STRATOBUS: A MULTIUSER PLATFORM SYSTEM FOR MAKING ACCESS TO LDB FLIGHT EASIER AND CHEAPER

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ABSTRACT

Interest in Long-Duration Ballooning (LDB) and, recently, in Ultra-Long-Duration Ballooning (ULDB as a means of performing experiments over a long duration of time at high altitudes) has grown over the years. These LDB trajectories are possible thanks to the polar vortex (both poles can be considered during a given period of the year). Other than the already operative Antarctica base at McMurdo, long missions can now rely on the upcoming launch base facilities on the Svalbard Islands. Their completion and subsequent availability will be a great occasion for the European scientific community. The STRATOBUS idea, if realized, should be capable of modifying its general structure by trying to fit, and not to exceed, the real needs of a given campaign. An organization of this type can launch balloons from any possible site of the world, even those requiring a flexible organization due to certain regional peculiarities. The project can manage platforms for housing either single or multi-experiments because it has the ability to produce a sort of standard in designing every part of the gondola system: a standard means for optimizing , reusing resources and , where possible, for sharing the room, on a stratospheric flight, between as much experiment as possible. Contrary to the recent past, the STRATOBUS organization will be able to look for "clients and/or experiments" within a world-wide audience and indicate the ride cost as function of the weight , volume and bit-rate required only. The Project should be ready to indicate any short- and mid-term programs, by mean of a dedicate web site, and be interactive by showing, in real time, the availability of the room for rent , flight by flight and campaign by campaign. The scientific world has to rely on regular scheduled missions in order to lead and develop research programs. The STRATOBUS Project has indicated a way in which to decrease the overall costs for a Balloon campaign. Every effort should be addressed to making research by balloons competitive with other means

The authors now are ready to collaborate with an international consortium aimed at optimizing efforts by designing all the devices borne to help arranging different experiments.

1. INTRODUCTION

Generally speaking, the success of a mission is dependent on the scientific results obtained from the experiment, and is also affected by the overall costs of the whole campaign. Many times, the cost of a campaign, is the factor that, by itself, determines whether a mission should be performed or not, without taking into account any other criteria, such as the scientific interest of the experiment, the scientific relevance of the results that may be obtained, etc. Minimization of the costs for the whole campaign represents a very critical issue to be considered. One possible way to improve the overall efficiency of a mission is to perform different kinds of experiments during the same flight and, naturally, to reuse resources from previous missions in order to reduce the overall costs. Improving the platform concept according to the multi-experiment criterion requires maximizing the ratio between the payload and the lift capacity of the balloon by reducing the mass of each system in order to increase the number of experiments that may be performed during the same flight. It also means satisfying a lot of possibly contradictory specifications among the functional requirements of the different experiments. The reusability of power supply systems, the pivot system, etc., requires defining of lightweight technical solutions that are capable of preserving the integrity of these systems during the various flights. Moreover, it should be noted that each time the duration of a mission exceeds a given observation time, it is possible to improve the results of the stratospheric measurements, which are generally ranked in a validation data class, so that they become self-consistent ones capable of resembling those supplied by dedicated instrumentation housed in satellites Within this framework, a small Italian Consortium, set up by IFAC-CNR of Florence, together with the Universities of Florence and Bologna, LEN of Genova, and the IASF of Bologna as well as some PMI representative industries, has been established, for the purpose of pursuing these

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objectives and approaching the multi-experiment concept by means of: the STRATOBUS project. **I**n order to keep flights cheaper and at a constant frequency rate , the STRATOBUS Consortium has begun to redesign many of the components involved in single-user balloon launches. A versatile and self-balancing platform that easily fit the needs of any combination of payload is, among other things , the most important factor in the mechanical design. The reusing of power sources, which need to be protected upon landing is a second part of the project

2. TECHNICAL FEATURES

The project should be capable both of studying and solving the many issues related to the design of multi-experiment platforms for LDB flights, and of providing guidelines for making the approach more systematic [1]. In brief the project involves:

- a versatile mechanical structure capable of balancing itself easily when housing different payloads without the addition of extra weight;
- variable bit-rate upon request;
- the use of renewable power sources arranged so as to ensure a safe landing. Solar Panels and fuel cells will be employed ,depending whether the measurements take place during the day or at night;
- attitude solution sent to all payloads (gyros , magnetometer …) as housekeeping data;
- azimuthal movement of the whole platform (by means of a pivot) and the possibility of controlling also the elevation motion if requested;

-eventual time sharing of the azimuthal movements, in the case of simultaneous and different scannings of sky patches;

- an interactive WEB site to book room (global audience) on a given flight . The ticket cost regards only the weight, volume and facilities required (such as bit-rate, scanning time etc.). Obviously, the success of the idea is closely connected with how the new concept will be popularized within the scientific world.

3. THE GONDOLA

As stated above, The project STRATOBUS was created in order to decrease the general costs of a flight. It proposed to design, at least, all the primary parts of a platform. Certain special requirements are left to the initiative of the experimenting scientific group . The versatility of the frame ,which is easily capable of hosting different experiments and satisfying some residual contradictory specifications, is a key part of the entire organization. It assembles the gondola in close relation with the STRATOBUS's web server which selects the users after verifying a minimum level of the mutual compatibility between them .

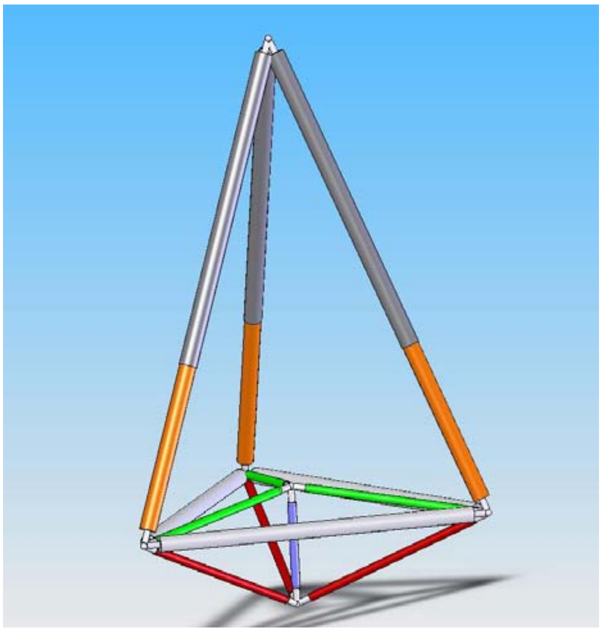

Figure 1. Modular structure in which each beam undergoes only tensile or compression stress.- In this way we can minimize the weight of the gondola

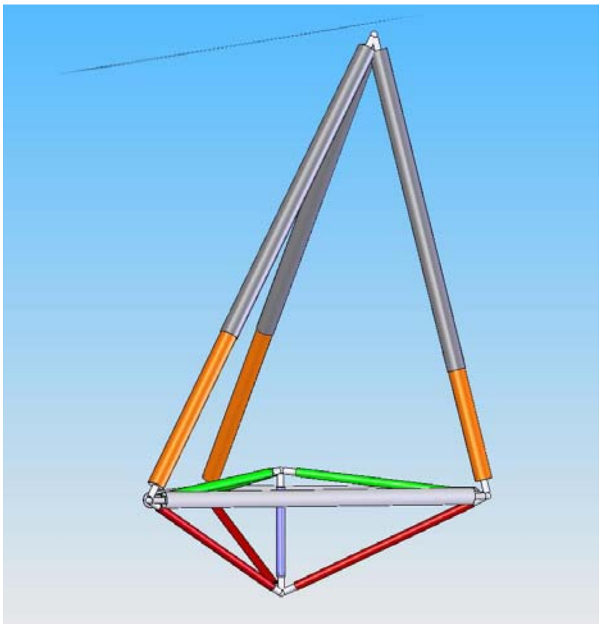

Figure 2. A different beam length makes the center of the mass and the rotation axis overlap without adding extra weight

Conversely the experiment , not accepted for that flight, will be included in another combination of users and housed in a different platform . Once the full load is known, the frame, can be easily assembled by fitting the volume required for a given flight . The only constraint to be respected is the maximum lift capacity of the balloon. Figures 1 and 2 show possible solutions for the frame. Each beams undergoes only tensile and compression stress as in Fig.1 by avoiding any banding moment between beams, the frame becomes lighter while remaining always capable of respecting the safety criteria imposed. Moreover figure 2 shows how the gondola is able to balance itself without adding extra weight thanks to a different length of the main beams

4. THE PIVOT

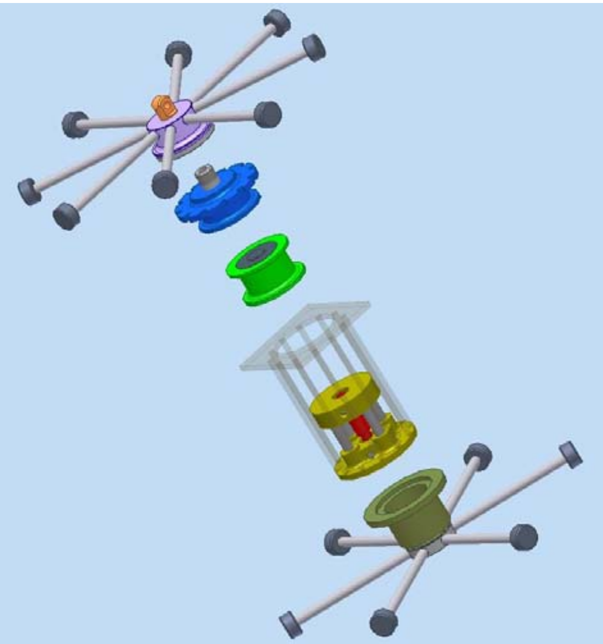

Figure 3. *The current features of the pivot , which are capable of suspending gondolas up to 2500kg of weight are sketched in an exploded view*

Both the pivot and the gondola structure comply with the NASA-NSBF safety factor of 10 G vertical, 5G 45 degrees: in particular the pivot can suspend up to 2500 kg of maximum payload weight (see figure 3)

Moreover the pivot, has been continuously updated in the last two decades [2] and at present possesses the following features:

- It complies with the Trapani base's safety criteria (STRAIN GAGE);
- It has a central hollow shaft that is able to host a 12 or 24 wire SLEEP RING;
- It houses Torque motor(s) with high torque sensitivity(1.4Nw.m/A); a Gear box module can be added when driving payloads with large inertia moment;
- It features different pointing strategies;
- It Can be mechanically overturned maintaining the same features during ground test.

5. THE ELECTRONIC PARTS

The electronic parts designed to drive primary necessities in a multi-user organization, include the Attitude Control System (ACS), the on-board CPU (OBC) and the Ground Support Equipment (GSE)

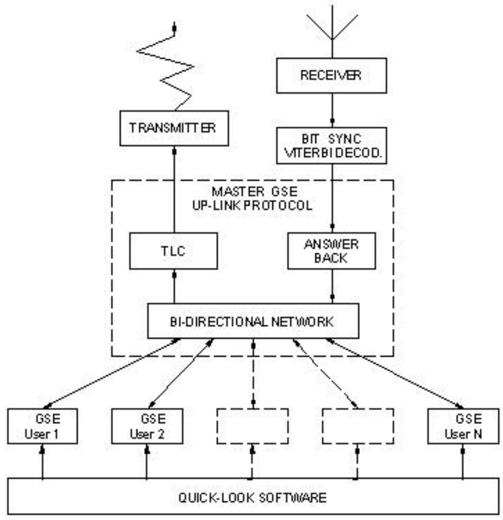

Figure 4. The features of the on board electronics (including the attitude control system) are shown

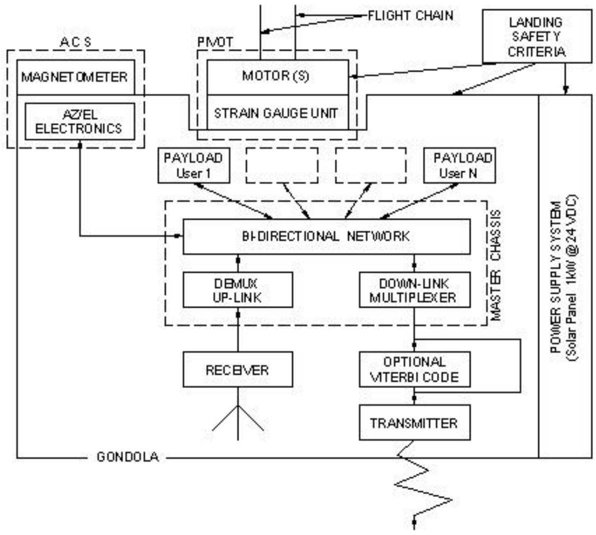

Figure.5 General organization of G.S.E.

The ACS works each time one or more experiments require (even in time sharing) to explore part of the horizon. The embedded electronic takes control of the motors in order to realize a given transfer function. By a CPU and I/O cards the project is capable of realizing

a full digital system that can easily control servo motors for any weight-inertia moment combination. The OBC is devoted to both receiving and transmitting the system's data (housekeeping and scientific). Inside the main up- down-link stream the master CPU collects and redistributes the sub data flow from and to the proprietary user. Figure 5. besides showing the schematics of the general organization also includes a magnetometer. This sensor must be considered a low-cost absolute heading sensor . In spite of its low accuracy (especially at high latitude) it leads the azimuthal movement of the platform during ground tests or when the payloads have to be oriented towards a given sky sector at float. Higher accuracy sensors are ready to join the magnetometer and, to supersede it, when higher accuracy is needed while scanning. The GSE electronics is depicted in figure 5 It counts a master console that takes charge of merging and splitting the up- and down- link flow from and to the different users.
In this way only one matrix will be transmitted and only one will be received. Moreover, the STRATOBUS project will supply each user the quick look code for locally viewing its own data stream .

6. THE STRATOBUS WEB SERVER

The WEB server is extremely useful and necessary in a multiuser organization and features an interface from the STRATOBUS consortium to potential users. A potential user can have access to the STATOBUS organization in different ways, but the most important one is by means of a dedicated WEB server. Whoever applies for a stratospheric ride can browse freely on the network and can then fill in a form with experiment structural data . Once all the information gathered from the web has been collected, the STRATOBUS consortium will identify those experiments that are mutually compatible and that are capable of making the best combination for a given gondola. It then returns , to each user within a limited time, the authorization for access to the flight and the cost of the ride , which in this case is closely connected to the volume , weight ,and bit rate required .
The WEB was been designed and dedicated to :
-Showing in real time the room available on a given flight for a given campaign
-Verifying the compatibility of the experiment requirements with those already accepted in order to proceed to completing the payload.
- Providing an answer within the space of a few days as regards acceptance on board of the new user and indicating the cost of the stratospheric ride and the date of the window of launch
-Awaiting the final acceptance of the user and, in the case of a positive answer, indicating the "payment" condition .

7. REUSING OF POWER SOURCE

One of the most important features for reducing the general cost of a generic campaign is reusing a of the power source. The factors capable of affecting the overall cost for the Solar Panel (SP) mainly involve man-power, the assembling frame and the cost of the total amount of the cells. In the past, many experiments (Boomerang, for example, during Antarctica LDB flights 1998 and 2002) had SP arranged in a fixed position even thought tilted by an angle of about 80 degrees from the horizontal plane. During the landing the SP suffered extensive and costly damage. The scientific community is now moving toward the design of mechanical structures suitable for protecting the SP on landing as in [3]. There are different approaches but the goal is the same : to guarantee that the SP survive at the end of the mission and to be able to reuse them for several future launches without added cost. This is certainly the key to a considerable decrease in the general costs of campaigns. [4]. The panel can be deployed or not at take off but must be stowed before the end of the mission. This solution is motorized in order to deploy/stow the SP and could also track the sun, at the expense of higher complexity, by means of another dedicated servo. Other solutions, for deploying/stowing the SP, are at present under development. The differences between them are in how many degrees of freedom the deployed SP should have. Other solution could also be implemented taking in consideration the 20 m. flight chain however any mechanical solution must consider a robust safety box for stowing SP. The cost of the silicon cells justifies a higher mechanical complexities

7.1. Fuel cell

Should there be an experiment that , for scientific reasons, needs to make a launching during long winter nights at a high latitude or simply for only one night at mid latitude, the on-board energy system would necessarily have to consist of lithium batteries (for a one-day mission) or of more efficient and reusable fuel cells. For LDB flights, the DMFC or H2FC are the best devices for producing electrical energy at relatively low temperatures (80-120 degrees). For this reason, it is now extremely important to investigate how to make the FC work in a very cold environment. This investigation will have to be carried out by means of a thermal analysis of the most critical parts, such as the stack and the pressurized tanks of H_2 and O_2 , as well as those of MeOH and O_2 [4] [5].

Another goal of the STRATOBUS project as to analyze, by means of CAD, FEM and Multi-Body simulation, whether the working temperature remains within the correct range despite the hostile environment. The analysis made was at simulation level but it was accurate enough to indicate the real possibility of its being employed as in figure 6.

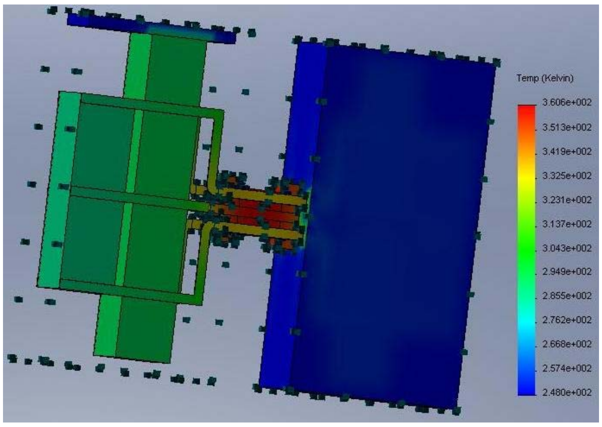

Figure 6. Thermal analysis of an example of pure hydrogen FC assembly (without taking into account the valve system, reactant flux control and by product. Both stack and tanks are in the correct operating range.

The simulation result displays a stack working temperature of 89 °C at steady state while the insulated 160-litre tanks, containing hydrogen pressurized at 200BAR, achieves about 43°C if protected by 60 mm of a styrodur-c sheet (polistyrene) [4]. Generally speaking the FCs have an efficiency of 50% which means that for 1 kw of thermal flux has to be dissipated for 1Kw of electric power generated . The main goal is to let the, heat produced by the stack, be transferred to the tanks, by means of conduction and then to check whether the thermal equilibrium, at the steady state, respects the temperature range of the FC system's component. The boundary conditions were established by considering what happens at a stratospheric level: the convection factor is extremely low and the heat transfer is mainly achieved by radiation. We realized the simulation thank to Solidworks and Cormoswork programs by introducing parameters such as 248K as room temperature , an emissivity factor of 0.96 and a visibility factor of 1. Such a high emissivity factor can be achieved only by using surface coating. There are currently some problems related to the employment of the FC in a stratospheric payload such as the current technology of the 700Bar tanks , which is still a prototype project. For this reason the thermal analysis was made by hypothesizing only off-the-shelf pressure devices . Obviously the cylinder weight is still a constraining factor on greater power autonomy, but it is desirable that the technology developments rapidly overcome the present limit. The power target is around 100kwh per 12 day mission.

8. *CONCLUSION*

The STRATOBUS Project has indicated a way in which to decrease the overall costs for a Balloon campaign. Every effort should be addressed to making research by balloons competitive with other means. The scientific world needs funds and regular scheduled flights. For this end , the project has already identified the milestones for creating a standard. Standard means optimization of the hardware , safety structures for landing and a cost-effective organization of the campaigns. This organization should be ready to grow on demand in order to enable launches from the most important sites of the world. The latitude and the duration of the flights are unimportant Furthermore, the success of the idea is closely connected with both how the new concept will be popularized within the scientific world and how easy and/or cheaper the access to the payload will be. It should be noted that ,in the absence of a mandatory directive and during LDB campaigns when a given flight may rely on 15-day circular trajectories , it is possible to consider taking advantage of some pointing resources in time sharing in the case that more than one experiment requires scanning different sky targets at the same time.

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