

Shape Memory Alloys in the European Space Agency Programme

Low Gravity to High Gravity Products Technology Transfer Works !

Adventures with Advanced Materials from Space-to-Earth

Tony Anson

Brunel University
Brunel Institute for Bioengineering
School of Engineering and Design
Anson Medical Ltd
Lombard Medical Technologies Plc
Diameter Ltd
Dynamic Materials Development Ltd



Shape Memory Alloys in the European Space Agency Programme

Low Gravity to High Gravity Products Technology Transfer Works !

- ESA/ESTEC Origins
- Microgravity and Life Sciences Research in Space
- ‘Converting’ Technology
- Smart Material Technology – Overview and Applications
- Technology Transfer, Medical Up-Take and Commercial Activities

Shape Memory Alloys for the European Space Agency Programme

Science & Technology
 μg to +g

Origins



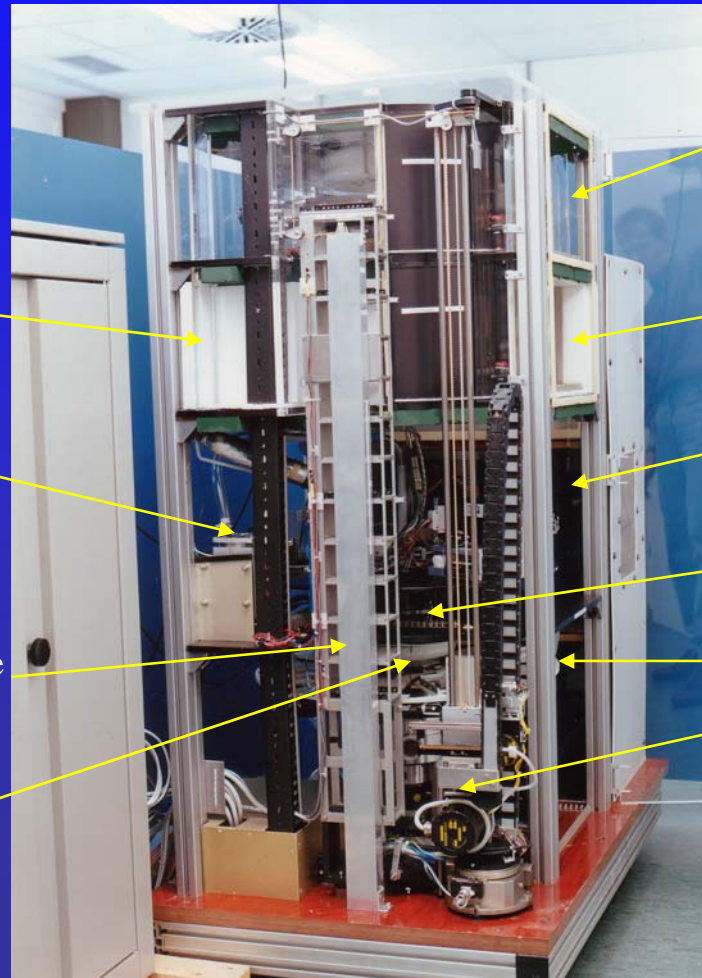
Microgravity, life science experiments were planned on-board Eureka, (European Retrievable Carrier) to research the effects of microgravity and/or cosmic radiation on simple living organisms, e.g. cells, plants, insects and fish.

A feasibility study was initiated by ESA, to develop an automated test-bed facility, "Biosample" This began at MRC (Medical Research Council) in conjunction With ESTEC, Dornier GmbH and other European space contractors and later at Brunel University, Institute for Bioengineering.

**First Eureka, launch from
the Shuttle cargo bay, 1992.**

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Biosample Module



Internal\External Access

Plant Handling Facility

Experiment Container Storage

Light Source for Photosynthesis

37 Deg. C Area

4 Deg. C. Area

Micro organism facility

Micro. G. Centrifuge

Insect Handling Facility

Experiment Container,
Pick and Place Device

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Biosample Module

All experiments were based upon 1g and micro-g reference and control centrifuges as a means to separate the effects of μg and radiation.

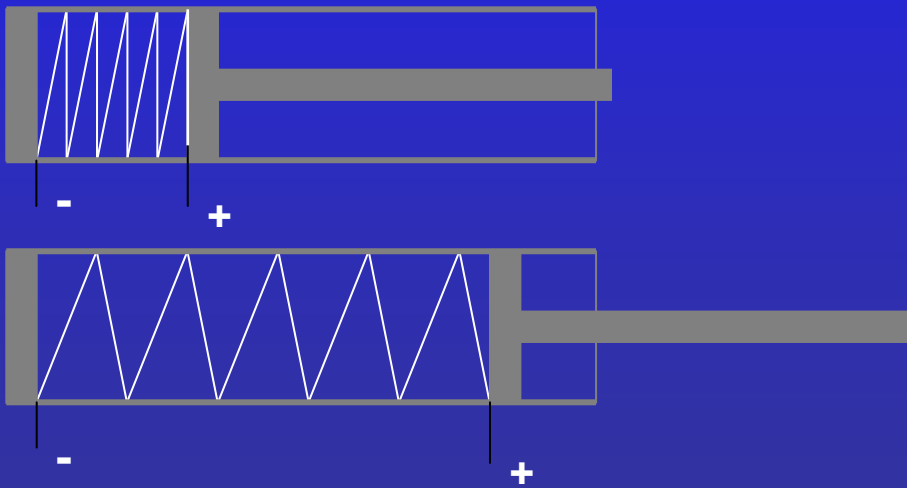
All experiments required nutrients, water, waste product handling, gaseous exchange and in the case of plants, a light source.
In addition, normal diurnal cycles had to be addressed.

....and a series of successive generations of the organisms were needed to identify any potential changes in cellular, metabolic, structure or function.

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Origins:

Ni-Ti Shape Memory Alloy. Linear Actuator resistively heated as a means to achieve axial (or radial) movements to simplify pick-and-place duties and actuation tasks.



Automated Biological test bed facility



Micro-step/servo controlled robotics

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Technology Overview 1

Approximately 15 different binary, ternary and quaternary metal alloys exhibit a recoverable and reversible phase change when subjected to high-low temperatures and stress induction.

Nickel-Titanium-Niobium-Copper-Hafnium-Iron-Zinc-Manganese-Aluminium-Gold-Cadmium comprise some of the metal alloy constituents

The metal alloy changes from BCC/FCC (body or face centred lattice) to Orthorhombic. This facilitates a geometrical change in the [memorised] alloy, demonstrated by the memory effect.....

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Technology Overview 2

... However, there are two generic properties, both described as the memory effect:

- **Thermally induced shape recovery**

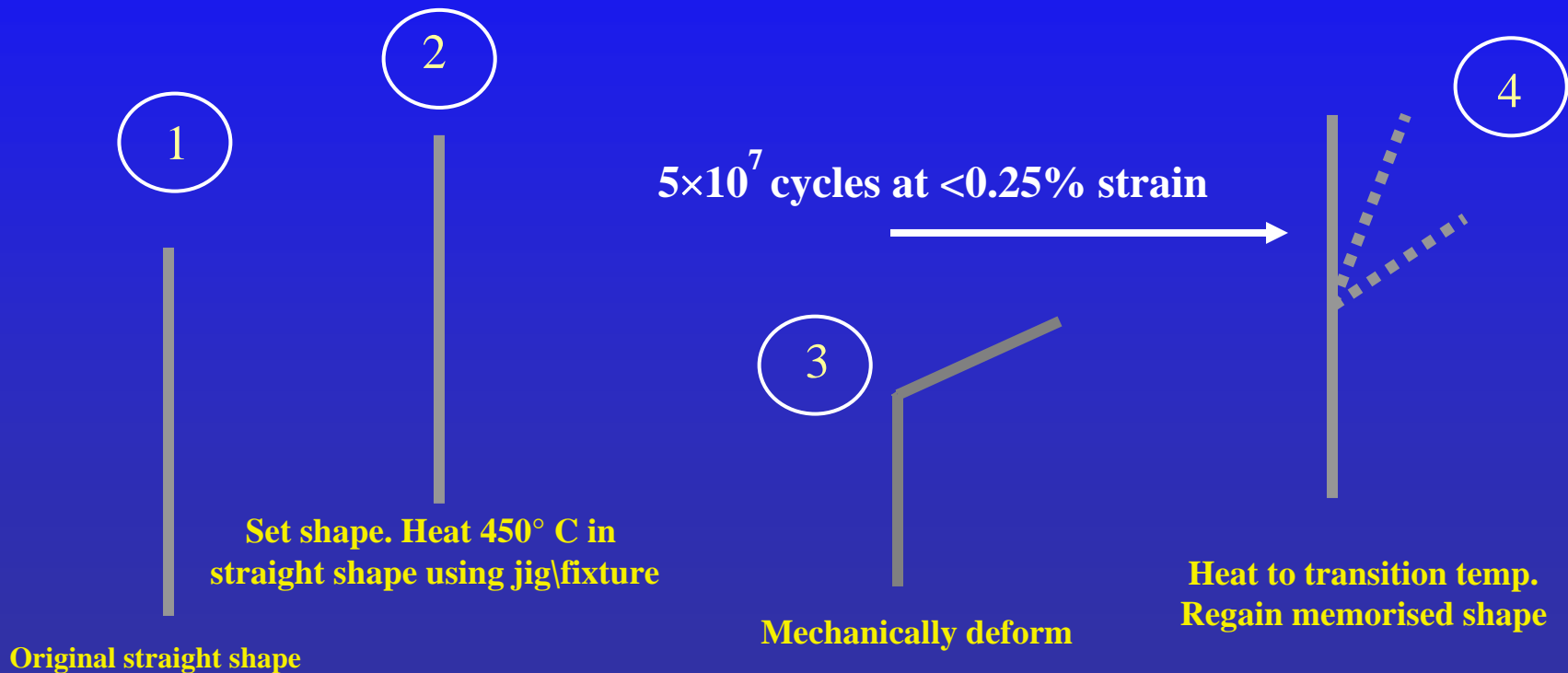
Heat treat 450-600 for memorising: deform when cool, memory recovers when heated, good for 5×10^7 operational cycles at 0.25% ϵ (strain)

- **Elastic (super/pseudo elastic) recovery**

Heat treat max. 450° C. for memorising: elastically deform at -30°C to +150°C (typical), good for min. 5×10^7 operational cycles at 0.25% ϵ (strain).
can display non-Hookean response i.e. constant force

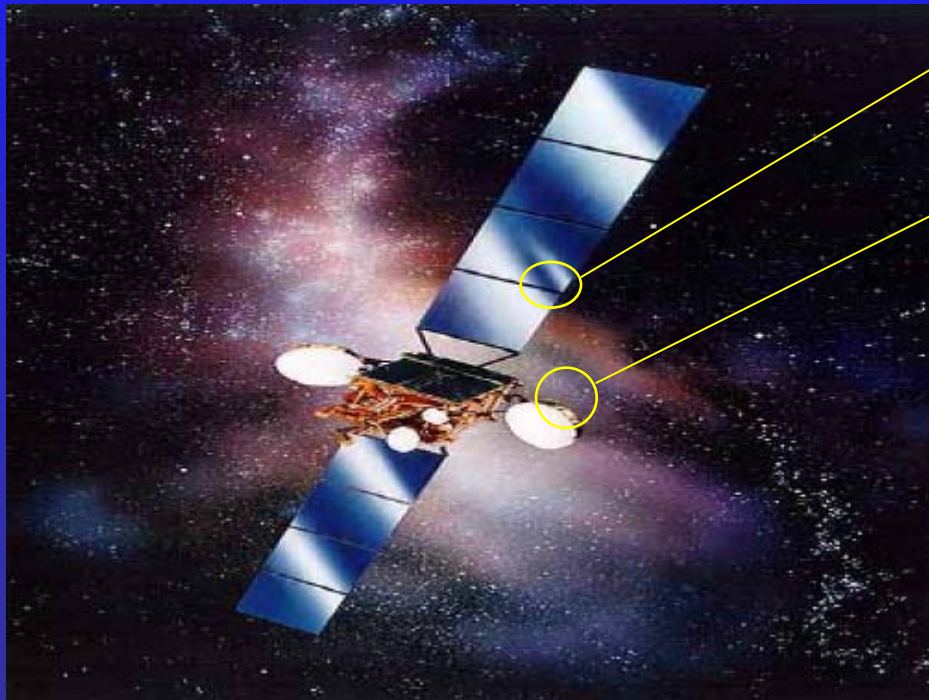
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Technology Overview 3



Shape Memory Alloys for the European Space Agency Programme

Adoption of Shape Memory Alloys for Space Applications



Solar panel release/deployment

Antenna array release/deployment

Flight hardware SMA developments

AFRL Shape Memory Alloy Release Device (SMARD)
MightySat I.

FalconSat Space Launch Vehicle (OSP-I) January 2000. AFRL SMA hinges and Lightweight Flexible Solar Array (LFSA) program, AFRL/DARPA/NASA/Lockheed Martin.

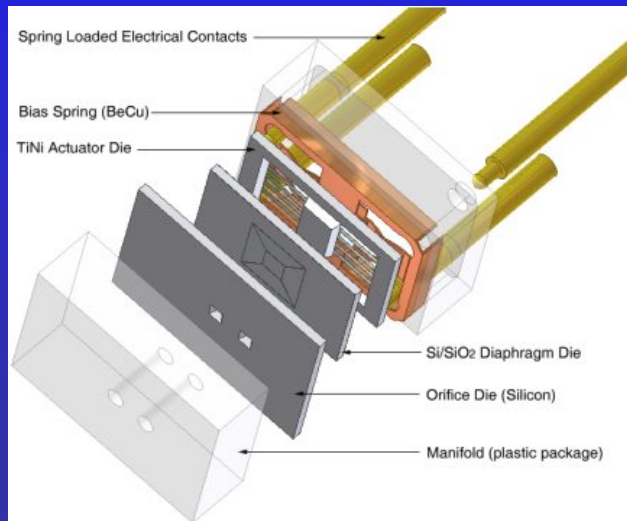
SMA hinges of the LFSA experiment on the Space Shuttle Columbia (STS-93) in July 1999

Rosetta – landing craft: helium release valve (current mission)

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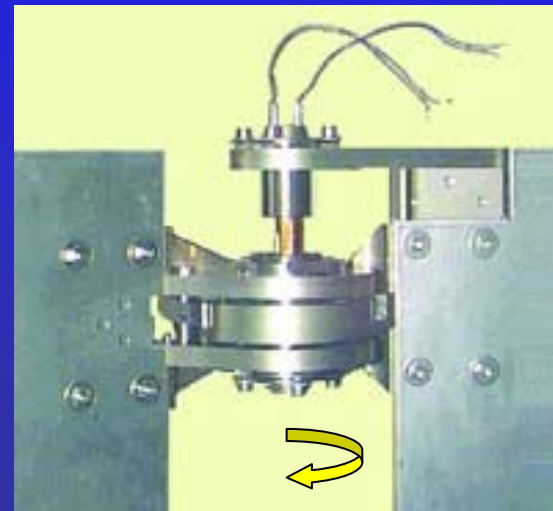
Adoption of Shape Memory Alloys for Space Applications

Aerospace shut-off or directional fluid valve. 5 grms. mass



(TiNi Inc.)

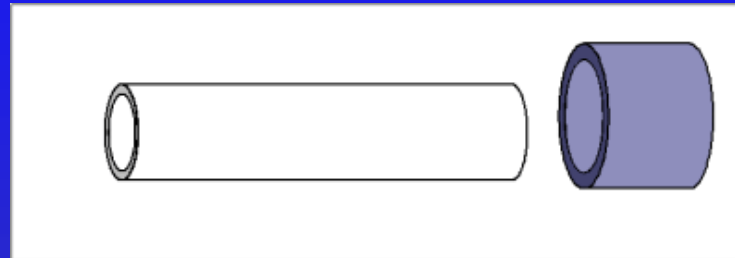
Motorised hinge for space applications



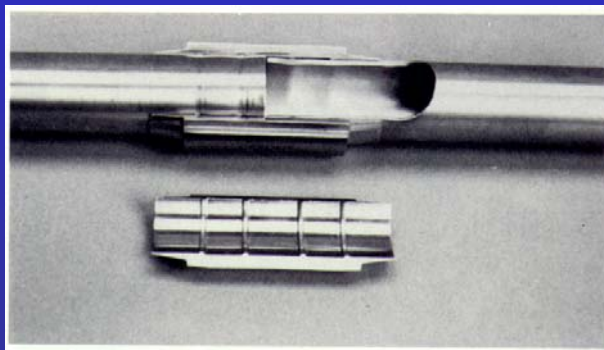
(EADS - Astrium)

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Adoption of Shape Memory Alloys for Aerospace Applications



High Pressure (280 Bar) pipe
Connector for aerospace
hydraulics + cryogenic line couplings

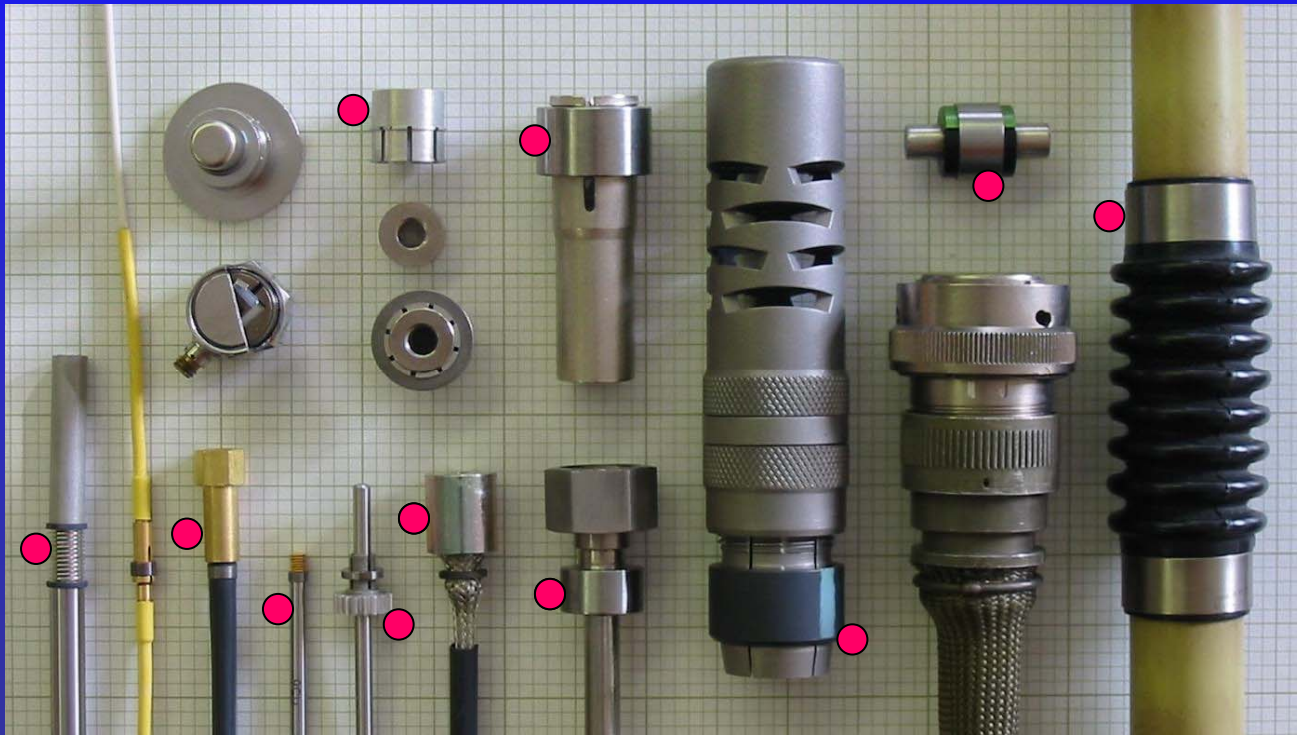


Undersized bush (Austenite), becomes
a clearance fit when cooled (Martensite).
diameter decreases at “memory” temp.
inducing hoop forces to seal two pipe-ends.

Cryofit®

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Adoption of Shape Memory Alloys for Aerospace Applications



SMA electrical cable connectors, stabilisers and seals

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Adoption of Shape Memory Alloys for Terrestrial Applications

Expanding assembly of Solid shape memory alloy Cylinders to split rock in the quarrying industries



20° C. L= 24.0mm F=8000 Kg



80° C. L= 25.0mm F=6000 Kg



EU funded CRAFT Project FP6 (BRST-CT98-5186)

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Adoption of Shape Memory Alloys for Terrestrial Applications



Super elastic
spectacle frames

Memoflex® Inc



Anti-scald
shower valve

MemrySafe®



Domestic Kettle-jug
With SMA temp. sensor
AMT. Bv. - Rowenta



SMA under wired brassieres

SMA orthodontic arch-wires



3M UniTec



Fishing Line
(Furakawa Corp.)

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Shape Memory Alloys - Medical Applications Facilitated by a Technology Transfer Spin-out



Keyhole placement of aortic valve



Orthodontic Correction



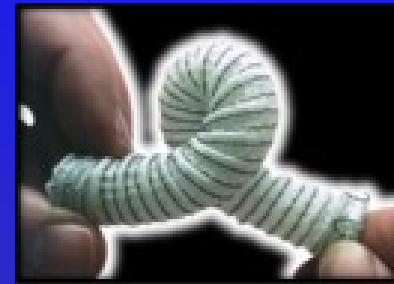
Bone Plate



Coronary artery stent



A general purpose gripper for soft tissue manipulations\stabilisation, DLC coated



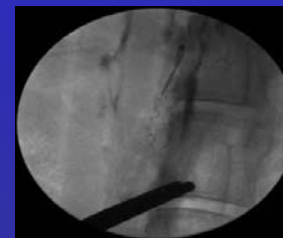
Aneurysm stent-graft



Integrated stent-graft



Generic stents



Stapled anastomosis

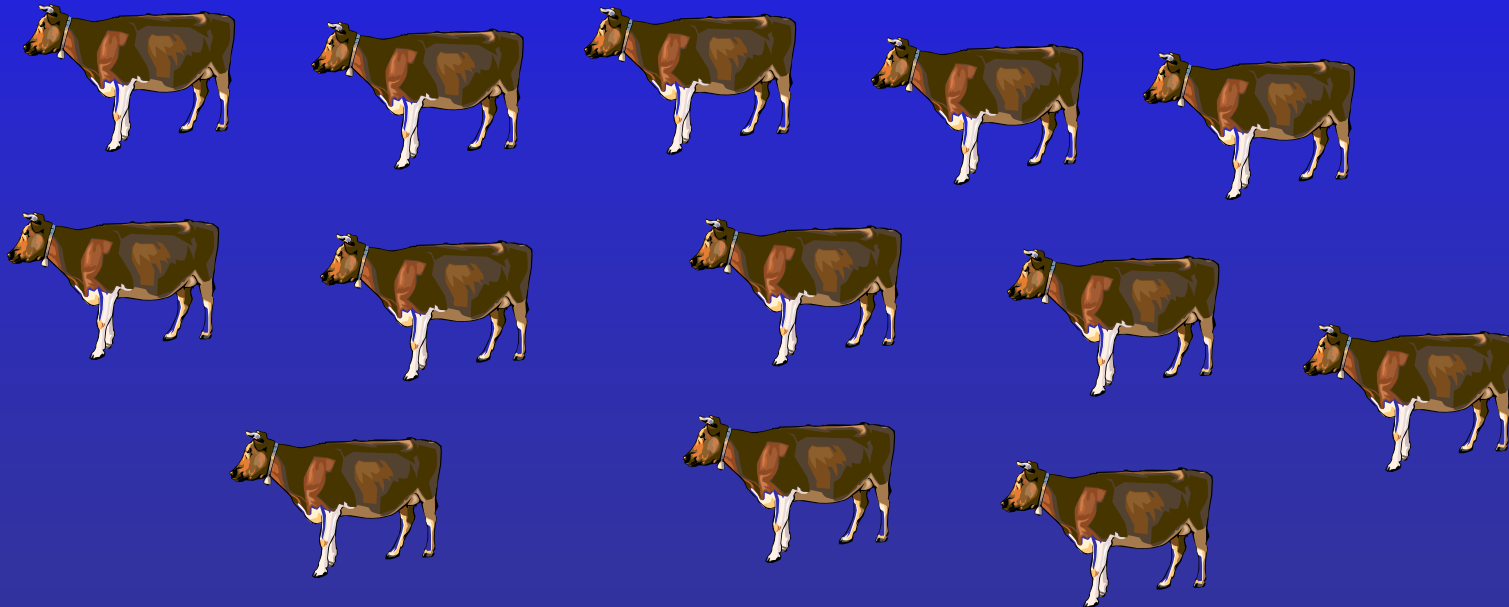


Sutureless Anastomosis

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Shape Memory Alloys – Transfer from Space to Earth

European Space Agency awarded 13 “Kau’s”^{*} technology transfer funding to investigate the use of “Smart Materials” technology from space research in life sciences discipline, to medical applications.



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Shape Memory Alloys - Medical Applications



Wire-form SMA staples to effect small bone, fracture fixation

Pitch relationship of the legs of the device change when Heated (37°): Pre-drill holes are positioned either side of a fracture, staple placed in these holes. The staple now draws the bone parts together with a precise force.



Halux Vulgus



A new form of SMA, modulus matched bone plate for fracture fixation

Differential or “zonal” heat treatment facilitates super elastic and thermally induced shape recovery properties to allow sympathetic flexure when bone structures are loaded. Fracture reduction is arranged by a change the pitch relationship of fixation holes/screws.



Tibial Fracture

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Shape Memory Alloys - Medical Applications

Ni\Ti general surgery staple for open and “keyhole” techniques. The staple is designed to attach tissue-to-tissue or tissue to graft



Disposable applicator



Vascular graft fixation (aneurysm's)

(Lombard Medical Technologies Plc)



Repositionable Staple

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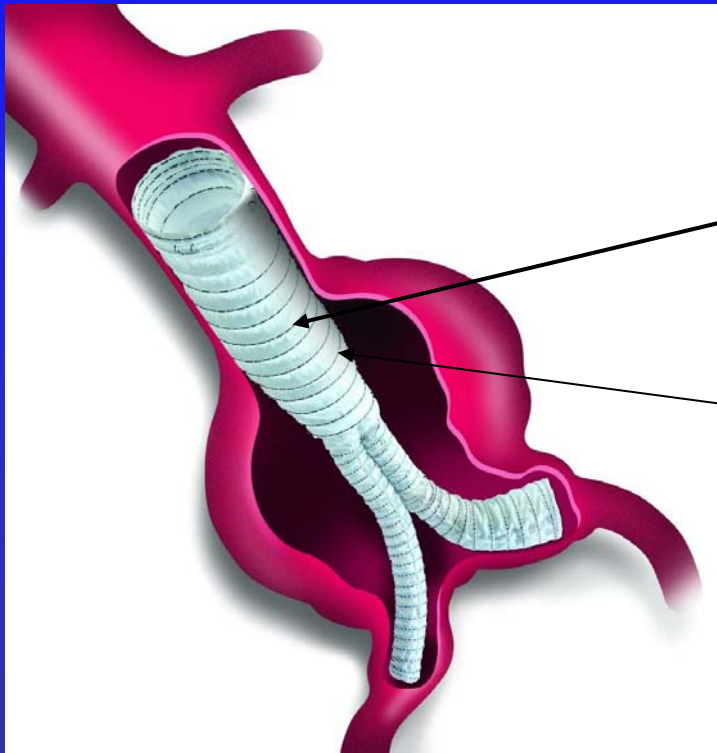
Shape Memory Alloys - Medical Applications

Vascular graft for the treatment of abdominal aortic aneurysms.

Polyester tubular structure

Super elastic Ni\Ti pre-formed wires
Attached to polyester by sewing.

Model of abdominal aortic aneurysm with reinforced graft, to exclude blood flow in the aneurysmal sac



Shape Memory Alloys for the European Space Agency Programme



Functional simplicity, reliability and longevity of shape memory alloy materials have led to diverse application in challenging environments such as in space and in the human body.

The requirement of these environments, will no doubt lead to other application in the future for shape memory alloys and other new materials

Equally, it may be anticipated that material applications in space will beneficially transfer to other terrestrial applications, increasing the scientific knowledge base and commercial endeavours.

Shape Memory Alloys for the European Space Agency Programme

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Contact: ansonbiomedical@aol.com
tony.anson@diameterltd.co.uk
proton@brunel.ac.uk