

# **Innovative Locomotion Concept for Long-Range Mission and study of Martian Wind**

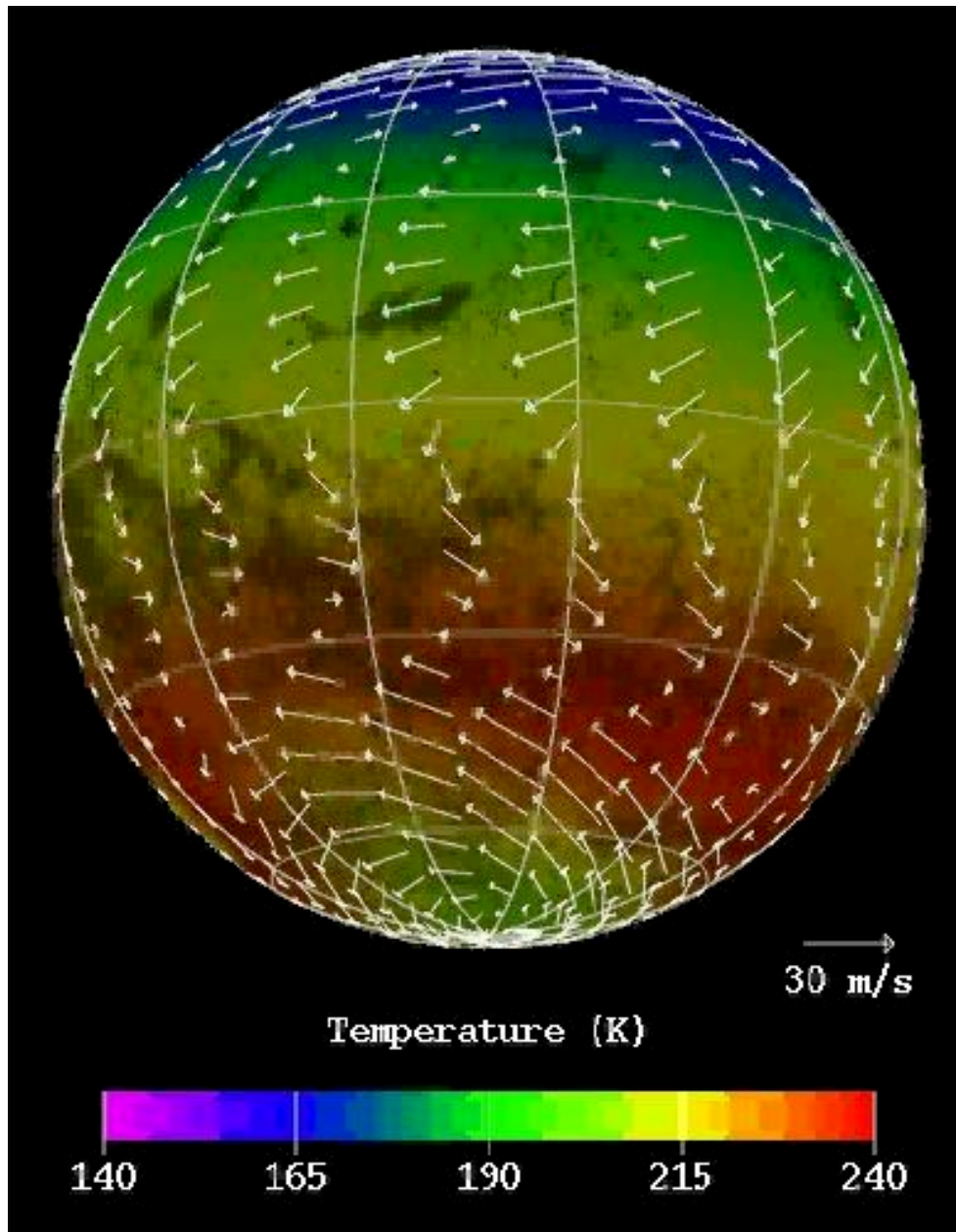
## **Windball Locomotion Concept**

- **Objectives**
- **Martian Environment**
  - Wind
  - Temperature
- **Application Scenario**
- **Robotic System**
  - Motion and Wind interaction
  - Thermal actuation
    - Shape Memory Alloys, SMA actuation
- **Conclusion**

## Windball Locomotion Concept

- **Increase autonomy of mobile robotic system**
  - ➡ limited by on board energy storage and production
  - ➡ limited by on board calculation power
- **Reduce need in energy storage**
  - ➡ Batteries are massive
  - ➡ Batteries are sensitive to thermal conditions
- **Reduce need in control for Navigation**
  - ➡ limit tele-operation from Earth
  - ➡ limit calculation power for path planning and obstacle avoidance
- **Take the best from the environment**
  - ➡ Specific system design for specific environment
  - ➡ Identify most direct mean to use local resources

# Mars Environment (1)



## ⇒ Planet

- Mass :  $6.42 \times 10^{23}$  (kg)
- Diameter : 6787 (km)
- Mars' distance from the sun varies by 20 %

## ⇒ Atmosphere

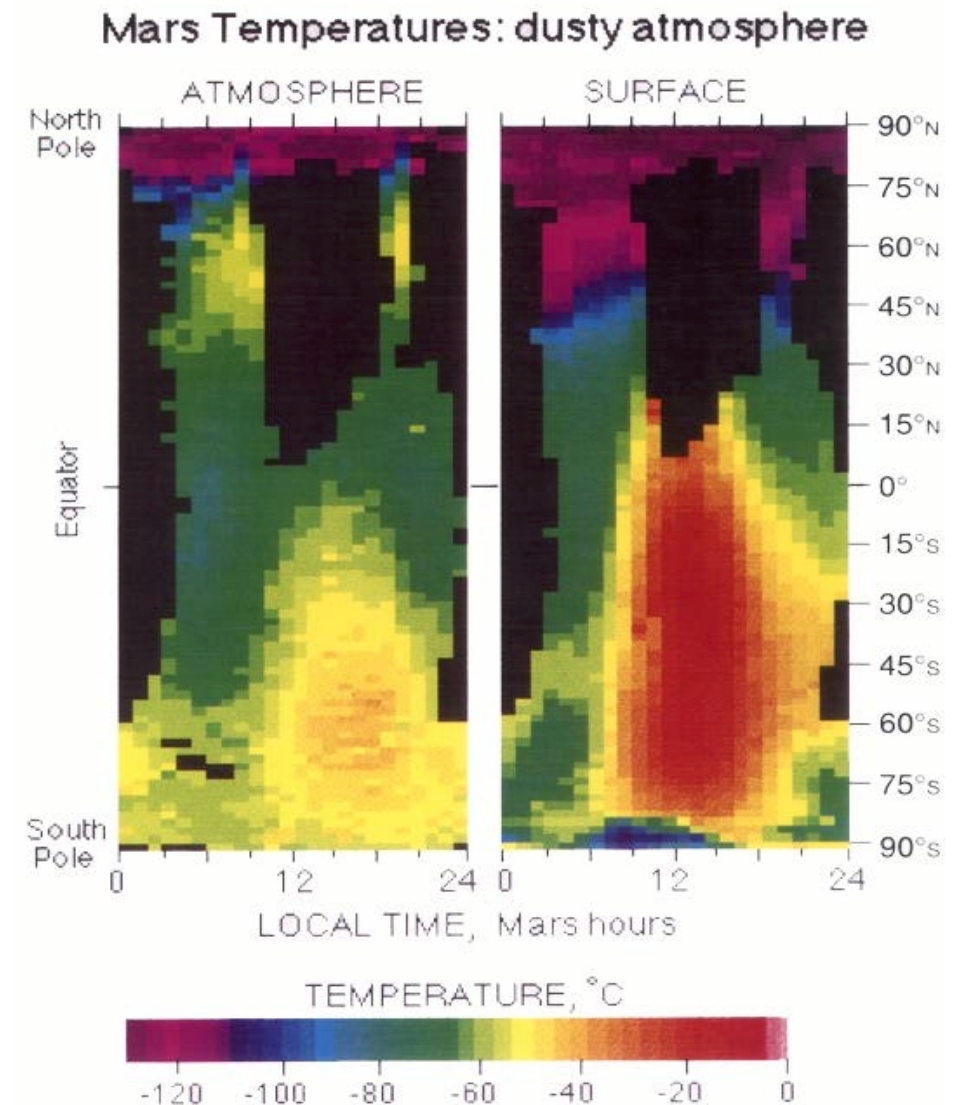
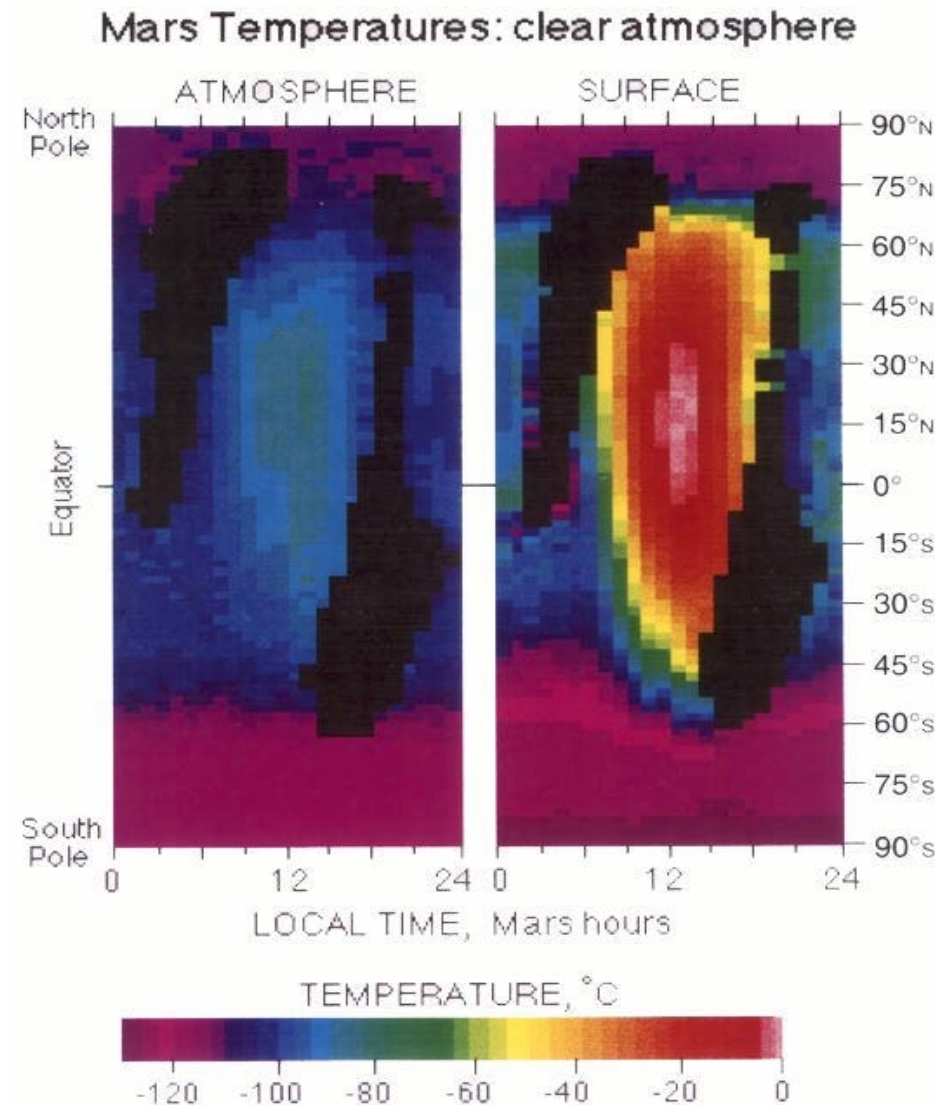
- Low density atmosphere  
~7 millibars
- 95% carbon dioxide,  
3% nitrogen,  
1.6% argon
- Omnipresent Wind  
speed average: 1-9 m/s  
Storms >20 m/s
- At aphelion, south atmosphere,  
storms travel at >100 m/s
- Pressure wind speed :  
10 N/m<sup>2</sup> (30m/s)

## ⇒ Temperature

- Surface temperature
- [140; 310] (K)

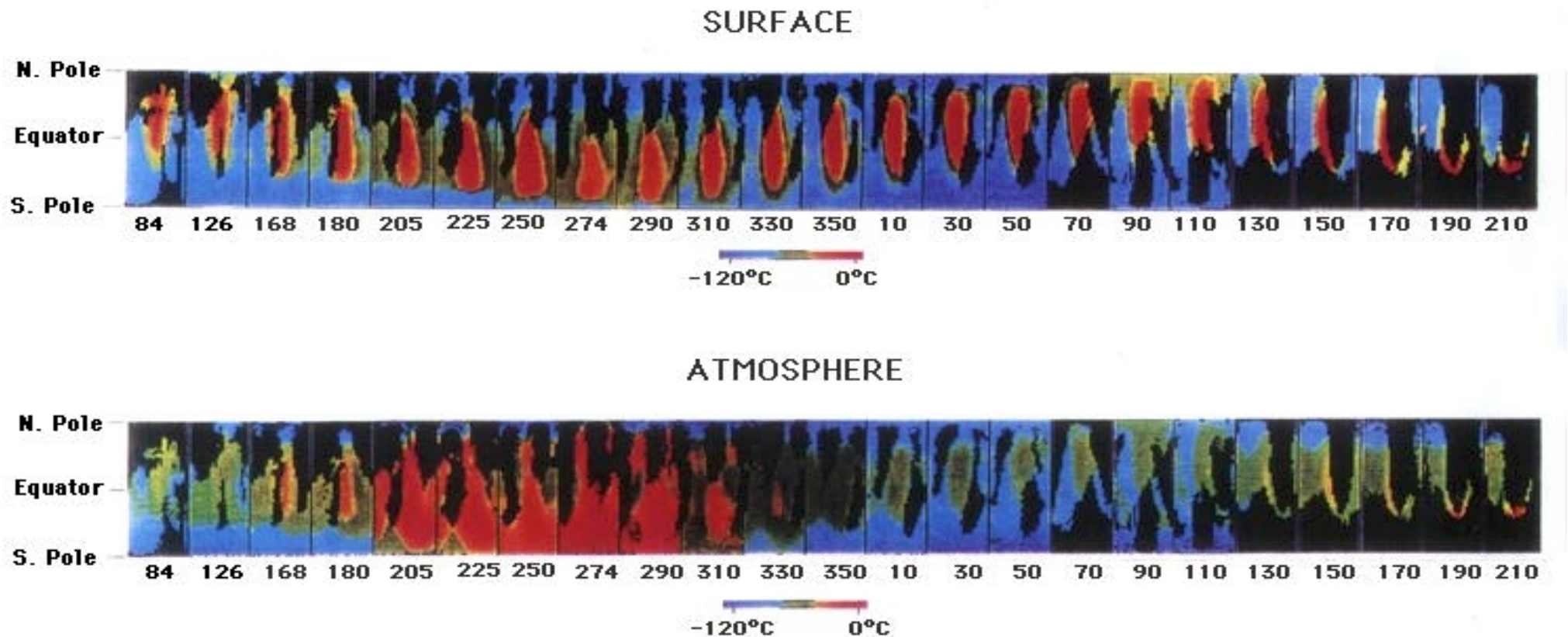
## Windball Locomotion Concept

- Daily Martian Temperature cycle

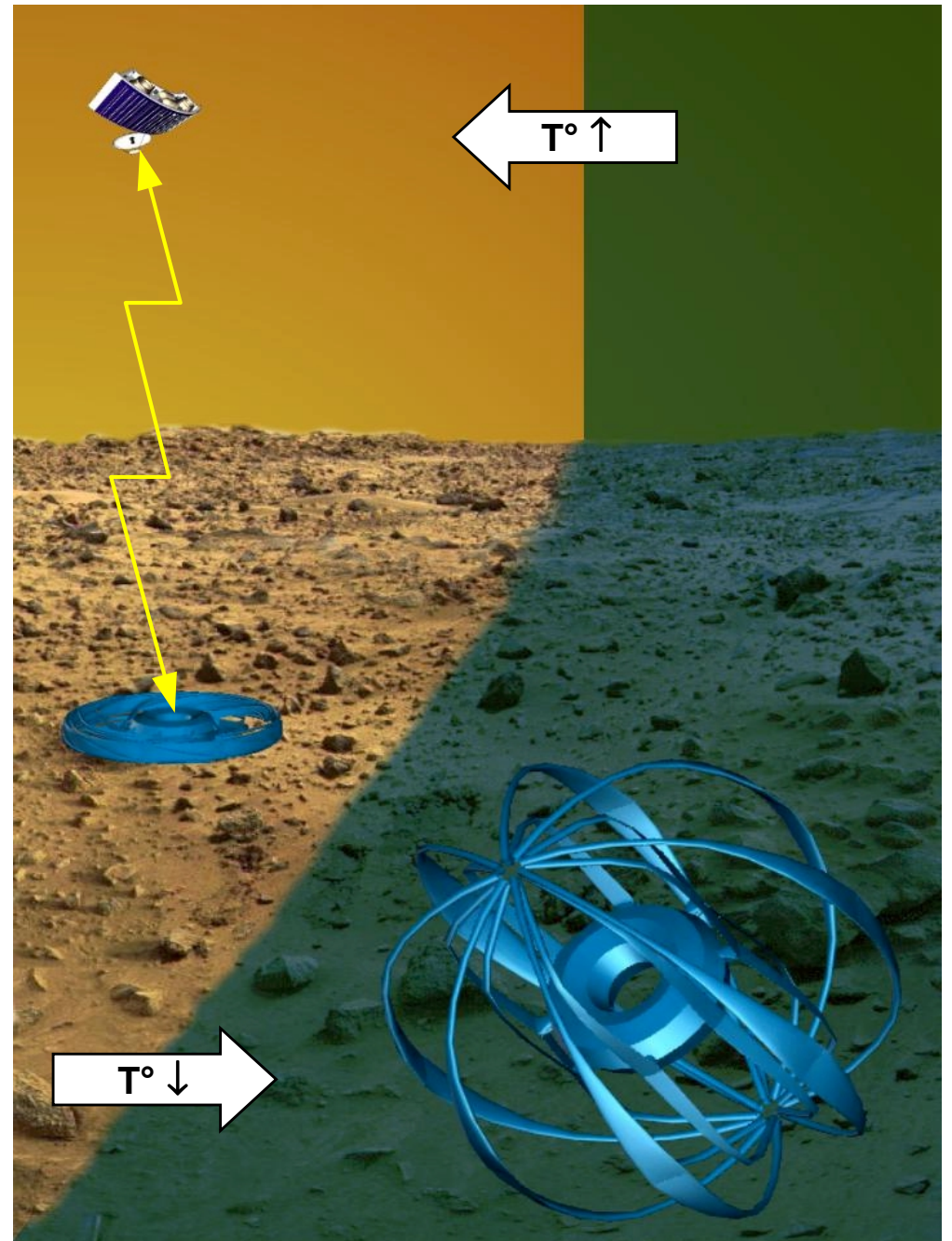




- Seasonal temperature behavior of Mars

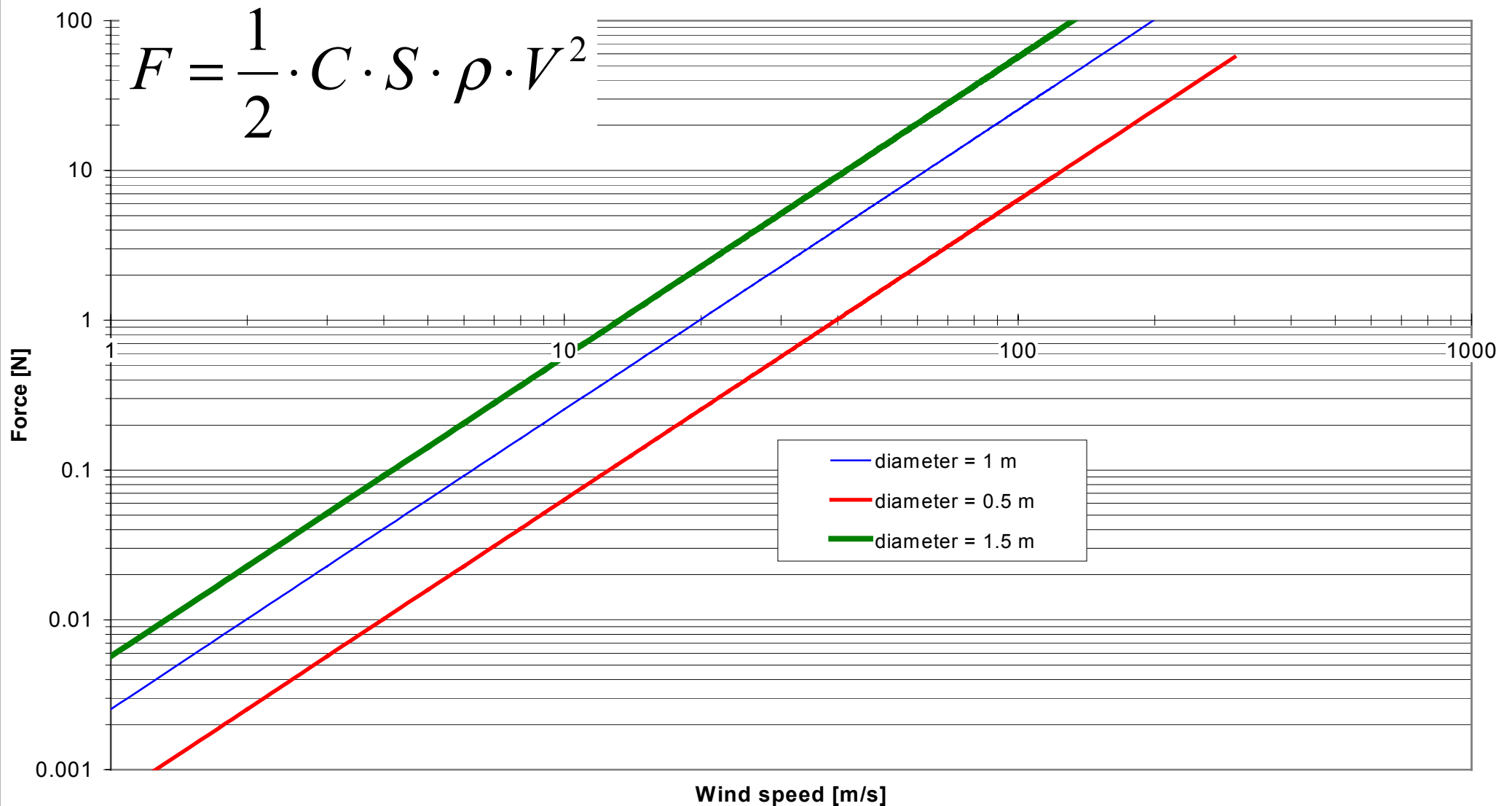


- **At Night  
(structure deployed)**
  - ⇒ spherical morphology
  - ⇒ max resistance to wind
  - ⇒ No need of energy
- **During the day  
(structure not deployed)**
  - ⇒ Payload in contact with ground
  - ⇒ energy generation for payload
  - ⇒ static measurements
  - ⇒ localization by orbiter



## Windball Locomotion Concept

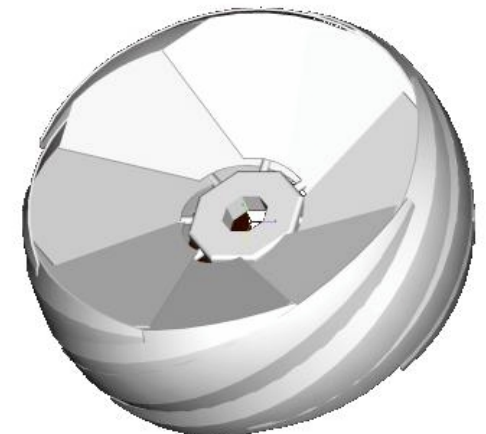
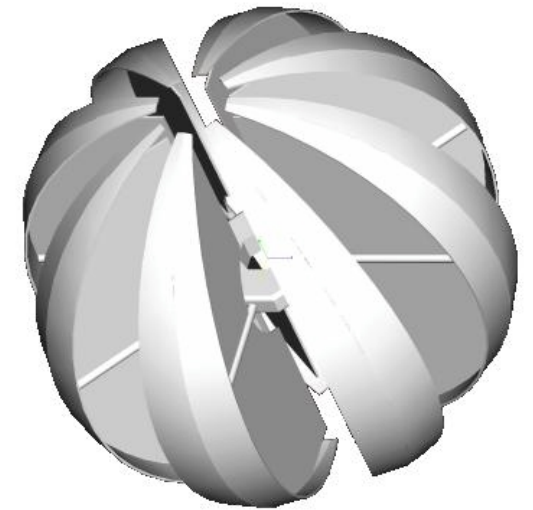
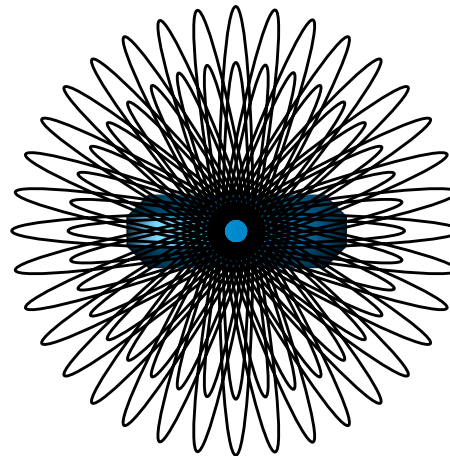
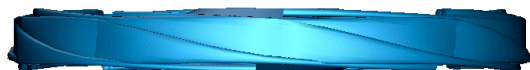
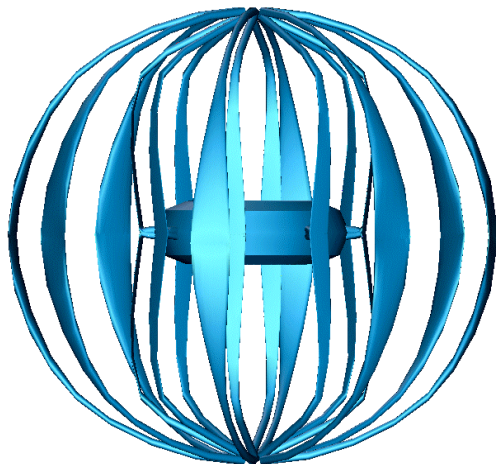
- Force applied by the Martian wind to the robot



## Windball Locomotion Concept

- Guidelines

- ⇒ Maximal cross section
- ⇒ Maximal  $C_x$
- ⇒ Minimal Mass
- ⇒ Maximal morphological transformation
- ⇒ Low fatigue (numerous cycles)
- ⇒ Maximal Payload Mass and Volume





## Windball Locomotion Concept

### ⇒ Phase transformation without diffusion

- Twinning

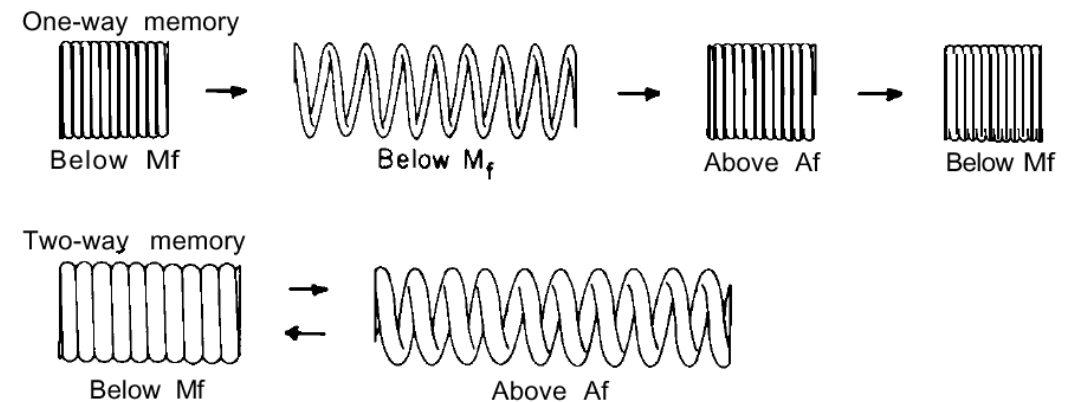
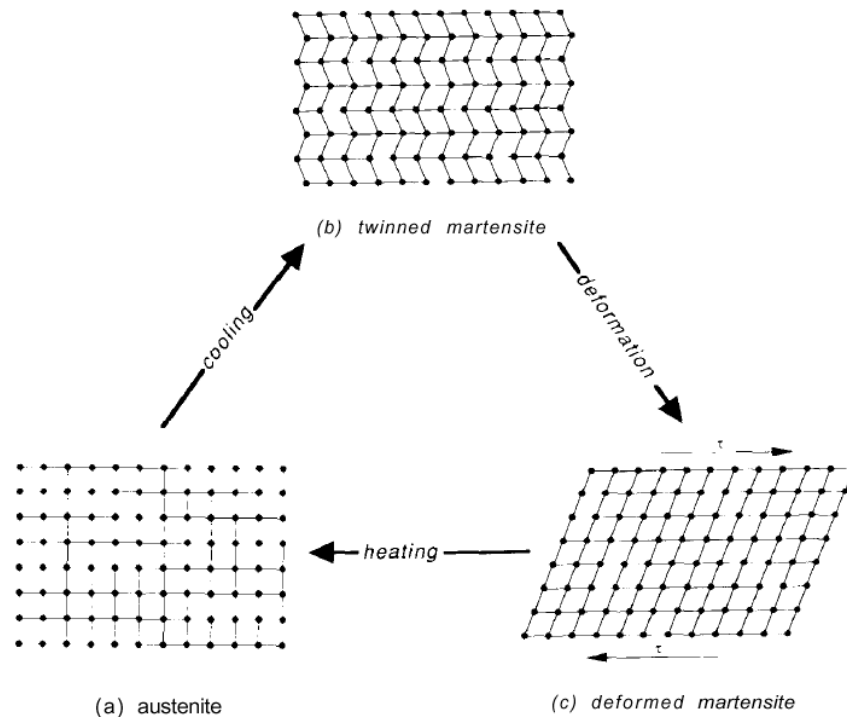
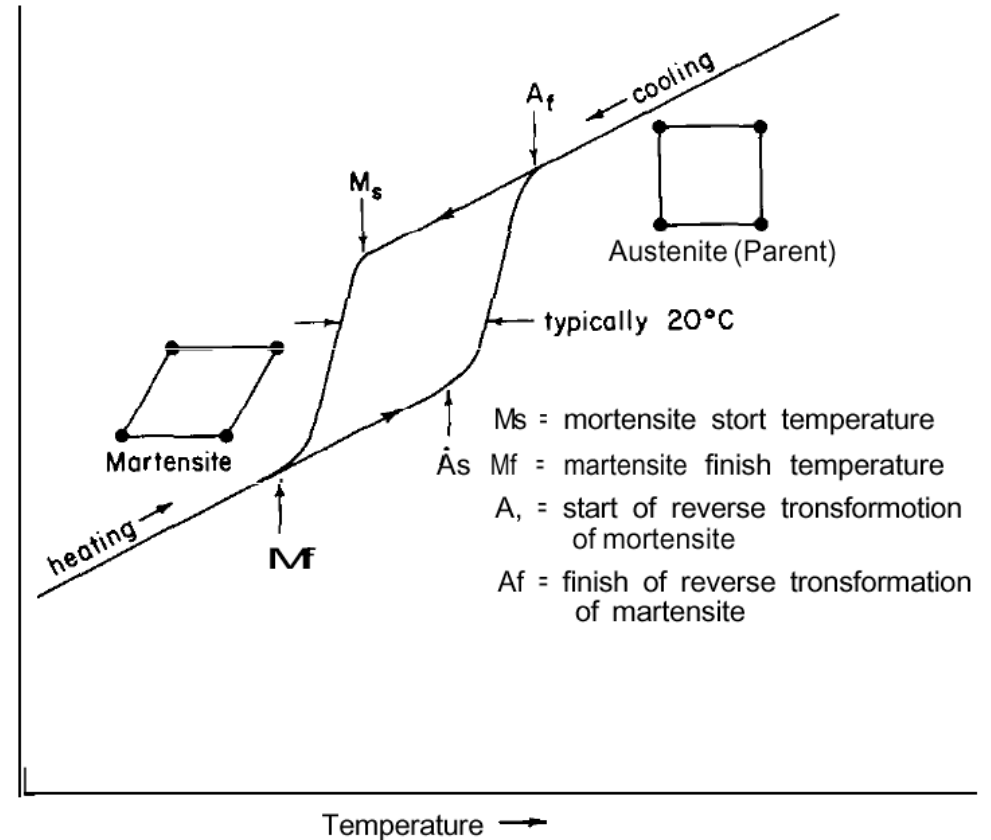
### ⇒ Austenite $\Leftrightarrow$ Martensite

- under temperature variation
- under applied stress

### ⇒ Mechanical Properties

- Shape Memory Effect
- Super-elasticity
- High damping capacity

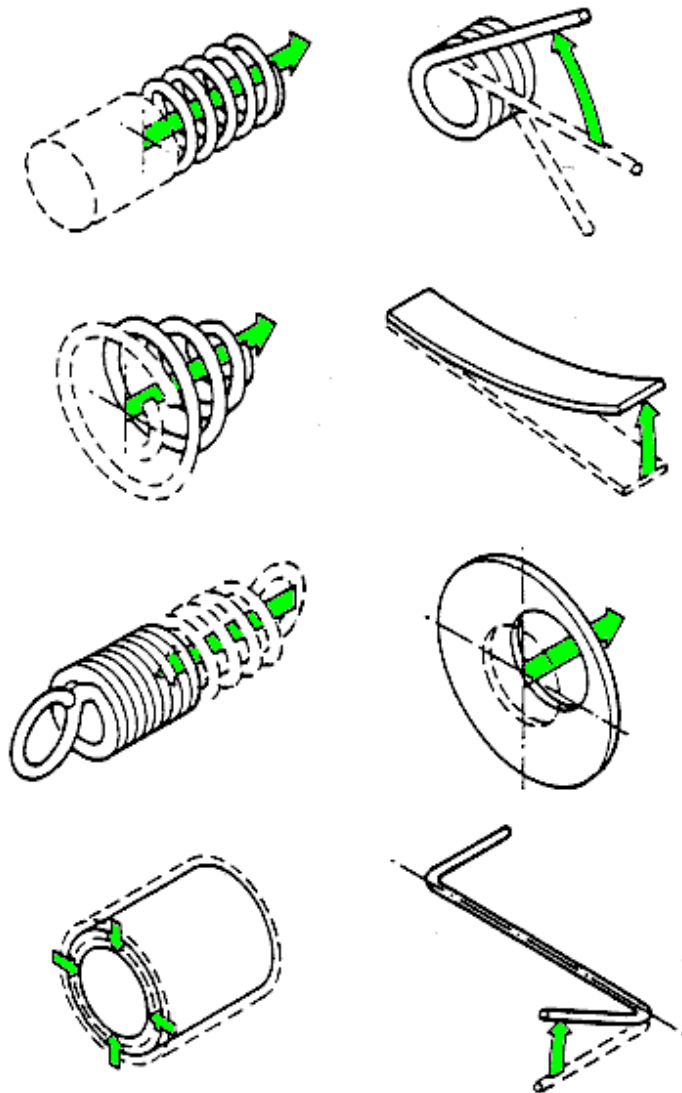
↑  
Electrical Resistance  
or  
Length Change  
or  
Volume Change  
etc.



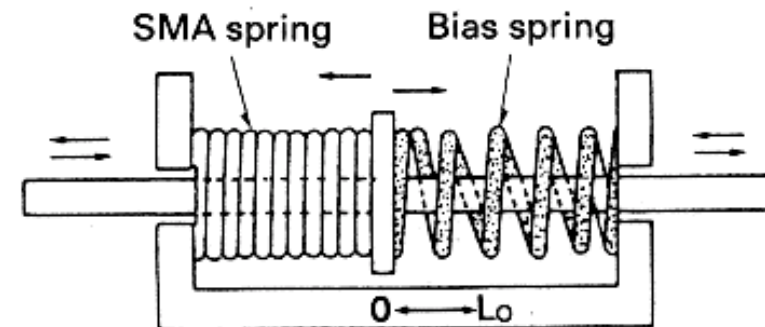
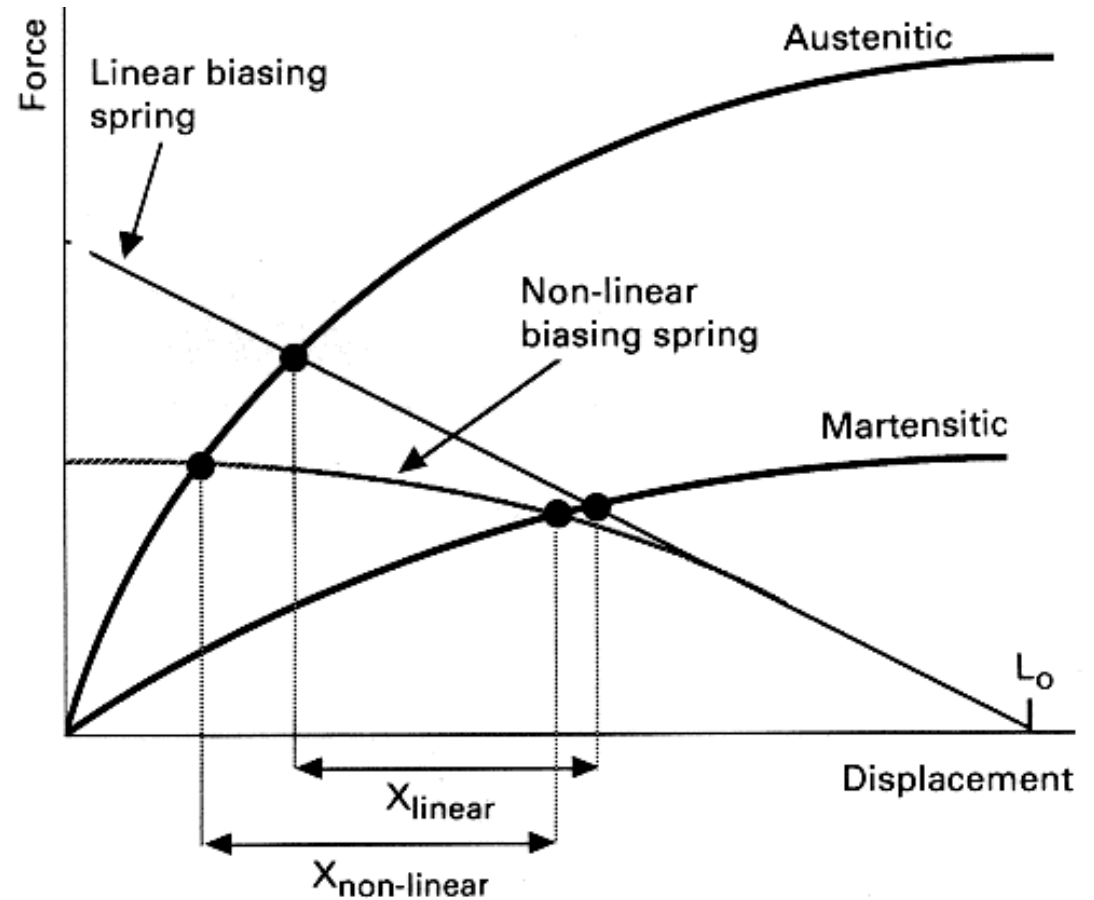
## Windball Locomotion Concept

	Austenite	Martensite
⇒ Young's Modulus	~ 83 Gpa	~ 28 to 41 GPa
⇒ Yield Strength	195 to 690 Mpa	70 to 140 Mpa
⇒ Resistivity	~ 100 $\mu\Omega\text{cm}$	~ 70 $\mu\Omega\text{cm}$
⇒ Thermal Conductivity	18 °C W/cm	8.5 °C W/cm
⇒ Melting Temperature : 1300 °C		
⇒ Density : 6.45 g/cm <sup>3</sup>		
⇒ Corrosion Resistance : similar to 300 series stainless steel or titanium alloys		
⇒ Transformation Temperatures range: [-200 ; 110] °C		
⇒ Shape Memory Strain: 8.5% maximum		
⇒ NiTi 49/51 at.% Ni	Temp range transformation [-50 ; 110] °C Transformation Hysteresis 30 °C Shape Memory Strain for several cycles ~ 4%	

## Windball Locomotion Concept



- Indicates high temperature shape
- - - Indicates low temperature shape
- Direction of movement on heating



- **Technology demonstration**
  - ⇒ Exploitation of Martian wind and storms for mobility
  - ⇒ Generation of mechanical energy with Martian temperature cycles
  - ⇒ Innovative locomotion concept
- **Scientific interest**
  - ⇒ Study wind, storms and dust devils effects at the surface
  - ⇒ Very long range (time) exploration
- **SMA**
  - ⇒ Mars compatible
  - ⇒ excellent performances