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


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Lombard Medical Technologies Plc
Diameter Ltd
Dynamic Materials Development Ltd



KTN Materials April 24th 2008
Materials of the Space Age
London

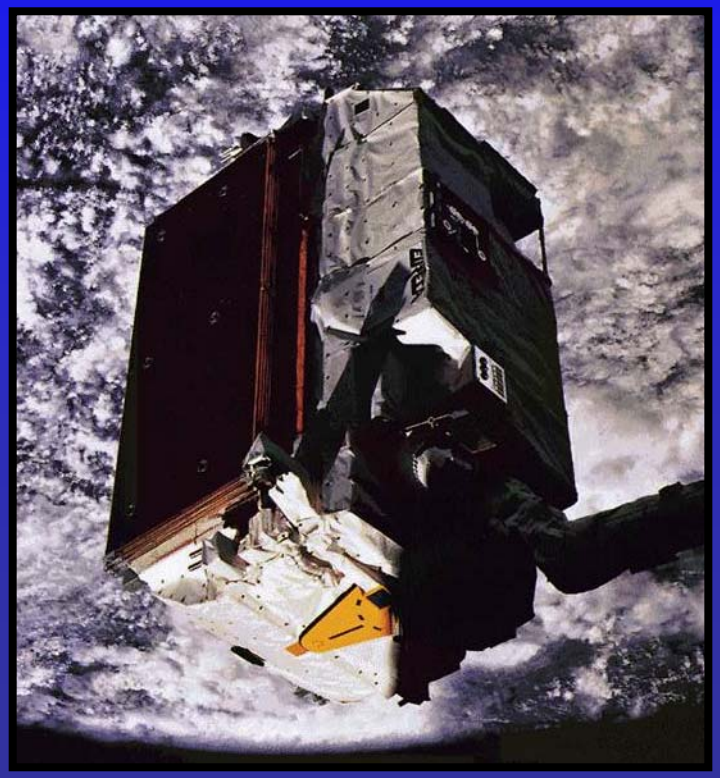
Shape Memory Alloys in the
European Space Agency Programme

# 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**



First Eureca, launch from the Shuttle cargo bay, 1992.

## Origins

Microgravity, life science experiments were planned on-board Eureca, (European Retrievable Carrier) to research the effects of microgravity and/or cosmic radiation on simples 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.

# Shape Memory Alloys for the European Space Agency Programme

## Biosample Module

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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.

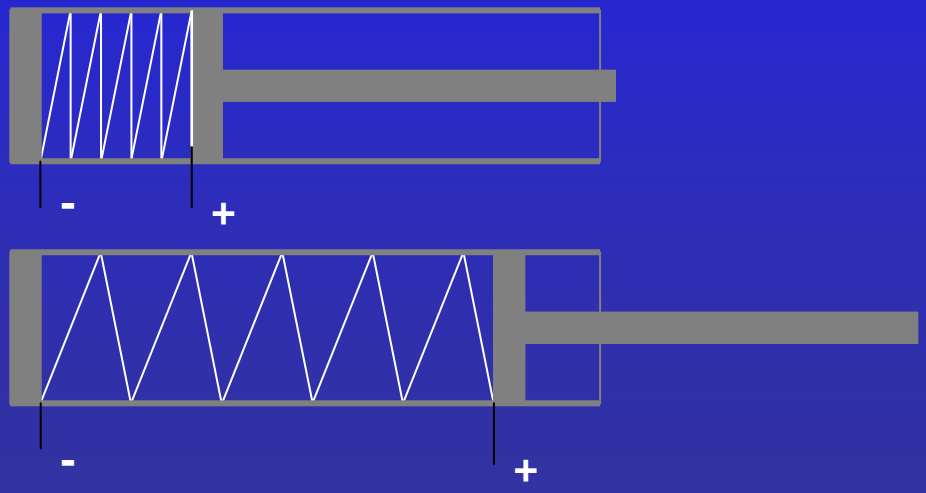
All experiments required nutrients, water, waste product handling, gaseous exchange and in the case of plants, a light source. In addition, normal diurnal cycles had to be addressed.

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

# Shape Memory Alloys for the European Space Agency Programme

**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

# Shape Memory Alloys for the European Space Agency Programme

**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

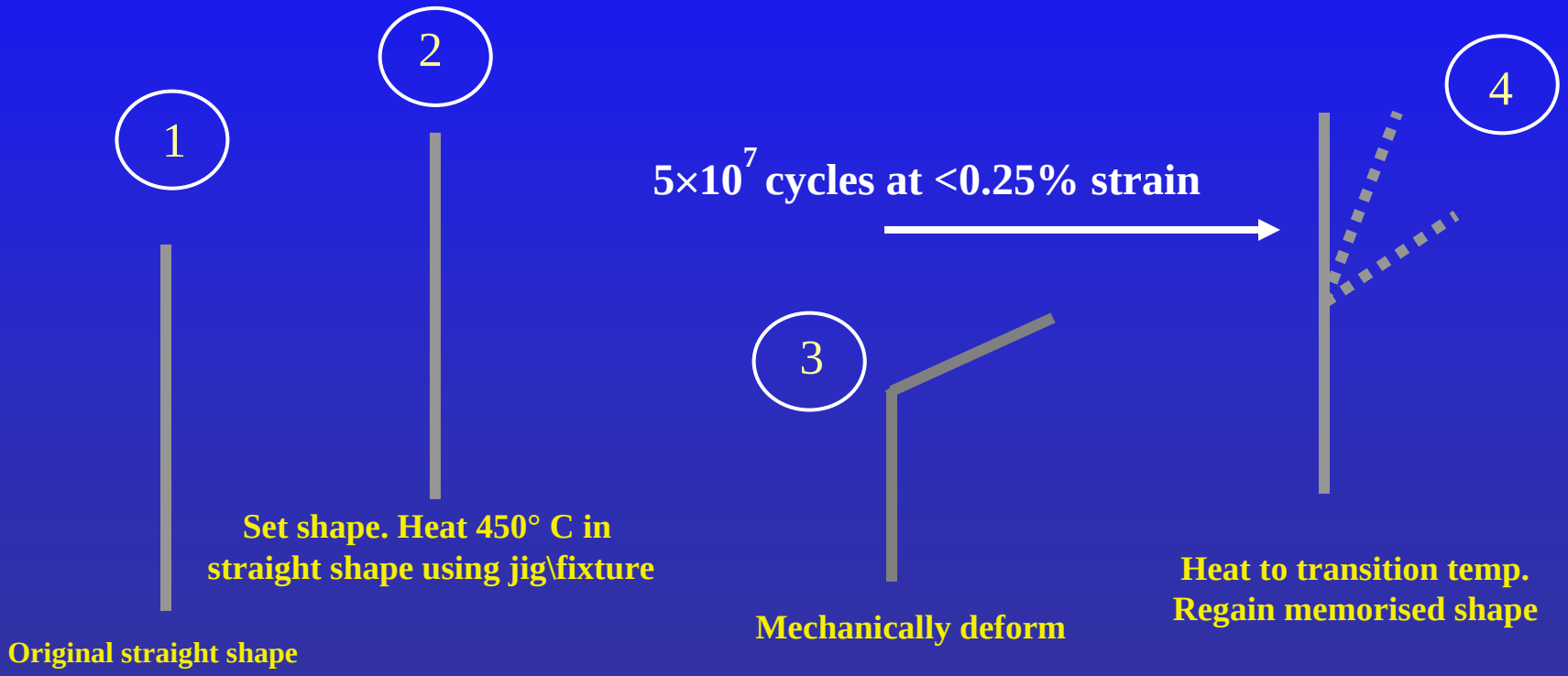
… However, there are two generic properties, both described as the memory effect:

- **Thermally induced shape recovery**
  Heat treat 450-600 for memorising: deform when cool, memory recovers when heated, good for $5\times10^7$ 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. $5\times10^7$ operational cycles at 0.25% **ε** (strain).
  can display non-Hookean response i.e. constant force

# Shape Memory Alloys for the European Space Agency Programme

## Technology Overview 3



# Shape Memory Alloys for the European Space Agency Programme

## Adoption of Shape Memory Alloys for Space Applications

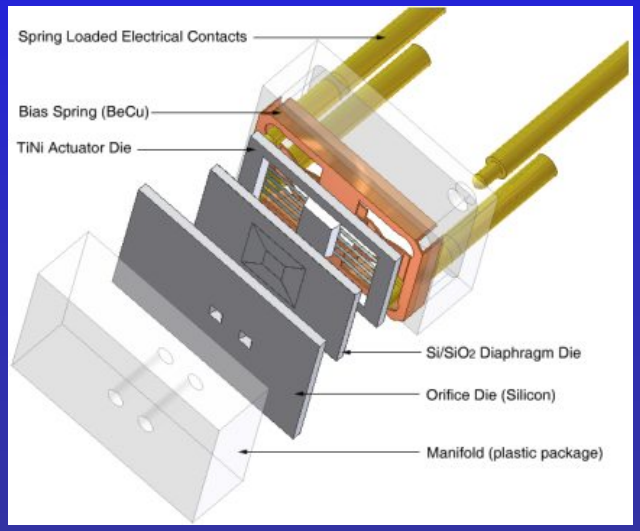

**Flight hardware SMA developments**

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)

# Shape Memory Alloys for the European Space Agency Programme

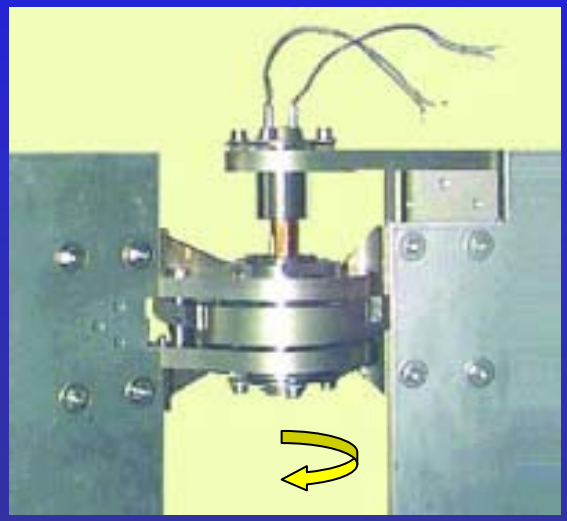
## Adoption of Shape Memory Alloys for Space Applications

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




(TiNi Inc.)

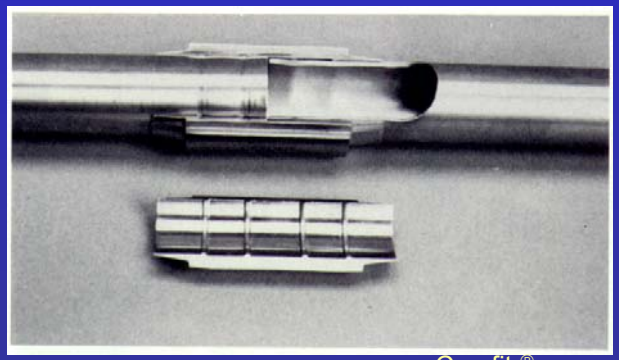
### Motorised hinge for space applications



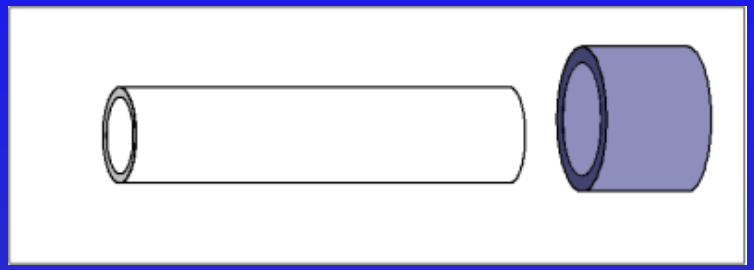
(EADS - Astrium)

# Shape Memory Alloys for the European Space Agency Programme

## Adoption of Shape Memory Alloys for Aerospace Applications



Cryofit ®

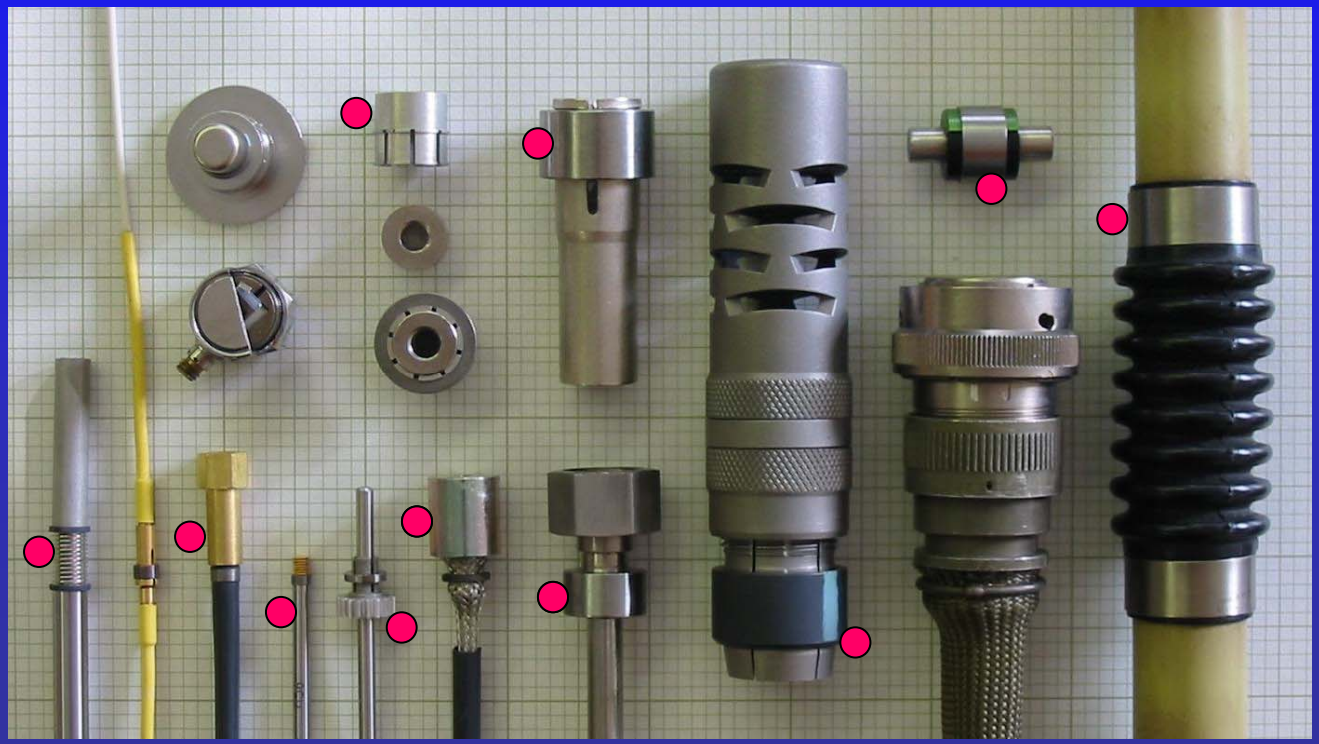


High Pressure (280 Bar) pipe
Connector for aerospace
hydraulics + cryogenic line couplings

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

# Shape Memory Alloys for the European Space Agency Programme

## Adoption of Shape Memory Alloys for Aerospace Applications

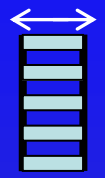


**SMA electrical cable connectors, stabilisers and seals**

(Intrinsic Devices Inc.).

# Shape Memory Alloys for the European Space Agency Programme

## 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)

# Shape Memory Alloys for the European Space Agency Programme

## Adoption of Shape Memory Alloys for Terrestrial Applications

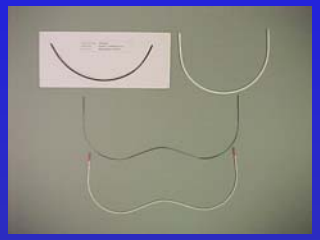
Super elastic spectacle frames

Memoflex® Inc

Anti-scald shower valve

MemrySafe®

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



SMA under wired brassieres


Fishing Line
(Furakawa Corp.)

SMA orthodontic arch-wires

3M UniTec



D.M.D

Brunel UNIVERSITY WEST LONDON

diameter ADVANCED MATERIAL APPLICATIONS

# Shape Memory Alloys for the European Space Agency Programme

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

Keyhole placement of aortic valve

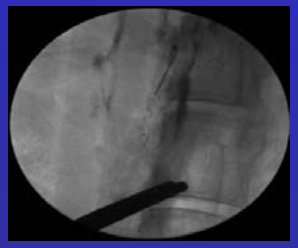
Orthodontic Correction

Bone Plate

Coronary artery stent

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

Aneurysm stent-graft



Stapled anastomosis

Integrated stent-graft

Generic stents

Sutureless Anastomosis

# Shape Memory Alloys for the European Space Agency Programme

## 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.

KTN Materials April 24th 2008
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London

*Kilo accounting units = 000’Euro’s

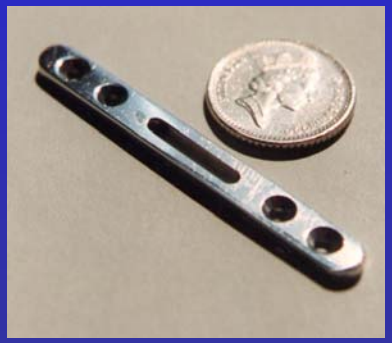
# Shape Memory Alloys for the European Space Agency Programme

## 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

# Shape Memory Alloys for the European Space Agency Programme

## 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**

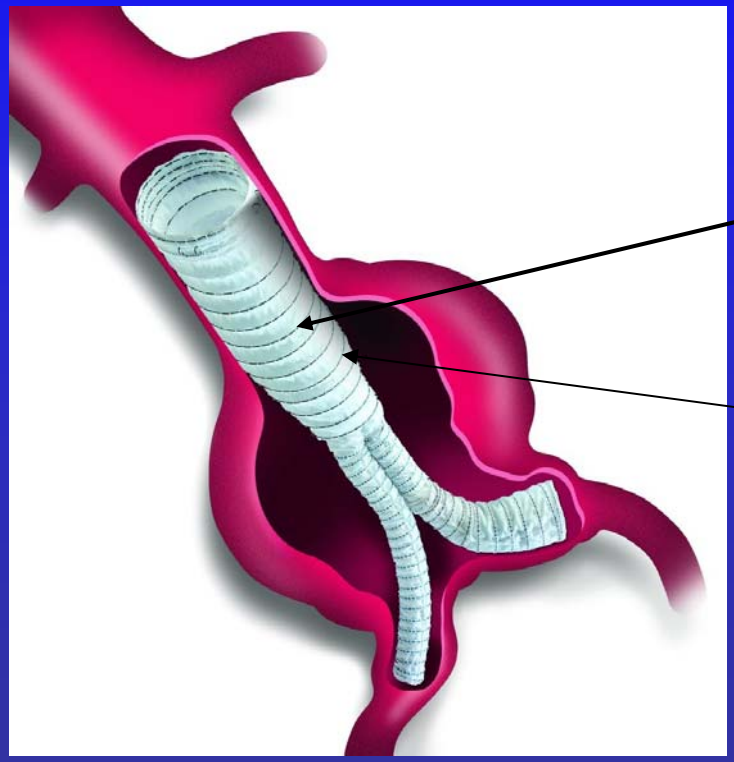
**Vascular graft fixation (aneurysm's)**

(Lombard Medical Technologies Plc)

**Repositionable Staple**

# Shape Memory Alloys for the European Space Agency Programme

## 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

**Acknowledgments:**

**ESA/ESTEC, Anson Medical Ltd, Lombard Medical Technologies Plc Intrinsic Devices Inc MemorySafe Inc. Cryofit Inc. Memoflex Inc Sorin BioMedica Spa. TiNi Corp. European Commission Furukawa Corp. Rowenta Gmbh AMT Bv. 3M Uni-Tec. EADS – Astrium.**
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