
PRESSURE
PSYCHO-PHYSIOLOGY
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Well-being *IN THE AIR*

Embraer teams up with universities to improve comfort on its airplanes

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Airplanes with very cramped spaces, too much noise and vibration, unpleasant temperatures and lighting, questionable air quality and few options for entertainment transform any trip into a stressful experience, even when there are no turbulence and short flights. On longer journeys, comfort — or the lack thereof — makes all the difference to people who need to reach their destinations ready to work, sightsee or face another leg of their journey. Airlines know that to make the time that people are confined in the cabin more agreeable, the conditions in the aircraft's environment need to be improved, and diagnoses and detailed studies of the problems must be carried out. The most visible result of this effort in Brazil to improve new generations of airplanes was the inauguration in April of the Comfort Engineering Center (CEC), the result of an Embraer project in association with the University of São Paulo (USP), the Federal University of Santa Catarina (UFSC) and the Federal University of São Carlos (UFSCar), with support from FAPESP and the Studies and Projects Funding Agency (Finep).

The comfort laboratory, as it is known, covers almost 300 square meters and reproduces a boarding lounge with a finger (the walkway that leads to the airplane), assembled in the Polytechnic School (known as "Poli") at USP in São Paulo, in the Thermal and Environmental Engineering Laboratory (Lete). The main part of the structure represents the cabin of a 170 or 190 jet, with 30 seats, which is installed in a pressure chamber that reproduces flight conditions. It is the only such laboratory in Brazil — one of the few in the world — and is similar to the one in the Institute for Building Physics, part of the Fraunhofer Institutes near Munich, Ger-

1. Researchers operating flight simulators is an integral part of the project

2. Outside view of the pressure chamber that is part of the comfort laboratory

3. Engine of an Embraer 170 jet: the main source of noise on airplanes

many. "We'll carry out integrated trials inside it to determine how the parameters of cabin air pressure, noise, vibration, ergonomics, temperature and lighting influence the perception of passenger comfort," explains Jurandir Itizo Yanagihara, coordinator of Lete and of the "Cabin Comfort" project. "The objective is to improve the inside of airplanes and provide superior levels of well-being for passengers," says Jorge Ramos, director of Technological Development at Embraer.

On-board comfort has been one of the priorities of airlines for some years now. In the early years of commercial aviation, what was important was that the airplane did not crash. Airplanes did not excel in comfort. Subsequently, the interest turned to economy. Over the last ten years, other attributes have become relevant. Comfort is now recognized as a distinguishing feature in the civil aviation market and has become a factor competitiveness in the sector. Embraer, the third-largest manufacturer of commercial airliners in the world, with net revenues of US$ 5.8 billion in 2011, could not fail to invest in efforts to improve passenger comfort. Airbus (with net revenues of US$ 140.5 billion) and Boeing (US$ 68 billion) are ahead. "All the big companies in the sector are looking in the same direction, within the limits of the peculiarities of each segment," says Jorge Ramos. "Research with passengers on flights on different aircraft in Brazil, carried out in 2009 by UFSCar with the National Civil Aviation Agency, indicated that the main complaints about the cabin were personal space, support for the feet and arms, inclination of the seat, noise, vibration and baggage space," says André Gasparotti, the manager responsible for the project in the company.

Although the new laboratory has only just become completely ready, researchers from the three universities have already been collaborating with Embraer for several years on the items identified in the UFSCar study and also on others that are perhaps even more important. Jurandir Yanagihara, from USP, for example, worked in partnership with the company in 2003 and 2004 to develop a computer model of the human respiratory system to study the effect of decompression on the human body at high altitudes. "The success of this software, coupled with other projects on forecasting thermal stress using a model of the human thermal system, helped strengthen cooperation with Embraer, resulting in the current project," says the coordinator. Members of that team, such as Mauricio Silva Ferreira, a professor at Poli/USP, are also participating in the "Comfort Cabin" project.

On-board comfort has become a priority for air carriers over the last 10 years

When the company decided to conduct a major study on comfort, the teams from USP, UFSCar and UFSC were consulted. They agreed to take part in the multidisciplinary partnership and distributed the research tasks (in general terms,

cabin pressure, ergonomics, vibro-acoustics and the thermal environment) among themselves according to the specialties of each group. Embraer and USP, through Yanagihara, then requested funding from FAPESP under the Research Support Program of the Technological Innovation Partnering Agreement financing system (Pite), granted in 2008. They subsequently did the same with Finep (see the figures on page 61).

ISOLATED STUDIES

In the first phase of the project, the various factors that play a role in aircraft comfort were studied individually. In the second phase, which begins in May, the new laboratory, with the cabin inside the pressure chamber (called a mock-up), will be used for trials that will bring together all of the subprojects do that better parameters than the current ones can be identified. A good example of this is the model for assessing cabin pressure comfort. Today, it is known that for passenger safety, civil aircraft in operation must maintain a simulated cabin altitude of no more than 8,000 feet (2,400 meters) above sea level. Because aircraft can easily reach more than 40,000 feet (12,100 meters), the air within the cabin is pressurized. The model that Yanagihara's team uses takes into account the exchange of gases that occurs in the middle ear (the inner part that leads to the labyrinth) and allows the team to foresee at what rates of altitude variation (pressure) within the cabin the passenger feels or does not feel discomfort. "We're doing experimental work in this area, which is likely to change some of these parameters," says the researcher from Poli. The models still used today in the aeronautical industry date from 1937, 1958 and 1967 and are conservative. "In our studies, which are on-going, we are identifying very different thresholds from those found in scientific literature."

30

are the total seats the cabin laboratory has, simulating the inside of an aircraft

3

EMBRAER

The research on vibration and noise within the aircraft, normally carried out separately, has been conducted in conjunction with the research on other factors affecting comfort. The researcher responsible for the vibro-acoustic subproject is Samir Gerges, an Egyptian aeronautical engineer, a naturalized Brazilian, and a professor at UFSC. Gerges is one of Embraer's oldest employees. Even before the company's privatization, he was already teaching courses and providing consultancy services for company employees. Participation in the "Cabin Comfort" project with USP and UFSCar is a continuation of his research, which aims to reduce noise to a level that is acceptable to passengers. "Reducing noise and vibration too much is not advisable, even from a safety point of view," he says. "People have to realize that they are in an environment that is different from their bed at home."

The team led by Gerges is working to quantify the actual noise and vibration in the cabin and is preparing a computer model to predict cabin noise and vibration. This tool will provide guidance on how to avoid uncomfortable noises and vibrations more quickly and less expensively than full-scale experiments. The model can be used to modify the design of future cabins and to identify new materials and devices that can reduce noise and vibration. The main sources of cabin noise are the turbines, the flow of air along the fuselage and the air conditioning, hydraulics and tire systems.

The ergonomics subproject started, like the others, with a conceptual model. To understand the main problems, Nilton Menegon's team from the Production Engineering Department of the Center of Exact Sciences and Technology at UFSCar carried out interviews in 36 Brazilian airports. A questionnaire was prepared to analyze what researchers call "pre-flight," and 377 passengers replied to questions about the degree of comfort within the airplane. "If they have problems before embarking, like overbooking or

a long waiting time in lines, this influences their sensation of comfort in the aircraft," explains Menegon. In the second stage of the research, a further 291 interviews were conducted during the flight to find out, among other things, how difficult it is to carry out activities within the cabin, such as reading, writing, interacting with flight attendants, eating, resting and going to the restroom.

The researchers also observed how the passengers acted, first by taking digital notes and then by filming them. "The objective was to establish the sequence of activities carried out during the boarding, flight and disembarking phases, to identify the distribution of these activities throughout the flight and to quantify all these actions," explains Marina Greghi, from Menegon's team, a psychologist and specialist in ergonomics who was awarded her PhD this year for her thesis on passenger comfort in aircraft. "Systematic observations also aimed to identify the visible behavior of the passengers, like gestures, postures, actions involving devices and communication, for example."

The filmed material was stored on site and can be seen by the passengers who agreed to take part in the process of reconstituting the data. This process consisted of a telephone or Internet interview to carry out more in-depth analyses, by comparing and contrasting the view of the researcher and that of the passenger. The information gathered made it possible to create an image and statistical database and to develop software to analyze the activities of people in a stressful environment from recordings and posture analysis, based on an observation protocol. With the software, one can digitally reconstruct the actions of passengers and, with this information, generate what researchers call posture envelopes, which help to determine the areas and volumes occupied by people when they are carrying out activities. "The envelopes can be used in the project to analyze the space in the cabin and the actions of its occupants in such a way as to identify whether or not it's possible to carry out a particular activity in that place," says Marina. Called Ilios Pose, the software in question has been patented. Nilton Menegon says that the next step will be taken in the comfort laboratory mock-up, where the information-gathering already carried out will be repeated in a controlled environment that is integrated with the other subprojects.

ICING ON THE CAKE

The same thing will occur with all of the subprojects. The studies on psycho-physiology should clarify the relation between passenger

For a pleasant flight

LIGHTING

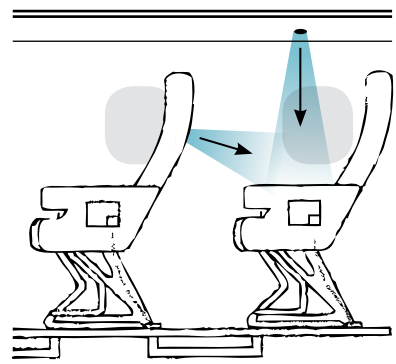
Do colored lights really have the power to reduce tension or enhance relaxation? Researchers want to learn whether the conventional understanding of color that is documented in the scientific literature is valid. If the established findings prove to be accurate, then the researchers will suggest colors for use within the aircraft.

WARM COLORS are closer to red. They are psychologically dynamic and stimulating and suggest vitality and movement. They can be used, for example, at meal times.

COOL COLORS are closer to blue. They are considered to be calming and soft. They appear to be ideal for moments of rest, after eating and during take-off and landing.

MICROCLIMATE

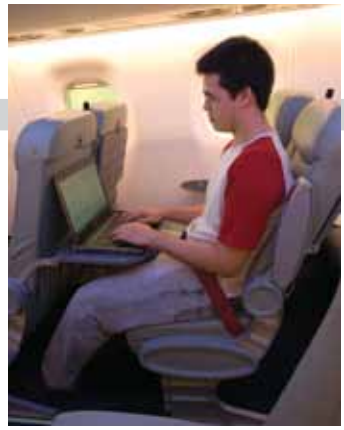
The goal is to let every passenger have a thermal sensation that is close to ideal, without affecting the people nearby. To make this possible, each occupied seat would have to have a variety of options that serve the passenger well. Heated or ventilated seats, different air-blowing options and a new geometry for air vents will be tested in the comfort laboratory.



Embraer jet: The cabin laboratory is just like the interior of the 170 and 190 models (below)

ERGONOMICS

The sensation of comfort in the cabin is directly linked to the activities that one can undertake in the cabin. Aspects such as seat access, how far the seat back reclines, reading, support positions for using a laptop computer and eating meals, and access to toilets will be studied.



PSYCHO-PHYSIOLOGY

The objective of this part of the research is to obtain subjective and objective comfort assessment measures. An attempt will be made to define what types of visual and environmental perceptions result in a feeling of well-being and to determine how to alter the interior design of the aircraft cabin in accordance with these perceptions.

VIBRO-ACOUSTICS

This part of the research examines the characterization and propagation of noise and vibration in aircraft systems and materials. There are also plans to build comfort prediction models regarding noise and vibration.

PRESSURE

The data currently used to study the effects of pressure variation in the ear at high altitude are quite old. The project team has collected new experimental data and has created a new model for assessing these effects.

THE PROJECT

Cabin comfort: development and integrated analysis of comfort criteria–no. 2006/52570-1

MODALITY
Technological Innovation Partnering Agreement (Pite)

COORDINATOR
Jurandir Itizo Yanagihara–Poli/USP

INVESTMENT
R$ 3.2 million (FAPESP) and R$ 4.5 million (Embraer)
R$ 4.3 million (Finep) and R$ 2.9 million (Embraer)

perception of mental and physiological well-being and discomfort in the cabin, explains Renato Ramos, a psychiatrist from the Psychiatry Biosciences Institute at the Clínicas Hospital of USP's School of Medicine, and a professor in the graduate health psychology program of the Methodist University of São Paulo. Entertaining yourself with a mental activity may reduce the feeling of discomfort and even affect the experience of the passing of time during the journey; objectively measuring this effect is one of the project's goals. "It's as if the passenger was so distracted with a book that he got to the end of the trip and said, 'I didn't even notice time passing'," says the researcher. Part of the research was conducted with volunteers using virtual reality to assess the degree of involvement of an individual with a particular task. In the tests already conducted, the passenger's heart beat frequency and how he visually explores the environment are monitored. In the second phase, experiments will be conducted in the mock-up to see how passenger comfort can be improved.

In the microclimate subproject, the passenger must have options for optimizing the temperature sensation inside the cabin. Individual air-blowing nozzles, which are above the seats, are likely to be increased in number and be better controlled, so that passengers can improve their own temperature sensation without affecting passengers seated next to them. The seats may also have internal cooling or heating systems. In the first part of the research carried out by the team of Arlindo Tribess, a Poli/USP professor, models fitted with temperature and heat flow sensors were used. A model of the human thermal system, integrated with computational fluid mechanics software, makes it possible to predict the reaction of the human body to changes in the thermal environment without the need to conduct tests with people. According to the developer, Mauricio Silva Ferreira, from Poli/USP, it is the first model of this type in the world.

Control of cabin lighting will be investigated to assess the influence of color on comfort. "There are reports in the scientific literature indicating that warm light, close to red, would be appropriate for activities such as eating, while cold light would have a relaxing effect, which is good for resting," says Yanagihara. It will only be possible to find out whether colored lights really influence passenger comfort after trials in the mock-up. "If this hypothesis is proved, we may even suggest new colors, depending on the activities inside the cabin."

The icing on the cake for this project lies in repeating the studies described above in the comfort laboratory. At that time, the tests will be fully integrated, with almost 1,000 volunteers involved in the trials that begin in May. The volunteers are required to be healthy, to have experienced air travel at least once and to live in the general São Paulo area. To volunteer, access www.lete.poli.usp.br/confortodecabine. A pilot, played by a researcher, will welcome volunteers aboard and give them instructions, as on a real flight, and a flight attendant will be hired to work in the cabin. At three points during the simulated flight, the volunteer passengers will assess their own comfort.

It was necessary to build the laboratory because it would be impossible to carry out experiments on Embraer aircraft. "An actual airplane would come with the limitations of its actual design, the cost would be very high and the availability limited," says André Gasparotti. The next generation of jets is expected to have cabin modifications that will make the experience of flying increasingly enjoyable. ■

EMBRAER