#### Sensors for Wide band Magnetic field Measurement SWiMM

ICI4

#### LPP (Laboratoire de Physique des Plasmas) & L2E (Laboratoire d'Electronique et d'Electromagnétisme) & DT INSU



#### The team

	Institute	Function		
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### Summary

SWiMM overview
Triaxial search coil magnetometer
Search Coil Pre-amplifier
AMR magnetometers
Digital board
Electronic box
Telemetry status
Funding status

### SWIMM OVERVIEW



- Tri-axis search coil magnetometer few Hz up to 30kHz, based on Ohmic design.
- 5x tri-axis AMR magnetometer from DC to 80Hz, based on PHD student work (Kaveh).
  - Analog to digital electronic board close to ICI3 design.

## Search Coil Antenna



 Heritage: CLUSTER, THEMIS(flying), Bepicolombo & MMS (on going)

ICI4 search coil will be design to fit OHMIC performances



• ICI3

- 3 sensors: 140mm length, 15mm diameter and 450g.
- 80fT/sqrt(Hz) @ 1kHz, 8kHz bandwidth
- Boom length ~70cm.
- No issues.
- ICI4
  - 3 sensors: 180mm length, 14mm diameter and 350g (45° rotation?)
  - SWiMM Sensors should be mounted on a boom (>50cm)
  - 20fT/sqrt(Hz) @ 1kHz, 4fT/sqrt(Hz) @ 10kHz, 30kHz bandwidth
- Backup possible with MMS or Bepi sensors.

## Search Coil pre-amplifier





• ICI3

- 2 stages amplifier & feedback manager
- 4nV/sqrt(Hz) & 10fA/sqrt(Hz) @ 10Hz
- ASIC design in CMOS 0.35µm technology.
- No issues.
- ICI4
  - 2 stages amplifier, feedback manager, high pass filter & temperature compensated voltage regulator.
  - Lower LF noise.
  - Input Protections added.
  - Low power consumption <2mA per channel.
  - 30KHz bandwidth.
  - ASIC design in CMOS 0.35µm technology.
- Backup possible with ICI3 ASIC already processed.

## **AMR Sensor / ICI3**









- Good results:
  - Core magnetic gain ~350
  - 200pT/sqrt(Hz) @ 0.1Hz
  - Ultra low noise electronic 300pV/sqrt(Hz) @ 0.1Hz
  - 300mW
  - Sensor design partially validated
- Problems:
  - Due to some critical operations on the lasts building steps, the sensor did break few days before the last integration.
  - Backup solution outside of the Search Coil.
    - 20nT/sqrt(Hz) @ 1Hz

## **AMR Sensor / ICI4**





- Configuration of 5x3 axis sensors spaced by ~ 5cm, placed in the electronic box.
- Based on a commercial 3 axis sensor HMC1043 (Honeywell).
- Performances:
  - 20nT/sqrt(Hz) @ 1Hz
     30nT/sqrt(Hz) @ 0.1Hz
  - 0.08% non linearity @ full scale
  - 0.5% cross axis effect
  - 80Hz bandwidth
  - >250mW per 3 axis sensor

## **Digital Board**

Design and code based on ICI3 with some modules from Solar Orbiter's LFR instrument.



### **Electronic box**





• ICI3

- 170x107x44mm
- ~500g
- ICI4
  - 100x100x40mm
  - ~500g
  - Same location as ICI3

## **Telemetry Status**

#### Search Coil waveform:

3\*16\*17361.1sps = 833332.8 bps (same as ICI3)

Search Coil Spectrum:

3\*16\*256\*7 = 86016 bps (slots ADM\_SubCom\_2)

AMR sensors waveform:

16\*24\*180.84sps = 69444 bps (slots ADM\_SubCom\_1)

• Total telemetry budget identical to ICI3.

FrameSync. MSB         FrameSync. LSB         SP1         SP2         SFID_LSB (0-5)bit         HK opt word + 2 Status Bits         ADM_LF1_MSB         ADM_LF1_LSB           AC1_MSB         AC1_LSB         SP3         SP4         AC3_MSB         AC3_LSB         ADM_SUBCOM 1_MSB         ADM_LF2_LSB           ADM_SubCom 1_MSB         ADM_SubCom 2_NSB         SP5         SP6         ADM_SubCom 1_LSB         AC3_LSB         AC3_LSB         ADM_LF3_MSB         ADM_LF1_LSB           ADM_SubCom 2_MSB         ADM_SubCom 2_NSB         SP1         SP2         ADM_SubCom 2_LSB         ADM_LF1_MSB         ADM_LF1_LSB           AC1_MSB         AC1_LSB         AC1_LSB         SP3         SP4         AC3_MSB         AC3_LSB         ADM_LF2_MSB         ADM_LF1_LSB           AC1_MSB         AC1_LSB         SP3         SP4         AC3_MSB         AC3_LSB         ADM_LF3_MSB         ADM_LF3_LSB           ARR_HK_SubCom_LSB         SP5         SP6         SM_C1_MSB         SM_C1_LSB         ADM_LF3_MSB         ADM_LF3_LSB           AC1_MSB         AC1_LSB         SP3         SP4         AC3_MSB         AC3_LSB         ADM_LF3_MSB         ADM_LF3_LSB           DC1-2_MSB         DC1-2_LSB         SP5         SP6         SME         AC3_LSB         ADM_LF3_MSB<								
AC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF2_MSBADM_LF2_MSBADM_LF2_LSBADM_SubCom_1_MSBADM_SubCom_1_NSBADM_SubCom_1_LSBADM_SubCom_1_LSBADM_SubCom_1_dummyADM_LF3_MSBADM_LF1_LSBADM_SubCom_2_MSBAAT_LSBADM_SubCom_2_LSBADM_SubCom_2_LSBADM_SubCom_2_LSBADM_SubCom_2_LSBADM_LF1_MSBADM_LF1_MSBADM_LF2_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF2_MSBADM_LF2_LSBARR_HK_SubCom_MSBARR_HK_SubCom_LSBSP5SP6SM_Ch1_MSBAC3_LSBADM_LF3_MSBADM_LF1_LSBARC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF2_MSBADM_LF2_LSBARR_HK_SubCom_MSBARC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF3_MSBADM_LF1_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP5SP6SP6CADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP5SP6SP6AC3_MSBAC3_LSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP5SP6SP6CADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP5SP6SP6AC3_LSBAC3_LSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP5SP6SP6AC3_LSB <th>FrameSync_MSB</th> <th>FrameSync_LSB</th> <th>SP1</th> <th>SP2</th> <th>SFID_LSB [0-5]bit</th> <th>HK opt word + 2 Status Bits</th> <th>ADM_LF1_MSB</th> <th>ADM_LF1_LSB</th>	FrameSync_MSB	FrameSync_LSB	SP1	SP2	SFID_LSB [0-5]bit	HK opt word + 2 Status Bits	ADM_LF1_MSB	ADM_LF1_LSB
ADM_subCom_1_MSBADM_subCom_1_NSBSP5SP6ADM_subCom_1_LSBADM_subCom_1_dummyADM_LF3_MSBADM_LF3_LSBADM_subCom_2_MSBADM_SUBCom_2_NSBSP1SP2ADM_subCom_2_LSBADM_SubCom_2_dumyADM_LF1_MSBADM_LF1_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_MSBAC4_LSBADM_LF3_MSBADM_LF2_MSBADM_LF2_LSBARR_HK_SubCom_MSBARR_HK_SubCom_LSBSP5SP6SM_Ch1_MSBSM_CH1_LSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF3_MSBADM_LF3_LSBDC1-2_MSBDC1-2_LSBSP5SP6AC3_MSBAC4_LSBADM_LF3_MSBADM_LF3_LSBDC3_MSBDC3_LSBSP1SP2ADM_LF3_MSBADM_LF3_LSBADM_LF3_LSBAC1_MSBAC1_LSBSP1SP2ADM_LF3_MSBADM_LF3_LSBADM_LF3_LSBAC1_MSBAC1_LSBSP1SP2ADM_LF3_MSBADM_LF3_LSBADM_LF3_LSBAC1_MSBAC1_LSBSP1SP2ADM_LF3_MSBADM_LF3_LSBADM_LF3_LSBAC1_MSBAC1_LSBSP1SP2ADM_LF3_MSBADM_LF3_LSBADM_LF3_LSBAC1_MSBAC1_LSBSP1SP2ADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP1SP2ADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSB	AC1_MSB	AC1_LSB	SP3	SP4	AC3_MSB	AC3_LSB	ADM_LF2_MSB	ADM_LF2_LSB
ADM_subcom_2_MSBADM_subcom_2_NSBSP1SP2ADM_subcom_2_LSBADM_subcom_2_dummyADM_LF1_MSBADM_LF1_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF2_MSBADM_LF2_LSBARR_HK_subcom_LSBSP5SP6SM_Ch1_MSBSM_CH1_LSBADM_LF1_MSBADM_LF1_LSBAC1_MSBARC1_LSBSP1SP2ADM_LF1_MSBADM_LF2_MSBADM_LF2_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF3_MSBADM_LF1_LSBDC1-2_MSBDC1-2_LSBSP5SP6ADM_LF3_MSBADM_LF3_MSBADM_LF1_LSBDC12_MSBDC3_LSBSP1SP2ADM_LF3_MSBADM_LF3_MSBADM_LF1_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF2_MSBADM_LF3_LSBDC1-2_MSBDC3_LSBSP1SP2ADM_LF3_MSBADM_LF3_LSBDC3_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF2_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF2_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP5SP6ADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP5SP6ADM_LSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP5SP6ADM_LSBADM_LF3_MSBADM_LF3_LSB <t< td=""><td>ADM_SubCom_1_MSB</td><td>ADM_SubCom_1_NSB</td><td>SP5</td><td>SP6</td><td>ADM_SubCom_1_LSB</td><td>ADM_SubCom_1_dummy</td><td>ADM_LF3_MSB</td><td>ADM_LF3_LSB</td></t<>	ADM_SubCom_1_MSB	ADM_SubCom_1_NSB	SP5	SP6	ADM_SubCom_1_LSB	ADM_SubCom_1_dummy	ADM_LF3_MSB	ADM_LF3_LSB
AC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF2_MSBADM_LF2_MSBADM_LF2_LSBARR_HK_SubCom_MSBARR_HK_SubCom_LSBSP5SP6SM_ch1_MSBSM_cH1_LSBADM_LF3_MSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP1SP2ADM_LF3_MSBADM_LF3_MSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP5SP6ADM_LF3_MSBADM_LF3_MSBADM_LF3_LSBDC1-2_MSBDC1-2_LSBSP5SP6ADM_LF3_MSBADM_LF3_LSBDC3_MSBDC3_LSBSP1SP2ADM_LF3_MSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF2_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP3<	ADM_SubCom_2_MSB	ADM_SubCom_2_NSB	SP1	SP2	ADM_SubCom_2_LSB	ADM_SubCom_2_dummy	ADM_LF1_MSB	ADM_LF1_LSB
ARR_HK_SubCom_MSBARR_HK_SubCom_LSBSP5SP6SM_Ch1_MSBSM_CH1_LSBADM_LF3_MSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP1SP2	AC1_MSB	AC1_LSB	SP3	SP4	AC3_MSB	AC3_LSB	ADM_LF2_MSB	ADM_LF2_LSB
Image: constraint of the section of	ARR_HK_SubCom_MSB	ARR_HK_SubCom_LSB	SP5	SP6	SM_Ch1_MSB	SM_CH1_LSB	ADM_LF3_MSB	ADM_LF3_LSB
AC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF2_MSBADM_LF2_MSBADM_LF2_LSBDC1-2_MSBDC1-2_LSBSP5SP6ADM_LF3_MSBADM_LF3_MSBADM_LF3_LSBDC3_MSBDC3_LSBSP1SP2ADM_LF3_MSBADM_LF1_MSBADM_LF2_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF3_MSBADM_LF2_LSBAC1_MSBAC1_LSBSP5SP6ADM_LF3_MSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP1SP2AC3_MSBAC3_LSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP1SP2ADM_LF3_MSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP1SP2ADM_LF3_MSBADM_LF3_LSBADM_LF3_LSBAC1_MSBAC1_LSBSP1SP2ADM_LF3_MSBADM_LF3_LSBADM_LF3_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSB			SP1	SP2			ADM_LF1_MSB	ADM_LF1_LSB
DC1-2_MSBDC1-2_LSBSP5SP6ADM_LF3_MSBADM_LF3_LSBDC3_MSBDC3_LSBSP1SP2ADM_LF1_MSBADM_LF1_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF2_MSBADM_LF2_LSBAC1_MSBAC1_LSBSP5SP6ADM_LF3_MSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP1SP2ADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP5SP6ADM_LF3_MSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP1SP2ADM_LF3_MSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP1SP2ADM_LF3_MSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF3_MSBADM_LF3	AC1_MSB	AC1_LSB	SP3	SP4	AC3_MSB	AC3_LSB	ADM_LF2_MSB	ADM_LF2_LSB
DC3_MSBDC3_LSBSP1SP2ADM_LF1_MSBADM_LF1_MSBADM_LF1_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF2_MSBADM_LF2_LSBAC1_MSBSP5SP6ADM_LF3_MSBADM_LF3_MSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP1SP2ADM_LF3_MSBADM_LF1_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF2_MSBADM_LF2_LSBAC1_MSBAC1_LSBSP5SP6ADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP1SP2ADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF2_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF3_MSBADM_LF3_LSBAC1_MSBAC1_LSBSP5SP6Format c	DC1-2_MSB	DC1-2_LSB	SP5	SP6			ADM_LF3_MSB	ADM_LF3_LSB
AC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF2_MSBADM_LF2_LSBImage: Constraint of the system	DC3_MSB	DC3_LSB	SP1	SP2			ADM_LF1_MSB	ADM_LF1_LSB
Image: series of the series	AC1_MSB	AC1_LSB	SP3	SP4	AC3_MSB	AC3_LSB	ADM_LF2_MSB	ADM_LF2_LSB
Image: section of the section of th			SP5	SP6			ADM_LF3_MSB	ADM_LF3_LSB
AC1_MSBAC1_LSBSP3SP4AC3_MSBAC3_LSBADM_LF2_MSBADM_LF2_LSBImage: Constant of the system o	5		SP1	SP2			ADM_LF1_MSB	ADM_LF1_LSB
Image: style       Style       Style       Style       ADM_LF3_MSB       ADM_LF3_LSB         AC1_MSB       AC1_LSB       SP3       SP4       AC3_MSB       AC3_LSB       ADM_LF2_MSB       ADM_LF2_LSB         AC1_MSB       AC1_LSB       SP5       SP6       Format counter MSB       Format counter LSB       ADM_LF3_MSB       ADM_LF3_LSB	AC1_MSB	AC1_LSB	SP3	SP4	AC3_MSB	AC3_LSB	ADM_LF2_MSB	ADM_LF2_LSB
Image: Marcine series         SP1         SP2         ADM_LF1_MSB         ADM_LF1_MSB         ADM_LF1_LSB           AC1_MSB         AC1_LSB         SP3         SP4         AC3_MSB         AC3_LSB         ADM_LF2_MSB         ADM_LF2_LSB           Image: ADM_LSS         SP5         SP6         Format counter MSB         Format counter LSB         ADM_LF3_MSB         ADM_LF3_LSB	2		SP5	SP6			ADM_LF3_MSB	ADM_LF3_LSB
AC1_MSB         AC1_LSB         SP3         SP4         AC3_MSB         AC3_LSB         ADM_LF2_MSB         ADM_LF2_LSB           Optimized         SP5         SP6         Format counter MSB         Format counter LSB         ADM_LF3_MSB         ADM_LF3_LSB			SP1	SP2			ADM_LF1_MSB	ADM_LF1_LSB
SP5         SP6         Format counter MSB         Format counter LSB         ADM_LF3_MSB         ADM_LF3_LSB	AC1_MSB	AC1_LSB	SP3	SP4	AC3_MSB	AC3_LSB	ADM_LF2_MSB	ADM_LF2_LSB
			SP5	SP6	Format counter MSB	Format counter LSB	ADM_LF3_MSB	ADM_LF3_LSB

### **Funding status**

#### •Available:

# 25k€ for instrument design and manufacturing (including boom)

#### •Pending:

•42k€ for meetings and travels up to the launch (shared with 3D plasma analyzer team)

#### SWiMM magnetic noise objective



Noise Equivalent magnetic Induction objective:

1.8pT/sqrt(Hz) @ 10Hz

18fT/sqrt(Hz) @ 1kHz 4fT/sqrt(Hz) @ 10kHz