Introduction to Spatial Kinematics

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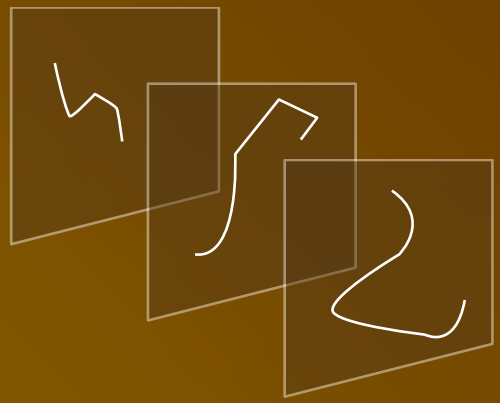
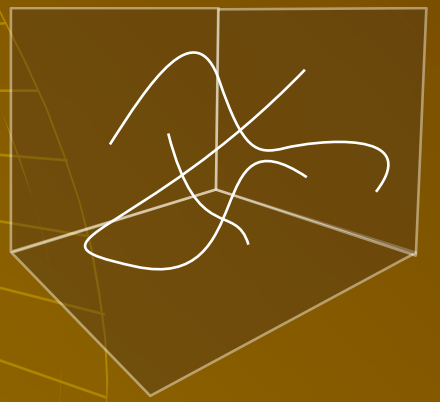
Planar versus Spatial Mechanisms

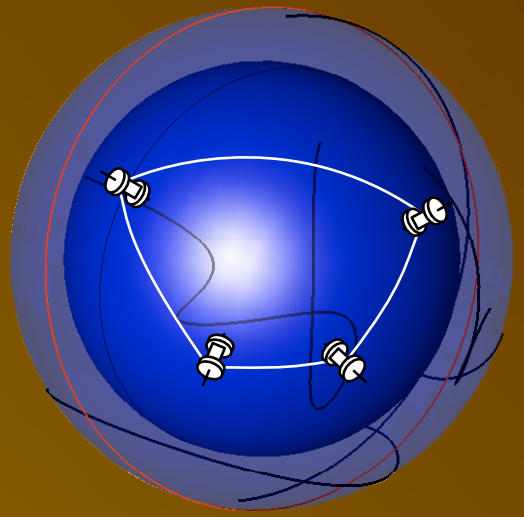
- A body has planar motion if all of its particles move in parallel planes.
- In a spatial mechanism, different particles may move in paths which don't all always remain in a plane.

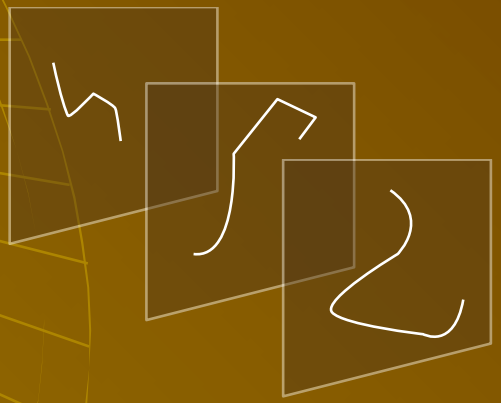




Planar versus Spatial Mechanisms

- A body has spherical motion if all of its particles move on the surface of concentric spheres.
- Notice that planar motion is the limiting case of spherical motion when the radius of the spheres goes to infinity!





Planar versus Spatial Mechanisms

- For instance, a four-bar linkage is a planar mechanism, even though it is constructed in three dimensions
- This car trunk link mechanism is a rather elegant example of a planar linkage system:

Planar versus Spatial Mechanisms

- With a planar linkage such as this, you can study the motion by making a two-dimensional model, say out of cardboard.
- You can project all the points of the different bodies onto one or more reference planes parallel to the planes traced by the individual particles.

Planar versus Spatial Mechanisms

- Viewed orthogonally from the side, the parts of the four-bar linkage on the left side of the car always are aligned with those of the linkage on the right side.

Planar versus Spatial Mechanisms

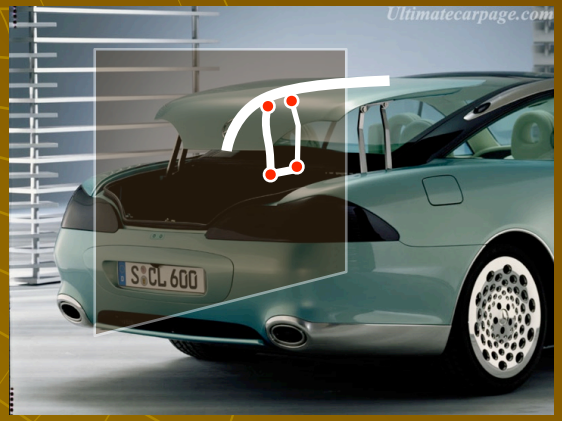
- All the hinge axes are perpendicular to a common reference plane which is why the mechanism remains planar.
- The linkage on the right side of the car produces the same motion of the particles as the one on the left, so from a kinematics point of view it is redundant.

Planar versus Spatial Mechanisms

- Viewed orthogonally from the side, the parts of the four-bar linkage on the left side of the car always are aligned with those of the linkage on the right side.
- It can be conceptually “collapsed” into a single planar our-bar linkage model.

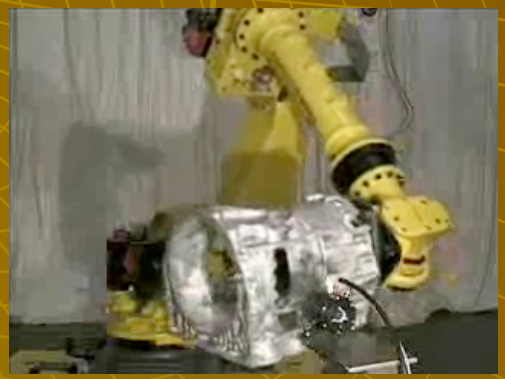
Planar versus Spatial Mechanisms

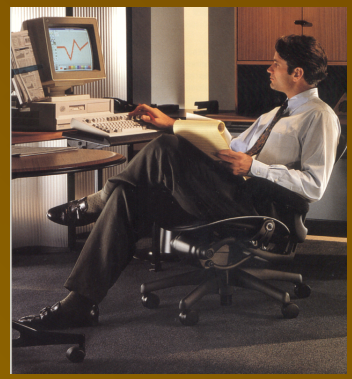
- Of course, if this were my car, I would not propose crushing it into a planar system compacted onto that single reference plane.
- The added three-dimensional parts add strength and structural stiffness to the mechanism but they don't change the kinematics.
- It is a planar linkage!



Spatial Mechanisms

- Spatial linkages can be synthesized for problems such as
  - Function generation
  - Path generation
  - Motion generation





Some Spatial Mechanisms

- Even though applications for general spatial mechanisms are less common than for planar linkages there are many useful spatial devices, such as folding baby strollers and cribs.

Some Spatial Mechanisms

- Sometimes things that appear to be planar mechanisms need to be designed for spatial motions to allow for flexing in the parts.

Some Spatial Mechanisms

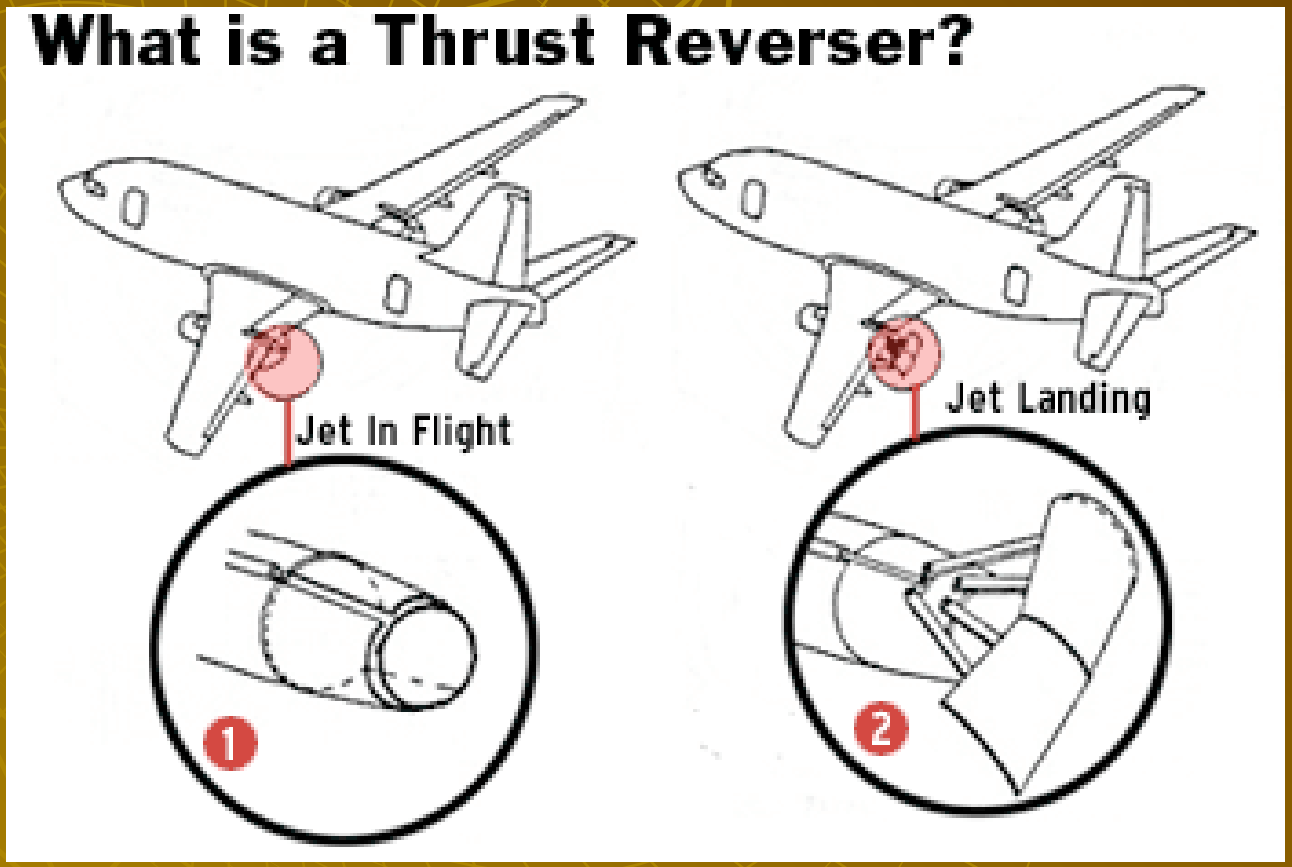
A Spherical Four-Bar

Some Spatial Mechanisms

Some Spatial Mechanisms

Some Spatial Mechanisms

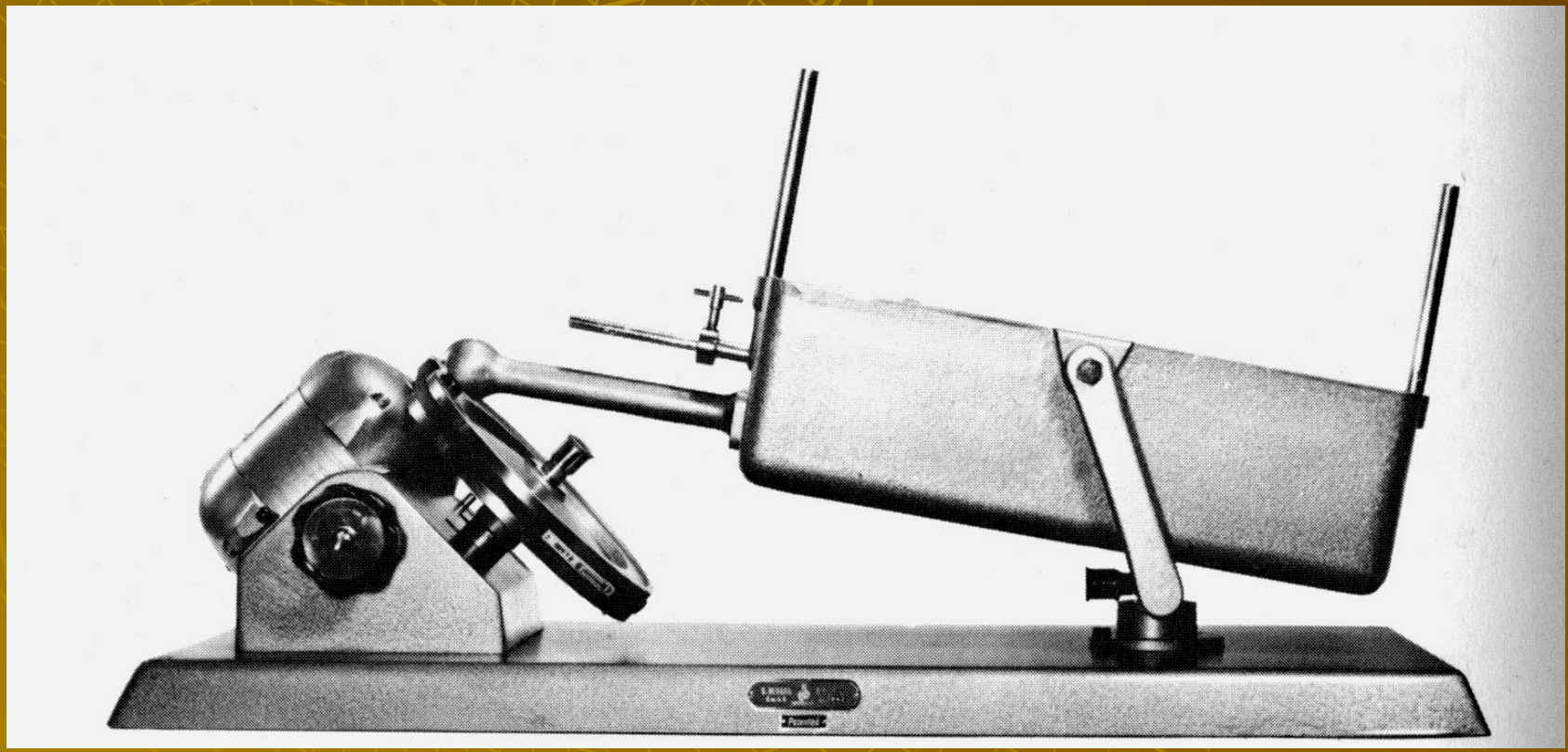
- Some types of aircraft thrust reversers come to mind as an important example:



Some Spatial Mechanisms

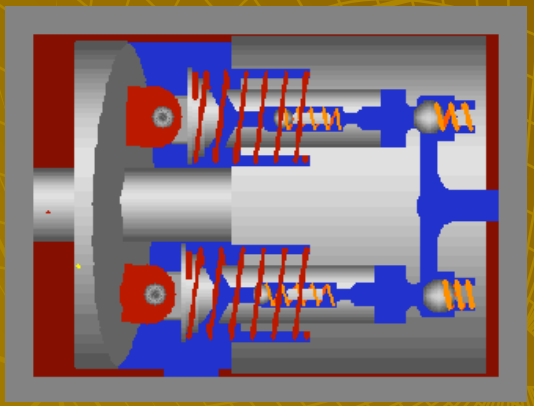
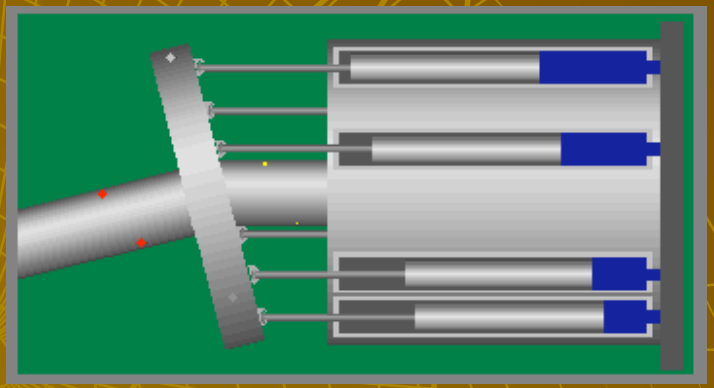
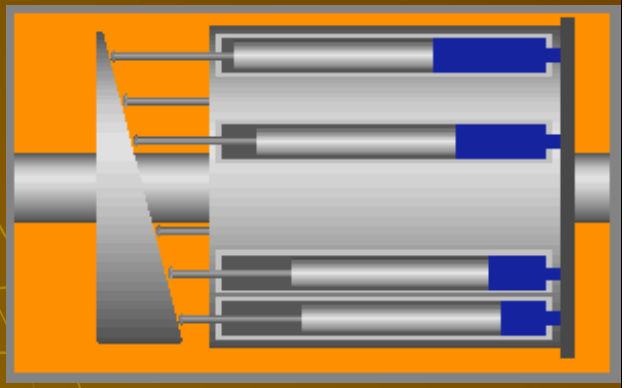
Some Spatial Mechanisms

- Here is a shaker laboratory mixer based on a spatial mechanism:



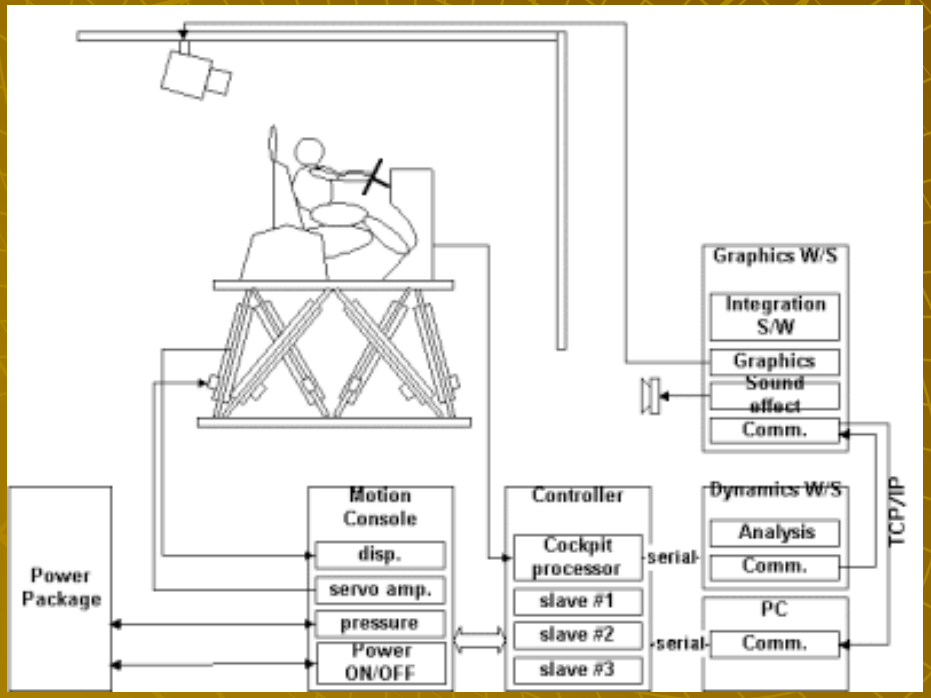
Some Spatial Mechanisms

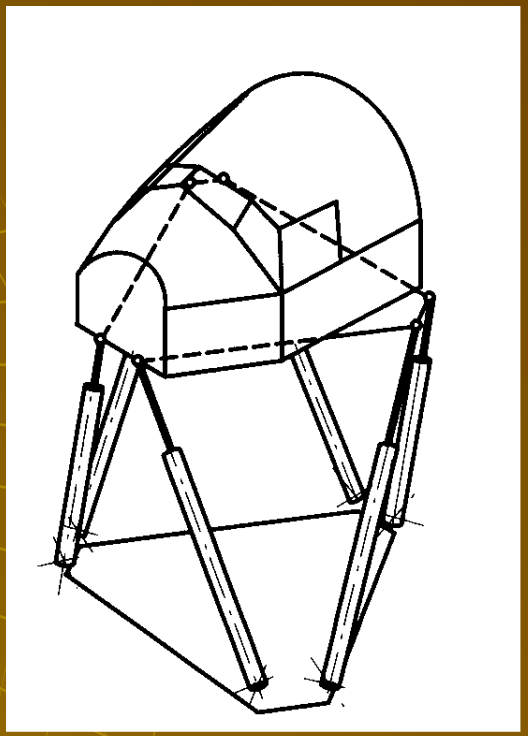
- Wobble plate pumps, bent axis pumps, and swash plate pumps use spatial mechanisms:

Some Spatial Mechanisms

- Simulators for pilot training or for vehicle driving often use a spatial robot called a “Stewart Platform”.



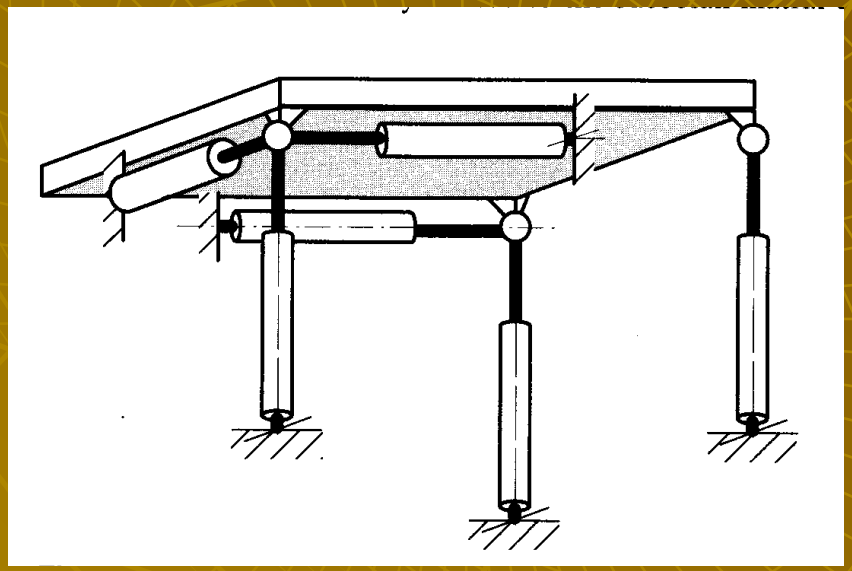


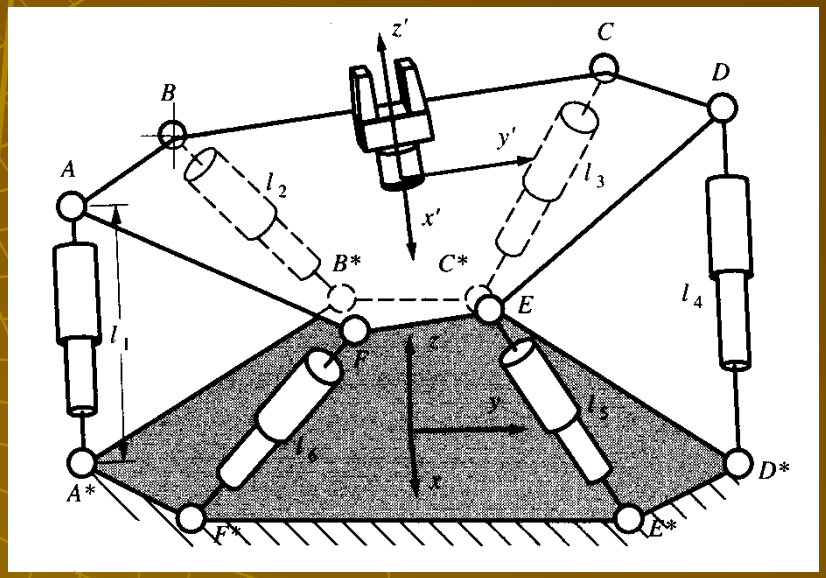
Some Spatial Mechanisms

Some Spatial Mechanisms

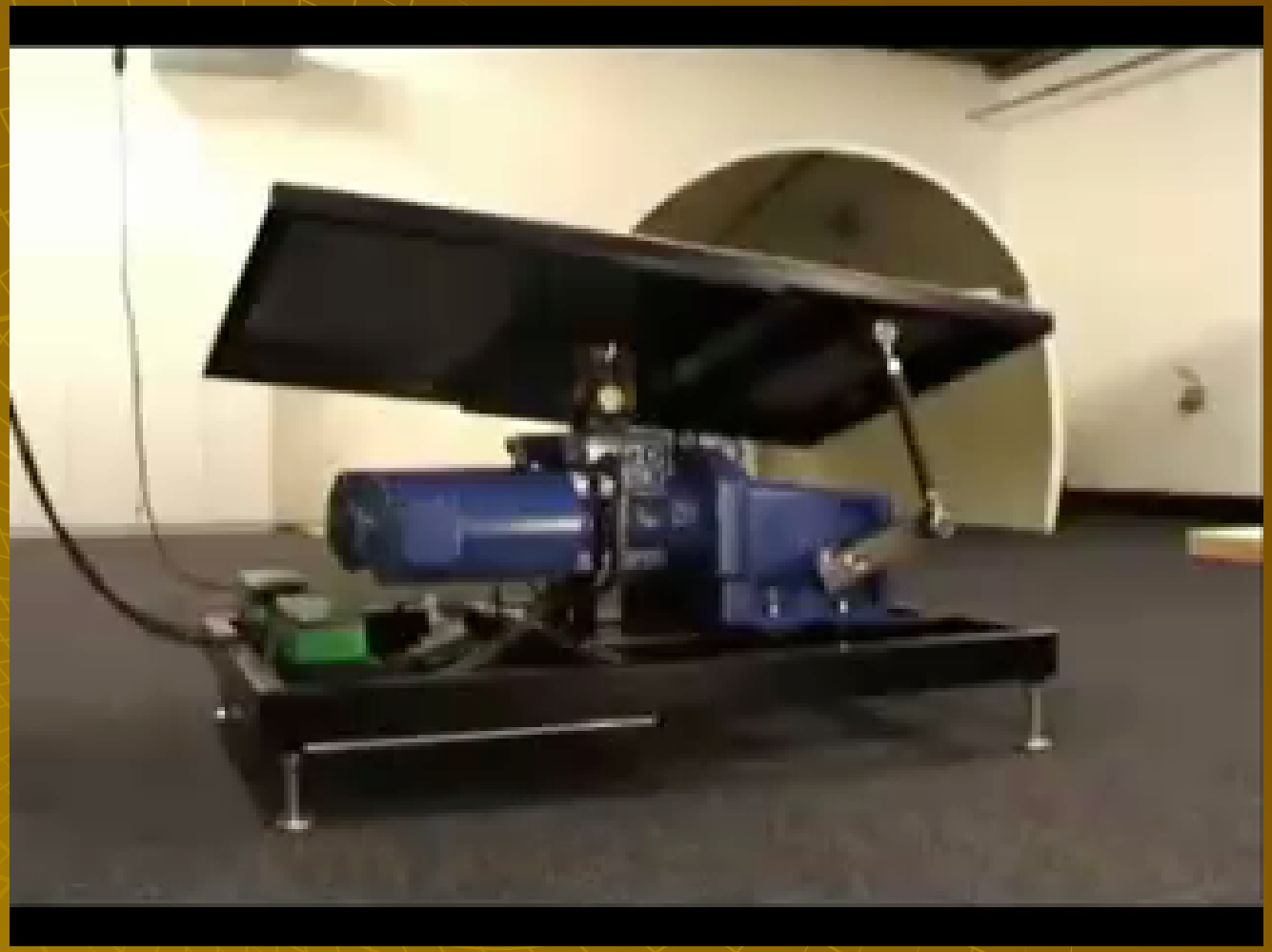
Some Spatial Mechanisms

- Here are some other useful spatial manipulator platforms:



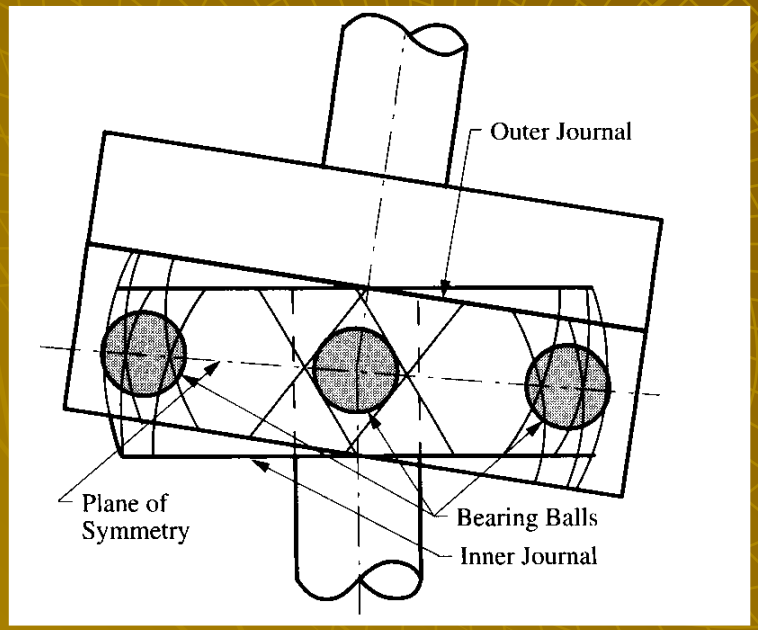


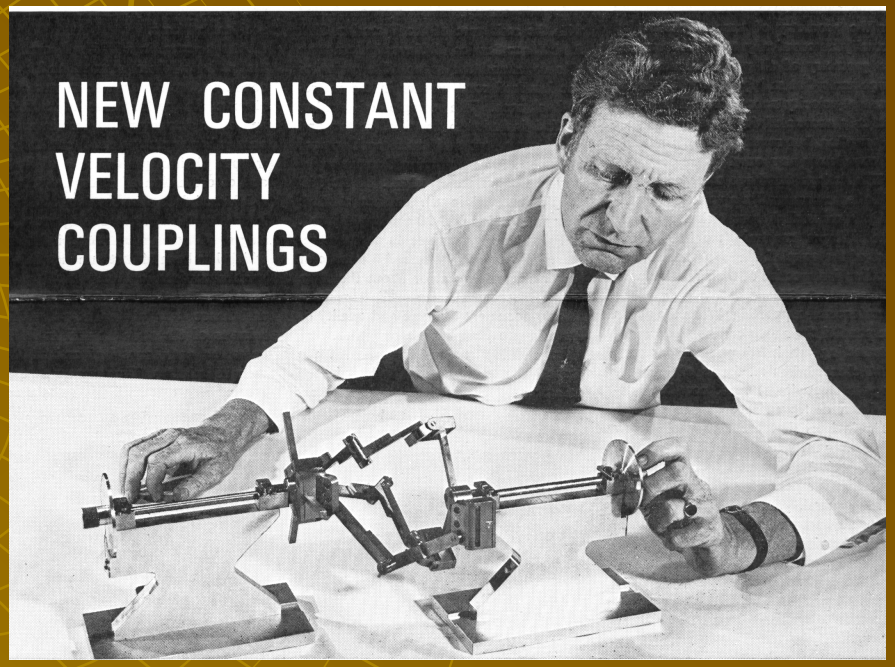
Some Spatial Mechanisms



Some Spatial Mechanisms

- One of the most common spatial mechanisms is the constant velocity coupling.
- Professor Ken Hunt developed a generalized way of designing all theoretically possible cv joints.

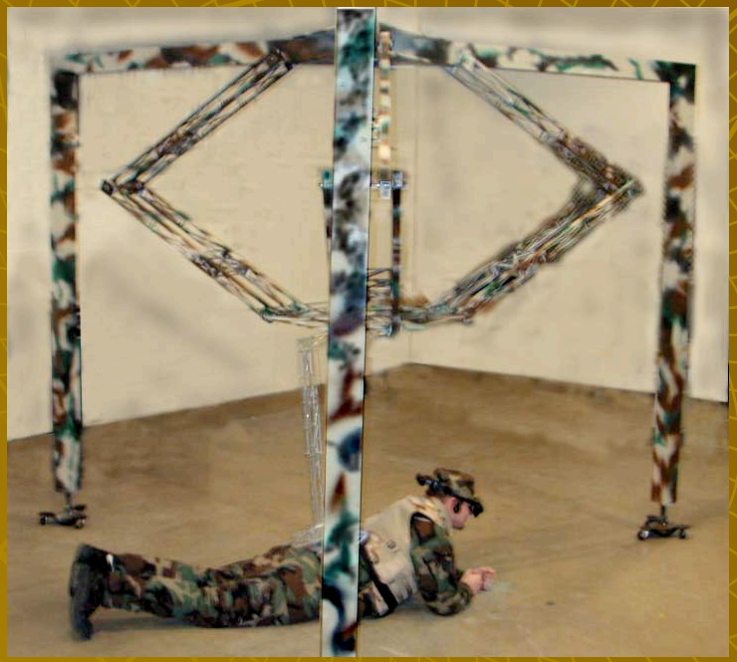




Some Spatial Mechanisms

Some Spatial Mechanisms

- Here is a spatial mechanism called a “Sarrus Mechanism” used in a virtual reality simulator for close quarter combat training of marines:



Some Spatial Mechanisms

- A few more picts showing additional spatial mechanisms on different versions of the marine training simulator:

Some Spatial Mechanisms

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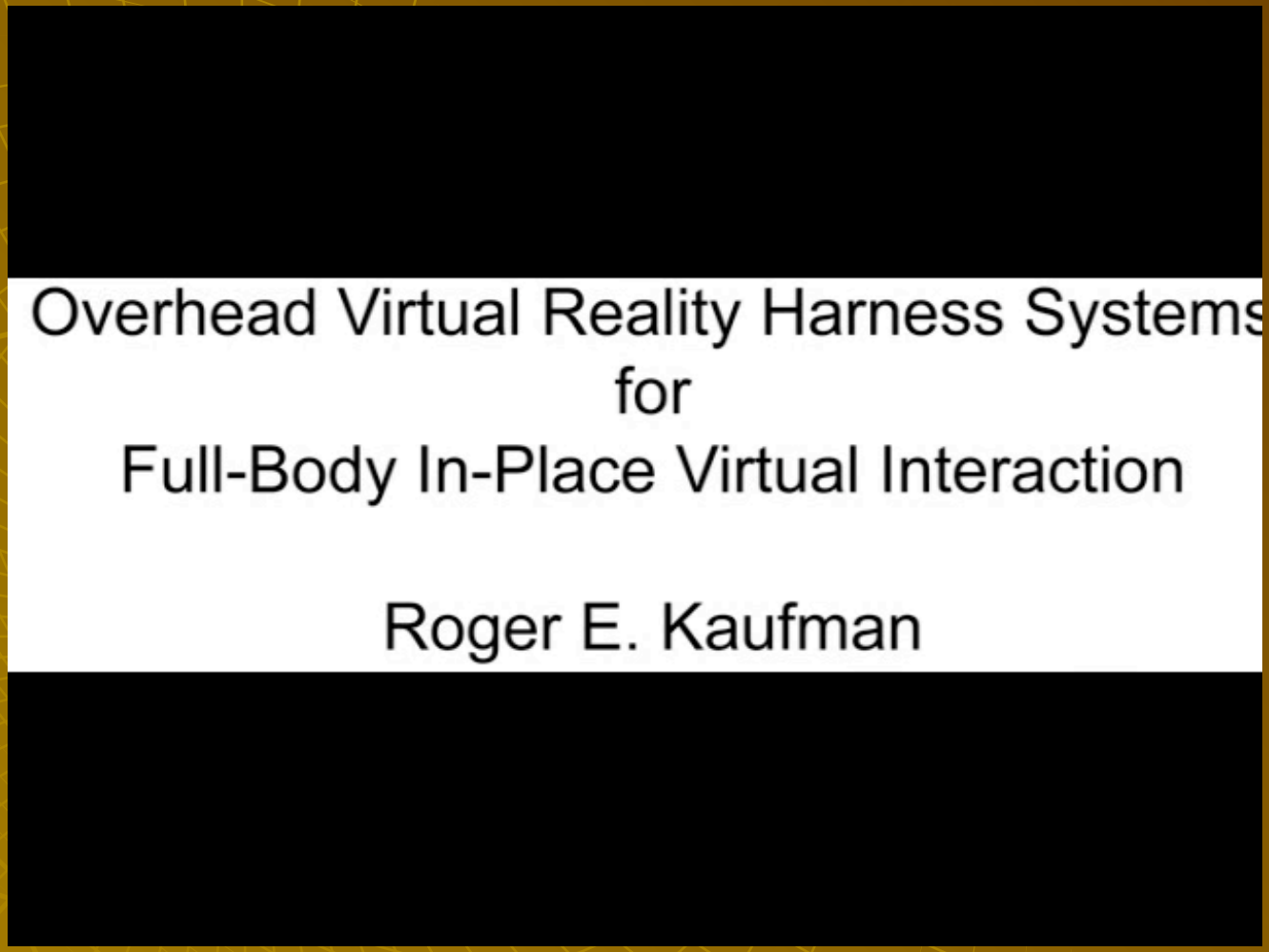
Some Spatial Mechanisms



Some Spatial Mechanisms

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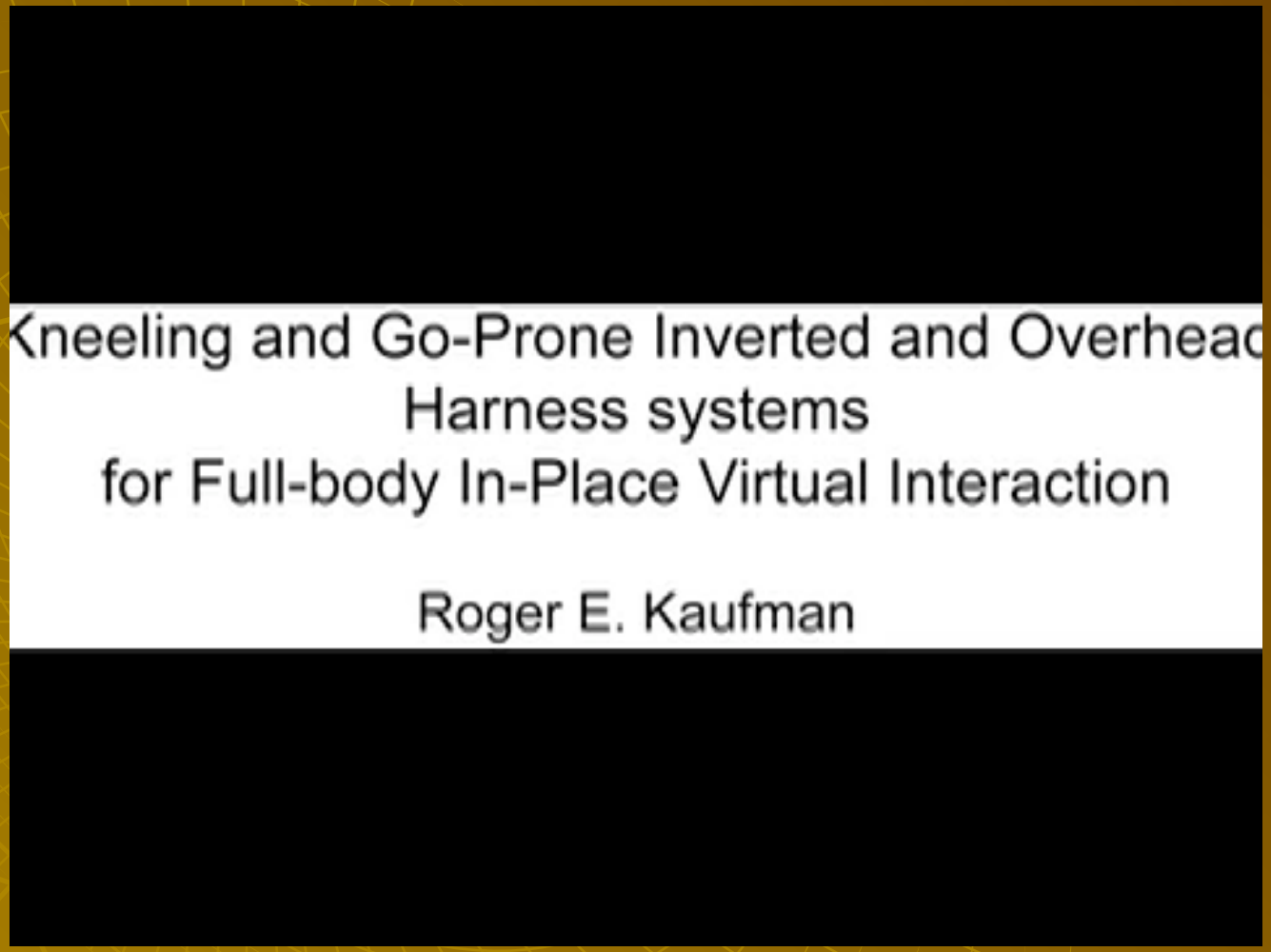
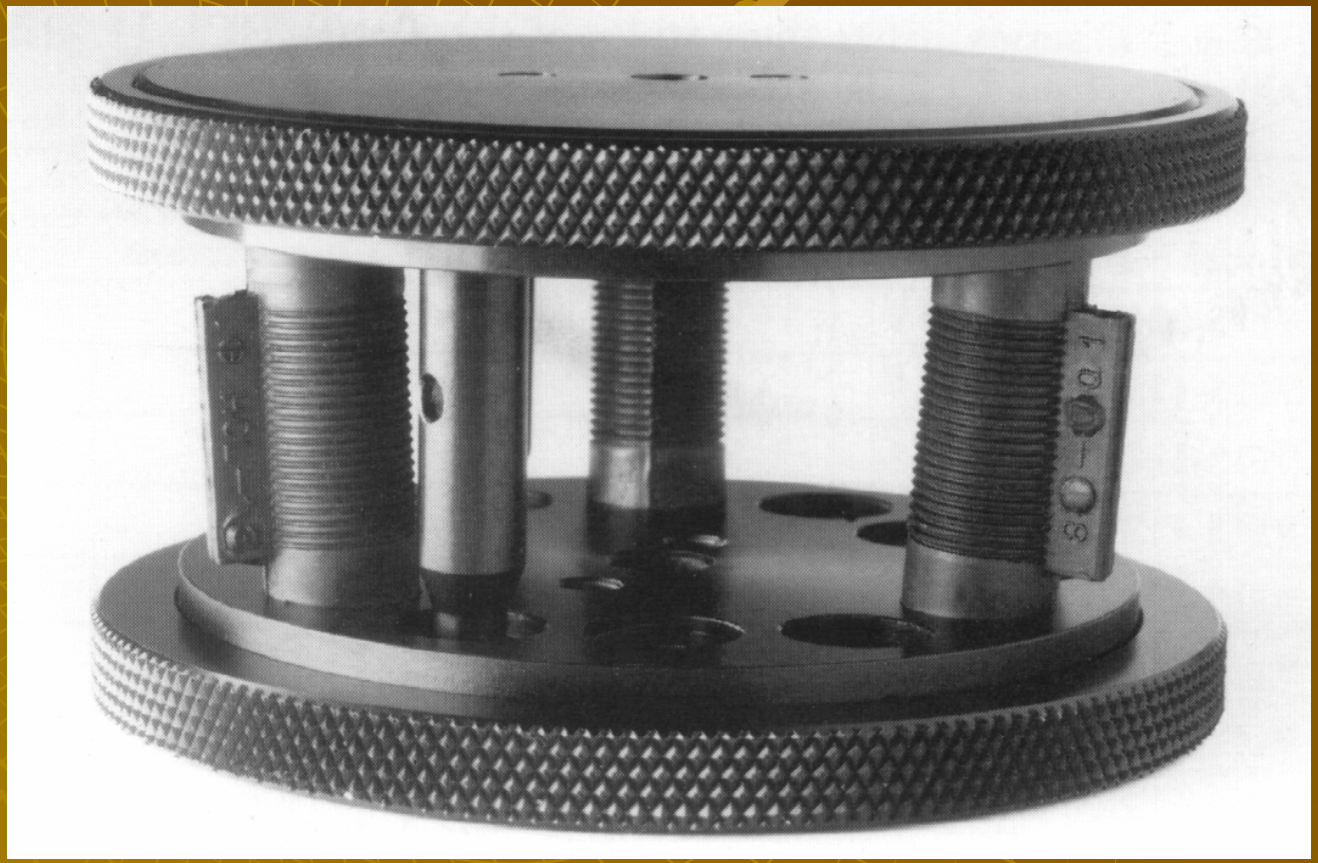


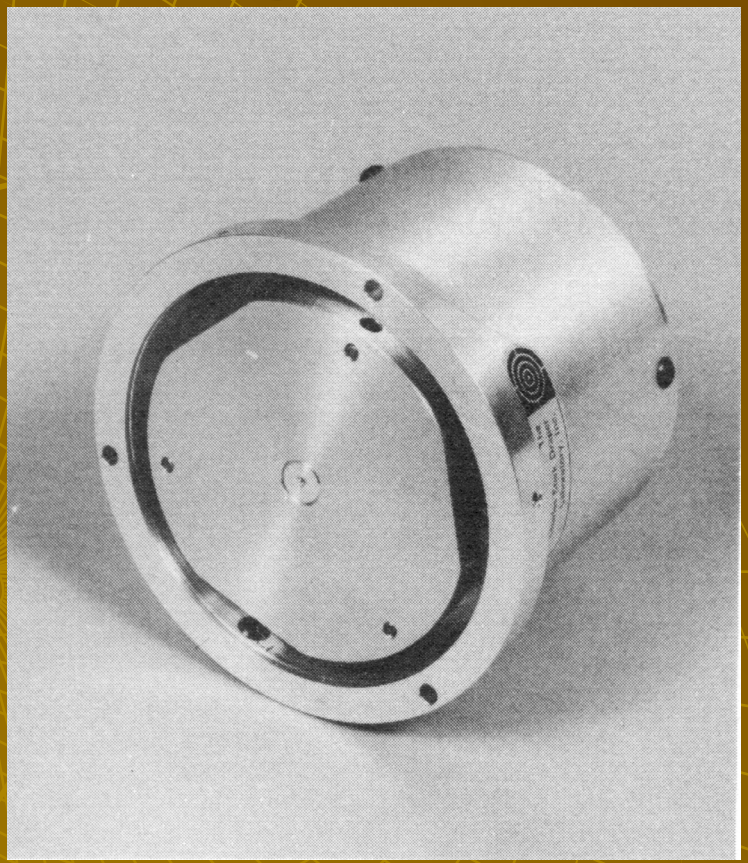
A remote center compliance- A motion generating mechanism

(First invented by yours truly at M.I.T.)



A remote center compliance- A motion generating mechanism

(From Draper Lab at M.I.T.)



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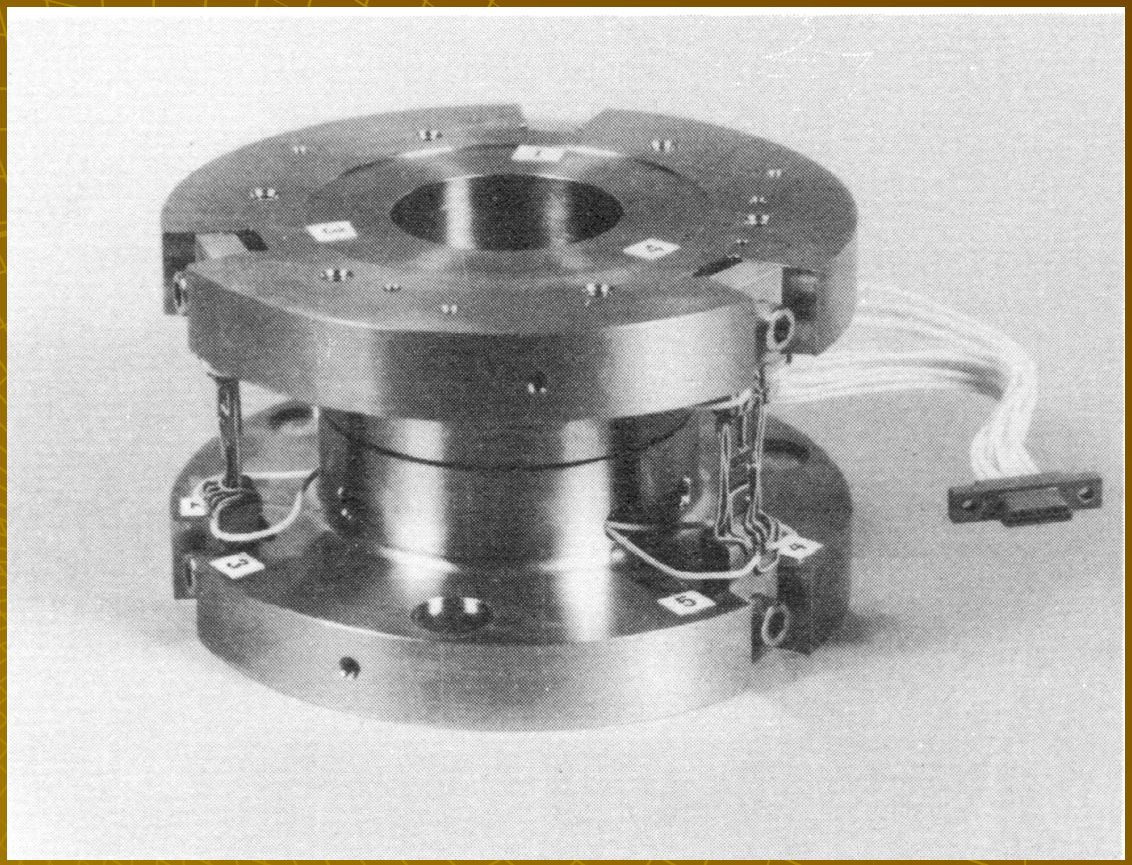

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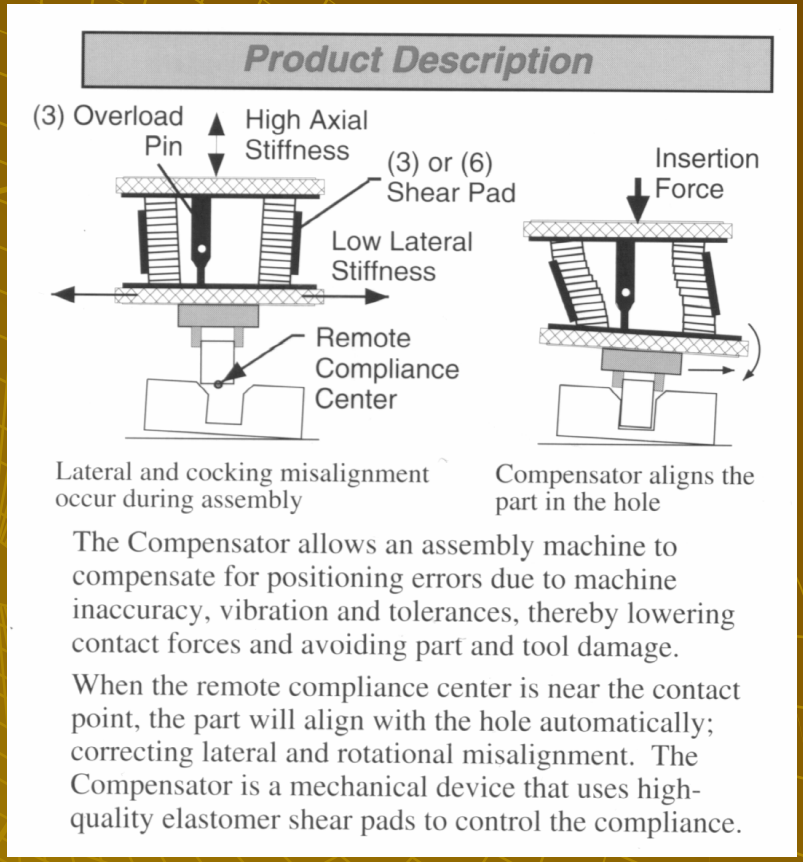

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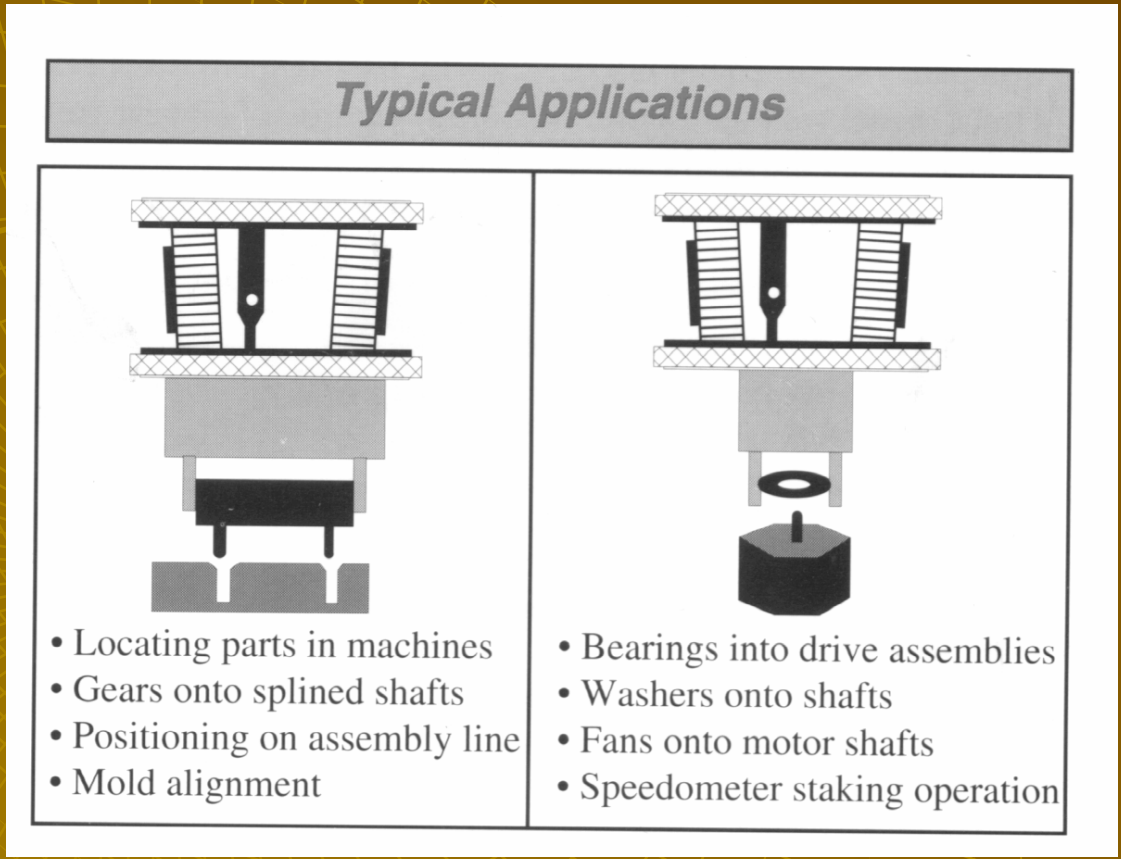

A remote center compliance- A motion generating mechanism

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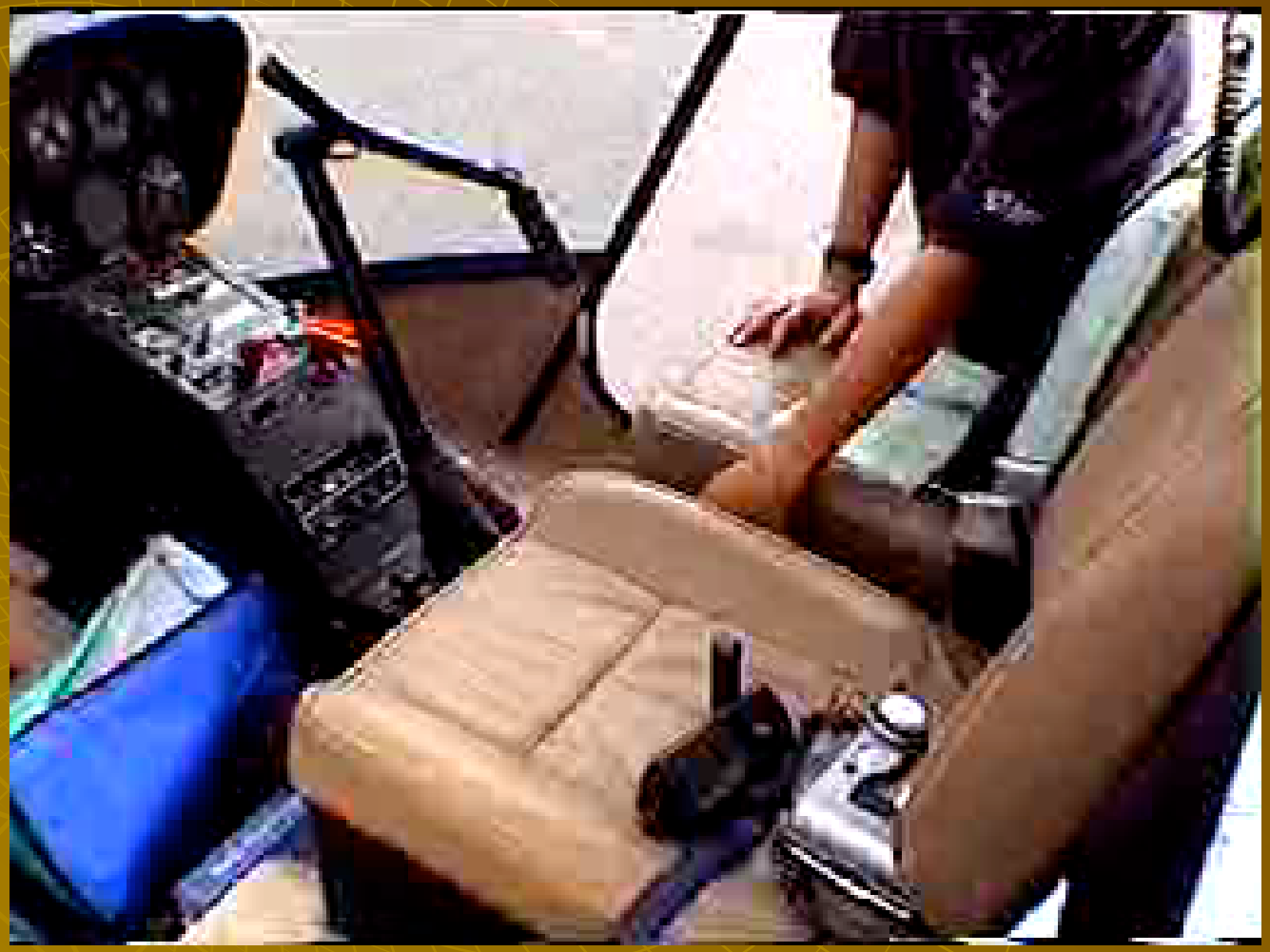
Helicopter swash plate
A function generating mechanism

Helicopter swash plate collective linkage

A function generating mechanism



Helicopter swash plate collective linkage

A function generating mechanism

Helicopter swash plate cyclic linkage

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Helicopter swash plate cyclic linkage

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