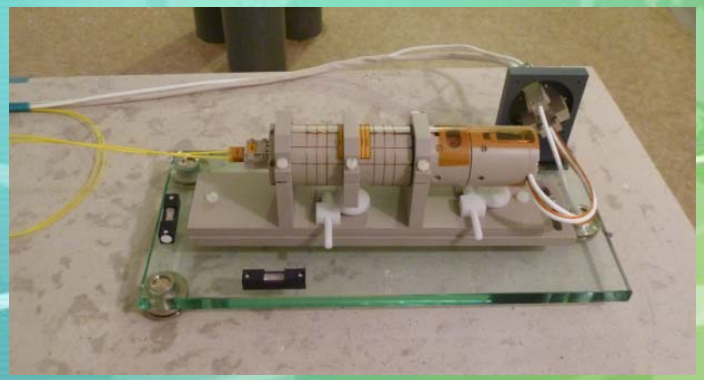
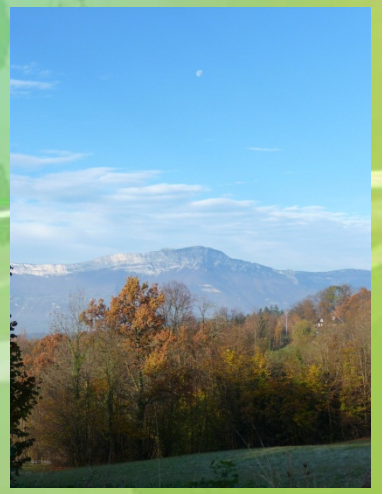




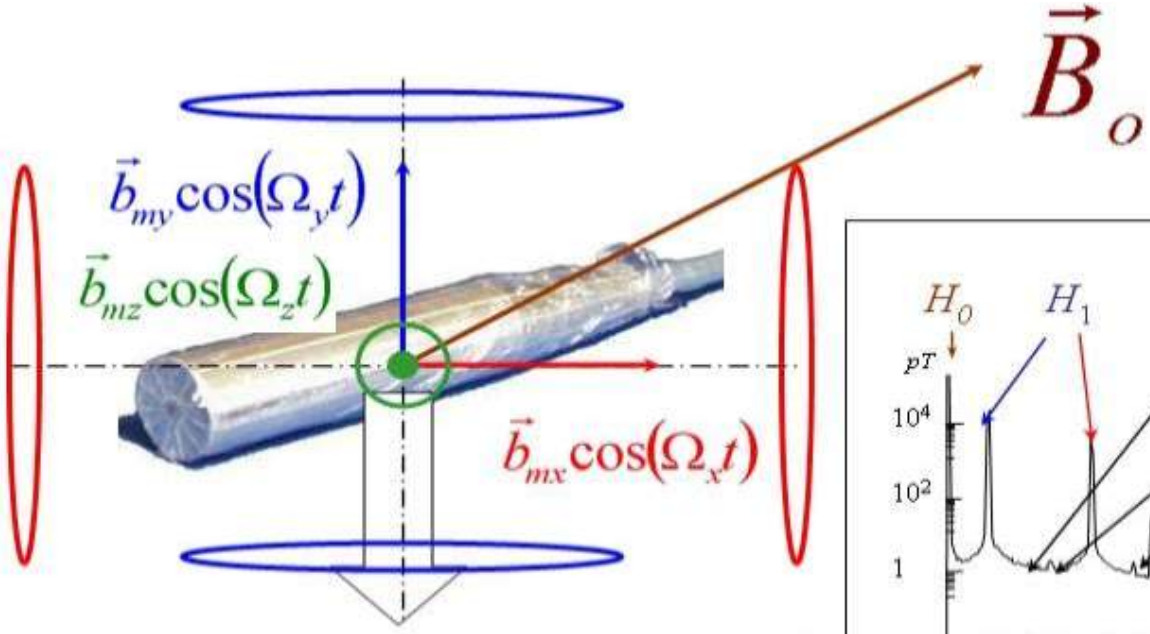
An absolute vector magnetometer dedicated to ground observatories

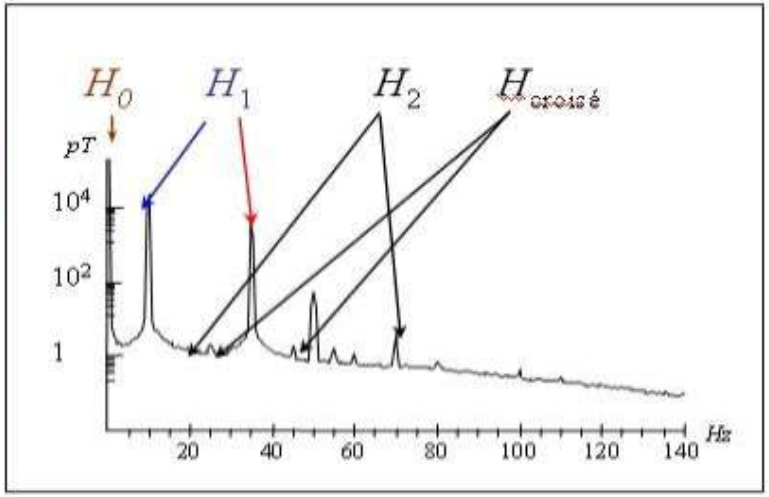
J-M. Léger, F. Bertrand, T. Jager *CEA-LETI, MINATEC*
I.Fratter *CNES*
A.Chulliat, X.Lalanne, K.Telali *IPGP*

Swarm absolute CW vector magnetometer (ASM-V)

Based on an ^{4}He atomic resonance SCALAR magnetometer

superposition of 3 AC modulations along 3 orthogonal directions





$$s = \left\| \vec{B}_{tot} \right\| = \left\| \vec{B}_o + \sum_{i=x,y,z} \vec{b}_{mi} \cos(\Omega_i t) \right\|$$

Real time analysis of the scalar output

For more details , cf poster 742 IAGA session J1 "The Swarm Absolute Scalar Magnetometer"

Main specificities of the ASM-V architecture

- No offsets ⇒ only six unknown parameters to be determined (3 transfer functions and 3 angles -deviations from orthogonality-) as compared to the 9 -at least- parameters of the best standard vector instruments

- Synchronous scalar and vector continuous measurements, performed at the same point
  - Auto-scaling capabilities and permanent measurement quality assessment
  - Perfect time synchronization (and exactly the same filtering)
  - Simplified EMC (but high constraints on Low Frequency -f < 50 Hz typically- ambient noise)

- Vector precision is proportional to $(B_0/bm)^* R_{scal}$, i.e better @ low fields (constant angular resolution) and high modulation amplitudes (as long as non linear effects are avoided)

Ground magnetic observatories specifities

- Fixed operation ⇨ instrument installation can be accordingly optimized to achieve the best performances

- To enhance the vector resolution of these magnetometers implies to amplify the modulation amplitude

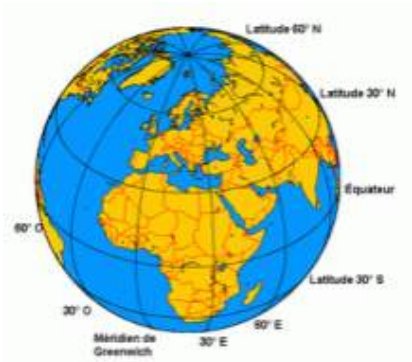
- In order to respect the maximum scalar modulation depth (related to the resonance linewidth), one can apply vector modulations only along two directions almost perpendicular to the magnetic field

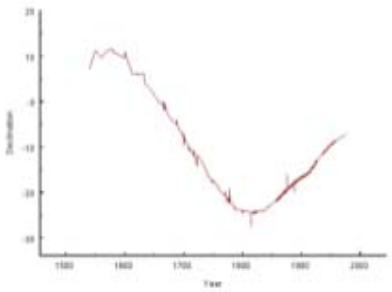
- This also directly relaxes constraints on transfer functions stability (the smaller the component along one direction, the lesser the constraints on the corresponding modulation amplitude accuracy)

Performance goals for ground measurements

- Derived from Intermagnet observatories specifications:
  - Sampling frequency: 0,2 to 1 Hz (bandwidth DC to 0,1 Hz)
  - Thermal stability: 0,25 nT/K
  - Long term stability < 5 nT/year
  - Dynamic range < 6 µT (auroral & equatorial zones)
  - Resolution: 0,1 nT
  - Accuracy: 1 nT

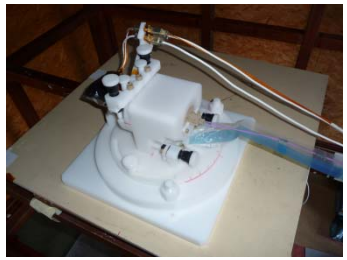
- Maintenance-free operation for one year achievable provided declination & inclination variation rates < 1°/yr (seems OK)





ASM-Obs characterization at Herbeys LETI premises

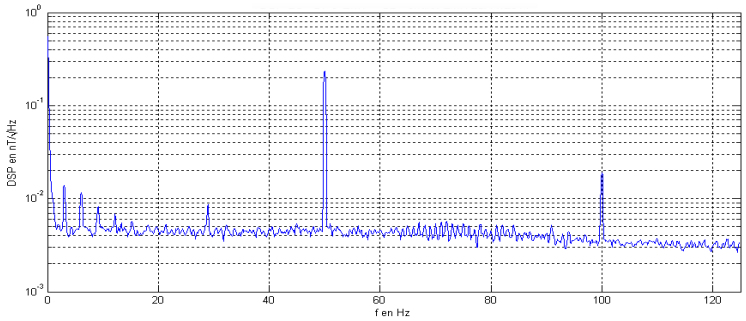
- Preliminary vector calibration of the ASM sensor without modulation amplification (x1) in 3D field simulator (#Swam's ASM-V



- Preliminary characterization of vector performances with increased vector modulations (x10-30-100) -noisy environment-

Vector modulations amplification	DSP Bx (nT/√Hz)	DSP By (nT/√Hz)	DSP Bz (nT/√Hz)
x1 (SWARM)	6.370	9.150	6.272
x10 (X off)		0.309	0.285
x30 (X off)		0.363	0.351
x100 (X off)		0.765	1.200

- Vector noise performance is limited by the intrinsic DPU EM2 resolution (# 4 pT/√Hz instead of 1 pT/√Hz for SWARM FMs)

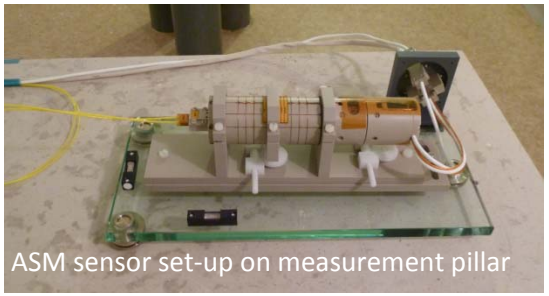


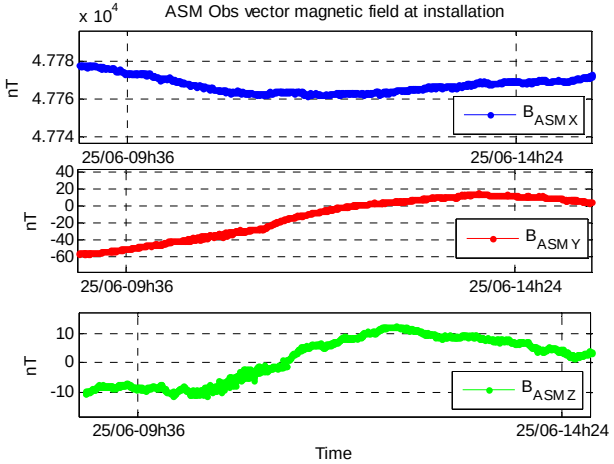
ASM-Obs installation at CLF IPGP premises

- ASM-Obs installation procedure
  - X axis set // B_{earth} and X vector modulation turned OFF
  - Y and Z vector modulation amplification x30

    (EMC issue at x100, resulting in extra noise)
  - Minimisation of Y&Z components through sensor orientation to guarantee the sensor linearity
  - Once properly set-up the field components along its Y & Z axes were respectively of about -60 nT and -10 nT

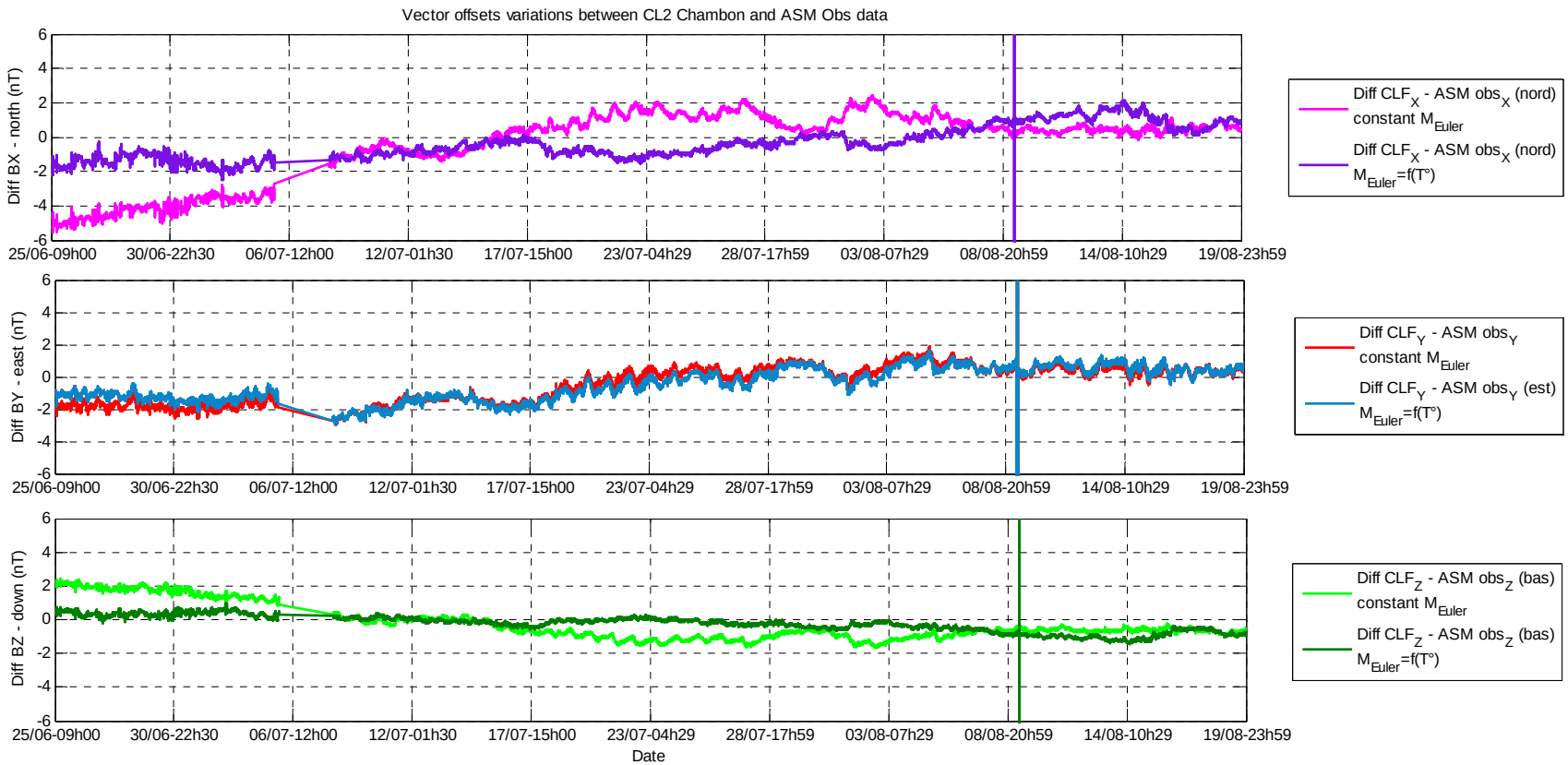
    ⇨ **modulation amplitude dependence on temperature can safely be neglected**


ASM sensor set-up on measurement pillar



Comparison of ASM-Obs & IPGP reference fluxgates

Data presented in NEC reference frame

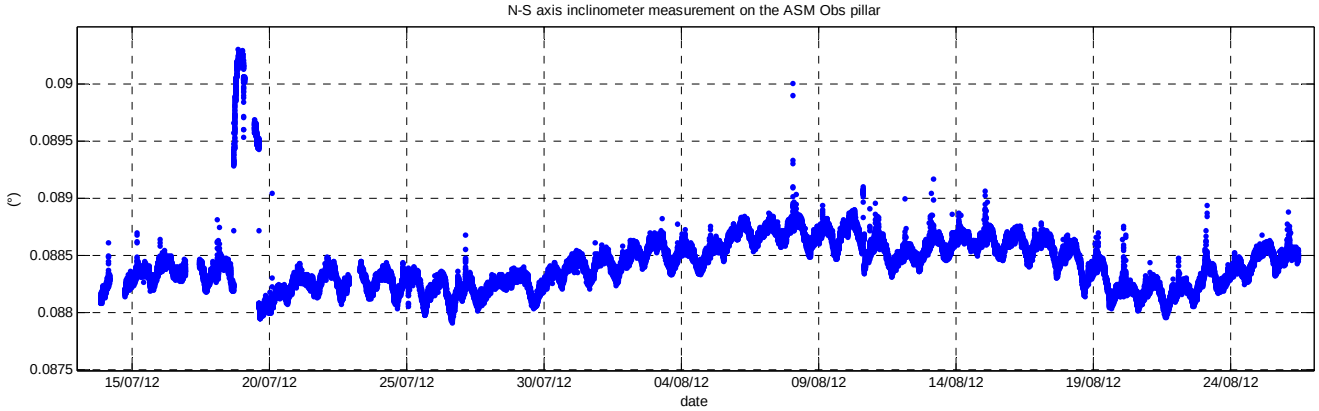


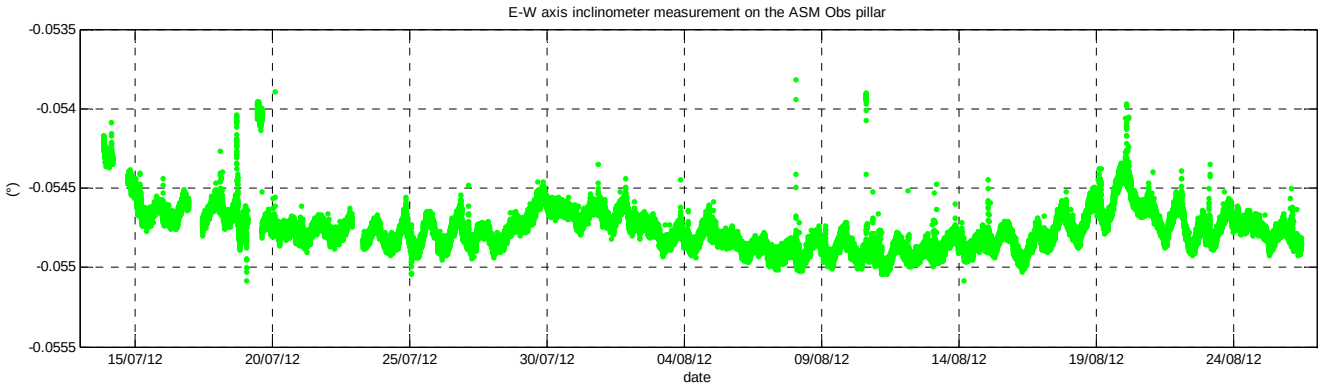
Components peak to peak variations: ± 2 nT (North) , smaller for the other directions, 16° C < T_{sensor} < 28 °C ; evolution observed mainly during the first weeks after the installation

NB: @ B_0 = 50 µT, a 10^{-3} ° sensor attitude variation can result in a change of up to about 0,9 nT for the perpendicular components measurement

Pillars stability verification

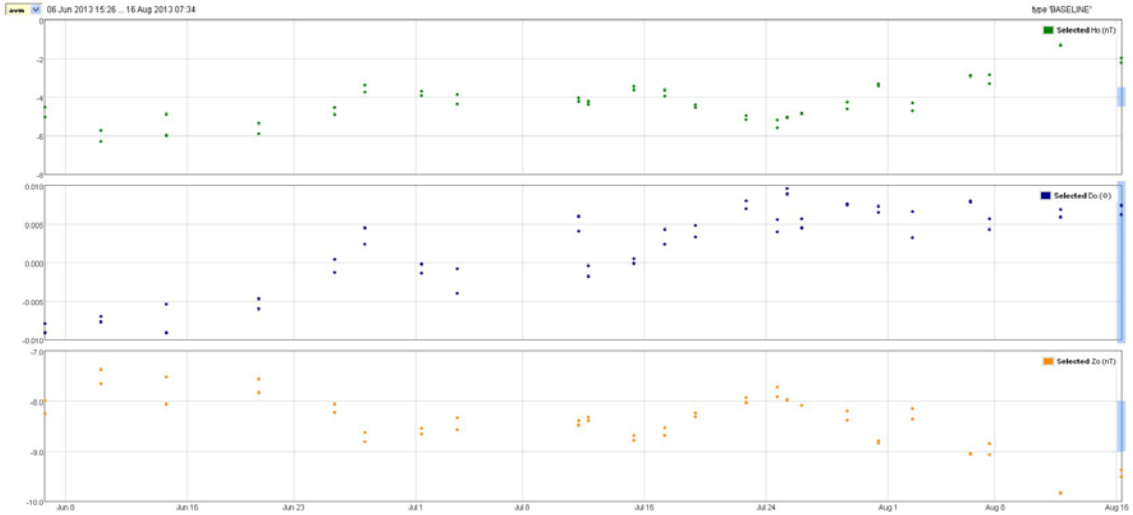
Installation of 2 inclinometers aligned in an horizontal plane respectively along the E-W and N-S directions

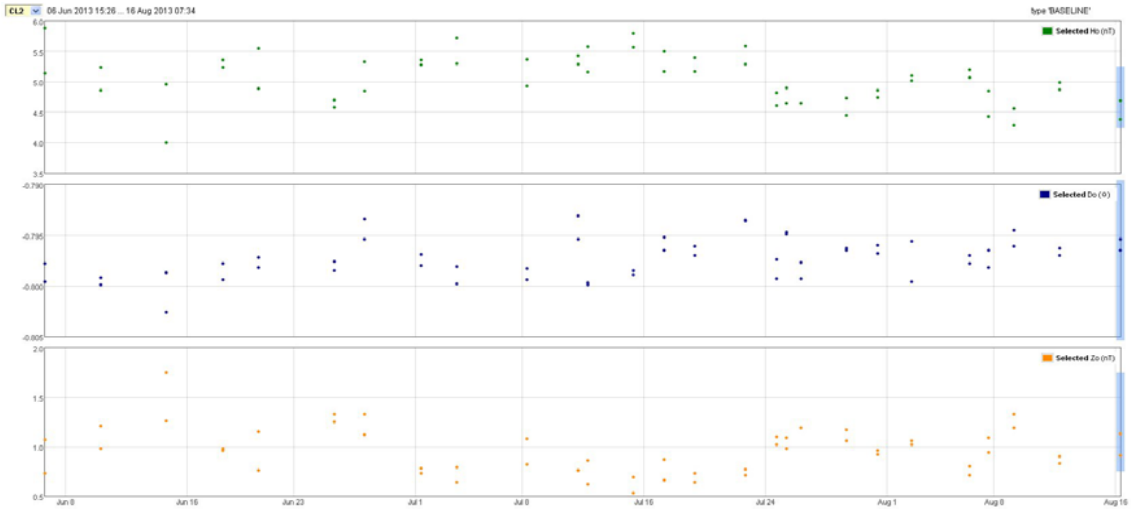




Peak to peak variations # 1 millidegree over a 6 weeks period… in 2012, <u>at constant temperature (25 +/- 0.5 °C)</u>

Comparison of ASM-V and CL2 fluxgate baselines





1st observation:
ASM-Obs exhibits performances Similar to those of a good observatory class fluxgate forH and Z, while a drift is observed on D (unexplained as yet)

Future prospects

- Extended duration of acquisition (2 months ⇨ at least 6 months)

- Detailed analysis of the potential error sources in the fluxgate measurement procedures (considered here as the reference to which the ASM-Obs is compared) and the differential comparison (ASM-Obs reference frame rotation)

- Differential measurements between 2 ASM-Obs after the Swarm launch (and replacement of the EM2 which has a lower resolution than the FMs) > much simpler direct comparison

- Replacement of the sensor's outer shell: use of a material with better thermoelastic properties (Swarm's Peek CTE: # 50 ppm/K)

More information @ http://swarm-mission.cnes.fr

Contact: jean-michel.leger@cea.fr

Leti

LABORATOIRE D'ÉLECTRONIQUE
ET DE TECHNOLOGIES
DE L'INFORMATION

CEA-Leti
MINATEC Campus, 17 rue des Martyrs
38054 GRENOBLE Cedex 9
Tel. +33 4 38 78 36 25

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Thanks for your attention

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