A deployable microsatellite gripper based on multi-segment dielectric elastomer actuators

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website: http://lmts.epfl.ch/DEA

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Collaborative Work

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Microsystems for Space Technologies Laboratory

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S. Rosset

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H. Shea

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Swiss Space Center

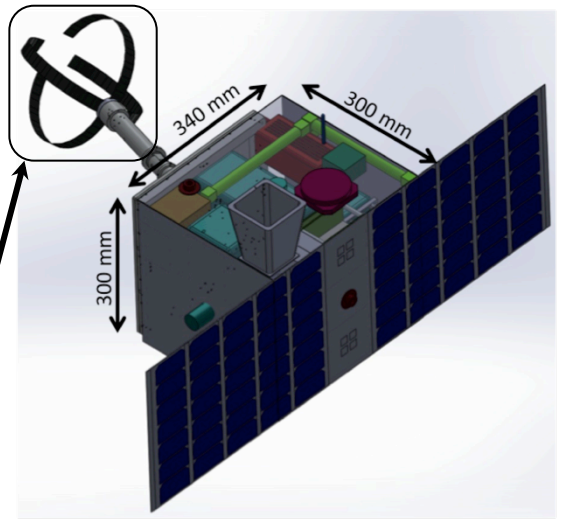
I. Gavrilovich

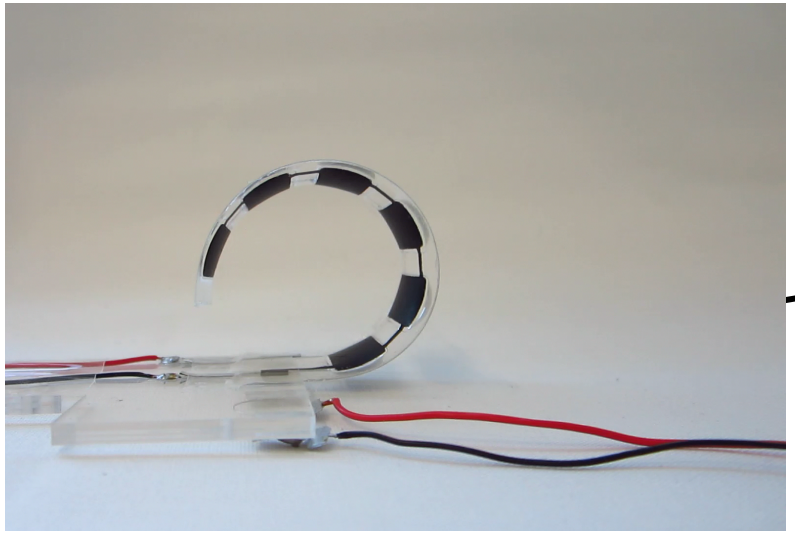
M. Richard

V. Gass

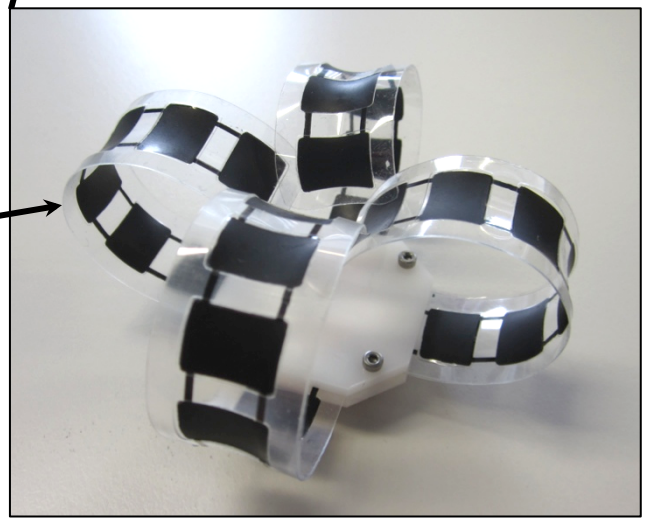
Novel Soft and Compliant Gripper

- A unique foldable/roll-able, soft and complaint bending actuator based on dielectric elastomer actuators
- The fundamental component of a deployable gripper for an active debris removal microsatellite

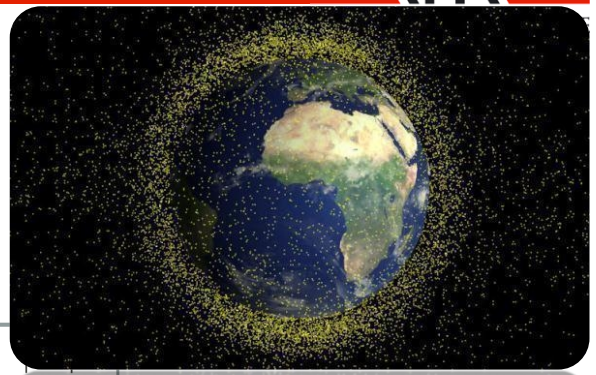


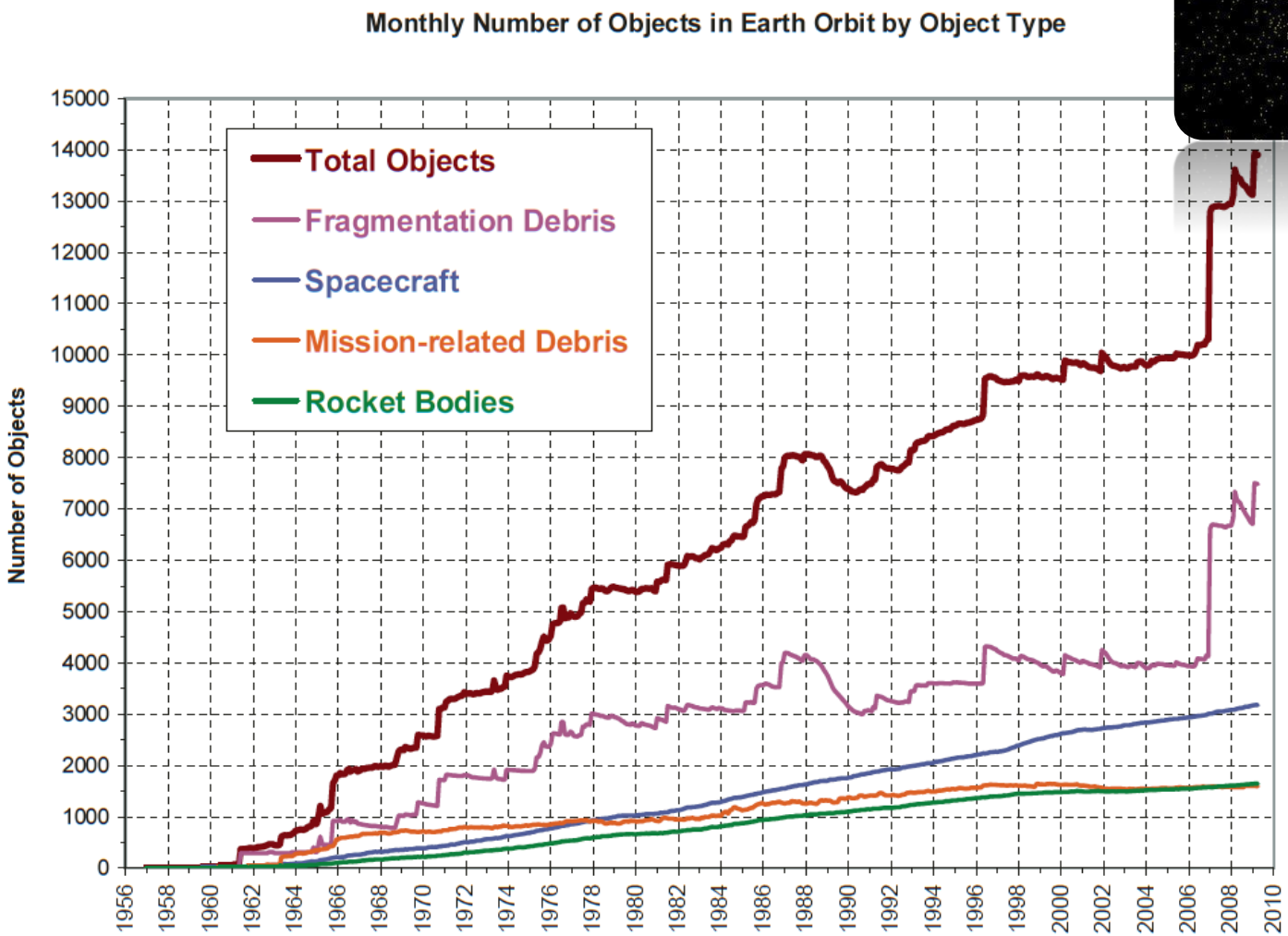


Multi-segment soft and compliant dielectric elastomer actuator



Ever Increasing Debris



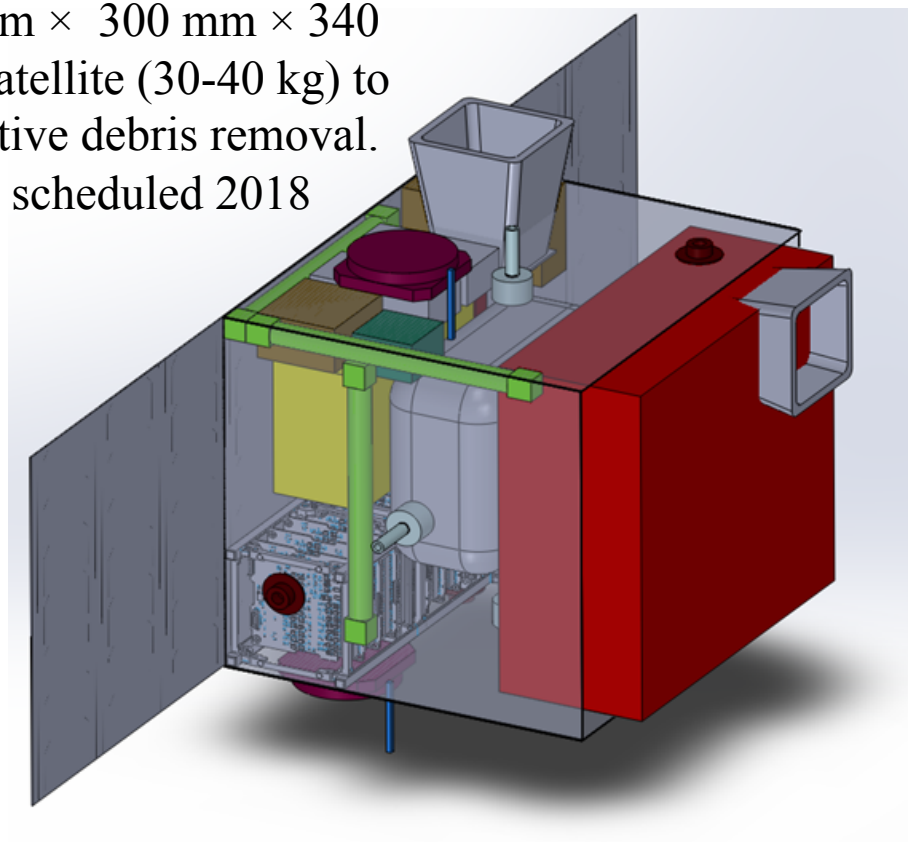


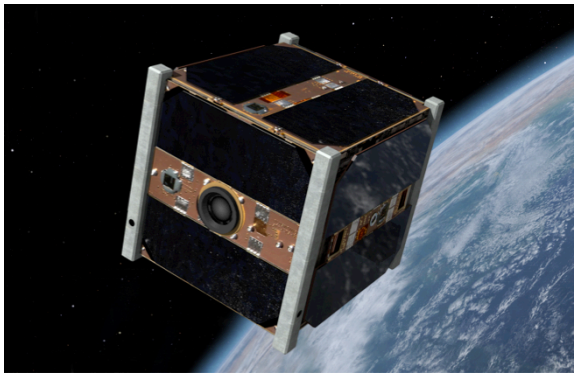
NASA, *Orbital Debris Quarterly News*, 13(2), 2009v

Towards a Solution…

CleanSpace One!

EPFL project to launch a low-cost 300 mm × 300 mm × 340 mm microsatellite (30-40 kg) to perform active debris removal. Launch scheduled 2018





SwissCube

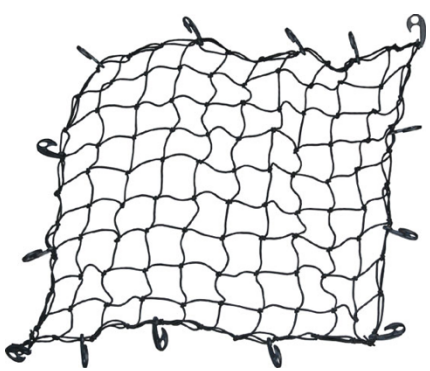
Capture target: 10 × 10 × 10 cm
EPFL microsatellite launched in 2009, still operational.

Not your average sized space debris, but important initial goal demonstrating the technology

The Need For An End-effector

Robotic Arms

Harpoon or Nets

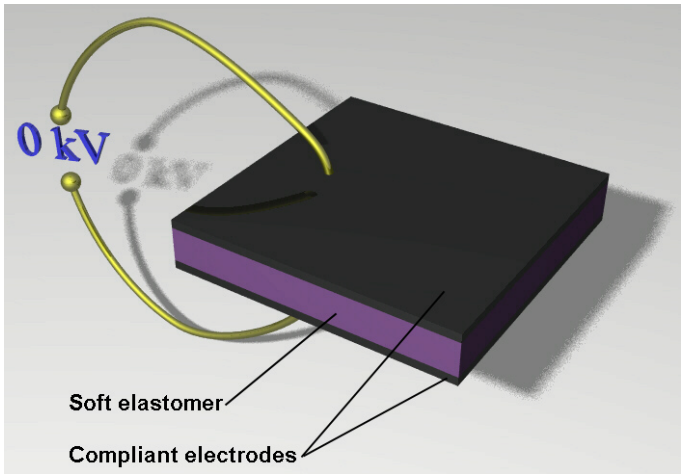


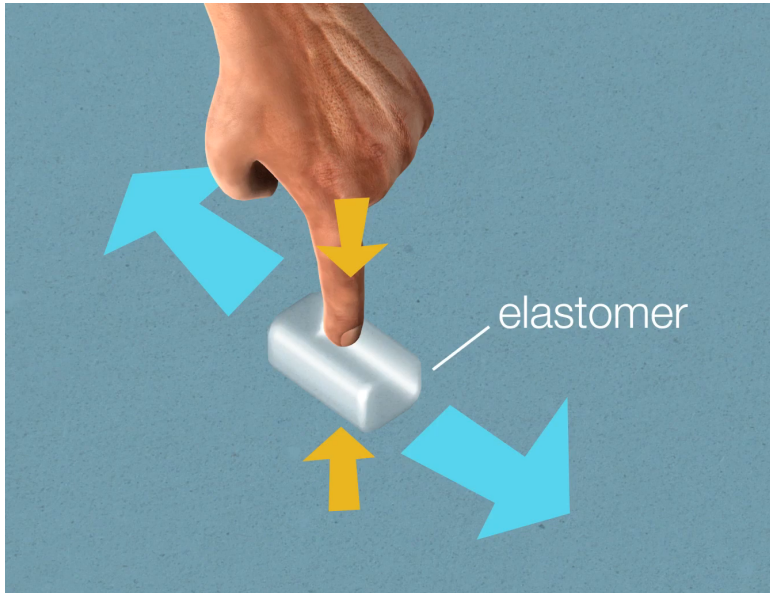
Ion Beam Shepard

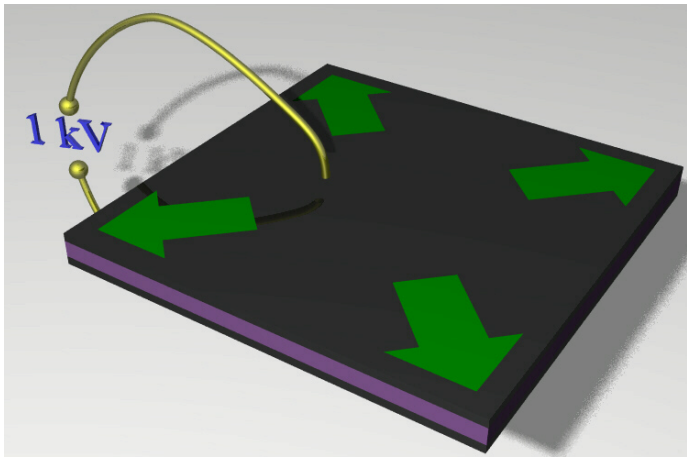
A Soft and Compliant Gripper

Dielectric Elastomer Actuators

- **Actuator + sensor + enenrgy harvester** consisting of:
  - soft dielectric (elastomer) and
  - compliant electrodes
- When kV voltage is applied, the elastomer is squeezed by the electrostatic force





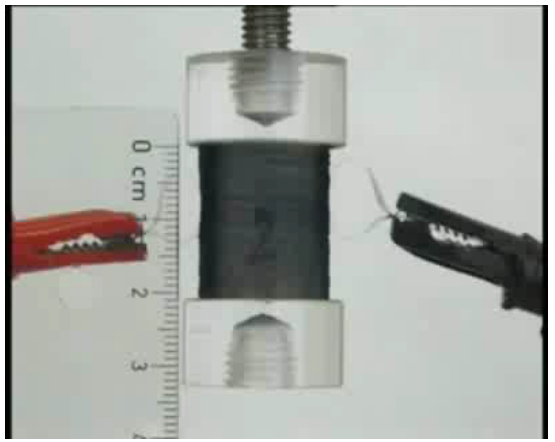


$$p_{\mathrm{el}} = \epsilon_0 \epsilon_r \left(\frac{V}{t}\right)^2$$

Features of DEAs

- **Large strain**:
  - over 1400% area strain demonstrated,
  - 30% to 80% for long-term operation today
- **Lightweight**: Energy density 3 MPa/m^3
- Soft: Young's modulus ≈ 1 MPa
- Thin: 20-50 μm
- Fast: > kHz
- Performance comparable to human muscles
  - ➢ Soft robotics
  - ➢ Interaction with soft tissue
- Can add intelligence through self-sensing

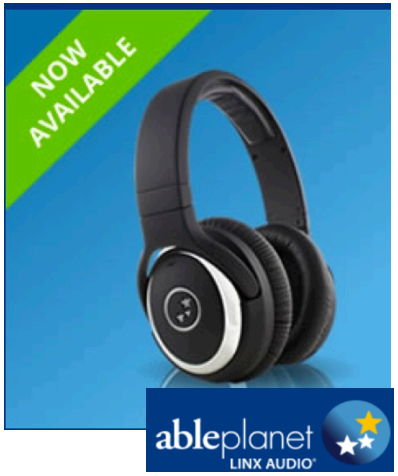
Motor Layer Linear Actuator (from EMPA)



EMPA's (Zurich) 7m long blimp: "swims" through the air using 4 artificial muscles

Commercially Available DEA Based Devices

Mophie Pulse



Optotune LSR

Commercial supplier of actuator materials

- Danfoss Polypower (Denmark) makes high-performance material with an industrial process
- Elastomer manufacturers (e.g. Wacker) selling rolls of thin films specifically for DEAs

The Need For An End-effector

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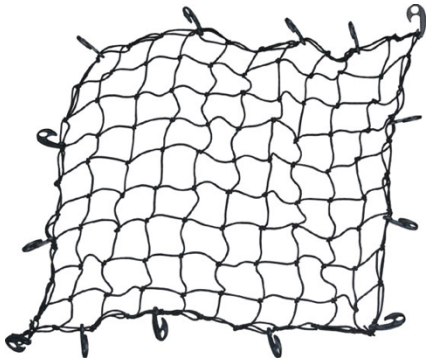
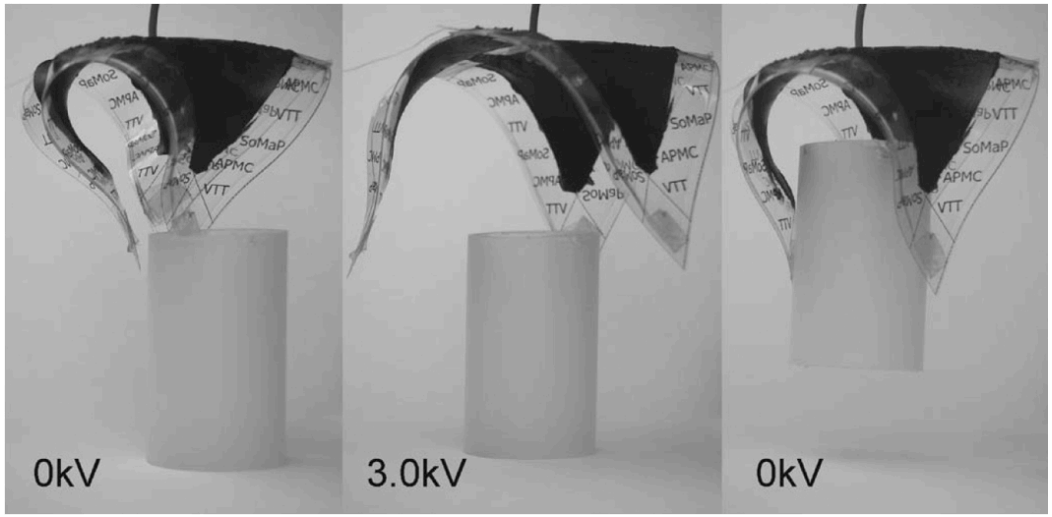


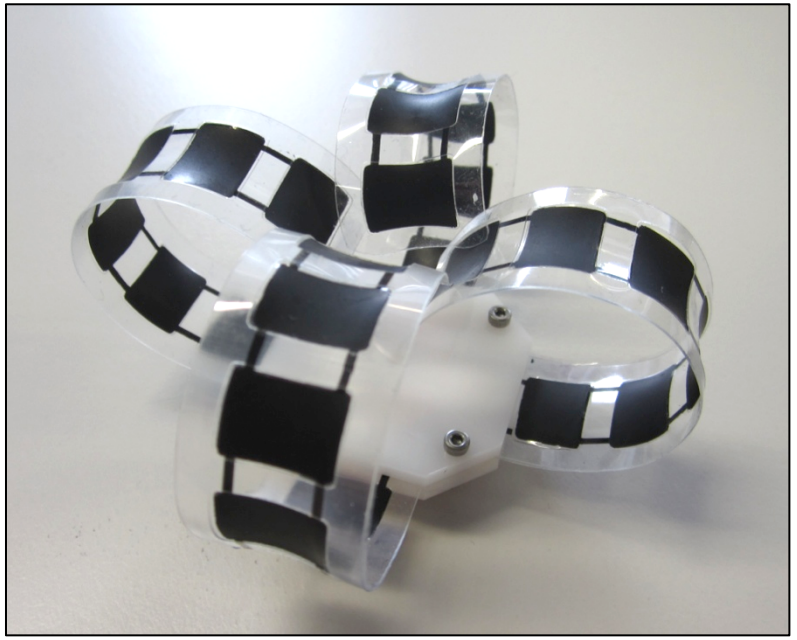
Ion Beam Shepard

A Soft and Compliant Gripper



G. Kofod et al., *Applied Physics Letters*, vol. 90 (8), p. 081916, 2007

Features of An Elastomer Based Compliant Gripper

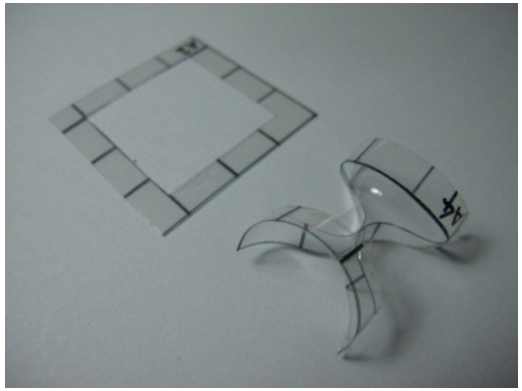


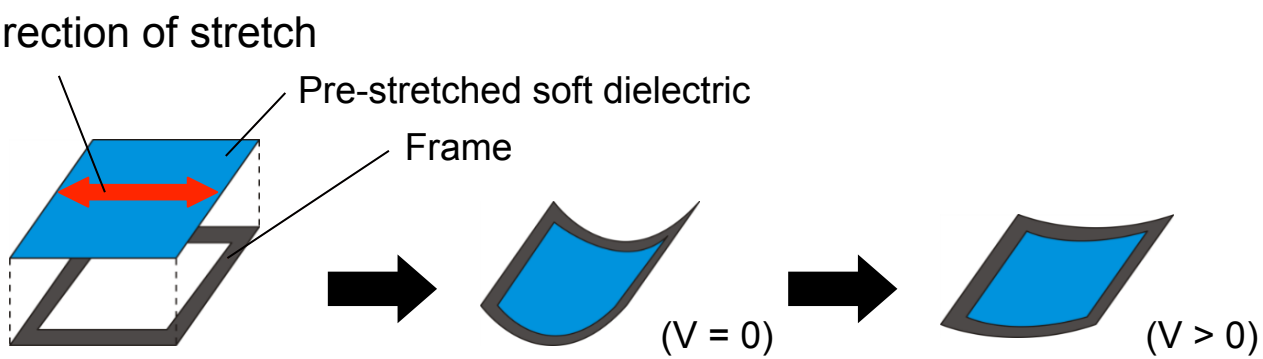
Advantages:

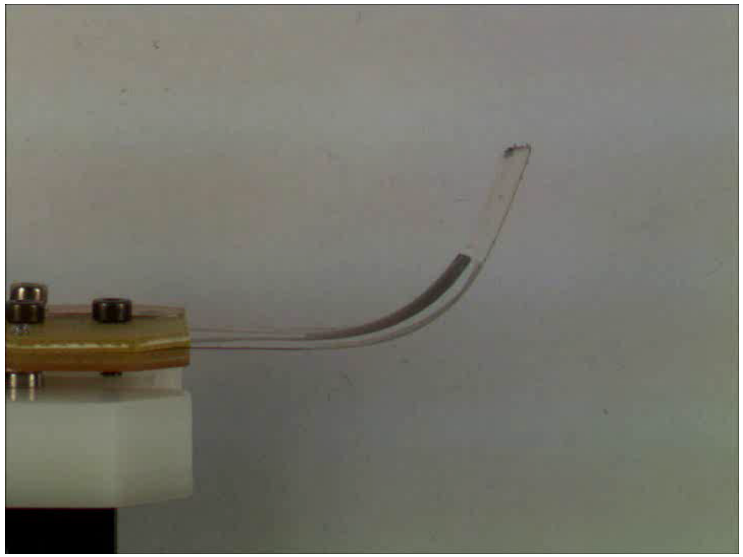
- Compact
- Light weight
- No complicated mechanical parts
- Adaptable to the shape of the debris
- Radiation tolerant[1]
- Remain flexible in the temperature range (-50 °C - +200 °C)

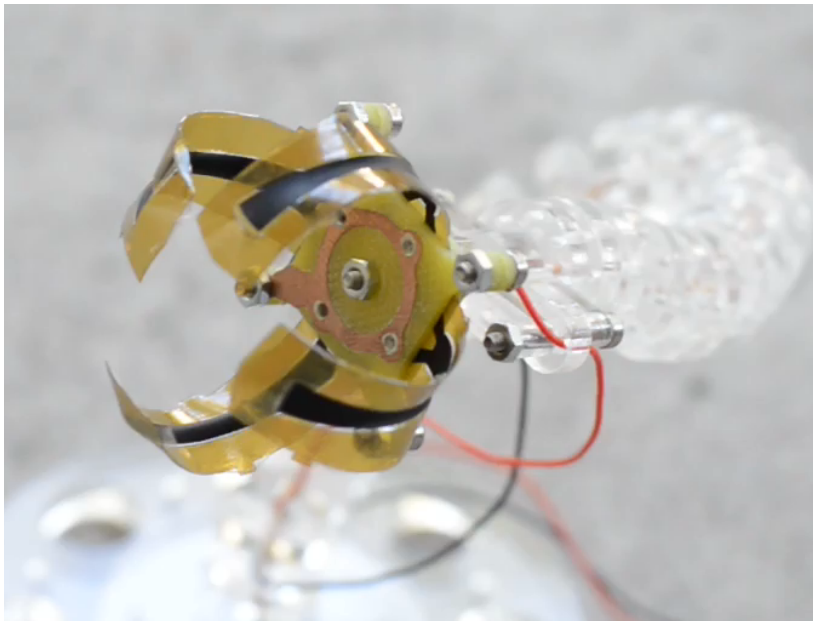
M. Niklaus, S. Rosset, and H. Shea, Proc.SPIE, 2010, vol. 7642, p. 76422K–76422K–12.
url: http://infoscience.epfl.ch/record/148575

How The Gripper Works

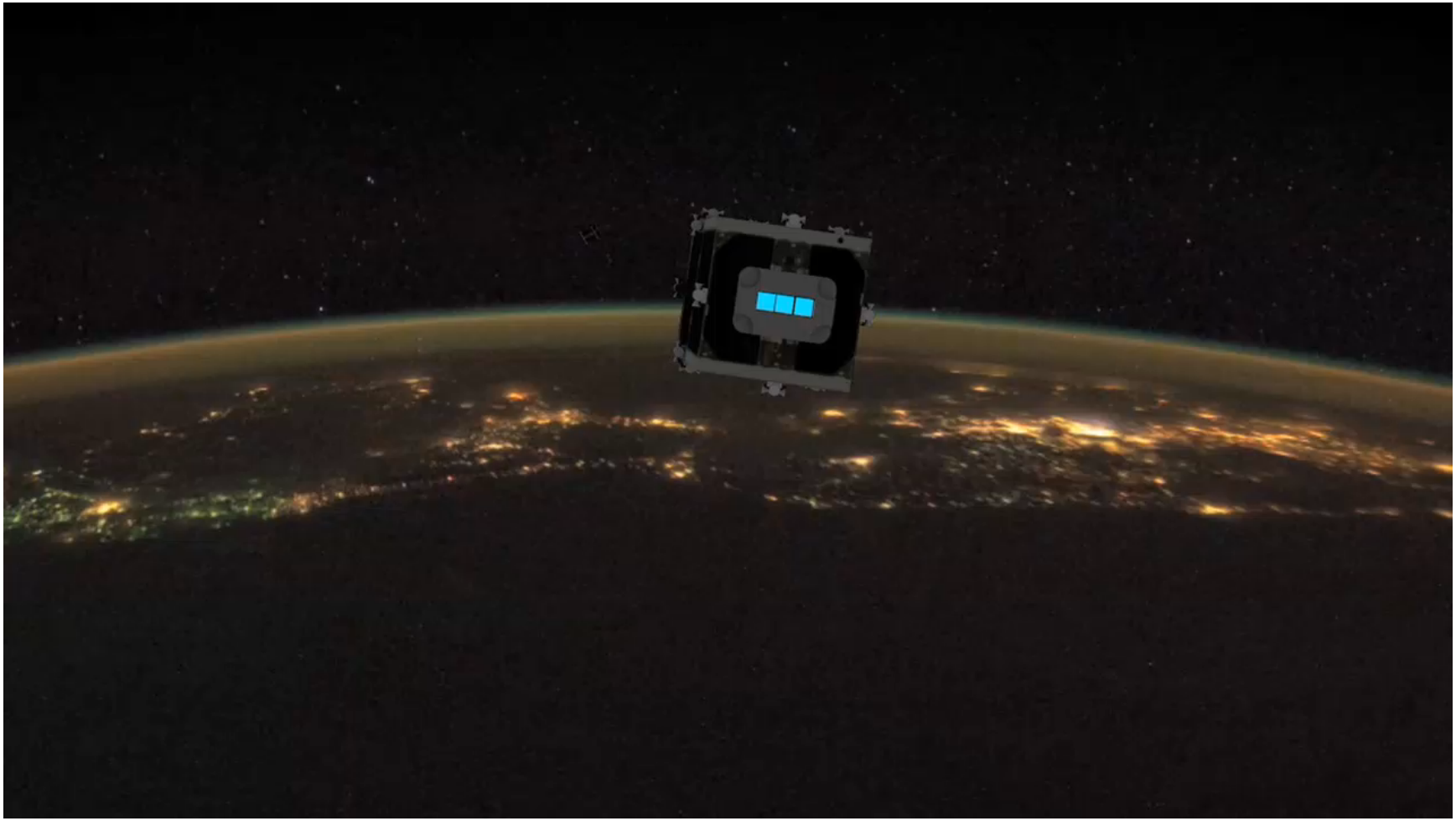






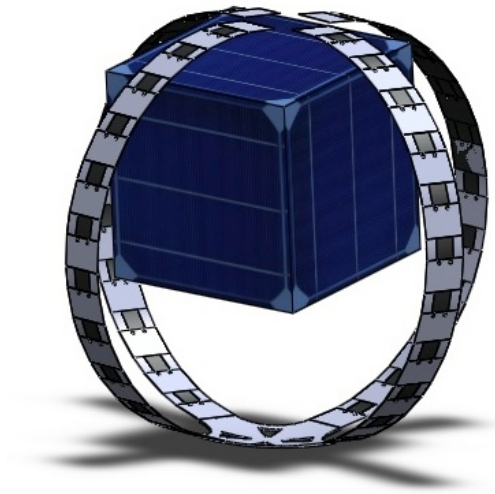


Capture Scenario

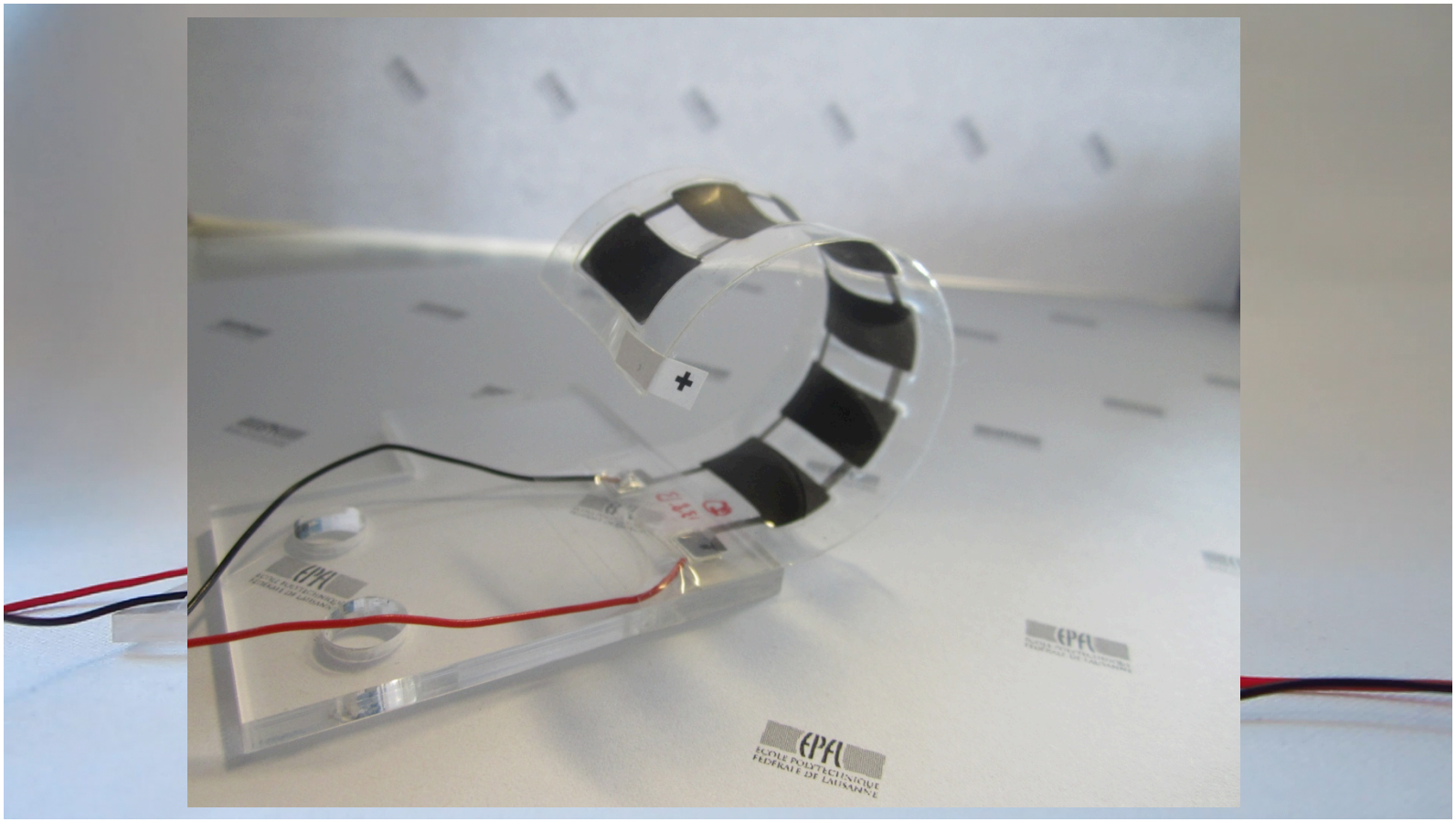


Design Requirements

- 30 cm long – (prototype devices 1/3 in length)
- Efficient storage - rolling
- Bending angle as large as possible
- Between 1 - 6 mN gripping force



Our Device



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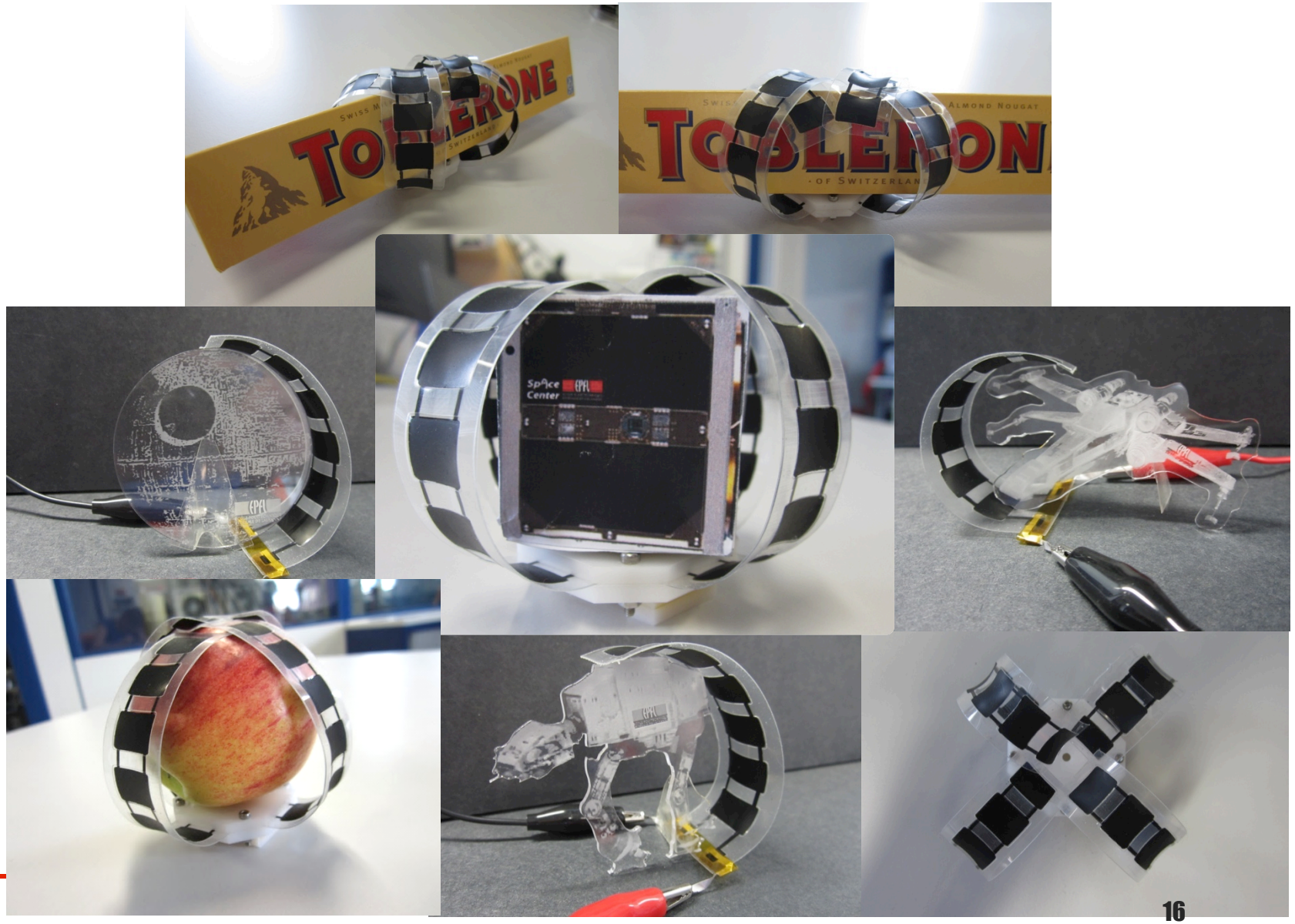
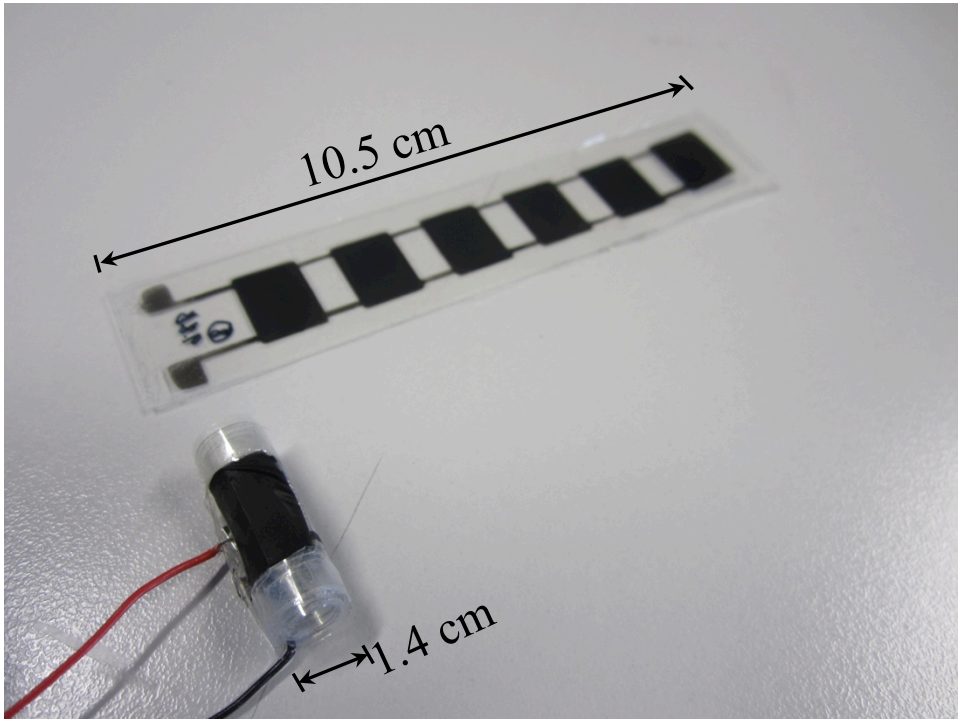
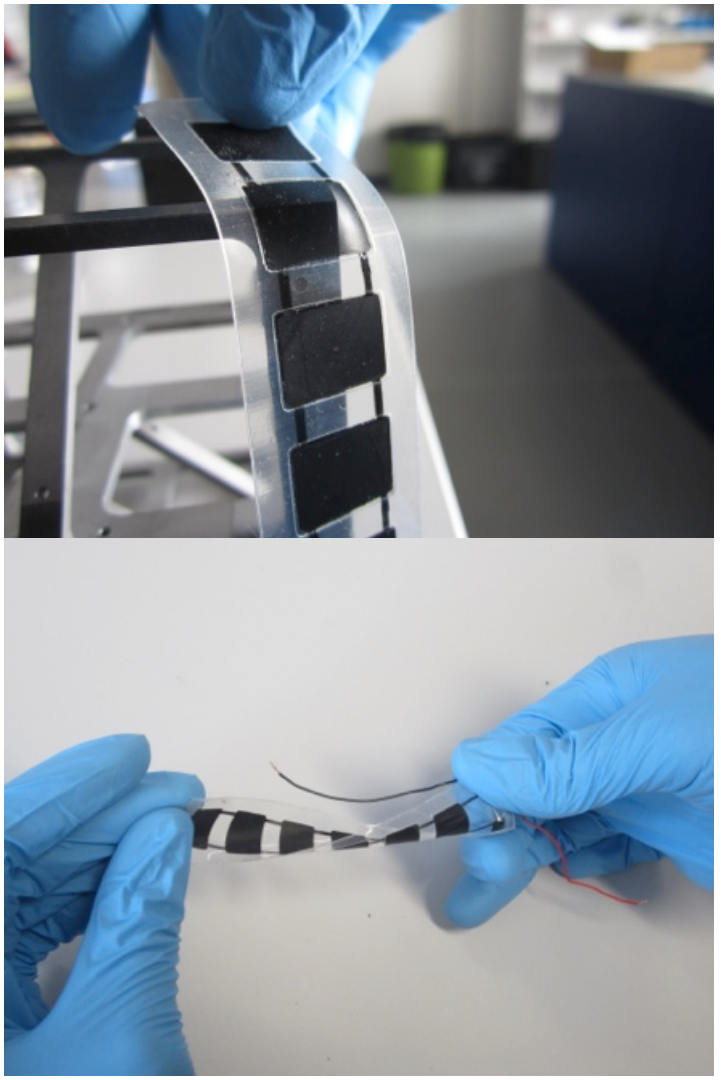
Conformity



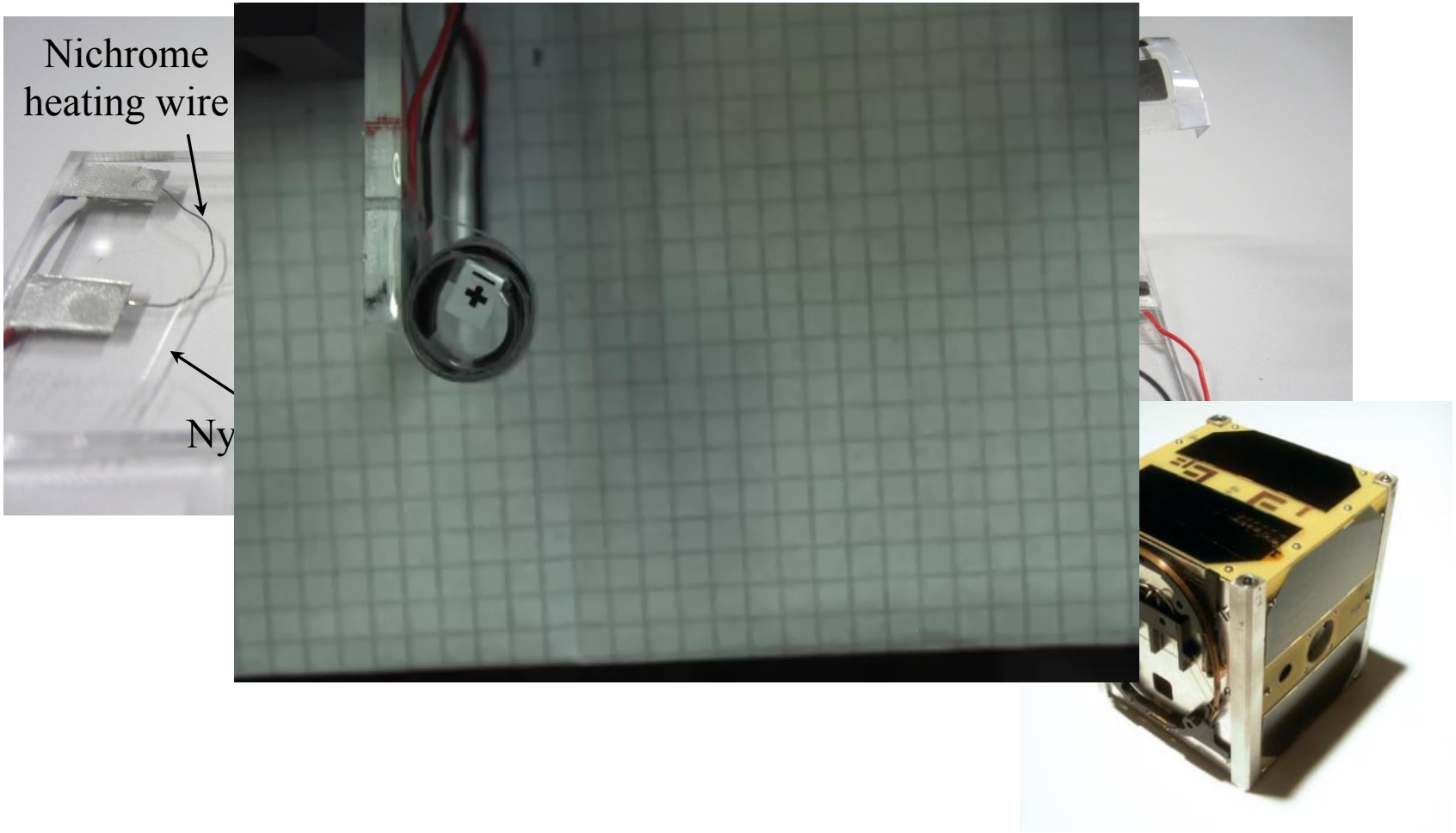
Mechanically Robust



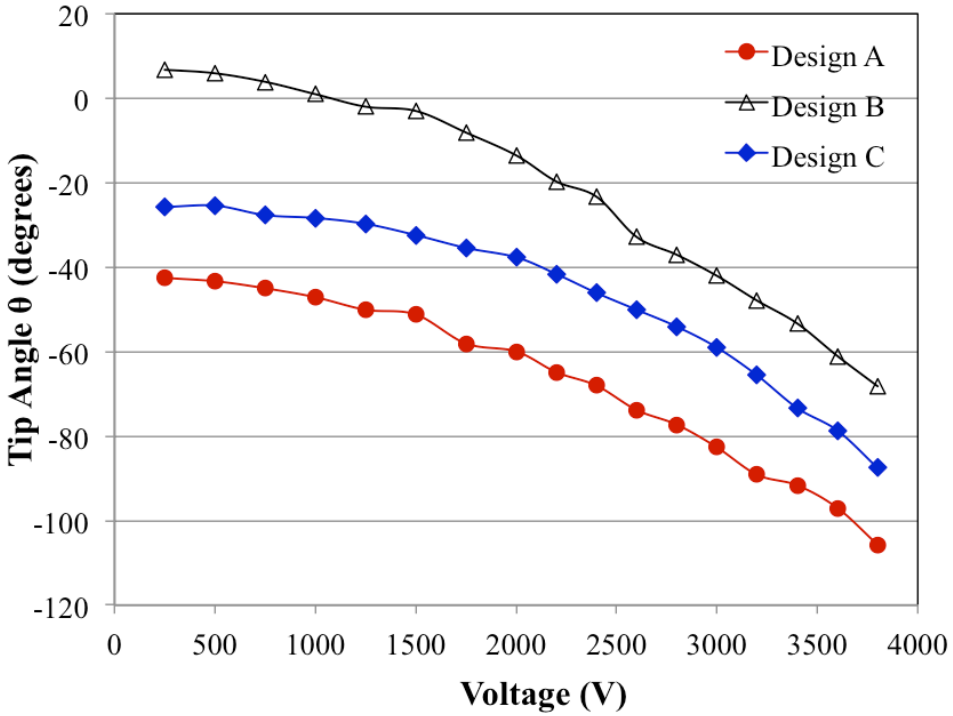


Deployment From Rolled State

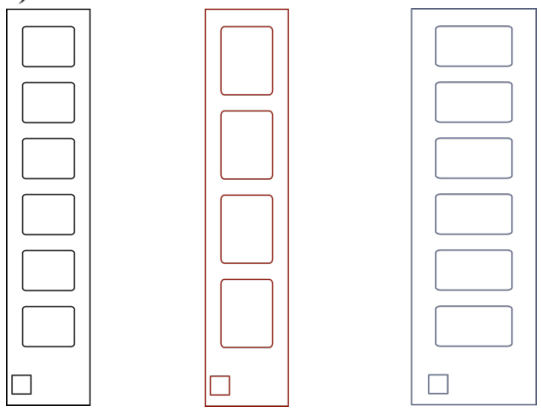
Deployment



Bending Angle and Gripping Force



	Max. reaction (gripping) force (mN)
Design A	0.76
Design B	0.94
Design C	2.2



O. A. Araromi et al., *IEEE Trans. Mech.*, in Press 2014. doi: 10.1109/TMECH.2014.2329367

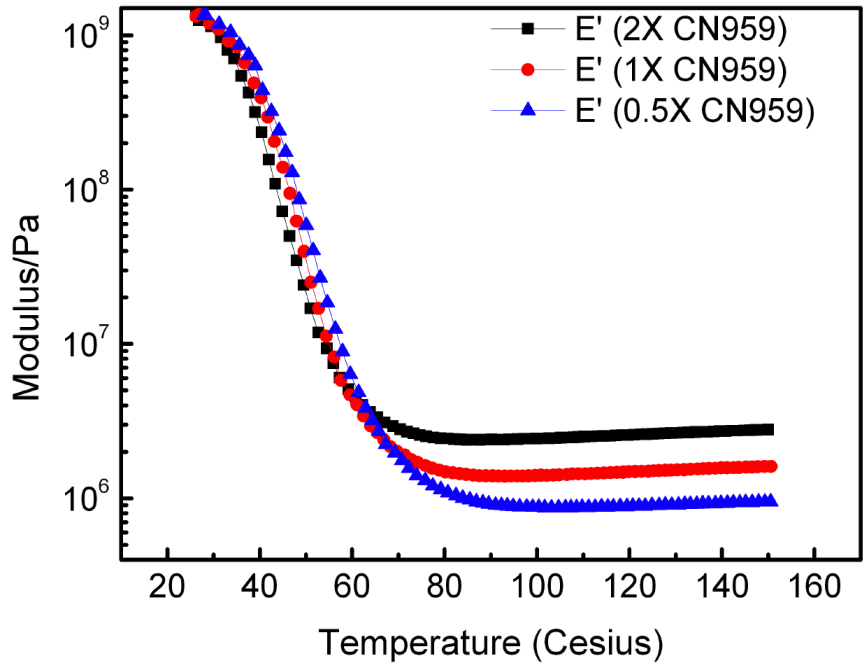
Enhancing Functionality

- **Sensing:**

Embedding flexible sensors or switches (i.e. using flexible thin film transistors) into actuator structure for smart sensing-actuation capabilities.

- **Variable Stiffness**

Use of commercially available variable stiffness polymers for **increased gripping force**.



Z. Ren, X. Niu, D. Chen, W. Hu, Q. Pei, *Proc SPIE*; 2014; Vol. 9056, p. 905621.

Demonstration of Variable Stiffness

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Variable Stiffness Dielectric Elastomer Actuator (VSDEA)

Bryan Schubert[1], Jun Shintake[1,2], Herbert Shea[2] and Dario Floreano[1]

Ecole Polytechnique Fédérale de Lausanne
[1]Laboratory of Intelligent Systems (LIS)
[2]Microsystems for Space Technologies Laboratory (LMTS)

LIS

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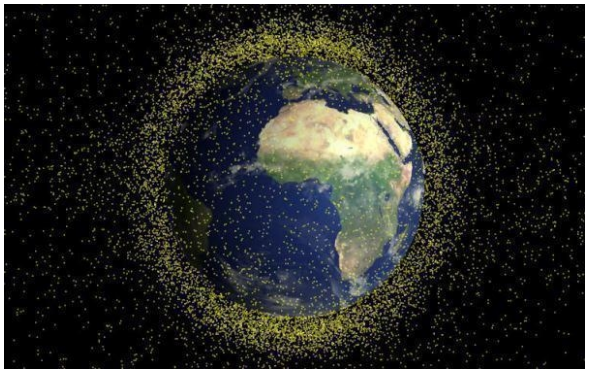
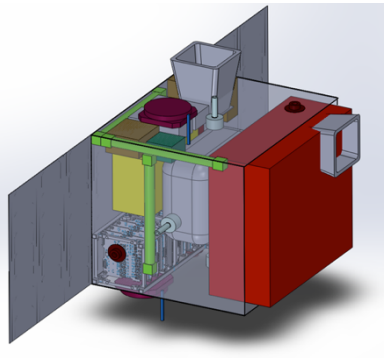
robotics Swiss National Centre of Competence in Research

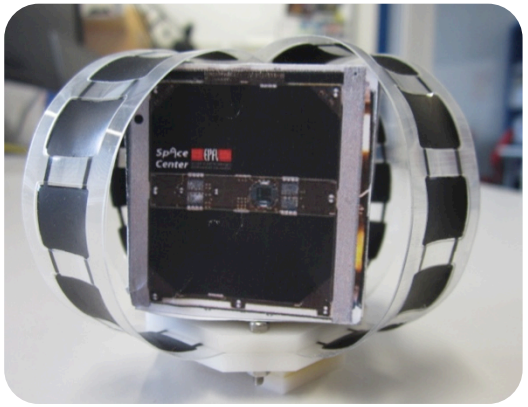
FNSNF

Summary

- Soft gripper capable of efficient storage developed as a light weight deployable gripper
- Large deflection actuation demonstrated
- Development of devices with enhanced sensing and variable stiffness functionalities commenced for contact/deflection sensing and increased gripping force







THANK YOU