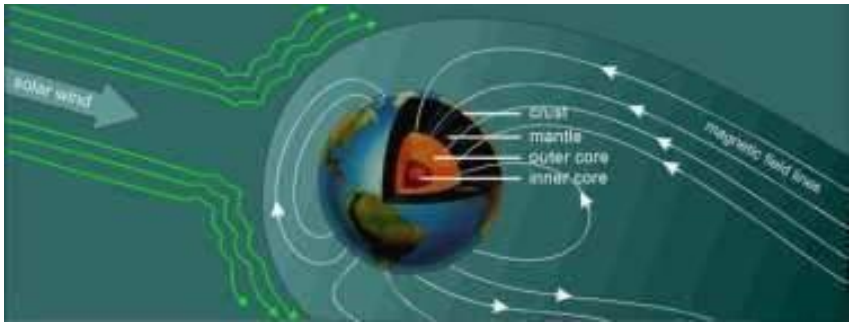
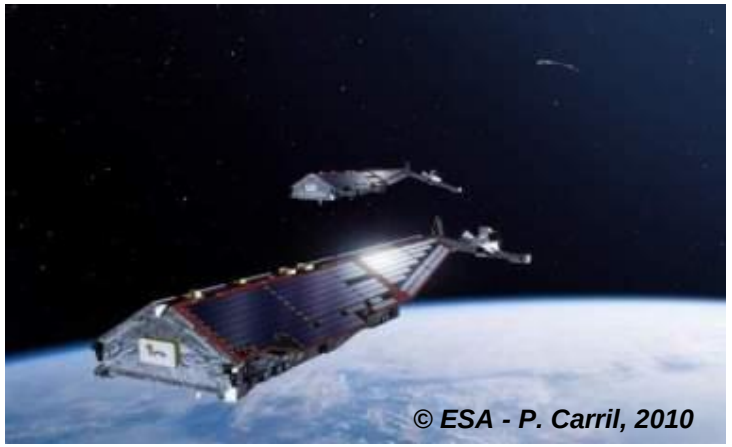
Swarm's Absolute Scalar Magnetometer performances

AGU Conference, San Francisco 12/12/07 J-M.Léger

The Swarm mission



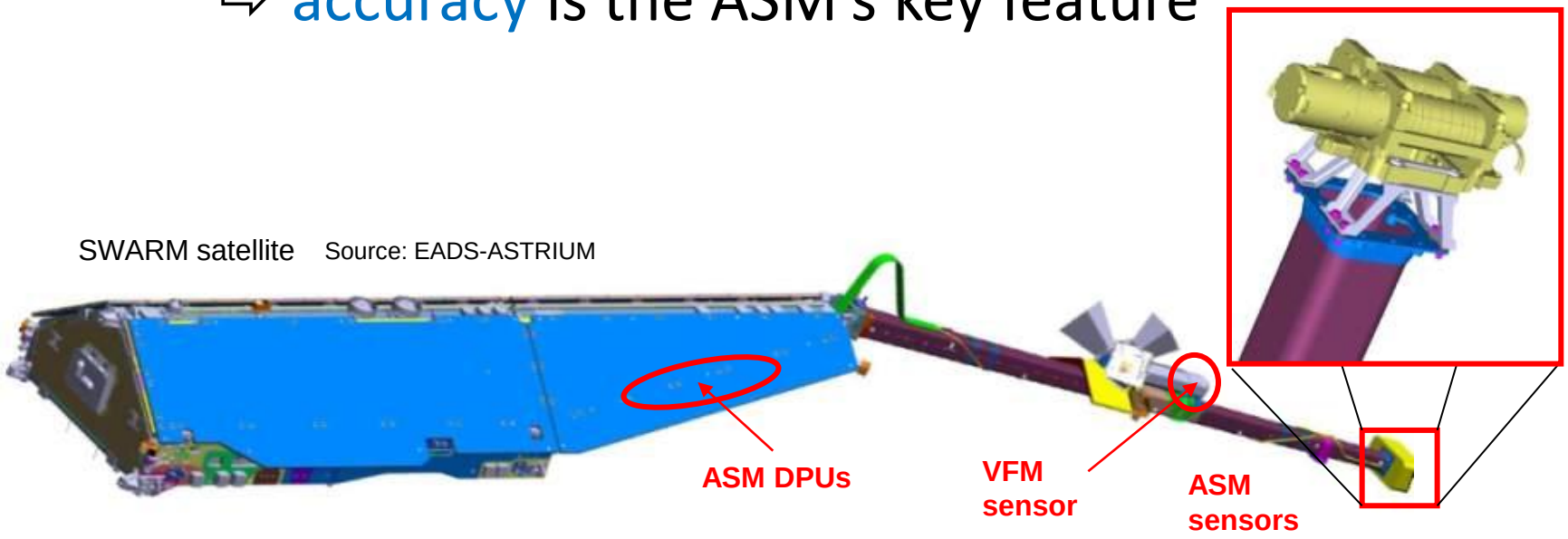


- Earth Explorer mission selected by ESA in 2004
- 3 identical satellites on different polar orbits (⇨ Earth's magnetic field sources separation), intended to deliver the best-ever survey of the geomagnetic field and its temporal evolution
- Launch currently scheduled during 2013 second trimester

Absolute Scalar Magnetometer's role

Calibration of the vector instrument and compensation of its long term drifts (mostly offsets & transfer functions)

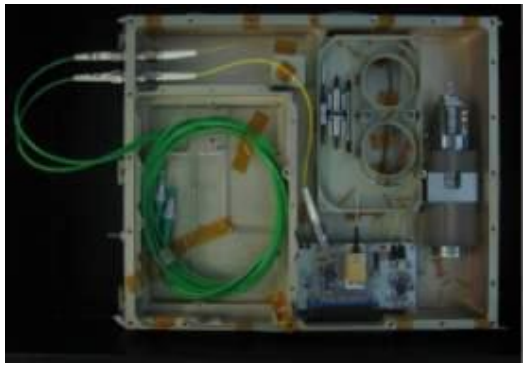
⇨ accuracy is the ASM's key feature



Swarm nominal magnetic payload:
VFM -fluxgates- & ASM -resonance scalar sensor-

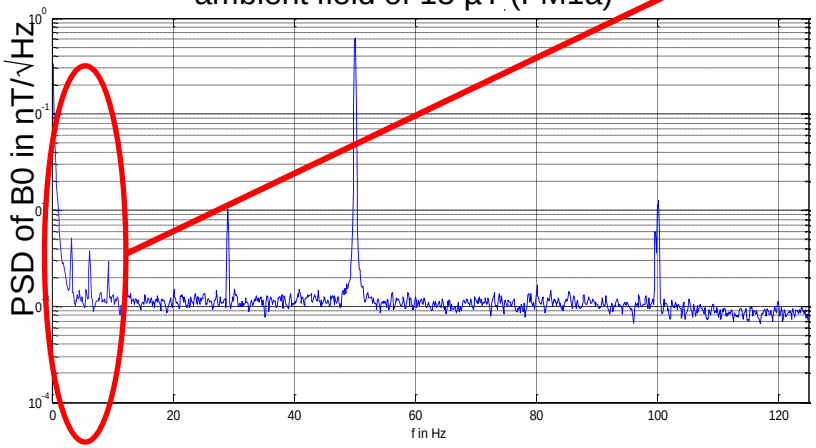
ASM specificities wrt Overhauser instruments
(Oersted/Champ scalar reference magnetometers)

- EMC issues are reduced (optical detection instead of signal pick-up coils)
- Sensor manufacturing is significantly simplified
- Sensor size can be easily reduced without impacting the instrument resolution (not exploited for Swarm -one challenge at a time!-)
- Several new components (athermal laser, piezoelectric motor, ASIC) ⇨ numerous additional qualifications required (carried out with CNES expertise and support) and increased complexity



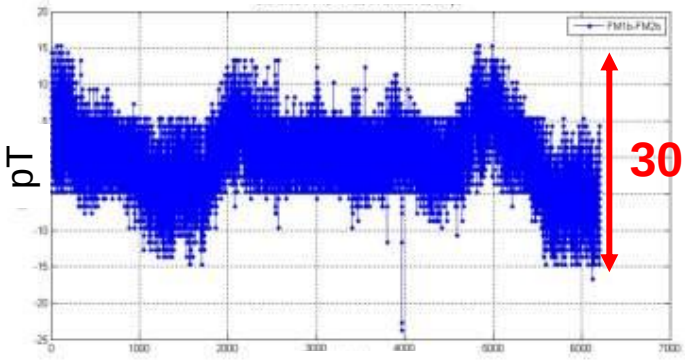
ASM performances: resolution

PSD of B0 in the [0-125 Hz] band,
ambient field of 15 µT (FM1a)

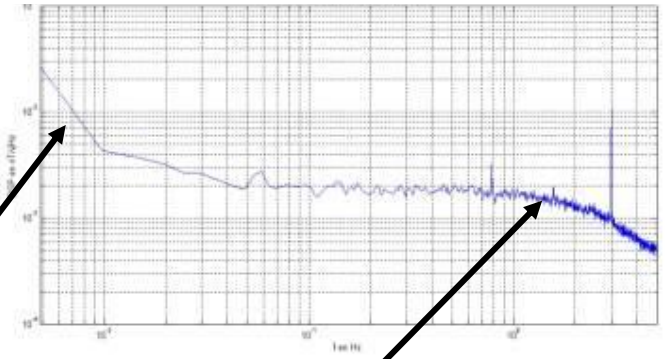


Zoom on ASM low frequency noise

FM1b-FM2b differential measurement



Combined noise of 2 FMs (PSD in nT/√Hz)



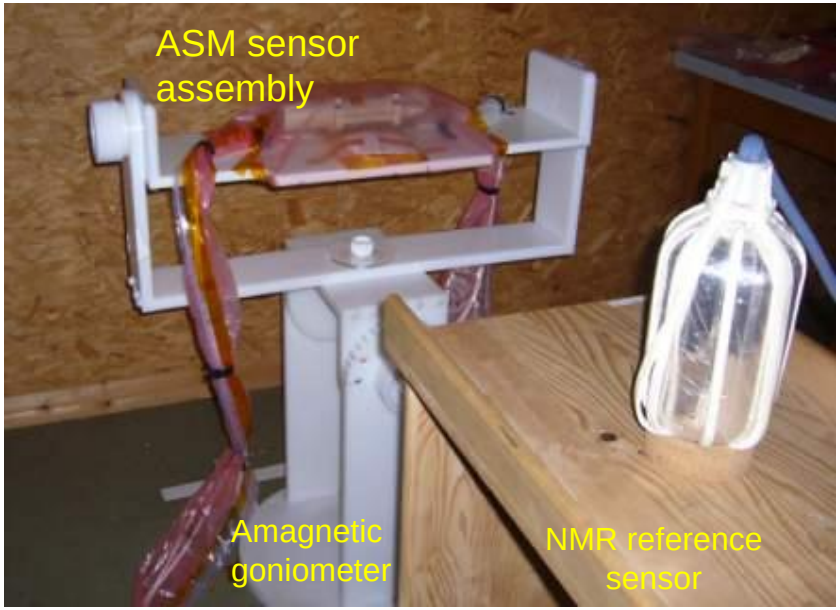
Residual magnetic gradient noise

Frequencymeter cut off
(- 9 dB @ 4 Hz)

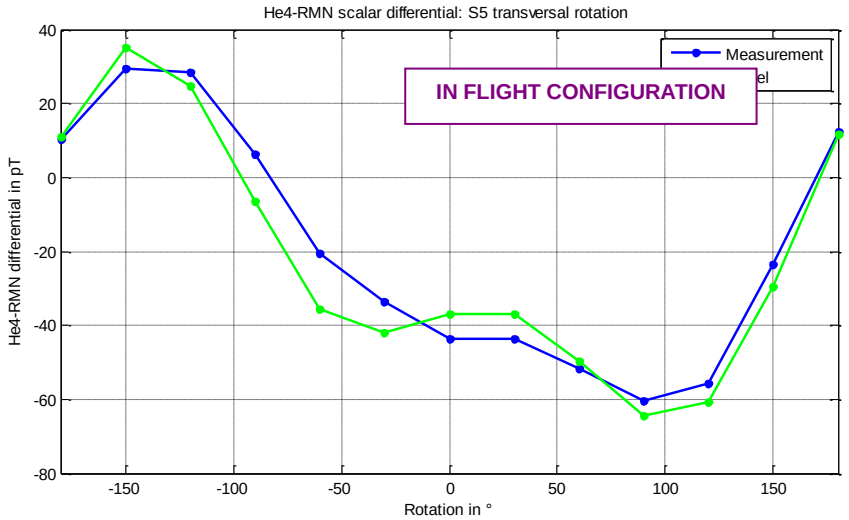
- **Resolution # 1 pT/√Hz, over the complete field range**
- **No 1/f noise**

ASM performances: accuracy (1/2)

Characterization of the residual sensor's remanent and induced effects thanks to differential scalar measurements with NMR reference sensors for several configurations



Typical differential measurement baseline stability < 20 pT



Residual error after correction < 25 pT_{pp}, $\sigma \cong 5$ pT

ASM performances: accuracy (2/2)

Definition of instrument level 1b corrections after extensive characterization of systematic errors (except for datation errors)

Error type	Bloch-Siegert error	Vector aliasing	ASM in-orbit anisotropy	PPS precision (system error) worst case : 5.10-7 x B0	ASM Datation (system error) worst case : 1 ms*30 nT/s	Quadratic norm of the residual errors σmax
Initial uncorrected ASM error	50 pT @ 46 µT	23 pT @ 46 µT	**≈ 100 pT**	32,5 pT @ 65 µT	30 pT	**122 pT**
Remaining error after ASM level 1B algorithm correction	< 5 pT	< 5 pT	< 5 pT	**32,5 pT** @ 65 µT uncorrected	**30 pT** uncorrected	**45 pT**

Stability demonstrated below 20 pT on a 15 days period

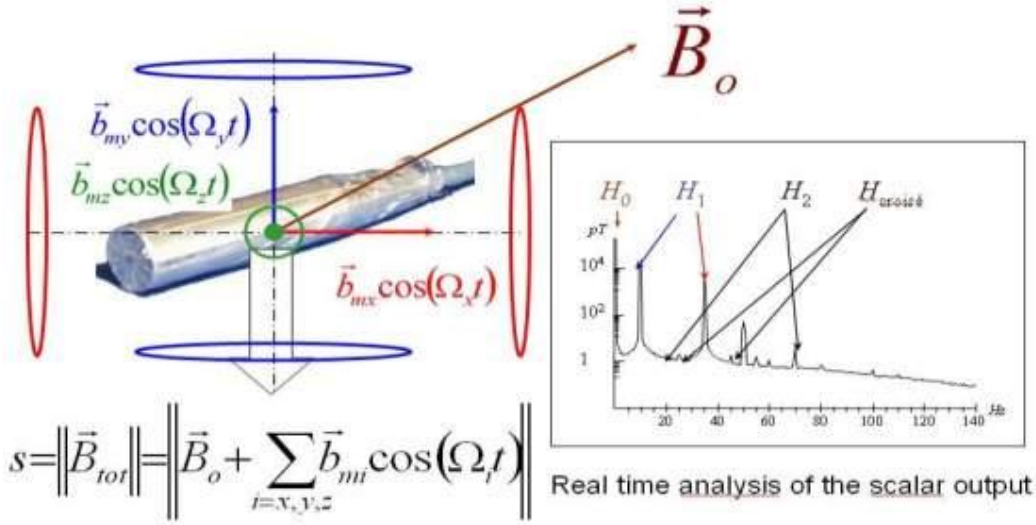
(Chambon-La-Forêt, IPGP, 2010)

ASM burst mode: towards higher frequency measurements

- Intrinsic bandwidth of the ASM is of the order of 500 Hz
- However, the nominal sampling rate of the ASM is set at 1 Hz (anti-aliasing filters limit the ASM bandwidth to # 0,4 Hz in this mode), so that the instrument's capabilities are not fully exploited
- A burst mode (Fs = 250 Hz) is implemented and will be operated for several orbits during low/medium/high magnetic activity periods during the commissioning phase

A new feature : the ASM vector mode

Superposition of 3 ac modulations along 3 orthogonal directions
(amplitude ~ 50 nT_p, $\mathcal{M}_t$ # 14 µA.m² & m_l # 8 µA.m² ⇨ < 1 pT_p @1,5 m)

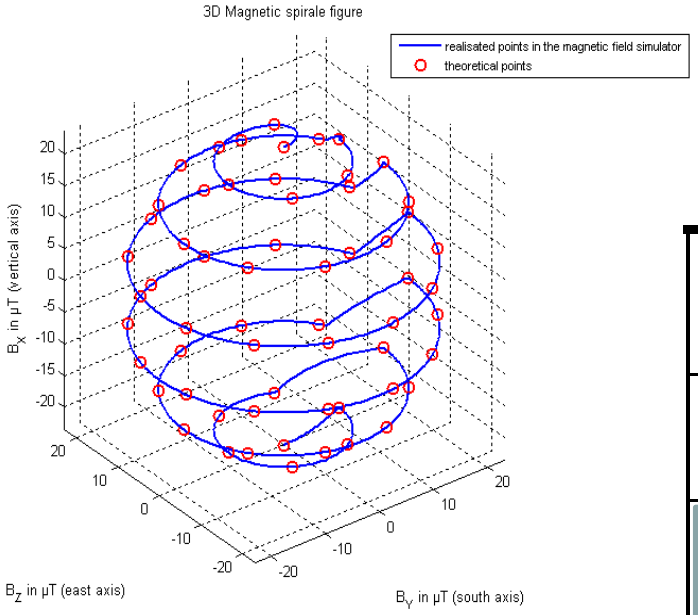


Real time analysis of the scalar output

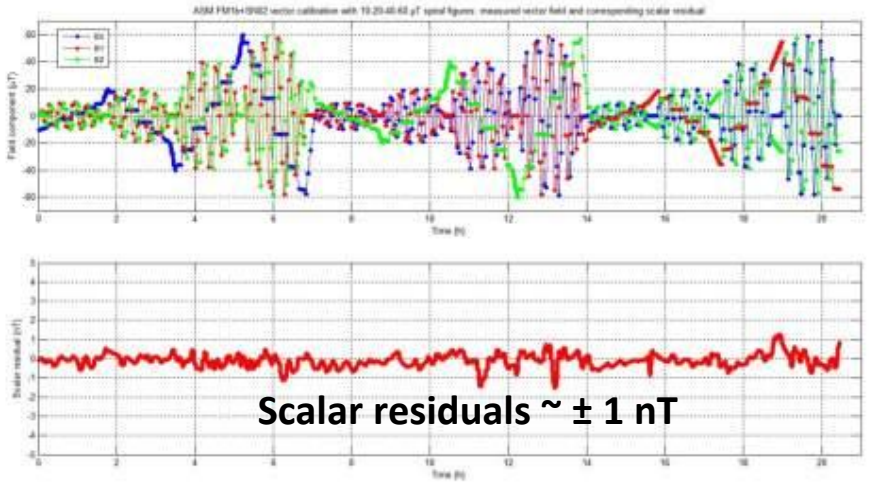
- **No offsets ⇒ only six unknown parameters to be determined**
  (3 transfer functions and 3 angles -deviations from orthogonality-)

- **Synchronous scalar and vector continuous measurements**
  - Auto-scaling capabilities and permanent measurement quality assessment
  - Perfect time synchronization (and exactly same filtering)
  - Simplified EMC (but high constraints on Low Frequency ambient noise)
- **Vector precision is proportional to B_0* R_{scal} , i.e better @ low fields** (constant angular resolution)

ASM-V preliminary performance assessment



Thins shell runs @ 10,20,40 & 60 µT along 3 revolution axes



Scalar residuals ~ ± 1 nT

The facility's characteristics prevent full vector performance assessment

Magnetic field amplitude (µT)	10	20	40	60
Vector resolution (nT/√Hz)	0,3	0,7	1,1	1,8
Scalar residual standard deviation (nT)	0,19	0,17	0,24	0,35

Conclusions

Courtesy of ESA / EADS

- Swarm satellites launch now scheduled for 2nd trimester 2013
- ASM will deliver high quality scalar data and vector measurements
- Burst data (250 Hz) can be collected if scientific interest is expressed (ionospheric studies)
- Opportunity to cross-calibrate two different vector magnetometers (VFM / ASM-V) in flight

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

www.leti.fr

Thanks for your attention

LLOYD'S REGISTER QUALITY ASSURANCE ISO9001

cea

MINATEC

INSTITUT CARNOT CEA LETI

SAVE THE DATE

leti innovation days

June 24-28, 2013 | Grenoble, France

www.leti.fr