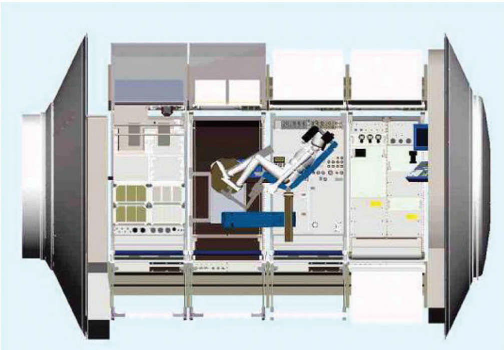
→ MARES

General-purpose instrument for (neuro-) muscular and exercise research on the International Space Station

The Muscle Atrophy Research and Exercise System - MARES is capable of assessing the strength of isolated muscle groups around joints by controlling and measuring relationships between position/velocity and torque/force as a function of time. This is done during exercises, while the MARES motor puts a programmed load on the astronauts movements.



esa	PROJECT: International Space Station		
TITLE: Muscle Atrophy Research and Exercise System	DOCUMENT N°: ESA-HSO-COU-024	REV. 2.0	

ERASMUS Centre - Directorate of Human Spaceflight and Operations

Facility Description

MARES' Main Box houses a powerful motor, battery, sensors, and its control electronics. The Microgravity Isolation Frame, to which the Main Box attaches, minimises disturbances to other payloads. The facility is completed by a Set of Human Adapters. These are pads and levers that adapt to different subject sizes and cover different movements. The Chair is a seat for the examined/exercising subject and is fixed to the Main Box by a pantograph arm. A Laptop computer provides the command and display interface to the subject. MARES is operated by dedicated experiment software. With a minimum effort, MARES can be tailored to a specific experiment: issuing automated instructions to the subject and setting the appropriate control algorithms for the motor.

MARES INSTRUMENTATION

Torque and angular position/velocity measurements and training of the left and right extremities are supported on the following joint movements:

MARES ANGULAR MOVEMENTS	
Ankle	Dorsi-plantar flexion
Knee	Flexion-extension
Hip	Flexion-extension
Trunk	Flexion-extension
Shoulder	Flexion-extension
Elbow	Flexion-extension
Wrist	Flexion-extension Radial-ulnar deviation Pronation-supination

MARES LINEAR MOVEMENTS	
Arm press	One arm Both arms
Leg press	One leg Both legs

MARES supports experiments on seven different joints for a total of nine different angular movements (either left or right limb) and for two additional linear movements (upper and lower limb), see the table above.

A careful coordination of the many capabilities of MARES is needed in order to ensure that measurements are made in a consistent and repeatable manner. In MARES, this is done by translating the steps of an experiment into a set of computer-based instructions, the so-called MARES Experiment Procedures.

Instructions are available that would allow the scientist to define within an Experiment Procedure the following functions:

- To prompt (via text instructions and/or graphical messages) the test subject to perform tasks, i.e.:
  - How to set-up the limb adapters.
  - How to restrain himself.
  - To power-on an external device.
  - To perform, for example, a Maximum Voluntary Contraction.
  - To perform a series of flexions / extensions.
- To accept and respond to feedback from the test subject.
- To activate a MARES Profile.
- To activate data displays for assessment by the test subject.
- To perform real-time data processing, the results from which could be used to influence the execution of the Experiment.
- To programme and command external devices.
- To select data for storage and/or downlink.

MARES can store internally a large number of such Experiment Procedures, with the possibility for new Experiment Procedures to be uploaded from the ground.

MOTOR CONTROL ALGORITHMS

Any desired limb movement can be described as a sequence of elementary steps.

These elementary steps are referred to as Basic Motion Units (BMUs), such that during any BMU the relationship between position or velocity and torque/force is governed by a single, relatively simple, mathematical formula. These BMUs cover the three possible basic modes of muscle contraction known from physiology (isometric, isotonic, isokinetic), plus eleven more BMUs that can be used in support of more sophisticated experimental requirements. MARES offers fourteen predefined BMUs as listed below:

MARES BASIC MOTION UNITS - BMUS

- isometric
- isotonic (concentric and eccentric)
- isokinetic (concentric and eccentric)
- spring
- friction
- additional moment of inertia/mass
- pseudogravitational
- position control
- velocity control
- torque/force control
- power control
- physical elements
- extended torque/force control
- quick release

Complex combination of these modes are possible.
The control algorithms for the motor are defined as so called 'Profiles' consisting of a linked sequence of BMUs.

GRAPHICAL EDITING OF A MARES PROFILE

MARES provides a simple graphical software tool that allows the experimenter to develop these kinds of Profiles according to his/her specific scientific needs. In this software tool, each BMU is graphically represented and the user can 'drag and drop' any of the fourteen BMUs into a sequence, thereby creating a Profile. In doing so, the user will be prompted to define appropriate end conditions for each BMU introduced into the sequence. This tool also supports looping and branching within the Profile.

SPECIFICATIONS

Maximum Ratings	
Torque	± 450 Nm continuous, ± 900 Nm peak (200 ms)
Force	± 240 N
Angular Velocity	± 9 rad/s (515°/s) concentric and ± 6 rad/s (343°/s) eccentric
Linear Velocity	± 0.5 m/s
Mechanical power	2700 W continuous, 4500 W peak concentric and 3750 W peak eccentric
Measurement Accuracy	
Torque	± 0.3 Nm for low torque's, ± 1 % for high torque's; 500 Hz
Force	± 0.125 N for low forces, ± 1% for high forces; 500 Hz
Angular Velocity	± 0.2°/s for low velocities, ± 0.5% for high velocities; 200 Hz
Linear Velocity	± 1mm/s for low velocities, ± 0.1% for high velocities; 200 Hz
Angular Position	± 0.5 % ROM (Range of Motion); 200 Hz
Linear Position	± 0.75 % ROM; 200 Hz
Interface Budgets	
Mass, overall	> 600 kg
Main-Box dimensions	103 x 52 x 52 cm
Average Power	350 W

The BMU end conditions are important because they define the transition between the BMUs. These transitions can be made dependent on: time, position, torque, subject interaction, external signals, and/or any other parameter.

This level of programmability opens up a whole range of operational possibilities, for example, to simulate the changing friction of rowing (back and forth), to design a complex motor-control experiment, etc.

EXTERNAL INSTRUMENTATION

MARES is designed to work in connection with other devices like electro-miographs, electro-cardiographs, stimulators, etc.

The Percutaneous Electrical Muscle Stimulator (PEMS II), (see image above) is one of the possible external instruments, delivers electrical charge pulse stimulation to non-thoracic muscle groups of the test subject, thus eliciting contractile responses.

PEMS stimulates muscle groups on the limbs (ankle, knee, thumb, elbow, and wrist) with electrical pulses applied via skin electrodes. The pulse duration and current amplitude are programmable to either 50 µs for up to 0.8 A or 250 µs up to 0.16 A. It provides either single pulses or fully programmable pulse trains, and can be triggered either manually or remotely, typically by MARES. A typical application is to study muscle strength independently of the subject's voluntary neural drive.

NASA astronaut Doug Wheelock during commissioning of MARES

PEMS is a self-contained item, stowed in a locker

Operations and Utilisation

ACCOMMODATION & TRANSPORT

MARES was launched in the HRF MARES Rack. For operation, MARES occupies the centre aisle and is attached to the ISPR.

OPERATIONAL CONCEPT

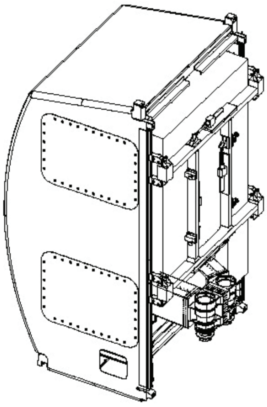
MARES is a component of the Human Research Facility in the Columbus laboratory.

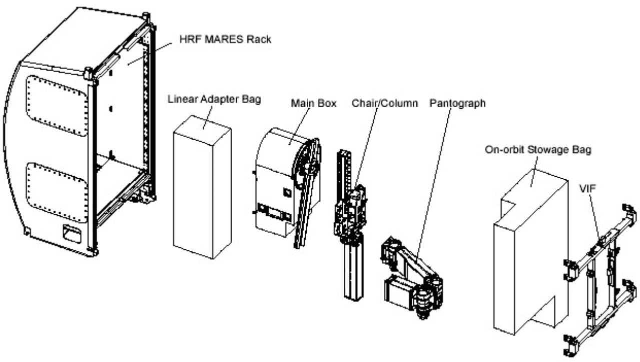
MARES uses the EPM portable computer for interacting with the subject/operator.

MARES is capable of acquiring data, controlling and providing power to external devices (EPM, PEMS, EMG amplifiers, etc.), and transfers real time data to the NASA Workstation or EPM for downlink. It is also capable of stand-alone data collection.

When not in use, all of MARES' elements are stored inside the ISPR.

The flight operations of MARES are managed by ESA via the User Support and Operations Centre (USOC) CADMOS in Toulouse.





UTILISATION SCENARIO

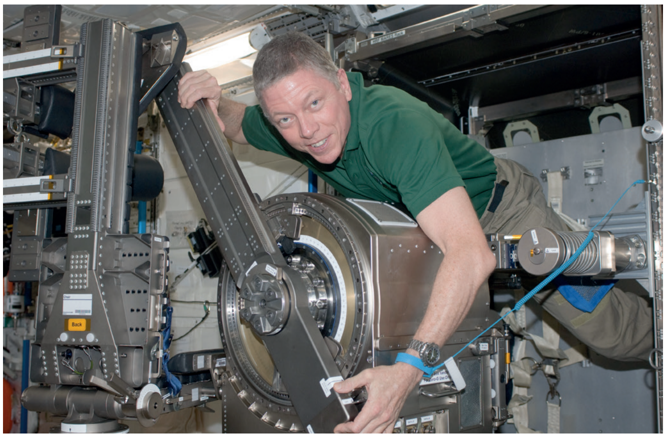
MARES is mainly intended for research, but it can work as well as an exercising device. It is an ideal tool to do research on the efficacy of countermeasures.

The MARES performances are ahead of any commercial research dynamometer.

SCHEDULE

MARES was launched to the ISS on board STS-131/19A Shuttle Flight on 5 April 2010.

NASA astronaut Shannon Walker during the installation of the MARES payload in the Columbus laboratory of the International Space Station



MARES mounted on the HRF MARES Rack by NASA astronaut Mike Fossum

NASA astronaut Doug Wheelock after full assembly of MARES