Coiled Hold-Release Mechanism Based on Shape Memory Polymer Composites for Aerospace Applications

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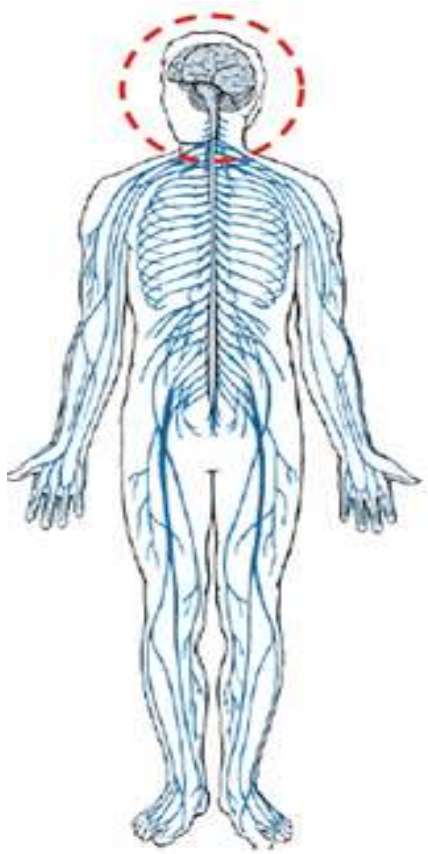
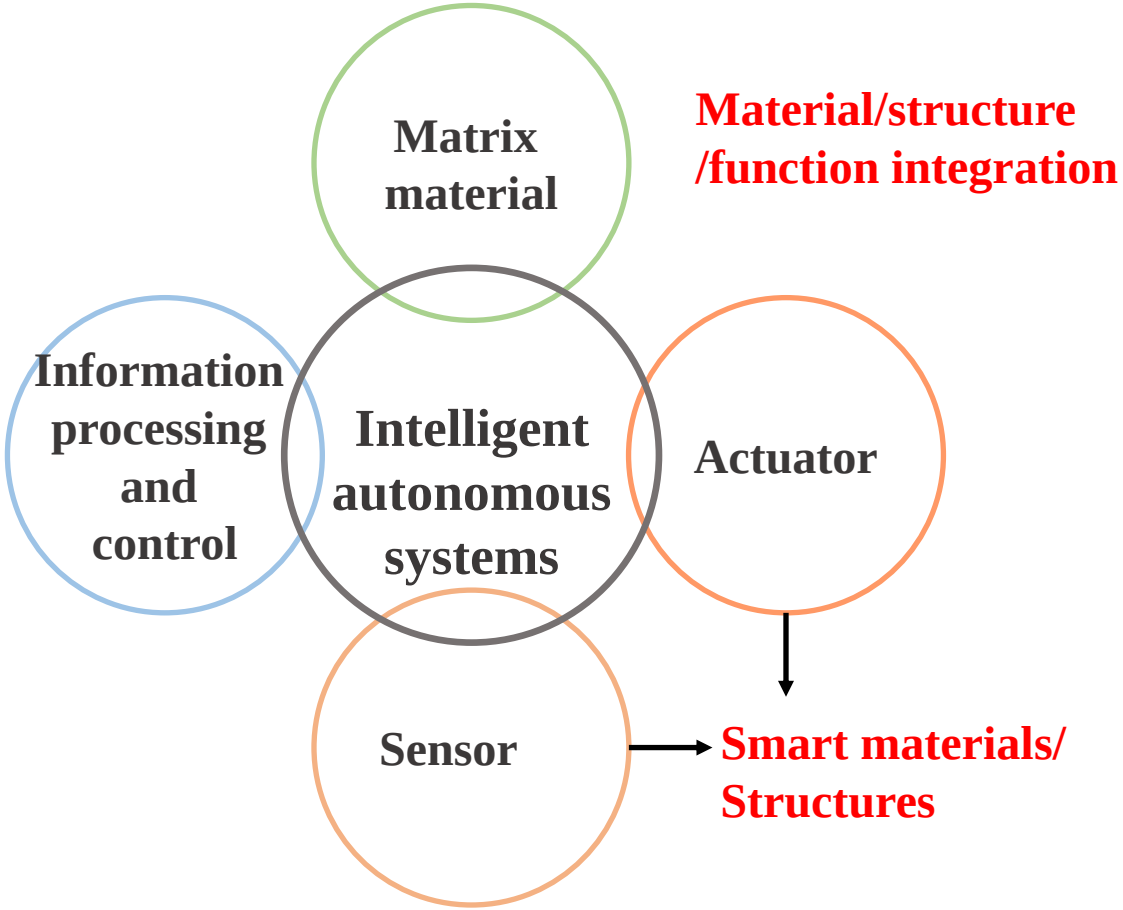
Smart material structure-Intelligent autonomous system

- ✓ **Smart material/structure is a new type of material/structure which can sense the change of external environments and respond actively**



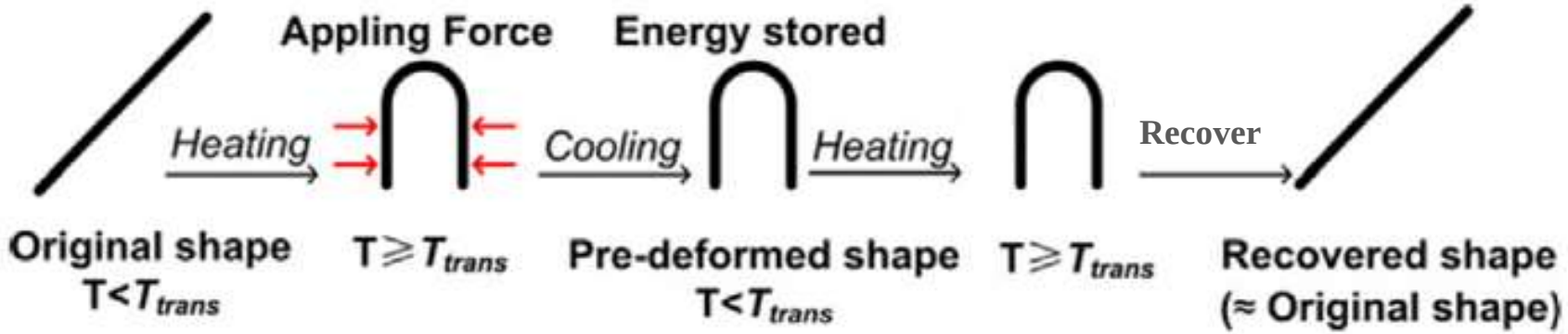


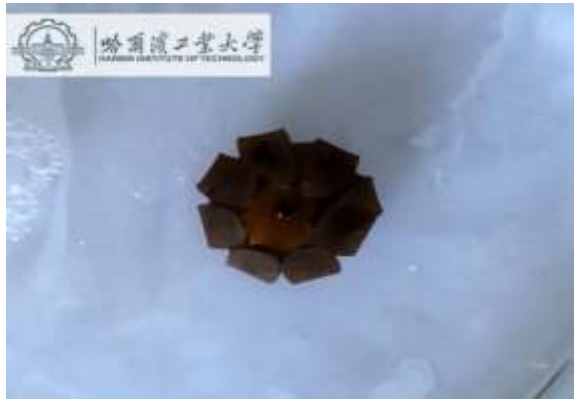
Leng JS, Liu YJ, Smart Composite Materials, China Railway Publishing House Co. LTD, 2022.

Background of Shape Memory Polymers

Shape Memory Polymers (SMP) are polymeric smart materials that have the ability to recover from temporary shape to their permanent shape induced by an external stimulus, such as temperature change.

- **Shape memory property;**
- **Variable stiffness,**
- **Elastic modulus change 200 times**



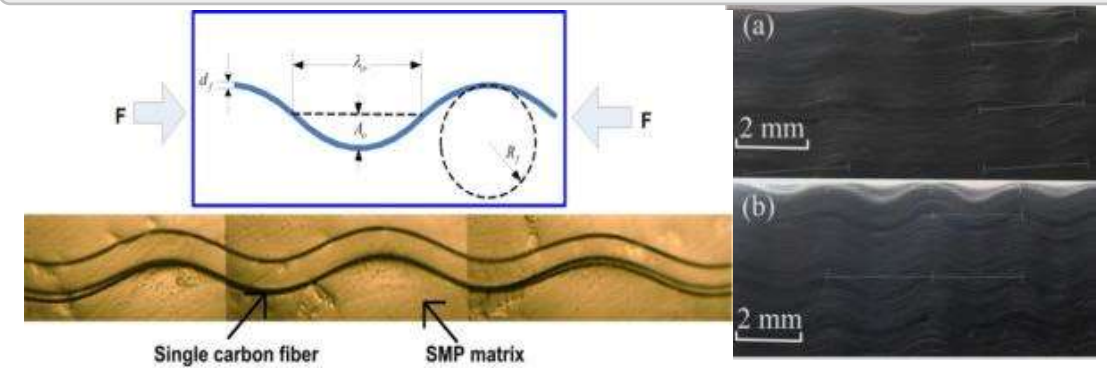


Leng JS, Lan X, Liu YJ, Du SY. Progress in Materials Science, 56, 1077-1135 (2011)
Wang WX, Liu YJ, Leng JS. Coordination Chemistry Reviews, 320, 38-52 (2016)
Liu TZ, Zhou TY, Yao YT, Zhang FH, Liu LW, Liu YJ, and Leng JS. Composites Part A, 100, 20-30 (2017).

Deployable Structures in Aerospace

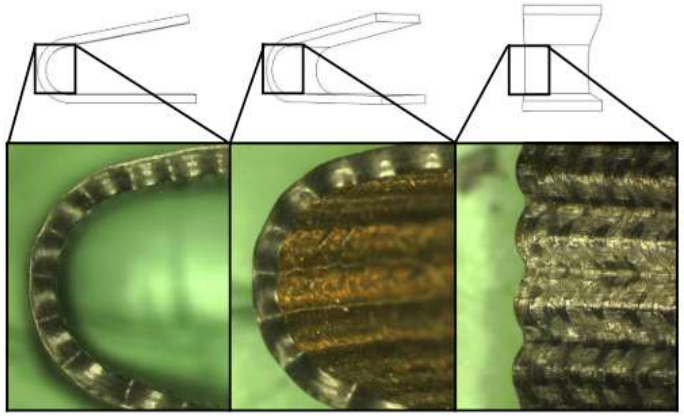
—— **Post micro-buckling** mechanics of SMPC under flexure deformation

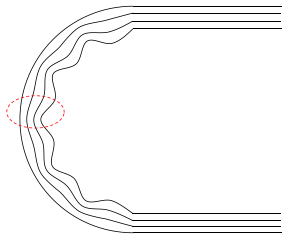
- The local **post-buckling mechanics** of unidirectional fiber-reinforced SMPC were investigated, and the problem of **small strains** and **large deformation** was considered.
- The analytical expressions of the **critical buckling curvature**, **buckling fiber wavelength** and **buckling fiber amplitude** were determined by the minimum energy principle.
- Based on the buckling deformation of fiber, the small material strain of fiber was used to produce **large geometric deformation of the composite structure**.

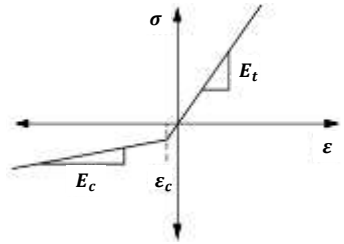


Micro-buckling configuration

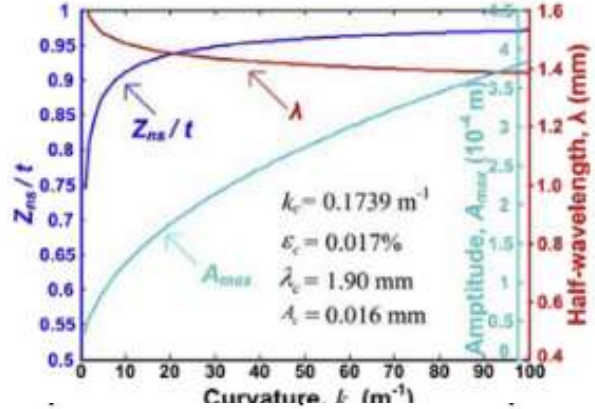
$$\lambda = \begin{cases} +\infty & (k < k_c) \\ \left[\dfrac{8\pi^3 v_f E_f I_f \left(z_{ns}^2 - \dfrac{4M^2}{k^2}\right)}{v_m G_m d^2 \ln\left(\dfrac{k z_{ns}}{2M}\right)} \right]^{1/4} & (k \geq k_c) \end{cases}$$







Micro-buckling wavelength at different curvature

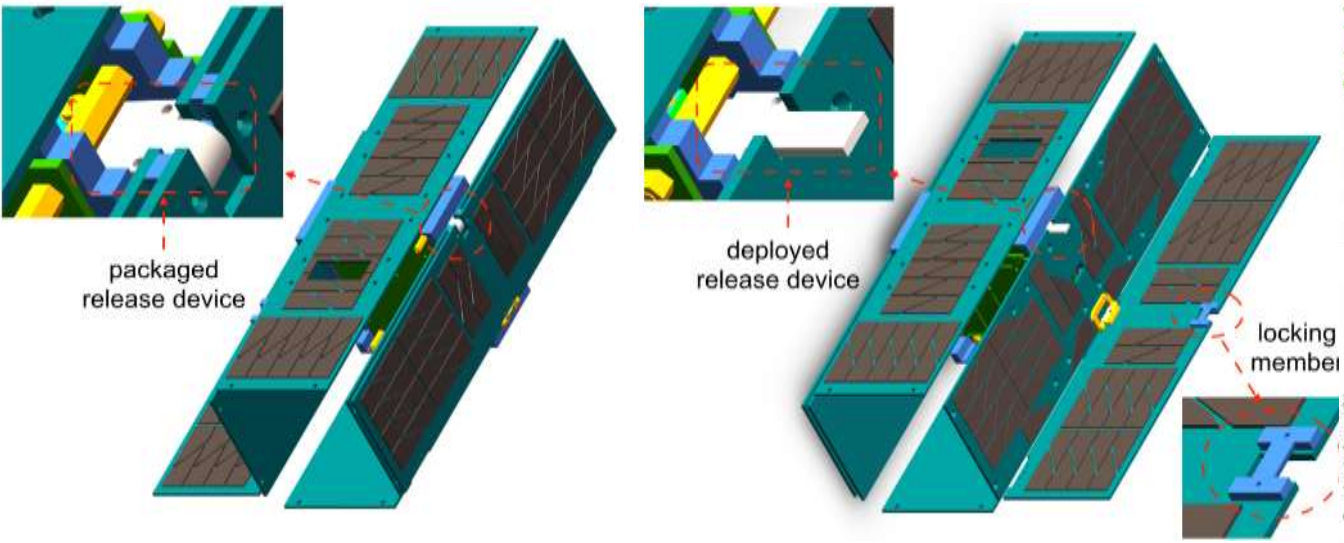


Curvature k (m^{-1})	Neutral surface Z_{ns}/t	Half wavelength λ (mm)	
Design value	Theoretical value	Theoretical value	Experimental value
20	0.936	1.45	1.24 ± 0.05
50	0.959	1.41	1.39 ± 0.11
100	0.971	1.42	–

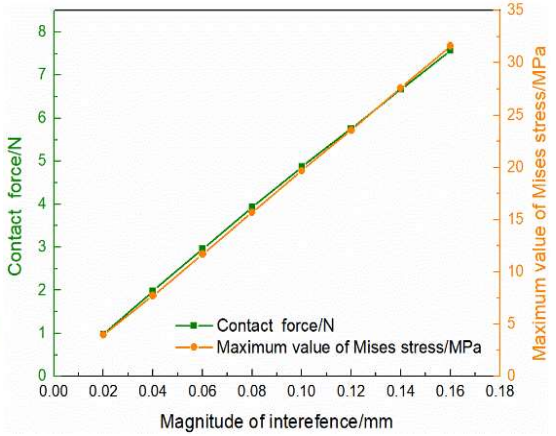
Lan X, Liu LW, Liu YJ, Leng JS, Du SY. Mechanics of Materials, 72, 46-60 (2014)

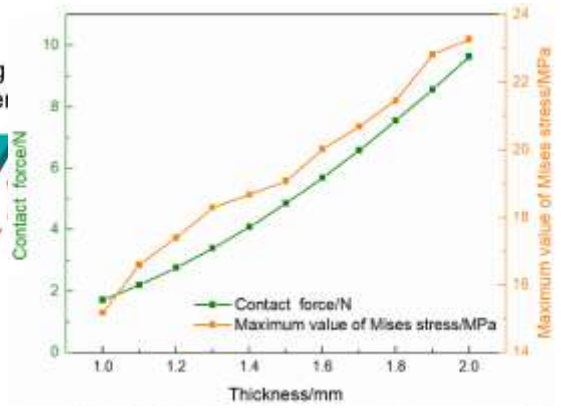
Deployable Structures in Aerospace

- Release device for CubeSat's deployable solar panels
- Latching force are adjustable through interference and thickness
- Featured in light-weight, small-shock and reusable



Schematics of the ultra-light release device





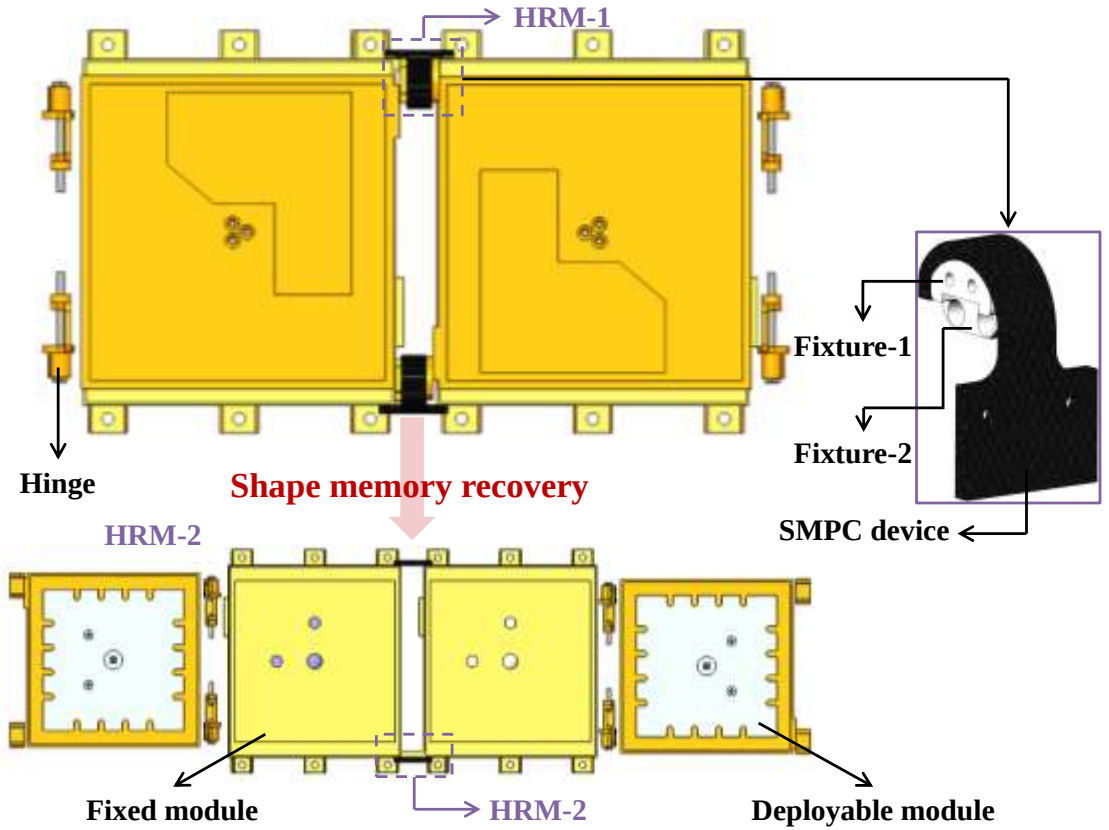
Latching force

Deployment on a prototype

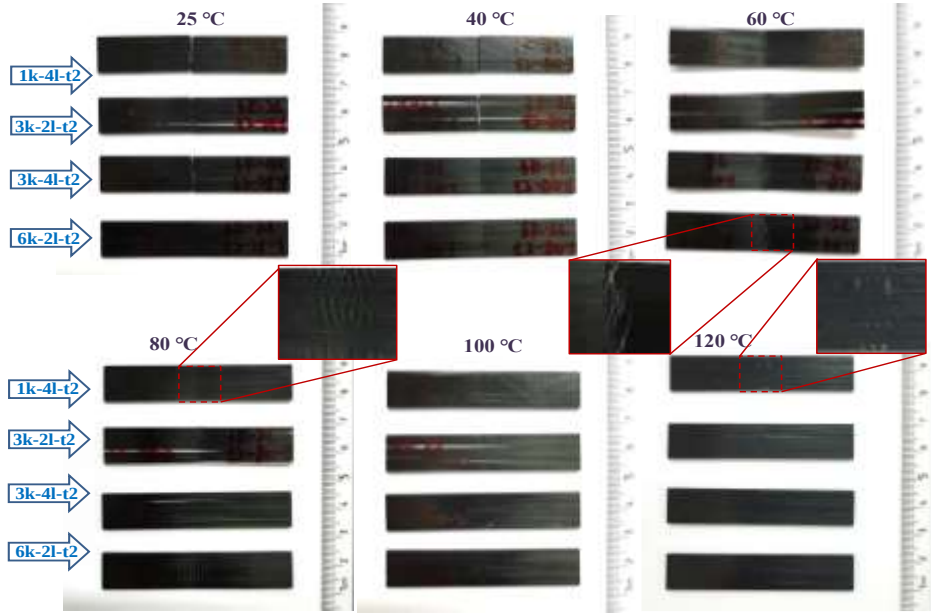
Zhang D, Liu LW, Leng JS, Liu YJ. Composite Structures, 232, 111561, 2020.

Deployable Structures in Aerospace

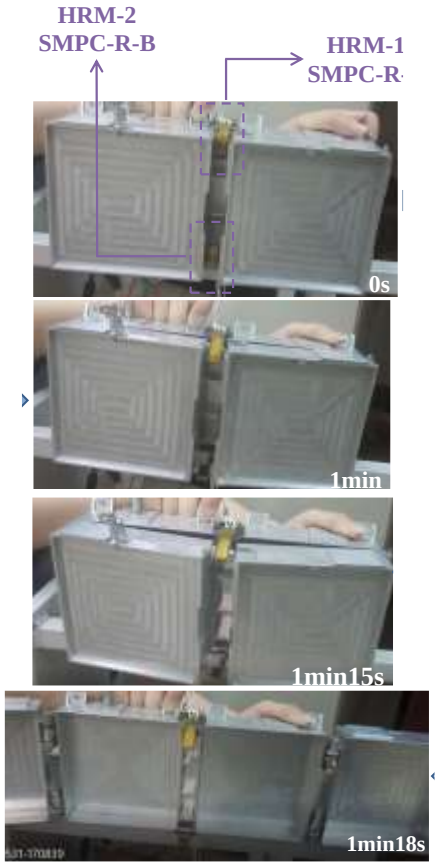
- Synchronisation of the deployment of symmetrical structures
- Damage evolution with temperatures
- Preliminary validation on a prototype with a less than 67 ms synchronisation



Schematics of the synchronous deployed structures



Damage morphology

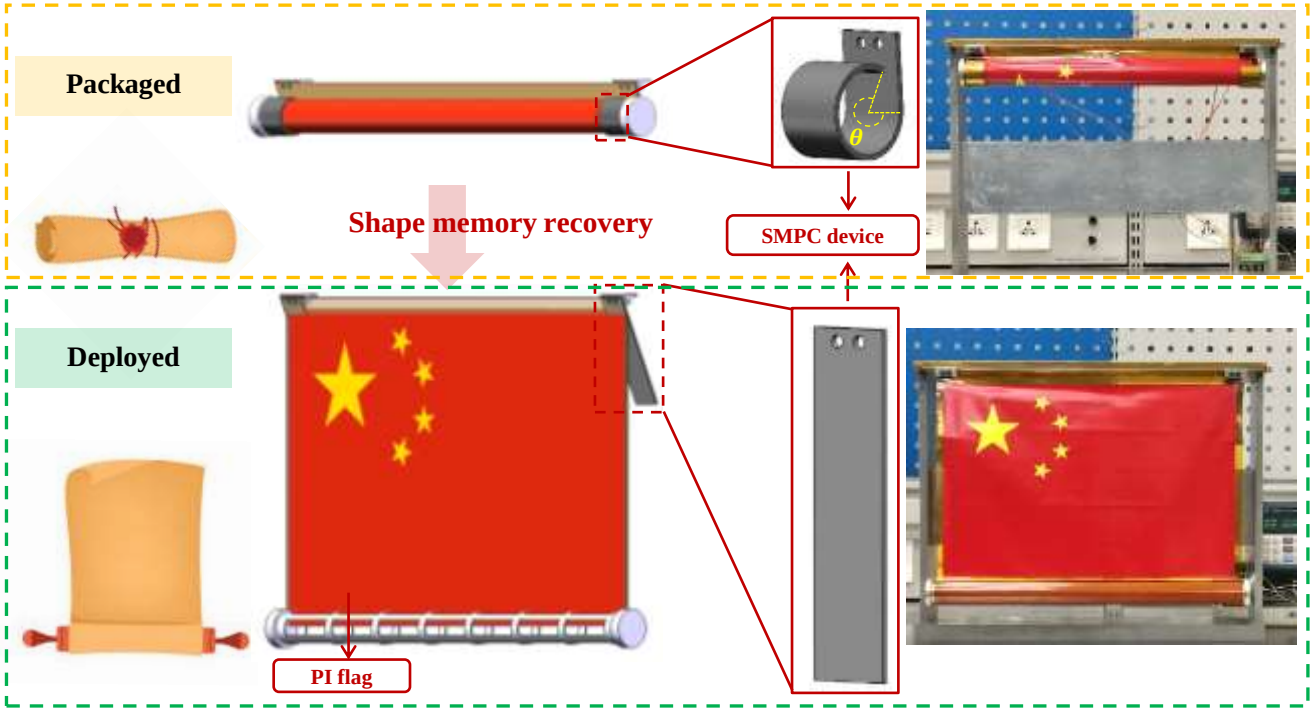


Deployment on a prototype

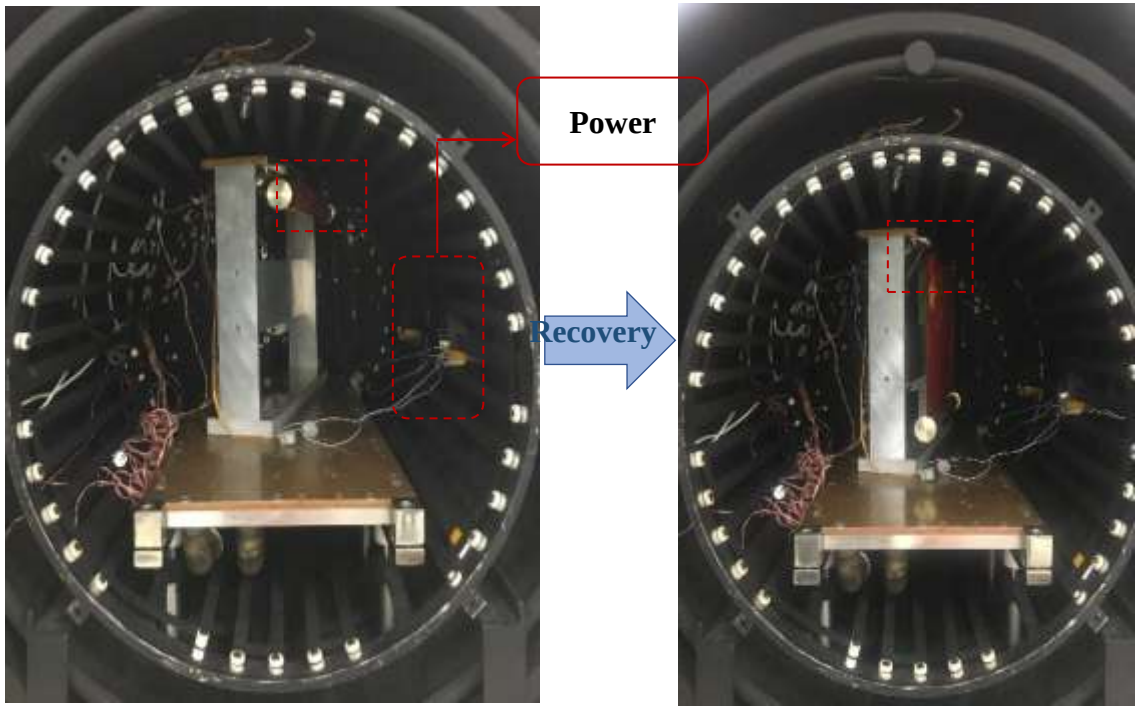
Zhang D, Liu LW, Lan X, Leng JS, Liu YJ. Composite Structures, 290, 115513, 2022.

Deployable Structures in Aerospace

- World's first application of SMPC in Mar exploration
- Dynamic demonstration of flag in deep space
- Deployment adaptability to voltage and ambient temperature



Self deployable mechanism for national flag



Deployment in a simulated Martian environment

Zhang D, Liu LW, Xu PF, Zhao YZ, Li QF, Lan X, Zhang FH, Wang LL, Wan X, Zou X, Zeng CJ, Xin XZ, Dai WX, Li Y, He YC, Liu YJ, Leng JS. Smart Materials and Structures

Deployable Structures in Aerospace

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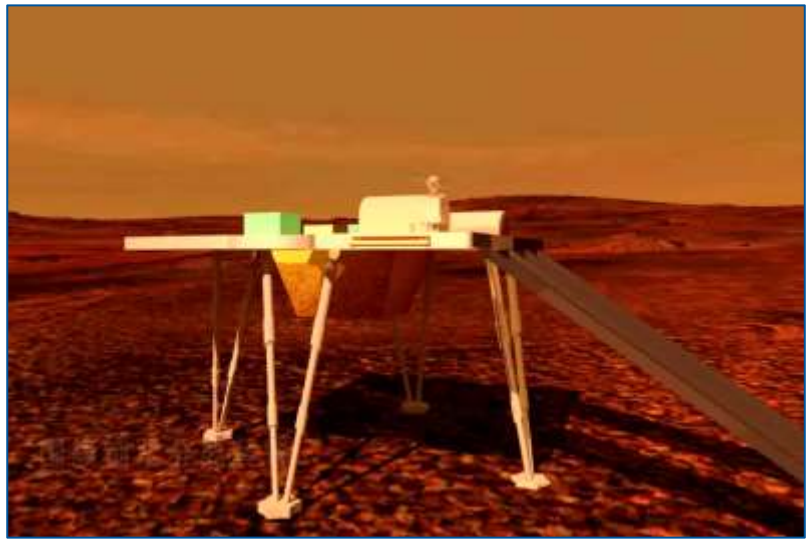
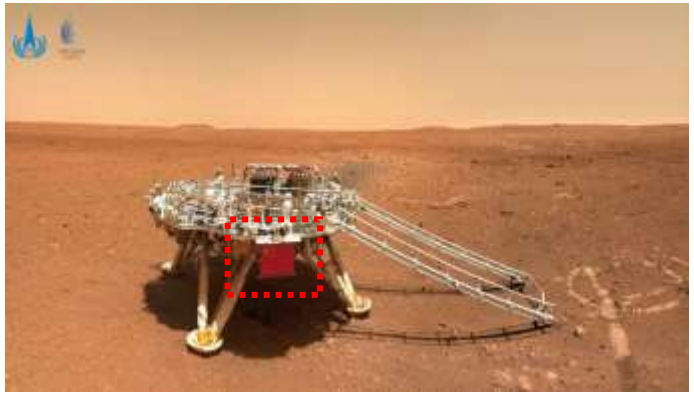
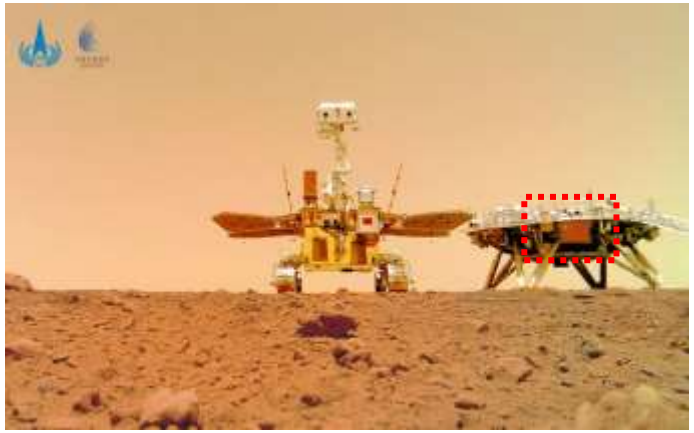
Mars probe landing



Dynamic deployment process





On-Mars deployment

Zhang D, Liu LW, Xu PF, Zhao YZ, Li QF, Lan X, Zhang FH, Wang LL, Wan X, Zou X, Zeng CJ, Xin XZ, Dai WX, Li Y, He YC, Liu YJ, Leng JS. Smart Materials and Structures

Thank you!