Perspektywy obrazowania magnetyczno-rezonansowego na Międzynarodowej Stacji Kosmicznej

Krzysztof Turek

Inicjatywa „Space MRI” – geneza i uczestnicy

Leader: Gordon E. Sarty, University of Saskatchewan
Team: 20 scientists, engineers and business experts from the following scientific and business and organizations:

University of Saskatchewan, Saskatoon

National Research Council of Canada, Institute for Biodiagnostics, Winnipeg

Alberta Innovates Health Solutions

Loma Linda University, US, California

AMAG, Kraków, designer and manufacturer of magnet systems

COM DEV International, COM DEV Canada, designer and manufacturer of space hardware

MRI-TECH, Kraków – Winnipeg, manufacturer of low-field MRI systems

MRI TECH CANADA

Prezentacja projektu dla CSA

- G. Sarty, S. Kontulainen, A. Baxter-Jones, R.A. Pierson, K. Turek, A. Obenaus, B. Tomanek, J. Sharp, A. Scott, L. Piche, "**Compact MRIs for Astronauts and Earthlings**", CASI** ASTRO2012, Abstract 8, Quebec City April 24-26, 2012.
- Zaprezentowana została koncepcja systemu o wadze poniżej 800 kg, wystarczająco małego aby zmieścił się w międzynarodowej, standardowego pojemnika ładunkowego
- Koszt wyniesienia 1 kg ładunku $30 000
- Budżet CSA* zbyt mały aby sfinansować ten projekt

* CSA – Canadian Space Agency

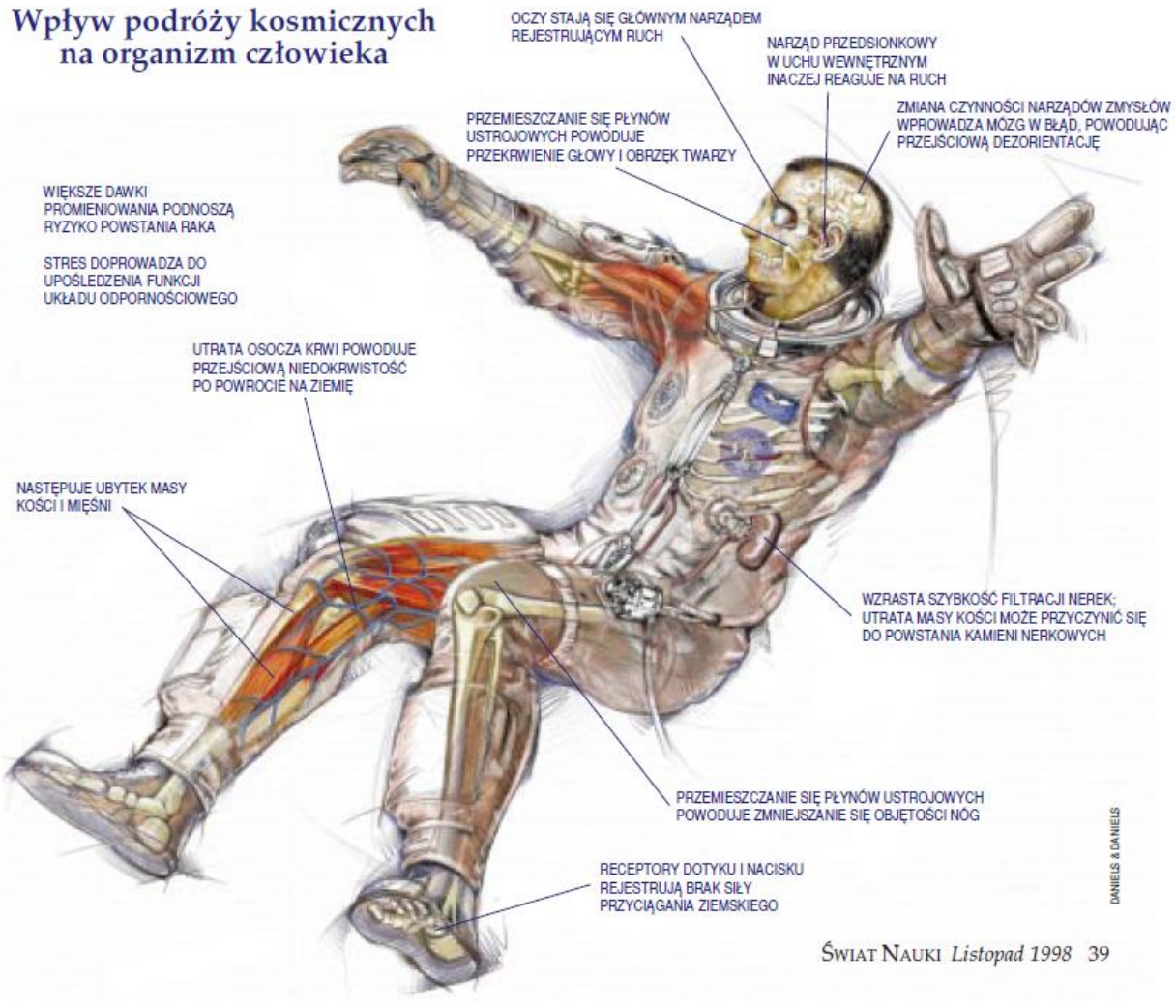
**Canadian Areonautics and Space Institute

Zmiana koncepcji

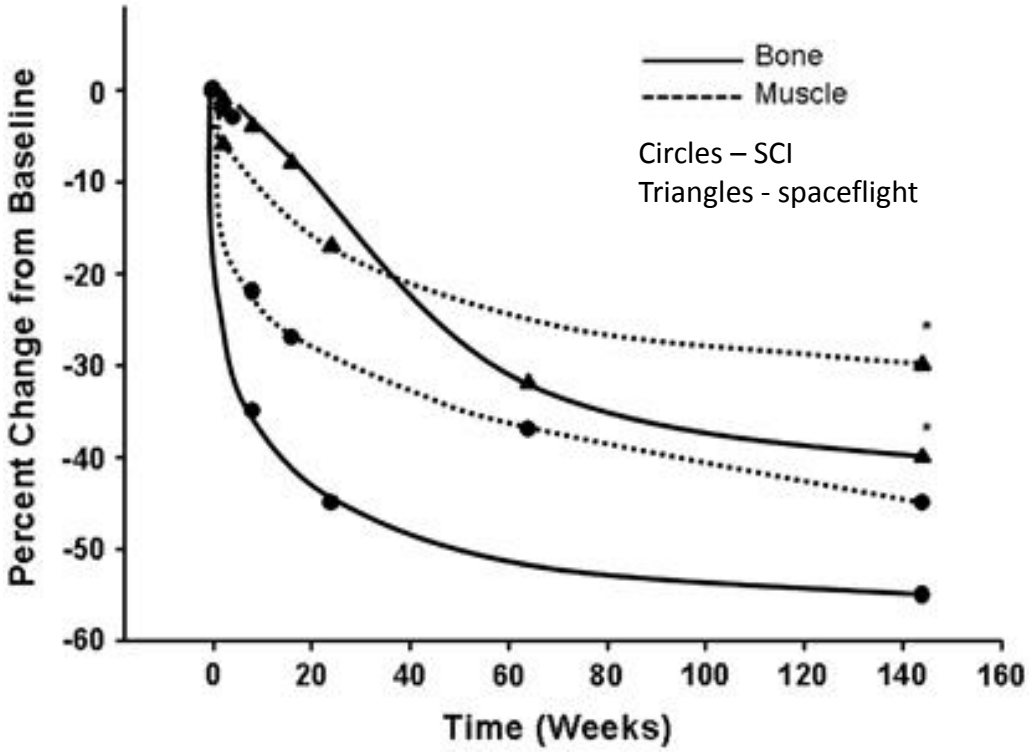
- Wrist compact MRI system
- Maj 2013. Public Works and Government Services Canada ogłosił w imieniu Her Majesty the Queen in right of Canada przetarg na opracowanie wstępnego projektu „Life science Research System”.
- Październik 2013. Zespół złożył do PWGSC ofertę zatytułowaną „Wrist Magnetic Resonance Imager: ISS-MRI”

Po co MRI na ISS?

Zdrowie ludzkie w warunkach mikrograwitacji

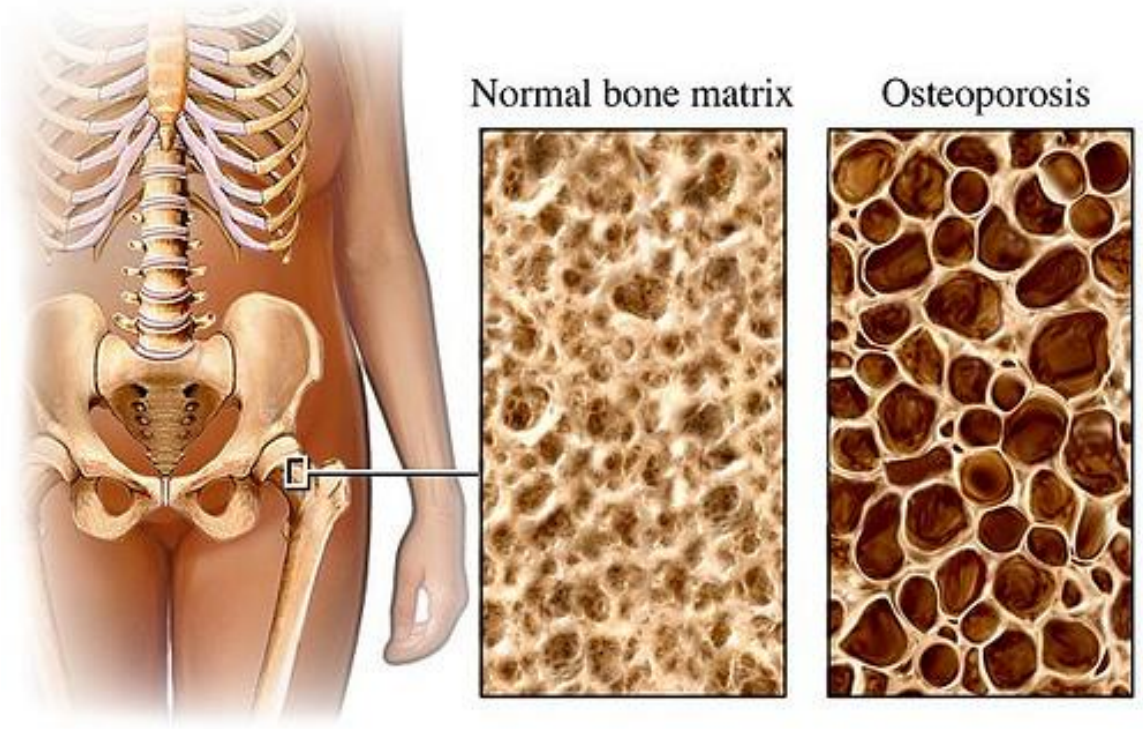


Atrofia kości i mięśni



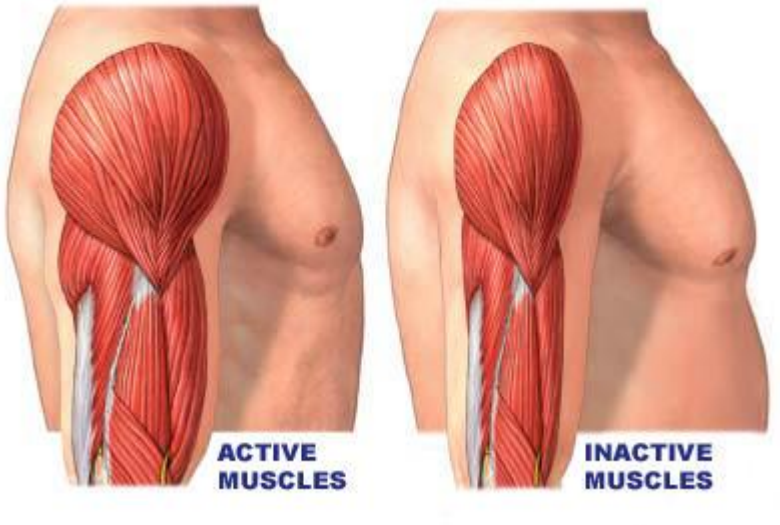
Challenges, concerns and common problems: physiological consequences of spinal cord injury and microgravity,
J M Scott, D E R Warburton, D Williams, S Whelan and A Krassioukov, Spinal Cord **49**, (2011) 4-16.

Atrofia kości



Ubytek masy kostnej i osłabienie struktury przestrzennej kości
http://www.thehealthage.com/2012/05/osteoporosis-bone-loss-detected-earlier-nasa/

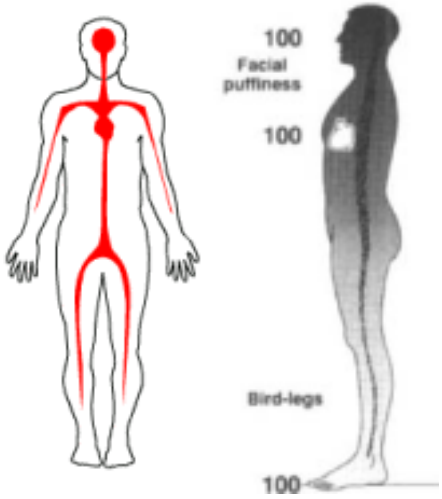
Atrofia mięśni



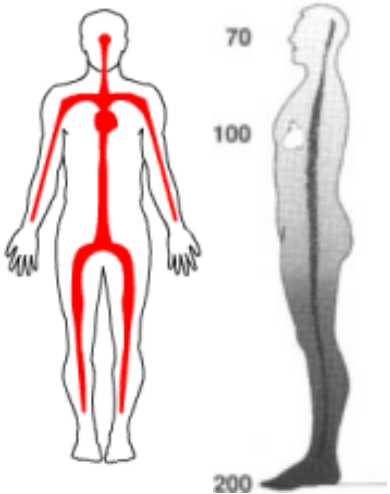
Astronauci tracą do 20% masy mięśni w czasie pobytu w przestrzeni kosmicznej

Przemieszczenie krwi

Mikrograwitacja



Przed lotem



Po powrocie

Monitorowanie powstawania kamieni nerkowych

- Wzrasta szybkość filtracji nerek w wyniku utraty masy kości
- Kamienie nerkowe mogą już obecnie być wykryte w czasie misji kosmicznych za pomocą Advenced Diagnostic Ultrasound in Microgravity (ADUM).
- MRI będzie istotnie łatwiejszy w użyciu dla astronautów
- Znacznie krótszy czas szkolenia

Plany wyprawy załogowej na Marsa

April 15, 2010 President Barack Obama w głównym przemówieniu o polityce dotyczącej przestrzeni kosmicznej w Kennedy Space Center on, U.S.:

By the mid-2030s, I believe we can send humans to orbit Mars and return them safely to Earth. And a landing on Mars will follow. **And I expect to be around to see it**.

The United States Congress has mostly approved a new direction for NASA: asteroid exploration in 2025 and orbiting Mars in the 2030s

Mapa drogowa NASA

Mapa drogowa NASA badań prowadzonych na ludziach określa 15 dyscyplin

Dyscypliny relewantne do projektu:

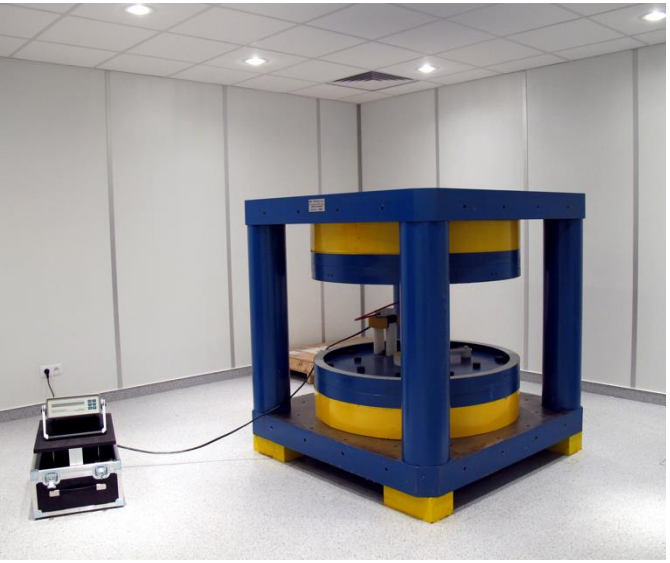
- Zdrowie ludzkie i środki zaradcze
- Zdrowie behawioralne i wydajność
- Zdrowie radiacyjne
- Autonomiczna opieka medyczna

Problems with Weight and Size

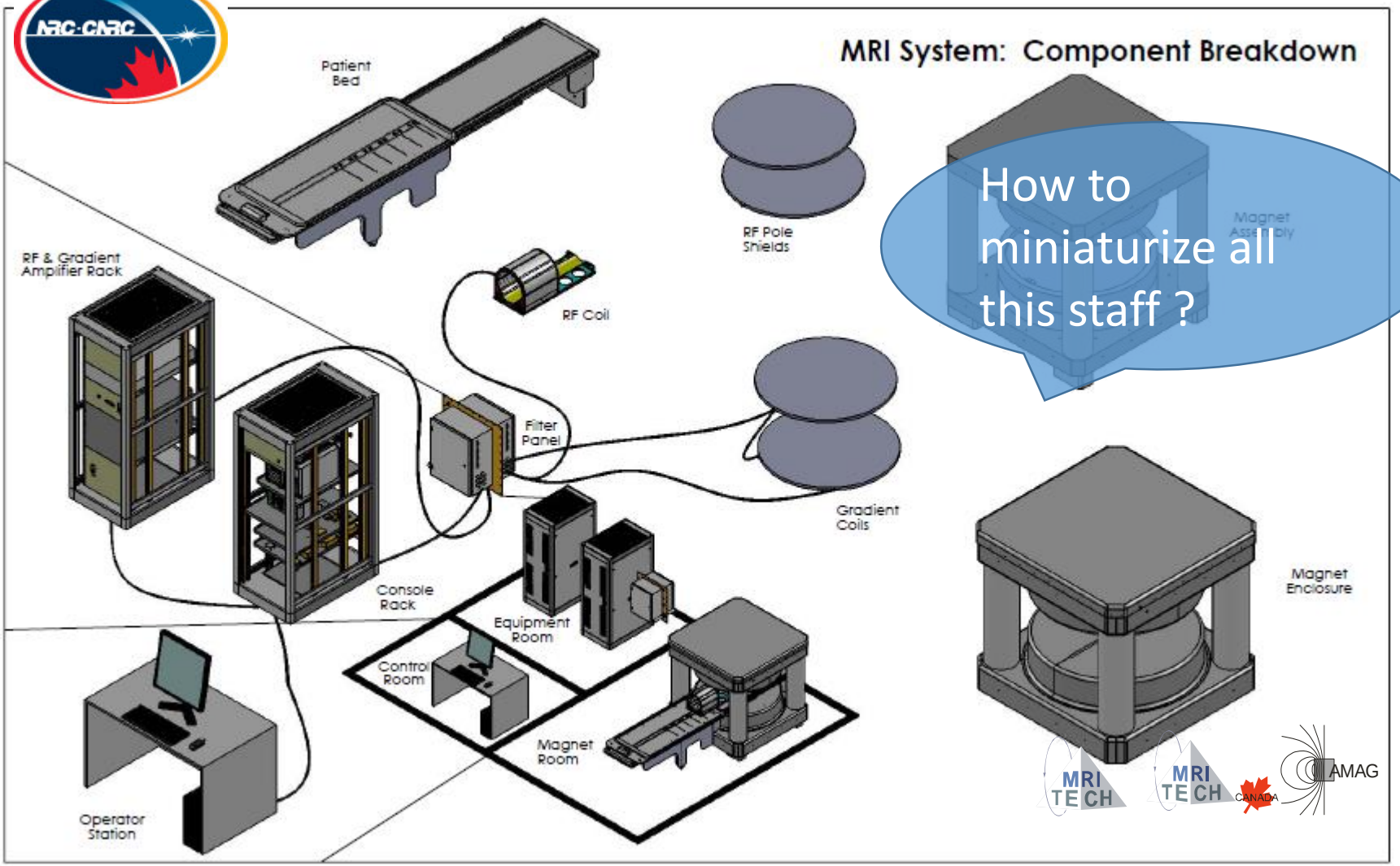
1,5 T, 3 t

0,35 T, 16 t

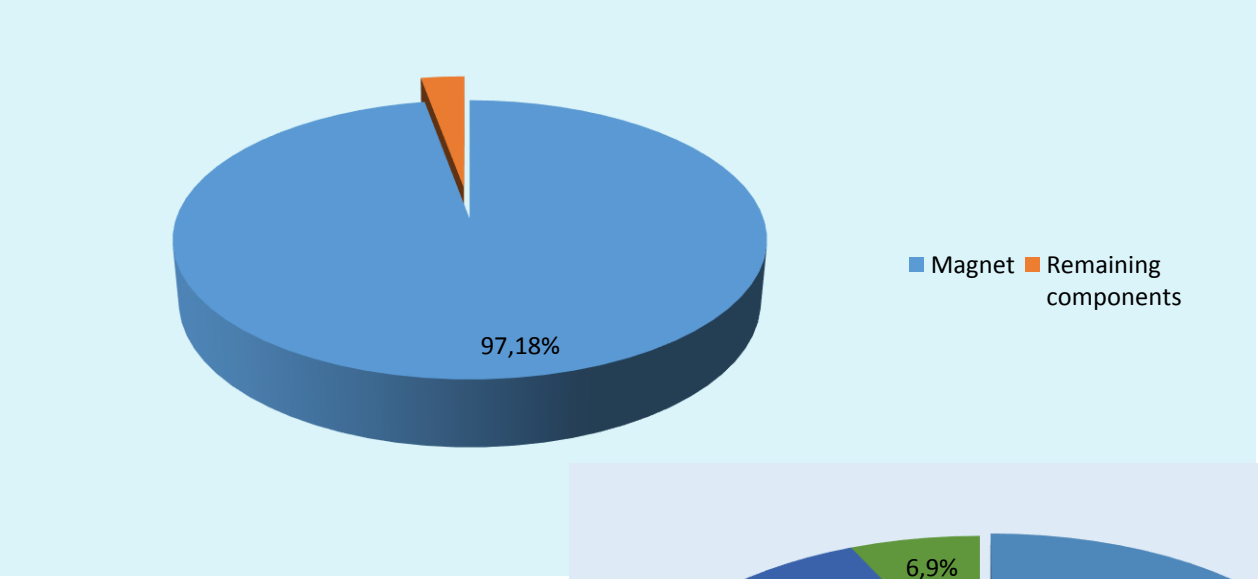
System Cirrus Open 0.2 T

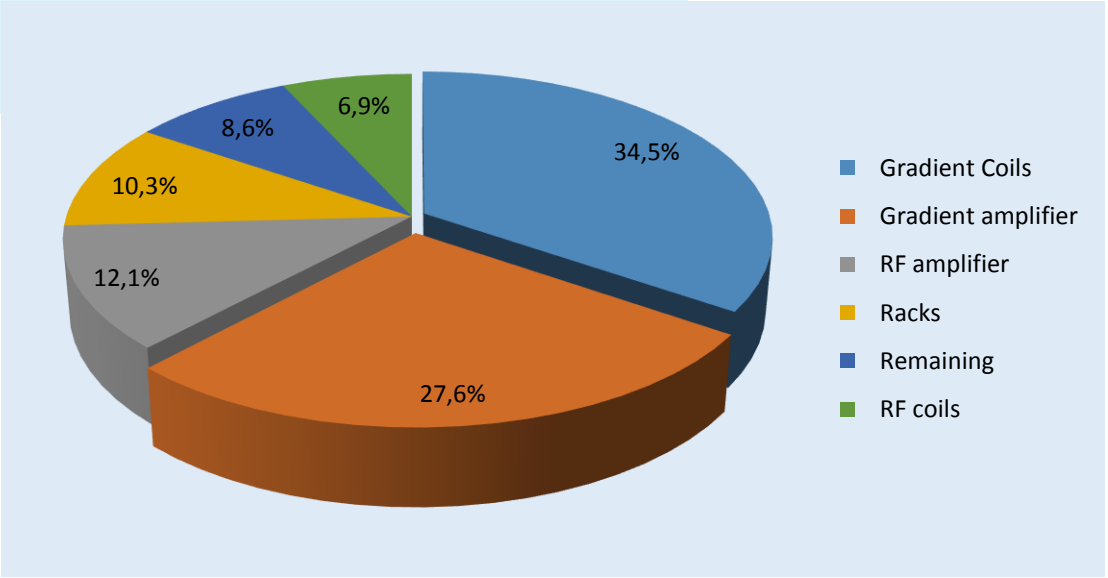


Components of MRI System



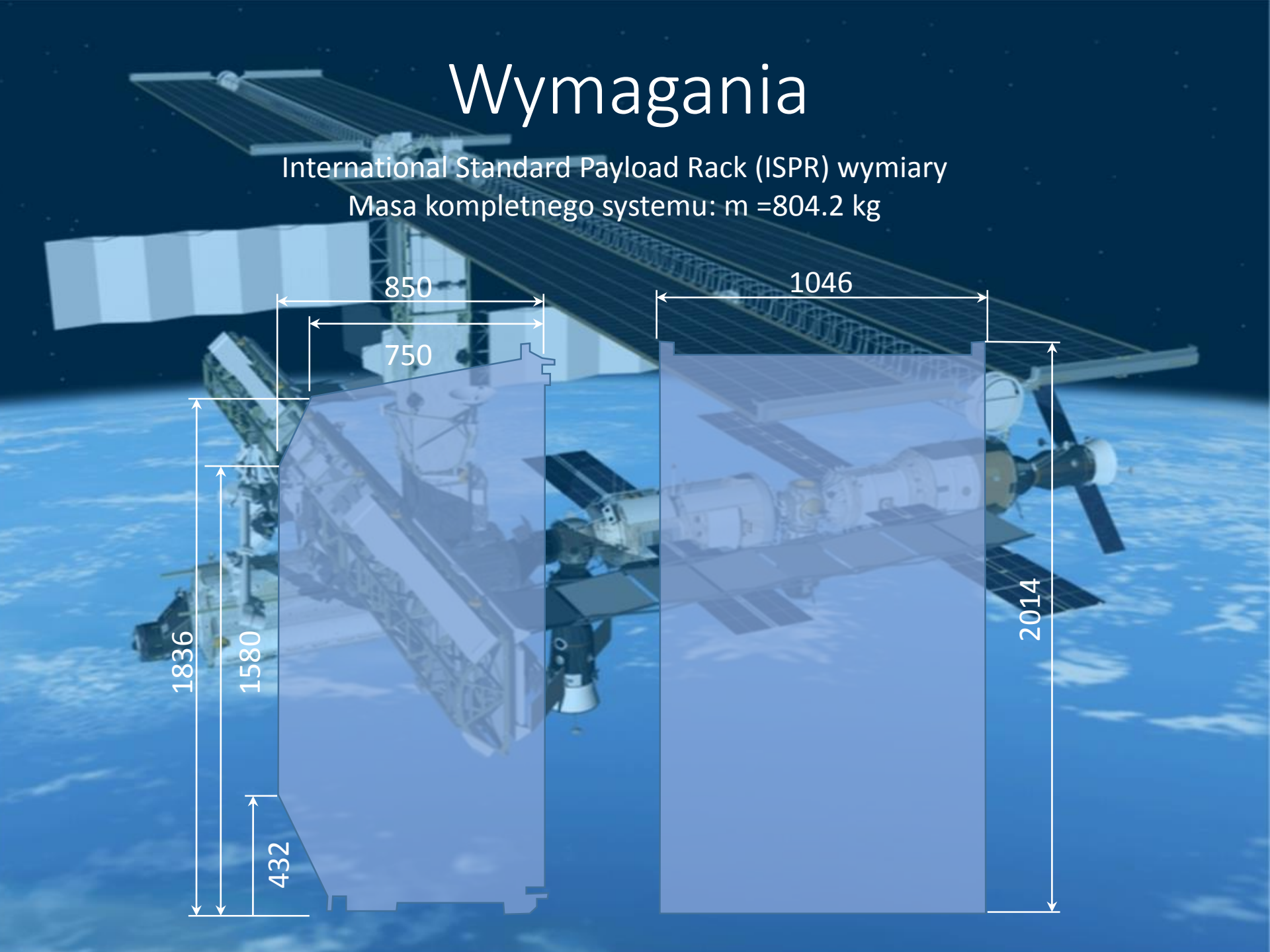
Problems with Weight and Size



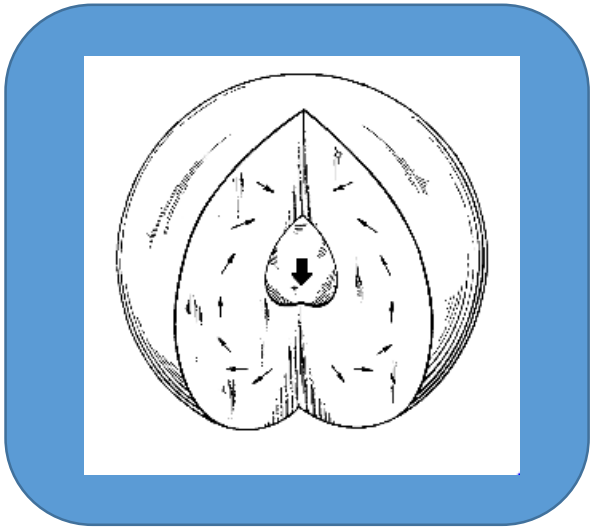


Wymagania

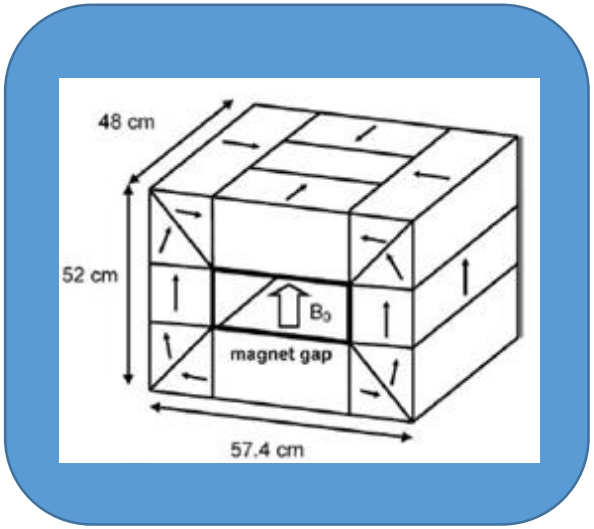
International Standard Payload Rack (ISPR) wymiary
Masa kompletnego systemu: m =804.2 kg



Current State of Art
Compact Mouse MRI

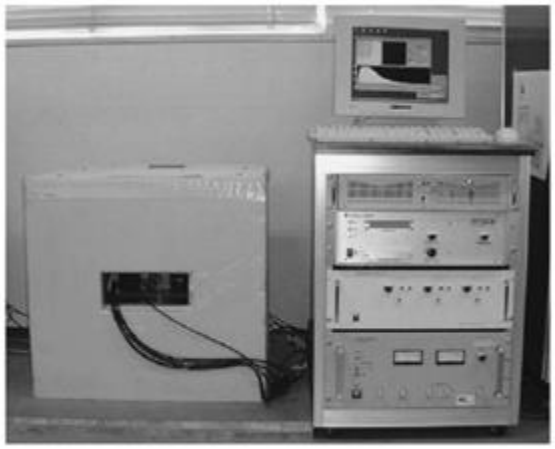


Hollow spherical flux source
Invented by H.A. Leupold 1988



Modyfication of the spherical structure for MRI application by NEO-MAX Co., Ltd. Japan
1 T magnet

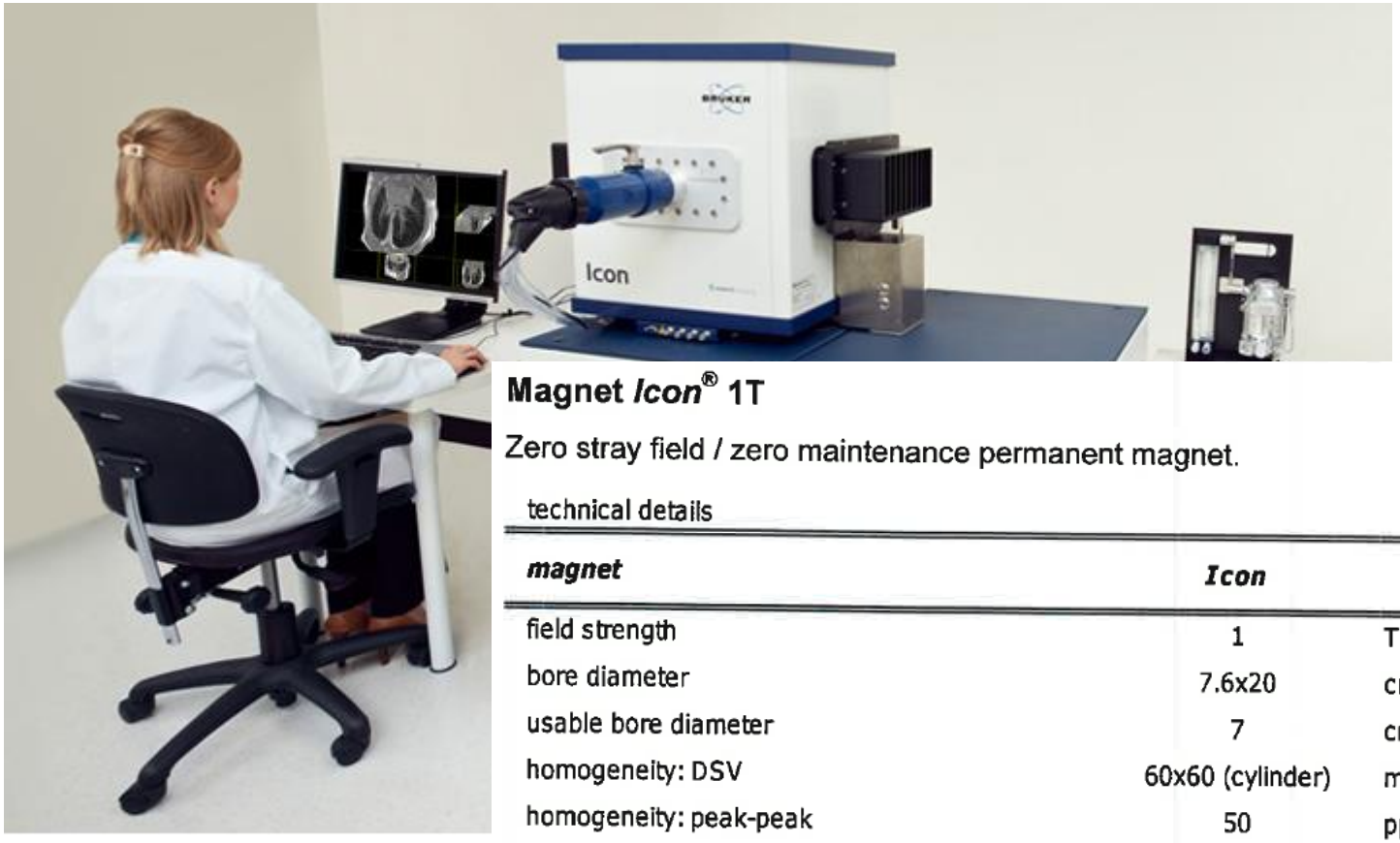
Current State of Art Compact Mouse MRI



B_0	1 T
Homgeneity over 30 mm DSV	10 ppm
Cylindrical imaging volume	3.5 cm (Diameter) x 5 cm (Length)
Size	57.4 cm (W) x 52 cm(H) x 48 cm (D)
Bore size	24 cm (W) x 9 cm (H) x 48 cm (D)

Shirai, T., et al. (2005). "Development of a compact mouse MRI using a yokeless permanent magnet." Magn. Res. Med. Sci. 4: 137 - 143.

Current State of Art. Bruker's Icon 1 T



Magnet *Icon*® 1T

Zero stray field / zero maintenance permanent magnet.

technical details

magnet	***Icon***	
field strength	1	T
bore diameter	7.6x20	cm
usable bore diameter	7	cm
homogeneity: DSV	60x60 (cylinder)	mm
homogeneity: peak-peak	50	ppm
stray field. center to 0.5 mT (lateral)	<0.7	m

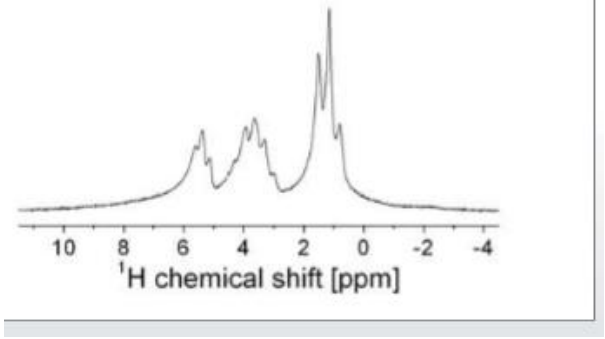
201104A

➢ *Peak-to-peak homogeneity specification including RT shims*

Current State of Art
Wrist MRI

Current State of Art
Magtritek's Compact MRI

Technical Specifications	
Operating frequency	20 MHz / 0.5 Tesla
Sample tube diameter (OD)	40 mm
Sample length	Clear bore
Field uniformity	< 1 ppm
Gradient coils	Active shielded - 0.25 T/m
Magnet weight	100 kg
Magnet dimensions	cylinder: ø = 30 cm length = 40 cm



Current State of Art Extremity MRI

GE Optima MR430s 1.5 T (superconducting)

Esaote O scan 0.35 T (permanent)

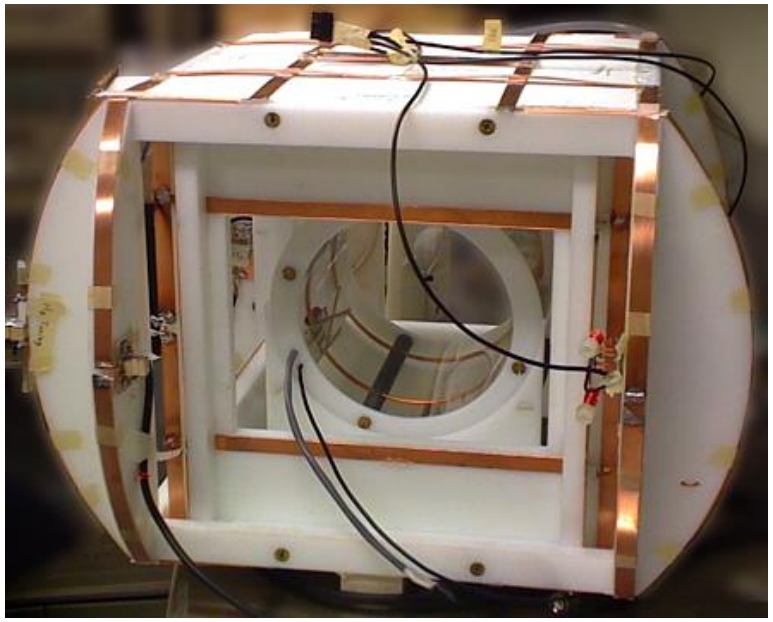
Rozwiązanie problemu

Kombinacja trzech istniejących technologii:

- Technologia TRACE MRI rozwinięta w IBD NRC
- Halbach MRI magnet developed by AMAG, Kraków
- Miniature RF amplifiers

G.E. Sarty, J. Sharp, B. Tomanek, K. Turek, A. Obenaus, A. Scott, L. Piche, S. Kontulainen, P. Chilibeck, J. Farthing, A. Baxter-Jones, R. Pierson, "**A Magnetic Resonance Imager for the International Space Station**", International Astronautical Federation, 63rd International Astronautical Congress, Naples, Italy, October 1-5, 2012.

TRansmit Array Spatial Encoding (TRASE) MRI



New method of spatial encoding using B_1 gradients produced by special RF coils

Sharp J.C., King S.B., Deng Q, Volotovskyy V. and Tomanek B., High-resolution, MRI encoding using radiofrequency phase gradients, NMR Biomed. 26 (2013) 1602-1607.

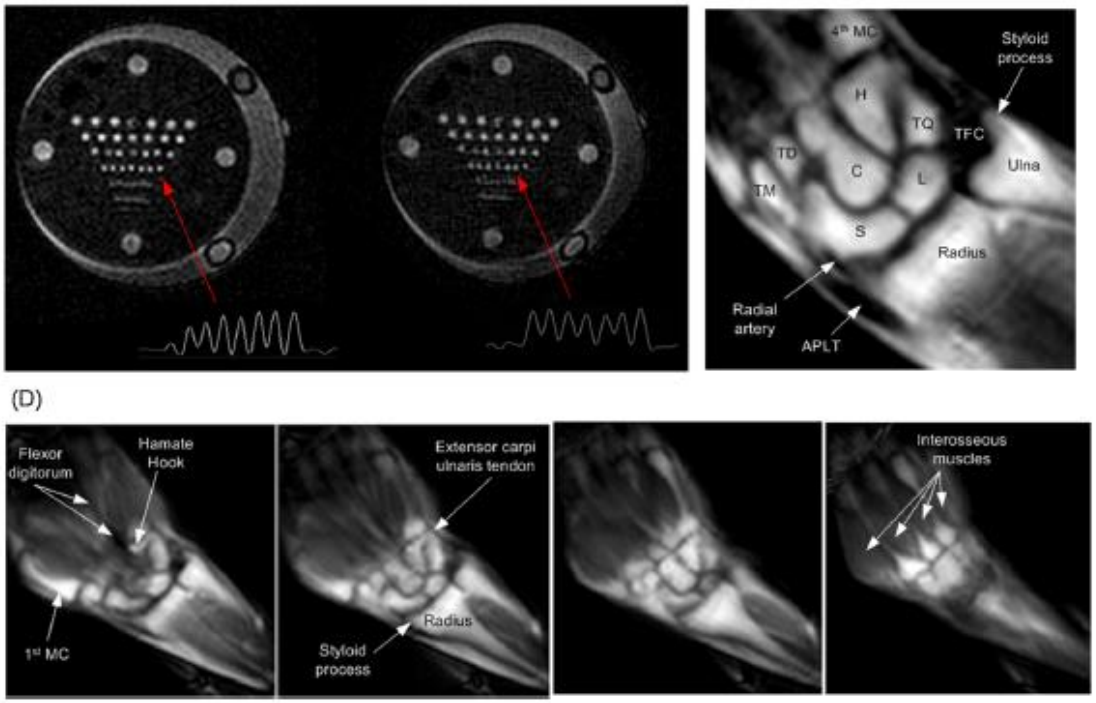
TECHNOLOGY

A cheaper, quieter MRI machine

Magnetic resonance imaging (MRI) is expensive, noisy and requires bulky equipment. It can also have side effects, such as stimulating nerves in patients. These problems arise from the constant switching between positive and negative magnetic-field gradients used to manipulate the spin of hydrogen nuclei throughout the patient's body. The energized nuclei produce radiofrequency signals, which carry the information used to build up an image.

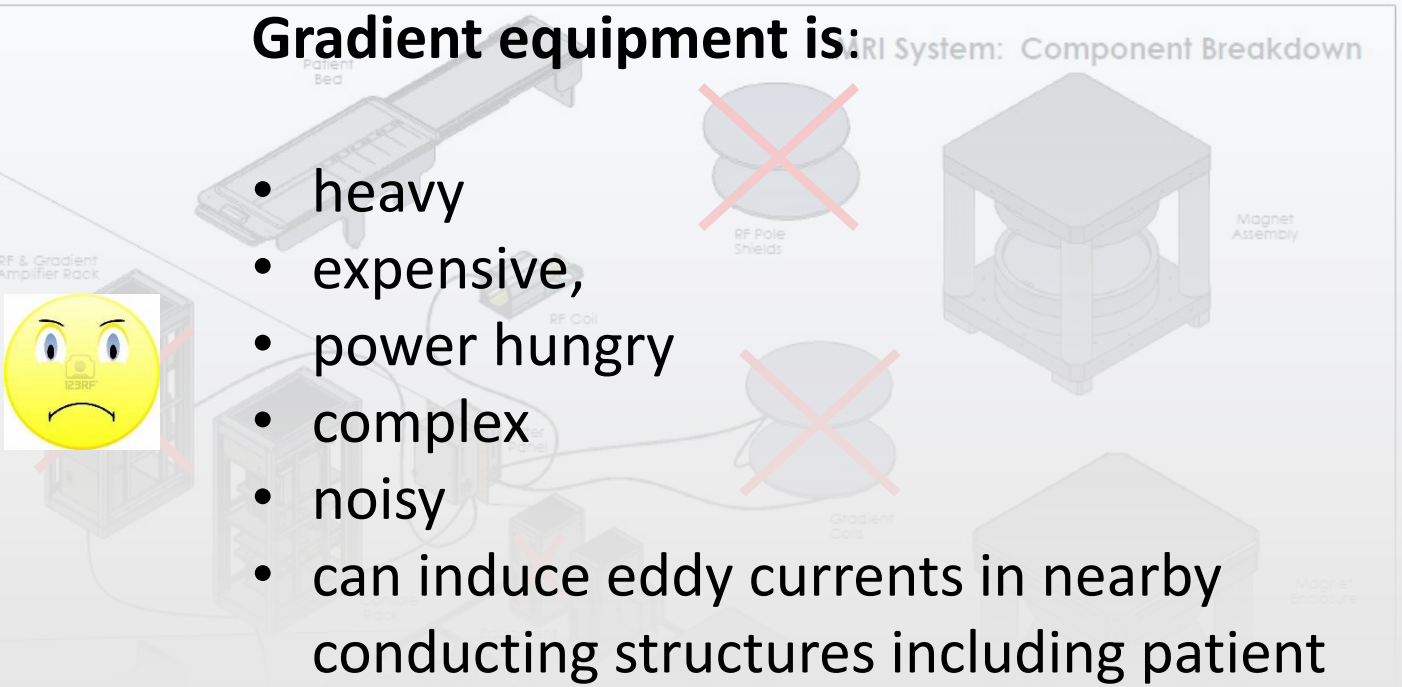
By exploiting the radiofrequency pulses used to prepare the nuclei, Jonathan Sharp at Alberta Innovates Technology Futures in Calgary, Canada, and his colleagues removed the need for switched magnetic fields. Instead, they manipulated the nuclei using pairs of resonant radiofrequency fields twisted in opposing directions and a static magnetic field. The technique could make MRI cheaper, accessible and quieter. ***NMR Biomed.*** **http://doi.org/nqf (2013)**

TRACE MRI - Obrazy



Sharp J.C., King S.B., Deng Q, Volotovskyy V. and Tomanek B., High-resolution, MRI encoding using radiofrequency phase gradients, NMR Biomed. 26 (2013) 1602-1607.

Effect of Utilizing TRASE Technology

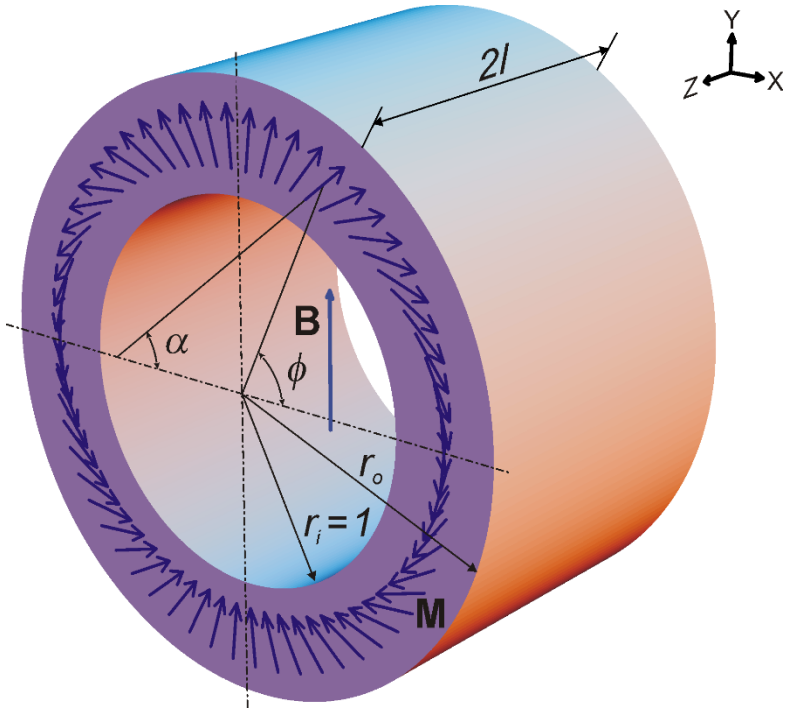


Gradient equipment is:

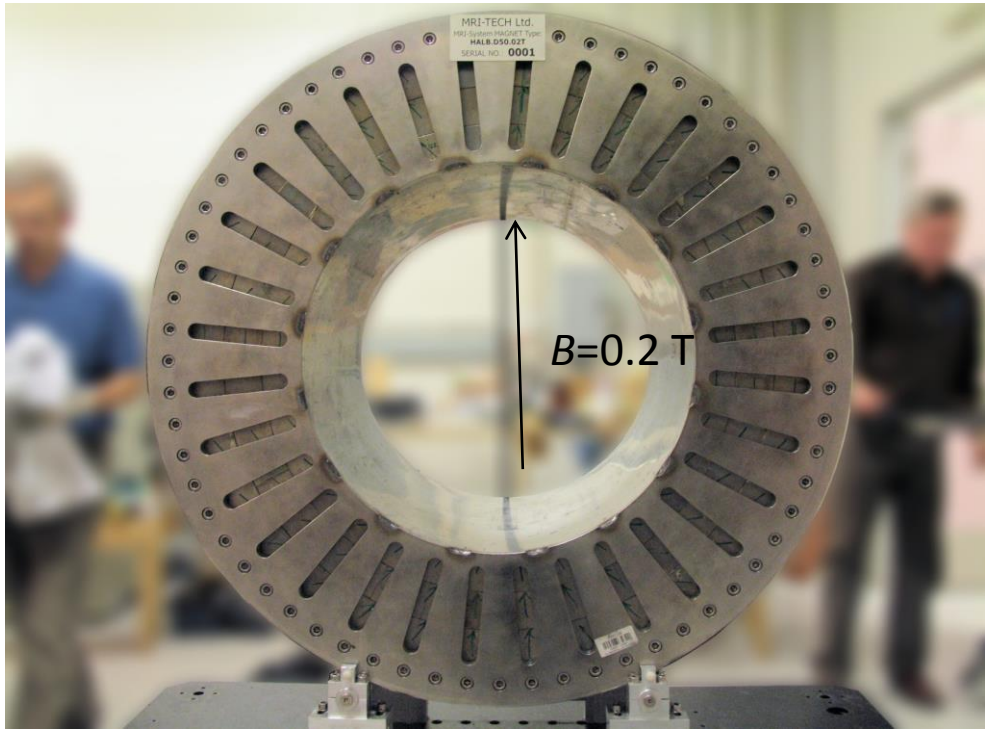
- heavy
- expensive,
- power hungry
- complex
- noisy
- can induce eddy currents in nearby conducting structures including patient

Fortunately it can be eliminated !!!

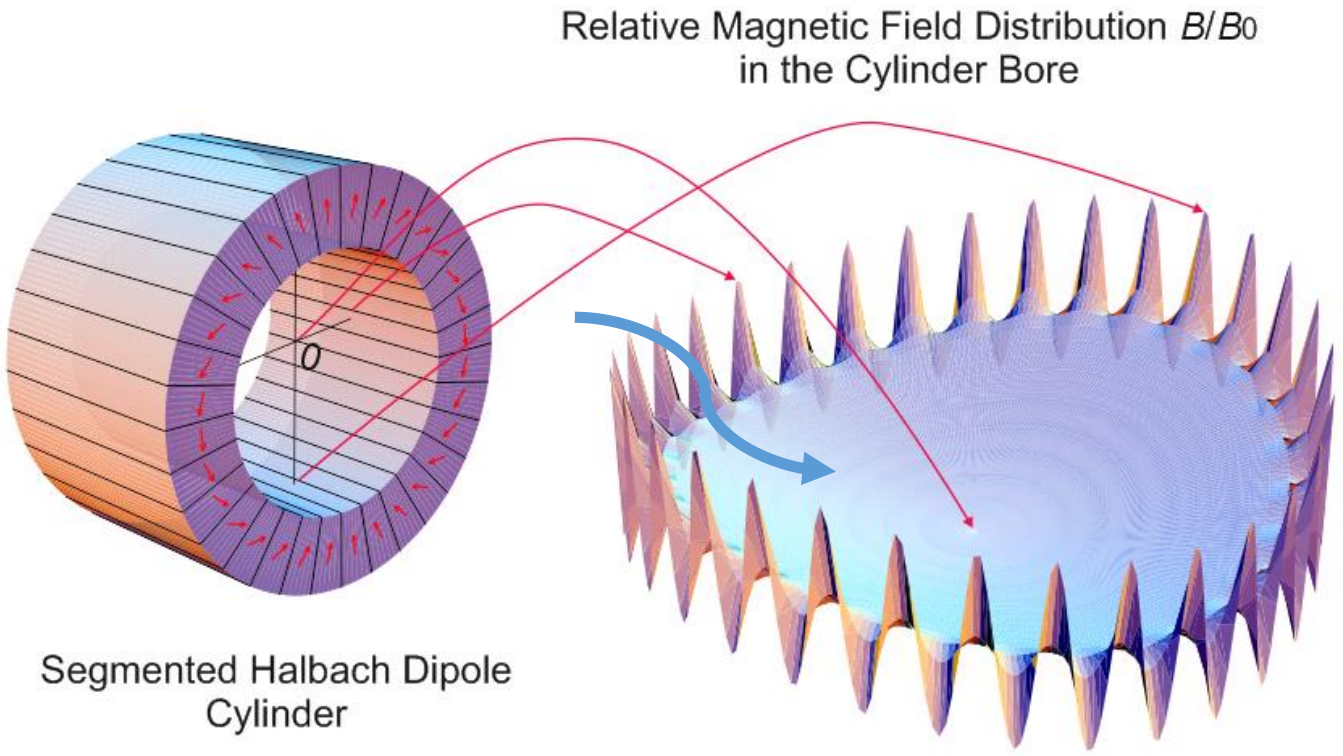
Halbach Magnets



$$\pi - \alpha = 2\phi$$



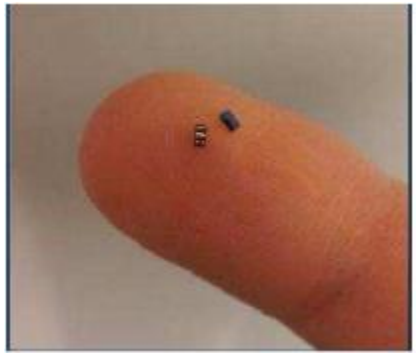
Mathematical Framework



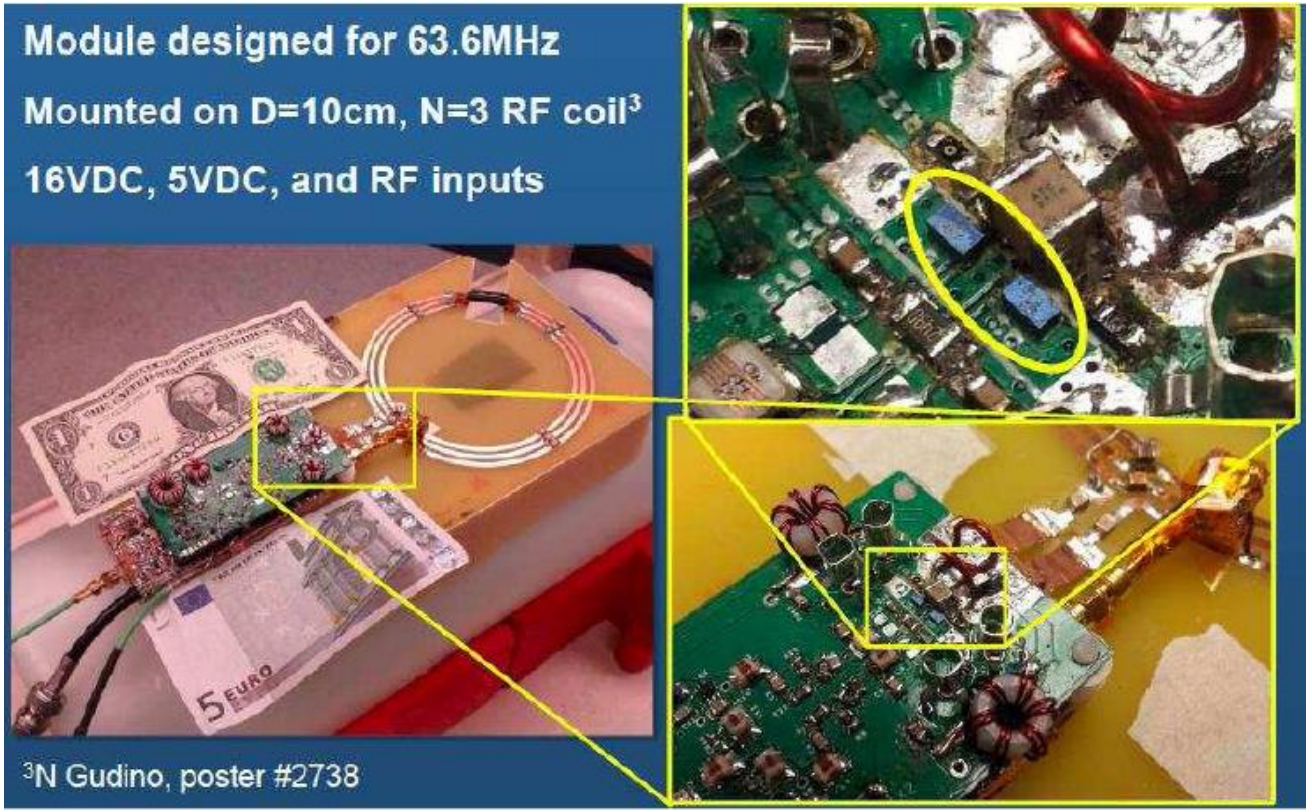
1. K. Turek, P. Liszkowski, Surface charege contribution to the 3D magnetic field in Halbach dipole cylinders (submitted to IEEE Mag.).

*2. K. Turek, P. Liszkowski, Perturbations of homogeneity of magnetic field generated by finite Halbach dipole magnets, JMR, **238** (2014), 52-62.*

Miniature RF amplifiers technology



The heart of the amplifier, eGaN FETs from EPC Corporation



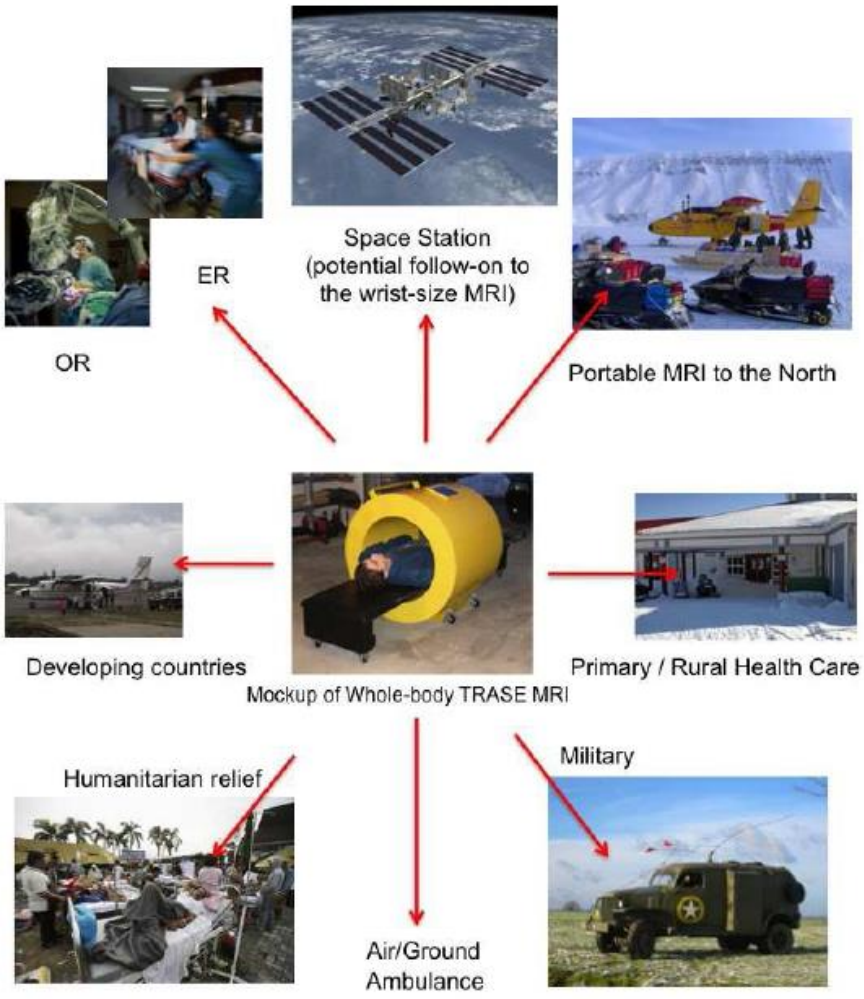
M. Twieg, M. J. Riffe, N. Gudino and M. A. Griswold, Enhancement Mode GaN (eGaN FETs for On-Coil MRI Transmitt Amplifiers, Proc. Int. Soc. Mag. Reson. Med. 21 (2013)

The amplifier as applied to a conventional MRI RF coil

Obecny status projektu

- Grudzień 2013 CSA przyjmuje ofertę sprzedaży Jej Wysokości Królowej Kanady studium wykonalności sytemu MRI nadgarstka do badań na ISS.
- Obecnie (10.01.2014) studium wykonalności projektu jest w fazie realizacji.

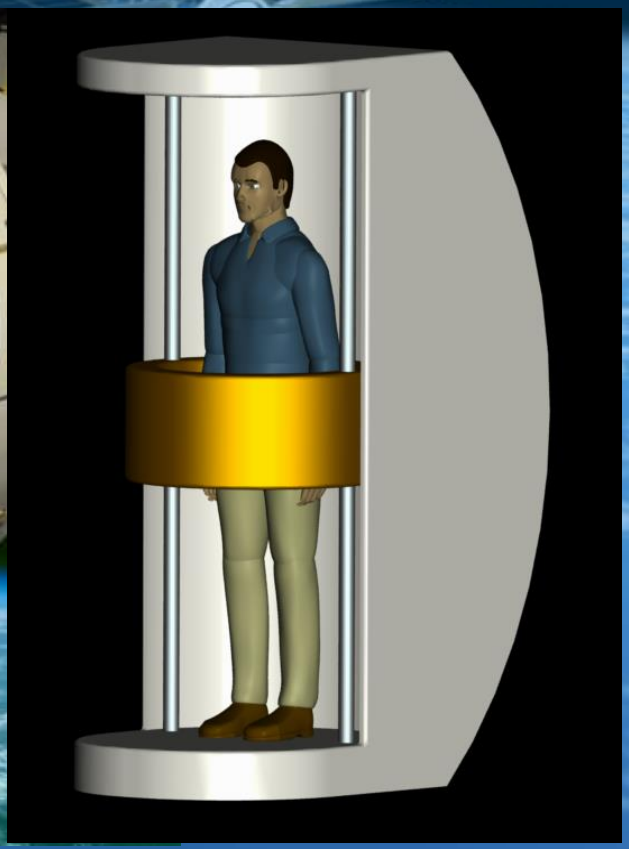
Z przestrzeni kosmicznej na ziemię



ER – Emergency Room
OR- Operating room

Autor rysunku: Gordon Sarty

Vision of the Space MRI Scaner



Dziękuję z uwagę