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Exploration Spaceflight; Health in Space needs for Health on Earth benefit

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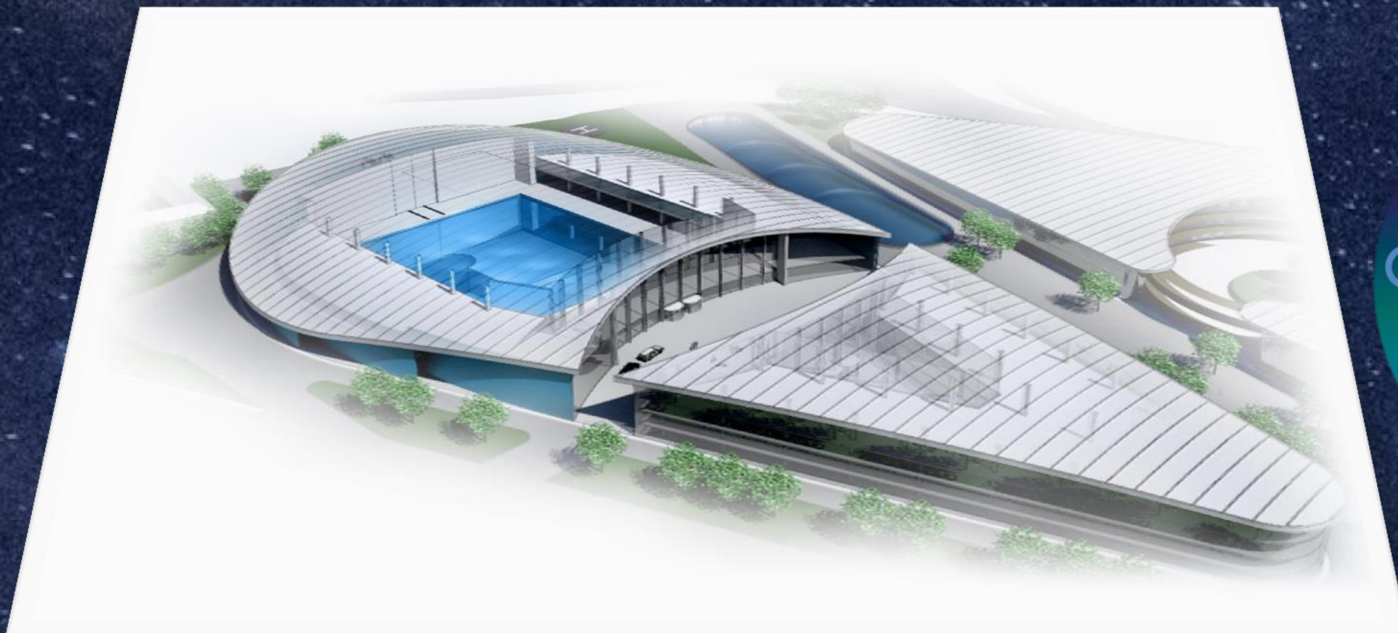


SeaSpace Research Ltd

UK Space L.A.B.S

UK Space Environments Association

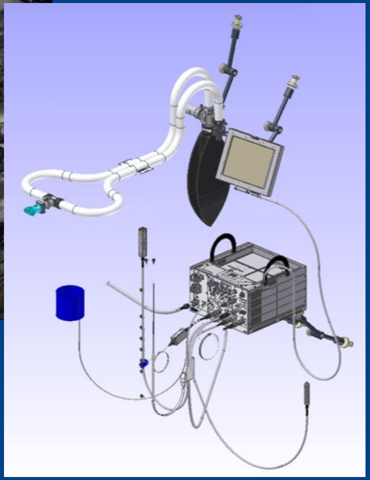
HuSCO
Human Spaceflight Capitalisation Office

www.community.space-environments.co.uk

Government Astronaut Health Support Today

Space Agency 'medical support'

- Medical Operations Teams
- Space Life Science R&D
- Mission Operations Teams



European Astronaut Centre

Space Medicine Office

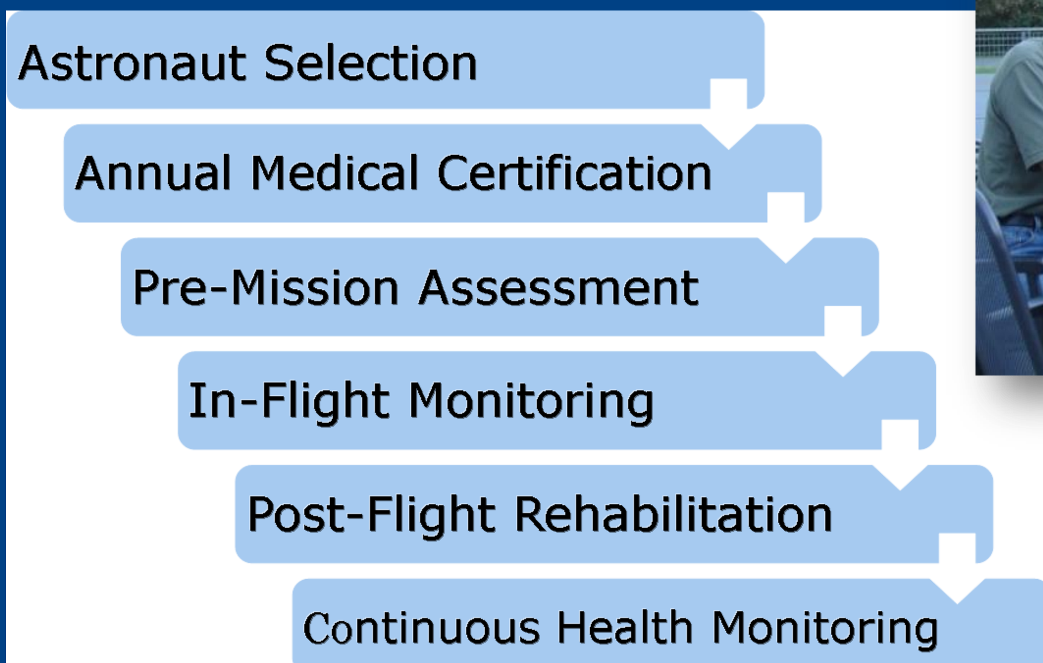
Head: Dr Guillaume Weerts

The Space Medicine Office comprises space medicine experts from a variety of health related fields whose task is to **ensure the physical and mental health of ESA astronauts** to help them be productive and thrive in the harsh environment of space.

3 Units ….

Medical Operations Tasks

- **Prevention**: Ensure that astronauts remain fit & healthy even when not assigned to a mission.
- **Certification**: Annual medical exams for astronauts to obtain the flight certification required to remain eligible for mission assignment.
- **Health monitoring and management**: Personal physician for each astronaut from mission assignment to after post-flight rehabilitation.



Operational Space Medicine Unit

Five/six physicians (Flight Surgeons) supported by a ‘Flight Nurse’ responsible for ESA astronaut health.

Pre-Flight Activities

- Astronauts’ **mission medical certification** in collaboration with clinical and environmental specialists.
- FS joins astronauts in the two-week **pre-flight quarantine**, providing healthcare until launch.

In-Flight Activities

- **Monitor** crew health and performance
- Ensure balanced work/rest **schedules**
- **Sleep and exercise** regimens
- Weekly **Private Medical Conferences** with the crew member

Operational Space Medicine Unit

Post-Flight Activities

- Provide primary care to the crew member **on landing** the space vehicle through to completion of r**ehabilitation**.
- Overall coordination of the rehabilitation team and specialist clinical treatments/assessments **until pre-flight health status** has been established.

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/ Engineering and Operations Support Unit

The team of ESA Biomedical Engineers (BME) are integrated in to the **global ISS control centre network**. They represent **ESA Medical Operations on console** during ISS real-time operations and act as **eyes and ears of the Flight Surgeons**.

BME Real Time Operations Activities

- Point of contact for medical related **questions** and information affecting ESA crew
- **Plan and implement a coherent mission** tailored to each ESA crew member
- Monitor **ISS environmental parameters** and mitigation steps
- **Inform ESA Flight Surgeon about off-nominal** situations with (potential) medical impact
- Coordination of regular **crew video/audio conversation** to family, doctor, psychologist, and exercise specialist

Medical Projects and Technology Unit

Medical Projects

- Managing ESA Astronaut health related hardware projects (e.g. health assessment devices, exercise devices)
- Liaising with the Life Science domain

Exercise and Countermeasures

- Pre-, in- and post-mission exercise and countermeasures support
- Monitoring of fitness level and prescription of training regime
- Annual astronaut fitness assessment and performance analysis

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Medical Projects and Technology Unit

Information Technology

- Providing and maintaining the SMO IT requirements
- Providing a central internet platform for collaboration with international partners
- Developing tools for effective information exchange

Medical Education

- Coordinating the continuing education and certification of the Space Medicine Office staff
- Managing the provision of space medicine expertise to education programmes eg Kings Space Health MSc
- Managing internship programme for university and school students

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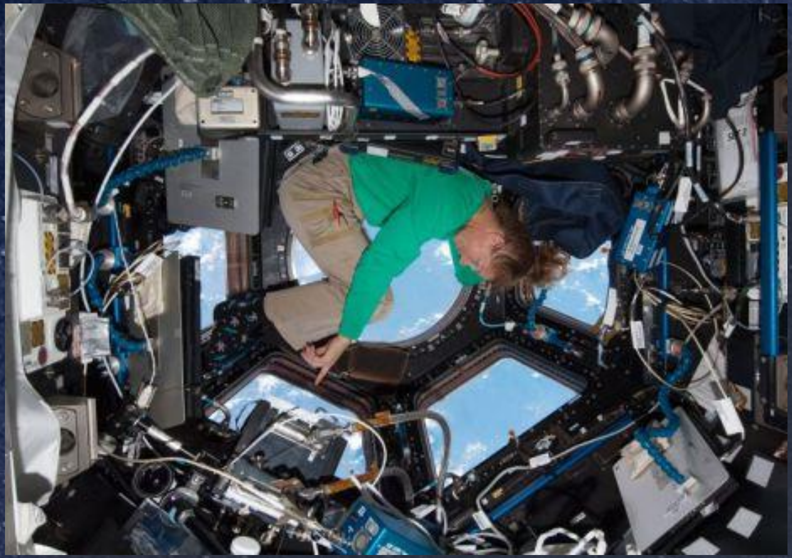
Constraints of the space environment

The constraints upon R&D, operations, equipment and procedures =

cost of getting in to space + extreme environment

1. Equipment and apparatus must have a small mass, volume and footprint.
2. Consumables must have long shelf lives.
3. Hardware must have low power consumption.
4. Hardware requires low and simple maintenance requirements.
5. Procedures must be simple so as to take the minimum amount of time.
6. Hardware must be durable and robust.
7. Everything must work in a microgravity and high radiation environment.



In no other sphere of civilian human endeavour are restrictions as severe as those encountered in space.

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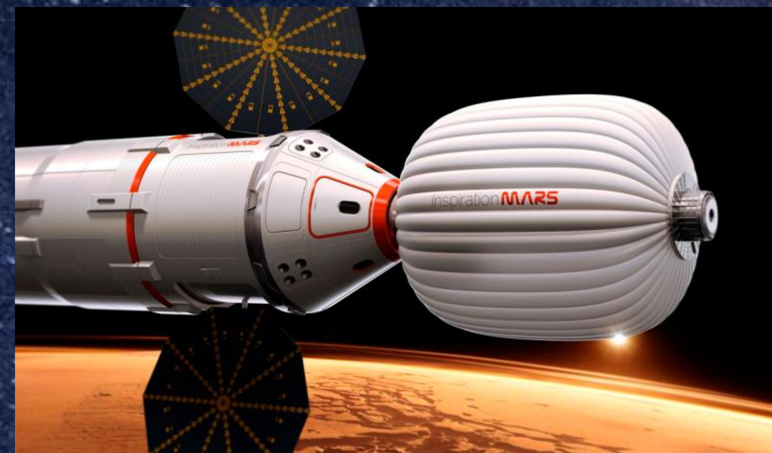
The coupling of ‘need and constraint’ drives innovation!

Challenges of deep space exploration

1. Distance
2. Isolation & confinement
3. Poor access to;
    - Expertise
    - Supplies
    - Equipment/facilities
4. Deconditioning?
5. Danger?



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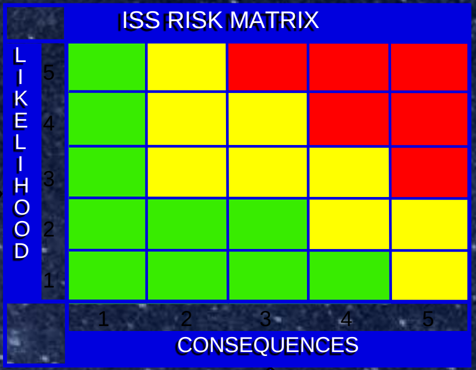
ISS PROGRAM RISK SUMMARY CARD

Likelihood Rating		
5	*Very Likely*	*Expected to happen in the life of the program* *Controls are missing or insufficient*
4	*Likely*	*Likely to happen in the life of the program* *Controls have significant limitations or uncertainty*
3	*Possible*	*Could happen in the life of the program* *Controls exist, with some limitations or uncertainty*
2	*Unlikely*	*Unlikely to happen in the life of the program* *Controls have minor limitations or uncertainty*
1	*Highly Unlikely*	*Extremely remote possibility that it will happen in the life of the program* *Strong controls in place*



Mitigation

- **High – Implement new process(es) or change baseline plan(s)**
- **Medium – Aggressively manage; consider alternative process**
- **Low – Manage within normal processes; monitor**

Consequence Rating	*1*	*2*	*3*	*4*	*5*
Mission Success / Operational Performance	Minor or no impact to mission objectives Nominal Execution of Mission Minor reduction in performance Minor or no impact to design or operating margins	Failure to meet any single mission objective Operating in a degraded state Moderate reduction in performance Can handle within design or operating margins Damage to non-critical system, element, ground facility, function, or emergency system	Significant impact to mission objectives Operational Workarounds available Significant reduction in performance Significant loss of design or operating margin Loss of any non-critical system, element, ground facility, or function Loss of emergency system	Loss of multiple mission objectives Major increase in operations timelineor s complexity Major degradation in performance Loss of all design or operating margin Damage to critical system, element, ground facility, or function Planned De-Crewing	Loss of entire mission No alternatives exist Loss of ISS or any critical system, element, major ground facility or function ISS in a condition which prevents rendezvous/docking operations Emergency Evacuation
Safety	*No injury*	Minor injury, minor illness	Significant or long-term injury, illness, impairment Non-disabling injury	Permanent injury, impairment or incapacitation	*Loss of Life* Disabling injury
Cost *- Score by cost of mitigating risk*	*Minimal impact (<$100K) or* *0 to 2.5% increase*	*Moderate impact ($100K up to $1M) or* *2.5% to 5% increase*	*Significant impact ($1M up to $10M) or* *5% to 7.5% increase*	*Major impact ($10M up to $50M) Or* *7.5% to 10% increase*	*Major impact (> $50M) Or >10% increase*
Schedule	*Minor or no impact*	*Can handle with schedule reserve, no impact to key project milestone or critical path*	*Project milestone slip* *No impact to Program critical path*	*Impact to Program milestone and/or Program critical path*	*Cannot meet program critical path milestone(s)*

Note: Risk management is a communication system where a *qualitative* score can help in understanding of a risk. This card is only a rough guide for determining a likelihood and consequence for a risk. Significant resources should not be spent scoring a risk. Score is relative to the risk's highest elevation, i.e. sub-org, Org, or Top Program Risk.

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Exploration Mission Impact on Healthcare Provision

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Healthcare Innovation for Space Exploration

Needs

- Maintenance of physician's skills over long periods
- Redundancy of medical skill sets
- Autonomous capability within team
- Robustness and resilience of capabilities and healthcare provision
  - In-house manufacturing and repair
  - Smart and expansive knowledge database
- Functional (personalised) healthcare

- Prevention and preparation …

→ needs require innovation!

/ Human Spaceflight healthcare innovation example

- **Historic – Skylab medical need.**

- Inflight Medical Support System – ability to deal with the injuries/illnesses most likely to occur in Skylab.
- Including the capability to take blood samples for routine monitoring and scientific investigation for 3 crew over weeks/months.

Many 60 ml samples needed - could not be returned immediately to Earth – high constraints on storage and return.

The need existed for the quantity of blood taken for each sample to be reduced by an order of magnitude!

Human Spaceflight healthcare innovation example

- **Historic – Skylab medical need.**

R&D effort lead to 6 ml samples being possible

1. Neither the ‘need’ nor the ‘constraints’ existed on the ground!
2. But terrestrial medicine gained significant benefit due to this coupling of factors in space.

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/ Space and terrestrial <u>deconditioning</u>

'Space' de-conditioning of the body = Parallels with ageing!

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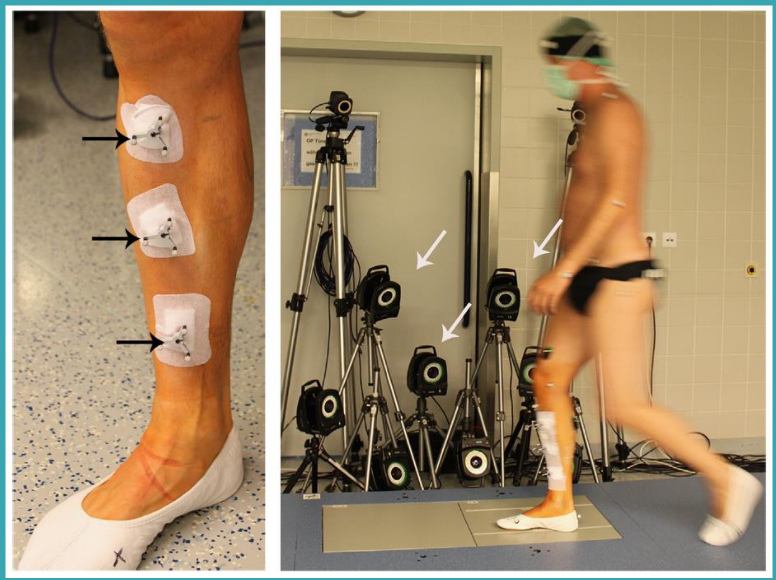
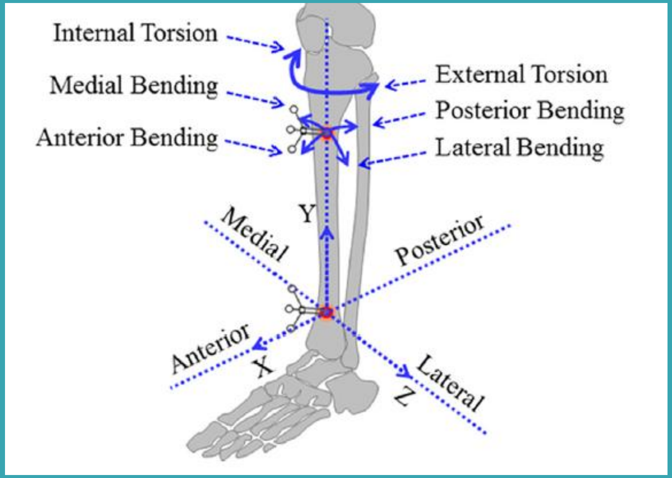
Current HSF Healthcare R&D Examples

Bone stimulation – not just direct loading



- Yang et al through in vivo force measurement during locomotor activities were able to note the significance of torsion and bending as bone stimuli.



- Thus we should shift our focus from simple loading magnitude to **loading patterns** in bone mechano-biology.
- The ‘form’ of exercise is as important as the ‘fact’ of exercise!

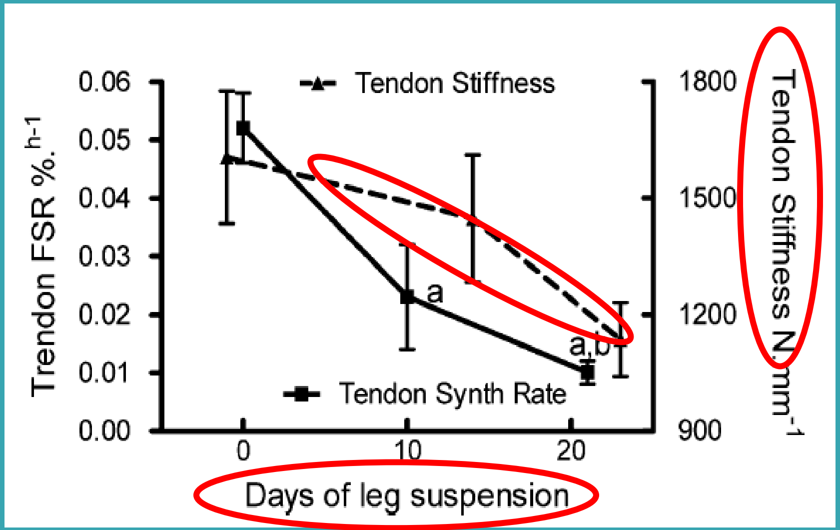
/ Muscle and Tendon deconditioning

- Time in space (or analogue simulation) leads to muscle atrophy and muscle fibre shortening.

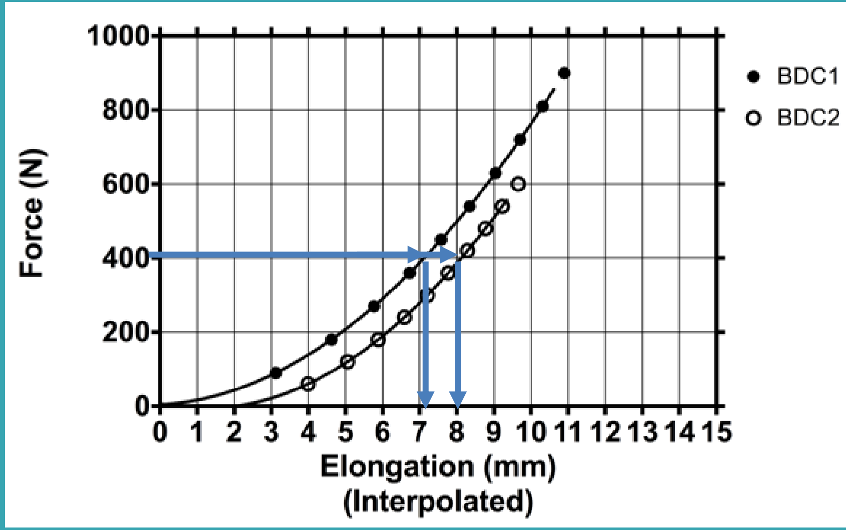
  Narici et al, 2002, Journal of Gravitational Physiology 9, 137P-138P.

- 90 d bed rest = increased tendon compliance

  Reeves et al, 2005, J Appl Phys 98, 2278-2286.



De Boer et al. *J Physiol* 585, 2007



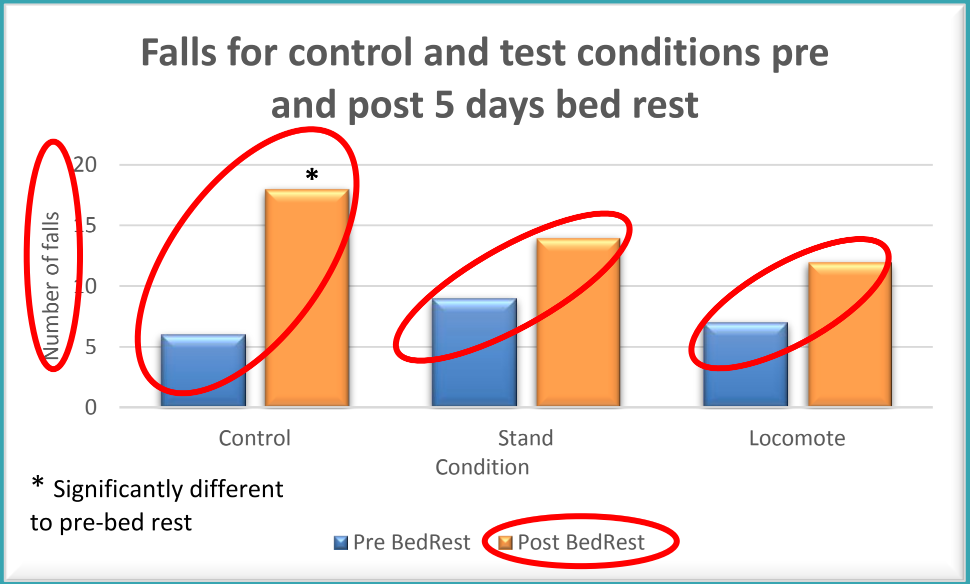
Tendon Elongation, Narici M

- Changes in muscle/tendon morphology will effect transmission of force.

Postural instability occurs after periods of bed rest.

- Postural instability occurs after periods of inactivity (bed rest).
- LeBlanc et al, 1997, Int J Sports Med;18 (Suppl 4):S283–5.

- Adoption of short periods of standing or simple locomotion type activity during periods of bed rest reduce postural instability when normal ambulation is resumed.
- Mulder et al, 2014, J Musculoskelet Interact, 14(3):359-366



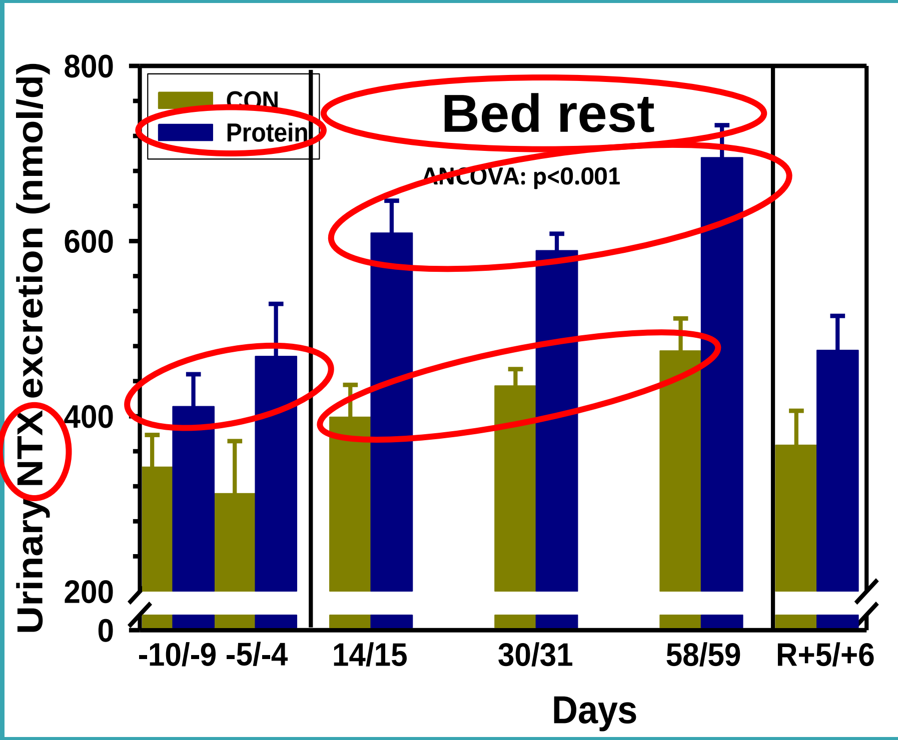
Falls due to postural perturbations (dynamic posturography) pre and post bed rest.

Mulder et al, J Musculoskelet Neuronal Interact 2014; 14(3): 359-366

Nutrition affects muscle and bone metabolism

- High protein intake during inactivity associated with increased bone resorption.

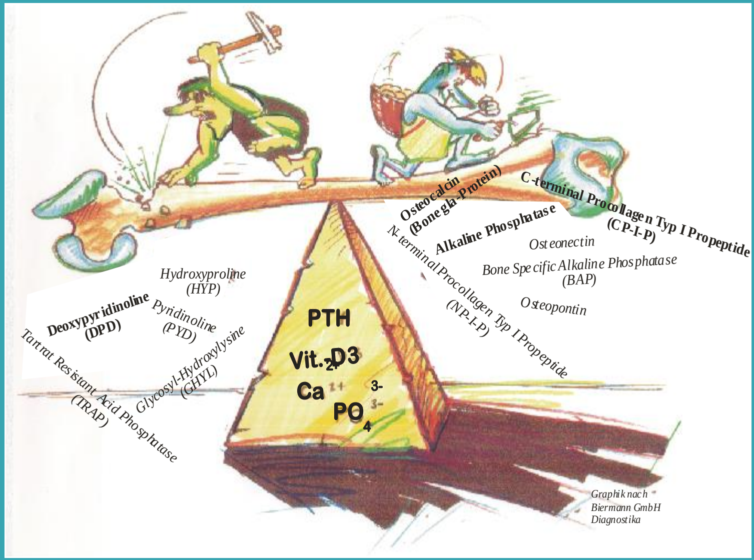
Smith et al, 2003, J Bone Miner Res, 18:2223-30



Increased NTX (bone resorption marker) with high protein diet in bed rest.
Heer et al, 2013, FASEB J; 27:615.15.

High protein intake can exacerbate bone resorption

- Need exists for high protein intake to counter muscle loss during inactivity.
  Kirk et al, 2010, Clin Nutr Metab Care, 13(1); 34-39
- Findings indicate that we can counter bone resorbing effect of high dose protein during inactivity with alkaline salt suplementation
  Heer et al, 2013, FASEB J; 27:615.15.
- Potential for high protein + alkaline supplements to aid muscle and bone maintenance during inactivity.



So to avoid deconditioning…

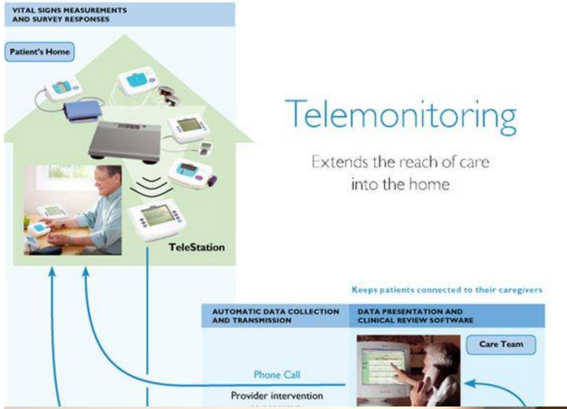
- **Appropriate 'form' of exercise to** optimise bone & muscle retention.
- We need to **find ways to avoid changes in muscle and tendon compliance** which affect transmission of forces to the bones.
- **Impose 'Gz stimulus'** to minimise postural instability.
- **Provide appropriate nutrition** for optimal bone and muscle maintenance during inactivity/best rest.
- This knowledge clearly **translates to terrestrial healthcare benefit** in an ageing society – nutrition, muscle, bone, balance.

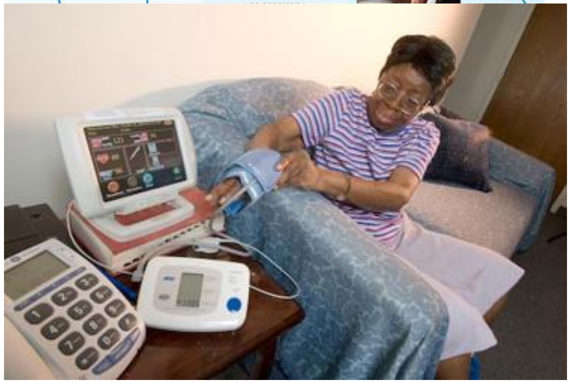
Preparing to meet tomorrow's Needs

- The R&D we do today must lead to innovation we can use tomorrow.
  …if we are to explore our solar system safely.
- We will need to be able to;
  - Maintain difficult to acquire skill sets
  - Conduct critical healthcare practices autonomously
  - Be self-sufficient and resilient
  - Access intelligent and expansive healthcare information databases

Space to Earth

- Many of the **products, capabilities** and much of the **knowledge** required for space exploration will directly **translate to the needs of an ageing society**.
  - Preventative medicine
  - Improve understanding of deconditioning and its prevention
  - Remote healthcare
  - Autonomous health monitoring and reporting
  - Robust and resilient biotechnology for use in the community





The New Space Age and the Age of Ageing

- A new age approaches for developed societies; one in which the percentage of the population considered elderly far exceeds that of today.
- But developed societies will not stop expanding the boundaries of our physical world and consequently space exploration will grow.
- So we must -
  - Embrace the constraints of space exploration to enable innovation that would otherwise not happen.
  - Harness the budgets and effort expended by the space medicine R&D to address the needs of exploring the solar system.
  - Collaborate to improve terrestrial healthcare AND enable space medicine.

New Space can help Old Age

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Thank you!

www.community.space-environments.co.uk

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FLY HIGH, DIVE DEEP

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