# Miniaturized Dielectric Elastomer Actuators

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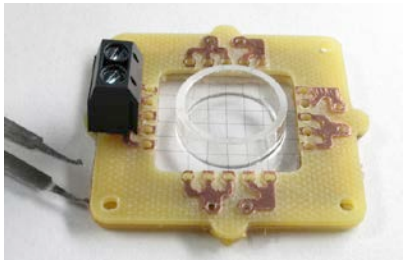
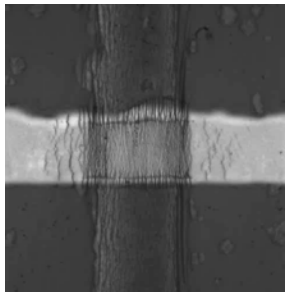


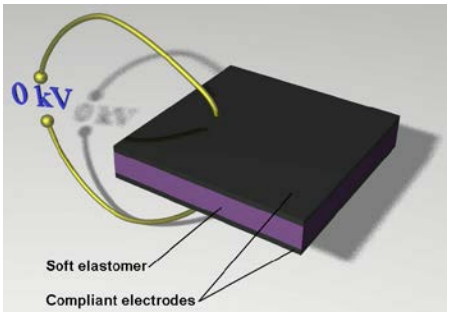
2 cm

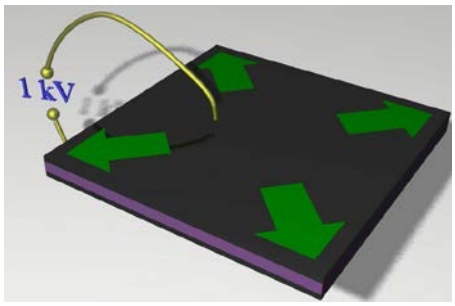


100 µm

## Dielectric Elastomer Actuators (one type of artificial muscle)

- Monolithic **actuator + sensor + structure** consisting of:
  - soft dielectric (elastomer) and
  - compliant electrodes
- When kV voltage is applied, the area expands up to 300%

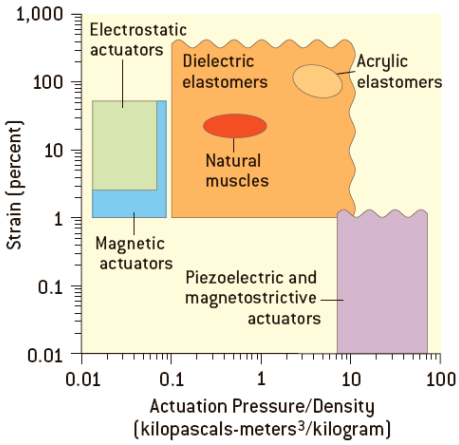



$$p_{\mathrm{el}} = \epsilon_0 \epsilon_r \left(\frac{V}{t}\right)^2$$

# Features of Dielectric Elastomer Actuators (DEA)

- **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
- Performance comparable to human muscles
  - ➢ Soft robotics
  - ➢ Interaction with soft tissue
  - ➢ Optics…
- Can add intelligence through self-sensing

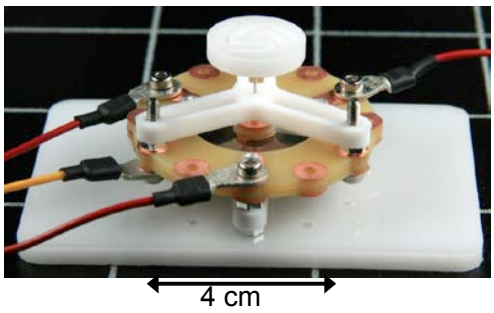



S. Ashley, *Scientific American* **289**, p.52 2003



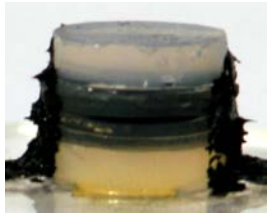
# Miniaturizing DEAs at EPFL

- **Small, Soft, Large % strain**
  - Fast (kHz)
  - Integration
  - Batch-fabricated




We have developed µm to cm scale artificial muscles:

- **Arrays of single cell-sized actuators for biology**
- Micropumps on a chip
- **Flexible rotary motors**
- **Grippers and bending actuators**
- 2-axis mirrors
- Tunable lenses (55 µs response time)
- RF phase shifters
- Soft energy harvesters



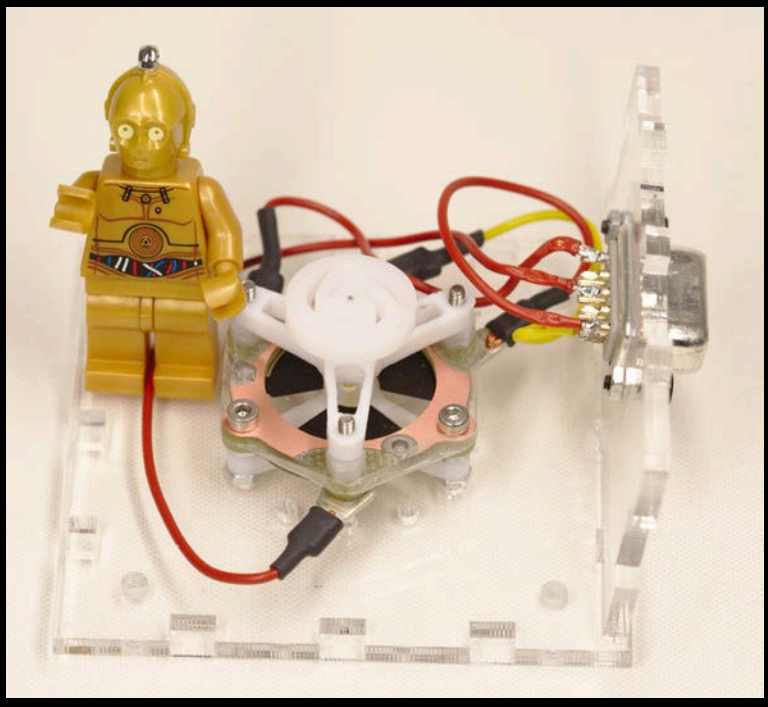
Energy harvester
Stack of 128 layers
5 mW in 1 cm$^3$

Details & movies: http://lmts.epfl.ch/DEA

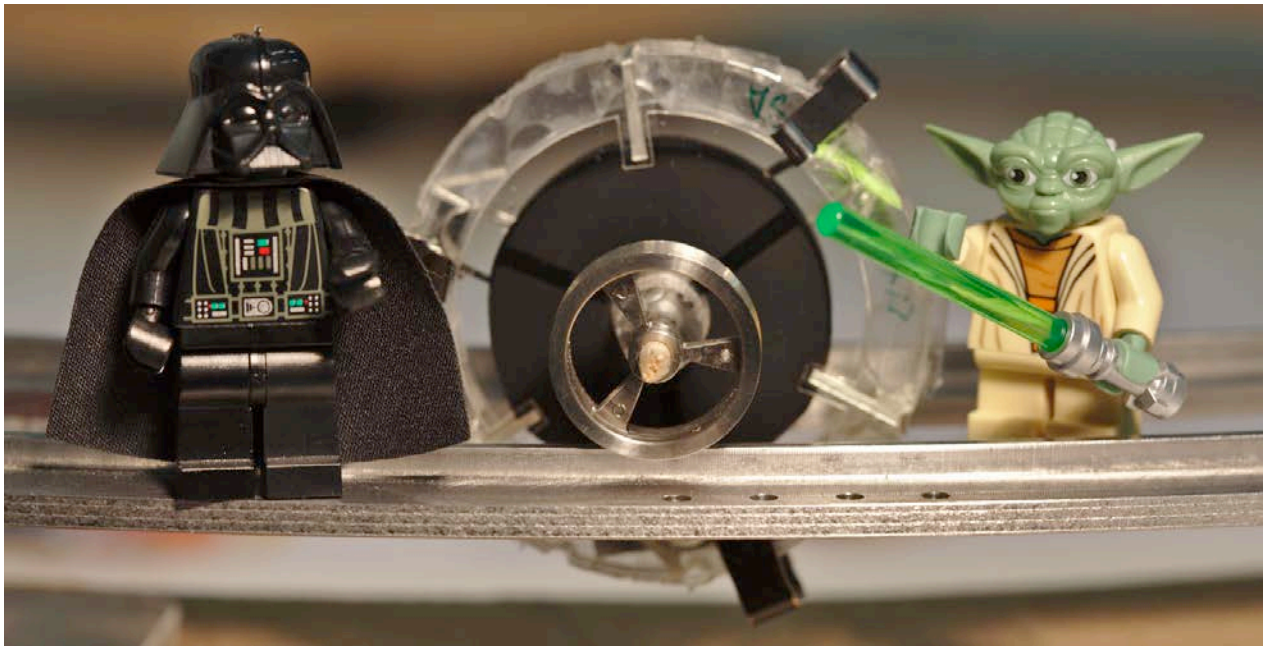
# *CAN SOFT THINGS BE FAST?*



Moteur rotatif rapide (25 tour/s) en silicone mou



## Rupert the Rolling Robot



http://lmts.epfl.ch/rupert



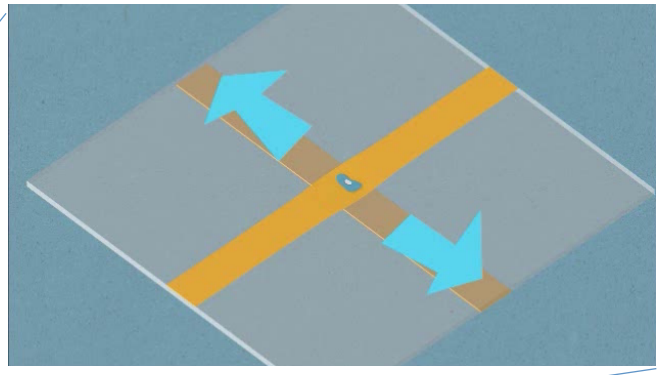
# ARRAY OF DEVICES TO APPLY MECHANICAL STRAIN TO BIOLOGICAL CELLS

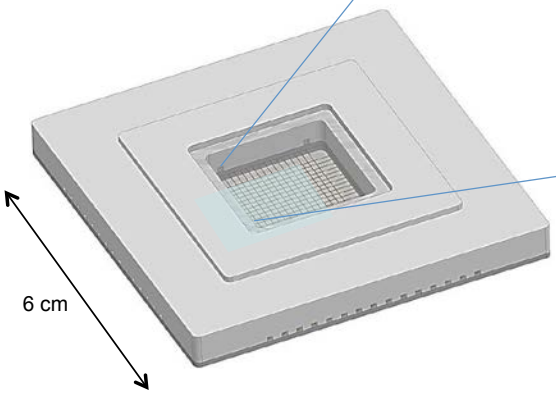
# How do cells respond to mechanical strain?

- **Cell cytomechanics** (= cytology + biomechanics): investigating gene expression, proliferation and differentiation, as a function of mechanical strain
- We make a tool for biologists to decipher cell mechanotransduction mechanisms, allowing many experiments on one chip.
- Would allow new therapeutic strategies
  - muscular dystrophy
  - osteoporosis
  - reversing age-related cellular degeneration

- Culture cells on the device
- Apply periodic mechanical strain, up to 20%
- Monitor the cell morphology or gene expression

Dielectric Elastomer Actuators (DEAs), soft

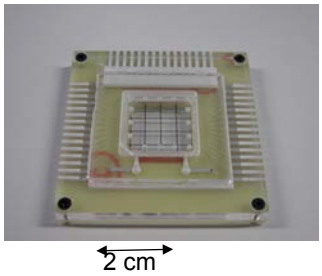


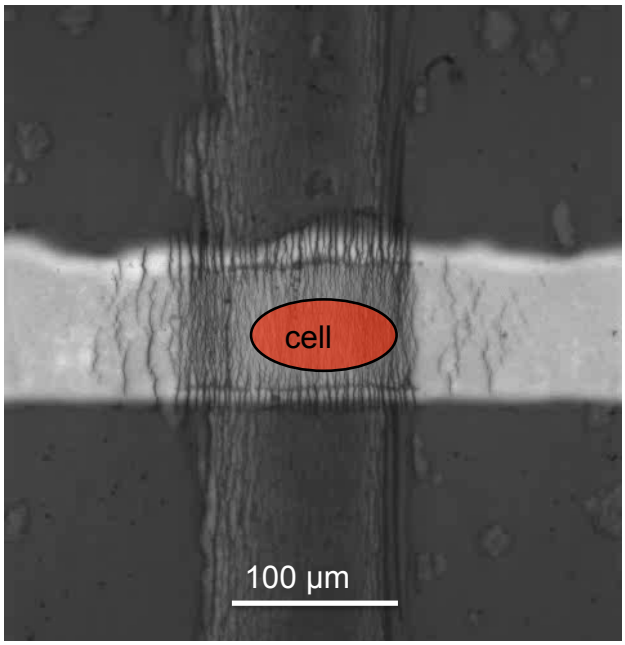



- Parallelization for high throughput
- Strain gradient, dynamic control

S. Akbari and H. Shea, *J. Micromech. Microeng. 22* p.*045020* (2012)
S. Akbari, S. Rosset, H. Shea, *Applied Physics Letters,* 102, p. 071906 (2013)

## Sub-second response time, large strain
## Stiffness well matched to cells



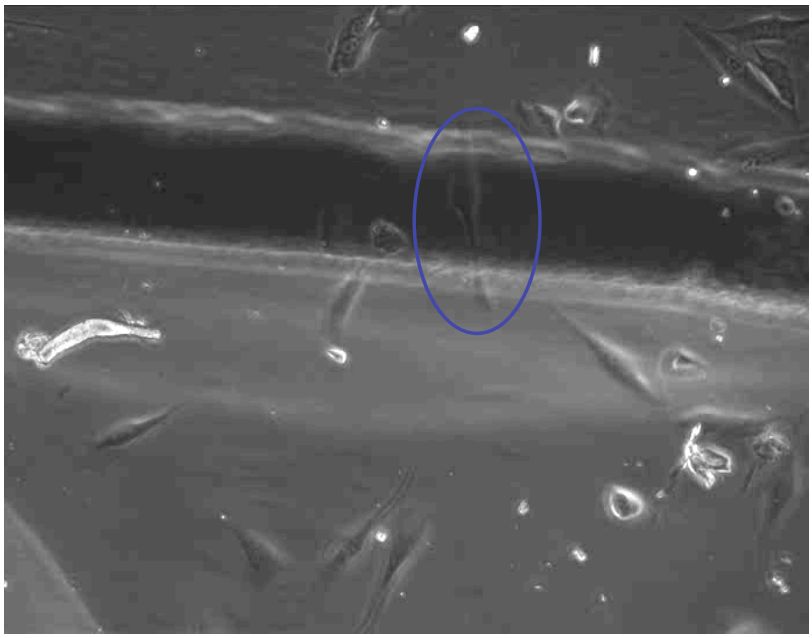




40% strain
at 1 Hz

S. Akbari and H. Shea, *Sensors and Actuators A,* 186, pp236–241 (2012)



## Stretching cells !

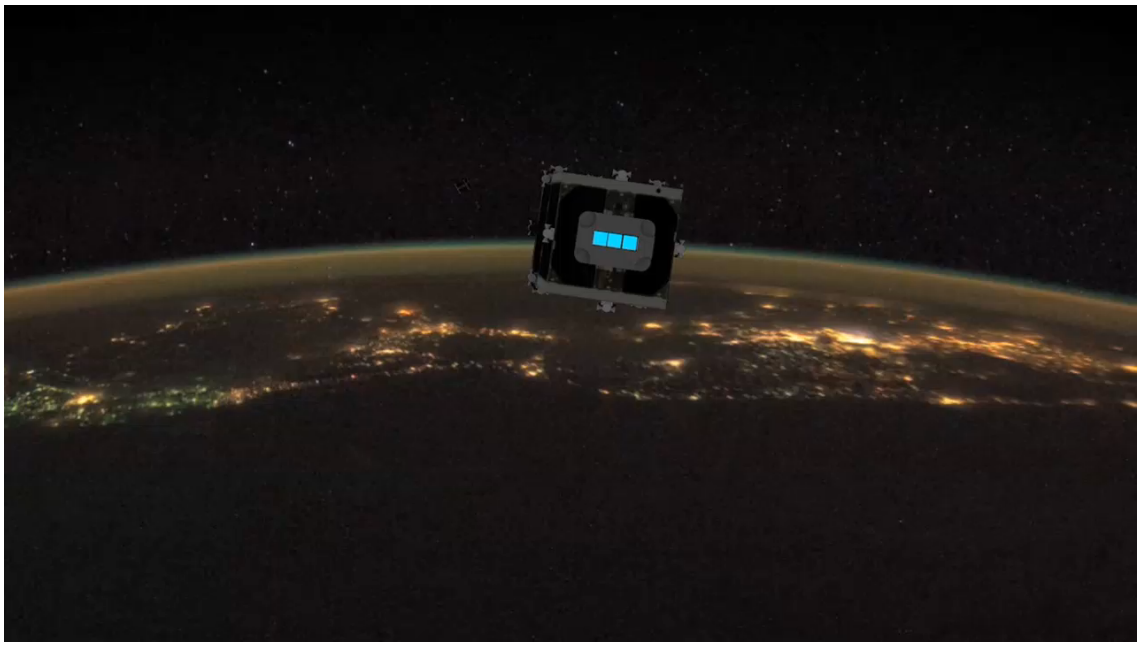


Now starting tests with cells with biologist partners at CSEM

# MULTI SEGMENT SOFT GRIPPER

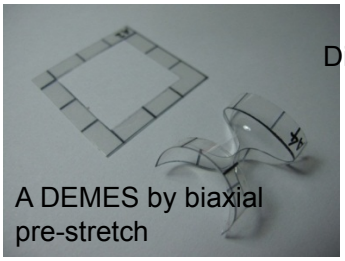


## CleanSpace One – a small satellite to remove space debris, which it needs to grab!

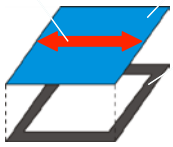


Movie credit: Swiss Space Center, E. Pignat

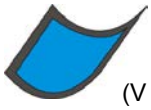
## Soft electrically-driven actuators, “minimum energy” DEA structures




Direction of stretch

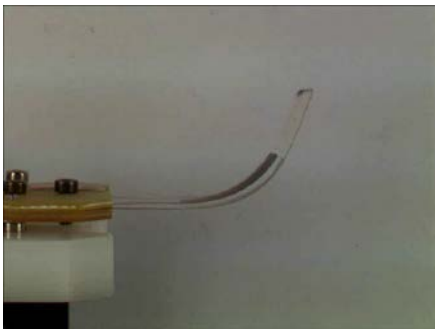


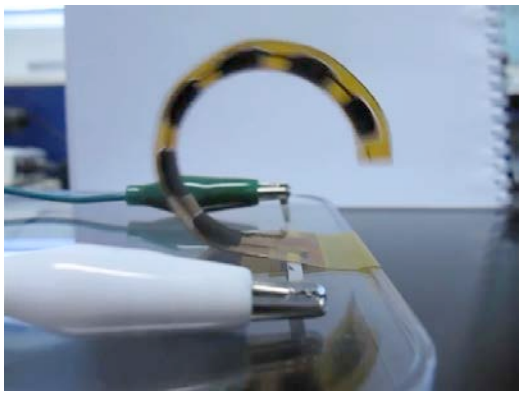
Pre-stretched DEA
Frame



(V = 0)

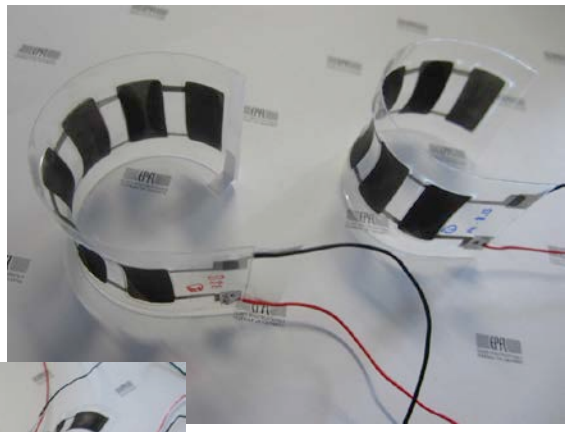
(V > 0)

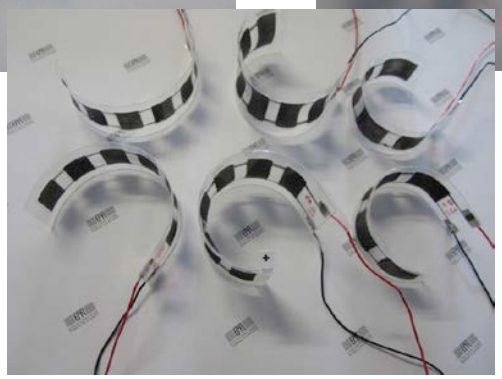




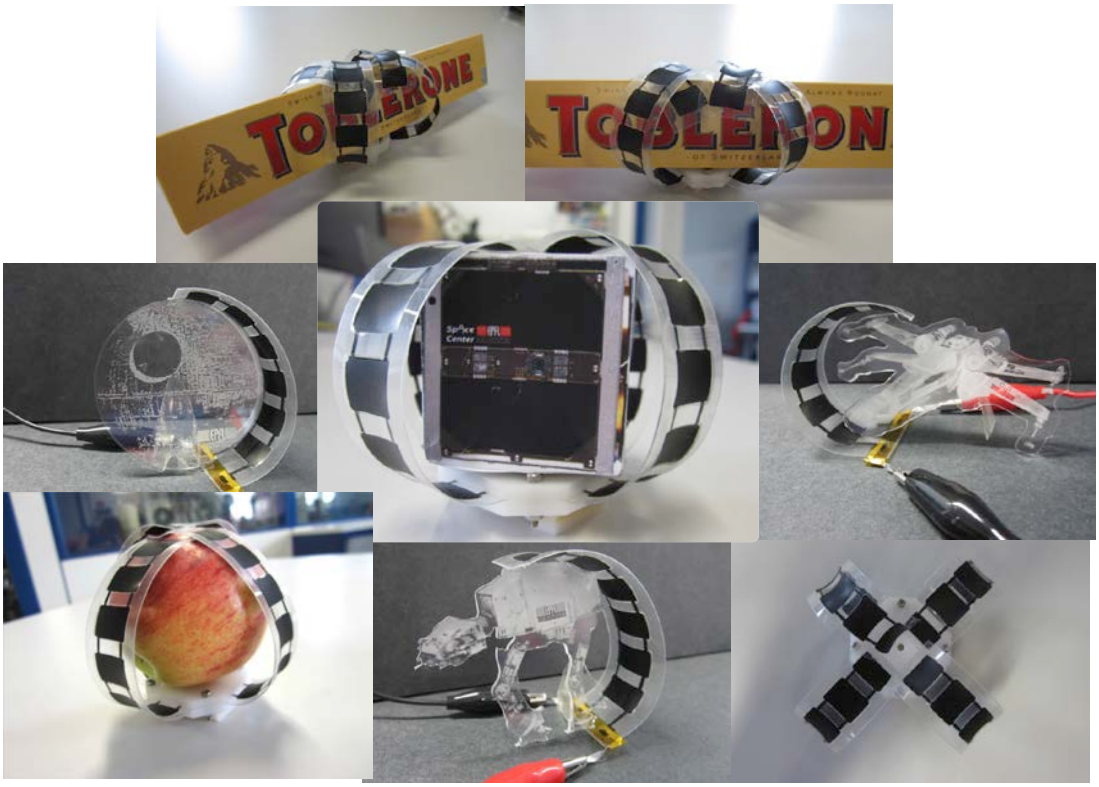


## Fabrication process is highly repeatable





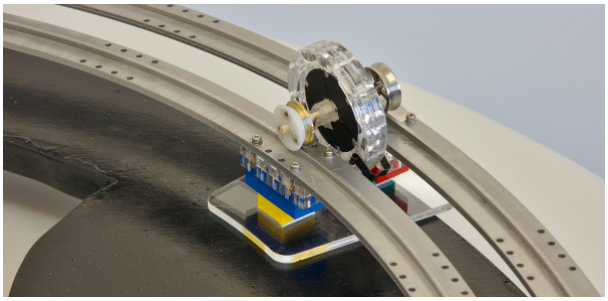
## High Conformity to many shapes





- Soft actuators enable new ways to think about systems
- Combine energy harvesting, sensing, distributed actuation all in one : **intelligent artificial muscles**

Many thanks for your attention!

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