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SCIENCES EDUCATION WITH PLANÈTE SCIENCES: A SQUADRON OF TOOLS AND PROGRAMMES TO GO ON SPACE CONQUEST

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ABSTRACT

Since 1962, and with the support of CNES and major aerospace industries, the French non-profit organization Planète Sciences has been providing young amateurs with facilities, tools and programmes to make their dream fly.
Young space conquerors are proposed to get hands on projects ranging from micro-rockets to experimental rockets but also stratospheric balloons and zero-gravity experiments. The projects proposed by Planète Sciences are performed within safety constraints and come with pedagogic and technical support and reviews from volunteers, several times during the project lifetime. They involve teamwork and the development of management and experimental process. They are made available to the widest and most popular range of participants and are the most important space outreach programs in the country. Planète Sciences is managing programmes, trainings, workshops, club projects in France and beyond.

1-INTRODUCTION

1.1 CNES, the French space agency established in 1961, is a public organization in charge of the development and management of the French space programmes. Its mission is to guarantee access to space capability and its use for all national and European needs. This includes support to space amateurs. Under the control of CNES, Planète Sciences, a non-profit organisation, was formed in 1962 to provide assistance to space clubs for the design, manufacturing and launching of the experimental space rocket projects.

1.2 Planète Sciences is a network of regional associations who promote sciences and technology through practical activities and experimentation to youth from elementary school to university levels [1]. The spectrum of thematics has broadened over the years and now includes space activities, astronomy, robotics, environment, meteorology, energy and archaeology.
Further to nation wide programs and trainings, Planète Sciences organises events or contests such as *Eurobot* and *Eurobot Junior* [2], *First Lego League*, *La nuit des étoiles* (the night of the stars), the national rocket launching campaign.

1.3 Support to amateurs

It originally started with space activities at a time when the space conquest was leading passionate people to build amateur rockets. Several of them lost their lives while tuning rocket engines made of World War II military ammunition collected from battlefields or by using approximate chemistry formulae.

To prevent further accidents, the French government prohibited any non-professional astronautic activities and assigned CNES to provide assistance to amateurs. The necessity to set specific programs for the youth emerged from the fear that a total prohibition would not eliminate the risk of accidents but on the contrary would promote clandestine usage. CNES, for practical reasons, could not have formal relations with individuals and therefore invited them to gather in clubs thus contributing to the establishment of an association named "Association Nationale des Clubs Spatiaux" (ANCS), now Planète Sciences (Fig. 1).

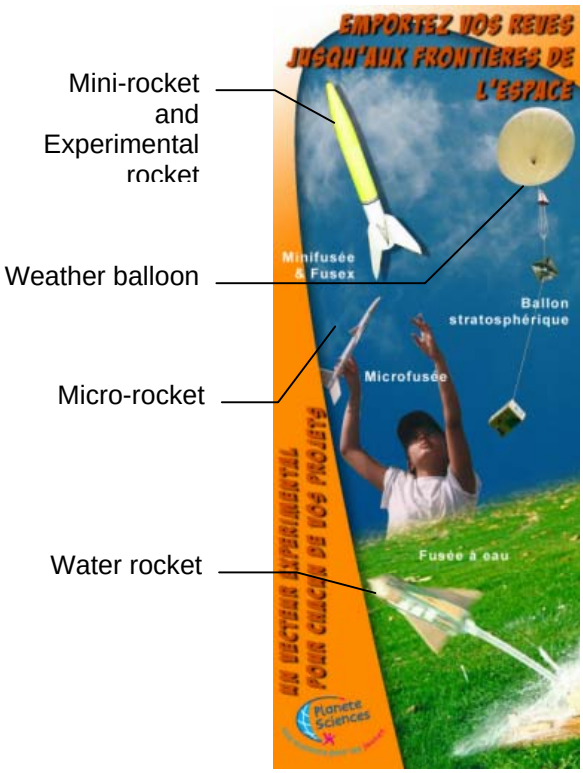

Fig.1: Space activities at Planète Sciences

Influenced by the professional background of its creators, who were members of the industrial world, the association developed avant-garde pedagogical methods that are based on concepts such as:

- To introduce youth to science and techniques through practical activities,
- To develop these practices as leisure activities,
- To promote teamwork,
- To offer youth the opportunity to engage in exciting projects such as rockets, where the tuning complexity naturally justifies the necessity to learn,
- To introduce youth to project management and experimental process since, in order to be successful, the capacity to manage a project is as important as the technical knowledge itself.

2-FIRST STEP TO SPACE: WATER ROCKET & MICRO-ROCKET

With micro-rocket or more recently water-rockets, available from the age of 7, the youngsters are brought to design and manufacture their first rocket and to learn the basics of aerodynamics, flight stability, propulsion and safety procedures. This can be performed within a couple of hours or days and the altitude reached by the rockets is from 50 to 100 meters, before falling back under a parachute.

Fig.2: Rocket scientist

Micro-rocket, propelled by A, B or C motors (from 2.5 to 10 N.s) are mainly made of cardboard, measure from ~15 cm to ~40cm and can reach 100m high with a 200km/h lift off speed (Fig.2) It is the ideal tool to experiment, to understand what makes a rocket stable and fly straight up. Kids are given the chance to handle tools such as glue gun or drill and raise them with more responsibility. Because safety is Planète Sciences activities' golden rule, micro-rockets motors are not part of any experiment. They are supplied from an approved manufactured, retailed by Planète Sciences and are launched by and certified adult (18 and above). The micro-rocket certificate (*agrément microfusée*) can be obtained from Planète Sciences after having successfully attended a 25 hours training session. The training deals with manufacturing, rocket flight, stability experimentation and evaluation, safety rules, launching campaign organization and pedagogy. Trainees are given a 75 pages reference book [3] gathering knowledge about propulsion and stability, safety, manufacturing techniques (basic rockets, multi-motors or multi-stage rockets, ignition box) and pedagogy (experimental process). Trainees then master the fundamentals to hold workshops and launch rockets in safety conditions with kids. Each year, about 50'000 micro-rockets are launched in France, a million since 1980.

Water rockets spread in the 90's: they are cheap, easy to build from soda PET bottles and easy to launch. Because it is not under the control of any regulation, Planète Sciences developed documents to guarantee safety, but also to highlight the pedagogic interest of this tool. Like other countries in the world, water rocket workshops are proposed by Planète Sciences to bring kids to discover about space, sciences and techniques through the excitement of a simple jet of water propelling their rocket in the air.

Fig.3 Water rockets: science and fun

3-A STEP HIGHER: MINI-ROCKET & EXPERIMENTAL ROCKET

When a team is willing to start a rocket project its first step is to make contact with CNES through Planète Sciences. The three parties are bound by a moral contract, which may be summarized as follows:
the tuning of a rocket engine is very dangerous for novices and this practice is prohibited by national regulations; alternatively, clubs are invited to design and build a rocket for which CNES provides with both a professional quality powder engine and the launching facilities. From its side, Planète Sciences organises technical assistance, the launching campaign itself and ensures that the activities fall within the European regulations.

The efforts of the clubs are thus focused on their mission which is the experimental content of the payload and the mechanical structure of the rocket. The set up of the propeller and the rocket launch are the responsibility of a professional pyrotechnician from CNES.
A typical experimental rocket is 2 meters long, weighs about 10kg and reaches heights of about 1500 meters as shown in Fig. 4. About twenty rockets of that type are built and launched every year by club members from ages 14 to 25, who come from regions across France,

and also from Japan, among regular foreign participants.

Before flight, a typical mini-rocket weights 1 kg and measures about 50 cm, with a 500 m altitude reach; a slowing down system must be deployed in order to make it land safely. The up flight lasts 20 seconds and fall may last a minute or more. The flight is stabilised thanks to 3 or 4 fins located at the bottom of the rocket. Initial acceleration is about 10 G.
Control procedures are also carried out for rockets, according to specifications. Rockets are made of PVC or even cardboard and are designed according aerodynamics constraints. For youth, the main experiment is to imagine and to achieve a way of extracting parachute at the right moment. But rockets may also be fitted with acceleration sensors, sun detection (to deduce the rotation of the rocket)…

Fig.4 Rocket launching by
the French club CLES-FACIL

Club members willing to turn their dreams to reality can register their rocket project from early October of each year. They are required to prepare for the definition of the mission and the experiments it would require. For that purpose, a set of online resources are provided by Planète Sciences, which will help the clubs in the development of their project:

- A project definition and summary spreadsheet, regularly updated, serving as a link between the clubs and Planète Sciences for the technical data of the project.
- The design constraints: a wide set of rules focusing on safety and pedagogy. It includes mechanical constraints (stability margins, dimensions, resistance to stress), experimental requirements, recovery systems, ground localization, telemetry systems and compliance with regulations and standards (frequency spectrum, modulation schemes), rocket implementation and results interpretation [4];
- A dedicated stability calculation tool [5];
- Technical documentation about the motors provided by CNES [6];
- A technical manual about the KIWI telemetry system developed by CNES for the purpose of such projects led by clubs [7];
- Technical tutorials dealing with electronics, sensors, parachutes as well as team and project organisation;
- Previous years' projects reports.

All of these resources are prepared, updated and translated into English by the volunteers of Planète Sciences.

The volunteers also provide technical assistance in the following manner:

- On the phone every Wednesday evening while they gather at Planète Sciences' premises,
- Online through a web-based forum,
- Live, once a quarter during meetings with the clubs.

Planète Sciences sets up the launching facilities depending on the needs of the clubs. Regional launching campaigns are organised for mini-rocket, while for experimental rockets, the national

launching campaign takes place in the heat of summer under the supervision of CNES and the assistance of the army.
Dealing with the national campaign, from the launching pad to the details of accommodation, everything is arranged to host about 30 mini or experimental rockets and more than 300 young amateurs, either club members or volunteers in charge of the organization.

The launching campaign is possible thanks to the involvement of the large number of volunteers (more than 40) and the trust of CNES authorities. Professional pyrotechnicians and ground safety managers from CNES assist the volunteers. CNES funds the launching campaign and supports the development of student space research programmes, such as PERSEUS for nano-satellite launchers, or CANSAT.

Fig. 5 The launching site set up at the national campaign

Fig. 6 From 14, teenagers handle their own mini-rocket project

Fig. 7 Even Japanese Space clubs enjoy the launching campaign: why not you?

4-CLOSER TO SPACE: STRATOSPHERIC BALLOON

The Stratospheric Balloon team members have to design and build all the experiments of their choice, which take place in a basket hanging below a weather balloon.

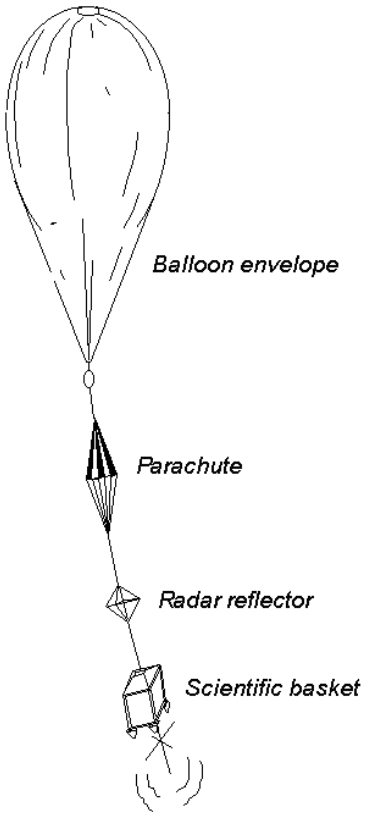

Fig. 8 Stratospheric balloon flying chain

Reaching very high altitude (up to 40 km, enough to observe the round shape of the planet), this vector allows studying the different layers of the atmosphere and its characteristics, to perform remote sensing, land recognition, image processing and other rared-atmosphere experiments. A dedicated telemetry transmitter is provided by CNES for the young space quasi-travellers assess their first results.

A reference document called *"Cahier des charges"* [8] describes the technical constraints baskets should comply with to be compatible with legislation and the loan of collective equipment. Other documents develop some specific technical aspects: flight mechanism, atmosphere properties, telemetry and methods for project management. These documents are written taking care to be as clear as possible in order to be understood by youth themselves and are regularly upgraded taking account of stated remarks.
Connected to documentation, the following equipment is made available to clubs by CNES: a balloon probe envelope, a radar reflector, a parachute, an helium tank, a suitcase containing lift-off equipment and if requested by the project, a KIWI telemetry receiver set [6].

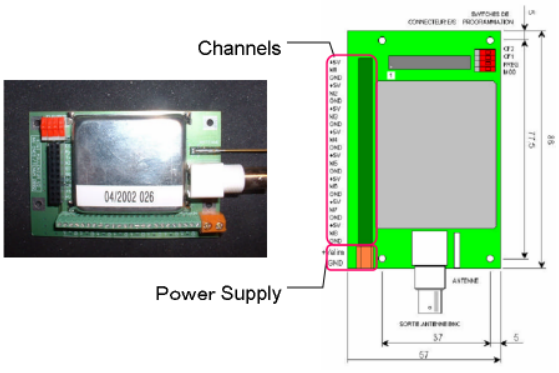

Fig. 9 KIWI transmitter

This equipment is regularly used for professional meteorology soundings but the transmitter that has been designed on purpose for youth with special care to make it cheap and easy to use. Typically, the balloon's volume is about 5 m^3 when lifted off and may carry a 2.5 kg basket up to 25 km; then it bursts and the parachute slows its fall. A typical flight lasts 3 hours: the basket flies with the winds and may land 250 km away from its starting point. The balloon flies high enough to reach troposphere where onboard sensors may record temperature and pressure close to spatial conditions. The balloon activity is fully compatible with aeronautics regulations, which served as a basis of the write up of the main rules described in the specifications stated by Planète Sciences and validated by CNES.

5- NEAR-SPACE MANNED FLIGHTS: ZERO GRAVITY PARABOLIC FLIGHT

State of microgravity (i.e. near zero gravity: ZeroG) can be achieved through parabolic flights. Such flight campaigns are carried out to perform scientific experiments or training of space crews. Because microgravity flights deal with space and experiment, Planète Sciences and CNES have been pioneering youth experiment in ZeroG. In 1988, leveraging *Aragatz* mission on Mir space station with a French spationaut, a set of simple modules has been developed to visually demonstrate zero gravity in space. Videos shot in the station have been further distributed in schools, as pedagogic material. In 1992, the first junior high school pupils boarded the *ZeroG Caravelle*. This ultimate human experience of space travel is nowadays achieved during regular *A300G* flight campaign. Schools, clubs of amateurs and university students are invited to submit their proposal for experiment. Once selected by CNES, they have 6 months to 1 year to complete their project before the in-flight test takes place. Experiments mainly deal with physics, such as:

- Dynamics of a marble,
- Test of a mass measurement device
- Behaviour of fishes in aquarium,
- Oil and vinegar separation by centrifugation,
- Movement of soda bubbles
- Heat transfer in a fluid

Fig.10 Space flight experience in ZeroG

A flight campaign is basically a set of 30 parabolae, each of them providing 22 seconds of microgravity. Planète Sciences provides assistance to youngsters (from 15 to 30 years) in the preparation of their project while CNES provides assistance during the flight. Since 1992, 10 projects have been tested in micro-gravity, and 12 youths have taken part to parabolic flights and enjoyed the feelings of evolving freely in the plane cabin out of gravity.

6- PROGRAMS & TRAINING

6.1 UBPE & UFAE

Programs named *UBPE* and *UFAE* are taking place at school either during official tuition times or during post-curricular activities proposed by teachers. Most of time, teachers fill in a spontaneous request form describing the educational purpose they want to achieve. Once the application is accepted by Planète Sciences (mostly based on youth motivation and teachers involvement), a volunteer assigned to the project team: he acts as a technical advisor, who visits the group several times during the school year to ensure the best development of the project.
He advises the teacher about methodology but never aims at replacing him. During his visits, the volunteer works either with the group itself or with the teacher to help him preparing lessons the way the latter wants.
Volunteers are mainly students or young adults working in technical fields.

UBPE has started in 1992; it is proposed to a wide scholar public (from primary school to high school). It is managed by a national responsible at Planète Sciences and relayed by regional divisions. A typical project will be composed of 3 to 4 experiments, plus the basket itself: 25 to 30 kids can be involved in the project.
From 30 schools for the first edition, the program is now proposed to 130 to 160 schools each year; half of these schools are proposed the program again, on purpose.


Fig11. Media often cover the release of a balloon project

UFAE has started in 1999 and is dedicated to the same public as *UBPE*; its overall organisation is also similar, carried out by volunteer and managed by employee from Planète Sciences. Today, about 20 schools are engaged in this program for a total of 90 projects. During the school year, with the same phases and methodology as already described, groups of 5 to 10 youth are working on the achievement of a mini-rocket.

Several documents are available to teachers and pupils; written by volunteers and validated by CNES, they explain the purpose of the programs, the way they are managed, and give all information needed to bring teachers self-confidence about such complex-looking projects.
The programs meet the annual scholar cycle. At the beginning of the year, teachers are even invited to a one-day information meeting organised locally by Planète Sciences.
Teachers may benefit from these programs to develop associated cultural projects: visits of industrial sites or museum, thematic studies connected with history, introduction to new concepts.

6.2 Trainings and pedagogy

Projects and programs would not take place without the contribution of volunteers, teachers and science communicators. Because they need to be taught about the techniques and pedagogy, each of the activities and programs comes with dedicated training sessions:

- *UBPE* and *UFAE* technical advisor
- Telemetry with KIWI
- Advanced telemetry and reception
- Aero technician (balloon release)
- Micro-rocket launcher certificate,
- Mini-rocket launcher
- Trainers training (to be sustainable)

Pedagogy is present throughout all of the trainings with the experimental process as one of the basic fundamental: seamlessly the following steps are crossed: Observation, Assumption, Experiment, Results, Interpretation, Conclusion. This ensures parameters to be clearly defined and isolated in order to achieve consistent results. Dream and game are not taken apart as we deal with youth and it is not rare to see a castle-shape rocket or a large lips shaped-balloon basket flying in the sky of Planète Sciences.

Fig.11 Students, teachers, leaders, parents: training contents are adapted

7-CONCLUSION

Planète Sciences is a non-profit organisation whose ambition is to contribute to the development of scientific and technical cultures among youth using pedagogical methods based on experimental methods and introduction to project management. Together with CNES, it brings rocket projects to reality by proposing a safe and structured organisation to design build and launch rockets. The space experience, throughout rockets, balloons or ZeroG flights, although below the 100km threshold, bring youngsters to achieve part of the dream that becomes a reality with tourism. No doubt that with the new space travel opportunities more experiments will be carried out by young generations, to develop the thirst for scientific knowledge higher and farther.

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