is to use images to more accurately detect cancer, computer scientists can design a strategy that examines the characteristics of the tumors, the available data, and the possible methods of diagnosis

2

### Develop a solution

The next step is to establish the sequence of steps that must be performed to solve the problem. In the example of cancer diagnosis, this involves analyzing the available medical images, comparing tumors and their volumes, and collecting data on how the disease progresses

3

### Translation and development

The solution is expressed in a programming language. Each step is translated into lines of code that contain the commands that are needed to execute it. Some algorithms are composed of millions or even billions of lines of code



## Who creates an algorithm?

The development of an algorithm can involve tens or even hundreds of experts, depending on its complexity

1

### Computer scientists

Computer scientists identify the solution and determine the steps that are needed to build the algorithm. They liaise with professionals from other fields

2

### Other professionals

Computer scientists are advised by professionals who have expert knowledge of the problem. They may be sociologists, demographers, economists, or doctors—this depends on the objective

3

### Programmers

Programmers are responsible for writing parts of the algorithm in computer language, without necessarily knowing anything about the other parts

4

### Algorithms

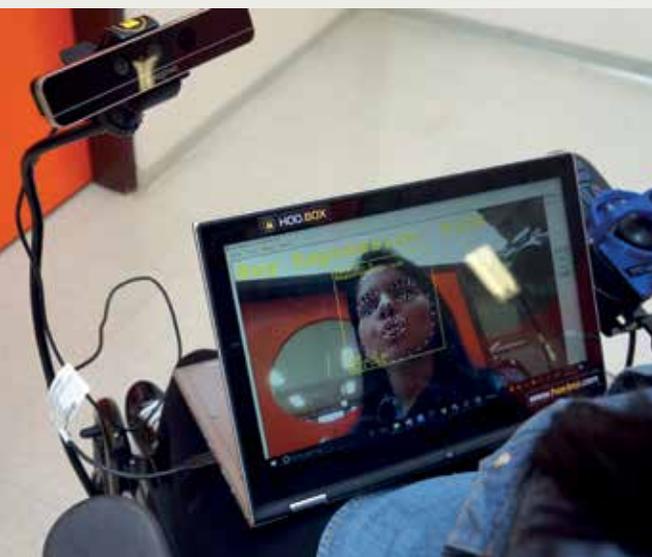
There are algorithms that are capable of developing other algorithms by modifying programming code that has been written by humans



# Facial Expression

Hoobox Robotics, which is a company that was founded by researchers from UNICAMP in 2016, has developed a system for motorized wheelchairs that enables quadriplegics to control the chair using only facial expressions. The algorithm that is used by the software, which is called Wheelie, translates up to 11 facial expressions, such as a smile or a raised eyebrow, into commands to move forward, backward, left, and right. The program is being tested by 39 patients in the USA, where the company has a research unit at the Johnson & Johnson laboratory in Houston. The system uses a 3D camera to capture dozens of facial points.

“The user can configure a command for each expression. A smile, for example, can move the chair forward, a kiss, back,” explains computer scientist Paulo Gurgel Pinheiro, who is the director of Hoobox. To learn to recognize key expressions, the Wheelie algorithm studied a set of facial data from 103 truck drivers. “We partnered with a transportation company to install cameras in trucks and record the facial expressions of volunteers over three months,” Gurgel explains.



An algorithm translates facial expressions into commands for controlling motorized wheelchairs

Although they play a role in even the most mundane tasks, such as traffic avoidance via mobile applications, algorithms are often viewed as intangible by the general population, who feel their effects but do not know or understand what they are or how they work. An algorithm is nothing more than a sequence of steps that are used to automatically solve a problem or accomplish a task, regardless of whether a dozen or a million lines of programming code are required. “It is the nucleus of any computational process,” says computer scientist Roberto Marcondes Cesar Junior, who is a researcher at the Institute of Mathematics and Statistics of the University of São Paulo (IME-USP).

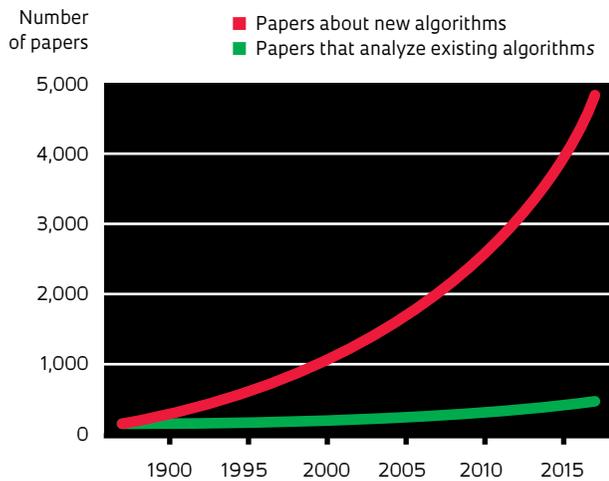
Consider the sequence of steps that are performed by the Facebook algorithm, for example. The choice of what to display in a user’s news feed is based primarily on the set of posts that have been produced by or are circulating among the user’s friends. The algorithm analyzes this information and discards posts that have been flagged as violent or inappropriate, posts that appear to be spam, and posts in which the wording is identified as “clickbait”—a form of exaggeration that is used to encourage users to click a link. Finally, the algorithm assigns a score to each post that is based on the user’s activity history and estimates how likely the user is to enjoy or share the information. The algorithm has recently been modified to reduce the reach of posts that have been made by news outlets.

## Robots are responsible for 40% of the decisions that are made on the Brazilian stock market

The development of an algorithm involves three steps (*see the infographic on page 59*): The first is to accurately identify the problem and find a solution to it. In this phase, computer programmers work with professionals who understand the task that must be performed. They could be doctors, in the case of an algorithm that analyzes imaging exams; sociologists, if the objective is to identify patterns of violence in regions of a city; or psychologists and demographers in the development of a dating application. “The challenge is to show that a practical solution to the problem exists, that it is not a problem of exponential complexity, for which the time needed to produce a response can increase exponentially, making it impractical,” explains computer scientist Jayme Szwarcfiter, who is a researcher at the Federal University of Rio de Janeiro (UFRJ).

# Rarely studied systems

An artificial intelligence journal\* was found to publish more articles that describe new algorithms than articles that study the behavior of existing ones



\* Proceedings of the Neural Information Processing Systems Conference

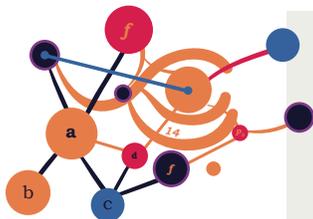
SOURCE RAHWAN ET AL. CLOSING THE AI KNOWLEDGE GAP. ARXIV, 2018

The second phase is also free of mathematical operations: it consists of describing the sequence of steps in normal language, for everyone to understand. Next, this description is translated into a programming language during phase three. Only then can the computer understand the commands—which can be simple, mathematical operations or complex algorithms within algorithms—all in a logical and precise sequence. During this stage, programmers are tasked with

writing the algorithms. On complex projects, large teams of programmers work together and share tasks.

At their origin, algorithms are logical systems that are as old as mathematics. “The expression comes from a Latinization of the name of Persian mathematician and astronomer Mohamed al-Khwarizmi, who produced famous works on algebra in the ninth century,” explains computer scientist Cristina Gomes Fernandes, who is a professor at IME-USP. They gained new impetus in the second half of the last century alongside the development of the computer, with which it was possible to create work routines for the machines. There are two reasons why algorithms are now so widely used in the real world and why they have become the basis of most complex software development: First, the increased processing power of computers has increased the speed at which complex tasks can be executed. Second, the advent of big data has made it cheaper to collect and store huge amounts of information, thereby enabling algorithms to identify patterns that are imperceptible to the human eye in a wide range of scenarios. Advanced manufacturing, which is known as Industry 4.0, promises to increase productivity by using artificial intelligence algorithms to monitor industrial plants in real time and make decisions on stock control, logistics, and maintenance.

**O**ne effect of the growing use of algorithms in computing was a boost to artificial intelligence, which is a field that was established in the 1950s and aims at developing mechanisms that are capable of simulating human reasoning. Through increasingly fast computations and the collection of data for statistical comparisons, computers can now modify their operations based on accumulated experience,



## Identifying Parasites

An IME-USP research project is being conducted in collaboration with UNICAMP's Laboratory of Image Data Science (LIDS) to improve the diagnosis of parasite infections using computer vision. Marcelo Finger, who is a computer scientist from IME, is testing an algorithm that can identify parasites by analyzing images of stool samples. “We have been able to identify 15 parasites in humans and some in animals, such as cattle, dogs, and cats,” he says. Diagnoses are currently obtained by

examining stool samples under a microscope. “A lab worker can usually analyze about six blades at a time. The aim is to automate this process,” says Finger. It seems simple; however, because algorithms operate by identifying patterns, any background noise creates an obstacle for the researchers. “It is one thing for the algorithm to be able to identify the parasite in a photo from a book; doing the same with an image in which the parasite is surrounded by dirt is quite another,” says the researcher.

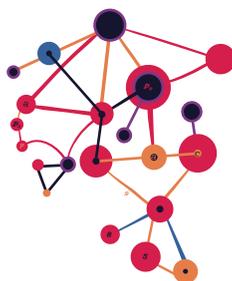
thereby improving their performance in a process that mimics learning.

Computers have proven capable of beating humans in many board games; this demonstrates how the field has evolved. In 1997, IBM's Deep Blue supercomputer succeeded for the first time in beating the world chess champion of the time, Gary Kasparov, who was from Russia. Capable of simulating approximately 200 million chess positions per second, the machine anticipated its opponent's decisions several moves ahead. However, this strategy was unsuccessful for *Go*, which is a Chinese board game, because there are too many possible moves at any time to anticipate—the number of possibilities exceeds the number of atoms in the universe. In March 2016, *Go* was finally defeated: the AlphaGo program, which was created by DeepMind, which is a subsidiary of Google, beat world champion Lee Sedol, who was from South Korea.

Instead of considering millions of possibilities, the program's algorithm used a more restricted strategy: By statistically analyzing data from previous matches between the game's best players, the program identified the most common and efficient moves, thereby resulting in a smaller set of variables, and was soon able to beat the human players. However, there was more to come. Last year, DeepMind developed a new program, namely, AlphaGo Zero, which outperformed the original AlphaGo. In the new program, the machine did not learn from humans, but from the previous versions of the program.

There are a growing number of practical applications for this type of technology. Artificial intelligence algorithms that were developed by computer scientist Anderson de Rezende Rocha, who is a professor at the Institute of Compu-

## Programmers should be aware of the implications of their work, says Nick Seaver, from Tufts University



there are files that are related to child abuse, the algorithm helps find them. “We exposed the robot to hours of pornographic videos from the internet to teach it what pornography is,” says Rocha. Then, to identify the presence of children, the algorithm needed to “watch” the videos of child abuse that were seized by the police. “This stage was carried out by police officers. Nobody at UNICAMP had access to this material,” he adds. Rocha says that these types of files were previously analyzed manually in most cases. “Automating the process makes it more efficient, giving the police more time and allowing them to examine more data.”

Many computer scientists use mathematical properties, theorems, and logic when working on algorithms, regardless of the immediate purpose

## Infinite commands

Numbers of lines of code in the algorithms that are used in various products and services

### SIMPLE IPHONE APP

10,000

### BOEING 787

14 million

### LARGE HADRON COLLIDER (LHC)

50 million

### FACEBOOK

62 million

### CAR SOFTWARE

100 million

### GOOGLE

SOURCE MCCANDLES, D.  
KNOWLEDGE IS BEAUTIFUL.  
HARPER COLLINS  
PUBLISHERS, 2014



Google's AlphaGo software beat South Korean Lee Sedol in a game of Go in 2016

of the application. In many scenarios, the only known algorithms are highly inefficient and do not perform well with large data volumes, for example, in the factorization of a number into its constituent primes (which is highly important in cryptography) or routing a welding robot through several weld points. There is little hope that efficient algorithms will be identified for these applications, which fall under unsolved problem of “P versus NP,” which is considered one of the greatest challenges in both computer science and mathematics.

Although there is more programming involved than basic science in the development of many of the algorithms that are used in everyday life, advances in knowledge are essential if new applications are to be explored in the future. Marcondes Cesar, who is from USP, is working on computer vision, which is a type of artificial intelligence that extracts information from images to simulate human vision. The technique is being explored in various industries, particularly in medical diagnoses. “Computer vision can detect anomalies more accurately and evaluate subtle details in magnetic resonance imaging, for example.”

The objective of the project, which is being carried out in partnership with the USP School of Medicine and the Children’s Institute of the

university’s teaching hospital, is to develop a mathematical model that can provide a more accurate analysis of the liver and brain in newborns. The models that are used to interpret magnetic resonance images are typically based on white adult males and have been developed in other countries, which can lead to inaccurate diagnoses in newborn babies in Brazil. However, the project’s success depends on several theoretical problems being solved first. “We do not yet know if we will be able to write an efficient algorithm. We are still studying properties based on graph theory,” he says, referring to the branch of mathematics in which the relations between objects of a specified set are studied by associating them to one another via structures that are called graphs.

The impact of algorithms has also been analyzed in other fields of knowledge. “Algorithms are already playing a moderating role. Google, Facebook, and Amazon have an extraordinary amount of power over what we are exposed to in culture today,” said Ted Striphas, who is a professor of the history of culture and technology at the University of Colorado, USA, and author of the book *Algorithmic Culture* (2015), which examines the influence of these online giants. American anthropologist Nick Seaver, who is a researcher at Tufts University, USA, is currently conducting ethnographic research and interviews with the creators of music recommendation algorithms for streaming services. His interest is in how these systems are designed to attract users and draw their attention and he is studying the interface between areas such as machine learning and online advertising. “The mechanisms that control attention and its technical mediations have become a subject of great interest. The formation of interest and opinion bubbles, as well as *fake news*, and political distractions, can be attributed to technologies designed to manipulate user attention,” he explains.

**R**ecommendation systems that are based on algorithms have become key players in the online entertainment industry. In an article that was published in the journal *ACM Transactions on Management Information Systems* in 2015, Mexican electronic engineer Carlos Gomez-Uribe described how the algorithms that are used by streaming service Netflix rank television series and movies according to the



Testing Uber's autonomous car prototype in San Francisco (USA)

individual profile of each user. The objective is to encourage customers to select a TV show to watch within 90 seconds of logging on—any longer than that and they tend to get frustrated and lose interest. The success of this ranking system gave Gomez-Uribe's career a boost and in 2017, he became head of algorithms and internet technology products at Facebook.

The influence and power of major internet companies do not depend solely on the creativity of their programmers. They are also linked to the huge volumes of data that have been accumulated and processed by their algorithms, which have generated highly valuable information. "What prevents another company from developing an application like Uber? This has already been do-

ne, in fact. But the traffic and customer behavior data that Uber has accumulated over time belongs only to them, and it is valuable," says Marcondes Cesar, who is from USP.

The recent Facebook user-data leak, which caused the value of the company to fall by US\$49 billion last month, revealed a vulnerability that was thought to be uncommon—algorithms that are used by Cambridge Analytica were able to access the behavioral data of 50 million Facebook users, which were subsequently used to influence political campaigns on social networks, including the Brexit vote and Donald Trump's ultimately successful bid to become president of the United States. The Facebook case is an example of the ethical challenges that are created by the widespread use of algorithms, although data misuse and abuse are only part of the problem. Data use has become as important for algorithms as the challenge of programming them. "Analyzing the characteristics of the data is fundamental to the construction of an algorithm; a mistake at this stage could lead to biases in the results," says Marcondes Cesar.

It is also common for algorithms to reproduce biases when they are based on human behavior. The Cloud Natural Language API, which is a tool that was created by Google that identifies the structure and meaning of texts through machine learning, has developed its own biases. A test by American website Motherboard demonstrated that when analyzing text to determine if it has a "positive" or "negative" sentiment, the algorithm classified statements such as "I'm a homosexual" and "I'm a gay black woman" as negative. "Programmers who create smart algorithms need to be aware that their work has social and politi-

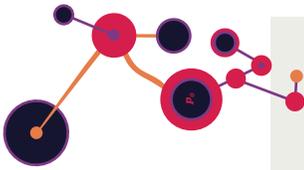
## CATTLE WEIGHT

Projeta Sistemas, which is a startup that is based in Vitória, Espírito Santo State, Brazil, has created an algorithm for assisting cattle farmers. The system, which is called Olho do Dono, uses 3D images to estimate the weights of cows. "The process of weighing cattle is very costly, time-consuming, and involves moving the animals around, which can cause stress and even weight loss," explains computer scientist Pedro Henrique Coutinho, who is the director

of the company. The software was developed based on computer vision techniques and associates the weights of the cattle with images that were captured by cameras. The system relies on a robust database. "We monitor the weighing of livestock on ranches throughout Brazil. Our algorithm is based on thousands of recorded images," says Coutinho. Development began in 2015 and the software will go to market in September.



System uses computer vision to estimate the weight of cattle



## Lost animals

CrowdPet is a smartphone application that was created by SciPet, which is a company that is based at UNICAMP, for helping find lost animals. The system uses an algorithm to compare pictures of lost pets that were provided by their owners with photos of animals on the streets that were taken by volunteers. “The application can match two images through visual recognition

methods and uses geolocation to locate where the photo of the lost animal was taken,” says Fabio Rogério Piva, who is the director of SciPet. The Animal Control Center in the municipality of Vinhedo, São Paulo, began using the application last year to register animals during welfare campaigns. SciPet has developed a prototype that can identify dogs and cats with 99% accuracy.

cal implications,” says Nick Seaver, from Tufts University. Various undergraduate and graduate computer science programs already offer classes that address computer ethics, including USP in Brazil and Harvard University and the Massachusetts Institute of Technology (MIT) in the US.

The transparency of advanced algorithms is another hot topic. The details of how these tools operate are often kept secret by developers. In some cases, the code is so complex that it is not possible to understand how the algorithm arrives at a decision and what its implications are. Systems such as these, which are opaque to external scrutiny, are known as “black box algorithms.” The debate has gained momentum after research into an experimental tool, namely, Correctional Offender Management Profiling for Alternative Sanctions (COMPAS), which is used in the US legal system to make sentencing recommendations and even to predict the risk that a defendant will reoffend. The study, which was conducted by the ProPublica organization in 2016, revealed that the COMPAS system is 77% more likely to classify black defendants as possible reoffenders than whites. Northpointe, which is the private company that created the algorithm, declined to share the code. “Algorithms used by public bodies should not be created or developed without the participation of public managers and administrators, as they are not neutral,” says Sérgio Amadeu da Silveira, who is a researcher at the Center for Engineering, Modeling, and Applied Social Sciences at the Federal University of ABC (UFABC).

In 2017, Kate Crawford, who is the head of research at Microsoft Research, and Meredith Whittaker, who is the leader of Google’s Open Research Group, founded the AI Now Institute, which is an organization that is dedicated to understanding the social implications of artificial

intelligence. Based at New York University, USA, the institute’s approach involves computer scientists, lawyers, sociologists, and economists. In October, it released a report that offered guidelines on the use of artificial intelligence algorithms. One recommendation was that public agencies such as those that are responsible for criminal justice, healthcare, welfare, and education should not use systems whose algorithms are not well known. According to the document, black-box algorithms should be subject to public auditing and validation tests to implement corrective mechanisms when necessary.

**A**nother objective of artificial intelligence algorithms is to free human beings from repetitive tasks—and there is frequent debate over the implications of AI software on the labor market. “The Future of Employment,” which is a report that was published in 2013 by economists Carl Frey and Michael Osborne from the Oxford Martin School, UK, estimated that sophisticated algorithms could soon replace 140 million professional jobs worldwide. The paper specifies examples, such as the increasing automation of decision-making in the financial market and even the impact on the work of software engineers—machine learning and algorithms can improve and accelerate various programming tasks. “Procedural intellectual activities that involve repetitive tasks, such as translating documents, have a great chance of one day being executed by computer algorithms,” says Sérgio Amadeu, who is from UFABC. It is important that we discuss the side effects of artificial intelligence, according to Marcondes Cesar, who is from USP; however, for now, they are far outweighed by the remarkable contributions that are made by these algorithms to the solution of problems of many types. ■



**T**he Brazilian technology sector had a remarkable first quarter of 2018. In less than two months, two startups joined the elite Unicorn Club—which is the name given by American investor Aileen Lee to the special group of technology companies that are valued at US\$1 billion or more. In an article written in 2013, the investor estimated that only 0.07% of startups go on to accomplish this feat—which makes it almost as “rare and magical” as the mythological creature.

The first Brazilian startup to join the group was 99 Tecnologia, which is a taxi app that was founded in 2012. In January of this year, 99 was valued at US\$1 billion and acquired by Chinese conglomerate Didi Chuxing, which first bought shares in the startup in January 2017 when it invested more than US\$100 million.

In March, the financial technology startup Nubank reached the same valuation after receiving US\$150 million of new investments. Nubank was founded in 2013 to offer credit cards with no annual fees and low interest rates. The company was created by three individuals: David Vélez, 36, a Colombian who graduated in engineering from Stanford University in the USA; Edward Wible, 34, an American who studied computer science at Princeton University in the USA; and Cristina Junqueira, 35, a Brazilian production engineering graduate from the University of São Paulo’s Polytechnic School (Poli-USP). All three have MBAs.

Vélez came to São Paulo in 2011 while working for Sequoia—a US venture capital fund—to look for investment opportunities in the Brazilian technology sector, but he found no companies of particular interest. In 2013, he left his job to

work on his idea for a new kind of credit card, which was managed solely through a mobile app. After receiving his first round of funding, he invited Junqueira, who had experience at Itaúcard, and Wible, an expert on big data who was working in Argentina at the time, to join his venture. More than three million credit card users later, Vélez announced in March this year that Nubank was officially a unicorn company. There is already speculation that Movile, which owns popular applications such as iFood and PlayKids, could be next.

Vélez has regularly mentioned that Nubank was founded and prospered during the Brazilian economic crisis. The adverse financial landscape of the last few years does not scare Renato Freitas, who is a mechatronics engineer who graduated from Poli-USP and one of the founders of 99 Taxis. “The interesting part of working with innovative projects is that they suffer very little from macroeconomic fluctuation. There is always space for new technology. With 99 becoming a unicorn and other startups following suit, I think Brazil will soon begin to attract more attention from foreign investors, which should be good for the startup sector,” he says.

According to Marcelo Caldeira Pedrosa, a professor at the School of Economics, Business, and Accounting at USP (FEA-USP) and the coordinator of the university’s Master’s Degree in Entrepreneurship, there are a number of factors that can lead to a startup becoming a unicorn. These include a proven business model that generates value; scalability, which is a company’s capacity for rapid growth; and



employees with skills that can give the company a competitive advantage. 99 is one of the companies that has fulfilled all of these criteria.

To start, the founders of 99 were inspired by a business model that has already been successfully tested abroad. According to Freitas, he had the idea for the company when Ariel Lambrecht, a mechatronics colleague at Poli-USP, traveled to Germany and used the world's first mobile taxi app, MyTaxi. "We thought it would be a great idea to launch in Brazil because of the transportation challenges people face here: expensive public transportation, heavy traffic, etc.," says Freitas. The initial investment was R\$50,000.

**T**he challenge of expansion has been overcome by in-depth knowledge of the characteristics and needs of the target audience. "At the time, taxi drivers still used what we call feature phones rather than smartphones. We put a lot of time into teaching them which smartphones to buy, how to use them, and which apps could help them in their day-to-day work," he says. Freitas says that he and Lambrecht searched for taxi points on Google Maps and then went around the city handing out flyers and raising awareness of their company practically every day in its first few months in 2012. "We already had our final application at that point—the only people who used it during the developmental stage were me and Ariel. But development has never stopped; we always have new things to add. This closeness with our customers allowed us to better understand them, and we were able to incorporate their thoughts into

the app. Surveys later showed that taxi drivers preferred our app because they considered it to be more intuitive and easier to use."

However, according to Freitas, neither the application itself nor the business opportunity was the main reason for the company's success. Instead, it was the third factor mentioned by FEA's Pedrosa: the skills of the team. "Many companies were developing the same application at

**Others developed similar apps but did not achieve the same success. What made 99 different was its team, says Renato Freitas, one of the founders of the company**

that time and had the same business opportunity, but did not achieve the same success. What made the difference at 99 was our team. We always seek to hire people with a passion for the challenges we face," he says. The initial staff was composed of Lambrecht and Freitas, who focused on product development, and Paulo Veras, a former Poli-USP student who had experience creating startups, such as Tesla. Tesla was one of the first companies specializing in website development and e-commerce, which he founded in the late 1990s.

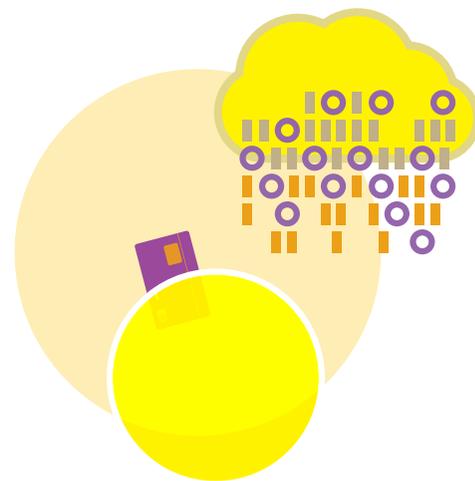
"The three of us are very different, although we all studied the same degree. I've always focused on the technology and how it relates to the product. Paulo deals with the business side of things; finance, marketing, and human resources. And Ariel was mainly responsible for product, he was the 'glue' that held the different areas together and focused on how they affect our customers," says Freitas. In 2017, 99 expanded its services. It began to accept private drivers, thus becoming a competitor of the US ride-sharing company Uber, which had been operating in Brazil since 2014. The company continued to grow and attracted the attention of Chinese conglomerate Didi Chuxing, whose intention was to surpass Uber in the global market by expanding into Latin America.

Today, under the control of Didi Chuxing, 99 connects more than 300,000 drivers to 14 million passengers in more than 400 cities and towns across Brazil. In February 2018, the company launched a new application, which was developed in partnership by the Brazilians and the Chinese. "More than 250 employees from the engineering and product teams in Brazil and China were involved in its development," says João Costa, product leader at 99. "The app uses artificial intelligence to better distribute pickups, reducing the amount of time passengers have to wait for a driver by 20%," he says.

After selling 99, Freitas and Lambrecht began a new project, this time in partnership with former Caloi CEO Eduardo Musa: a bicycle-sharing service where bikes are released via a mobile app. The service uses a "dockless" model that requires no bicycle stations. Bikes are fit with GPS trackers and can be left anywhere after use. The next user simply unlocks the bike using their cell



## The ecosystem has evolved, but startups are still too focused on the domestic market, says UFSCar's Marcelo Pinho



phone to scan a QR Code that is printed on the frame.

The company is called Yellow and plans to offer 20,000 bicycles for use in the city of São Paulo starting in July, with that number increasing to 100,000 in the near future. “We came up with the idea for Yellow in China, where we used a similar service. We really enjoy seeing how companies have solved problems in other countries. But we do not want to simply copy other ideas. We developed our solution from scratch, learning from other companies and taking our own values into account,” says Freitas.

**T**he success of these innovative new companies came as no surprise to those who study the world of business. According to Moacir de Miranda, head of the FEA department at USP, Brazil’s innovation ecosystem may finally be reaching maturity. “We are at last beginning to enter the 21st century,” he says. Miranda believes that the market has now realized that strategic knowledge management is the key to survival. “Companies are investing in knowledge as a competitive advantage. What we were discussing 20 years ago is now starting to happen on a large scale.”

According to the researcher, greater involvement of the private sector is one of the main factors behind the increasingly favorable environment for startups in Brazil. “Ten years ago, incubators were almost exclusively university initiatives. Today, large corporations regularly fund incubators and coworking spaces, creating business units designed to produce disruptive innovations. By taking on this leading role, private companies have brought a new dynamic to the industry,” he says. The private sector’s interest in innovation grew alongside diminishing public investment as a result of the economic crisis.

“Public investment in innovation has dropped dramatically since 2014. Today, it is at its lowest level in the last 10 years,” says Miranda, referring to data from the Brazilian Funding Authority for Studies and Projects (FINEP). According to the *National science, technology, and innovation indicators 2017* report by the Brazilian Ministry of Science, Technology, Innovation, and Communications (MCTIC), private investment in R&D increased from R\$37.4 billion to R\$38.1 billion between 2014 and 2015 despite the economic crisis. The release, which is based on information

from the IBGE Innovation Survey (PINTEC) and studies by the Organisation for Economic Co-operation and Development (OECD), provides an overview of innovation in Brazil.

According to Marcelo Pinho, an industrial and technological economics researcher from the Center for Exact Sciences and Technology at the Federal University of São Carlos (UFSCar), universities play an important role in the development of future entrepreneurs, but the technological strategy is part of the corporate experience. It is at this point that most Brazilian startups commit their “fatal error.” “Brazil’s tech companies do not usually develop global innovations or target markets outside the country,” he says.

Pinho notes that Brazilians generally operate in niches, which limits their growth to the markets in which they were created. These limitations are usually the result of a technology strategy that does not lead to primary innovation. “These companies often reproduce businesses that have already been developed abroad.” He is not so optimistic about the current state of the startup ecosystem in Brazil.

Pinho believes that because other obstacles to growth have been removed in recent years—through an increasing number of private funding options and new legislation that encourages partnerships between universities and businesses, such as the Brazilian Legal Framework for Science, Technology, and Innovation—there is a view that the startup environment in Brazil has evolved. However, technology companies are still primarily focused on the domestic market, which is a problem that is shared with other periphery economies. ■



The jet during one of its certification flights



#### **E190-E2**

**Capacity**  
114 passengers

**Range**  
5,278 kilometers

**Length**  
36.2 meters

**Wingspan**  
35.1 meters

**Start of operation**  
April/2018

# A more efficient jet

Embraer's new aircraft delivered better-than-expected performance in certification tests



Details of tail (above), turbine (top), and landing gear (right) of the E-Jets E2: the aircraft are more economical and quieter than aircraft of the previous generation

**T**he world's third-largest commercial aircraft manufacturer and leader in the 150-seat-and-under aircraft segment, Embraer is expected to deliver the first model of its new generation of E-Jets E2 planes in April this year. Named the E190-E2, the aircraft will be a part of the fleet of Norwegian airline Widerøe, which is Scandinavia's leading regional airline. With a capacity of 114 passengers, the jet delivered better-than-expected performance during its certification-testing period, which is the final stage before an aircraft begins commercial operations. Flight tests showed that the new airplane has a longer flight range and lower pollution emissions, and it is more economical and quieter than originally specified by Embraer.

The superior performance achieved by the E190-E2 is a result of the research and development (R&D) work carried out in Embraer's labs,

the experience of Embraer's engineers in designing and developing new aircraft, and the lasting partnerships developed with university researchers. "In the past 17 years, no other aircraft manufacturer has developed as many planes as we have," says Rodrigo Silva e Souza, vice president of marketing at Embraer Commercial Aviation. "During this period, we created the first generation of E-Jets for commercial aviation, various models of executive jets such as the Phenom and Legacy, the KC-390 cargo plane for the defense sector, and finally, the E2."

According to Embraer, the E190-E2 will arrive in the market replete with innovations—in the fuselage, wing design, landing gear, engines, interiors, avionics, etc.—that will make it the most efficient single-aisle jet on the market. This category includes the traditional Boeing 737 and Airbus A320, as well as the C Series family of aircraft



from Bombardier, the Brazilian airline's chief rival in the regional aviation market. "Our new jet was designed to have a 16% lower fuel consumption performance than the current generation of E-Jets, but it exceeded that target and hit 17.3%," Souza reports. He adds that with this rating, the plane is about 10% more economical than its direct competitors, the Canadian C Series jets.

This reduction in the fuel consumption gives the E190-E2 two important advantages in the highly competitive aerospace market: the aircraft has lower pollution emissions and better range. Embraer estimates that with the 1.3% improvement in fuel consumption, each jet will emit about 1,700 fewer tons of carbon dioxide (CO<sub>2</sub>) over 10 years. For its range, the E190-E2 can reach destinations up to 5,300 kilometers away, as opposed to the 4,500-kilometers range of the current generation of E-Jets. "This additional distance will give airline companies an ability to reach more distant airports, increasing the plane's adoption," the Embraer executive pointed out.

Most of the projected 16% reduction in fuel consumption was due to the use of the new Pratt & Whitney engines, which are more efficient than those on the first-generation E-Jets. The use of these engines accounted for 69% of the improvement initially projected, followed by that due to the introduction of a new wing design (22%) and improved fly-by-wire system (9%). "A fundamental factor in the better-than-expected reduction in fuel consumption—1.3% better—was the improvement of the fly-by-wire system," Silva notes. With this technology, control of the mov-

ing parts on the wings and tail of the airplane (flaps, ailerons, spoilers, slats, and elevators) is performed by computerized electronic controls. Responsible, along with the wings, for the flight characteristics of the airplane, these aerodynamic elements are actuated by the pilot to change the direction, orientation, and level of the flight.

The improvement of the fly-by-wire system of the new jet permitted a 20% reduction in the empennage area (the terminal part of the fuselage, located at the rear, known as the airplane's tail), minimizing drag and weight. The fly-by-wire system on the E-Jets E2 is the fourth generation designed by Embraer. This technology, which significantly increased the aircraft's degree of automation, replaced the traditional control system made up of steel cables and hydraulic actuators.

#### **PARTNERSHIP WITH FAPESP**

Embraer also managed to reduce the noise emissions of the E190-E2 more than originally planned. Designing and developing quieter aircraft capable of operating at airports without disturbing the surrounding residents is a considerable challenge in the aviation industry. "In many airports in Europe and Japan, the landing fee the airline pays is multiplied by the noise factor. So a quieter aircraft can have a lower operating cost," Silva explains.

In order to measure and tabulate aircraft noise levels, the International Civil Aviation Organization (ICAO) has established a metric called EPNdB, short for "effective perceived noise in decibels." This index varies according to airplane

Assembly line at the plant in Gavião Peixoto, São Paulo: Embraer has already received 280 orders for the three models in the E2 family

# The research investigated ways to improve comfort and reduce aircraft noise

size and considers the noise produced by aircraft during takeoff, overflight, and landing approach. During testing, the Embraer jet achieved a cumulative margin of 20 EPNdB in relation to the ICAO limits, 3 EPNdB more than had been projected. The greater the cumulative margin—i.e., the greater the difference between the noise index attained by the airplane and that established by ICAO—the quieter the jet is.

To reduce the noise emitted by its aircraft, Embraer developed an extensive research project. With funding from FAPESP's Partnership for Technological Innovation (PITE) program, the study "Quiet aircraft: An aeronautics investigation" identified and evaluated the noise generated and propagated by the company's first generation of E-Jets. The study focused on aerodynamic noise, which is the sound generated by the flow of air passing around the wing and fuselage of an airplane.

"The knowledge generated throughout the study helped Embraer improve the aerodynamic design of its E2 jets," says engineer Julio Romano Meneghini of the Polytechnic School of the University of São Paulo (Poli-USP), who coordinated the PITE project conducted from 2008 to 2011. "The research resulted in several numerical simulation tools and generated an international patent for a seal [small strip of flexible material] on the tip of the flap. This was one of the solutions we found to reduce the noise generated by a vortex [spiral of spinning air] during landing and takeoff."

E190-E2 test cabin: the study prioritized passenger comfort



PHOTOS EMBRAER

To engineer André Gasparotti, manager of Embraer's technological development program, the reduced noise emissions of the E190-E2 is largely due to Embraer's R&D work over the last 10 years, including that funded by FAPESP. "Our partnership with the Foundation has allowed us to increase our knowledge about noise as well as passenger comfort," he says.

Another PITE project, whose results were applied to the E190-E2, involved the investigation of passenger well-being during flights; further, criteria for comfort were defined, which were used as planning and design parameters for the company's new jets. "In our research project 'Cabin comfort: Development and integrated analysis of comfort criteria,' we study the influence of different environmental parameters on the passenger, such as of noise, lighting, temperature, pressure, and vibration," says engineer Jurandir Itizo Yanagihara, also from Poli-USP and the principal investigator for the PITE study. According to Yanagihara, one important feature of the E-Jets E2 is the cabin design, which received contributions from tools developed during the research.

## LIST OF ORDERS

Embraer's new series of E2 jets, which began development in 2013, includes two other models, the E195-E2 and the E175-E2. Embraer received 280 orders for the three aircraft as of March of this year, in addition to approximately 420 intention-to-purchase agreements. Including the four models of the first generation of E-Jets (E170, E175, E190, and E195), the order list jumps to 1,800 firm orders, of which 1,400 have already been delivered.

The Brazilian airline Azul will be the first to receive the E195-E2, the largest commercial aircraft designed and built in Brazil. With a length of 41.5 meters and a 35.1-meter wingspan (distance from wingtip to wingtip), the E195-E2 has a capacity of up to 146 passengers. Delivery of the first unit is planned for 2019. The "baby of the family," the 90-seat E175-E2 is due to debut in 2021. ■

## Projects

1. Quiet aircraft: An aeronautics investigation (no. 06/52568-7); **Grant Mechanism** Partnership for Technological Innovation (PITE); **Partnership** Embraer; **Principal Investigator** Julio Romano Meneghini (USP); **Investment** R\$3,741,069.33.

2. Cabin comfort: Development and integrated analysis of comfort criteria (No. 06/52570-1); **Grant Mechanism** Partnership for Technological Innovation (PITE); **Partnership** Embraer; **Principal Investigator** Jurandir Itizo Yanagihara (USP); **Investment** R\$3,205,550.76.

## Scientific articles

ILÁRIO, C. et al. Prediction of jet mixing noise with Lighthill's acoustic analogy and geometrical acoustics. **The Journal of the Acoustical Society of America**. v. 141, p. 1203-13. Feb. 2017.

MENEZHINI, J. et al. Wake instability issues: From circular cylinders to stalled airfoils. **Journal of Fluids and Structures**. v. 27, p. 694-701. July-Aug. 2011.

# A blimp over the forest

A pilotless aircraft built in Brazil will monitor environmental reserves in the Amazon

**Marcos de Oliveira**

PUBLISHED IN MAY 2018

When flying slowly at low altitudes over an Amazonian forest in the region of Mamirauá, the blimp Noamay will locate and capture signals emitted by radio collars on monkeys and jaguars. Using sensors, this aircraft may also collect data on the air and soil. The unmanned airship, which measures 11 meters (m) long and 2.50 m in diameter at its widest point, was designed to fly unguided along a predefined path or be controlled remotely by a pilot on the ground. "We took the first flight in remote-control mode on March 3 from a runway in the city of Balsa Nova, Paraná," says electronic engineer Samuel Siqueira Bueno, the researcher at the Renato Archer Center for Information Technology (CTI), a part of the Brazilian Ministry of Science, Technology, Innovation and Communications (MCTIC) in Campinas, which headed Project DRONI (an acronym for "Innovative Concept for a Robotic Dirigible").

Noamay (which means "care and protection" in the indigenous Yanomami language) will begin operation during the second half of this year at the Mamirauá Sustainable Development Institute (IDSM, a social organization linked to the MCTIC), which also participated in Project DRONI. The Institute works in the Mamirauá and Amanã ecological reserves, which total 3.4 million hectares. Project DRONI was funded by the National Science and Technology Council (CNPq) from 2014 to 2017.

The blimp has an important innovation, according to Bueno: four electric motors with propellers are installed so that they rotate 360° and operate independently, allowing the craft to take off and land vertically, hover in the air, and maneuver. "This new system, which we call multidimensional vectorization, permits more precise control of the aircraft on its three axes, which facilitates hovering even in the presence of side winds. This groundbreaking system makes it easy to control the airship at low speeds, and consequently, we are preparing patents to be filed in Brazil and abroad," explains aeronautical engineer Christian Amaral, a partner at Omega Aero-Systems, the company in Campo Largo, Paraná, that designed and built the airship and was also part of Project DRONI. Amaral explains that airships are more useful than drones in some situations because they can fly for longer, carry much larger loads, and hover more stably. Drone batteries generally last no longer than half an hour.

"For now, the blimp can fly autonomously for an hour, but in the future, we will be able to keep it in the air for even longer, sustained by helium gas and battery-powered electric motors," explains Bueno. For the sensing equipment to be carried on the airship, he adds, "we could install an antenna and a receiver to locate and track animals that have radio collars, cameras in different spectrum bands, a LIDAR laser [for light detection and distance measurement] for mapping the ground and trying to find ruins due to ancient humans, or other sensors to measure the composition of the air over the forest."

Noamay has high-capacity lithium-polymer (LiPo) rechargeable batteries. Without helium gas and carrying only the equipment necessary to fly, the blimp weighs approximately 38 kilograms (kg) and is able to carry an additional 6 kg. When empty and folded, the inflatable body of the blimp (known as the envelope) fits inside a large suitcase.

## A MULTIPURPOSE PLATFORM

Another challenge for researchers is to finish developing Noamay's pilotless control system. "In 2002, we completed the development of an autonomous flight system for our first airship, which was purchased abroad in 1998," says Bueno,





Noamay in the air: four electric motors with propellers that can independently rotate 360°

who directed Project AURORA (Autonomous Unmanned Remote Monitoring Robotic Airship) (*see Pesquisa FAPESP issue no. 84*). The aircraft was controlled by an onboard computer and sensors. "With this system, the airship was able to cruise on its own, but takeoff, landing, and hovering were controlled by a pilot on the ground," he says.

Establishing of overall control, which includes taking off, hovering over a chosen point, landing, and even autonomously determining the route and mission based on data captured by the airship, requires methods that are still being developed in simulations for later testing. "Automatic pilot methods for airships that perform all these phases of flight do not exist anywhere in the world. As a result, we have several graduate students involved in these studies," says the researcher. In addition to the CTI, Omega, and the IDSMS, the following universities are participating in

the project: the Federal University of Amazonas (UFAM), the University of Campinas (UNICAMP), the Brazilian Air Force Technical Institute (ITA), and the Superior Technical Institute of Lisbon in Portugal. This multi-institutional collaboration is continuing research and applications relating to Noamay within the National Institute of Science and Technology for Cooperative Autonomous Systems (INSAC).

Electrical engineer José Reginaldo Hughes Carvalho, a professor at the Institute of Computing at UFAM, says that Noamay could be transformed into a multipurpose platform that is a safer and cheaper alternative to manned flights (for tracking animals and collecting environmental information) as well as for data acquisition because it offers wider coverage than fixed sensors. "The difference is that it is quiet and simultaneously flexible, able to hover over one point of interest and proceed to the next," he adds.

The blimp requires 40 cubic meters (m<sup>3</sup>) of helium. This gas can be purchased in cylinders in Tefé, the city that houses the Mamirauá Institute. The average price is R\$120.00 per m<sup>3</sup>, which means it costs R\$4,800.00 to fill the airship. "We are designing a reservoir of synthetic material to store the gas and not lose it, in case it becomes necessary to drain the blimp's envelope," explains Omega's Amaral. In the future, the company intends to produce this type of aircraft on a larger scale. "The world market for airships, whether remotely piloted or autonomous, for environmental and sensing applications is still in development and represents major potential for expansion in the medium and long term." ■

# High-level delivery

Akaer Group is poised to become a global provider of aerospace systems and components

PUBLISHED IN AUGUST 2018

**A**kaer Group, a conglomerate of five high-tech companies based in São José dos Campos, São Paulo, aims to become a global supplier to the aerospace industry, a market estimated to be worth more than US\$100 billion annually. Founded in 1992 by marine engineer Cesar Augusto Teixeira Andrade e Silva, the company took an important step towards this goal in May of this year when it announced the acquisition of a 10% equity interest in Saab Aero-náutica Montagens (SAM), a Swedish aerostructure manufacturer in São Bernardo do Campo, São Paulo, owned by Saab AB. The plant produces assemblies for the Gripen fighters acquired by the Brazilian Air Force (FAB). The first of the 36 fighters in the program are scheduled to be delivered next year.

“We are the only Brazilian company with a stake in SAM. In addition to gaining experience from a program of this scale, Akaer is working and is on track to establish itself as a Tier 1 aerospace supplier,” says Silva, who has previously worked at Embraer for 15 years. Tier 1 suppliers provide complex aeronautical components, systems, and assemblies known as aerostructures, such as wings, fuselages, landing gear, air brakes, and tails. Of Embraer’s approximately 70 local

suppliers, many are Tier 2 companies, but none are Tier 1. These companies largely supply components with less added value, such as machined parts that are used to build large assemblies.

Akaer’s cooperation with Saab began in 2009 when it was selected as an international partner to the program that develops the new generation of the Gripen fighter, which took its maiden flight in December 1988. The Brazilian firm was engaged in the structural design of the wings, main landing gear door, central fuselage, and rear fuselage. “It is interesting to note that Akaer became a Saab supplier well before the Brazilian Air Force picked the Gripen for its fleet. This was a testament to the company’s high-caliber staff,” says economist and aerospace expert Marcos José Barbieri Ferreira, a professor at the School of Applied Science at the University of Campinas (FCA-UNICAMP).

The success of the collaboration, which also involved technology transfer to the São Paulo-based firm, led Saab to acquire a 15% interest in Akaer in 2012, which it increased to 25% four years later. This year, its stake further grew to 28% through a stock swap, when Akaer acquired 10% of SAM. “We established a partnership to broaden our aerospace footprint and supply aerostructures on a global scale,”

Details of a tool used to build aircraft fuselages



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## COMPANY

### AKAER GROUP

#### R&D Center

São José dos Campos (SP)

#### No. of researchers

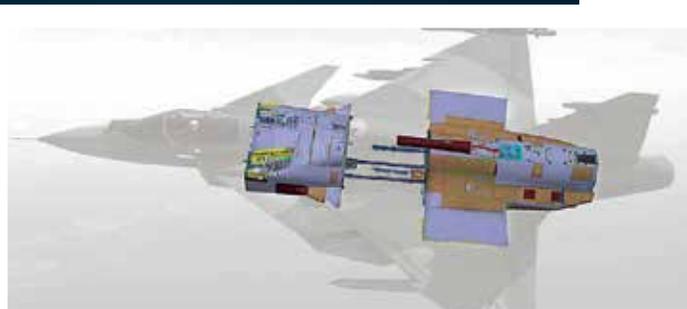
37

#### Main products

Aerospace engineering,  
aerostructures (wings,  
fuselages, landing gear),  
tooling for the production  
of aircraft parts,  
and aerospace systems



The Swedish Gripen (*left*), purchased by the Brazilian Air Force, and a schematic drawing showing the parts, components, and assemblies designed or developed by Akaer (*below*)



says Akaer Chief Operating Officer Fernando Coelho Ferraz, a materials engineer. “The capital injection has been used to expand the group and to develop a new headquarters facility at the Technology Park in São José dos Campos and in aerospace acquisitions.”

Among Akaer’s acquisitions are Equatorial Sistemas, a firm that develops and integrates aerospace and satellite payload systems; Opto Eletrônica’s Aeropace & Defense division, which was renamed Opto Space & Defense and that designs and builds optoelectronics technologies such as cameras for space applications; and Troya, which manufactures tooling used in aircraft assembly. These acquisitions now form Akaer Group alongside Akros, a manufacturing arm focused on

high-tech products, and Akaer Engenharia, the group’s original business, which provides aerospace engineering and design services.

Underpinning Akaer’s internationalization ambitions are significant investments in research and development (R&D). The company allocates R\$5 million per year—or approximately 10% of its revenue—to programs in the areas of advanced manufacturing, flexible tooling, and technology transfer in advanced optoelectronics, among other ar-

eas. “We have more than 10 active RD&I [research, development & innovation] projects in collaboration with partners such as universities, research centers, and local and global firms,” says Akaer RD&I Director Joselito Rodrigues Henriques, a mechanical engineer.

Approximately 10% of the company’s 350 employees are dedicated to R&D. “Approximately 65% of our employees have undergraduate degrees, and 20% have a master’s degree or PhD. Most are engineers in different fields, aerospace designers and draftsmen, as well as physicists, chemists, computer scientists, and mathematicians,” says Henriques.

The firm’s most high-profile R&D investment is in Industry 4.0. With R\$40.5 million in funding and 72 researchers (from Akaer and partners), the program works across multiple fronts, one of which is the development of flexible tooling for the aerospace industry. This category includes essential supporting structures used in aircraft assembly lines, such as mobile platforms, robots, and stairs.

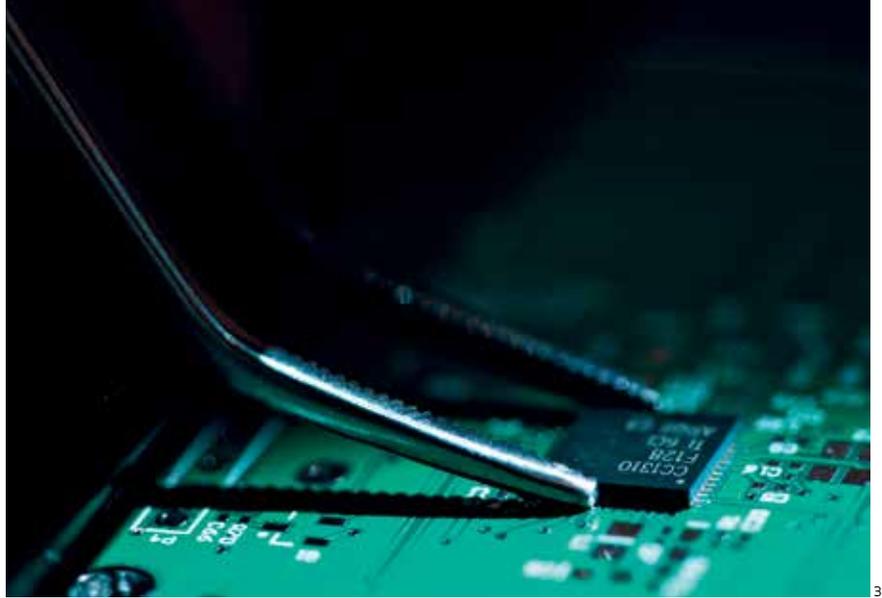
“The conventional tooling used to build a wing or fuselage is developed on demand. The tooling used to make one wing cannot be used to build the other. This carries a high cost that accounts for approximately 30% of the total product cost,” explains Henriques. These structures are typically anchored to the

## RESEARCH TEAM

Some of Akaer Group’s R&D staff and their *Alma Mater*s

Cesar Celeste Ghizoni, electronic engineer, Executive Director, Equatorial division	Federal University of Rio Grande do Sul (UFRGS): undergraduate degree Brazilian National Institute for Space Research: master’s degree Cornell (US): PhD
Joselito Rodrigues Henriques, production engineer, Director, Research, Development & Innovation (RD&I)	Methodist University of Piracicaba (UNIMEP): undergraduate degree Technische Universität Darmstadt (Germany): master’s degree
Fernando Coelho Ferraz, materials engineer, Chief Operations Officer	Federal University of Rio de Janeiro (UFRJ): undergraduate and master’s degree
Mário Antônio Stefani, electronic engineer, R&D Director, Opto Space & Defense division	University of São Paulo (USP): undergraduate, master’s, and doctoral degrees
Érika Gabriela de Carvalho, physicist, optics researcher at the Opto Space & Defense division	USP: undergraduate, master’s, and doctoral degrees

Assembling a chip onto a board that is used in aerospace cameras



floor and subsequently discarded when the production of a given part has been completed. “The advantage of flexible tooling is that it can be used in building multiple aerostructures. Neither Boeing, Airbus nor Embraer use flexible tooling,” says Henriques.

Another important field of research is the metal additive manufacturing, or 3D printing, of aerospace parts. In the conventional manufacturing process, aircraft assemblies such as wings, landing gear, fuselages or tails are machined from steel or aluminum blocks or sheets. In metal additive manufacturing, these assemblies are built using 3D printers. In this computer-aided process, materials such as powders or wire are deposited layer by layer.

Research by GE has shown that 3D printing can reduce a small turbo-prop engine from 855 to only 12 parts and make it 5% lighter. “3D printing provides greater geometric flexibility, as well as greater material and cost savings. 3D printing is a game-changing technology that is still in development,” says Fernando Ferraz.

In the last three years, Akaer posted average revenues of just over R\$50 million. While its largest customer is Saab, the company has also been a supplier to Embraer since 1993 and has been in-

involved in virtually all major programs of the Brazilian aircraft manufacturer, including its E2 range of new-generation regional jets (see *Pesquisa FAPESP issue no. 265*) and the KC-390 military transport aircraft, which is the largest ever built in Brazil (see *Pesquisa FAPESP issue no. 225*). Akaer developed the central fuselage and wing spar for the E2 program as well as the front fuselage, vertical empennage, tail cone, and spoilers for the KC-390 program. Other customers include Boeing, Airbus, and helicopter manufacturer Helibras.

The firm’s main project under development for the space sector is a camera

for nanosatellites, a designation given to cube-shaped satellites as small as 10 centimeters in size. With funding from the FAPESP Technological Innovation in Small Businesses (PIPE) program, Opto Space & Defense—an Akaer Group company—has designed a camera capable of capturing high-definition, multispectral, multicolor imagery of the earth’s surface with nearly 1-meter ground resolution. The company has been awarded grants for six PIPE projects to date, two of which are currently in progress.

“These cameras are an improvement on previous technology. Their optical architecture can be scaled to different nanosatellite platforms, which is an advantage,” explains Ferraz. The equipment, he says, is the first of its kind to be developed in Brazil. It will equip a nanosatellite due to be launched next year, which is under development by Brazilian firm Visiona Tecnologia Espacial in partnership with the National Service for Industrial Training (SENAI). “This is another project that is further strengthening our position as a global provider of high-tech solutions,” says CEO Cesar Silva. ■ Yuri Vasconcelos

A technician inspects an etching mask used in the fabrication of aircraft fuselage panels



## Projects

1. Digital data processing electronics for remote sensing imaging instruments (no. 16/50150-7); **Grant Mechanism** Technological Innovation in Small Businesses (PIPE); **Principal Investigator** Roney Ferreira Mazullo (Akaer); **Investment** R\$516,162.00.

2. Systems design for EQUARS mission and microsatellite platform (no. 16/50167-7); **Grant Mechanism** Technological Innovation in Small Businesses (PIPE); **Principal Investigator** Cesar Celeste Ghizoni (Akaer); **Investment** R\$193,167.00.

# The (almost) unknown Villa-Lobos

Analysis of his musical oeuvre, particularly the symphonies, reveals the Brazilian composer's complex creative process

Christina Queiroz | PUBLISHED IN MAY 2018

With a catalog of hundreds of works, including symphonic poems, concertos for various instruments, and ballets, the composer and conductor Heitor Villa-Lobos (1887–1959) achieved critical acclaim for pieces that showcased elements of national identity, including Afro-Brazilian rhythms and allusions to indigenous cultures. However, a new aspect of the Rio composer's production, which also included 11 symphonies, 3 operas, and 18 string quartets, is beginning to be better appreciated, and it involves exactly those works in which these Brazilian elements do not prevail, as the results of two recent research projects show.

The first of these, *Villa-Lobos, um compêndio – Novos desafios interpretativos* (Villa-Lobos, a compendium: New interpretive challenges; UFPR Publishing House, 2017), a book of essays by several researchers, reveals the complexity of the artist's compositional processes. The second project, the restoration and complete recording of his symphonies by the São Paulo Symphony Orchestra (OSESP), puts into circulation a set of his works that had almost been forgotten. "Villa-Lobos created his works from a complex process that combined elements of Brazilian popular music with the European musical tradition," explains Paulo de Tarso Salles, a professor in the Department of Music at the School of Communication and Arts of the

The symphonic scores contained errors that compromised their performance

VILLA-LOBOS MUSEUM



- Symphonia - (I)

H. Villa-Lobos (Op. 112)  
Rio, 1946

(I = Tempo)

*Mai Moderato*

1<sup>o</sup> Solo  
Flauti  
2<sup>o</sup> Solo  
Solo  
Solo  
Solo

*Mai Moderato*

## Errors in scores are not exclusive to Villa-Lobos. Mozart and Beethoven, for example, have also had their manuscripts revised

University of São Paulo (ECA-USP) and one of the book's editors.

This image differs from the accepted critical view, according to which the artist composed without technique or rigor, and the vision held in the popular imagination, of the purely intuitive composer. Such viewpoints appear, for example, in the documentary *Indio de casaca* (The Indian in a tailcoat), produced by the Manchete TV in 1987 and directed by journalist Roberto Feith. The film contains an account by Antônio Carlos Jobim (1927–1994), who tells of his encounters with Villa-Lobos, during which the composer would compose huge scores while smoking a cigar and listening to symphonies with the TV on and a soprano and a pianist rehearsing in the living room of his small apartment. Jobim recalls that, even in this chaotic environment, it was possible to observe Villa-Lobos's obliviousness to it all during his creative process. At one point, the narrator of the documentary says that Villa-Lobos was a genius when he composed intuitively, but when he was guided by reason, his music sounded erratic. "Villa-Lobos himself collaborated in propagating this idea of the composer who is driven by intuition to create," says musicologist Manoel Aranha Corrêa do Lago, a member of the Brazilian Academy of Music (ABM). The book challenges this idea by showing the sophistication of his creative process.

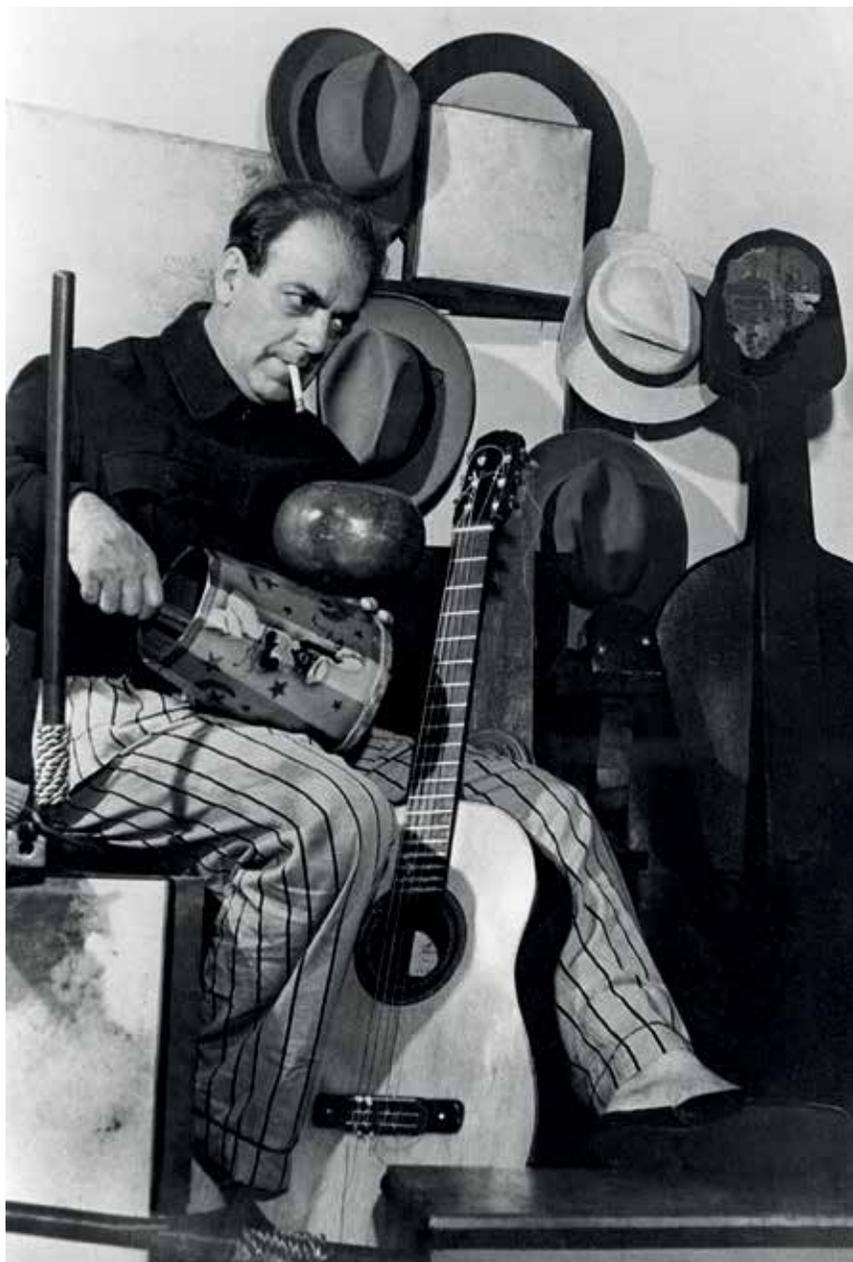
Nahim Marun, a pianist and professor at São Paulo State University Arts Institute (IA-UNESP), São Paulo campus, notes that works such as the series of nine *Bachianas Brasileiras* and the fourteen *Choros* are frequently played in concert halls. "Villa-Lobos was one of the most active composers of the twentieth century, but he became known for only a small fraction of his productive output," he says. This fraction of well-known pieces includes those in which the Brazilian influence is evident, while the repertoire associated with the European tradition, such as his symphonies and string quartets, is less recognized. "Villa-Lobos's work on these compositions was seen as a paradox in his creative career, as something he stubbornly insisted on doing despite his 'precarious' technical training. He was regarded as a composer whose intention was to exalt the national identity," explains Salles, from USP. The researcher is finalizing a book to be published in the second semester, in which he analyzes the artist's compositional process in his quartets: "I identified that he composed by establishing a dialogue between elements of the sonata form and Brazilian sonorities."

Salles explains that part of the idea that Villa-Lobos had no technical background comes from the fact that he did not complete his formal studies. Other Brazilian composers, such as Carlos Gomes (1836–1896), were able to carry out studies in Europe. Villa-Lobos's participation in *rodas de choro* (jam sessions for playing *choro*, a Brazilian instrumental music genre) in Rio de Janeiro helped to reinforce this idea. "However, as an autodidact, he studied the scores of European composers in depth, such as those of Claude Debussy [French, 1862–1918] and Igor Stravinsky [Russian, 1882–1971], while he lived in a universe of popular music, playing not only at the *rodas de choro* but also with *seresteiros* [groups playing *serestas*—Brazilian serenades]," he observes. For Salles, the composer's experience with musicians who played *choros* and *serestas* was part of his learning process and was incorporated into his compositional methods, combining with his knowledge of European classical music. One of the elements that provides evidence for the technical precision that went into his compositions is the concept



Score manuscript excerpts from the symphonies (above and below) and the new score (in the background), after editing





Villa-Lobos in Paris: unusual instruments appear in his compositions

lished in the book *Villa-Lobos, um compêndio*. In his article, Waizbort dialogues with the theoretical framework of the German philosopher and sociologist Walter Benjamin (1892–1940). He goes on to observe that some indigenous elements used by Villa-Lobos in his music stemmed from his contact with recordings of the melodies and songs of the Pareci and Nambiquara natives from the Serra do Norte (northern range) region. The recordings were collected by Edgar Roquette-Pinto (1884–1954) in one of his expeditions with Cândido Mariano da Silva Rondon, known as Marshal Rondon (1865–1958). The material is archived at the National Museum and is, in Waizbort’s estimation, somewhat worn out by the countless times Villa-Lobos listened to it. The composer incorporated not only the indigenous music into his works but also the technical defects heard in the recordings: “Thus, in his compositions it’s not exactly the indigenous music that’s present, but something created using it as a starting point. Villa-Lobos brought the performance of the machine itself into his music.” With the development of postgraduate programs in music and musicology in Brazil since the mid-1980s, musicological study has expanded, and Villa-Lobos has emerged as a special subject for research, which has come to reveal previously unknown aspects of his career and his works.

#### RESTORING THE SYMPHONIES

The creation of quartets and symphonies is considered fundamental to achieving a serious reputation as a composer. In general, all original scores, from the simplest to the most complex, need to be proof-read by someone other than the author. “Throughout music history, it’s common for the scores of even great composers such as Ludwig van Beethoven [1770–1827] or Wolfgang Amadeus Mozart [1756–1791] to contain errors, but in the case of the European composers, critically revised editions have already been published,” notes Marun, from UNESP. With symphonies, the proofing process requires greater efforts when compared to the restoration of string quartet scores, for example, which involve fewer instruments. “With quartets, it’s

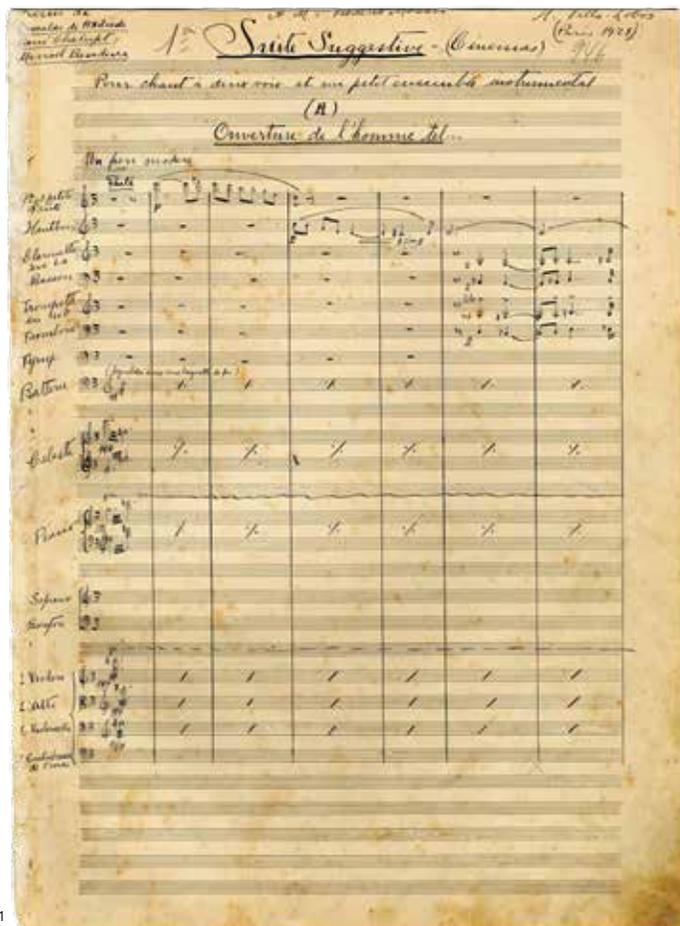
of symmetry, which appears in various works, including the symphonies. “Villa-Lobos was concerned with creating musical structures that were rhythmically and harmonically balanced, in the same way that conservatory-trained European composers were,” explains Salles.

Leopoldo Waizbort, a professor in the Department of Sociology at USP, also argues that Villa-Lobos adopted compositional procedures common to other European artists, including the use of the octatonic scale, frequently employed by Russian composers Igor Stravinsky and Mikhail Glinka (1804–1857).

This procedure involves the creation of eight-note musical scales within

the range of an octave, with the best-known example being the symmetric scale formed by alternating intervals of a whole step and a half step. “This scale was widely used by Villa-Lobos as a constructive element in his compositions, a method that has historically been neglected or diminished in studies of his music,” the researcher says. For Waizbort, a better understanding is needed of how the composer combined and organized the elements of Brazilian and European music in his works.

This understanding was one of the objectives of the study he developed, which gave rise to the article “How, when and why Villa refuted Benjamin,” pub-



Manuscript from *Suite Suggestive*, one of the Brazilian composer's more experimental pieces

first four between 1916 and 1919 and the other seven between 1944 and 1957. "We decided to revive them and make new recordings because they had been rarely performed even in Brazil, and the only complete recording was done by a German orchestra that has little familiarity with the composer's music," says Arthur Nestrovski, OSESP artistic director. He counted hundreds of errors in the symphonies' handwritten scores, which may have been committed by either the composer, who was not in the habit of revising his work, or by those who helped him copy out the notation onto paper. The revision and editing project conducted by OSESP between 2010 and 2017 was based on copies of these hand-written manuscripts.

One of the errors identified involves passages in which several instruments play the same melody. When the score moves to the next page, one of the instruments disappears from the melody. "This means there was a transcription error for that instrument on the part of whoever was copying out the work. Making a parallel example with literature, it's as if a sentence were cut in half," explains Nestrovski.

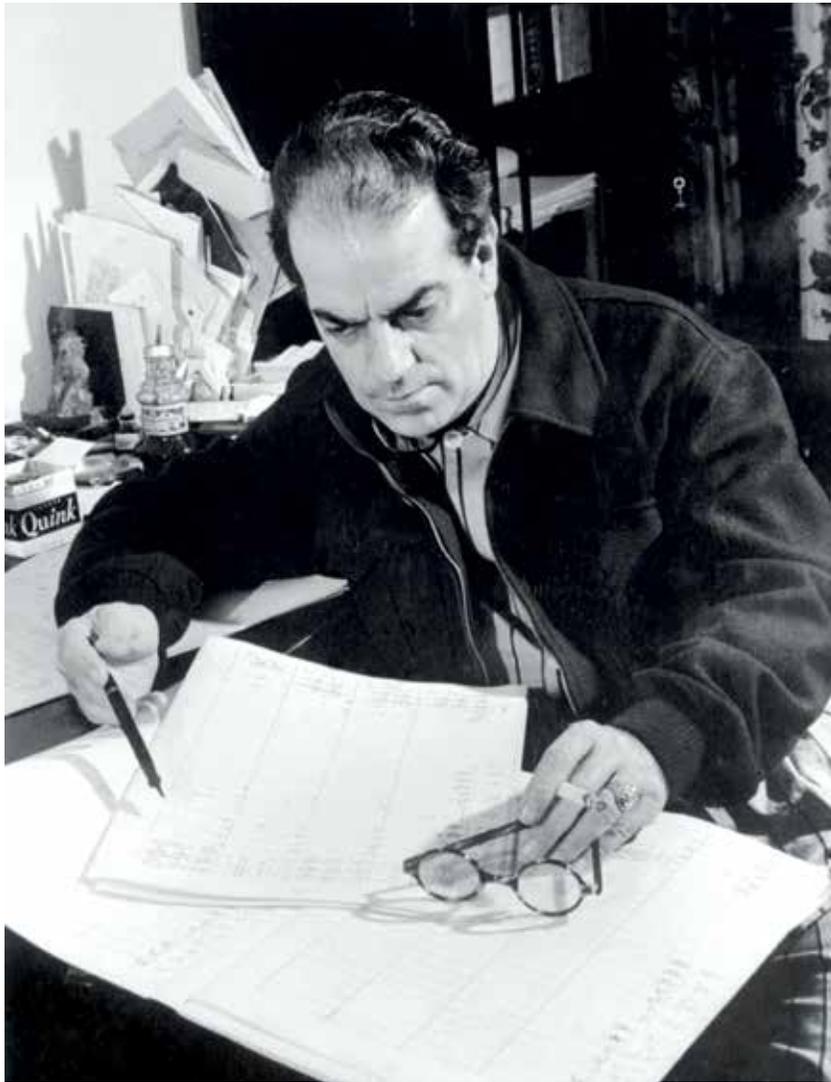
In addition to the corrections made by the conductors, during rehearsals, the musicians further indicated any elements that did not make sense involving harmonies, connections between notes, and melodic continuity. Recordings of the symphonies were only possible after the correction of new errors, such as problems with unity, sonority, and dynamics, were perceived after three or four performances. Analysis of the scores alone did not allow such flaws to be identified.

The edited scores are now available for use on the Brazilian Academy of Music website. Neves, of OSESP, says that French publisher Max Eschig holds the copyrights for some scores — including symphonies 1, 8, 9, 10, 11, and 12 — until 2029, when they will enter the public domain. However, that publisher only partially revised the manuscripts created by the composer and his last wife, Arminda Neves de Almeida, "Mindinha," who helped him as copyist. The ABM, in Rio de Janeiro, owns the rights to the scores for symphonies 2, 3, 4, 6, and 7. The fifth symphony has been lost.

often possible to correct the principal errors during rehearsals, after analysis and discussion among the musicians. That's unfeasible for symphonies, which include dozens of instrumentalists and, in some pieces, also lyric singers," adds Salles, from USP. Villa-Lobos's eleven symphonies have been rarely performed, not only due to their lack of direct allusions to Brazilian popular music but also because of countless errors in the scores and the large number of instruments required for their performances. Now, they've gained new life with a project coordinated by conductor Isaac Karabtschewsky and the Center for Music Documentation (CDM) at OSESP and directed by conductor Antonio Carlos Neves. With this project, OSESP revised and edited the scores, presented them in concerts, and recorded the entire set of eleven symphonies. Prior to this undertaking, only the Stuttgart Radio Orchestra had recorded the symphonies, from 1997 to 2000, under the direction of Carl Saint Clair.

The symphonies were a long-term project for Villa-Lobos, who wrote the

## Villa-Lobos combined elements of Brazilian popular culture with the European classical music tradition



The composer produced hundreds of musical pieces, including symphonies, quartets, operas, songs, and ballet scores

In the view of Flávia Camargo Toni, a professor and researcher at the Brazilian Studies Institute (IEB-USP) and at ECA-USP, the symphonies probably are not as well-known

due to hasty critical judgment. Villa-Lobos was a celebrated composer, and everything he produced was received with great expectations. As soon as they were composed, his works would promptly be performed by an orchestra, and the critics were quick to analyze them. "The symphonies indicate a more evident dialogue with the tradition of European music. They didn't fit the tacit interpretation that Villa-Lobos composed in order to exalt Brazilian culture, so in the immediate evaluation of the critics, they were considered of minor importance in his musical oeuvre," she believes. She recalls that Stravinsky also experienced similar treatment in the second stage of his career, when he strayed from the established aesthetic values that had brought him critical acclaim. "People expected him to compose a new *Rite of Spring*," she notes, mentioning his most famous work.

Toni believes that the symphonies illustrate Villa-Lobos's considerable technical capabilities, in that they were part of a long-term composition project, begun in 1917 and completed only a few years before his death in 1959. "The works have a coherency between them and were created in a coordinated manner," she adds. Salles, from USP, believes that OSESP's work with the symphonies will provide ground for new academic studies and will encourage research on the composer's other lesser-known works, such as the string quartets. "One of Villa-Lobos's most experimental works, the *Suíte Sugestiva* written in 1928, has only one known recording, made by a Finnish orchestra. It is just one of the many forgotten works in his repertoire that deserves to be rediscovered," he concludes. ■

To OSESP's Neves, the earliest Villa-Lobos symphonies, dating from 1915 to 1920, denote the influence of French composers such as Claude Debussy, Maurice Ravel, and César Franck in their sonic language, and in the way the melodies are developed, "...expressing a certain spirit of the Belle Époque." As an example, he notes, "The second symphony contains a waltz in the second movement." The latter symphonies, written after 1945, contain the composer's own characteristic and mature language, in which he more subtly combines European influences with elements of popular culture, especially in the slow movements. "In the symphonies, the Brazilian identity is not so explicit or thematized. It's a more intellectual music, with less allusions to elements of popular culture," explains Nestrovski.

Corrêa do Lago, of the ABM, agrees that the symphonies were relegated to

the background because they did not contain such evident elements of "Brazilianess," except for the tenth symphony, titled *Amerindia*. "When Villa-Lobos chose to name his works as quartets or symphonies it meant that they present a universal and not a local character," he stresses. As a result of the project coordinated by OSESP, Lago believes there will be a trend for the symphonies to be performed more frequently around the world. In addition, OSESP's recordings of the symphonies should establish a new standard for other orchestras with which to interpret the works, since they were performed by mostly Brazilian conductors and musicians, who are very familiar not only with the Villa-Lobos repertoire but also with Brazil's musical language, including the rhythms and melodies used in *choros*, *sambas*, and *serestas*.

#### Book

Salles, P. de T. and Dudeque, N. (org.). *Villa-Lobos, um compêndio: Novos desafios interpretativos*. (Villa-Lobos, a compendium: New interpretive challenges). Curitiba: Ed. UFPR, 2017.



DEMOGRAPHY ▲

# ENTRY STRATEGY

In less than a decade, new dynamics in migration flows and key features of legislation have led to a 34-fold increase in requests for asylum in Brazil

PUBLISHED IN MARCH 2018

**B**etween 2010 and 2017, requests for asylum in Brazil rose from 966 to 33,000 per year. Although at the beginning of this decade Haitians led all nationalities in the number of requests (442, or 46%), today, an influx of Venezuelans makes up the majority of the petitions, with a total of 17,000 applications sent to the Brazilian government last year. The data come from the National Committee for Refugees (CONARE) and are published in the *Atlas temático do Observatório das Migrações em São Paulo – Migrações internacionais* (Thematic atlas of the migration observatory in São Paulo: International migrations) developed by the Elza Berquó Center for Population Study at the University of Campinas (NEPO-UNICAMP) and

released at the end of 2017. In the assessment by the researchers who drafted the document, the exponential growth can, to some extent, be interpreted as a result of the growing barriers immigrants face upon entering European Union countries and the United States. However, it also reflects the peculiarities in Brazilian immigration legislation, which makes seeking asylum the most reliable route for certain groups of foreigners to legally gain entry into the country. Adopting this strategy, however, far from securing their residency status in Brazil. The entire immigration process is marked by uncertainty.

Until the end of last year, the Foreigner Statute, defined during the military dictatorship and in effect since 1980, regulated the Brazilian migratory policy according to logic based on national security. Rosana Baeninger, a NEPO researcher and professor at the Institute of Philosophy and



Michel Charles has been in Brazil three years as part of a group of Haitians who immigrated after the 2010 earthquake

Human Sciences (IFCH) at UNICAMP, explains that the statute established certain conditions under which foreigners could obtain permanent or temporary visas in Brazil. These conditions varied according to bilateral agreements between specific countries, but certain circumstances gave migrants the right to residency, such as marriage to Brazilian citizens, the birth of children within Brazilian territory, or offers of employment. The statute prohibited those who entered without a visa from regularizing their status after already entering the country. “Reciprocity agreements allowed them to stay for up to 90 days, as tourists. After this period, many immigrants were legally undocumented, which restricted their access to certain rights,” explains Baeninger.

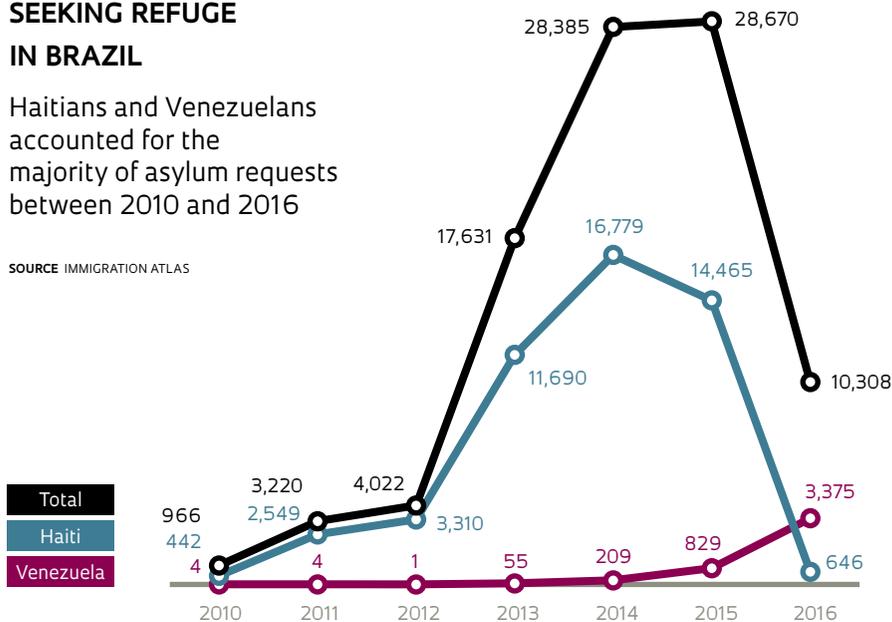
For South American immigrants, the situation began to change with the 1991 establishment of Mercosul, a regional integration process in which all South American countries currently participate, except for Venezuela, which was suspended from the bloc in 2017. “Mercosul allowed citizens of member countries to request temporary residence and work in Brazil,” Baeninger observes. When the New Immigration Law went into effect last November, foreigners of certain nationalities acquired the right

Immigrants seek work and documentation at a state government processing center in São Paulo

## SEEKING REFUGE IN BRAZIL

Haitians and Venezuelans accounted for the majority of asylum requests between 2010 and 2016

SOURCE: IMMIGRATION ATLAS



to regularize their status without the need to leave the country, as had previously been the case. “The new legislation seeks to facilitate the establishment of residence for groups of migrants emigrating for humanitarian reasons, or for individuals with low levels of education, something that did not exist in the previous law. However, since all of its resolutions are not yet defined, foreigners do not know for sure the best way to have their presence in Brazil regularized.” She believes that both the past limitations of the Foreigner Statute as well as the uncertainties of the new law have

caused some immigrant groups to bet on seeking asylum as a way to increase their chances of remaining legally in Brazil.

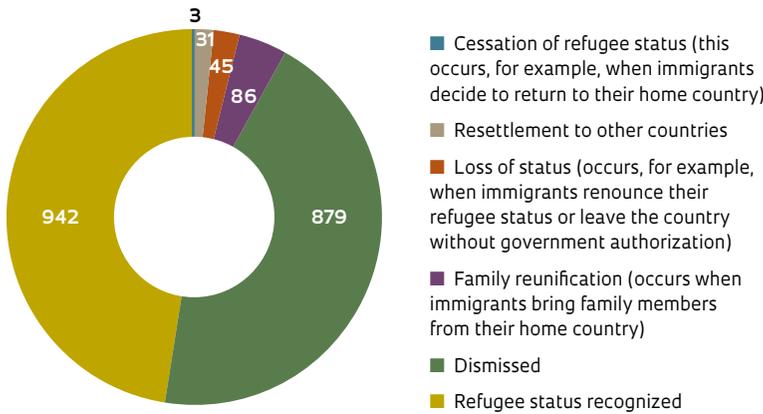
Asylum is governed by the 1951 United Nations Convention Relating to the Status of Refugees. It is this document that establishes standards for the treatment of this type of immigrant, defined in different ways by the signatory countries. In Brazil, asylum is governed by Law No. 9474/97. Enacted 20 years ago, it was not directly affected by new immigration legislation. To have their refugee status recognized, immigrants must prove that they suffer from “well-founded fears



PHOTO PUBLICITY DEPARTMENT FOR JUSTICE AND THE DEFENSE OF CITIZENSHIP OF THE SÃO PAULO STATE GOVERNMENT

## CASES ANALYZED BY CONARE

In 2016, 10,308 requests for asylum were received; the agency adjudicated 1,986\*



SOURCE: IMMIGRATION ATLAS

\* Most of the cases adjudicated in 2016 involved asylum requests from previous years

of persecution on grounds of race, religion, nationality, social group, political opinion, or grave and widespread human rights violations” in their home country.

Once the application is registered, the immigrant becomes entitled to all rights of the regularized citizen, such as temporary residence, a work permit, and medical care through the government’s Unified Health System (SUS) as well as a guarantee they will not be deported. The process for requesting asylum is free, unlike the visa application process. The requests are judged by CONARE, an interagency institution that also includes the Federal Police, the United Nations High Commissioner for Refugees (UNHCR), and non-governmental organizations. “Requests for asylum have been taking a minimum of two years to be decided,” says Gustavo da Frota Simões, a professor of international relations and coordinator of the Sérgio Vieira de Mello Chair at the Federal University of Roraima (UFRR).

The entry process of Haitians since 2010 can help us understand how, under certain circumstances, seeking asylum can function as a strategy for entering Brazil. Haitian immigrants arrived after the 2010 earthquake that resulted in the deaths of 316,000 people in their Caribbean homeland. The first immigrants crossed the border through the states of Acre and Amazonas. In 2010, 442 Hai-

## Once their request for asylum has been filed, immigrants secure rights to receive work permits as well as medical care through the government health system

tians sought asylum. In 2011, there were 2,500. While awaiting adjudication, they all had the right to work permits and the right of residence. “The Brazilian government did not recognize the Haitians as refugees. However, it identified that they were immigrating for humanitarian reasons and created a visa so that they could have their status regularized in Brazil. This visa would serve those who were in Haiti with the intention of em-

igrating and applying from the Brazilian embassy in their country,” explains economist Duval Magalhães Fernandes, professor of the Postgraduate Program in Geography at the Pontifical Catholic University of Minas Gerais (PUC-MG). He adds, however, that initially the government limited the number of these visas it granted to 1,200 per year. “This fact led to conditions of chaos on the doorstep of the Brazilian embassy in Port-au-Prince and further increased the numbers of immigrants arriving along the northern border who requested asylum,” recalls Fernandes. He adds that for Haitians who requested asylum and had their request denied, the government granted permanent residence visas. “At no point were the Haitians in the country under illegal conditions. So, requests for asylum became a mechanism for obtaining legal residency status in Brazil,” Fernandes notes. Between 2012 and 2014, requests for asylum by Haitians jumped from 3,300 to 16,700.

### MIGRANT FLOWS ON THE RISE

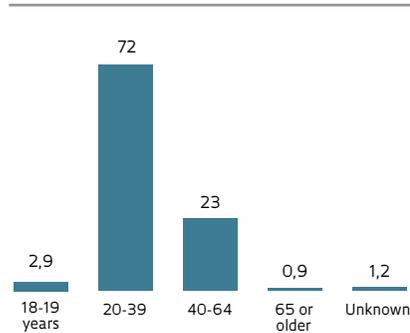
A report published in February by the newspaper *O Globo*, based on information from the Federal Police, showed that during one 45-day period, 18,000 Venezuelans requested asylum. This was more than the total number recorded over the entire year of 2017. It is currently estimated that between 40,000 and 60,000 Venezuelans live in the capital city of Boa Vista, a municipality with 350,000 inhabitants in the state of Roraima, which borders Venezuela. Not all of the Venezuelan migrants, however, want to settle in Brazil. “Some people try to remain close to the border, so they can visit and take money, food, and medicine to family members who stayed in their home country, and others plan to return to Venezuela,” says João Carlos Jarochinski Silva, a professor of international relations at UFRR. He observes that until 2015, Venezuelans customarily went to Boa Vista and Pacaraima to buy food and would then return home. In 2016 more people began choosing to remain in one of these cities, which, according to the researcher, increased the number of requests for asylum.

Despite being part of Mercosul until 2017, Venezuela had never adapted its legislation to integrate with the simplified visa system. “The suspension of Venezu-

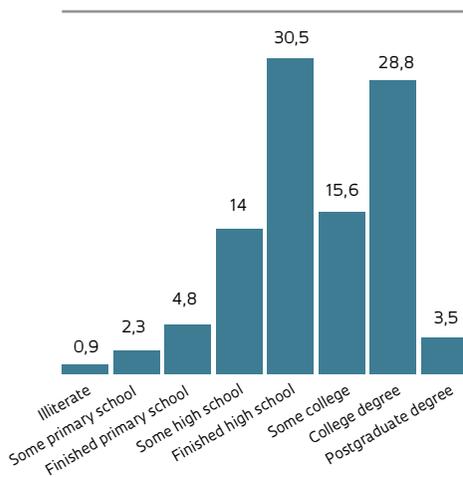
## SOCIODEMOGRAPHIC PROFILE OF VENEZUELAN IMMIGRATION

Study carried out between June and August 2017 with 650 nonindigenous adult Venezuelan immigrants living in Boa Vista, Roraima

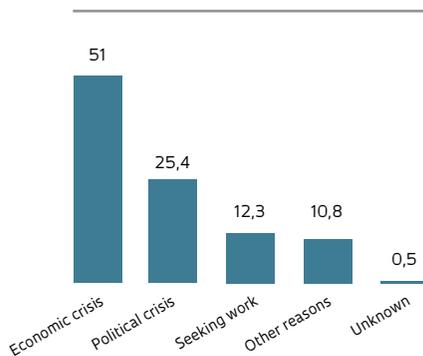
AGE (%)



EDUCATION (%)



REASON FOR IMMIGRATION (%)



SOURCE THE SÉRGIO VIEIRA DE MELLO CHAIR / UFRF, SOCIODEMOGRAPHIC AND LABOR PROFILE STUDY OF VENEZUELAN MIGRATION IN BRAZIL, 2017

ela from the bloc did not affect the way the entry permission policy for Venezuelans was developed in Brazil. In March of 2017, the National Immigration Council (CNIg) issued Normative Resolution No. 126, authorizing the temporary residence of migrants from bordering countries, a measure that benefited Venezuelan asylum seekers,” he observes. He adds that the procedures for applying for a residence permit became free of charge due to a judicial decision three months after the resolution was published. Even so, requests for asylum continued to be the path chosen by most Venezuelans who were unaware of the resolution but did know that presenting documents was not mandatory. “People can file the request for asylum wearing only the clothes on their backs,” Jarochinski says. The Brazilian government has not recognized Venezuelans as refugees and has only granted 14 of the 3,300 requests made in 2016. “Many Venezuelans immigrate to Brazil to escape hunger, inflation, and violence; however, others leave their home country because they suffer political persecution, which does guarantee the recognition of refugee status. The government must analyze each case individually before granting the request,” he explains. The stream of requests for asylum by Venezuelans has increased only recently, and most of the applications have not yet been adjudicated.

While the Venezuelan immigration can be seen as a result of an ongoing crisis within a country bordering Brazil, the arrival of recent migrant flows of Syri-

## Recent migration flows result from Brazil’s global political policies and an ongoing crisis in a bordering country

ans and Haitians is related to Brazilian political policies regarding these more distant nations. Rosana Baeninger notes that Brazil’s role in the United Nations Stabilization Mission in Haiti, begun in 2014 after the fall of then-President Jean Bertrand Aristide, explains, at least in part, the interest Haitians have in trying out life in Brazil. As regards the Syrian refugees, in 2013 CONARE published a normative resolution simplifying the issuing of visas and the process for requesting asylum. Requests for asylum had already been arriving from both the Syrians themselves and other foreigners affected by the civil war since it began in 2011. According to the Migration Observatory’s atlas, of the 391 requests sent by Syrians in 2016, 326 were accepted.



Venezuelans await Federal Police processing in Boa Vista, Roraima

Although it does not grant full citizenship, by recognizing the request for asylum, the Brazilian government confirms that in addition to the rights granted to typical immigrants, asylum seekers receive certain special rights, such as the guarantee that they will not be forcibly returned to their home country and the issuance of a passport.

Luís Renato Vedovato, a professor at the School of Applied Sciences at UNICAMP, believes that the establishment of this resolution happened at a time when the Brazilian government wanted to increase its political presence in the Middle East. “Brazil was seeking a permanent seat on the United Nations Security Council, so part of its openness to receiving Syrians was due to interest in this new positioning strategy as well as its desire to strengthen ties with other countries of the Global South,” he says. Despite the openness policy, Brazil currently harbors few Syrian refugees. There are approximately 2,200 people, a small community compared to those comprised



The Brazil Mosque in São Paulo: the CONARE resolution permitted this family of Syrian refugees to enter the country

of the millions of Syrians currently living in Turkey and Jordan, observes Igor José de Renó Machado, a professor at the Federal University of São Carlos (UFSCAR) and coordinator of the Migration Anthropology research group. Recent migrant flows of Syrians, Haitians and Venezuelans as well as those arriving from other Latin American and African countries, Baeninger notes, are evidence of an intensification of the South-South migration movement at a time when the countries of the Global North have begun to impose progressively more barriers to the entry of foreigners.

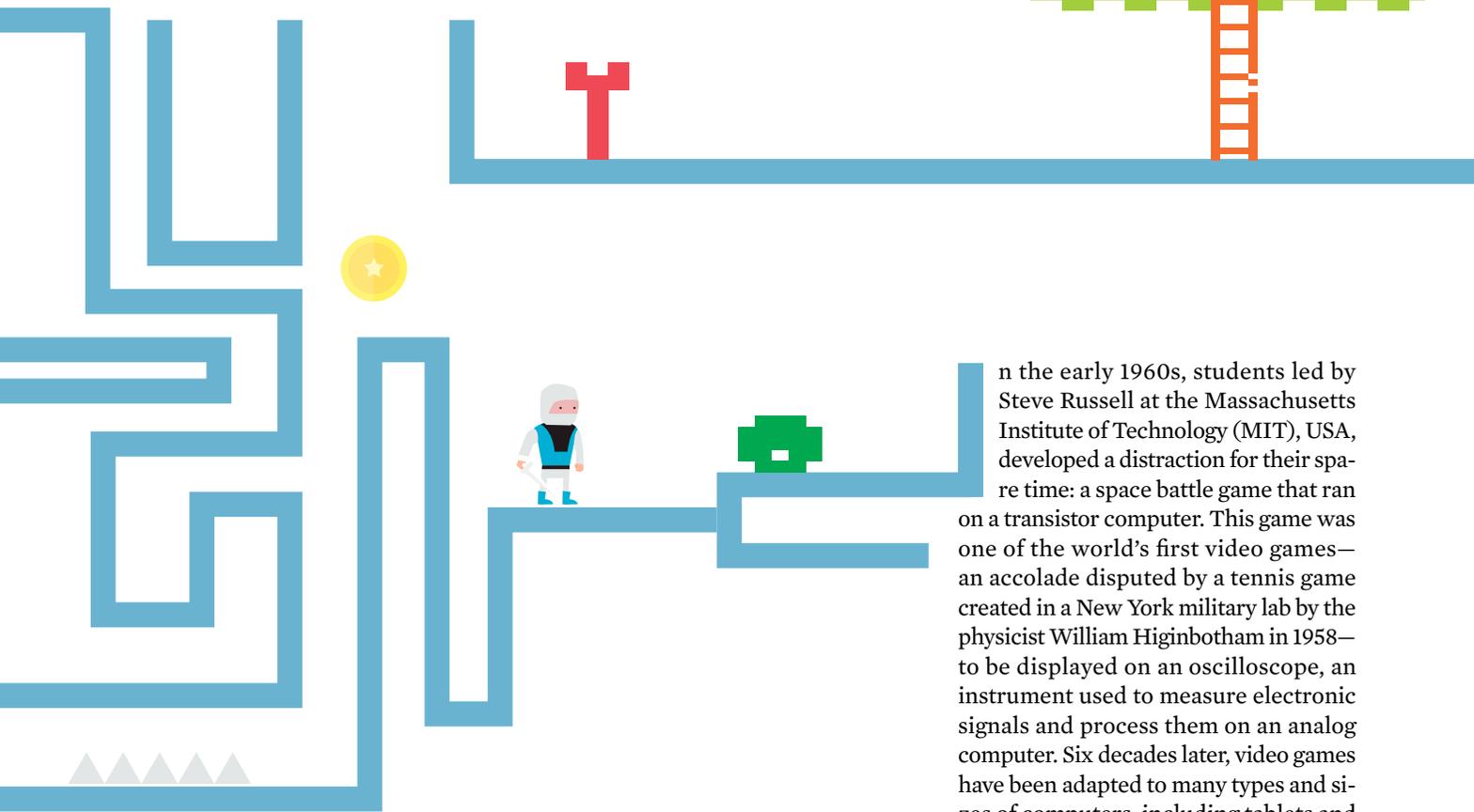
In 2016, refugees and asylum seekers totaled 25.9 million people worldwide according to the *International Migration Report 2017* recently published by the United Nations. With the signing of the New York Declaration for Refugees and Migrants in 2016, UN member states committed themselves to developing public policies to accommodate these displaced populations. The UN is expected to approve the Global Compact for Safe, Orderly and Regular Migration during its Intergovernmental Conference scheduled to take place in December 2018 in Morocco. ■ **Christina Queiroz**



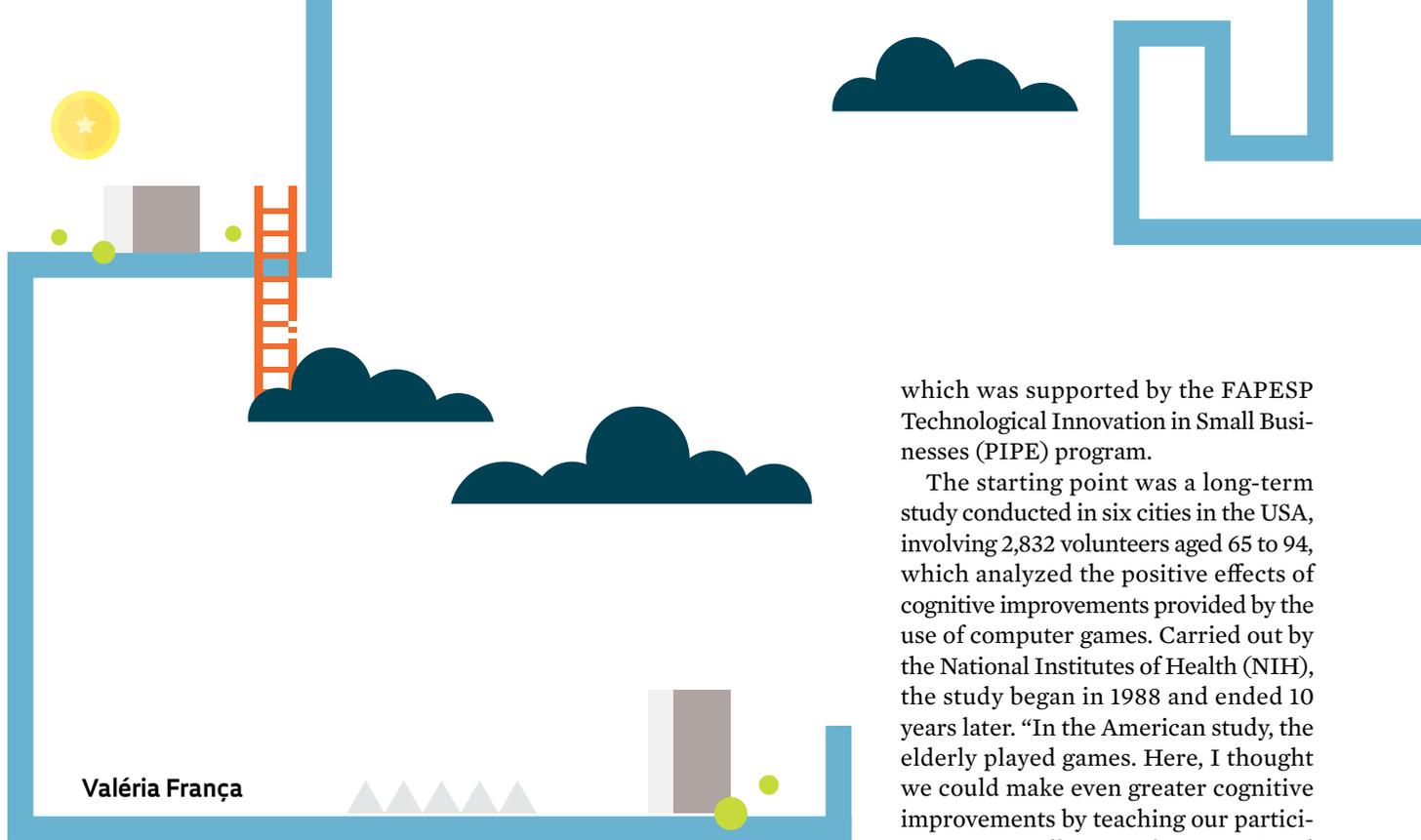
### Project

Migration Observatory in São Paulo: Contemporary internal and international migration in the state of São Paulo—NEPO-UNICAMP (No. 14/04850-1); Grant Mechanism Thematic Project; Principal Investigator Rosana Aparecida Baeninger (UNICAMP). Investment R\$962,356.42.

# science and video games



In the early 1960s, students led by Steve Russell at the Massachusetts Institute of Technology (MIT), USA, developed a distraction for their spare time: a space battle game that ran on a transistor computer. This game was one of the world's first video games—an accolade disputed by a tennis game created in a New York military lab by the physicist William Higinbotham in 1958—to be displayed on an oscilloscope, an instrument used to measure electronic signals and process them on an analog computer. Six decades later, video games have been adapted to many types and sizes of computers, including tablets and smartphones. Video games are played by 2.3 billion people worldwide, according to the 2017 *Global Games Market Report*, and are now regularly the subject of scientific research. As well as assessing the impact of their use—according to a



Valéria França

## Researchers discover new uses for computer games

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recent classification by the World Health Organization (WHO), excess use can be considered a mental disorder (*see box on page 94*)—researchers from different fields of knowledge are discovering new applications for video games.

This is the case for Fabio Ota, who has an MBA in strategic IT management from the Getulio Vargas Foundation (FGV-SP), a diploma in gamification from the University of Pennsylvania, USA, and is CEO of the International School of Game (ISGAME), which offers games development courses in São Paulo. After organizing a course at the University of Campinas (UNICAMP) for people over 50 interested in preventing the adverse conditions that often accompany human aging, Ota created a project with the objective of improving cognitive function in the elderly by teaching them to develop video games,

which was supported by the FAPESP Technological Innovation in Small Businesses (PIPE) program.

The starting point was a long-term study conducted in six cities in the USA, involving 2,832 volunteers aged 65 to 94, which analyzed the positive effects of cognitive improvements provided by the use of computer games. Carried out by the National Institutes of Health (NIH), the study began in 1988 and ended 10 years later. “In the American study, the elderly played games. Here, I thought we could make even greater cognitive improvements by teaching our participants to actually write the games,” said Ota. He initially planned to work with a group of 20 people, but after receiving 74 volunteers, he decided to expand the initiative.

With a mean age of 65, most of the participants, an equal number of females and males, have at least a high-school education. Before starting, the volunteers took memory tests and physical exams. They also responded to questionnaires designed to evaluate their quality of life and underwent psychological testing to measure their degree of cognition and track possible cognitive losses, including the Mini-Mental State Examination (MMSE), which assesses spatial and temporal orientation, memory, and arithmetic ability. They then filled out the Kihon Checklist, used to provide a fragility index, and other tests to calculate their motor skills and coordination.

The volunteers were then divided into three groups: players (14 participants), developers (45 participants), and a control group (15 participants). Between August and December 2016, those in the first two groups took game development classes, while the control group received digital inclusion lessons. The students’ mission was to create a simple, two-dimensional game. The PIPE project lasted for nine months and involved special software that enabled the participants to develop games without having to write

computer code. Each class consisted of a physical warm-up followed by 70 minutes of programming and a stretching session at the end. In the third month of classes, the volunteers were submitted to another round of tests, which were also repeated one week after conclusion of the course.

At the end of the experiment, the results of the three phases were compared. Ota found that the developers group achieved the best performance, followed by the players. The study showed that the game development classes improved memory and cognition. The control group showed no change, suggesting that computer use alone is insufficient to improve these traits. “In developing the game, the elderly performed activities that they previously thought impossible, and they were even able to share the experience with their grandchildren, creating new bonds with the younger generation,” explains Ota. As well as developing a teaching methodology for the elderly, which has led to a number of courses aimed at improving cognition, memory, and concentration, the research also helped validate a video game created by ISGAME for use in one of the classes.

Long associated with sedentary habits, computer games also attract researchers interested in understanding



their potential for stimulating physical activity. Mateus David Finco, a professor at the Federal University of Paraíba (UFPB), studied exergames—which track the real movements of the player’s body and translate them into the virtual universe on the screen — during his PhD in informatics in education at the Federal University of Rio Grande do Sul (UFRGS). Exergames are played on con-



## Video game addiction

Classification as a disorder by the WHO is likely to boost research

Those who suffer from gaming disorder spend hours immersed in video games, unable to work, study, or even socialize. The disorder was added to the WHO International Classification of Diseases (ICD-11) in June. It was also added to the American Psychiatric Association’s Manual of Mental Disorders (DSM-5) in October last year. According to the DSM, unhealthy video gaming can be recognized as a disorder when symptoms manifest themselves for a year or more. Depending on the intensity, the disorder can be classified as low, moderate,

or severe. In general, it affects children and young adults from 12 to 20 years of age.

Gaming disorder still needs further study. Recognizing the disorder was necessary to enable advances in knowledge on the subject, explains psychologist Cristiano Nabuco, coordinator of the Technology Dependency Group of the Impulse Disorders Program at the USP Institute of Psychiatry.

The USP School of Medicine’s teaching university in São Paulo has had a gaming addiction clinic since 1996. Over the last 10 years, it has treated 400 patients. Diagnoses are

based partly on international tests, such as the Gaming Addiction Scale, which looks at 21 aspects of the patient’s daily routine. Once the disorder is confirmed, patients are put into groups of 12 and undergo psychotherapy together for 18 weeks. When necessary, they are prescribed medication. “Games are just a small part of the addiction problems created by the internet,” Nabuco says. When the internet became available on cell phones, he notes, social media and gaming addictions exploded: “I had a young patient who spent 55 straight hours in front of the computer, without even going to the bathroom.”

soles and often use a peripheral platform on which the player stands during yoga or aerobics exercises, for example. More advanced versions use a camera and infrared tracking to capture movement.

Five years ago, when Finco decided to create an exergames laboratory in partnership with a college in Porto Alegre, he realized that by switching the joystick for motion capture, the industry was developing a new form of interaction, and, like tablets and cell phones, it had potential as a new educational tool. “The idea was to investigate how they could help engage students who do not generally enjoy physical activity,” says Finco.

In Finco’s study, each of the 24 volunteers, aged 11 to 17, was allowed to use the equipment for 50 minutes three times a week over six months and was filmed doing so. The goal was to record the participants’ development, their social interactions, and how they used the equipment. By analyzing the videos, Finco found that the device served as a motivational resource, increasing interaction between students and improving motor skills. “The project showed that an exergames laboratory can offer an alternative to regular physical education classes,” summarizes Finco, who believes such games could also be useful for students with motor, physical, and mental disabilities.

Research recently completed by the Pennington Biomedical Research Center at Louisiana State University indicates that virtual games that require physi-

## Studies indicate that video games can help increase cognitive capacity in the elderly

cal movement, combined with virtual support from physical trainers, can improve the health of obese children. Titled “Home-based exergaming among children with overweight and obesity: A randomized clinical trial,” the study, led by developmental psychology expert Amanda Staiano, involved 46 children aged 10 to 12 and will be published in a special edition of the scientific journal *Pediatric Obesity*. Half of the participants and their respective families comprised the players group, and the other half,

a control group. At the end of the six-month program, 22 of the 23 families in the players group had completed 94% of the gaming sessions and attended 93% of the video-chat sessions. Children in this group reduced their body mass index (BMI) by 3% and their cholesterol levels by 7%, while those in the control group showed increases of 1% and 7%, respectively.

### ATTRACTIVE LANGUAGE

Since video games involve a predetermined narrative, characters, and objectives, they can also function as a means of communication, according to Sérgio Bairon, a professor at the School of Communication and Arts of the University of São Paulo (ECA-USP). “With technological resources continuing to advance rapidly, especially with respect to artificial intelligence, video games serve as a language capable of expressing the interaction between living beings and scientific concepts. Sometimes even in a more meaningful way than the written word,” he says.

Despite being studied in various areas of the humanities, video games are rarely used as language in academia. “My supervisees have developed projects in which they use video games as a support tool, but it is still not common for examining bodies to accept forms other than the written word,” says Bairon, noting that such acceptance already happens outside Brazil. He believes that this form of language could be a way of democratizing academic production: “I believe we could use this to transform a lot of scientific content into teaching material for schools, for example.”

Preliminary data from the 2<sup>nd</sup> Census by the Brazilian Digital Games Industry, released at the end of June by the Ministry of Culture, indicates that 1,718 games have been produced in Brazil in the last two years—874 of which were educational and 785 for entertainment. In the last five years, the number of game development studios in Brazil has increased from 142 to 375. ■

Salah H. Khaled, Jr., a doctor of criminal science and a professor at the Federal University of Rio Grande (FURG) Law School, believes the WHO classification is misleading, partly because the comparison with gambling and drugs is tenuous since video games are cultural products. For him, officially defining gaming disorder is a case of “pathologizing” games. “The supposed ‘addiction’ may be a symptom of another condition, such as anxiety or depression, for example. The emphasis on this symptom can leave a bigger problem untreated,” he says.

“The pharmaceutical industry is behind the creation of several ‘disorders’ treated by psychiatrists and psychologists. These classifications result from historical debates, and they do not reflect absolute truths,” observes Khaled, author of *Videogame e violência: Cruzadas morais contra os jogos eletrônicos no Brasil e no mundo* (Video games and violence: Moral crusades against video games in Brazil and worldwide). “Similarly,” he notes, given a review of the literature on the subject, “there is no concrete evidence that games provoke violence.”

### Project

Game programming as a means of developing logical reasoning and preventing cognitive decline in the elderly (no. 15/08128-1); Grant Mechanism Technological Innovation in Small Businesses (PIPE); Principal Investigator Fabio Ota (ISGAME); Investment R\$181,488.40.



# A Swedish filmmaker in Copacabana

Research reveals the Brazilian dimension of the work of Arne Sucksdorff, best known for documentaries about nature

**Luisa Destri**

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Sucksdorff (left, in a dark shirt), with Flavio Migliaccio and the children who starred in the film: Toninho Carlos de Lima, Cosme dos Santos, Josafá da Silva Santos, and Leila Santos de Sousa

The Swedish filmmaker Arne Sucksdorff arrived in Brazil in 1962, when filmmaking was dominated by the desire to turn the camera into an instrument of political intervention and the awareness of the national condition. Working on a project developed by the Brazilian Ministry of Foreign Affairs and the United Nations Educational, Scientific and Cultural Organization (UNESCO), his mission was to train filmmakers in the new technology of location sound recording that was revolutionizing world cinema. Here in Brazil, the documentary filmmaker worked with young people interested in Cinema Novo.

To give the reader an idea of what the scene was like at the time, in the year he arrived here, the film *O Pagador de Promessas* (*The Given Word*), by Anselmo Duarte, had received the Palme d'Or at Cannes, and *Barravento* by Glauber Rocha and *Arraial do Cabo* by Paulo César Saraceni were being exhibited as films nominated for young filmmakers awards. 1962 was also the year that *Cinco Vezes Favela*, a series of short films produced by the Center for Popular Culture of the National Students Union (UNE), premiered.

When he landed in Brazil, Sucksdorff (1917–2001) had already made a name for himself with animal documentaries,

such as the 1941 short film *A Summer Tale*, which shows life on the banks of a lake on the outskirts of Stockholm. However, his work was still little known here and, as a fish out of water, he ended up reversing the usual stereotypes that associated Europeans with the avant-garde and primitive things with South America. “In this case, the Cinema Novo was the vanguard,” observes Esther Império Hamburger, a professor in the Department of Film, Radio, and Television at the School of Communications and Arts of the University of São Paulo (ECA-USP), who is making a documentary that includes interviews with former students



Scenes from  
*Fábula*

and others who lived and worked with the Swedish filmmaker in Brazil. She explains that even in regards to technical questions brought about by the cutting-edge equipment, there were tensions.

One example concerned the recording of location sound using the Nagra tape recorder. Such equipment was revolutionizing filmmaking methods around the world because allowing quality sound to be captured simultaneously with images prevented the need for studio reconstructions later. This advance supported the ideal of the handheld camera, with which the devotees of the Cinema Novo were identified. “However, Sucksdorff used a tripod, dolly, and artificial lighting, so his ability to capture spontaneous movement was more limited than in Direct Cinema,” Hamburger notes, noting that this limitation reinforced the “academic” character of the filmmaker’s relationship to the image.

Although he was an award-winning director — he had received the Oscar for his short film *Rhythms of the City* in 1948 — to this day, it is not known exactly why Sucksdorff was chosen for the project. Filmmaker Eduardo Escorel, who attended the course Sucksdorff taught between November 1962 and February 1963 in Rio de Janeiro, classifies him as “unlucky.” In a series of texts dedicated to the “Sucksdorff mission,” drawn up in 2012 from UNESCO documents, his former pupil says that the Swede was not included among the film directors initially shortlisted for the project, which included better-known names such as the French filmmaker François Reichenbach (1921–1993).

Even so, Sucksdorff’s course was highly sought after. In the book *Mito do cinema em Mato Grosso: Arne Sucksdorff* (A myth of the cinema in Mato Grosso: Arne Sucksdorff), published in 2008, filmmaker Luiz Carlos de Oliveira Borges notes that more than 230 students registered for it. After two qualification screenings, only 18 participated in the practical stage, which fewer than 10 would actually finish. Under the direction of fellow pupil and journalist Vladimir Herzog (1937–

1975), as its final project, the group produced the documentary *Marimbás*, a short film that used equipment brought in specifically for the course. This was, in fact, one of Sucksdorff’s legacies: outside school hours, he often loaned the Nagra to other filmmakers. Important films of the time, such as *Vidas Secas* (*Barren Lives*) by Nelson Pereira dos Santos, were completed at the editing table acquired by the Ministry of Foreign Affairs.

Having had the intention of making a film in Brazil from the beginning, in 1965 and 1966, Sucksdorff made *Fábula* (titled *My Home is Copacabana* in the English and Swedish versions). An 88-minute black-and-white film, it tells the story of four children living between the hillside slums of Babilônia and the beaches of Copacabana. “Sucksdorff believed that Cinema Novo prioritized political issues at the expense of poetry. And he made what is perhaps his most critical film — and, in that sense, political — after this clash, or perhaps because of it,” Esther Hamburger notes. Valued not only for being one of the first visual records of a favela (shantytown) but also, and especially, for the unique way it portrays the lives of its protagonists, *Fábula* has been the subject of research by anthropologists since 2010.

The initial scenes are breathtaking. The camera follows Jorginho, a boy holding a kite at the top of a hill above Rio, and captures a sweeping view that includes Copacabana beach, Pão de Açúcar, and Santos Dumont airport. This opening scene is, according to the researcher, one of its most important features: “In many films about Rio communities, the hills almost suffocate the camera. Here, the method of filming does not close off hope or reduce the characters to social categories with predetermined destinies.” Completed at the beginning of the mili-

tary dictatorship (1964–1985), *Fábula* was denounced for promoting an undesirable image of the country. It had been showing in Rio for only a week when the cinema exhibiting it received bomb threats.

Abroad, it encountered a better reception, and it was screened in Cannes, France. It is difficult to see the film in Brazil even today: there is one copy at the film library of the Museum of Modern Art in Rio and another at USP, brought from Sweden as part of Hamburger’s research. This second copy also prompted a comparison study between the more documentary foreign version and the Brazilian edit, which emphasized the fictional story. The differences, probably resulting from the censorship that the film faced in Brazil, have become the subject of a DVD that the researcher hopes to release soon.

Interested in producing a documentary about an indigenous community, Sucksdorff traveled to Mato Grosso in 1966. The movie was never released, but afterwards he decided to remain in Brazil. In 1970, he married a Brazilian woman and settled in the tropical wetlands known as the Pantanal, living in a kind of encampment, the daily life of which the filmmaker recorded in a documentary screened by Swedish television in the 1970s. Their intention was to found a biological reserve, but the couple was unable to do so. “They were persecuted by powerful local landowners and had their land confiscated,” the researcher says. Sucksdorff remained in Brazil until 1993 when, in poor health, he was taken back to Sweden, where he lived on government support until his death.

*Fábula* is considered his masterpiece and, in Esther Hamburger’s evaluation, has every element needed to be recognized in Brazil as one of the most important films of the time. “We are living, today, in dystopian times, in which people cannot view beyond the horizon. His film is full of sweeping horizons and vast vistas. Sometimes the form is as important as the story that’s being told,” she concludes. ■

#### Project

A poetic look at Brazilian inequality (no. 12/00466-7); Grant Mechanism Regular Research Grant; Principal Investigator Esther Império Hamburger (USP); Investment R\$201,600.60.

Excerpts from the film *Fábula* and the interview with Esther Hamburger are available at: <http://bit.ly/ArneSucksdorff>



## *Dispersal by water*

When fruit falls from trees overhanging the rivers of the Pantanal, the local fish spring into action. The piraputanga (*Brycon hilarii*) in the center of the photo, which was taken in the Bonito region, is pictured snagging a wild fig. As part of the Peixes de Bonito (Bonito Fish) project, biologist José Sabino studies the role that these animals play in maintaining riparian forest ecosystems. By maintaining constant movement, these fish help disperse seeds along the river by eating at one point and defecating in another.

*Image submitted by José Sabino, a professor at UNIDERP University*

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