RISTRETTO : A French Space Agency Initiative for Student Satellite in Open Source and International Cooperation

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ABSTRACT

The EXPRESSO (EXpérimentations et PRojets Etudiants dans le domaine des SystèmeS Orbitaux) is a French acronym for a CNES (French Space Agency) initiative that aim at fostering networks of universities, laboratories and industries in the field of orbital systems. This program, started in 2006, strives to serve as an educational platform, promoting space and science and attempting to involve students in all aspects of a project from project management to "hands-on" development. The first call of ideas EXPRESSO (2006) has permit to select three projects among witch we have a cubesat for the validation of laboratory test methodologies for bipolar technologies, named ROBUSTA leaded by University of Montpellier (South of France). Today, ROBUSTA is on the way to be ready for launch and it is already a real success on pedagogic point on view (see article SSC09-XII-10). It's launch foreseen by VEGA launcher and the operational data collection are awaited to complete this success on scientific point of view. Therefore, CNES has decided to continue the experience with a future more ambitious initiative named RISTRETTO in the frame of EXPRESSO program. This paper presents the CNES internal studies on-going on technical and programmatic feasibility of the RISTRETTO concept

1. INTRODUCTION

RISTRETTO (Réseau International de SysTèmes oRbitaux ETudiants basés sur une Technique de développement en Open source) is a French acronym for International Network of Students satellites Projets based on Technical Development in open source

The idea of RISTRETTO is to federate international student community around a common project : studying, developing and using a new concept of student satellites.

RISTRETTO will extend the concept Cubesat to a larger size of satellites of 30 cm, 30W, 30 kg to enlarge the possibility of the embedded targets.

Its main characteristics will be :

- Compatibility with all kind of launchers by the way of a standard interface
- Low cost and reduced time of development using COTS
- Studied and developed via an OPEN SOURCE concept by an international student community
- Part of the GENSO (students ground segment in development) initiative

This new concept of small students satellites could be used by students themselves but we can imagine that it could be also of a great interest for scientific communities or used as demonstrator for validating new technologies or applications for industries.

2. RISTRETTO CONCEPT

CNES's (French Space Agency) policy is to support students' satellites projects. As the Cubesat concept is nowadays very commonly used by universities, the idea is to go higher with a similar concept called RISTRETTO to set up a new family of students satellites:

- done in international cooperation
- With higher ambition as regards technical performances

in order to allow more technical, scientific and application missions.

The initial targets defined for RISTRETTO satellites is a size around 30 cm for each face, an electrical power about 30 watts and a weight of approximately 30 kg. These targets have to be validated or adapted during the feasibility study.

RISTRETTO satellites main characteristics will be:

- Compatibility with several kinds of launchers by the way of a standard interface
- Low cost and reduced time of development using COTS
- Studied and developed via an OPEN SOURCE concept by an international student community in some ways similar to what is being done for the GENSO project (students ground segment currently in development)

Before starting this program, the CNES has been performing an internal study on its feasibility on 3 aspects: type of payloads compatible with such satellite bus, technical feasibility of the bus and performances limits, programmatic feasibility (organization, planning, open source …)

In fact under the RISTRETTO program there are:

- A generic satellite bus adaptable to various missions and orbit
- A ground segment for operation (~ GENSO +)
- A launch separation interface.

The payloads and any related specific element are not part of RISTRETTO. However, to support the development of RISTRETTO it would be wise to simultaneously develop one or two payloads using RISTRETTO in order to test and qualify RISTRETTO through the launch and in orbit operation of one or two satellites making use of the RISTRETTO "kits".

3. FEASIBILITY ANALYSIS OF POTENTIAL MISSIONS

The orbits considered for RISTRETTO are LEO and GTO, i.e. orbits compatible with most launches as auxiliary passengers.

Different mission types are possible with the RISTRETTO concept:

We know that most often the university satellites are used to test in orbit or demonstrate new technical solution (equipment, subsystem architecture, components …). Another technology mission is related to the measurement of radiations and test in orbit of electronic components (cf. ROBUSTA).

But small university satellites have also performed and could continue to do scientific missions in astronomy, earth study …

Also small satellites could be used for applications for instance in the field of telecommunication (data collection, localization of mobiles …) or in the field of earth observation (ground surface, atmosphere, waters …).

We know that applications are more demanding in the field of pointing accuracy, data transfer capability, reliability and/or power availability.

Having considered the existing lines of product (for instance the Cubesats), the various possible missions in the university satellite range, and the need to remain cheap and feasible in less than 3 years in universities, we concluded that there is a need for a family of satellite in the 30 kg, 30 W, 30 cm ranges.

4. TECHNICAL FEASIBILITY

4.1 Specifications

A preliminary specification of the RISTRETTO bus says:

- Orbit : LEO, GTO
- Life duration : One year
- Satellite mass : around 30 kg with at least 5 kg for the payload
- Dimensions : 30 liters (or a cube of about 30 cm)
- Electrical power : 30 W total

- 3 axes stabilized

- Orbit control capability (and end of life de-orbitation possible)

- TT&C : via S-band

This specification has been validated through various studies but remains to be decided with partners ready to contribute to the design and development of RISTRETTO.

4.2 System architecture

The system architecture design should be done keeping in mind the RISTRETTO basic philosophy:

- Design and development in international cooperation with universities and other actors

- Open source

- Cheap and fast to develop

In fact we went to the conclusion that the design should be as modular as possible to allow an easy sharing of tasks between various partners and to later on allow easy evolution of the product.

As regards the mechanical architecture, several modular options have been considered and a trade off remain to be done, considering mass, volume, thermal and mechanical isolation, structure type, and technical solution selected for the various subsystems.

4.3 Electrical power subsystem

One of the real limitations in the use of satellites is, apart the launch (and the fear in some spirits that small satellites could prove useful), the power available for the payload and for the transmission of the data it produces. Therefore it is one good reason for having studied a wider and more powerful satellite than the conventional and very successful cubesats.

Of course it would be possible to use unfoldable solar panels as it has been yet done on several nanosatellites (for instance on CUTE-1 from Tokyo Institute of Technology).

In Ristretto we had the a priori that we should try to put a solar array drive mechanism. To day after several studies we have acquired the conviction that this is feasible and would bring a plus to the small satellites.

In a preliminary study done by the French engineer school –école des mines de Douai- the OPUS-30 team of students recently concentrated on the power subsystem of Ristretto (and on propulsion). They reviewed the state of the art in small satellites solutions and in the potentially usable technologies. With that in hands they studied a possible solution using solar panels with an original solar array drive mechanism they designed (preliminary design solution with a slip ring capsule and a step motor). The solar panels are folded at launch and unfolded in orbit (cables cut). They have been considering for that the use of the CYPRES item (Cybernetic Parachute Release System), a product designed for Skydivers.

The deployment systems of the solar panel would be a MAEVA hinge, a system developed by CNES for small satellites.

The solar cells could be of a triple junction types.

As regards the battery, several possible solution based on lithium technology exist.

All in all the weight of such a power subsystem would be in the 2.5 kg range.

But this is only an example of what would be feasible. It consolidates the overall feasibility of Ristretto.

4.4 On board data handling -

Ristretto like every modern spacecraft will have computers on board to process data. A large part of the computers workload is for the attitude control. But several other subsystems require computing capabilities.

In Ristretto for reasons of sharing of work between universities during initial development as well as evolution capabilities through the various Ristretto satellites that would be made later on, we considered better having a decentralized architecture i.e. several computer rather than one centralized computer. This means that we will have to carefully choose a data exchange standard (hardware and software).

Several solutions have been studied preliminarily but no decision made. We think better to provide elements to the future project team and having them decide as this data standard is certainly very much linked to the detailed share of work to be decided between partners.

4.5 TT and C subsystem

CNES has itself a strong experience in designing such TT&C systems for small satellites and other similar uses. Many types of equipment exist but one may also imagine new solutions, for instance based on mobile telephone technology.

There is in the TT&C domain no large problem of feasibility.

4.6 Attitude and Orbit Control subsystem

Through the missions list that we consider compatible with the Ristretto class of spacecrafts, we have not identified it would be mandatory to have a very accurate 3 axes attitude control of the satellite. In fact with rather limited sizes it is not easy to design an instrument able to "see" with a high accuracy. But even if it is not strictly necessary we have chosen to conceive Ristretto with a star sensor and wheels able to make a very accurate high attitude control. This because we think that today it is not much more complicated and much more expensive, and also because we would like to see this done by universities i. e. with cheep and light solutions, for this class of satellites.

The Ristretto family in the same spirit will have a propulsion system for control of the orbit. A GPS receiver could provide the orbit data. A cold gas propulsion system would provide the needed propulsion capability.

A preliminary technical solution has been studied by the OPUS-30 team yet mentioned.

4.7 Parts and equipments - reliability

Even if all what is possible to improve reliability of the satellite has to be done in principle, a high priority has also to be given to shorten the development duration and to lower the cost of the Ristretto satellites. The COTS (commercial off the shelf) elements are the base for the realization of Ristretto. But of course in doing a careful trade off it is very often possible to select a solution with better quality and reliability and not really more expensive or more lengthy to get.

At final integration of the spacecraft the set of electrical, mechanical and environmental tests will screen most of the defects. We assume that most missions –i.e. technology test and demonstration, science- will be more than happy with a life time of one year. Application mission may like more. But the life time of Ristretto satellites is not really be limited except by fuel, if orbit control is required. Other limitations are essentially random failures as only few equipments will be redunded.

4.8 Ground Control segment

Any new satellite system has to consider which control ground segment will be used. Ristretto will be compatible with most existing S-Band ground stations currently used by space agencies for their satellites. This S-Band is not far from S-Band used for GPS, Galileo and other navigation systems or for satellite telecommunication transmission or even from GSM telephony. This means that a large number of equipments exist usable or adaptable to Ristretto needs.

Ristretto is also very much expecting the finalization of the GENSO project. The idea of interconnecting a large number of ground space stations via internet to set up a network offering a quasi continuous communication between the Earth and a low orbiting satellite, appear to Ristretto a good way to control/ command the satellites in LEO and even collect data from their payloads. Currently GENSO is in amateur UHF/VHF or S-Band but a similar system in agencies TT&C S-Band, let's say a GENSO +, would offer even more capabilities.

Even if Ristretto will need only one station for its operations, the availability of a network similar to GENSO would offer a close to real time control possibility and would increase a lot the ability to collect data from the payload.

We imagine that such a real time control capability would allow a remote control of the line of sight of any telescope on board the satellite. This "joy stick" control was demonstrated from the station in visibility for the TUBSAT C satellite. In Ristretto, thanks to the availability of a "GENSO +" network, such a joy stick control would be feasible from any point on the earth, at any time (or close to).

4.9 Launch

Ristretto has to be compatible with most launch systems. An interface has to be designed as was designed the P-POD for Cubesats.

Students from INSA Lyon have developed such a system for nanosatellites. No doubt they would be able to do so for Ristretto.

Several other universities in the world have similar capabilities.

We all know that the launch of small satellites remains a difficult question, for Ristretto like for any

other small satellites. The size of the satellite doesn't change the situation.

4.10 End of operations – de-orbitation

The Ristretto bus will have an orbit control capability very useful for missions where an accurate altitude and inclination must be achieved. It would permit compensation of potential inaccuracy of injection at launch. But this is also very useful during the whole life of the satellite and at the end of life.

As a matter of fact, it is now recommended that satellite be removed from their working orbits at the end of their mission.

Ristretto with its propulsion capability could be then placed at the end of mission on a safer orbit, presumably an orbit prone to higher natural atmospheric drag i. e. entering in the atmosphere sooner than what would be achieved without such a maneuver.

Of course the small satellites with their small volume and weight are not the major source of concern with regards to debris. Ristretto with its 30 Kg produces on the long range, all things equal, 100 times less debris than any 3 tons satellites on the same orbit.

Too often small satellites are considered as "debris" by some official or industrial representatives. Let's build and launch hundred Ristretto satellites and on their end of life we will note how many tons or more precisely kilograms are left in orbit in comparison to other spacecrafts.

5. RISTRETTO PROGRAM ORGANIZATION

Based on the assumption that the Ristretto bus will be available in open source from the team that has develop it and assuming that the study and development will be conducted essentially in an international university frame, we propose to establish a central project team in Toulouse with representatives from universities (for instance one for each university in charge of major subsystems). Administratively speaking this team could be organize under the French association law (association loi 1901) which seems by far the easiest and more flexible solution. Any partners would be essentially "committed" through "a best effort clause" to study and provide one equipment, subsystem, software or service.

Part of the association, we also imagine that it would be useful to have freshly retired engineers from space industry and agencies, as we assume they would have some availability, that they keep their contact networks and their technical knowledge.

Agencies, research laboratories, industry would not be kept outside the project as long as they accept the general philosophy and especially the open source frame. This frame doesn't means that you have to unveil your industrial or other secrets but that any plan or drawing developed for Ristretto and necessary to reproduce the bus will be available without restriction. In each reuse of the Ristretto bus, the payloads, being specific for each user will remain out of the scope of the Ristretto agreement and project. But also in each reuse, any modification, improvement of the bus would be put available in similar conditions (i.e. Open source) than the original Ristretto to the space community.

This project team and association would have agreement signed with all partners of the project, i.e. all those who accept to contribute to the study and development of this new satellite bus (and other components linked to the bus such as ground control-command system, launch attachment and separation devices …)

The open source type of commitment has been studied as part of the feasibility study conducted in CNES. Details remain however to be fixed by the funding partners.

CNES has been up to now studying the interest and feasibility of such a new platform. CNES is ready to continue pushing and helping for its detailed study ands its development. But it may not be a CNES program. It must be an international program with a strong university involvement.

Several space actors have indicated a preliminary interest 'in principle" for the idea. The Toulouse university is prepared to study the provision of rooms and other technical means to support the project team. Several industrial companies as well as CNES and other institutional bodies are prepared to study the allocation of funds for instance to cover doctor thesis.

The decision would then be related to a call for partners sharing the views here expressed and willing to support or participate in this development. Partners would be as said before, from governmental and intergovernmental agencies to local agencies, from industry to research laboratories, and from universities to more specialized technical school. We could think that may be some foreign institutional partners would wish to organize or relay the call for their countries and of course we would love that.

6. CONCLUSION

We have in hands all the elements for a decision for a go-no go decision. We have not yet decided to officially contact potential interested partners. We, as a Space agency, are used to work with other space agencies but not with foreign universities. Or we contact French universities and up to them to contact partners or we contact our traditional partners (NASA, ESA, JAXA …) and ask them to organize their national contribution, or a mix of both ways

We certainly would appreciate reactions, for instance by informal mail, or verbally or any other mean on the way to go, on the potential interest of our idea and even better on the preparedness to talk with us to organize the project.

Any how CNES will continue to study with universities the various subsystems, some key elements and will present informally this topic to partners French universities for instance, foreign agencies and universities, each time the occasion is given. But we could also decide to go a bit faster and decide to develop the line of product, with foreign and French partners

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