Shape memory alloy demonstration - a bit about how it works … …

The higher temperature crystal phase structure of the NiTi alloy material is known as Austenite. As you cool a transformation occurs to a Martensitic crystal structure.

This transformation occurs by a displacive transformation in which small atomic shuffles of less than one atomic spacing take place. The temperature at which martensite forms is known as the Martensitic start temperature Ms. As it cools this martensitic transformation occurs throughout the material with a co-operative motion of the atoms until the material is fully martensite. This is at the Martensitic finish temperature, Mf.

Note the interface between the austenite and martensitic phases must be highly coherent and this is why so few materials exhibit a shape memory effect. To maintain this coherency the interface should be undistorted and unrotated. A plane satisfying this condition is termed an invarient plane.

In the low temperature Martensitic phase if the material is deformed by applying stress the deformation is accommodated by invariant boundary movement. The variants in the direction of stress will grow or shrink depending whether stress is tensile (stretching) or compressive or torsional (twisting).

The great thing about this expanding or shrinking variants in the structure is that no internal stress is generated. (Normally when you deform a metal beyond its elastic state deformation is permanent due to disruptions to the crystal structure called dislocations). So … when you bend this special Shape memory material in its martensitic state it holds its new shape in a stress free condition.

To recover its shape all you have to do is heat the material up. As you heat it the Austenite starts to form, this happens at the austenitic start temperature, As. The martensitic plates shrink back and the Austenite nucleates in the places it was before. As the temperature increases to Austenitic finish temperature, Af, then all the material is now back in Austenitic crystal structure and the material recovers to its original shape. Hence the Shape Memory Effect (SME).

Are the temperatures Ms = Af and Mf = As?
No the material exhibits a delay in temperature depending on which way you are going around the loop. As > Mf and Af < Ms. We call this hysteresis.

What is superelasticity or Psuedoelasticity?
Superelasticity (sometimes called Pseudoelasticity) is when the material is just above Ms temperature. In other words it is at a temperature when it is still Austenite but not too far away from the transformation temperatures. If you apply stress, such as by bending the material in the video then it pushes the austenite crystal structure to the martensitic structure by generating nucleation sites for the martensite which can then grow as the material is deformed further and austenite shrinks. Provided no permanent plastic deformation has taken place then releasing the stress (by letting go) the martensite will spontaneously transform to austenite and the material snaps back into its original shape. This elasticity can be greater than 8% in some alloys and is more than 10 times the normal elasticity in most metals which makes these shape memory alloy materials unique.