ONERA

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Châtillon, 7 janvier 2002

N° DMPH/L – 005/02/SN

Dear Stephano,

During the November FPAG meeting held in ESA headquarter, I have been invited to present the status of the MICROSCOPE mission and I have been informed of some concerns related to the performance of the mission raised by Pr Anna Nobili in her letter of October 17, 2001.

In her letter, beside the recognized importance of the MICROSCOPE mission as a selected space mission for the test of the Equivalence Principle with exciting performance and reasonable schedule, she points out three characteristics of the mission : the radiometer effect on the test masses, the differential architecture of the instrument and the background of the space electrostatic accelerometer.

For the first point, she refers to a recent communication in Phys. Review. Informed of the draft, we have answered to Anna Nobili in March 2001. As a summary of our response, we point out that this effect was not new for us and already considered in the SuperCACTUS design for the ESA SOREL project in the seventies and in all the definition and evaluation of the instruments like ASTRE, STAR, SuperSTAR, STEP, LISA, GOCE and MICROSCOPE instruments. While the Einstein's expression of the radiometer effect is well considered in Anna Nobili's paper, wrong figures have been used to depict the instrument and the environment leading to wrong conclusions. In spite of our comments to the draft, it has been published with these wrong figures.
Recently in December, Pr. Nobili sends us a new manuscript reconsidering this perturbing effect and adding to the random effects the possibility of tone errors as we mentioned in our response in which we detailed the specifications for the instrument thermal stability expressed in PSD and also in sinus : temperature gradient less than 0.1 $K/Hz^{1/2}$ over the 0.1 meter maximum length of the mass or 0.3 mK sine @ EP test frequency and phase. See Touboul and Rodrigues Class. Quantum Grav. 18, 2487-2498 and Touboul et al. Acta Astronautica, under press, manuscript submitted in February 2001 after the IAF presentation in October 2000. Response to this paper is attached showing Pr. Nobilli error and pointing out that the design of the instrument and of its accommodation on board the satellite, performed by CNES's and ONERA's teams, is compatible with the expected 10^{-15} EP test accuracy.

The second item considered by Pr. Nobili concerns the instrument configuration. MICROSCOPE instrument takes advantage of the drag-free satellite environment. The full scale range of the electrostatic space accelerometers is optimized, through the selected configuration and then in orbit through the selection of setting voltages, to the very weak residual acceleration to be measured in orbit (here is one of the major reason to perform the test in orbit and not in the lab!). Then, the requirement for the ratio between the accelerometer range and the resolution is not so large (less than for the SuperSTAR instruments for the NASA GRACE mission or for the space gravity gradiometers of the ESA GOCE mission) and the difference of the two accelerometer outputs must only be performed with a rejection ratio of 10^{-4} (10 times less than for the GOCE instrument and much less than for the

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STEP one). The requirement is much more stringent for the ground experiment in normal gravity environment to be rejected by the factor 10^{-12} or 10^{-15} according to the EP accuracy objective. Thus, even if it is easily possible to design the differential accelerometer with a direct differential output, performing the difference of the acceleration, digitized measurements has been preferred because it allows all possibilities of on ground post-processing and verifications.

The last item is a nasty allusion to the observed behavior of the STAR accelerometer in orbit. This accelerometer has been launched on board the CHAMP satellite on July the 15th, 2000. Since the switch-on of the sensor, few days after launch, it provides continuously the six accelerations of the satellite exhibiting a resolution better than specified. The observed malfunctioning of the instrument concerns the stability of the bias of the third and less sensitive axis. This malfunction has been analyzed and is certainly due to the failure after qualification of one electrical components. This failure introduces around the levitated mass an electrical potential applied on one of the surrounding electrodes that is not fully controlled. Fortunately, because of the robustness of the instrument concept, the provided data can be corrected. The accelerometer measurements are considered very fruitful for the geodesic mission by the P.I. Chris Reigber (GFZ-Postdam) and by the data science team : measurements of the AOCS thrust, of the satellite structural behavior, of the fluctuations of the atmospheric density correlated to sun activity have been clearly performed. Furthermore, the GRACE team, permanently informed of the STAR accelerometer flight functioning has also analyzed the data and conclude positively for the SuperSTAR instruments : the pre-ship review of the GRACE mission has been done in December with two comities from JPL and from GSFC, and the two satellites are scheduled to be launched on March, the 5th 2002 from Plessek.

In conclusion, the MICROSCOPE instrument takes obviously advantage of the STAR and the SuperSTAR developments and in orbit operations. Its dedicated design, optimized for the test of the Equivalence Principle in space will be finely verified in microgravity conditions with the ZARM facility. Pre-tests have been already performed with a double capsule devoted to obtain further limitation of the residual accelerations. Efforts are presently paid in ONERA to define and produce the instrument Engineering Model, in OCA to pursue the mission analysis while CNES micro-satellite team is optimizing the instrument accommodation. The expected performance of the MICROSCOPE mission is certainly limited with respect to the more ambitious STEP mission but MICROSCOPE has been defined taking into account the constraints of the micro satellite accommodation and of the limited development schedule. ESA is providing one of the major element of the satellite, the electrical propulsion. The MICROSCOPE mission will then open the way for the LISA and the STEP mission.

Be sure that all the MICROSCOPE team in ONERA and OCA will give his best for the success of the mission and to consolidate the scientific return of this public money investment.

Sincerely Yours,

With my best whishes for the new year,

Director
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Pierre Touboul
MICROSCOPE PI

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