Astro-particle shielding superconducting magnet cryogenic design for space travel missions

Romain Bruce and Bertrand Baudouy

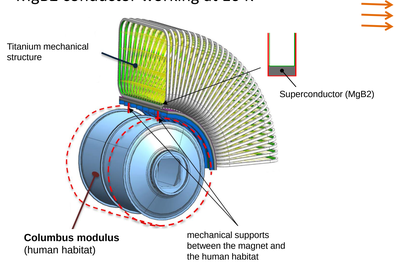
CEA Saclay, IRFU/SACM=, 91191 Gif-sur-Yvette, France

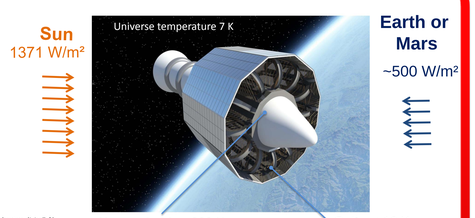
The SR2S project

The **S**pace **R**adiation **S**uperconducting **S**hield (**SR2S**) European project aims at studying a large superconducting toroid magnet to protect the human habitat from the ionizing radiations coming from Galactic Cosmic Ray and Solar Events during long term missions in deep space

Magnet Characteristics and Thermal Environment

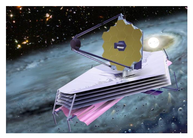
- Toroïdal configuration magnet
- Field integral of 4 T.m
- 120 coils
- 10 m long and 12 m diameter
- MgB2 conductor working at 10 K



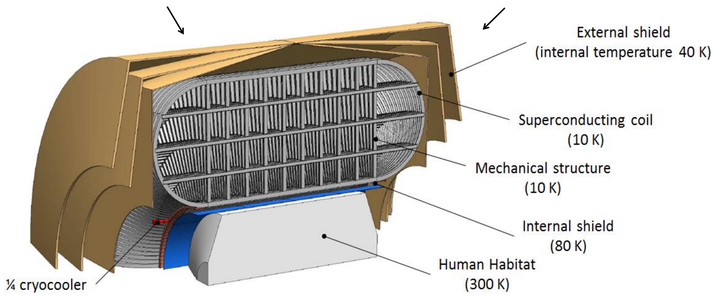


Component	Total Mass [kg]
Superconductor	36668
Racetrack (Thin Panels)	42080
Racetrack (Tie Rods)	7564
Tube (Sandwich)	5844
Tube (Formers)	11504
Tube/Racetrack	2400
TOTAL	106060

General Cryogenic Design

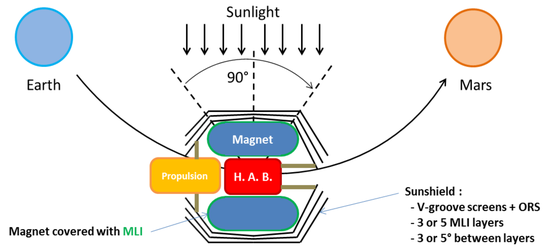


Combination of space and terrestrial technology



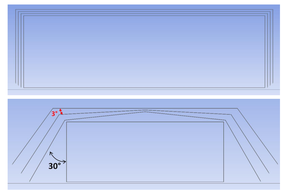
Passive Thermal Protection : The Sunshield

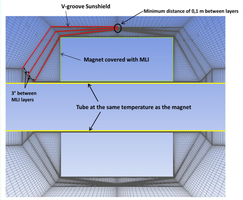
V-groove + **MLI** sunshield system covering the magnet system to reduce the radiations heat loads coming from the sun or planets

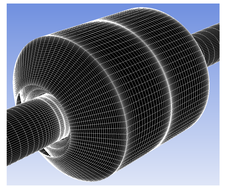


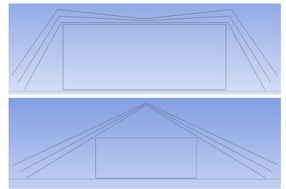
3D numerical thermal radiation simulation

- S2S radiation solver from ANSYS Fluent
- ~100 000 radiating faces
- 3 or 5 V-groove layers (10 mm thickness)
- 3° or 5° between layers
- MLI conduction modeled in every layer
- Emissivity 0,1 (aluminum)







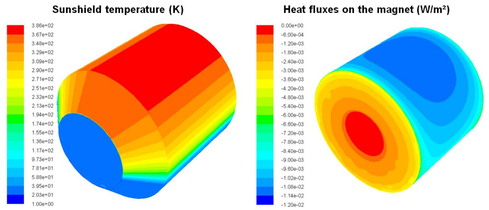


5 V-groove layers configuration

Configuration		Straight (no angle)	3° normal	5° normal
Sunshield	Surface (m²)		968	1116
	Mean temperature (K)		172	170,7
	Max temperature (K)		386	386
Magnet (after the MLI)	Max heat flux (W/m²)		0,012	0,008
	Total heat flux (W)	16,7	3,66	2,7

3 V-groove layers configuration

Configuration		Straight (no angle)	3° normal	3° invert	3° tipi
Sunshield	Surface (m²)	641	789	744	1149
	Mean temperature (K)	155	208	197	215
	Max temperature (K)	522	534	450	564
Magnet (after the MLI)	Max heat flux (W/m²)	0,18	0,06	0,09	0,06
	Total heat flux (W)	46,61	16,33	21,23	20,37



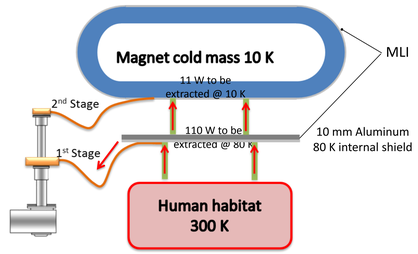
Reduction of the heat load at the surface of the magnet **from 200 kW** to **3 W**

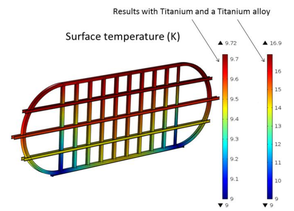
Superconducting Coils Cryogenics

80 K shield necessary to lower the heat fluxes from the human habitat

8 pulse tube cryocoolers (4 W @ 10 K) needed to cool down the entire magnet

- Superconducting coil cooled by the cryocooler 2nd Stage with solid thermal link using the structural material of the conductor as thermal link
- 80 K thermal shield cooled with the cryocooler 1st Stage with forced flow or thermal links

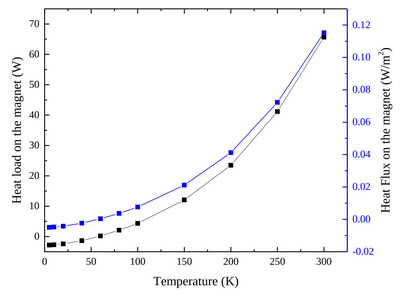


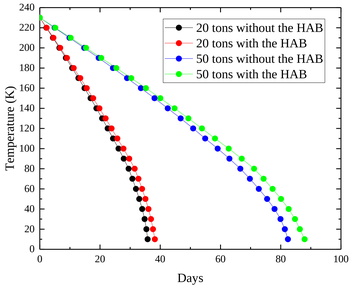


Magnet Cool-down

Multiple simulations have been performed to evaluate the heat fluxes reaching the surface of the magnet depending on its temperature :

- Without the human habitat connected to the magnet, the temperature of the magnet protected by the sunshield is about 50 K in space
- With the human habitat the temperature of the magnet is about 230 K
- Using 8 cryocoolers, it take about 40 days to cool down a 20 tons magnet and 80 days for a 50 tons magnet
- The cool down difference time with and without the human habitat is about 10 %





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