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(Review)

French Program of Science in Microgravity

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Abstract

CNES, the French space agency, covers five major areas of activity: Ariane launcher, Science, Earth observation, Telecommunication and Defense. In the Science area, in order to better understand the origin of the Universe, further our knowledge and understanding of its constituent parts, the CNES science program develops and exploits space instruments to study astrophysics, fundamental physics, solar system, exobiology and supports science in and for microgravity. The Physical science program covers hydrodynamics, evaporation, transfer, supercritical fluids, particles and suspensions, foam, material solidification, gas and solid combustion… The objective is to help laboratories simplify the study of various physical phenomena through access to microgravity. These research themes are mainly studied in relationship with European Space Agency. About 150 French scientists are involved in more than 40 ESA Topical Teams. In France, with the CNES support, forty laboratories are assembled in an association of researchers using microgravity. An annual meeting is organized to exchange about main updates and discuss possible improvement and cooperation. CNES Science program funds the necessary complement to develop or adapt the scientific instruments to space experimentation. This funding contributes also to the data use, simulation and numerical modeling. Numerical simulation, tests in the zero-G airplane and then long term experiments in ISS is the regular way to take progressively advantage of the space facilities. This is made essentially through the ESA organization frame but also in direct cooperation with other space agency, within or outside Europe. Indeed, CNES has direct access to ISS independently of the ESA program through cooperation with NASA that guaranties use of the ISS beyond 2020. Solid skills of the French community in instrumentation, modelling and simulation are widely recognized and we hope that future cooperation, supported by CNES through access to the zero-G test environment, can be developed in the future.

Keyword(s): CNES, Physical Science, Microgravity, zero-G airplane

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1. Introduction

This document intends to present a quick over view of the CNES program of science in microgravity and give some example of research we currently pursue.

CNES participates to the European program of research and has also its own national program to prepare the future and to collaborate with others space agencies. CNES national program funds R&T, parabolic flights, ISS use and a hundredth thesis and PhD each year. CNES funds also the ESA program ELIPS in life and physical science to support European program of science.

2. CNES Physical Science Program

Physical science program support 40 French laboratories to access to the microgravity environment and facilities:

- Pre-development / feasibility
- Development of experiment
- Adaptation to Zero G facilities
- Logistic
- Communication
- Exploitation in flight / Data treatment

Those 40 laboratories belong mainly to the national research center for science (CNRS) and to the French Alternative Energies and Atomic Energy Commission (CEA) or also to higher school of engineering laboratories.

This represents 150 scientists assembled in an association of researcher using microgravity for fundamental physics and applications (Groupement de Recherche – Microgravité Fondamentale et Appliqué). CNES program covers quite all the themes where microgravity is necessary. The following pages give some example and most remarkable results.

The CNES program covers quite all the physical domains of the condensed matter and fundamental physics:

- Combustion Science
  Solid, Gaz, Supercritical reacting Fluids
- Fluid Physics
  Flows, Boiling
- Complex Fluids
  Foams, Colloids, Granular
- Materials Science
  Solidification,
- Biophysics
  Blood flow and endothelial dysfunction, Bioparticules
- Fundamental Physics
  Cold atoms and EEP

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3. Some Examples of Research made in Microgravity by French Laboratories

3.1 Combustion of Fuel Aerosols [1)]

Dr C. Chauveau U-Orléans studies Fundamental laws of spray combustion. He particularly works on the propagation of flame in a cloud of droplets ~20 µm.

He shows that the presence of liquid fuel droplet triggers cellular instabilities on the flame surface which greatly increase the flame speed.

In its future developments he will use a new optical diagnostic (tomography LASER) to observe the local deformation of the flame and simultaneously, he will characterize the size of the droplets thanks to the interferometry Laser Imaging for Droplet Sizing (ILIDS) technique.

It is one of the subjects where we are looking for cooperation with others space agencies and foreign laboratories.

3.2 Solid Combustion of Electrical Wire [2)]

Dr G Legros UPMC in cooperation with Pr O. Fujita U-Hokkaido studies the propagation of a flame along an electrical wire. The experiences are first of all made in the zero-G airplane in France to determine the conditions of the tests and to optimize the mean of test. The final test will be made in 2017 on board ISS KIBO. Those experiments have the objective to understand and to put the physical laws in equation and also to improve the spacecraft electrical standard.

3.3 Effects of Long-term Spaceflight [3)]

It is well known that microgravity modifies the amylase activity and the Red Blood Cell composition and that such phenomenon affect the human life. But Pr Misbah LIPHY U-Grenoble has shown that there are also mechanical effects due to the modification of the lift force on the blood cells. The blood rheology is then modified as demonstrated on ground on a capillary network where the level of gravity were simulated by the viscosity of the fluid. Furthermore, the LIPHY team demonstrated other endothelial dysfunctions by Mimiking microgravity by simulation of the destruction of the glycocalix by enzymes in vitro with real glycocalix and red blood cells in a glass circuit. But those effects which are not only relative to the life in microgravity but also to numerous illnesses on ground have to be verified in real microgravity and after long term test.

This field of research requires analyses of blood vessel of mammals which have spent a while in microgravity and this could be done through an inter-agency cooperation which is proposed and expected.

3.4 Universality of Critical Phenomena [4)]

Y. Garrabos, S. Marre, C. Lecoutre ICMCB perform Weightless experiments in DECLIC on board ISS to prove universality of fluid critical behavior. They just publish an important article in Physical Review.

3.5 Boiling Crisis near Liquid-vapor Critical Point [5, 6)]

Dr Vadim Nikolayev CEA studies the phenomenon of the boiling crisis by comparison of experiments made in parallel in DECLIC onboard ISS and in LHYLA by magnetic compensation.

3.6 Characterization of the Directional Solidification in 3D Samples [7)]

Once again in DECLIC, onboard ISS, with a third Insert, N. Bergeon IM2NP observes in real time the interfacial microstructure of solidification. She demonstrates the existence of a periodic variation of the tip-position which characterizes the dynamic of the solidification.

3.7 Current Experiments in Fundamental Physics

Space tests of gravitational physics can provide clues to unify General Relativity and Quantum Physics and reach a new physics beyond the Standard Model of particle physics

- **Test of the Einstein equivalence principle in low earth orbit**: universality of free-fall, variation of fundamental constants, redshift
- **Tests of general relativity in the solar system** (light deflection, navigation anomaly, ephemerides)
- **Direct detection of gravitational waves**
  4 CNES projects of very high precision are or will be very soon in space for those purposes
- **T2L2** Time transfer by laser link on board Jason-2, 2008-2015
- **PHARAO** delivered to ACES in July 2015 for Clock comparison, tests of GR on board ISS, feb.2017
- **MICROSCOPE** Electrostatic accelerometers to test the EP at the basis of GR, on board a CNES microsatellite, apr.2016
- **LISA Pathfinder** contribution to the optical bench and data analysis, nov.2015 (demonstration for the L3 ESA mission to detect GW)

4. A New Zero G Airplane AIRBUS A310

A new airplane is now qualified to replace the previous one. The plane is based at Bordeaux under the control of NOVESPACE. Two CNES campaigns per year are planned and are ready to welcome scientists from around the world in the frame of inter-agency cooperation.

5. Summary

40 French laboratories represent about 150 scientists who are assembled in the GdR MFA and who participate to the ESA Topical Teams.

2 fruitful programs of cooperation are in progress with NASA and JAXA, respectively Supercritical fluids in ISS/DECLIC and

Solid Combustion.

A new AIRBUS zero-G is operational and has perform its first campaign in 2015

We are particularly looking for cooperation in 3 domains of study:

- ●Gaz combustion
- ●Blood Rheology
- ●Endothélial Dysfunction

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