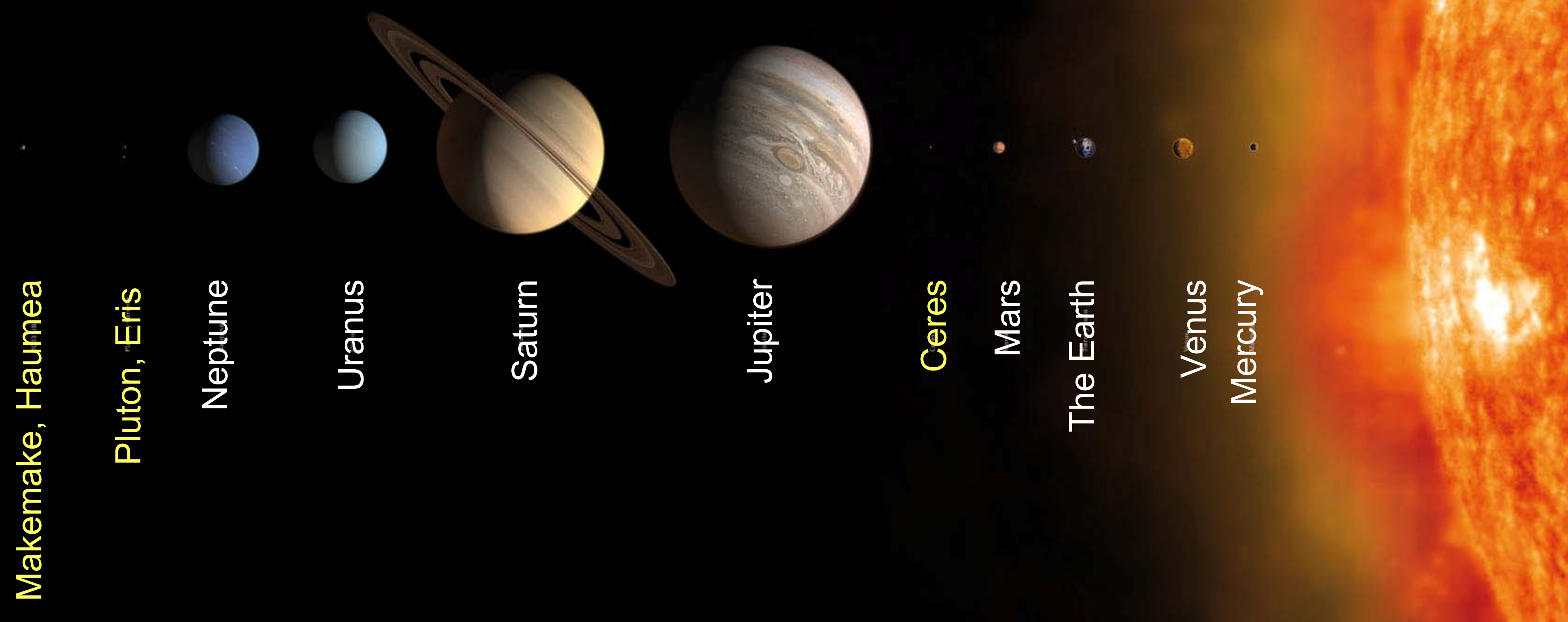
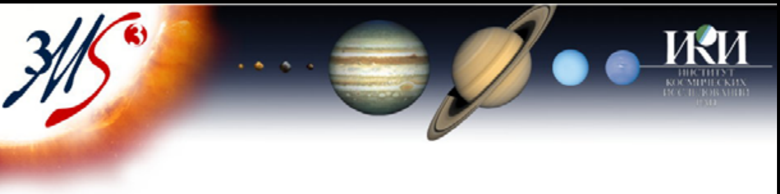
Compact magnetic sensors for magnetic mineralogy





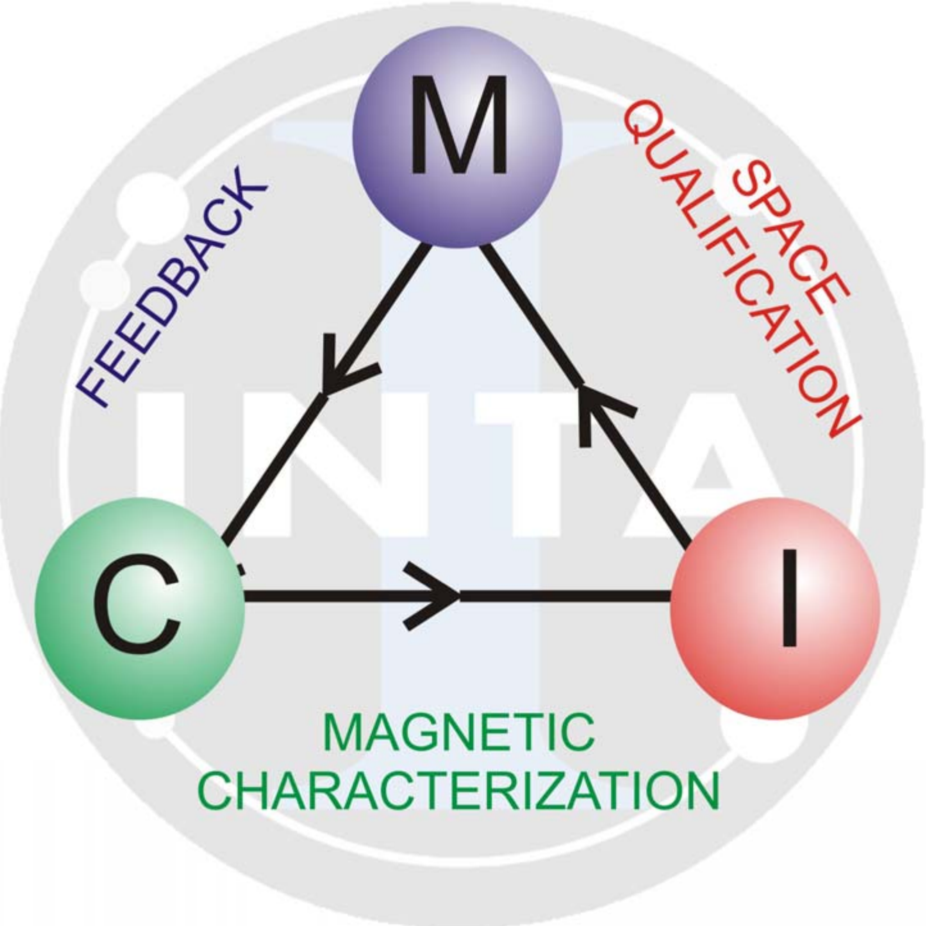
M. Díaz-Michelena - INTA
diazma@inta.es

CONTENTS

Who we are in the Spanish Magnetic Map?

High density of groups of Magnetism in a very small sample!

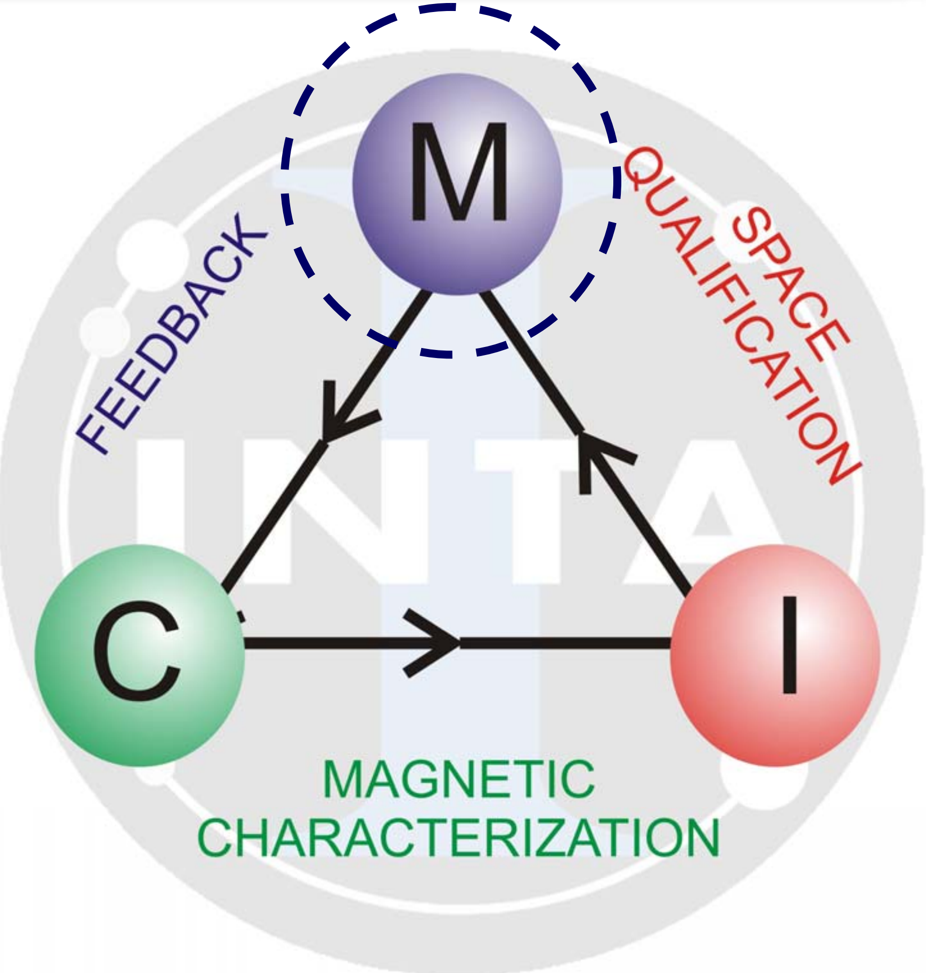
MAGNETIC COTS FOR SPACE
INTA STRATEGY



C: COMPONENTS
I: INSTRUMENTS
M: MISSIONS

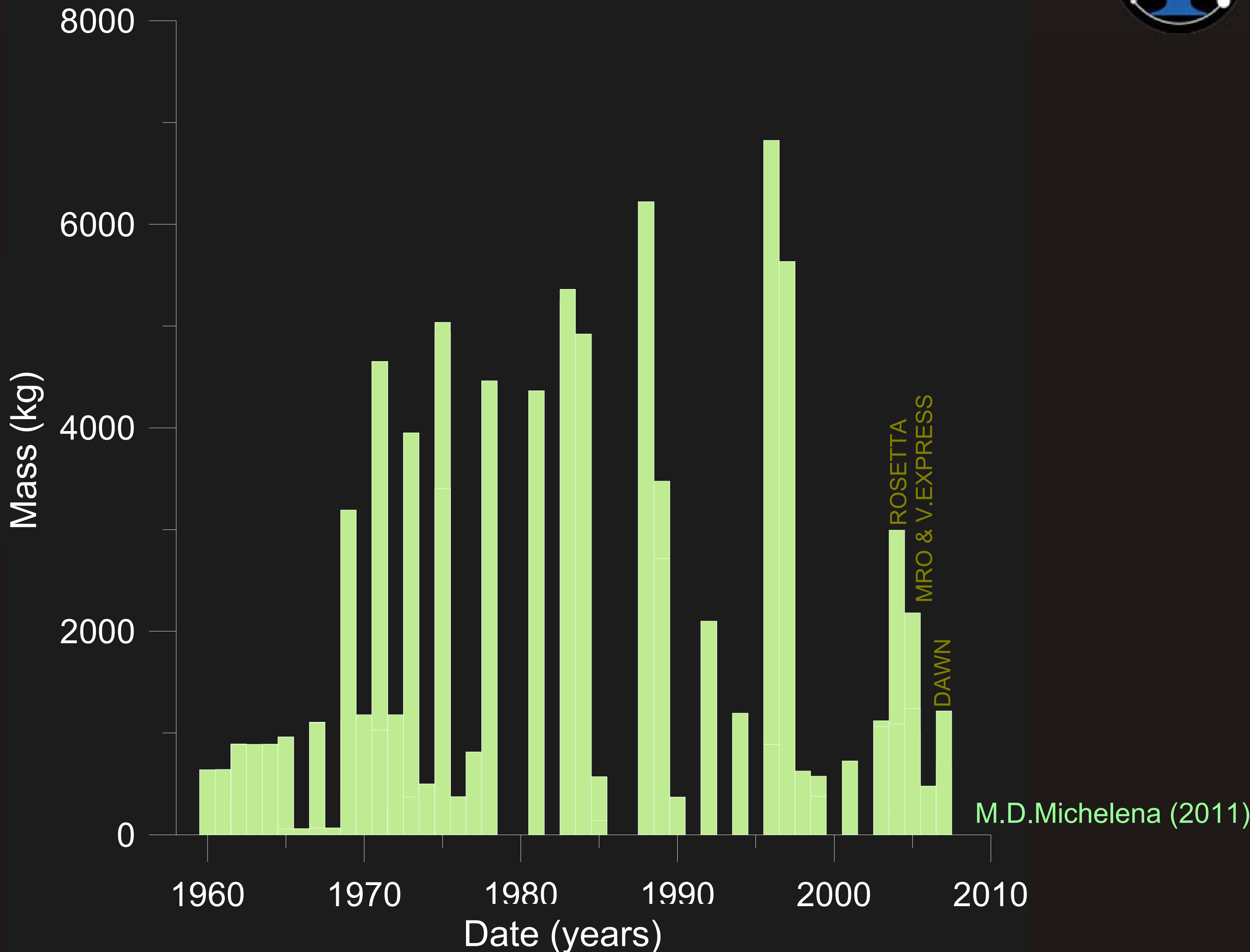
Why magnetic microsensors?

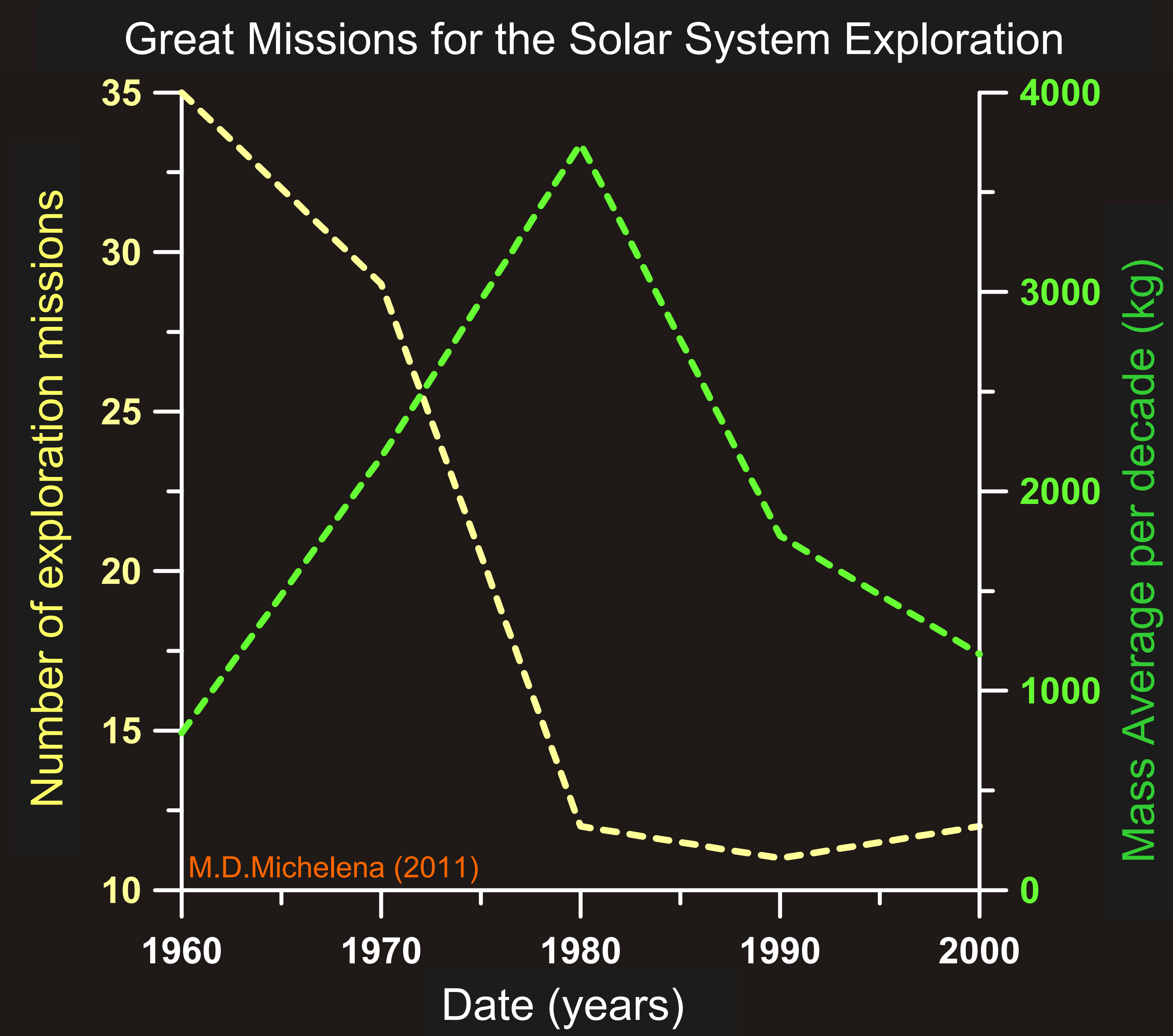
MAGNETIC COTS FOR SPACE
INTA STRATEGY



C: COMPONENTS
I: INSTRUMENTS
M: MISSIONS

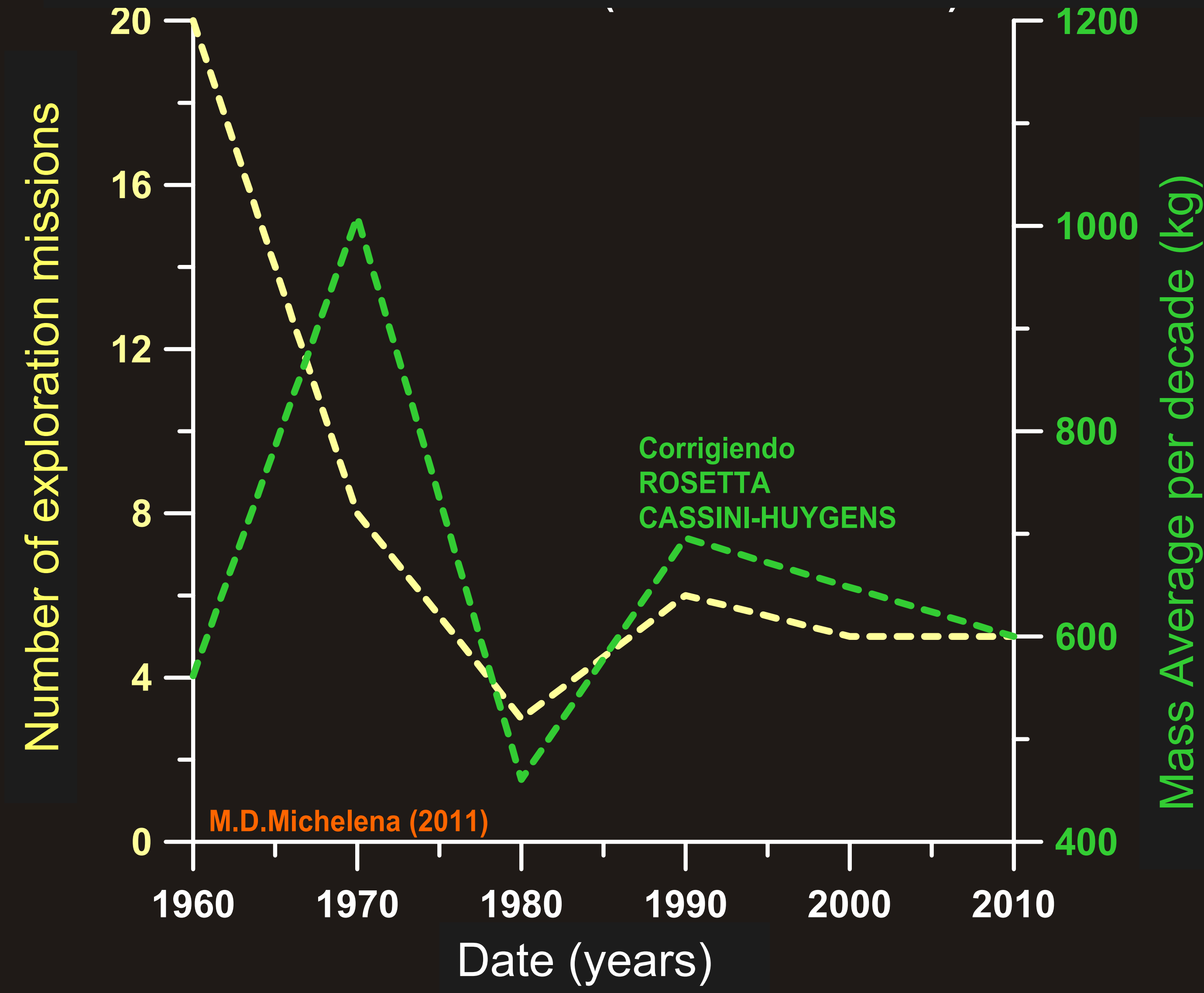
Great Missions for the Solar System Exploration





Great Missions for the Solar System Exploration
Number of exploration missions
35
30
25
20
15
10
4000
3000
2000
1000
0
Mass Average per decade (kg)
M.D.Michelena (2011)
1960
1970
1980
1990
2000
Date (years)
INTA

Great MAGNETIC Missions for the Solar System Exploration (Earth included)



A “new approach” to space

High integration level. Compact devices

Low Mass and Volume

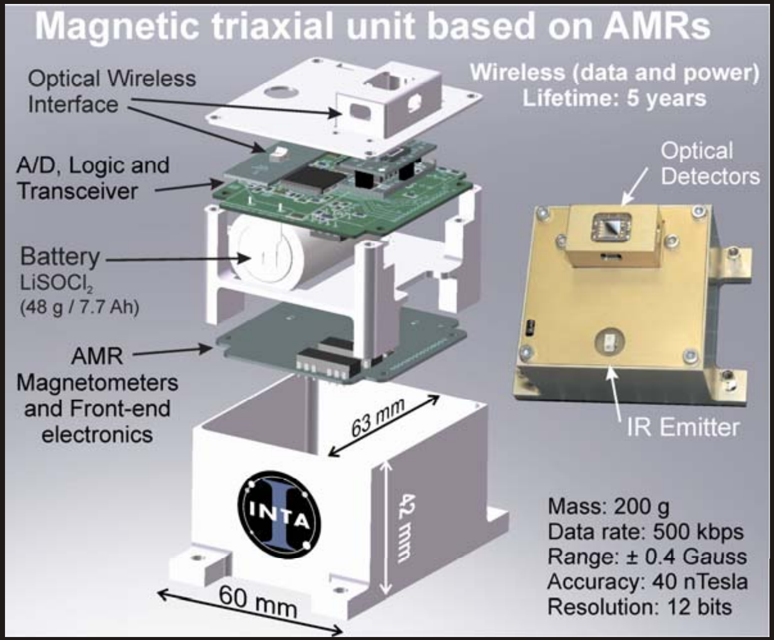
Low Power

High Functionality

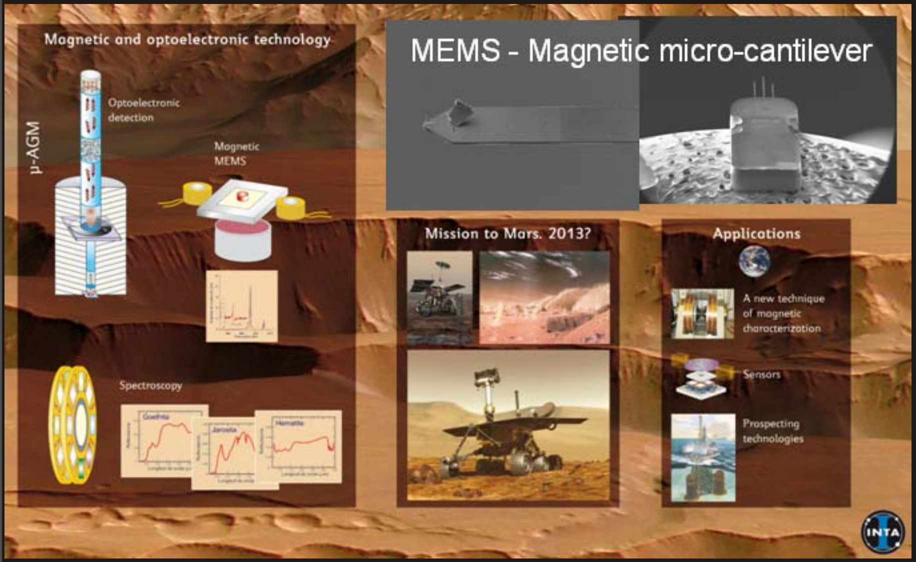
Fully autonomous devices

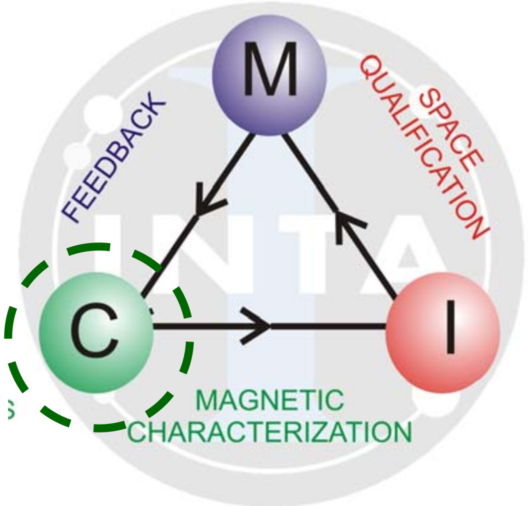
A “new approach” for Space Magnetometry

COTS and more…

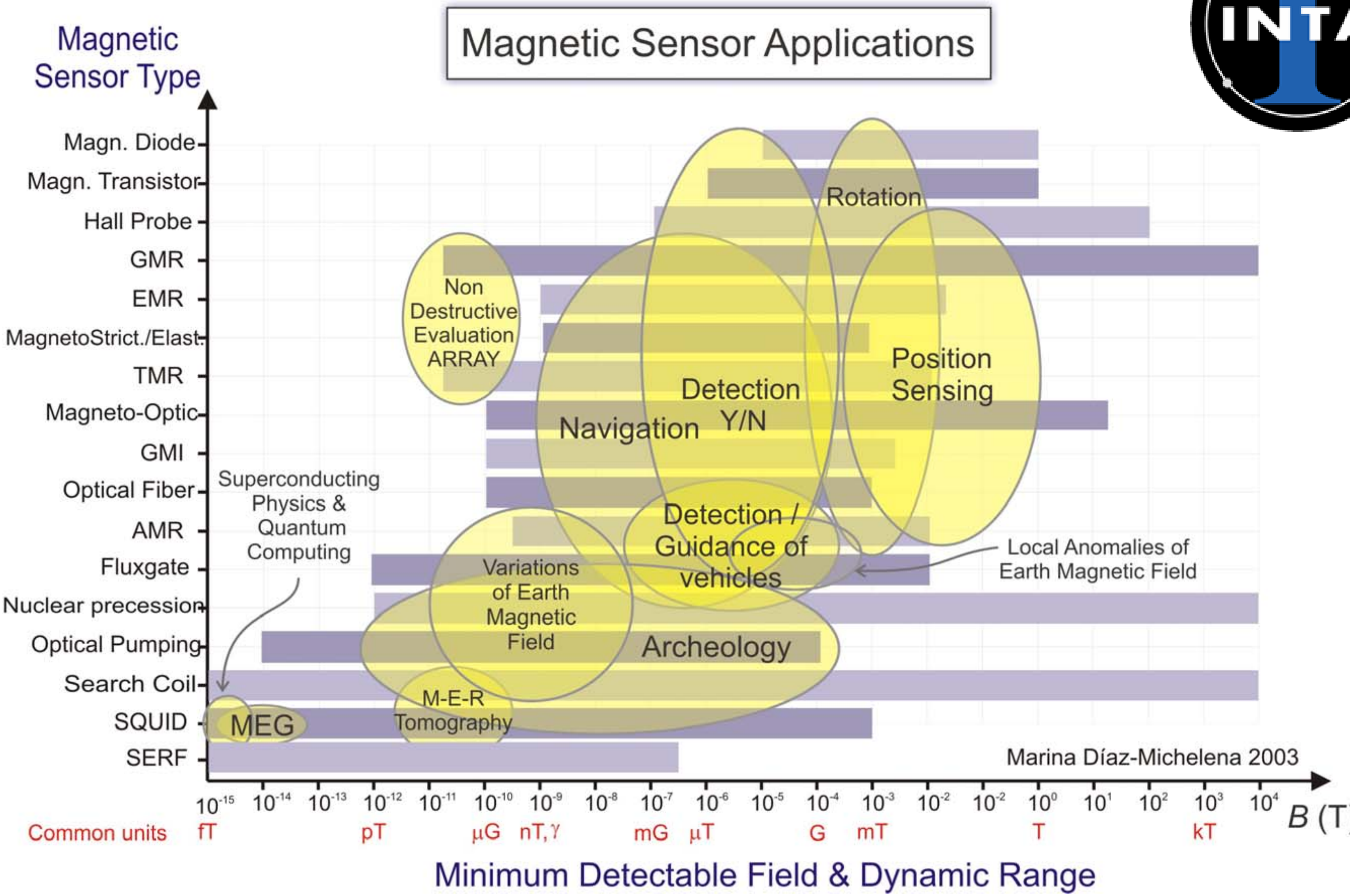


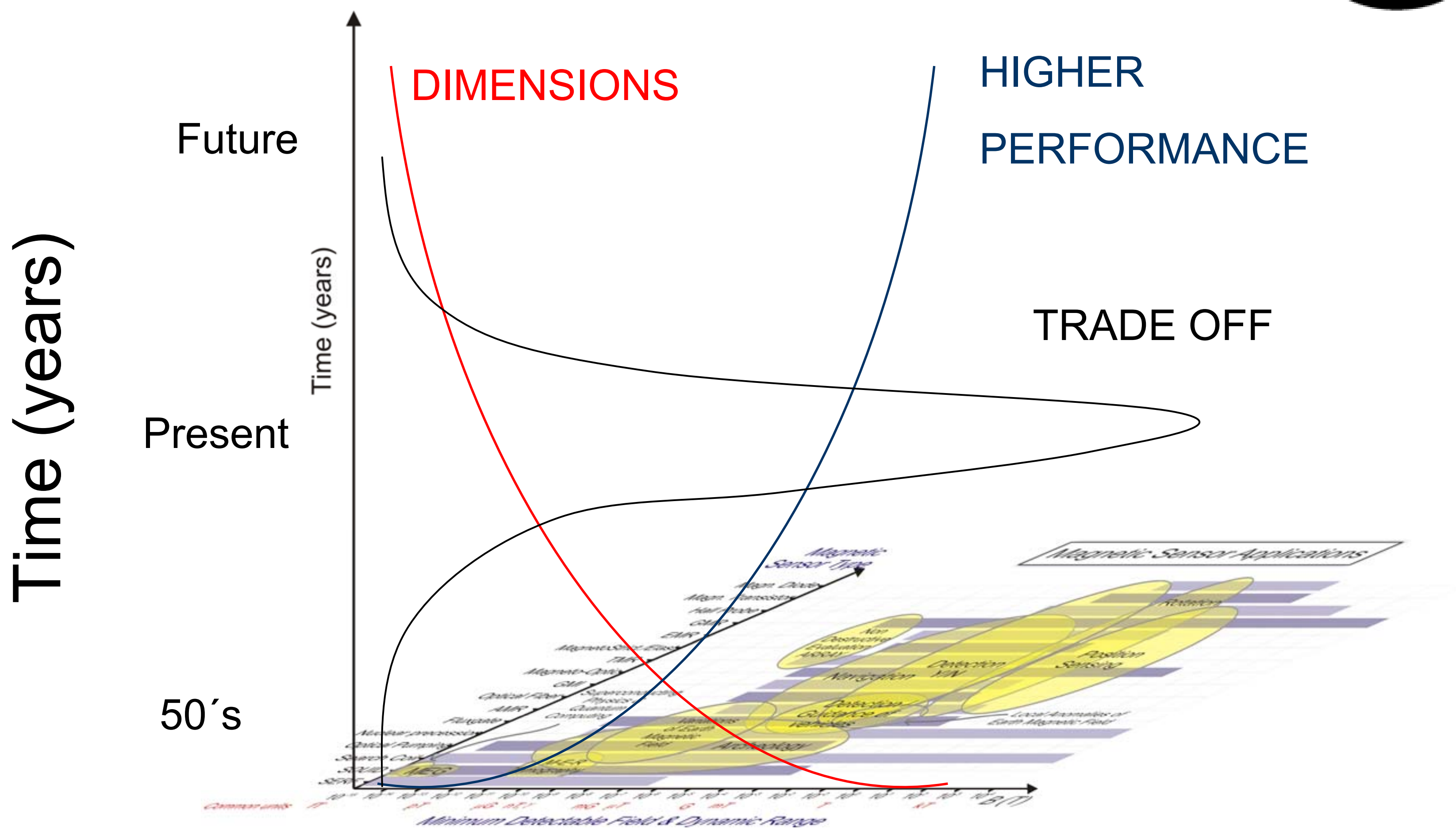
Swarm vector magnetometer (DTU)



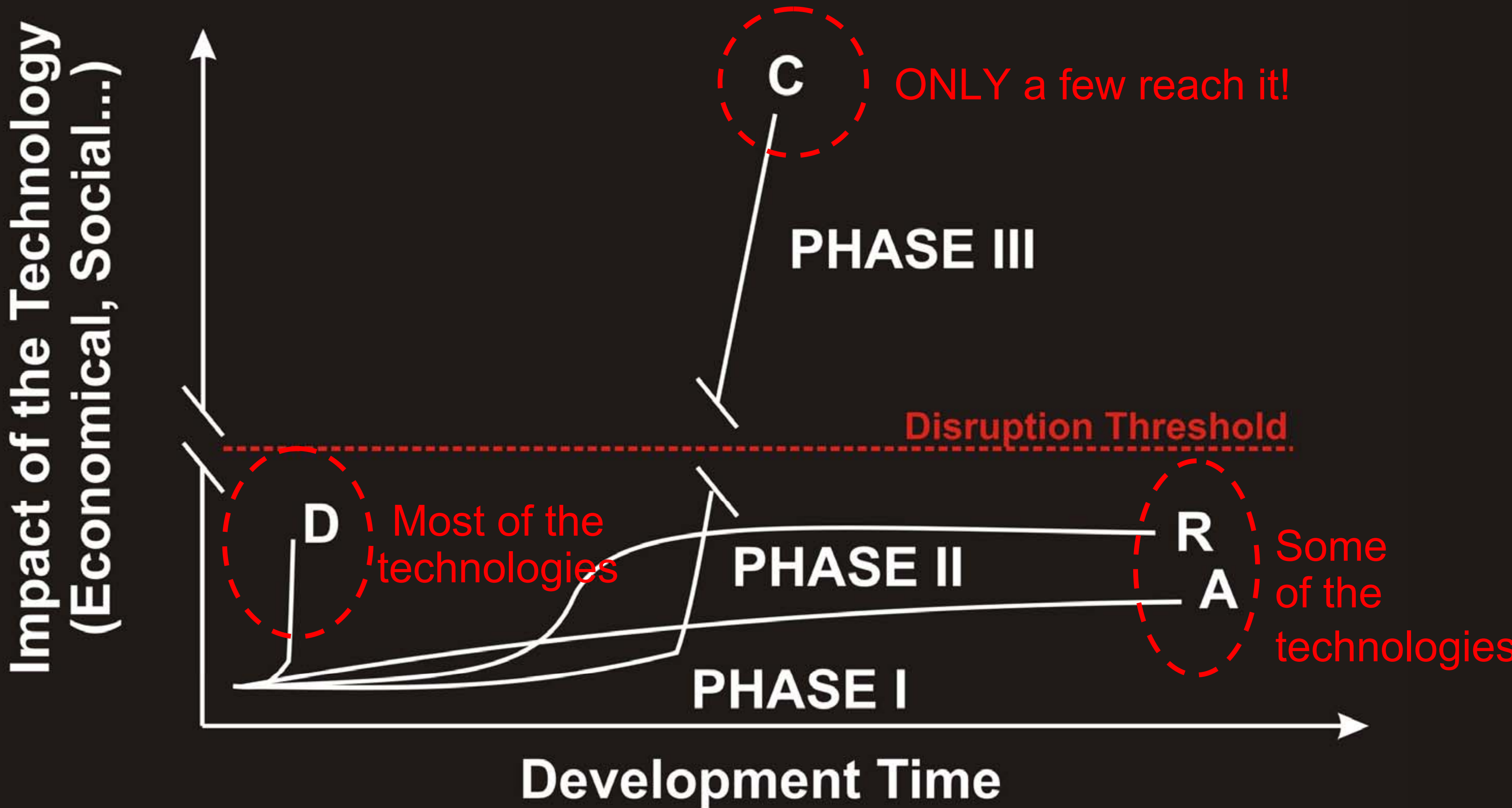

M
FEEDBACK
SPACE QUALIFICATION
C
I
MAGNETIC CHARACTERIZATION

The goal…


Magnetic Sensor Applications
Magnetic Sensor Type
Magn. Diode
Magn. Transistor
Hall Probe
GMR
EMR
MagnetoStrict./Elast.
TMR
Magneto-Optic
GMI
Optical Fiber
AMR
Fluxgate
Nuclear precession
Optical Pumping
Search Coil
SQUID
SERF
Rotation
Non Destructive Evaluation ARRAY
Position Sensing
Detection Y/N
Navigation
Superconducting Physics & Quantum Computing
Detection / Guidance of vehicles
Local Anomalies of Earth Magnetic Field
Variations of Earth Magnetic Field
Archeology
M-E-R Tomography
MEG
Marina Díaz-Michelena 2003
10^{-15} 10^{-14} 10^{-13} 10^{-12} 10^{-11} 10^{-10} 10^{-9} 10^{-8} 10^{-7} 10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-2} 10^{0} 10^{1} 10^{2} 10^{3} 10^{4}
B (T)
Common units
fT pT μG nT, γ mG μT G mT T kT
Minimum Detectable Field & Dynamic Range


Time (years)
Future
Present
50´s
Time (years)
DIMENSIONS
HIGHER
PERFORMANCE
TRADE OFF
Magnetic Sensor Applications
Minimum Detectable Field & Dynamic Range

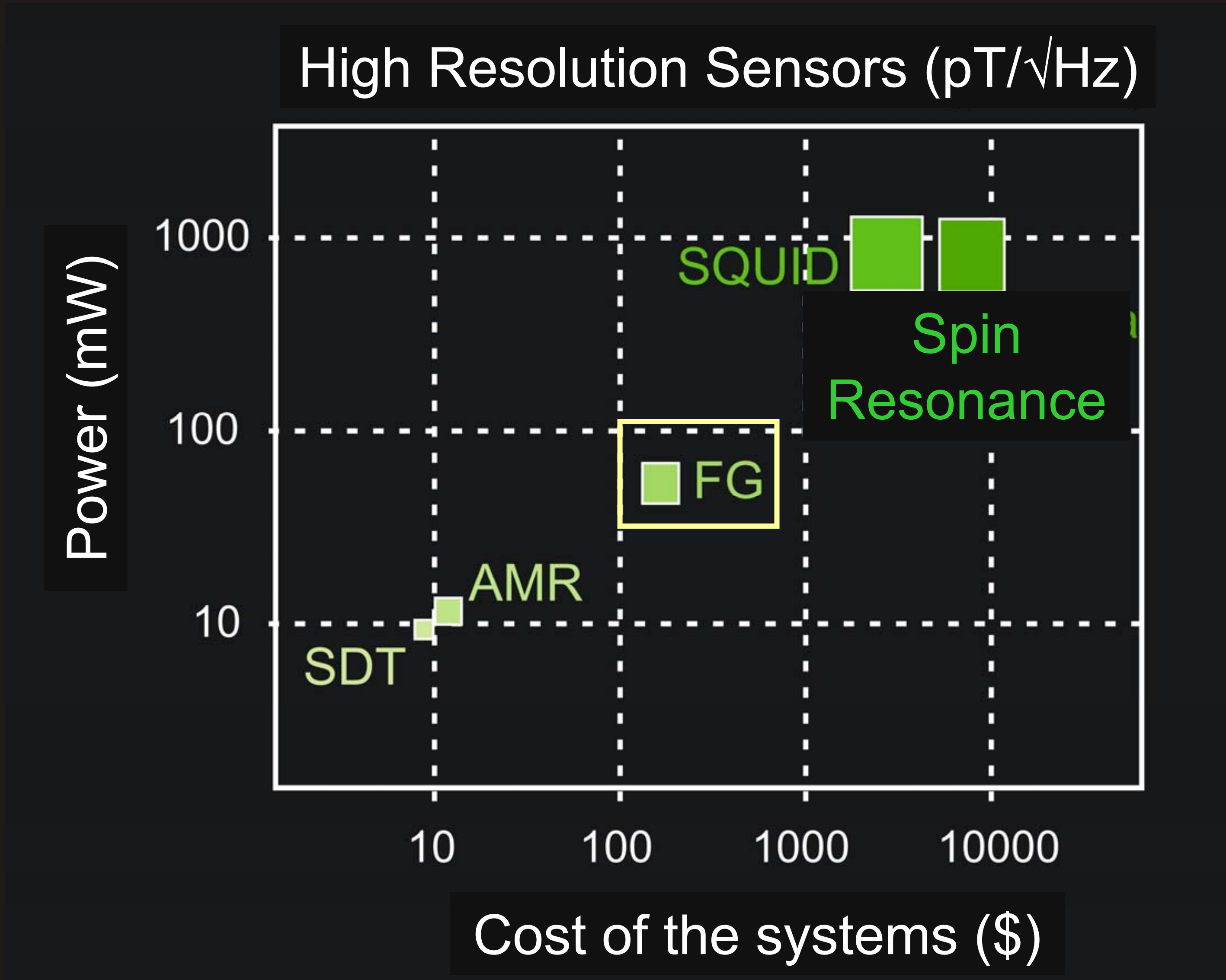
Magnetic Sensors Technology and Disruptions



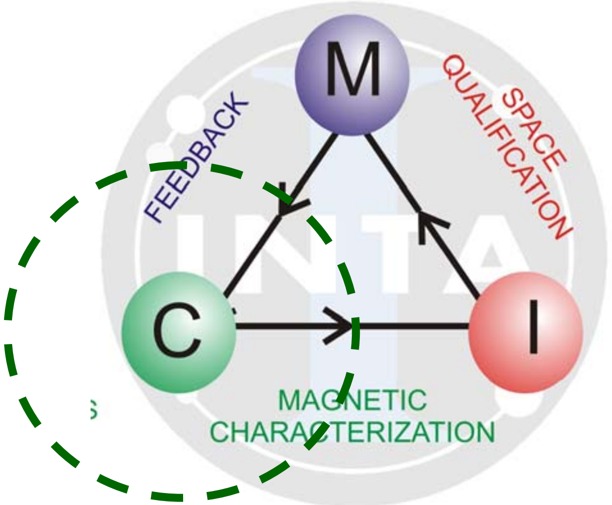
Magnetic Sensors				
Operation Principle	**Size (mm)**	**Noise (pT/√Hz @ 1Hz)**	**Thermal Drift (nT/K)**	**Exciting Power (mW)**
Fluxgates				
Ring	25	3.8	0.1	50
Lineal	70	2.5	0.5	70
PCB	30·8·1.8	17	2	20
Thin Film	3·3	1000	?	10
CMOS	1.5	15000	?	10
Induction	100	2	Sólo AC	0
GMI	10	100	30	5
IWE*	80	?	5	20
AMR	4 ·11·1.7	200	10	55

*Inverse Wiedemann Effect

Ripka et al.



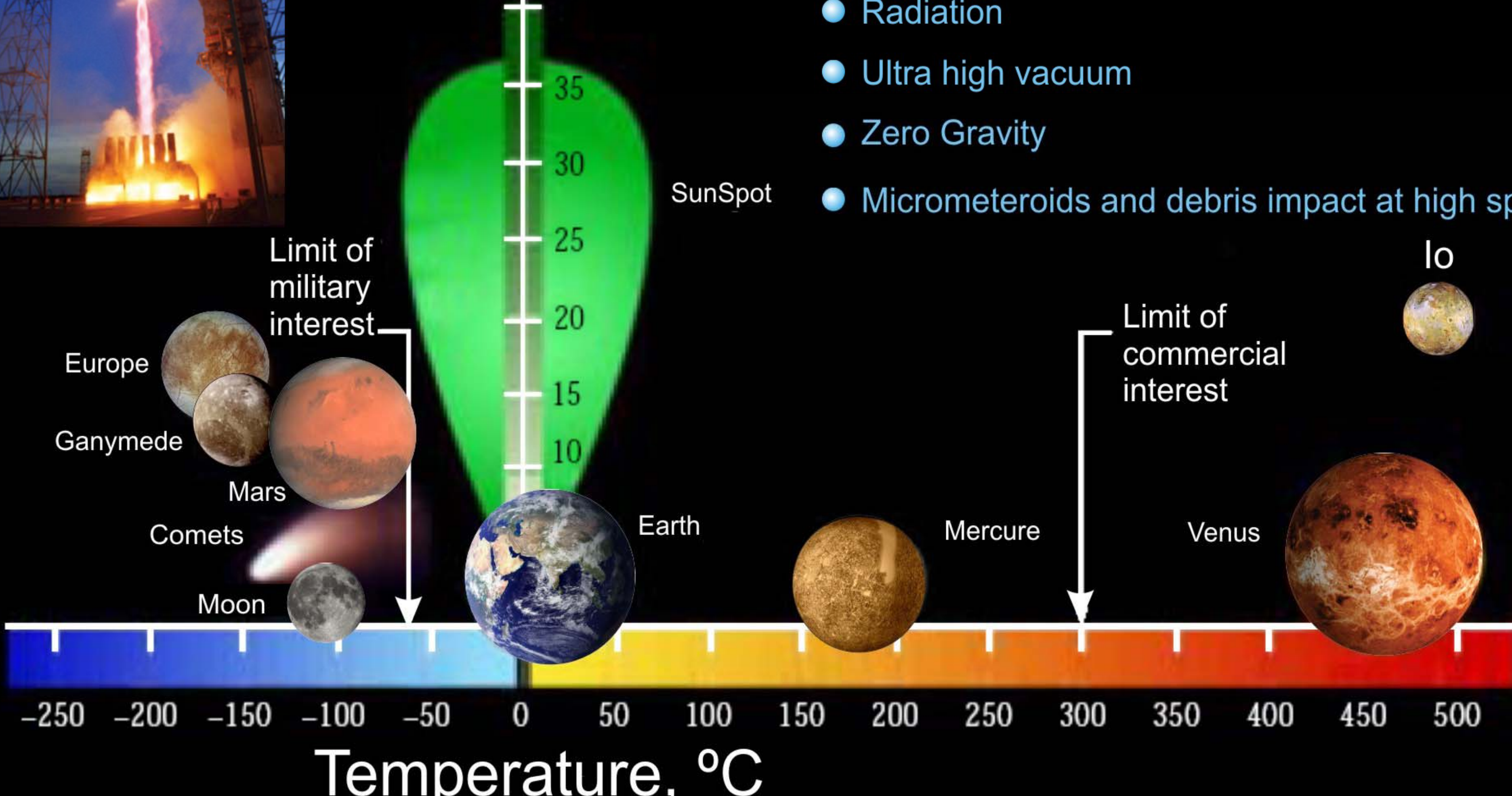
Adapted from "*GMR and SDT Sensors and Arrays for Low-Field Magnetic Applications*" Carl H. Smith & Robert W. Schneider



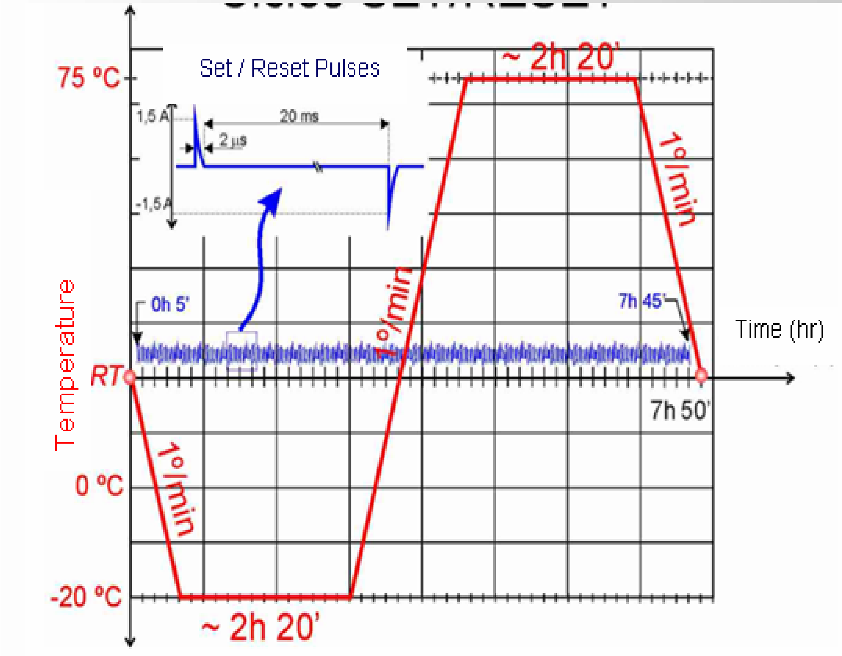
We can only use robust technologies

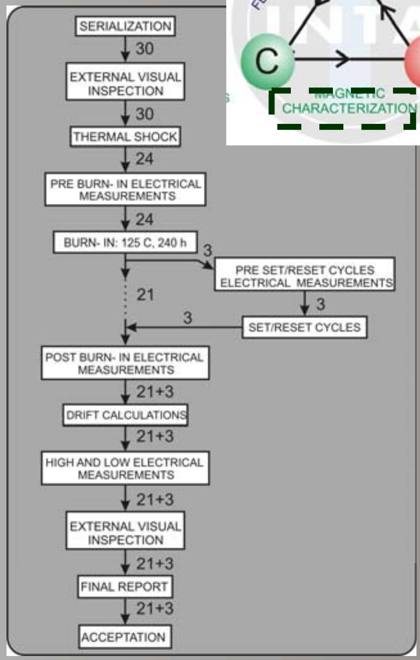
Space: *Working under Extreme Condition*

- Vibration and shocks (launching and landing
- Temperature Variations
- Radiation
- Ultra high vacuum
- Zero Gravity
- Micrometeroids and debris impact at high sp

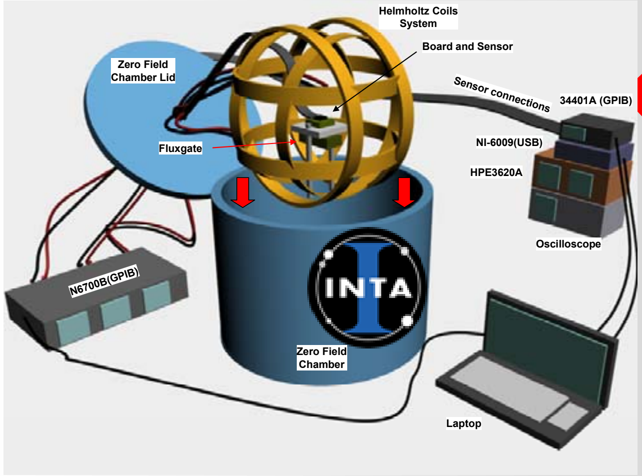


Temperature, Vacuum…



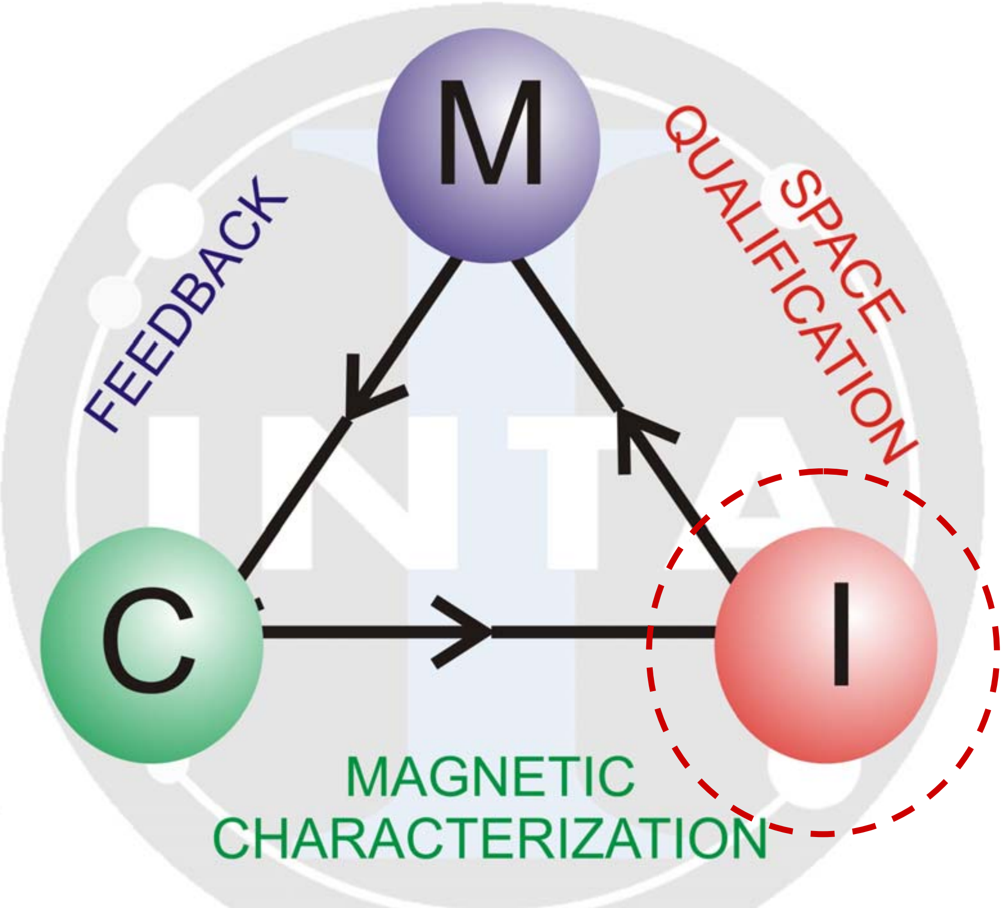


Radiation…

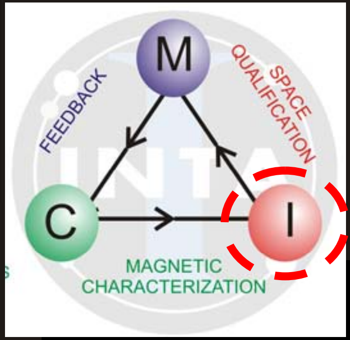


EXHAUSTIVE TESTING

MAGNETIC COTS FOR SPACE
INTA STRATEGY



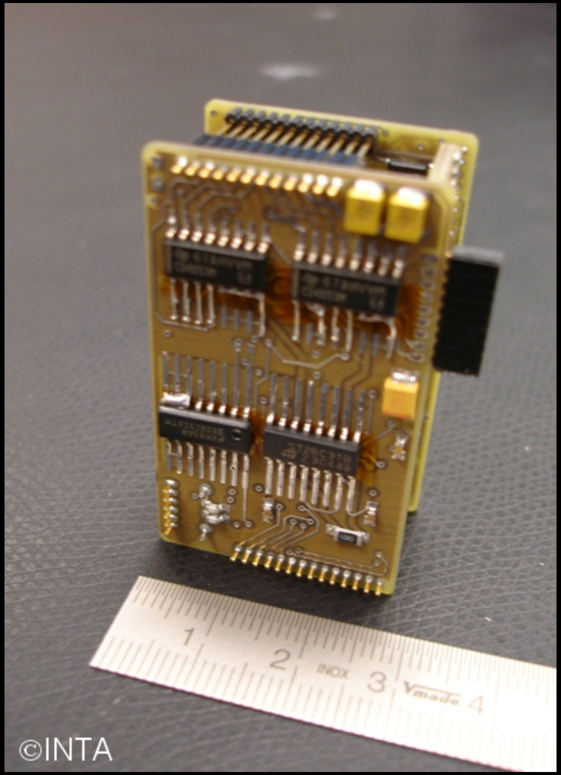
C: COMPONENTS
I: INSTRUMENTS
M: MISSIONS

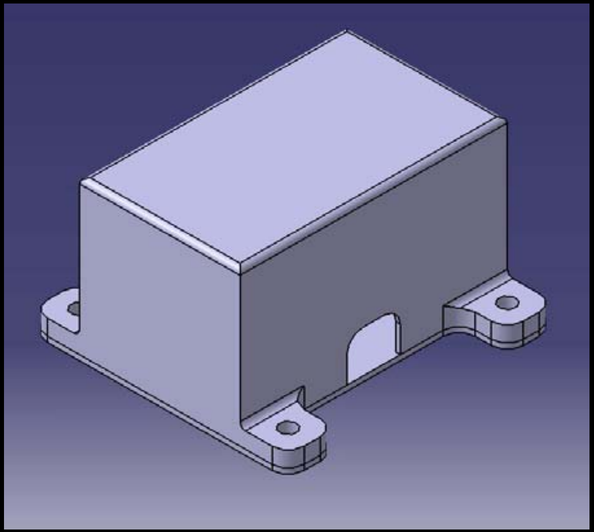


We need to cope with the magnetic signature of the ICs

MOURA

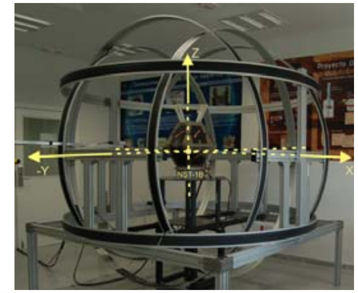
First prototype





The convenience of using PEMs

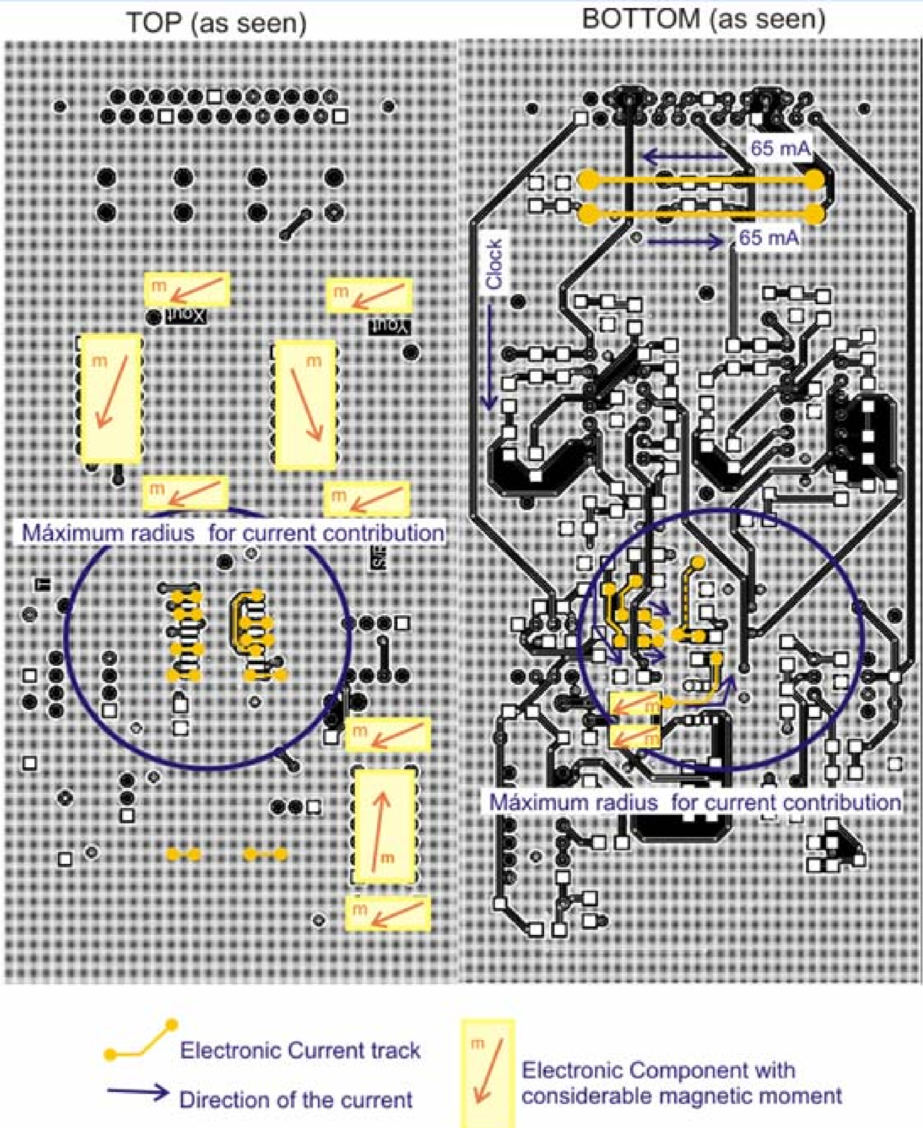
And not only for the magnetic sensors…



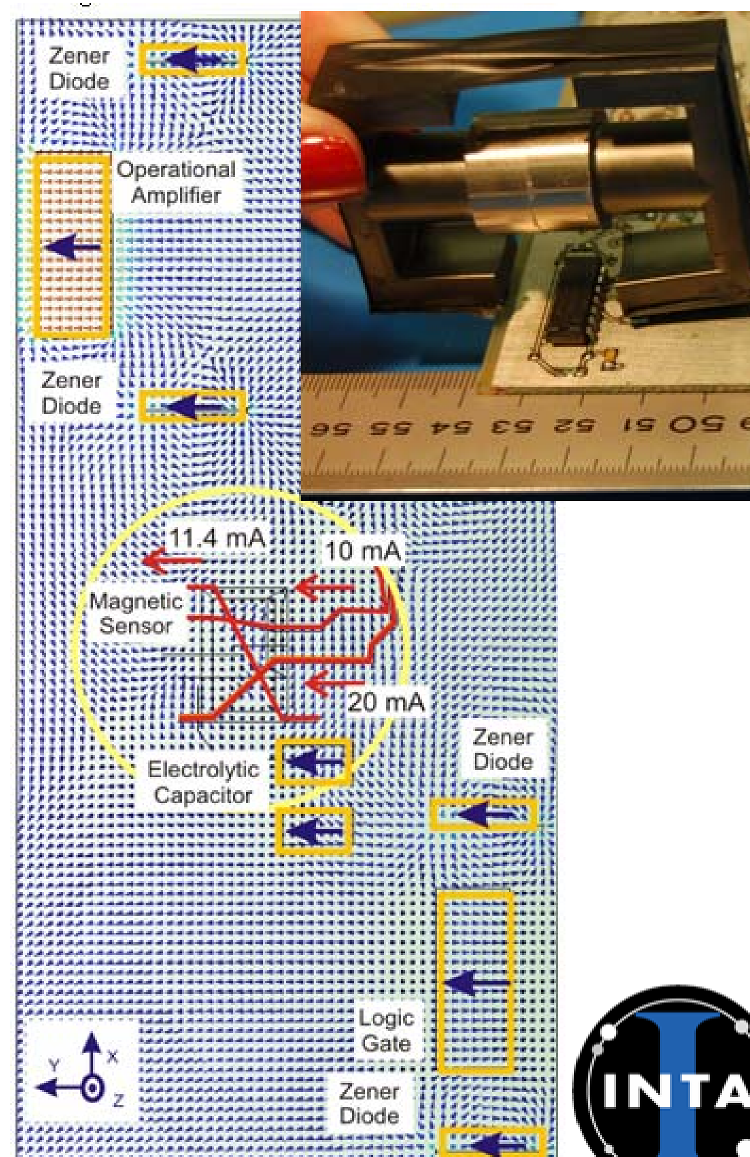
Component	Distance (mm)							
	5	10	15	20	25	30	35	40
MOSFET 2P + 2N	-481280,0	-60160,0	-17825,2	-7520,0	-3850,2	-2228,1	-1403,1	-940,0
FPGA (A54SX32A)*	B > 1727 nT					1727,0	859,0	750,0
PROGRAMABLE VOLTAGE REG	B > 1513 nT					1513,1	641,1	486,0
16 CHANNEL MULTIPLEXOR	-55248,0	-6906,0	-2046,2	-863,3	-442,0	-255,8	-161,1	-107,9
422 DRIVER	-9232,0	-1154,0	-341,9	-144,3	-73,9	-42,7	-26,9	-18,0
16 bits ADC	-9624,0	-1203,0	-356,4	-150,4	-77,0	-44,6	-28,1	-18,8
12 bit DAC	-2716,0	-339,5	-100,6	-42,4	-21,7	-12,6	-7,9	-5,3
MOSFET	1520,0	190,0	56,3	23,8	12,2	7,0	4,4	3,0
INSTRUMENTATION AMPLIFIER	1504,0	188,0	55,7	23,5	12,0	7,0	4,4	2,9
OPERATIONAL AMPLIFIER	1016,0	127,0	37,6	15,9	8,1	4,7	3,0	2,0
OPERATIONAL AMPLIFIER	800,0	100,0	29,6	12,5	6,4	3,7	2,3	1,6
M39006/22-0549 JAN 26769 9832A 40uF 30V	176000,0	22000,0	6518,5	2750,0	1408,0	814,8	513,1	343,8
RWR80	-957600,0	-119700,0	-35466,7	-14962,5	-7660,8	-4433,3	-2791,8	-1870,3
CWR06	-29856,0	-3732,0	-1105,8	-466,5	-238,8	-138,2	-87,0	-58,3
CDR34	-9760,0	-1220,0	-361,5	-152,5	-78,1	-45,2	-28,5	-19,1
572D336X0010P2T	-5348,0	-668,5	-198,1	-83,6	-42,8	-24,8	-15,6	-10,4
M55342K06B1F00R (TBL-325)	-1710,4	-213,8	-63,3	-26,7	-13,7	-7,9	-5,0	-3,3
CDR01BX102BKSS	-1324,8	-165,6	-49,1	-20,7	-10,6	-6,1	-3,9	-2,6
SMC3HR400102101C (RIS-032)	-957,6	-119,7	-35,5	-15,0	-7,7	-4,4	-2,8	-1,9
Resistor (LOE-070)	-514,2	-64,3	-19,0	-8,0	-4,1	-2,4	-1,5	-1,0
PG270K81-M83	-67,5	-8,4	-2,5	-1,1	-0,5	-0,3	-0,2	-0,1

ICs Magnetic Signature (nT)

PSPICE and FEM Simulations

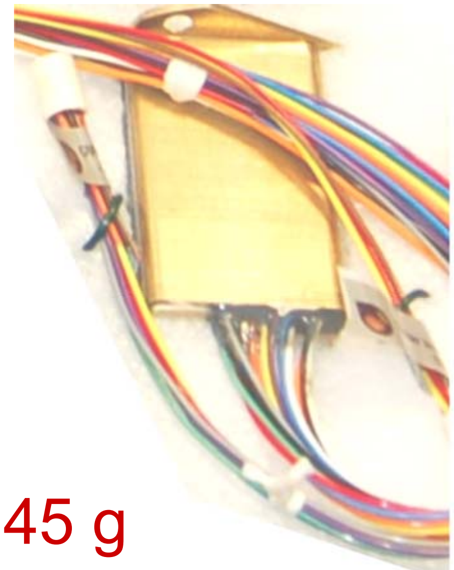


Experimental Measurements

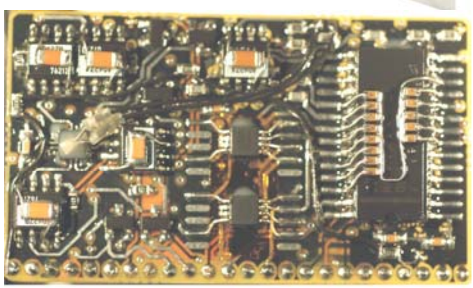


MOURA Evolution… Making Progress

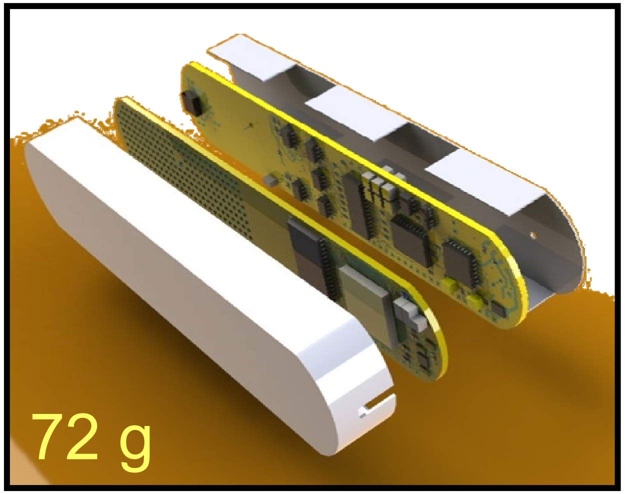
2010 MMPM-EQM

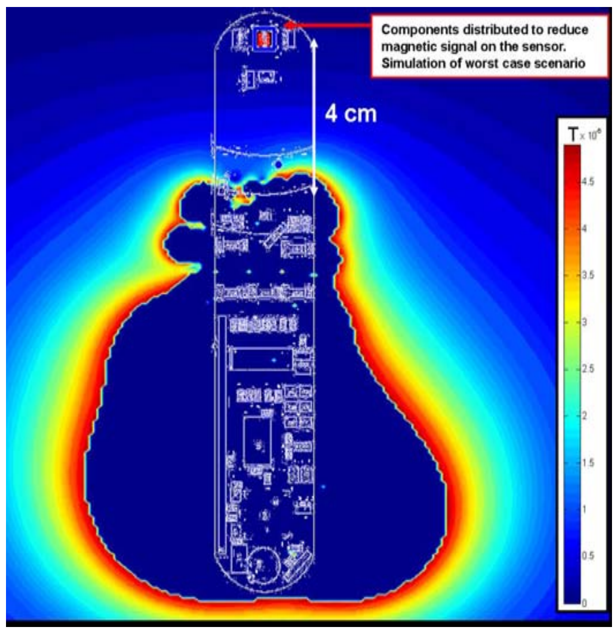


45 g

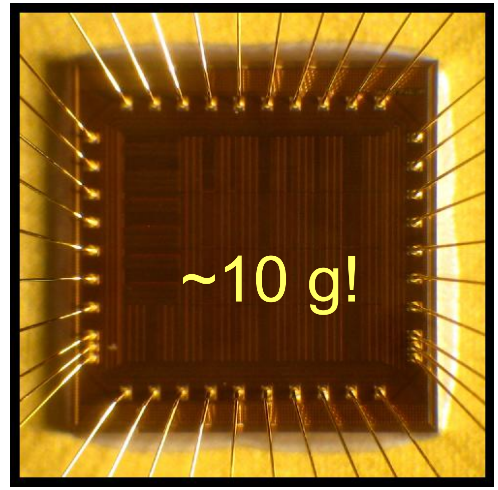


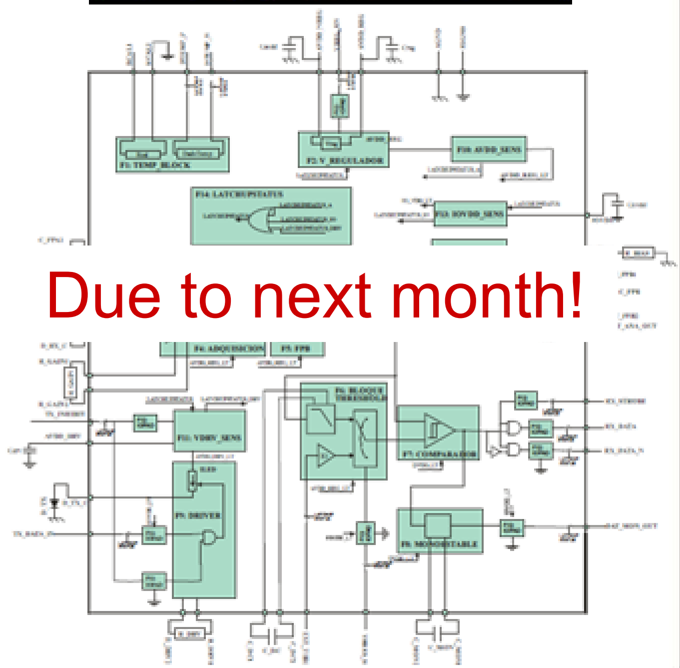
2011 MMPM-FM

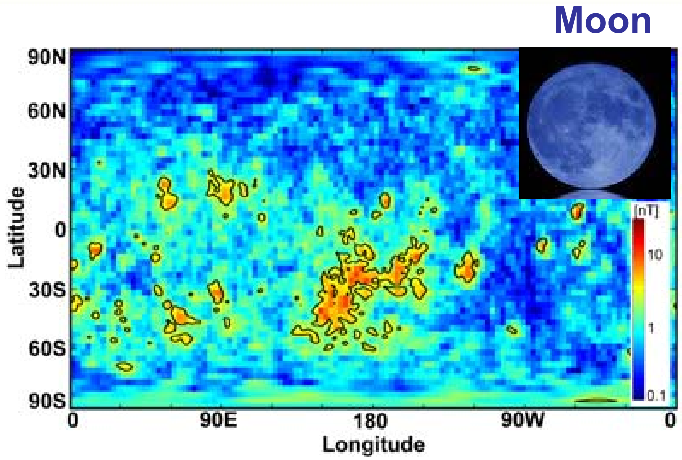


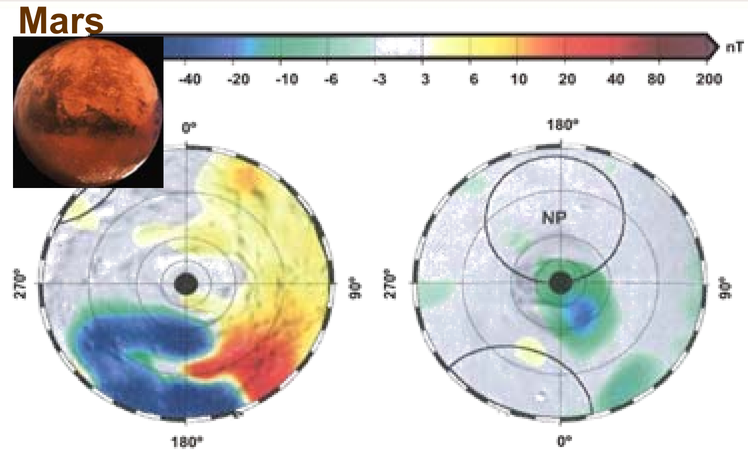


2012 Mixed ASIC



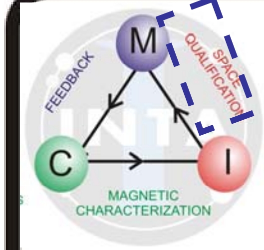






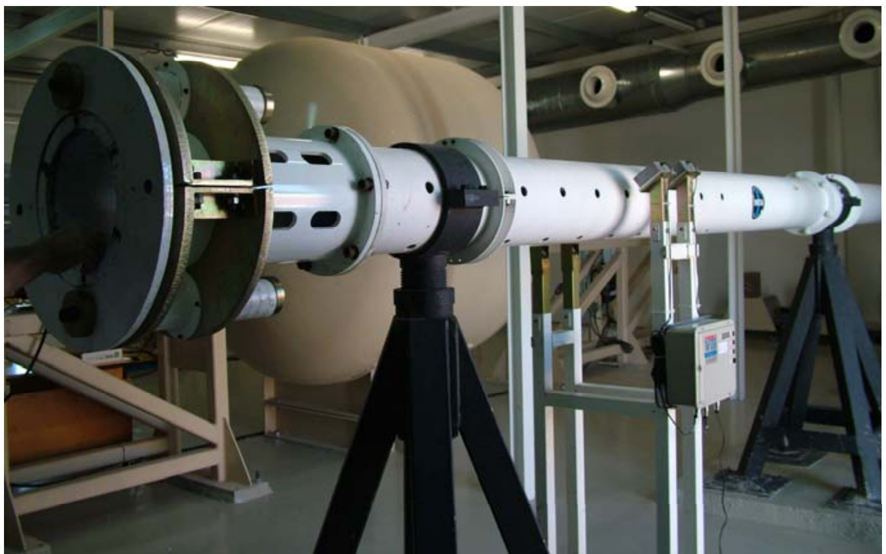
Lock-in techniques integrated in the ASIC for better performance and more robustness

Arquitecture	Noise (pT)	BW (Hz)	Robustness		Complexity	Consumption (mA) @ 5V
			to high fields	to temperature swings		
Open Circuit S/R	200	0.6	High	Need exhaustive calibration	Low	86
S/R Lock-in	100	50	High	Need exhaustive calibration	Moderate	~ 86
Lock-in with Offset	100	1	Moderate	Need exhaustive calibration	Moderate	~ 86 + 42
Mixed Lock-in	50	50	High	Need exhaustive calibration	High	~ 86 + 42
Mixed lock-in + temperature compensation	50	50	HIgh	High	High	~ 86 + 42



BESIDES

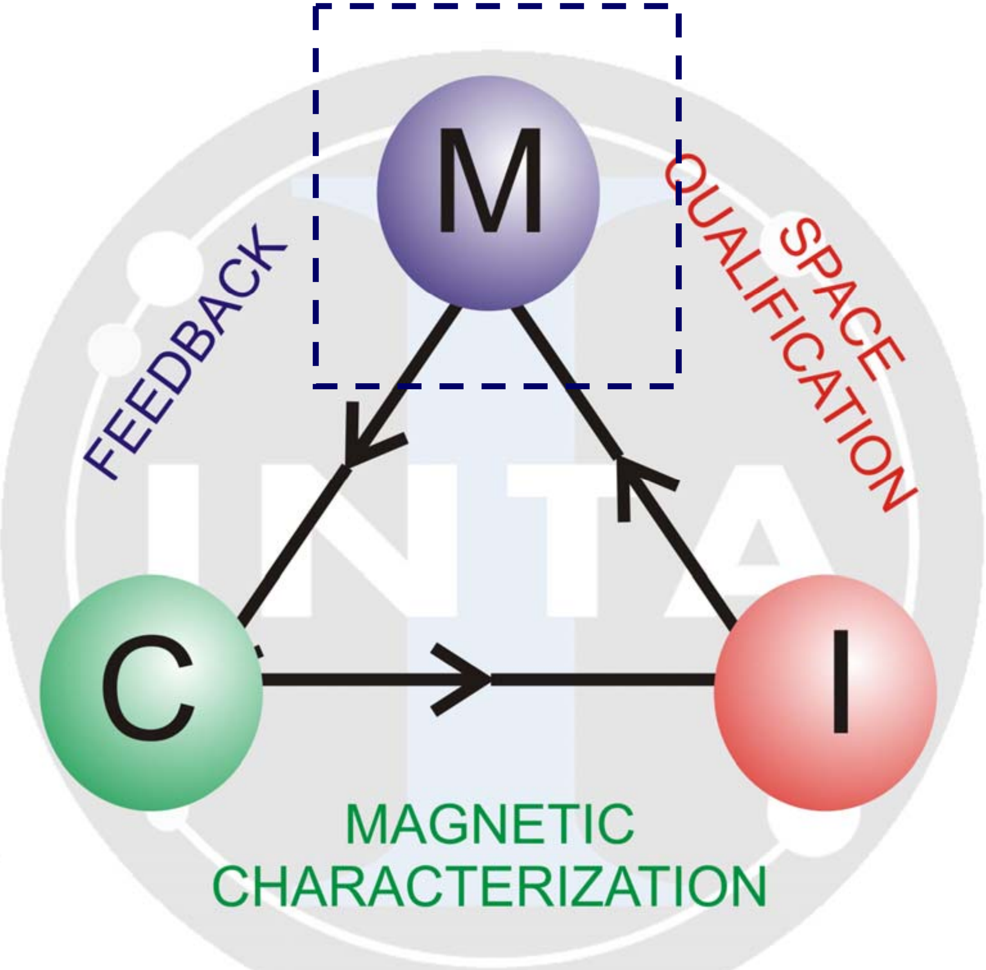
- Circuits Technologies: **PCB**, **welding**…
- **Glues & foams** (structurale, optic…)
- **Identification** of components (**no ITAR**):
  - **COTS** (Commercial-Of-The-Shelf)
  - **PEM** (*Plastic Encapsulated Microcircuit*)
- Tecnologies ***"magnetically clean"***
- *"**Spectral integrated**" Tecnologies*



INTENSIVE TESTING

Shock, vibration, thermal cycling, thermal vacuum, magnetic cleanliness...

MAGNETIC COTS FOR SPACE
INTA STRATEGY



C: COMPONENTS
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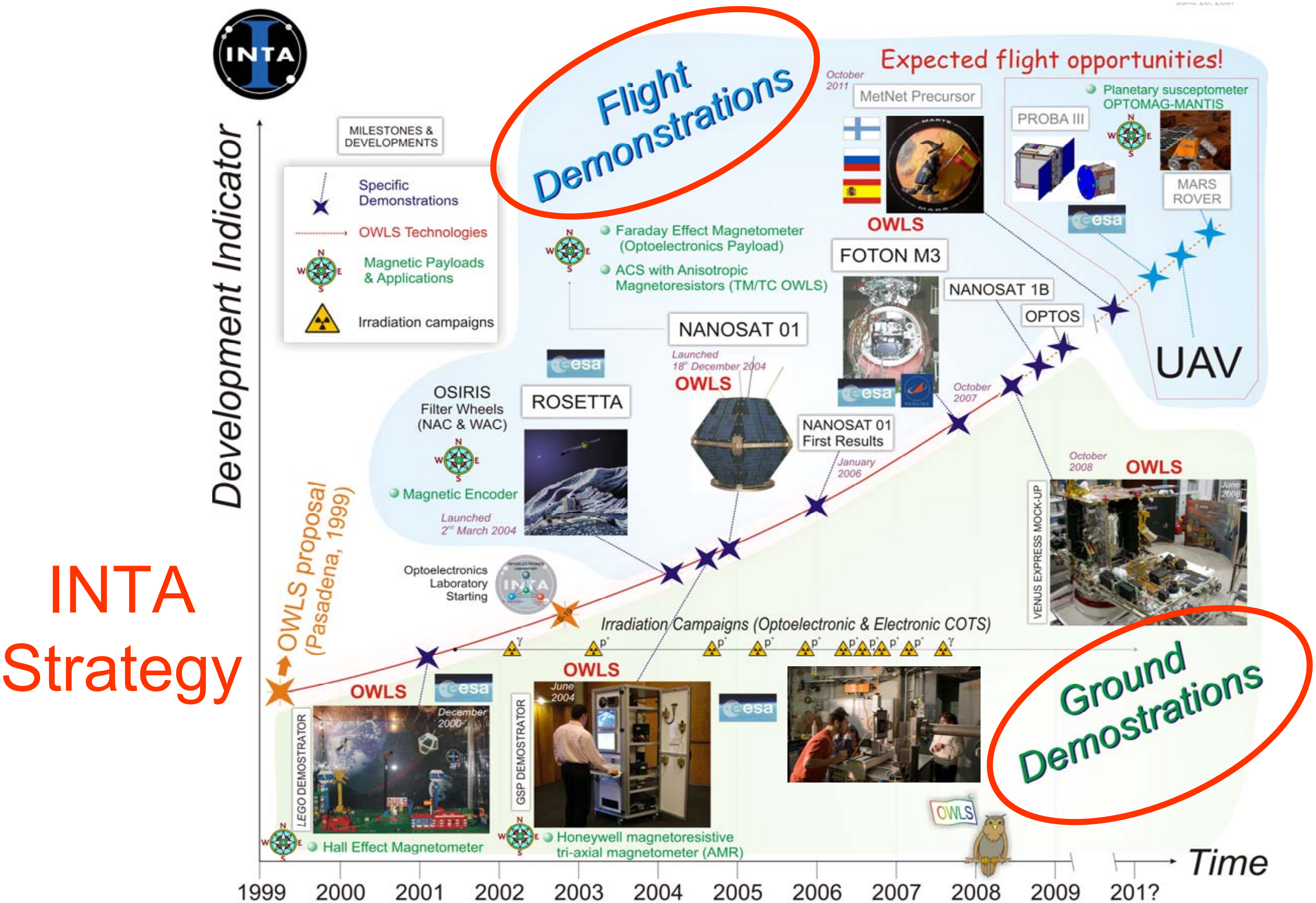
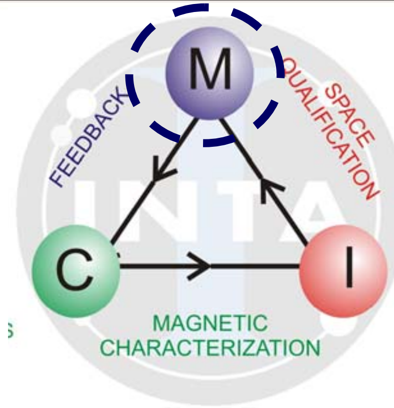
INTA´s strategy of COTS-based magnetic payloads



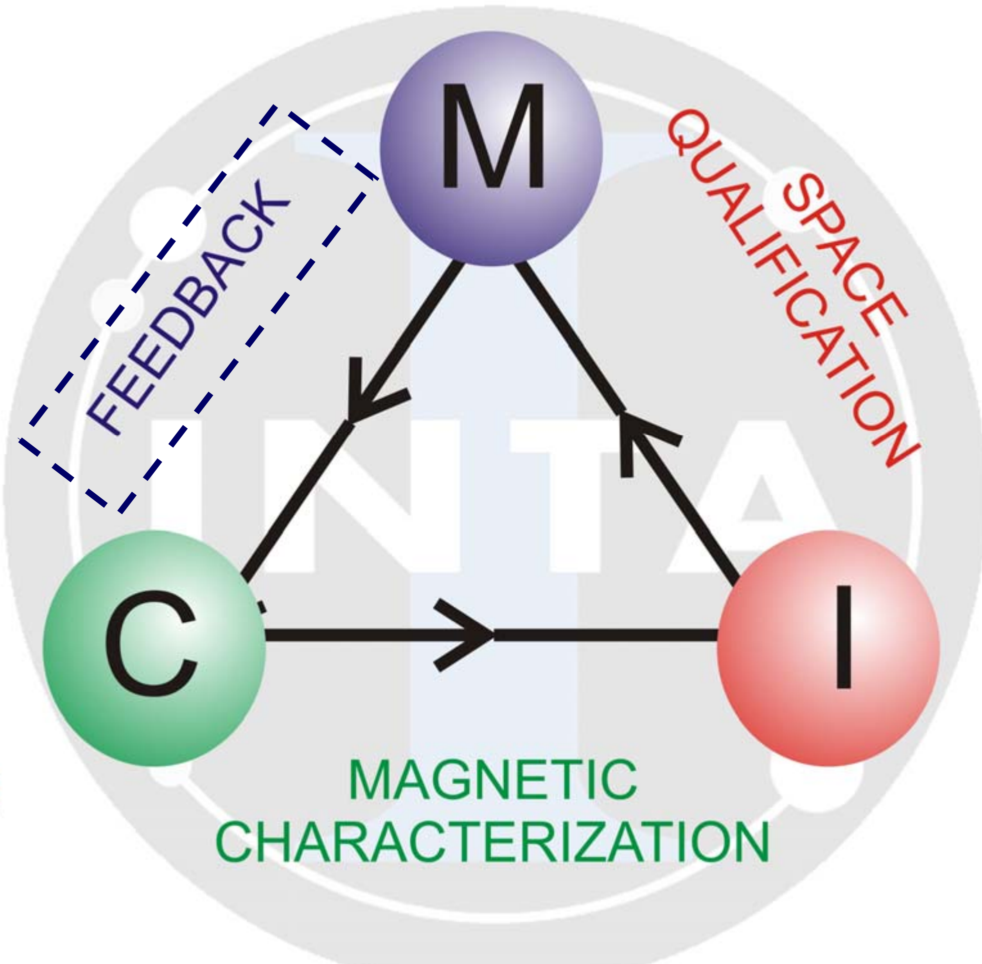
* OWLS - Optical Wireless Links for intra-Satellite communications



Technology Readiness Level - TRL

High	TRL-9	Real System qualified in flight By sucessed mission operations
	TRL-8	Complete real System and qualified to fly by demostrations and tests
	TRL-7	“Demostrador“ Prototipe of a system in a real environment
Medium	TRL-6	Model system /subsystem or “demostrador“ validation within a relevant enviroment
	TRL-5	Component or functional model development within a relevant environment
	TRL-4	Component or functional model development within a laboratory environment
Low	TRL-3	Analysis and critics experiments of the function or characteristic in conceptual test
	TRL-2	Technological concept and/or application formulation
	TRL-1	Basic rudiments: observation and reference

MAGNETIC COTS FOR SPACE
INTA STRATEGY



C: COMPONENTS
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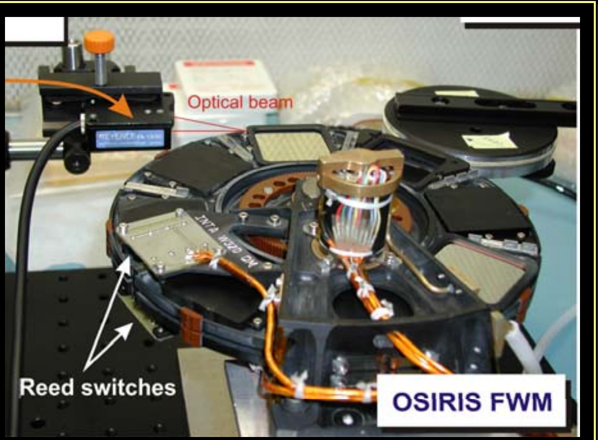
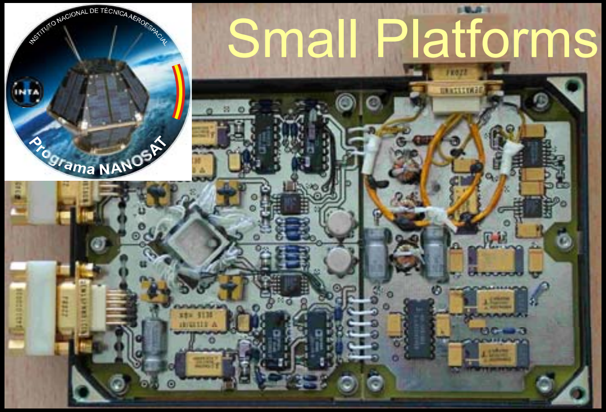
M: MISSIONS

From…

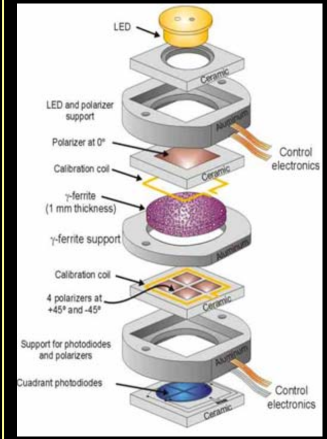
ROSETTA

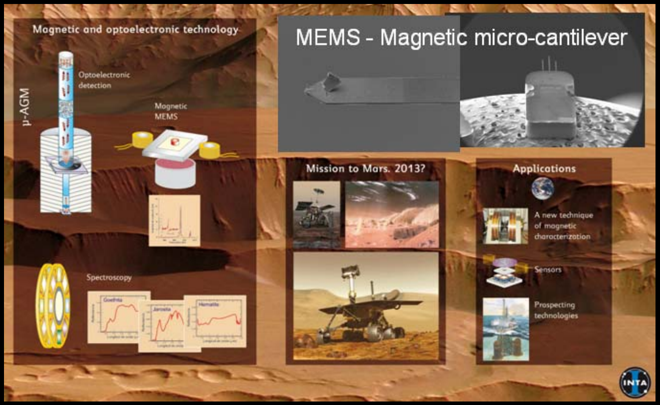


Small Platforms



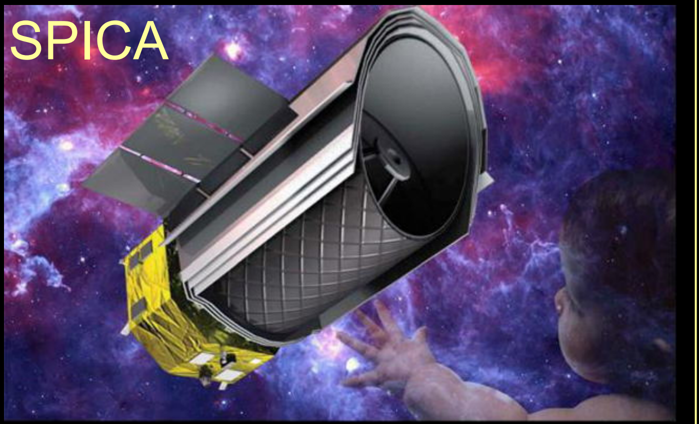
Susceptometers / Gradiometers





To…

SPICA

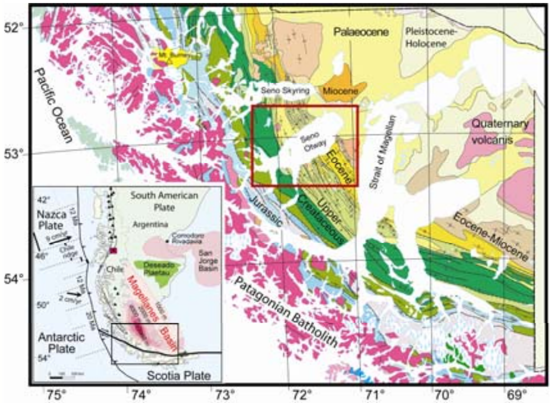


Solar System Exploration

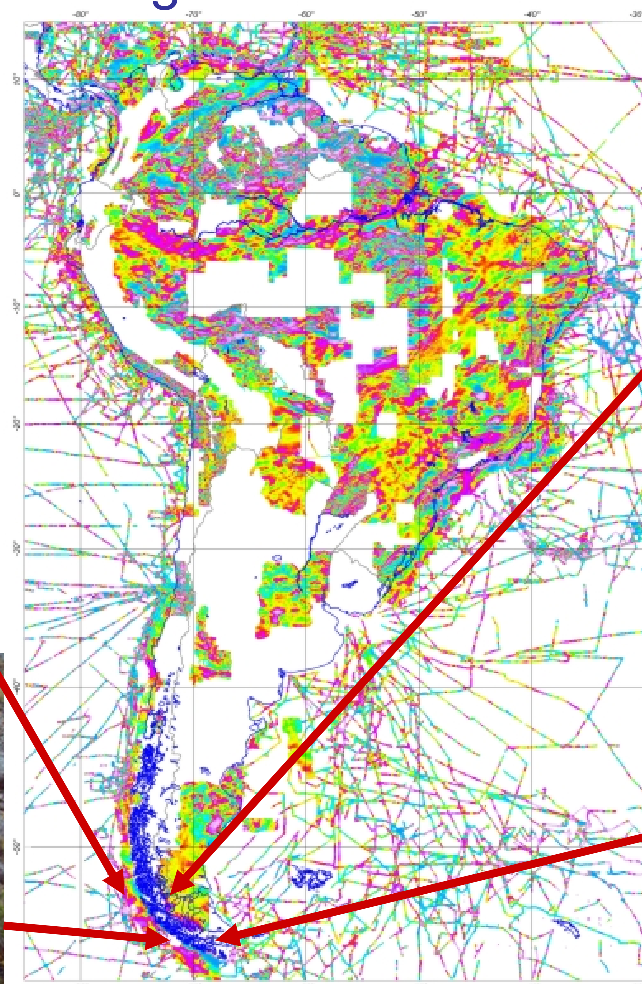
Instruments for the future

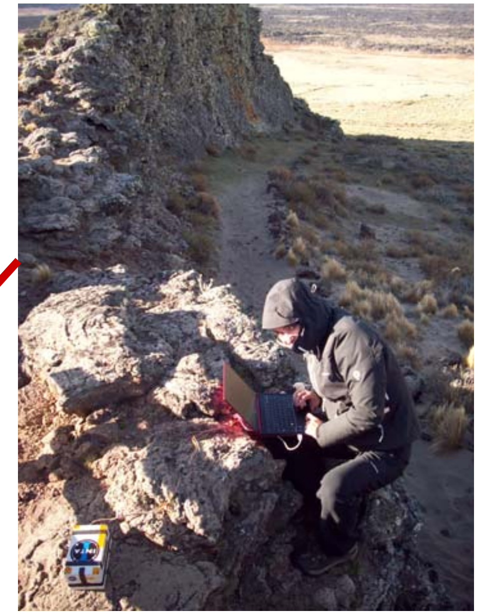
MOURA Evolution… Making Progress

Magellanes Geology



South America magnetic anomalies





Per aspera ad astra

Thank you!