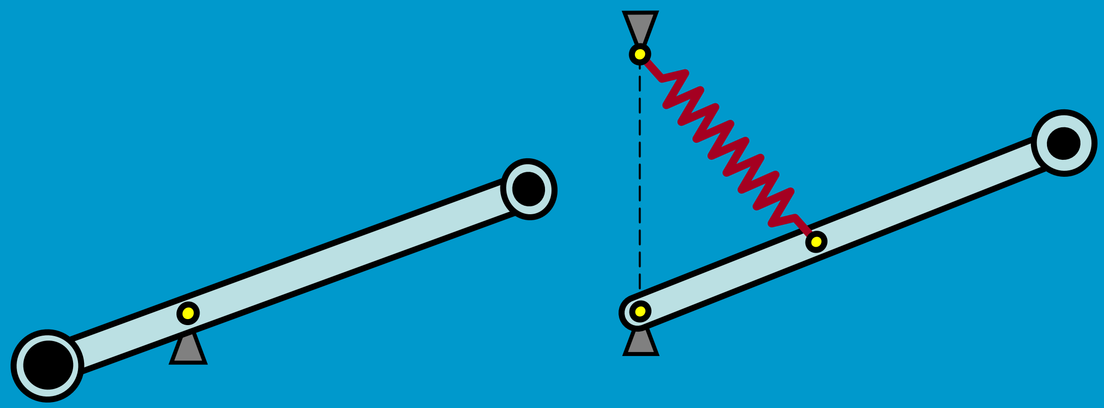
Orthoses

Carrying Orthosis, Elbow Orthosis, ARMON

Just Herder



Wb2308 Biomedical Engineering Design
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Faculty of Mechanical, Maritime, and Materials Engineering (3mE)
Department of BioMechanical Engineering (BMechE)

Delft University of Technology

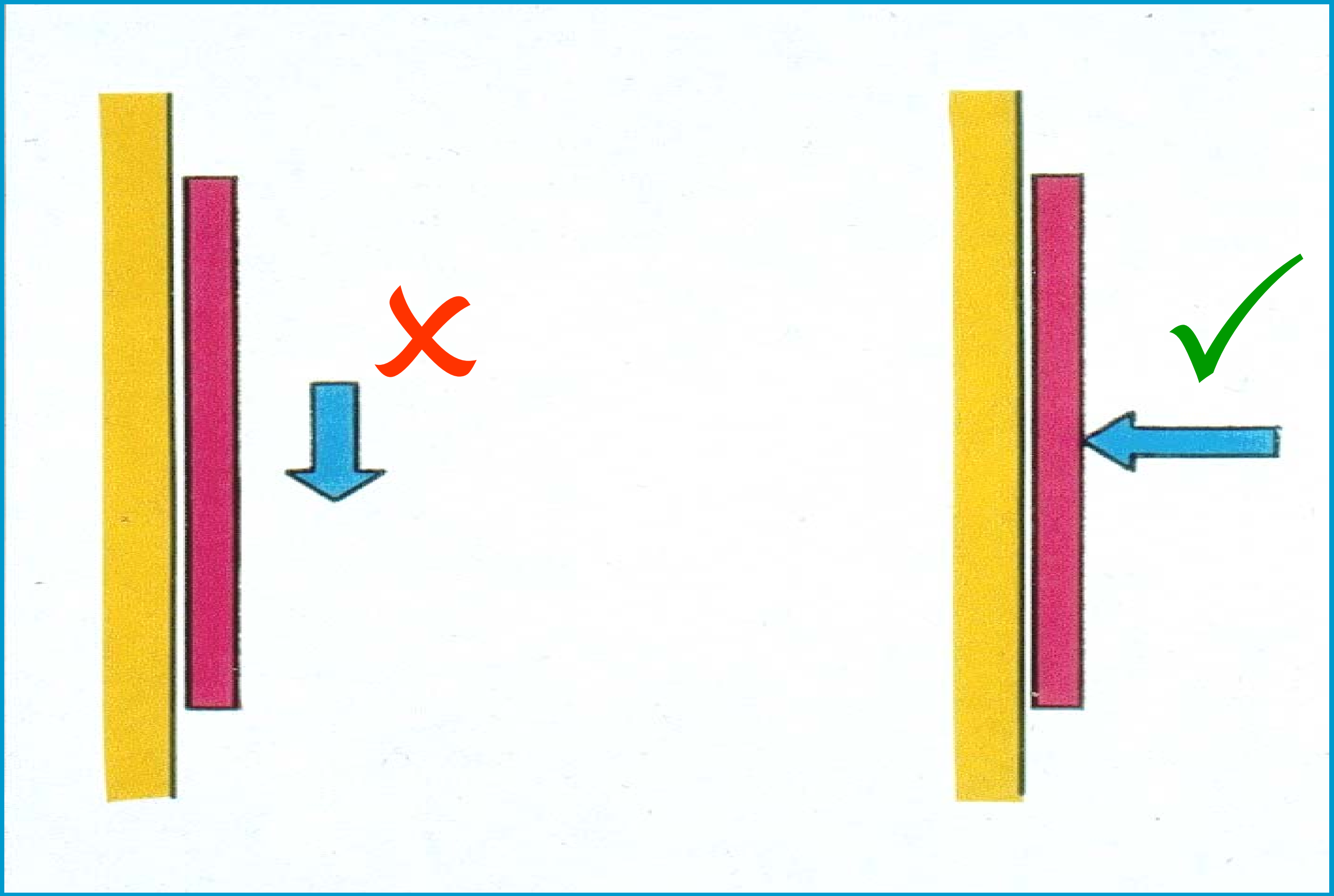
Overview

- Carrying Orthosis
- Elbow Orthosis
- ARMON

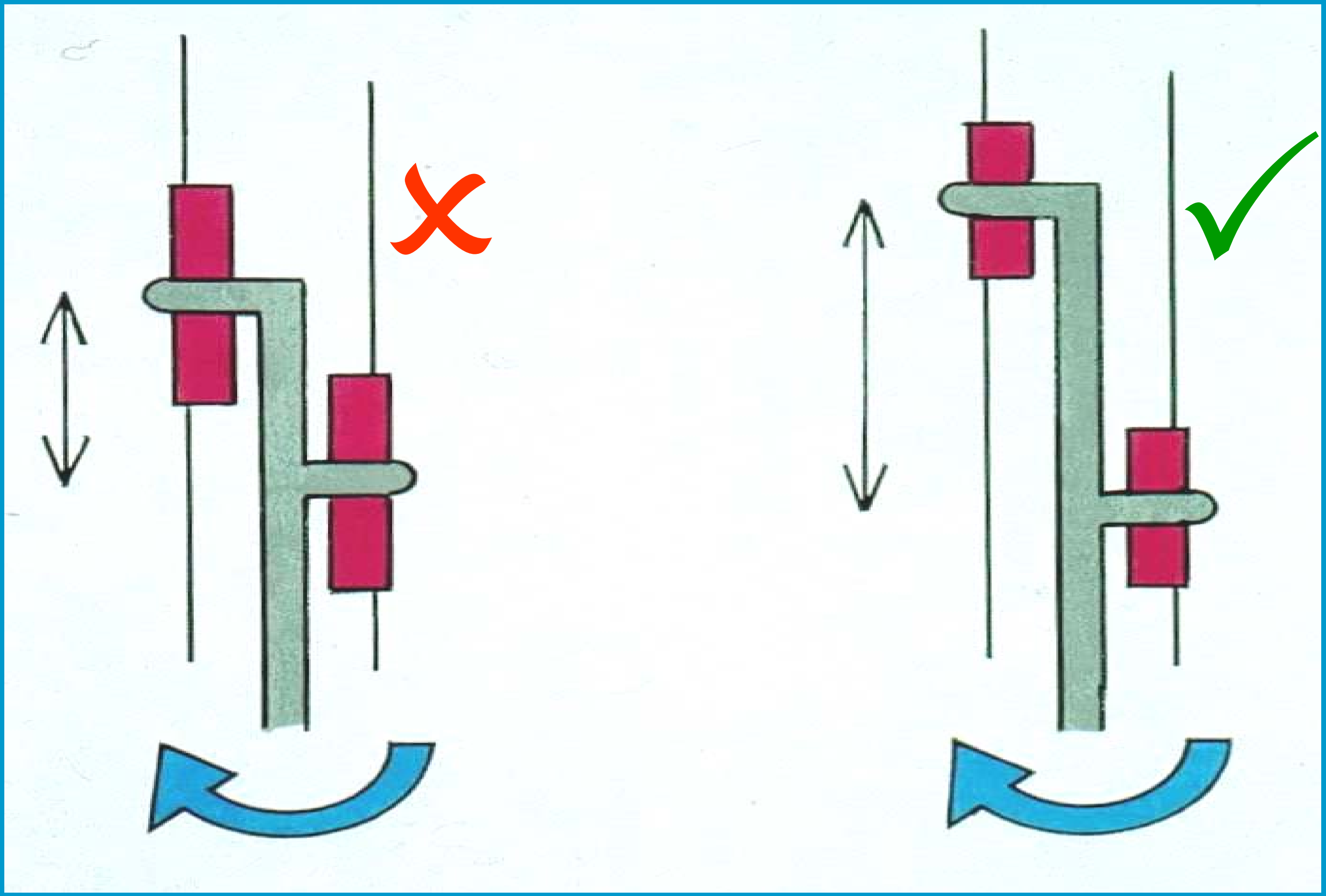
Design guidelines

- Cosmetics: appearance, natural usage
- Comfort: lightweight, ‘breathing’
- Control: low mental and physical load

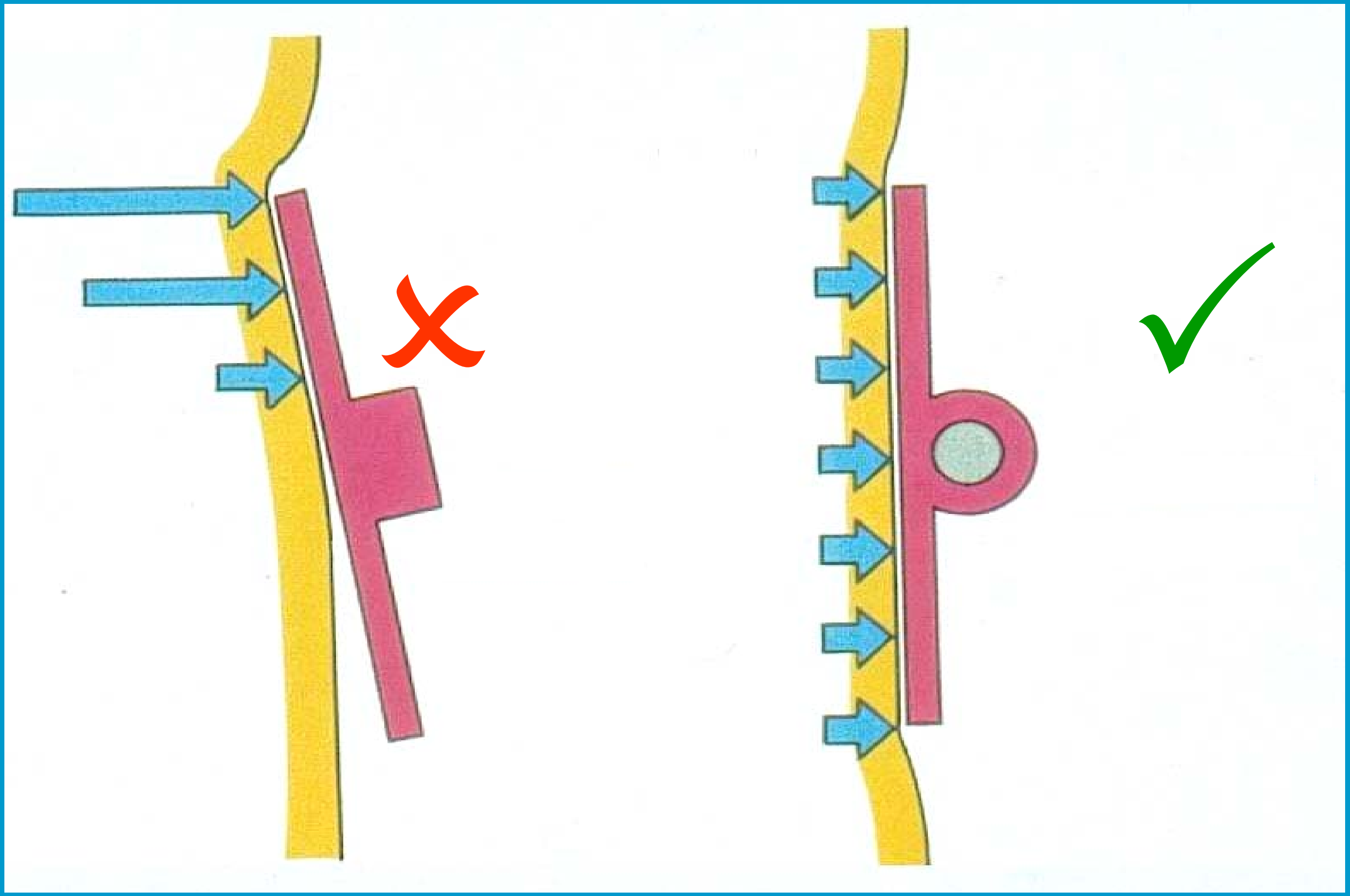
1. No shear forces!



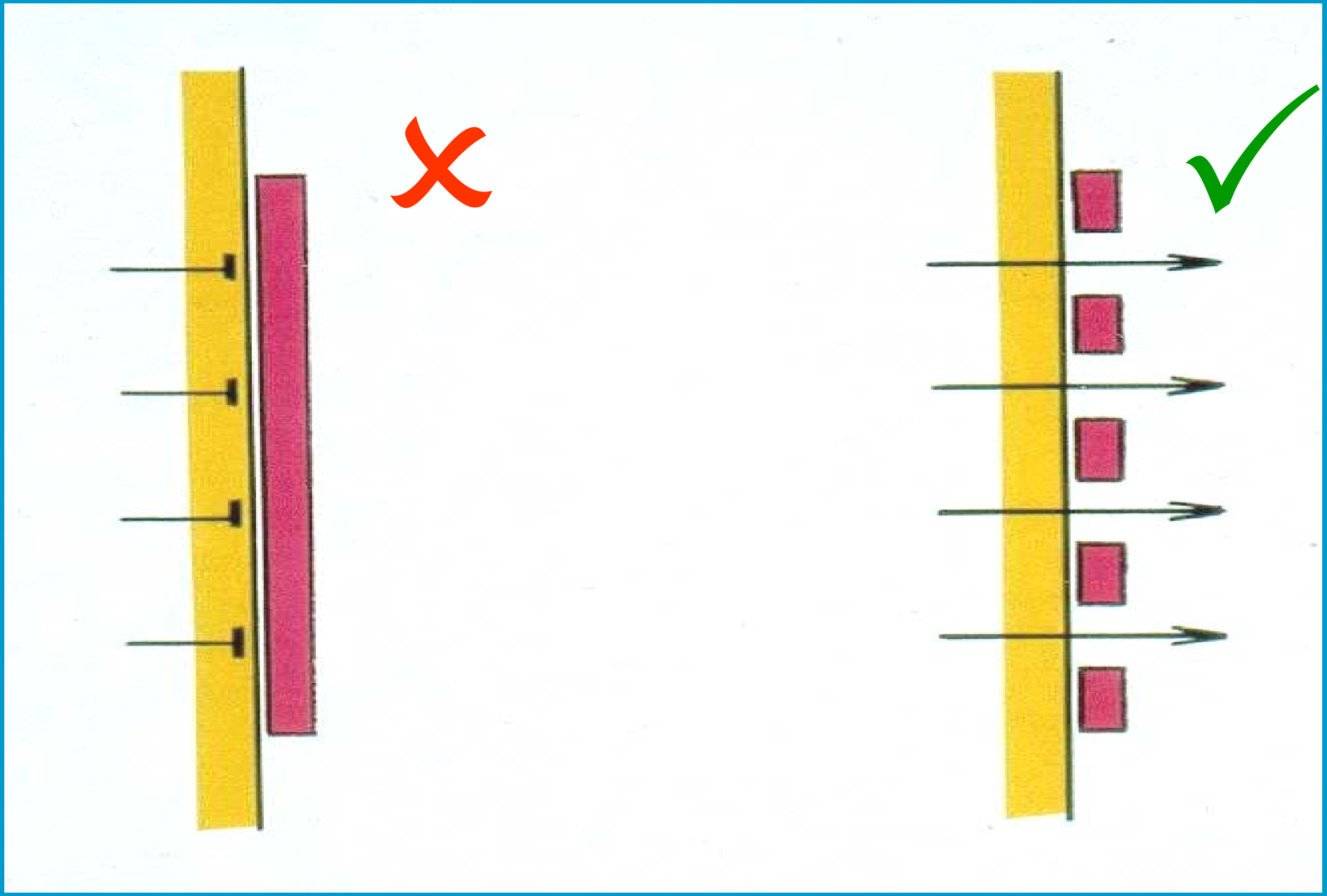
2. Distance between interfaces!



3. Make interfaces adaptive!



4. Perforate the interfaces!



Design perspectives

- Motion directed design: starting with desired motion (or positions), add actuators later.
- Force directed design (FDD): start with desired forces (or force distributions), take care about motion later.

Same mechanics, different design perspective!

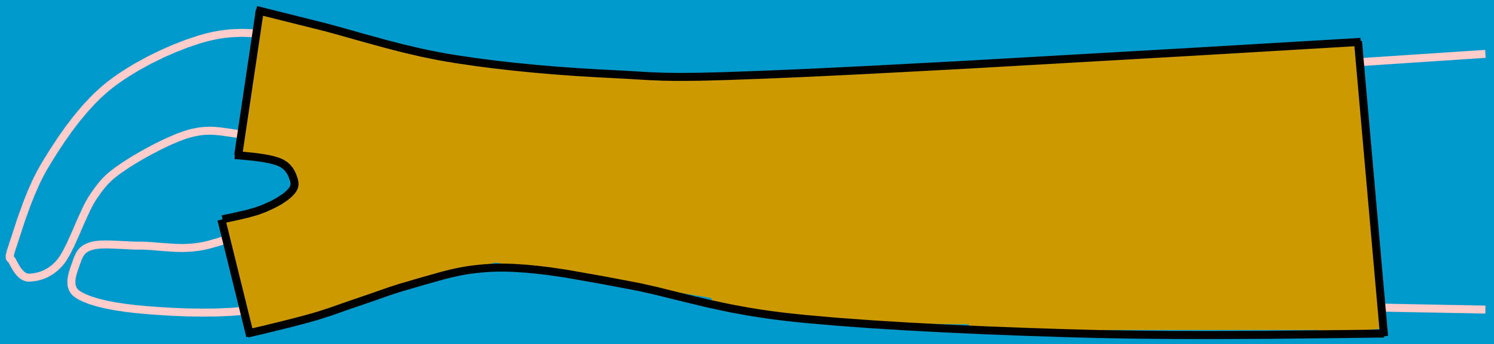
Example 1

Given situation

Desired situation

Example 1

Solution according to motion directed design



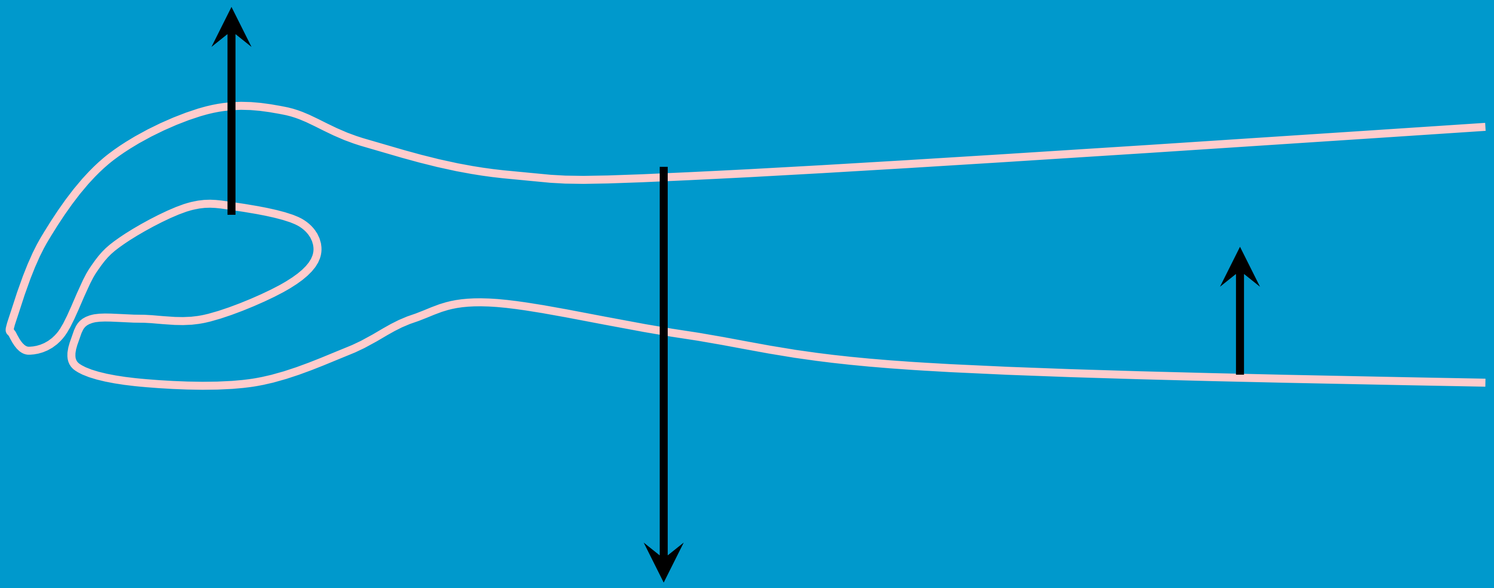
Example 1

Solution according to force directed design

Equilibrium through addition of appropriate forces

Example 1

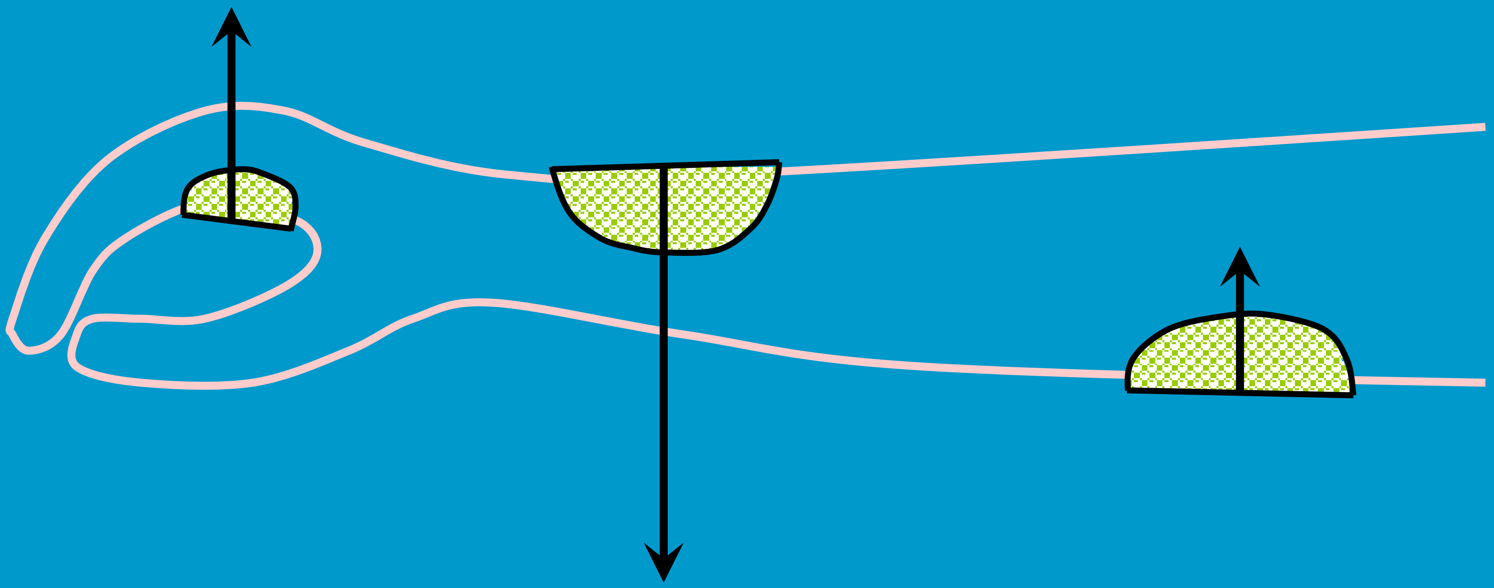
Solution according to force directed design



Equilibrium through addition of appropriate forces

Example 1

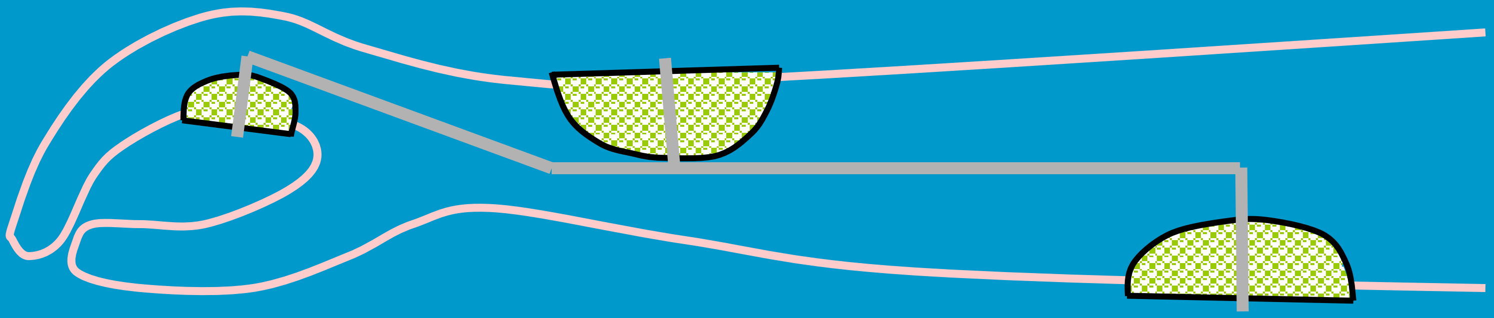
Solution according to force directed design



Equilibrium through addition of appropriate forces

Example 1

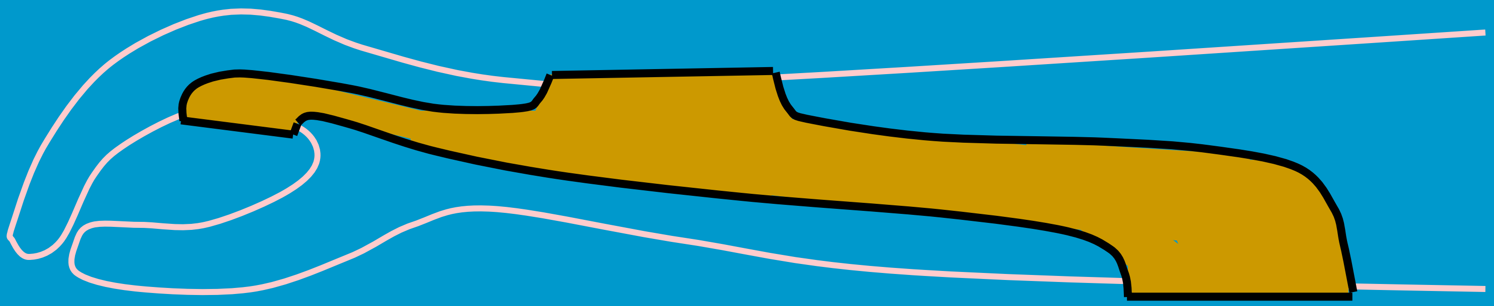
Solution according to force directed design



Equilibrium through addition of appropriate forces

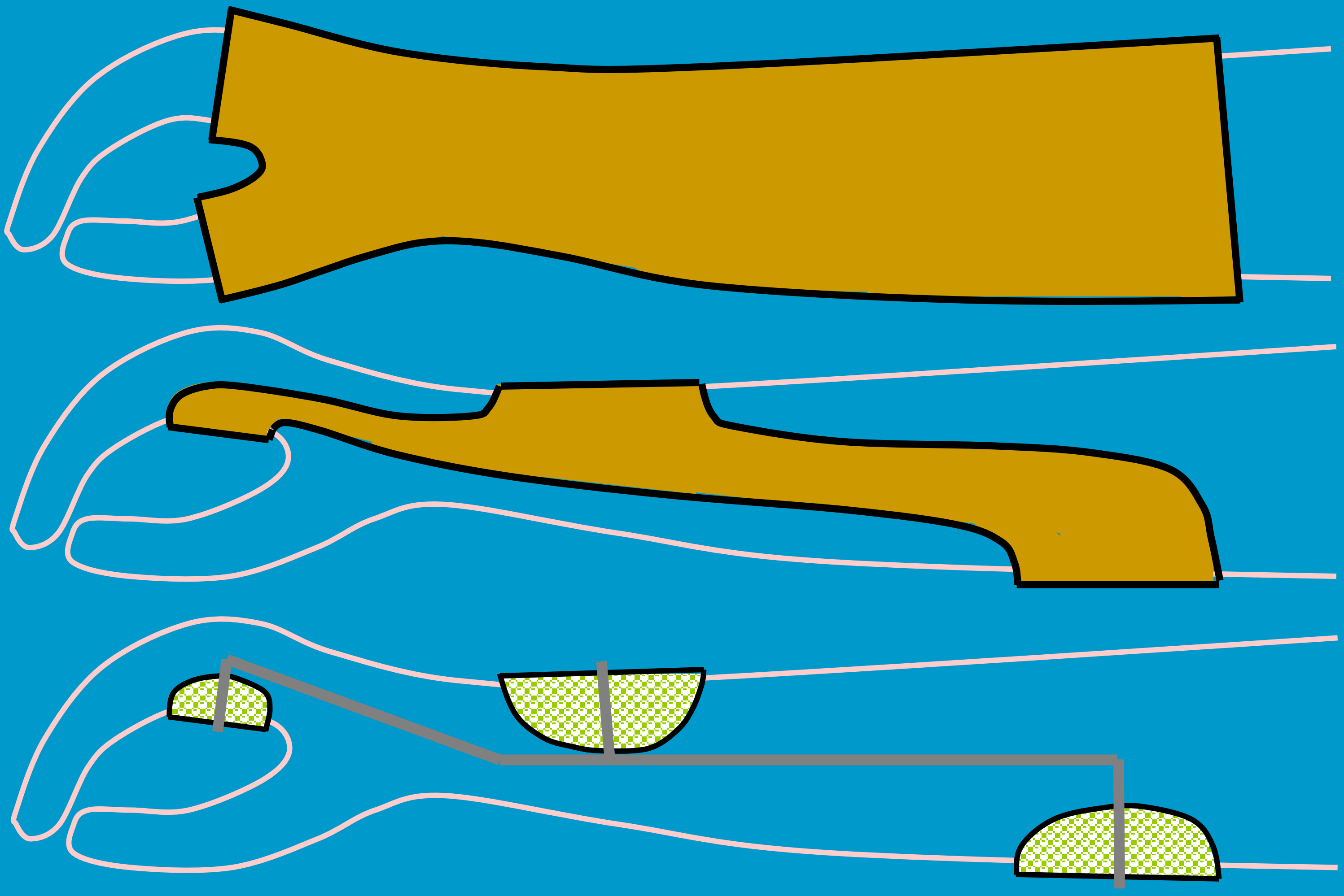
Example 1

Solution according to force directed design



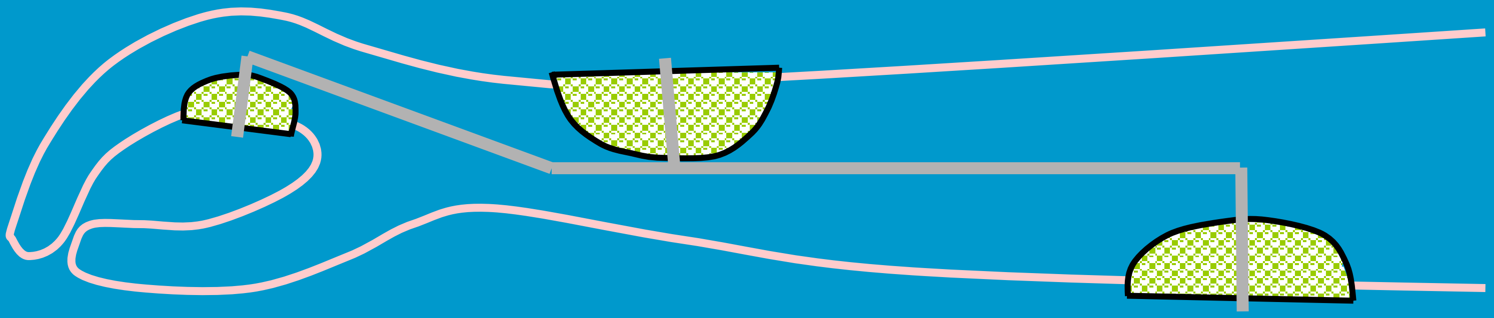
Equilibrium through addition of appropriate forces

Example 1



Example 1

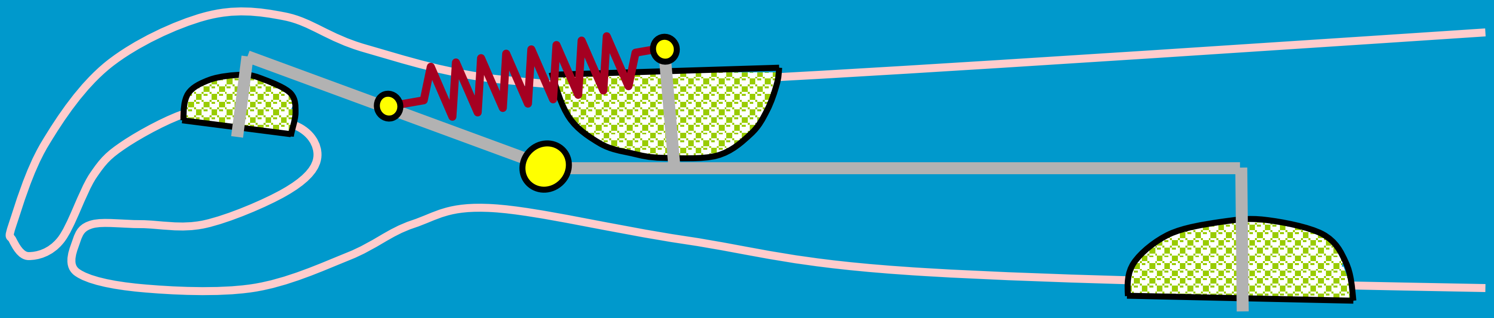
Solution according to force directed design



Equilibrium through addition of appropriate forces

Example 1

Solution according to force directed design



Continuous equilibrium through static balancing

Conclusion example 1

- Start with desired forces or force distribution
- Make equilibrium with other forces
- Select profitable force application points
- Apply guidelines
- Connect application points with minimal material
- If mobility desired: static balancing

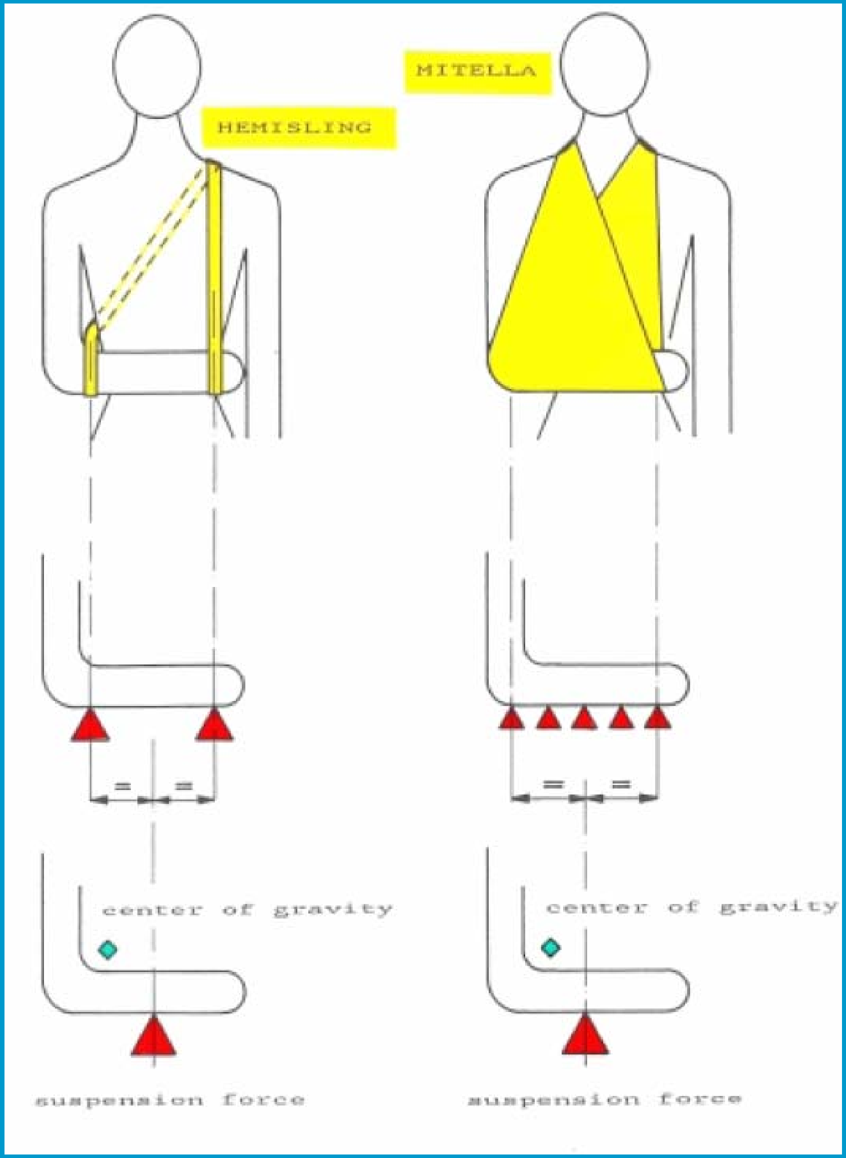
Shoulder orthosis

a.k.a WILMER Carrying Orthosis

Shoulder orthosis

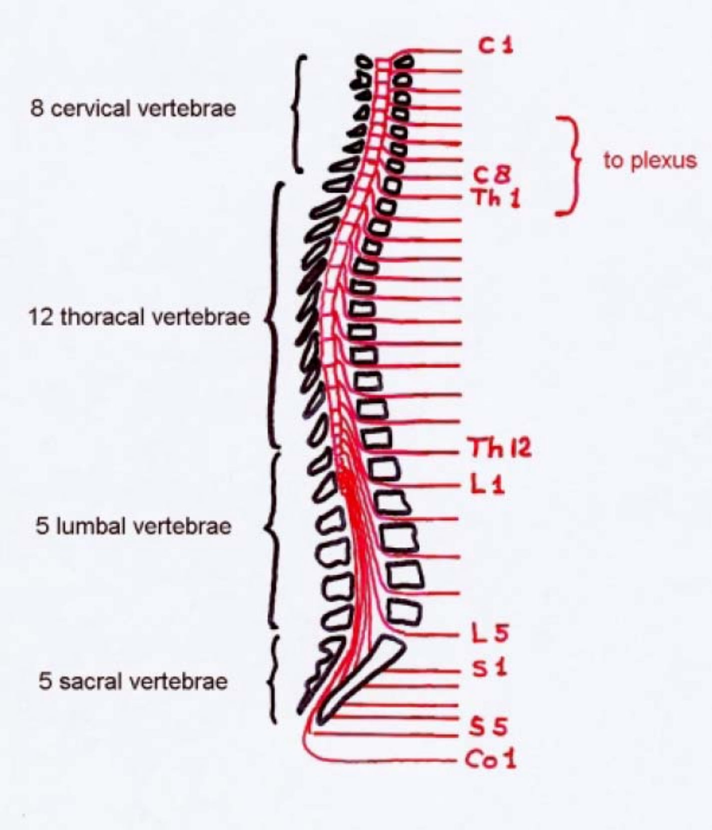
a.k.a WILMER Carrying Orthosis

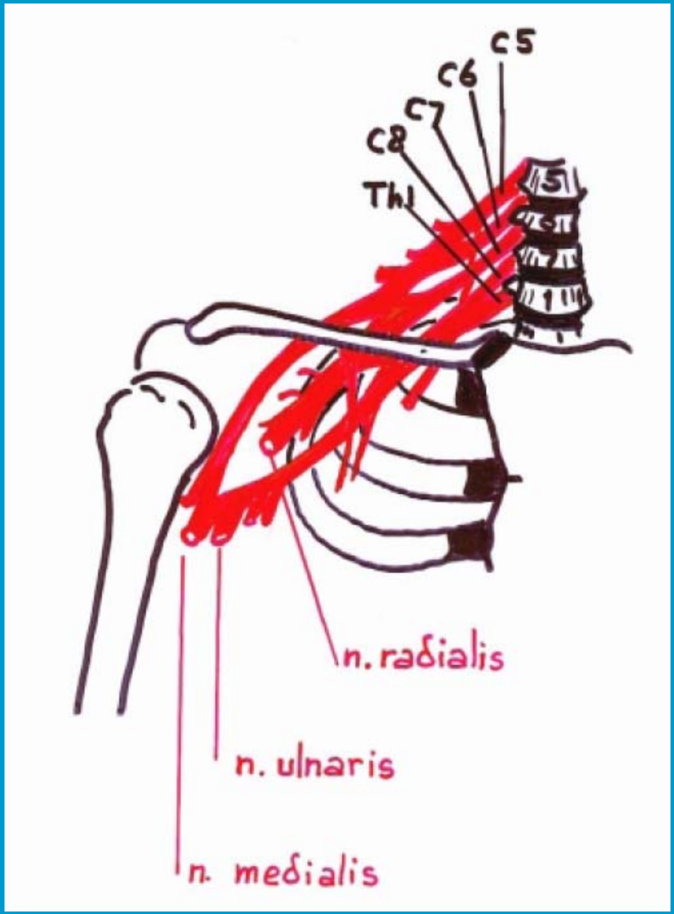
Present solutions
do not work

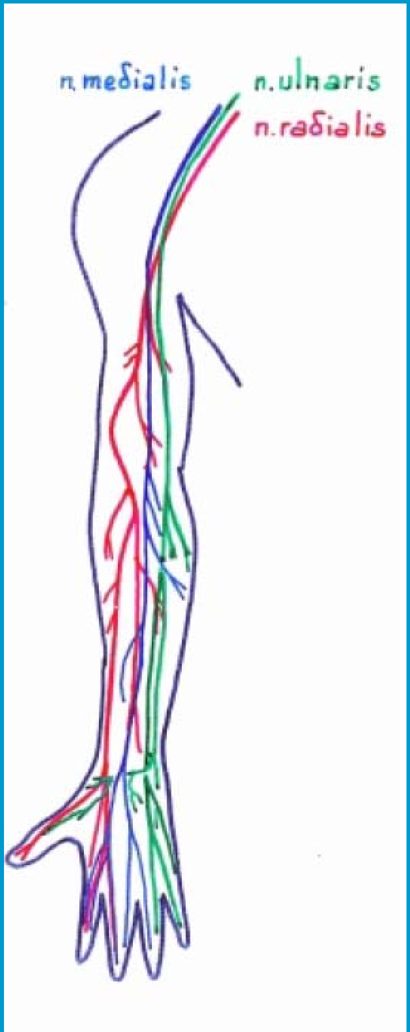


Shoulder orthosis

a.k.a WILMER Carrying Orthosis







Shoulder orthosis

a.k.a WILMER Carrying Orthosis

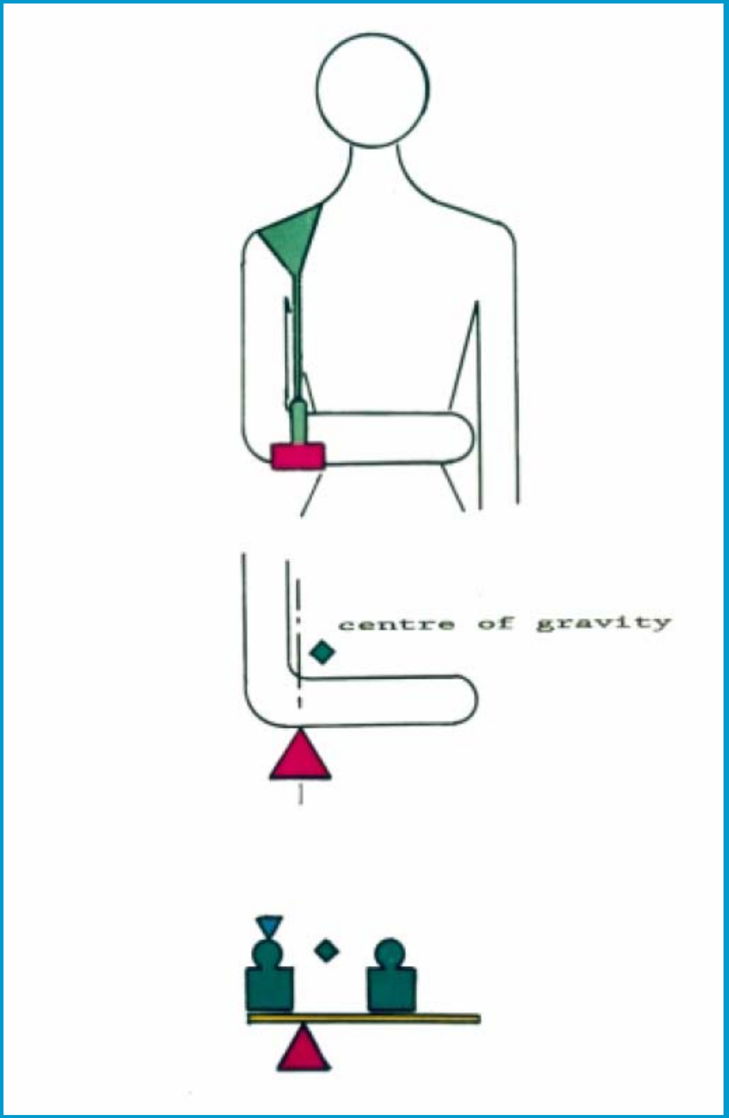
Result:

Flail arm

Subluxation

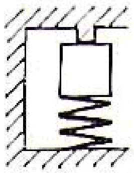
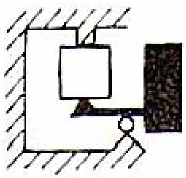
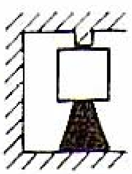
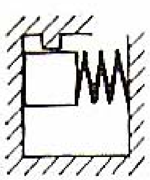
Shoulder orthosis

a.k.a WILMER Carrying Orthosis



Shoulder orthosis

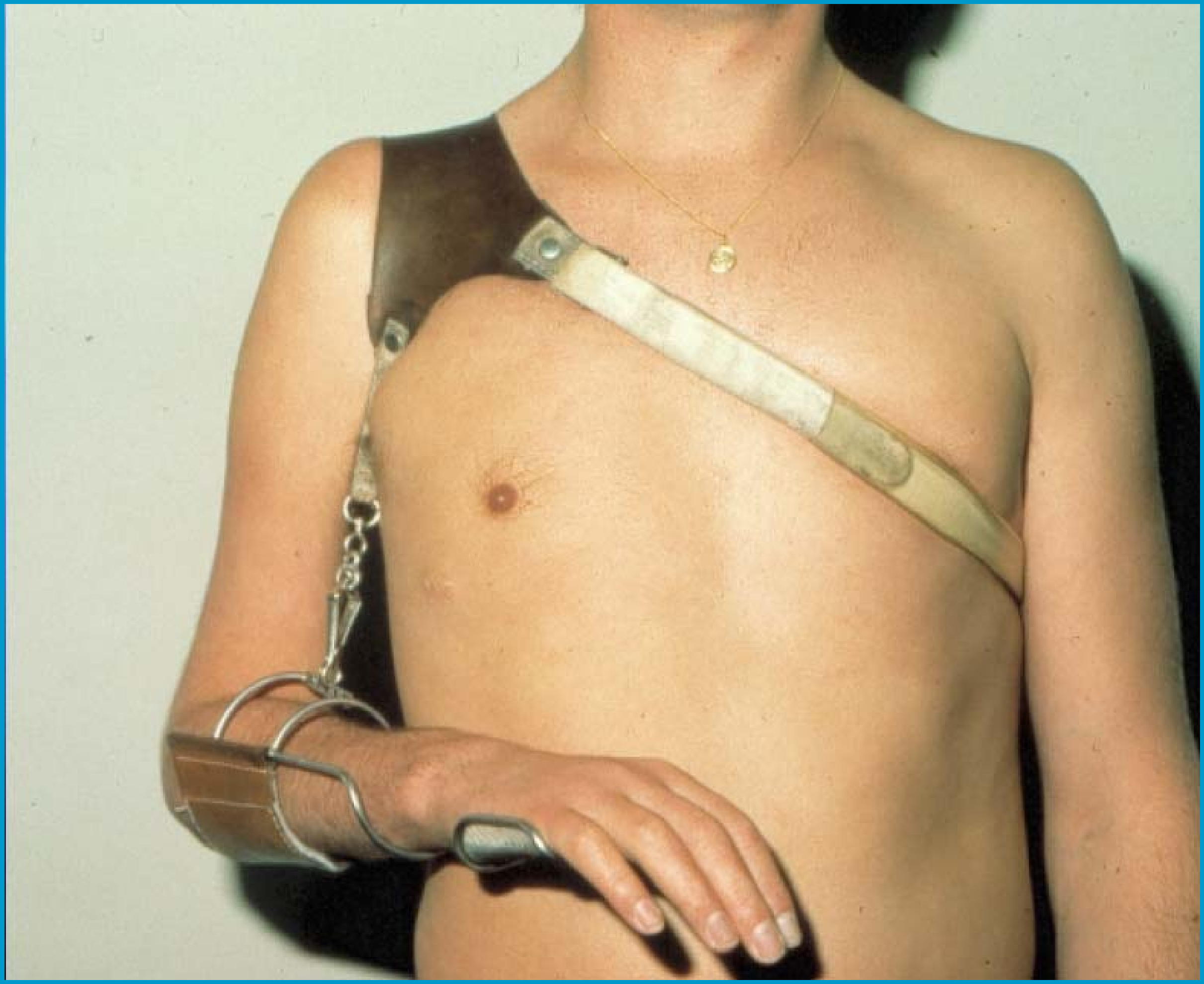
a.k.a WILMER Carrying Orthosis

	Description	Advantages	Disadvantages
a 	Elevation force applied by spring	Controlled subluxation	Variable shoulder force
b 	Elevation force applied by counterweight	Controlled subluxation constant shoulder force	Heavy and voluminous because of counterweight
c 	Elevation held by clamping	Insensitive to disturbing (dynamic) forces	Sensitive to movements of fixation point
d 	Elevation held by friction		Sensitive to disturbing forces High normal forces

Cool 1989

Shoulder orthosis

a.k.a WILMER Carrying Orthosis



Shoulder orthosis

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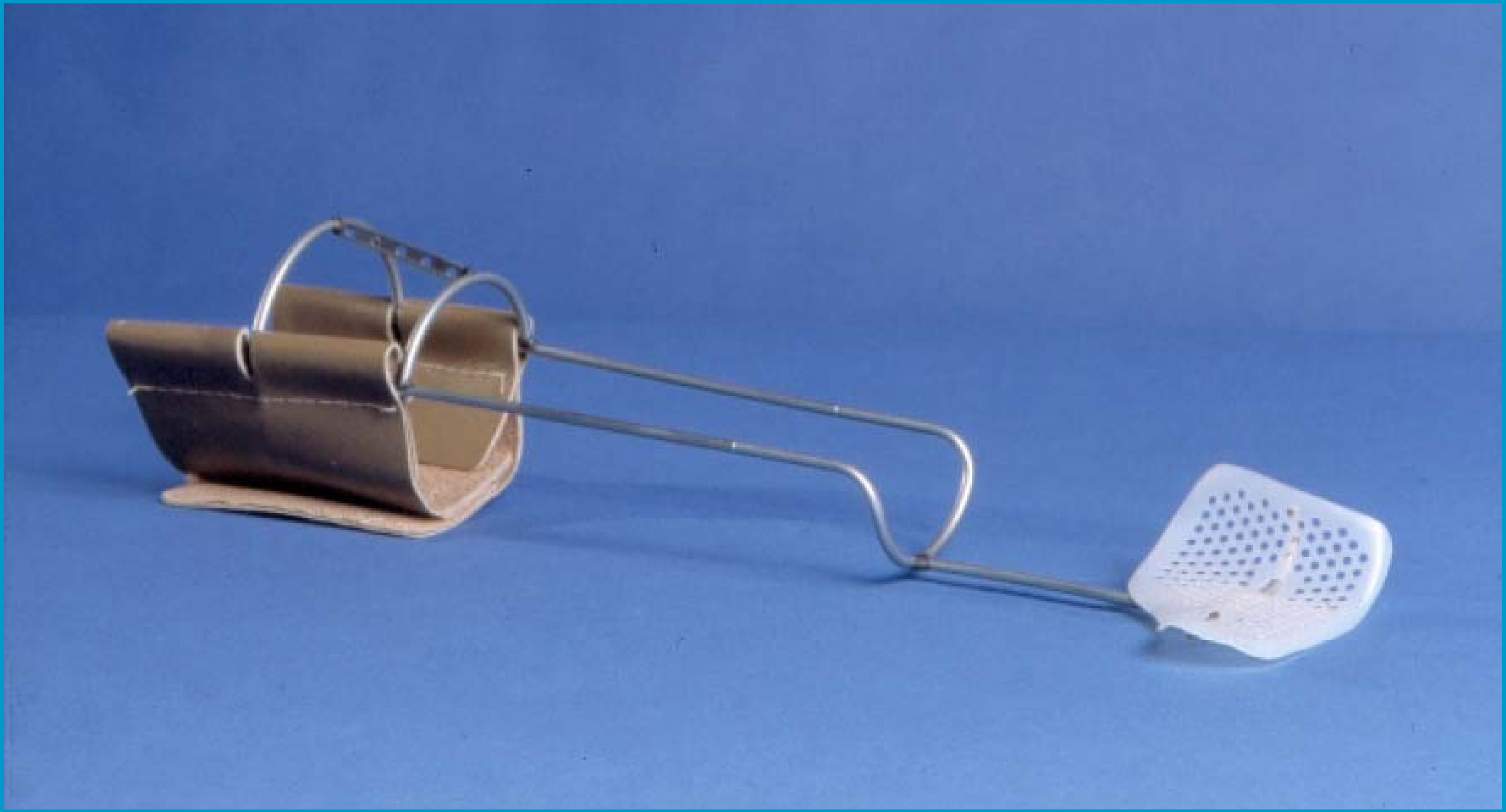

Shoulder orthosis

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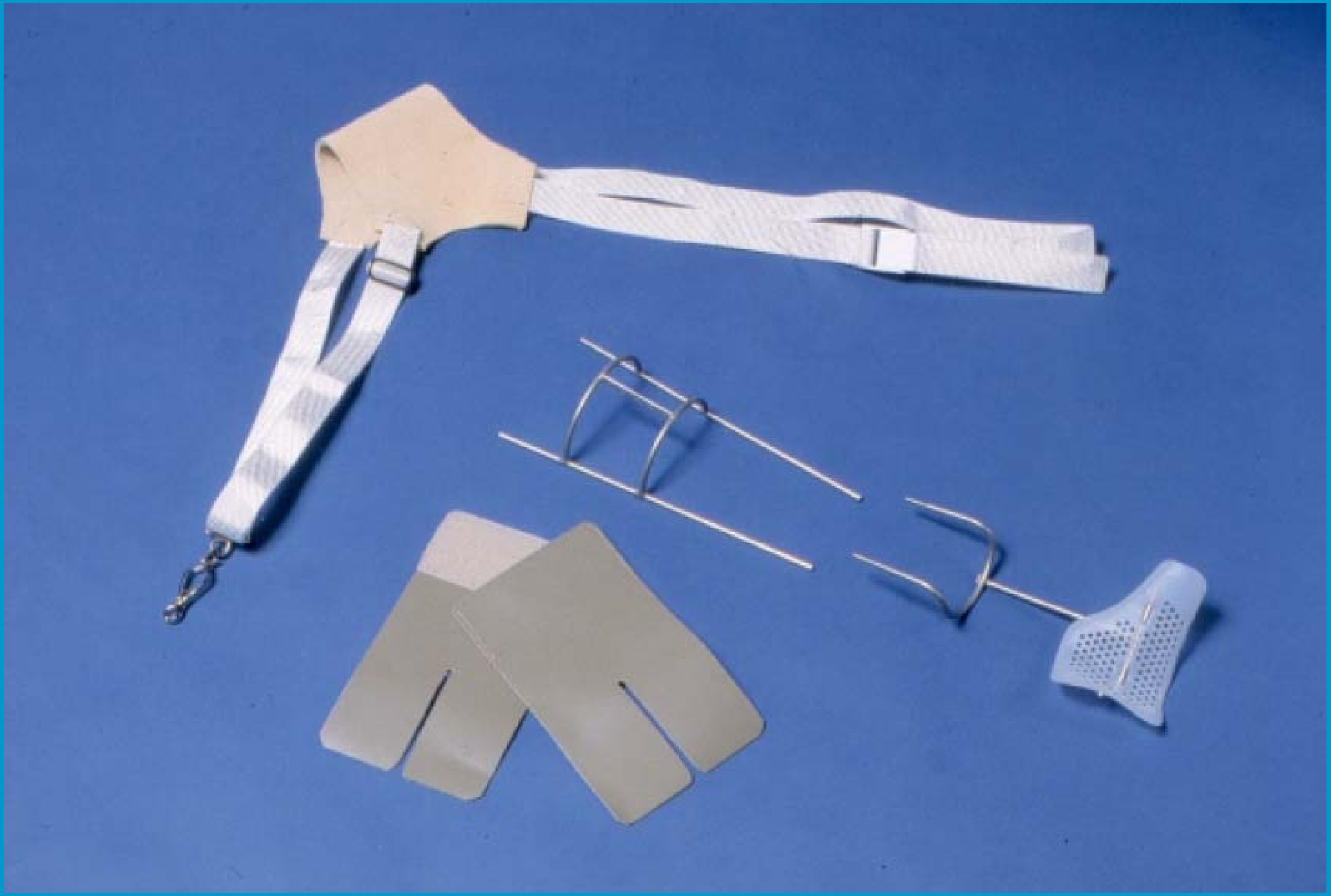
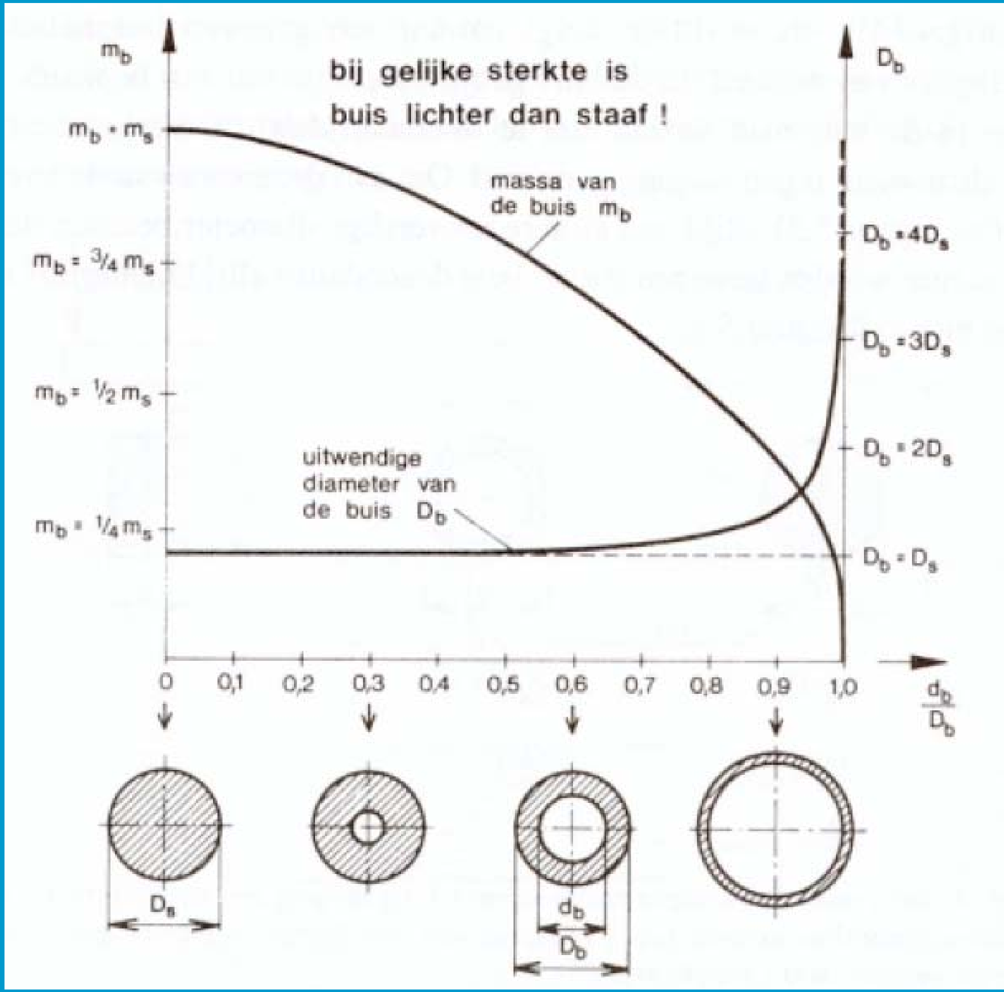


Shoulder orthosis

a.k.a WILMER Carrying Orthosis

Made out of
stainless steel tube



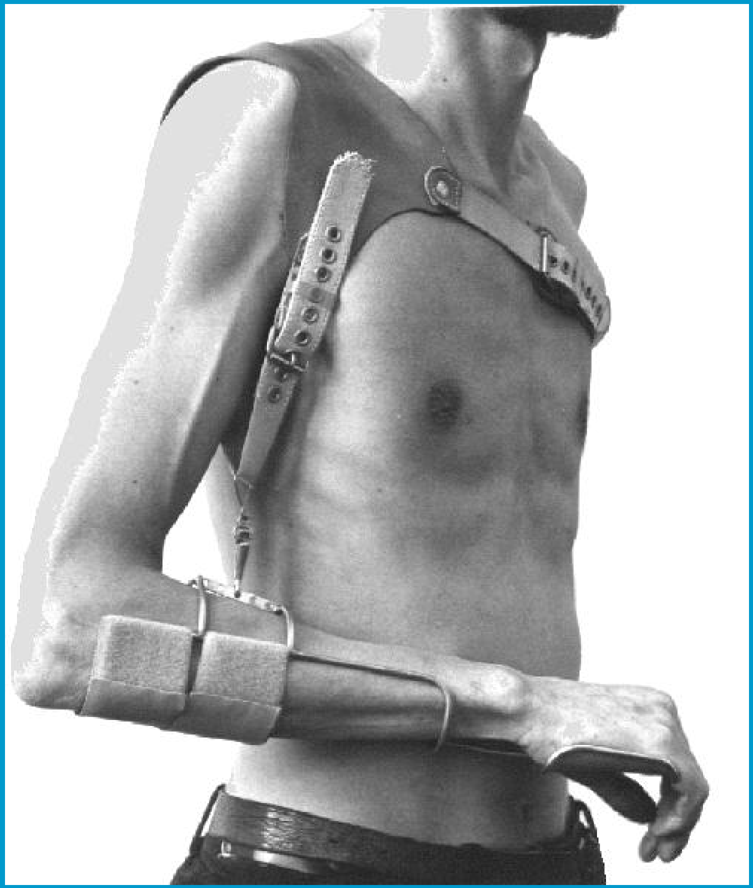
Shoulder orthosis

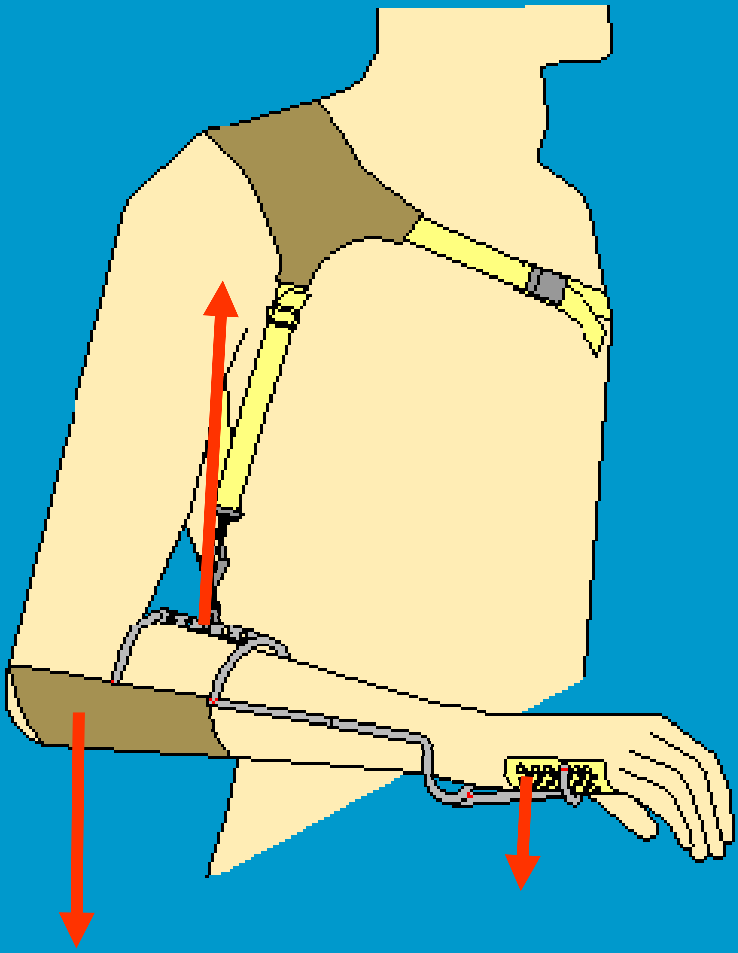
a.k.a WILMER Carrying Orthosis

- Neutralization of subluxation
- Suppression of oedema
- Reduced pain
- Protection
- Allows passive motion
- Low mass
- Comfortable
- Invisible
- Easy donning and doffing

WILMER

Carrying orthosis





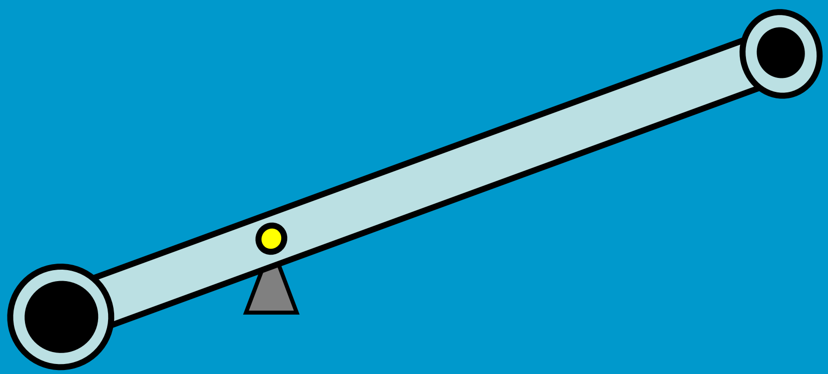
TU Delft

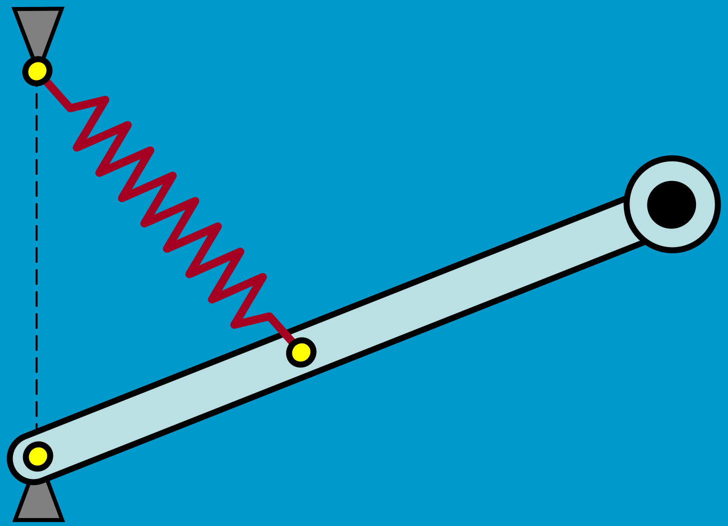
Elbow Orthosis

Elbow Orthosis

State of the Art...

Use of springs

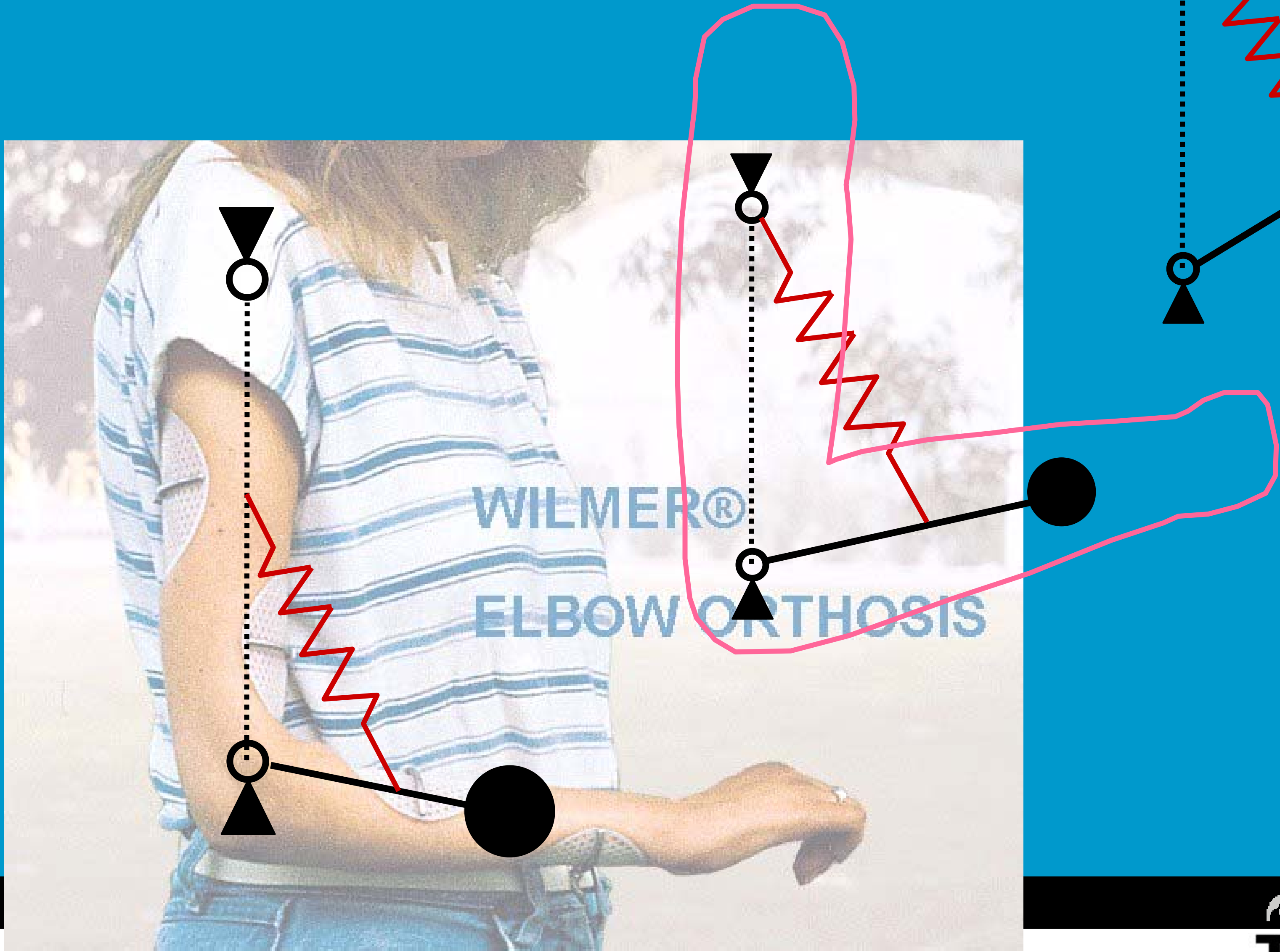


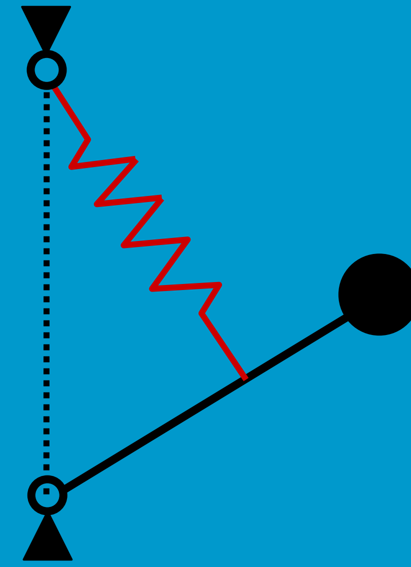


Mass-to-mass (counterweight)

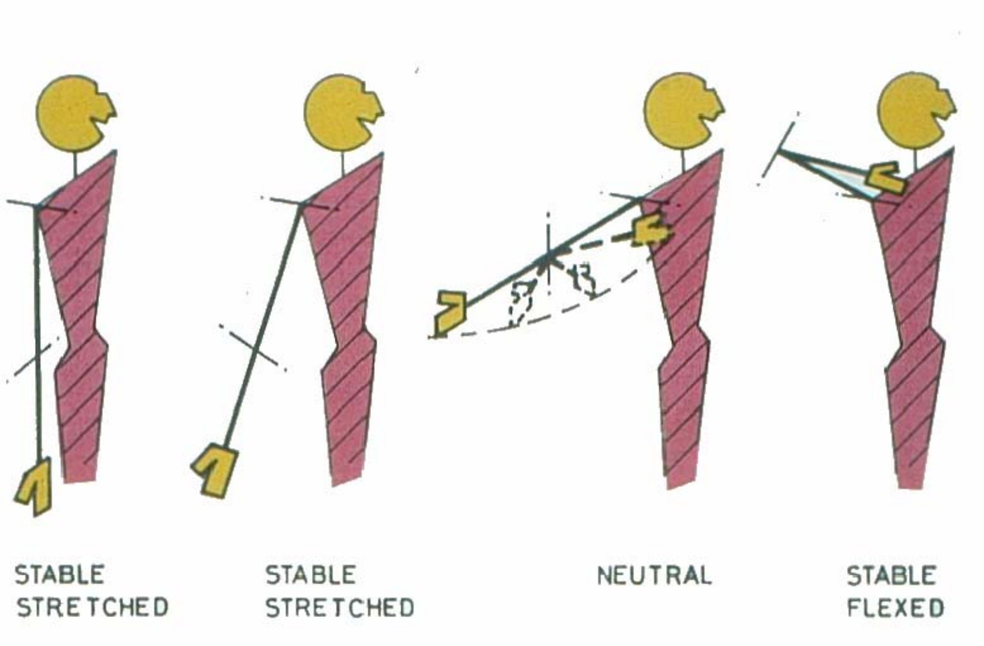
Mass-to-spring (counterspring)

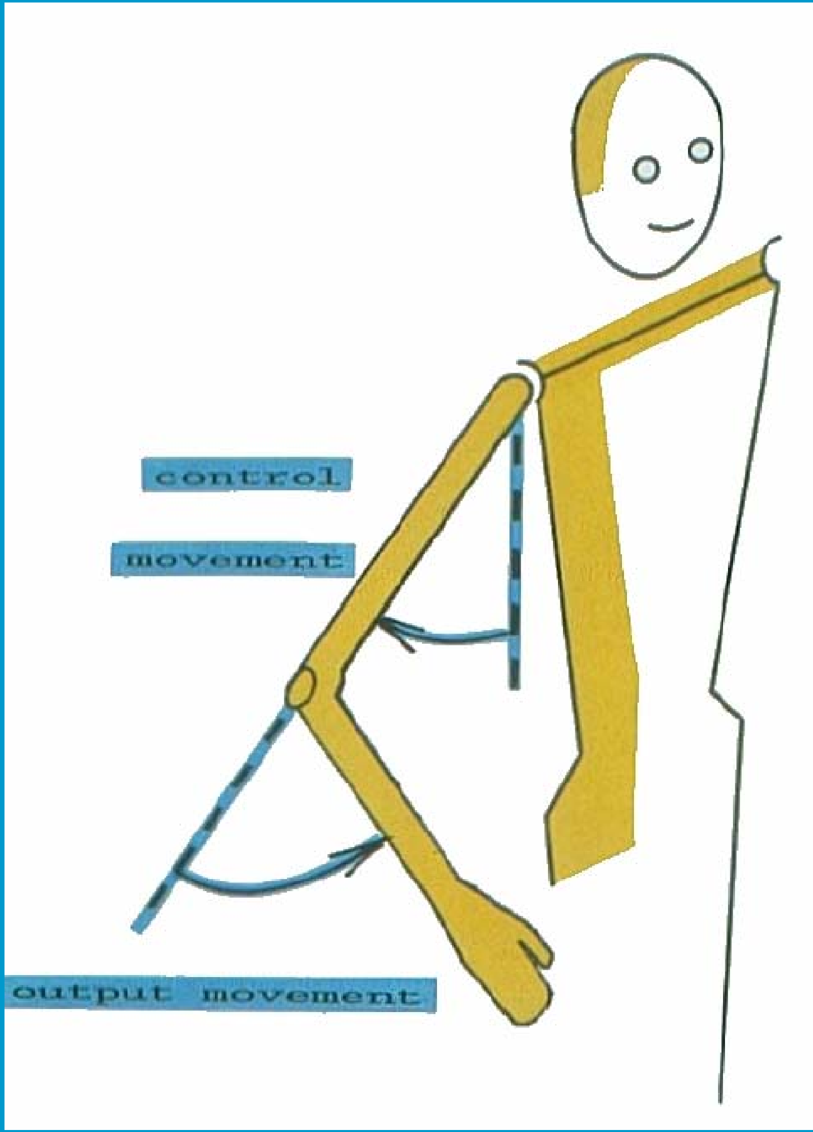
Elbow Orthosis



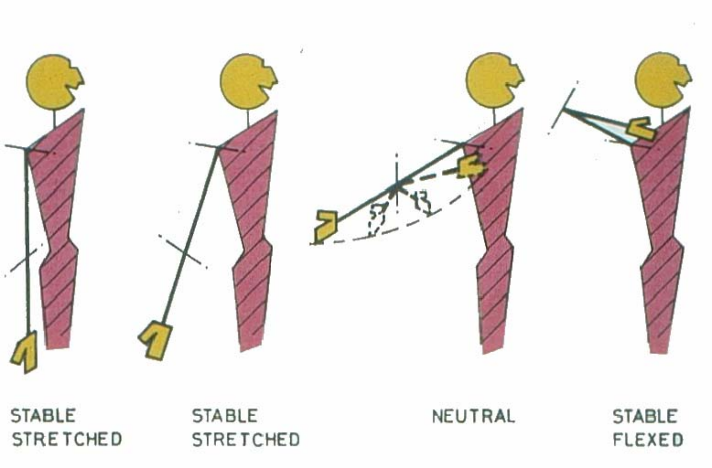


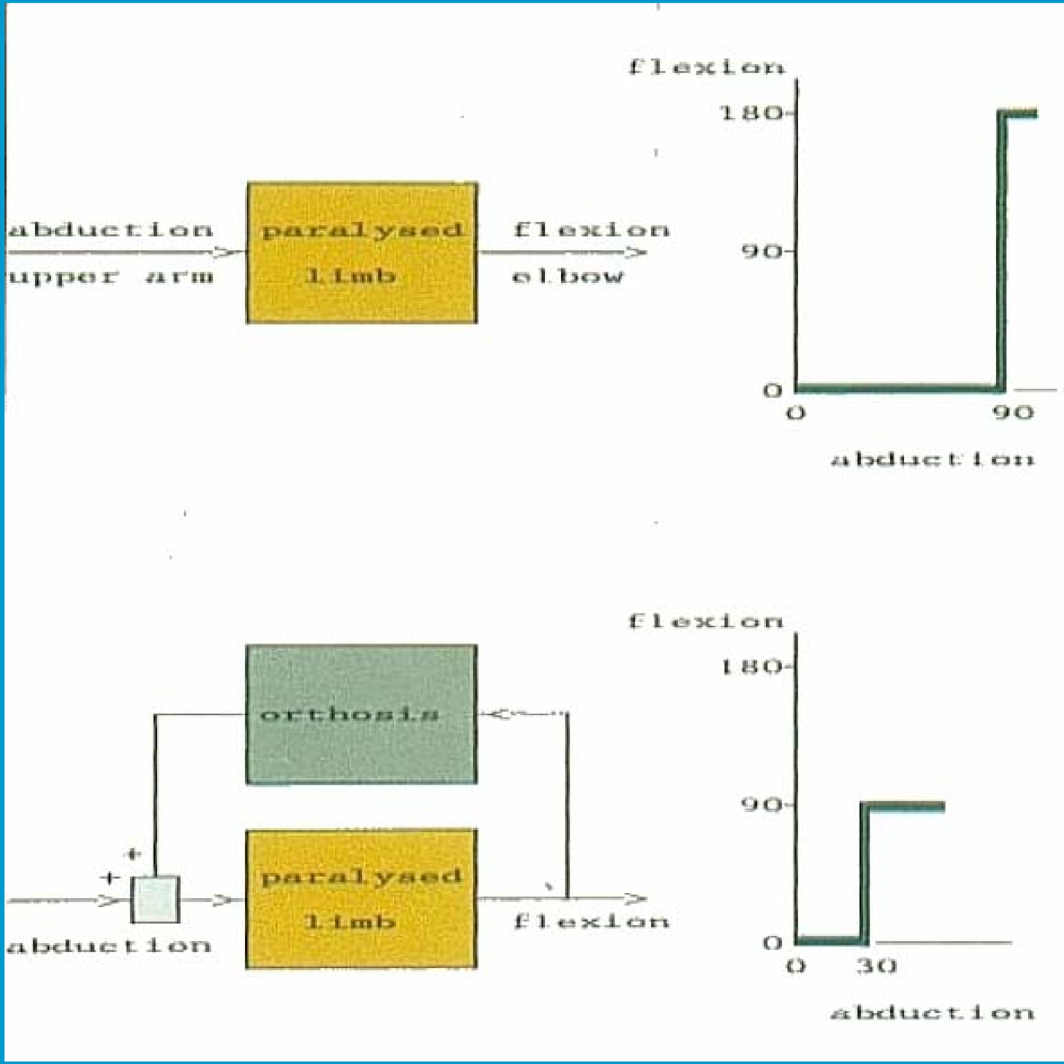
Elbow Orthosis



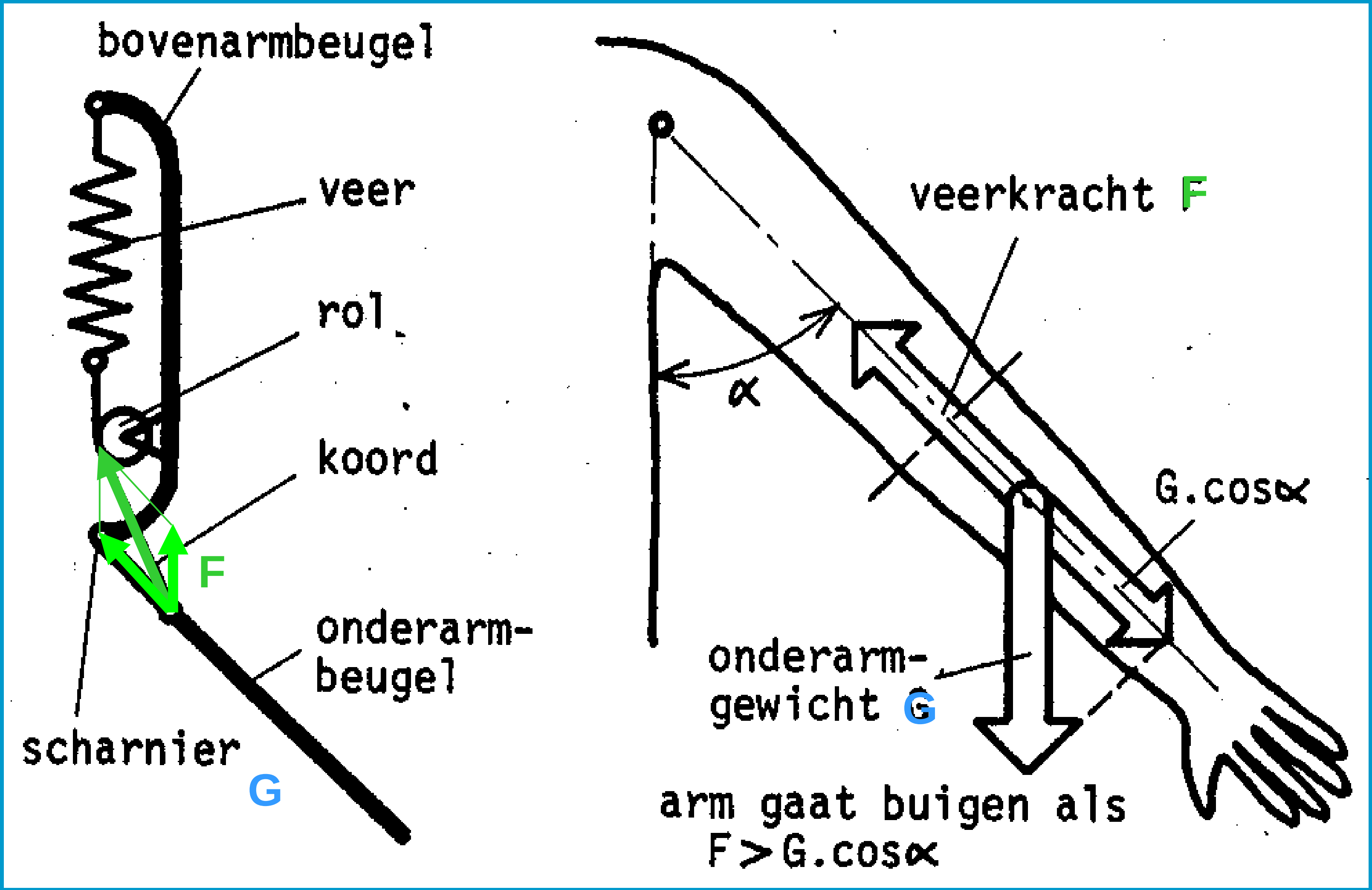


Elbow Orthosis

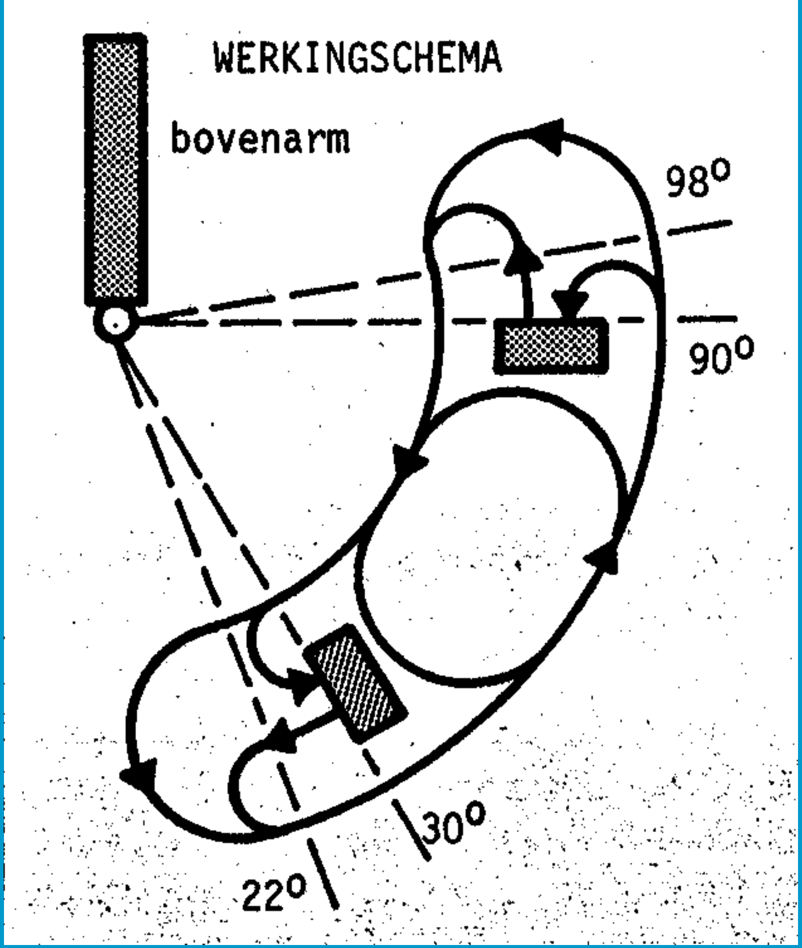


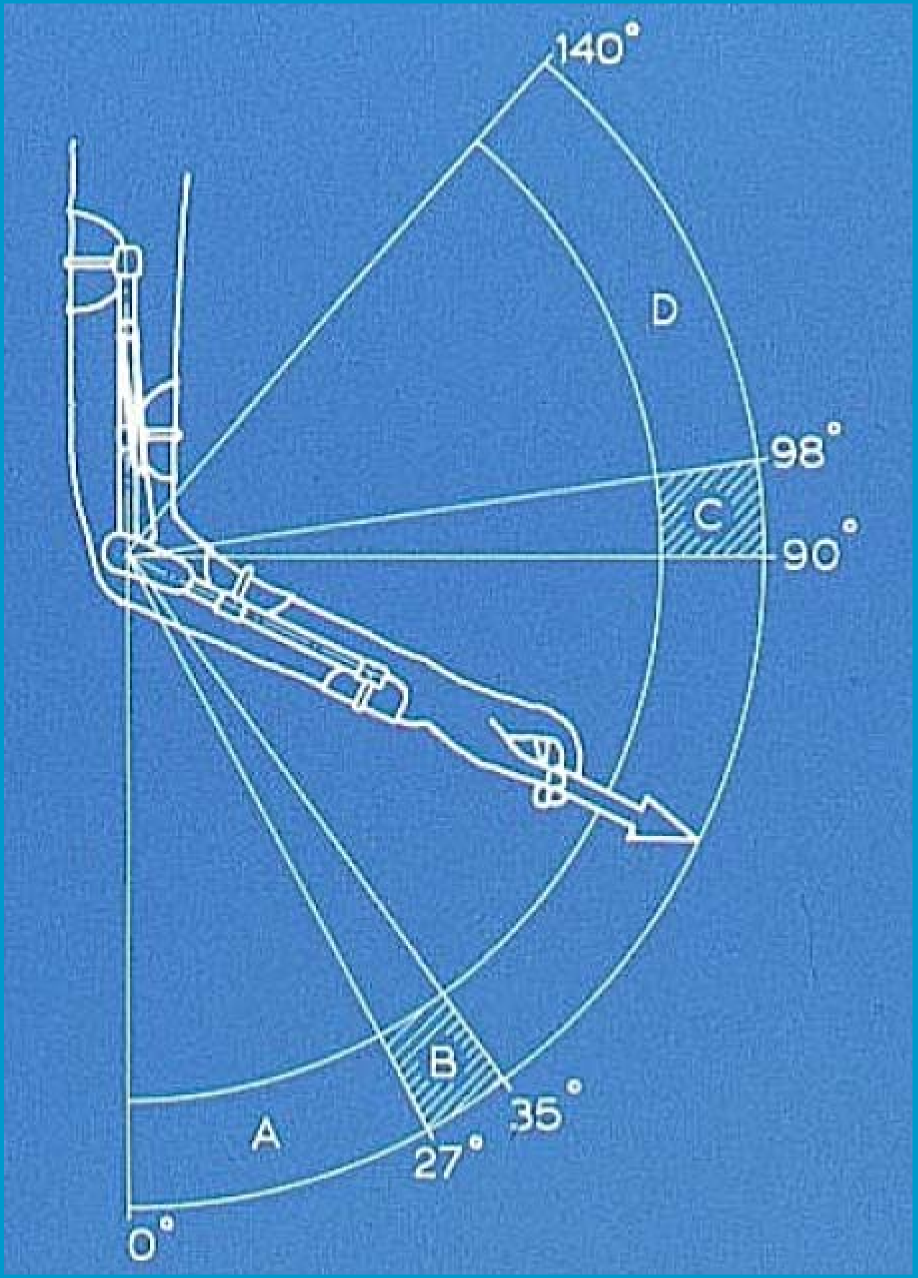


Elbow Orthosis

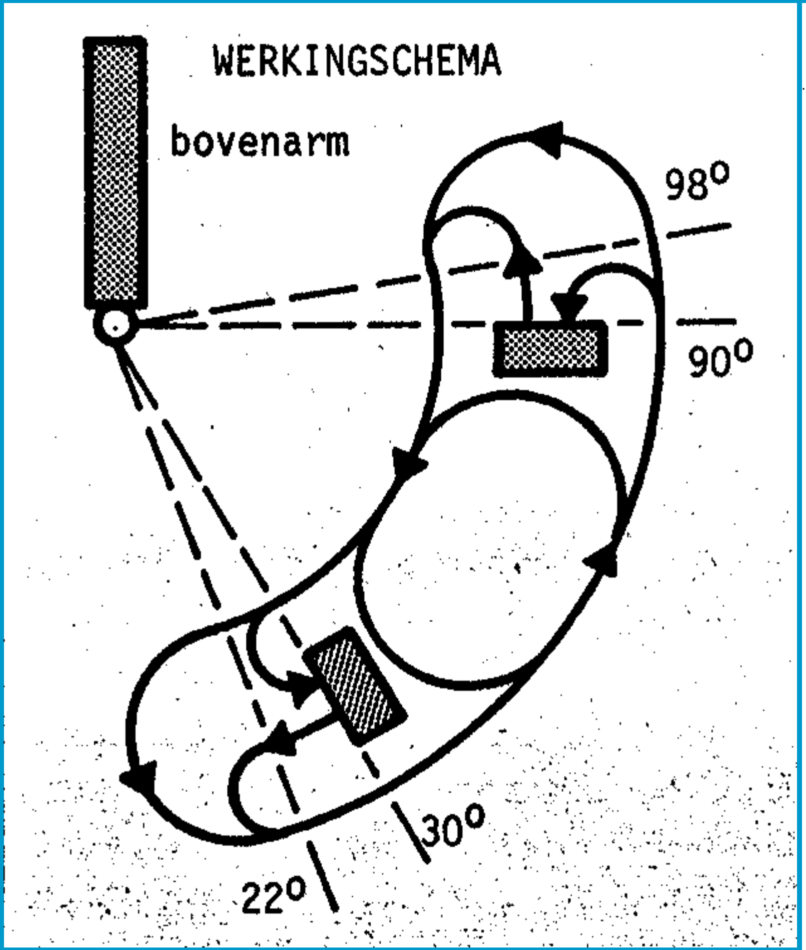


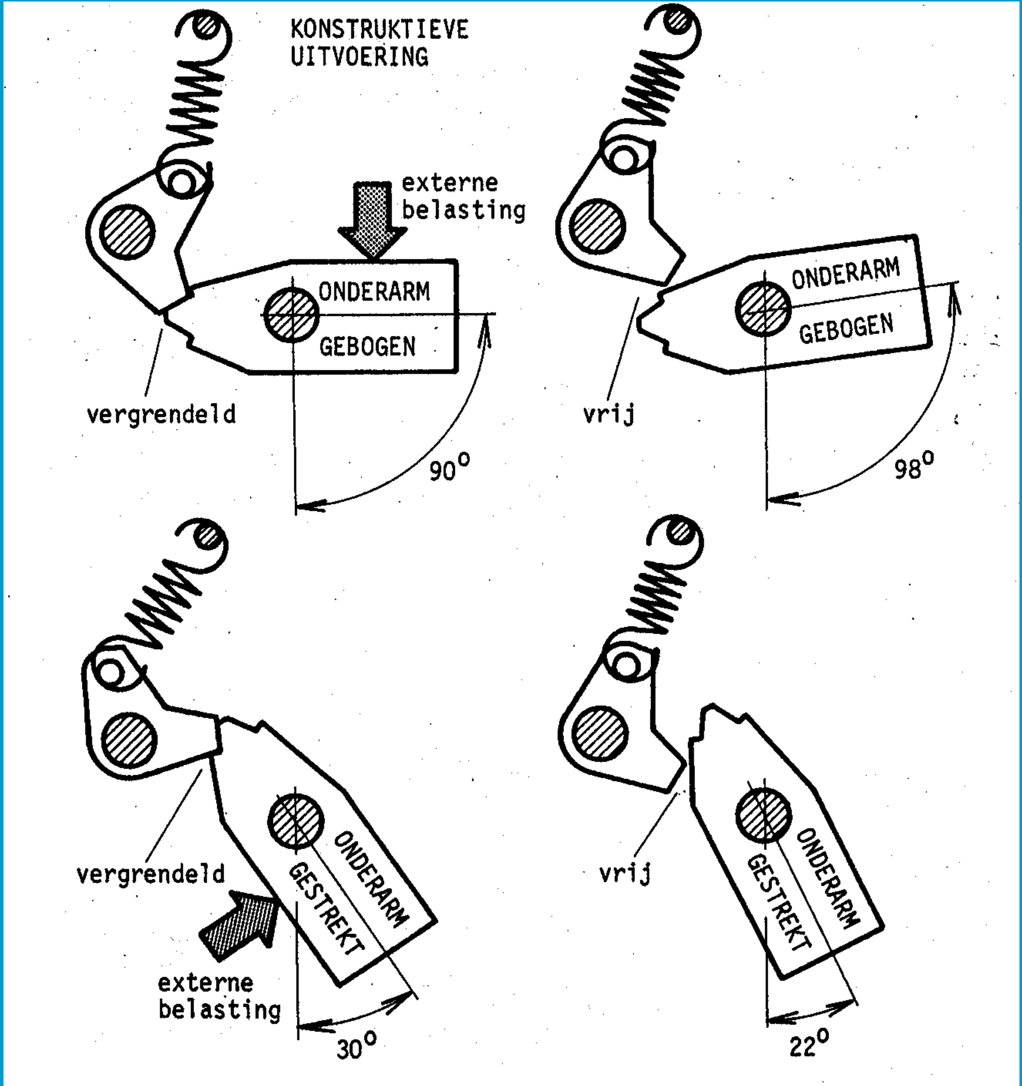
Elbow Orthosis





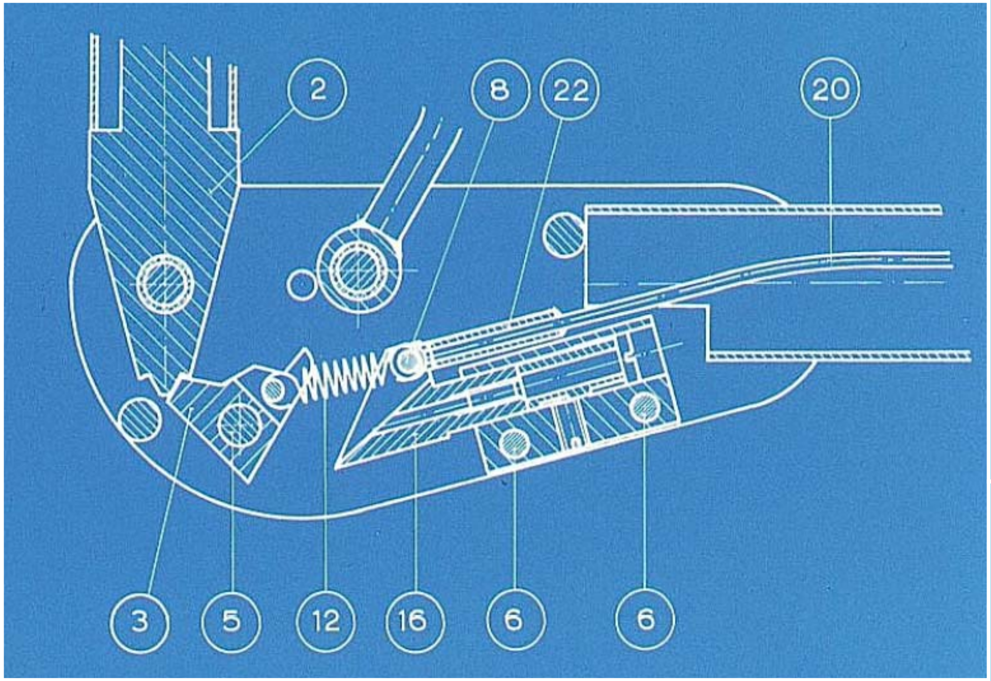
Elbow Orthosis

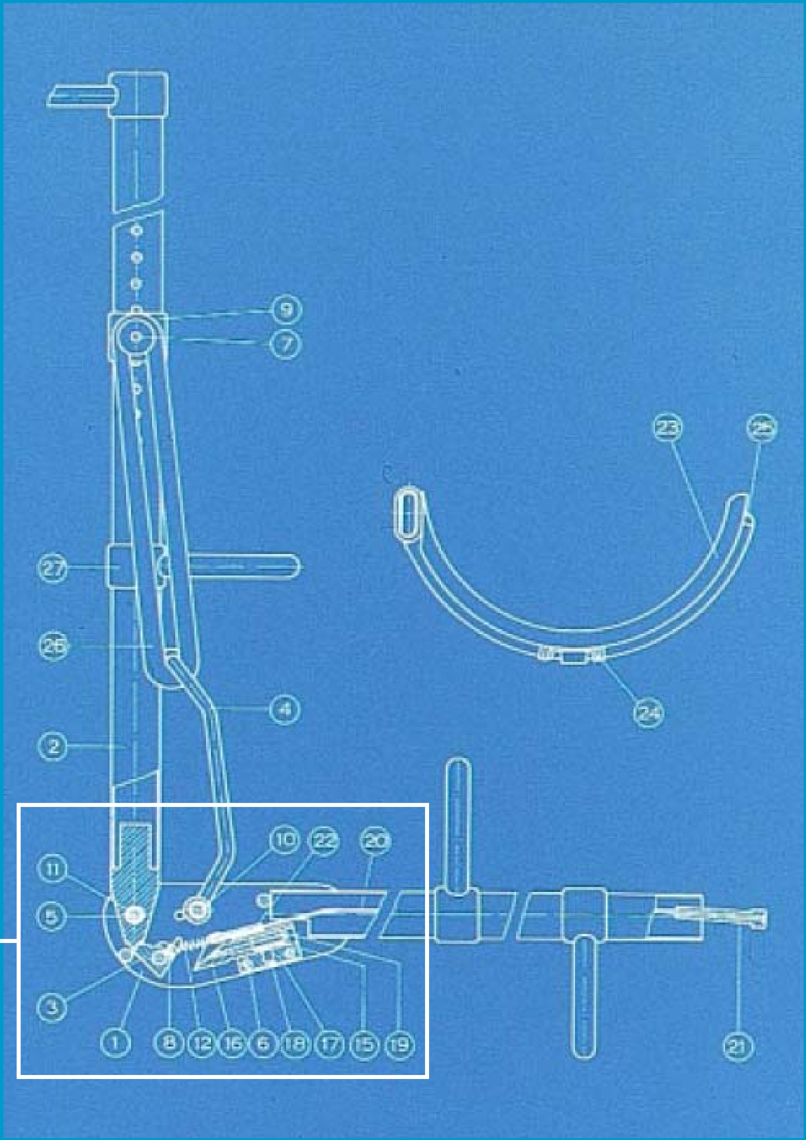




TU Delft

Elbow Orthosis





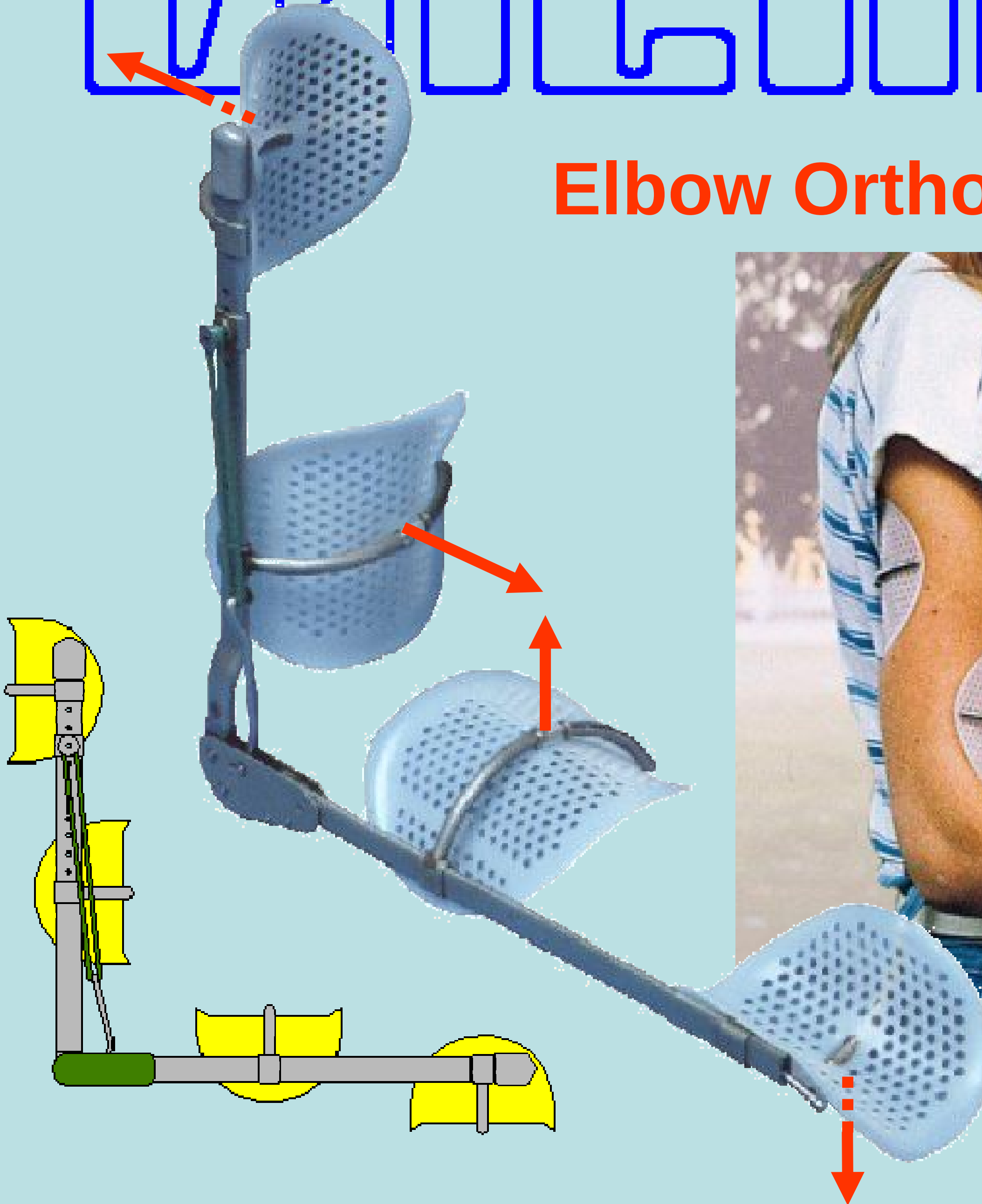
Elbow Orthosis

Elbow Orthosis

- Restores (some) elbow function
- Comfortable
- Low mass
- Invisible
- Cosmetically pleasing
- Easy donning and doffing
- Straightforward fitting procedure
- Automatic locking device

WILMER

Elbow Orthosis



Anglepoise (Carwardine, 1934)

Example 2: Neuromuscular diseases

600 variants identified

Muscular Dystrophies (Duchenne DMD)
Motor Neuron Diseases (Spinal Muscular Atrophy SMA)
Inflammatory Myopathies
Neuromuscular Junction Diseases
Endocrine Abnormalities
Peripheral Nerve Diseases
Metabolic Diseases of Muscle

Over 1 mln. people affected in USA

SMA alone 12 .. 40 per mln of the adult population
Neonatal from 40 per mln (USA) to 200 per mln (SA)

Spinal Muscular Atrophy (SMA)

Inherited

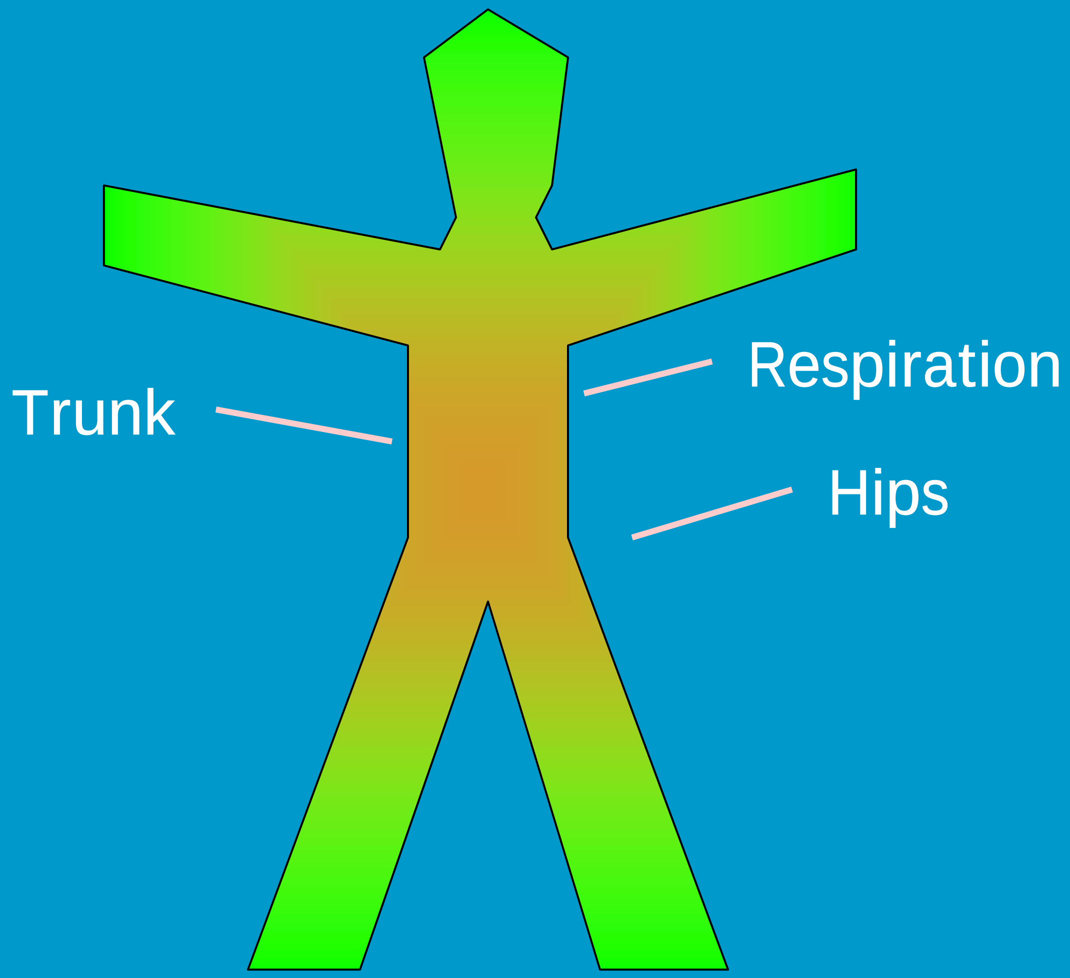
Affects motor neurons voluntary muscles

Senses not affected, normal or above-average intellect

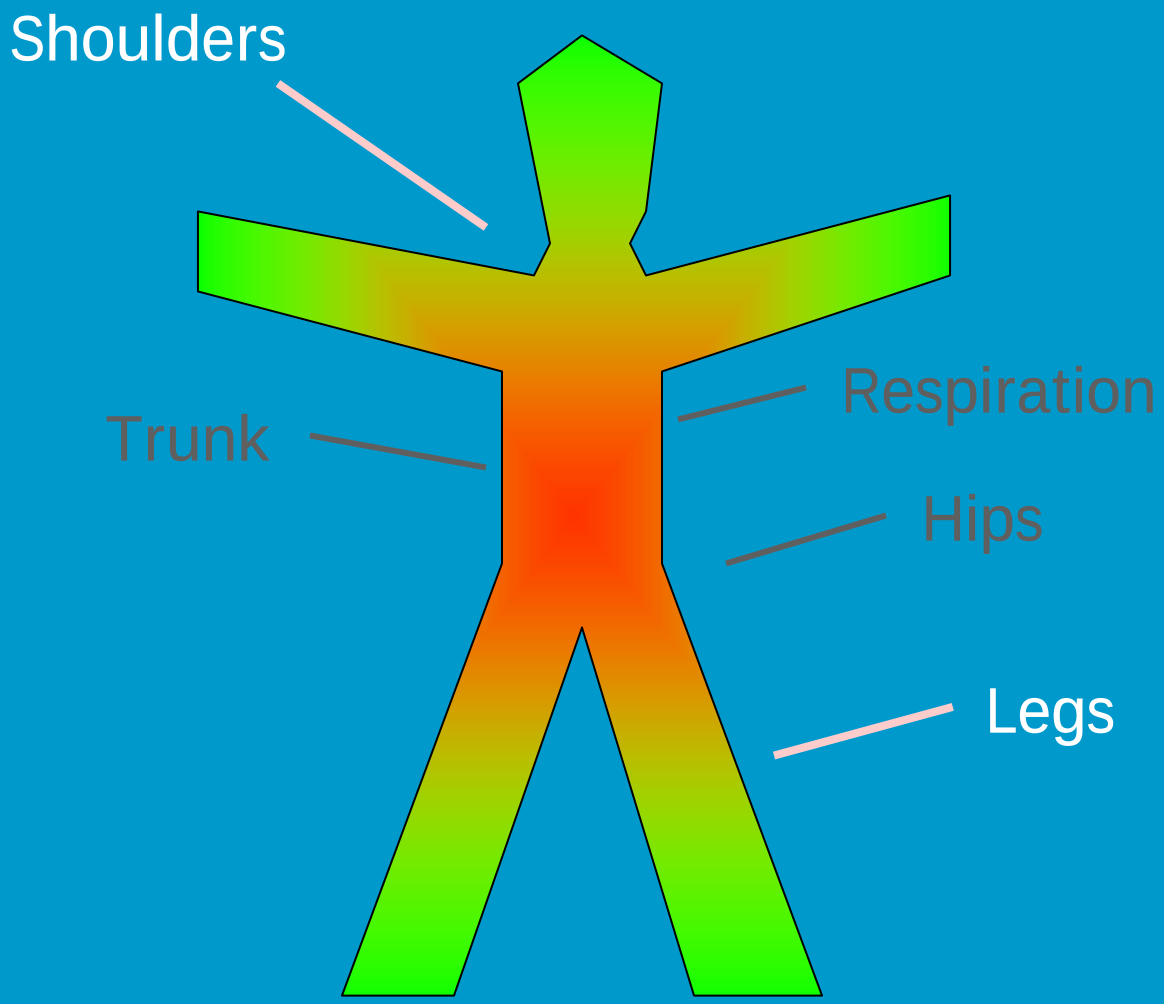
Incurable

Progressive

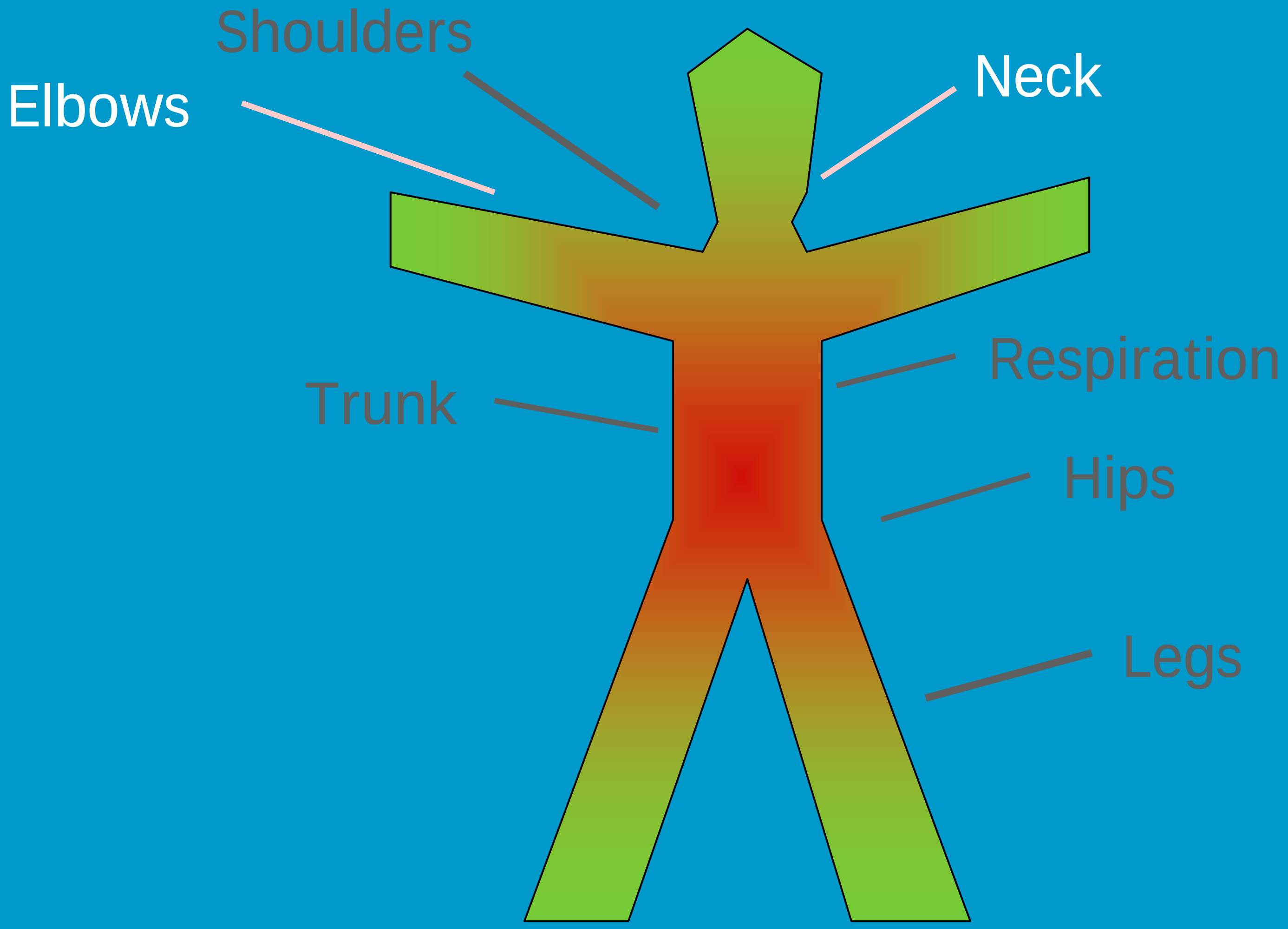
Spinal Muscular Atrophy (SMA)



Spinal Muscular Atrophy (SMA)



Spinal Muscular Atrophy (SMA)



Two of our volunteers!

A

Academic degree

Head support

Scoliosis, A had surgery, B not

Wheelchair bound

Arm on armrest

Good sense of touch

Slight deformations in hands

B

Design Criteria

System preference

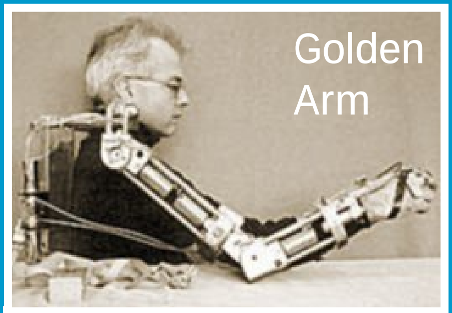
1: Separate Manipulators

2: Powered Orthoses

3: Passive Orthoses

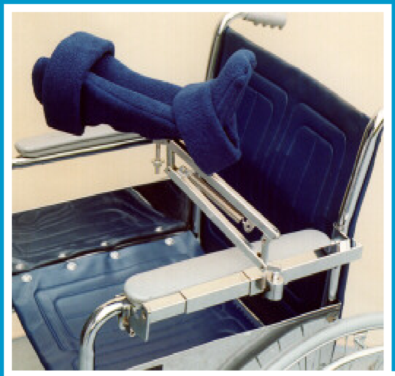
Weston

Manus ARM



MULOS

WREX

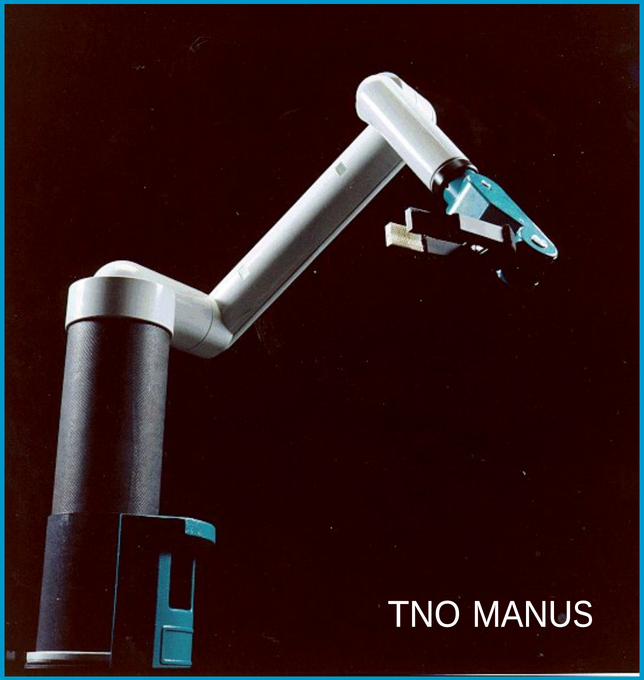


Universal Radial

Focal TOP

Available assistive devices

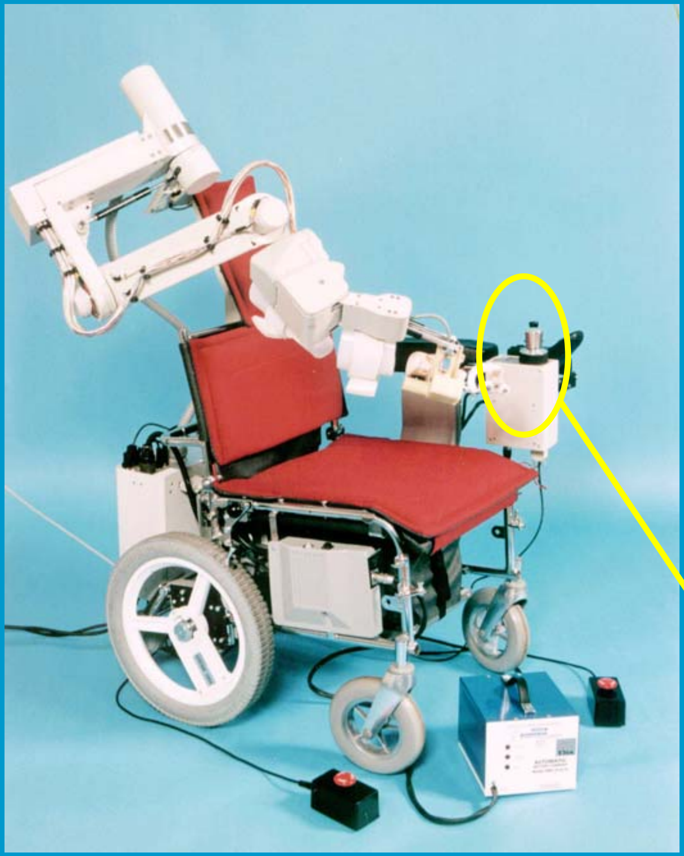
1. Rehabilitation robotic manipulators

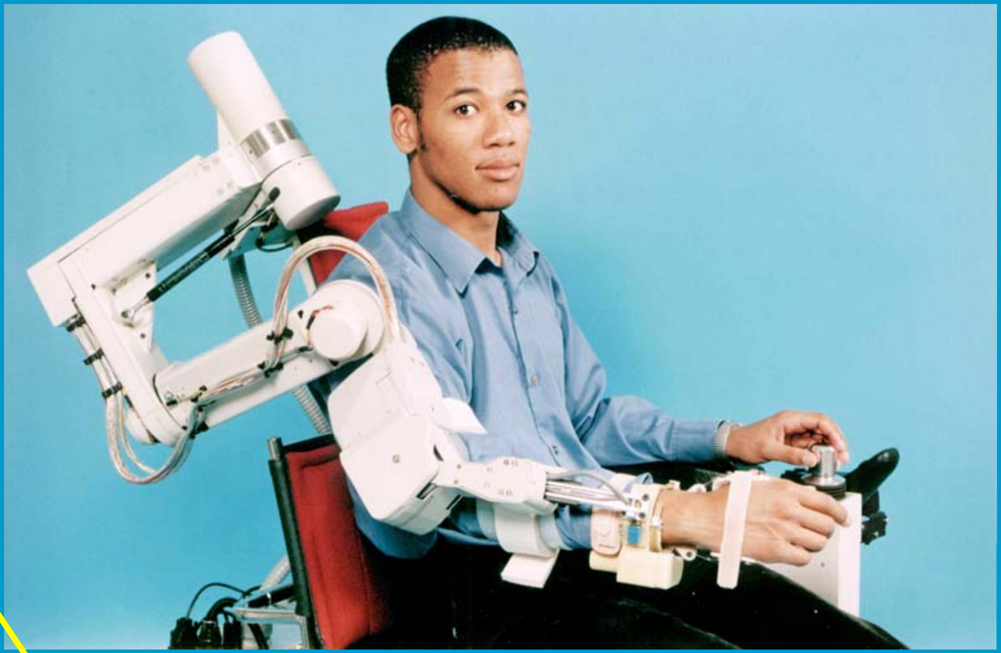


No use of hand function
Control by joystick

Available assistive devices

2. Powered orthotic devices





Use of hand function
Control by joystick

Available assistive devices

3. Passive orthotic devices: *static balance*

Universal Healthcare Systems

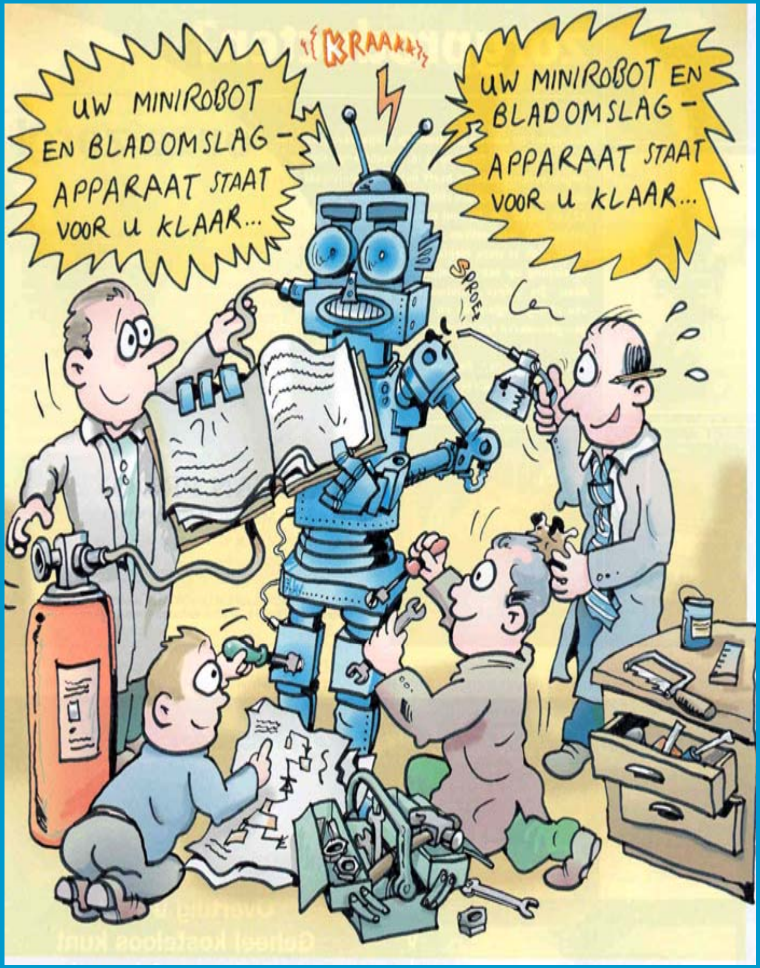
FOCAL

Use of hand function
No separate control

Design Criteria

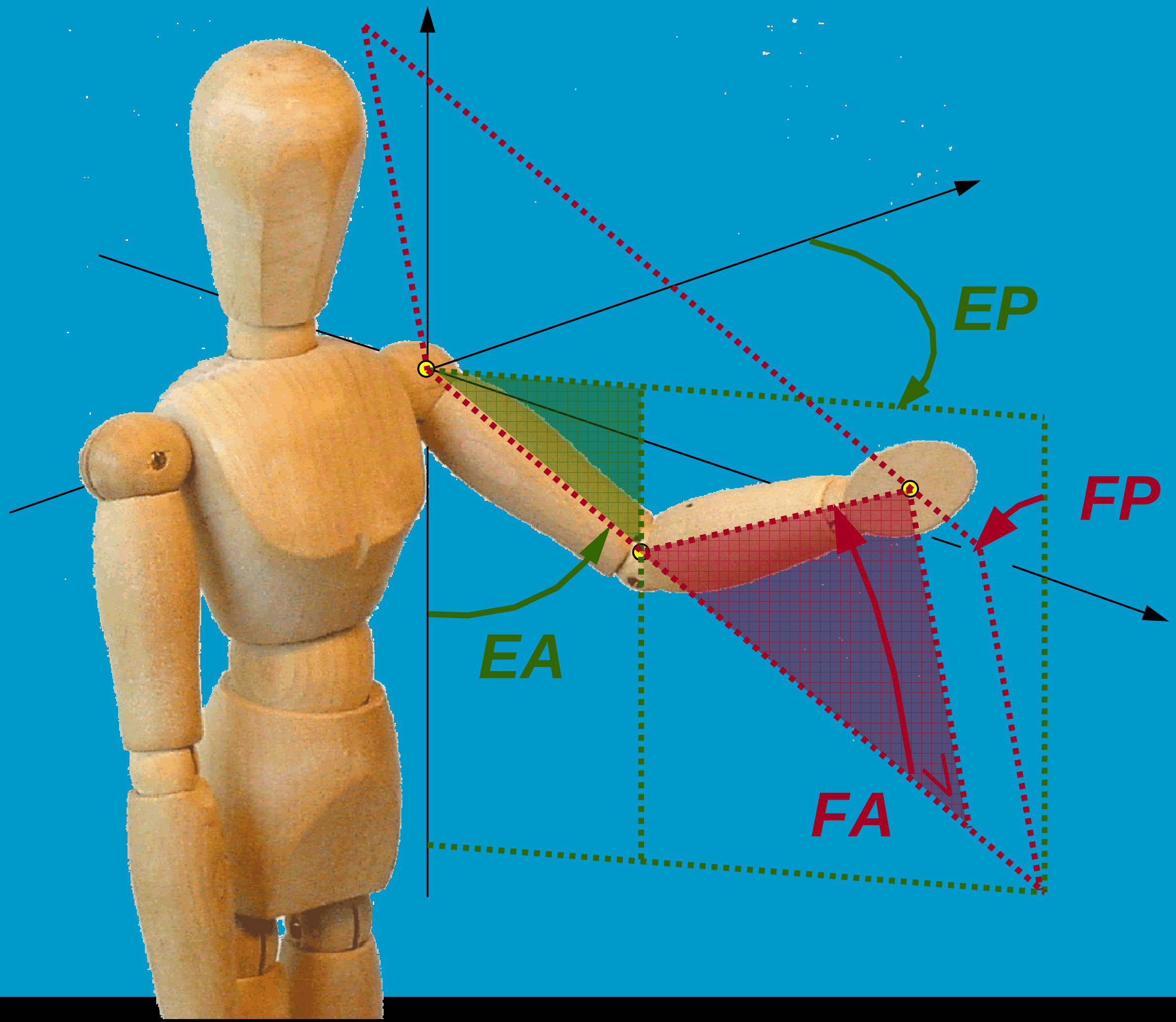
Based on home visits

- Independence
  - Personal Hygiene
  - Cooking, eating
  - Computer work
- Social activities
  - Have dinner
  - Shake hands
- Trunk balance
  - Arm rest essential
- Inconspicuous!



"Your page turner is ready..."

Clinically driven approach
Range of motion for desired activities



EP 0 .. 135 deg

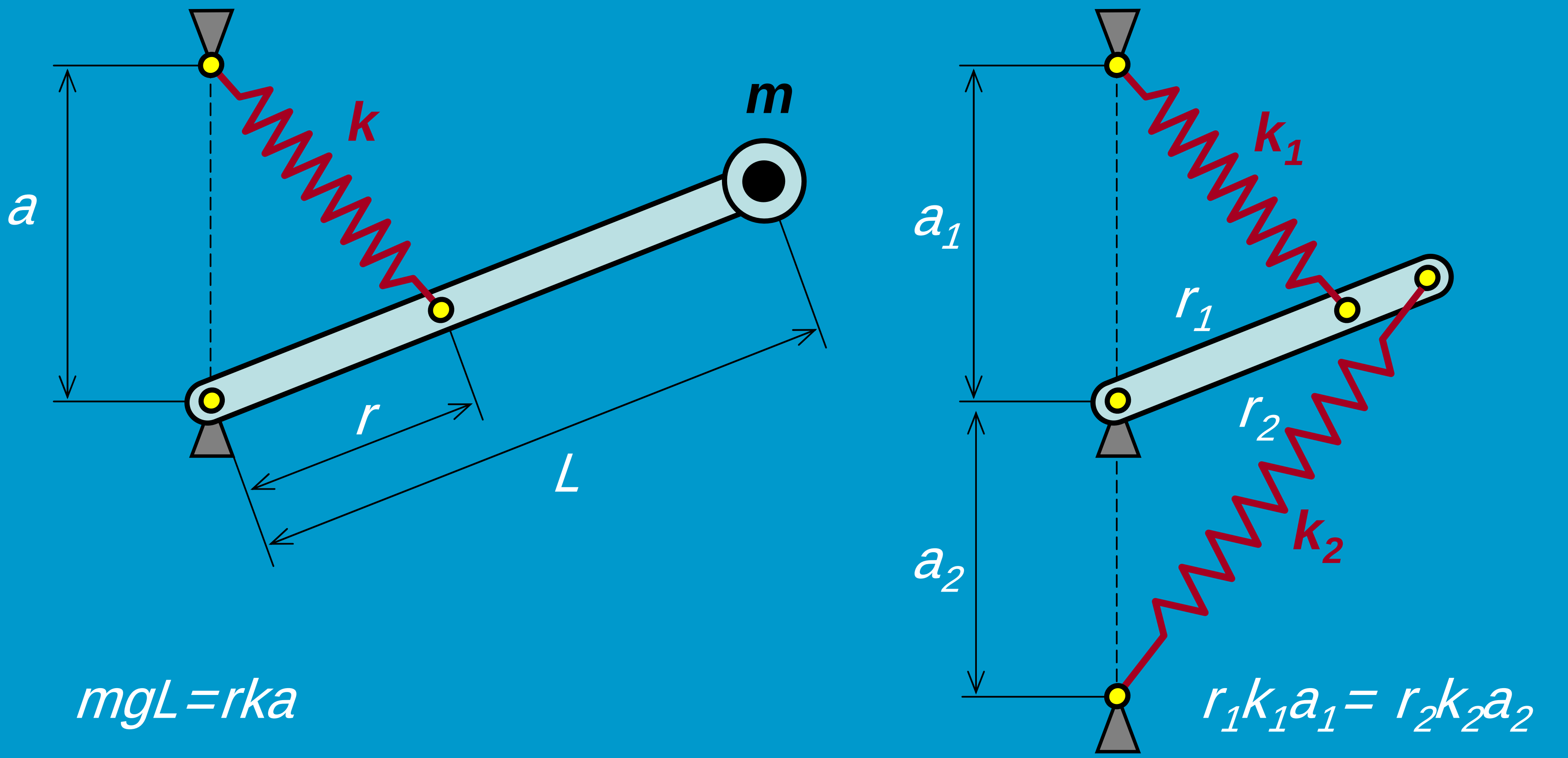
EA 0 .. 90 deg

FP 0 .. 90 deg

FA 0 .. 150 deg

EA and **FP** most important

Springs and masses



$mgL = rka$

$r_1 k_1 a_1 = r_2 k_2 a_2$

Conception framework

Parameter variation

Rotation

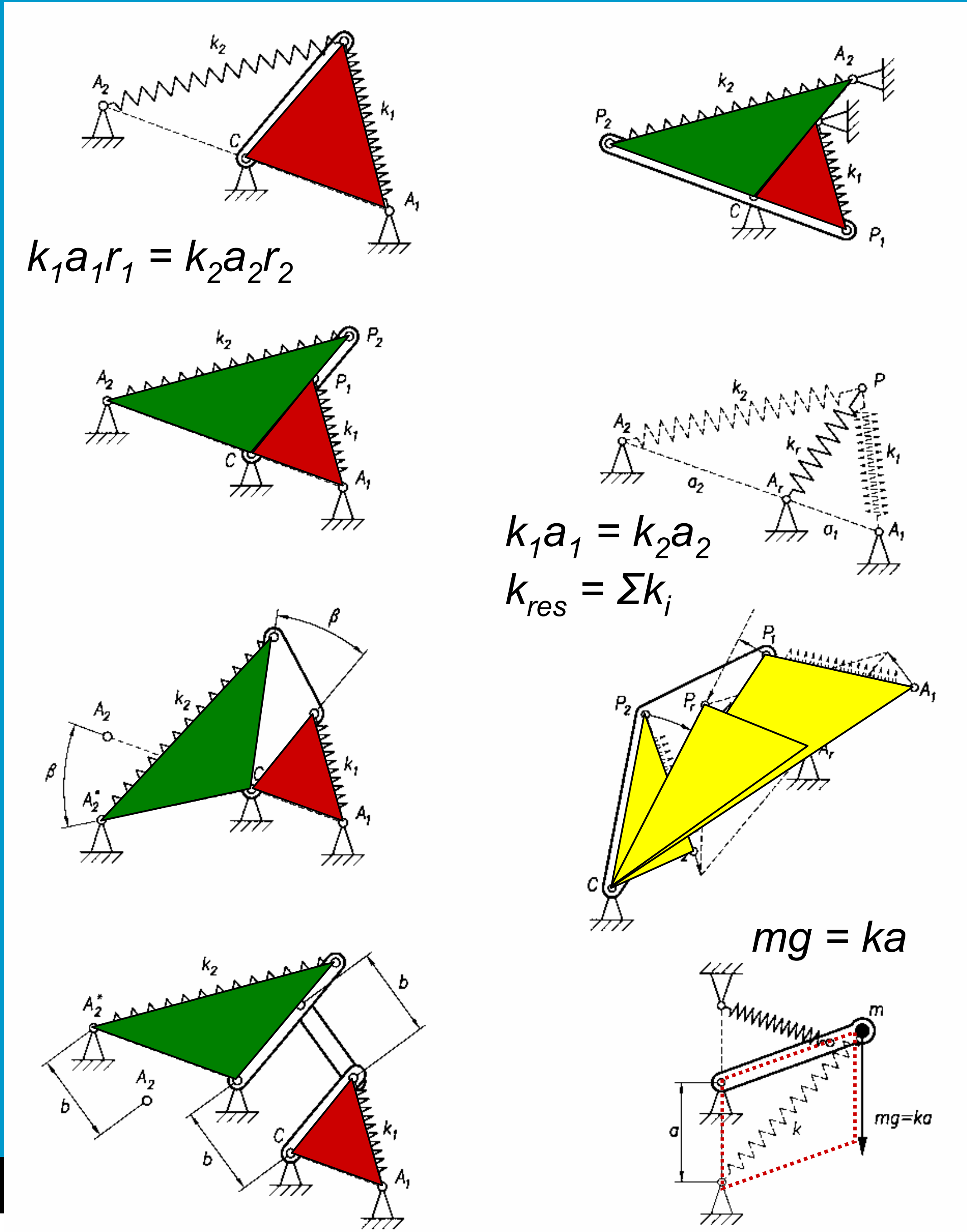
Shift

Kinematic inversion

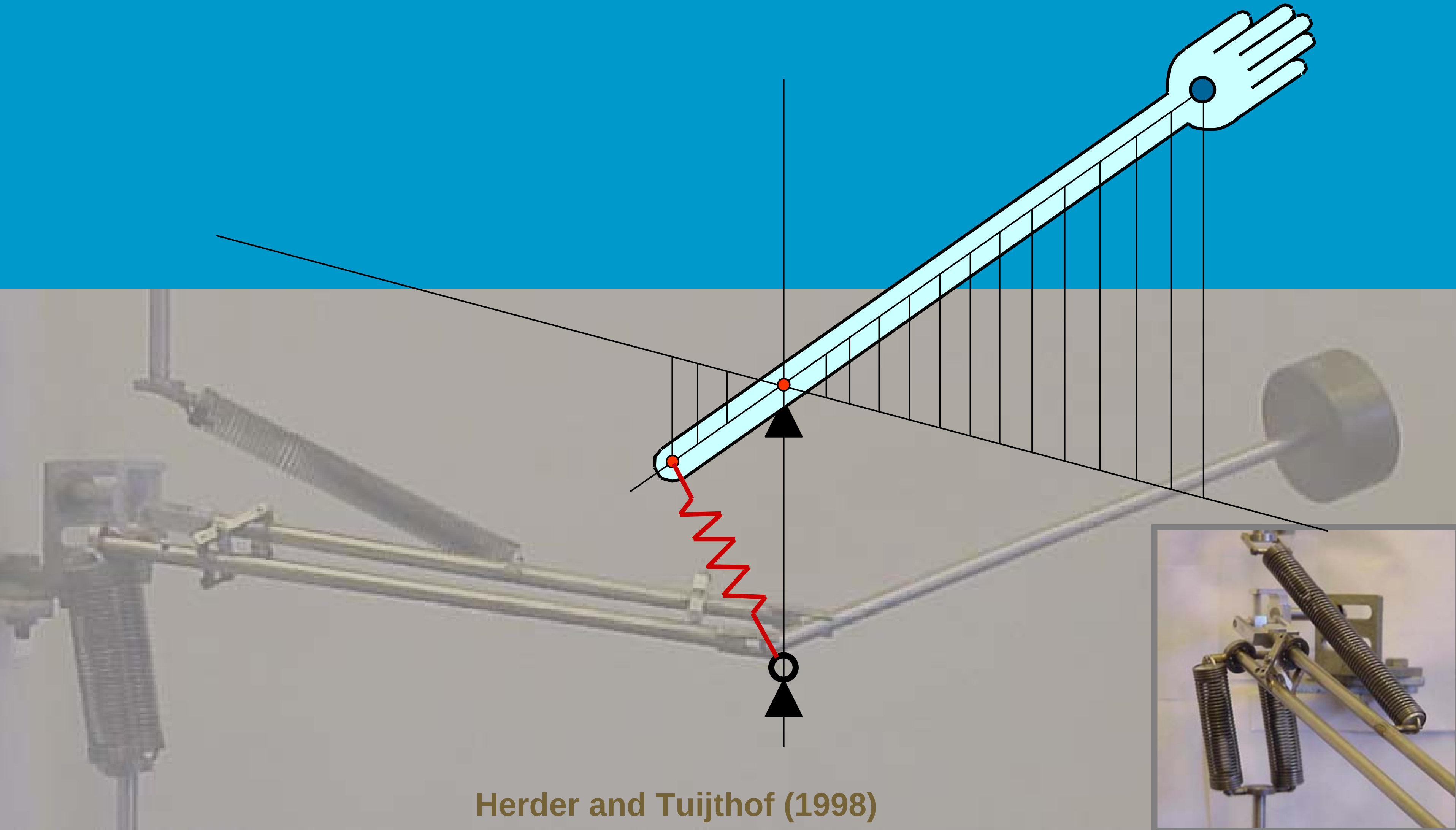
Resultant spring

Res. spring element

Similarity mass-spring

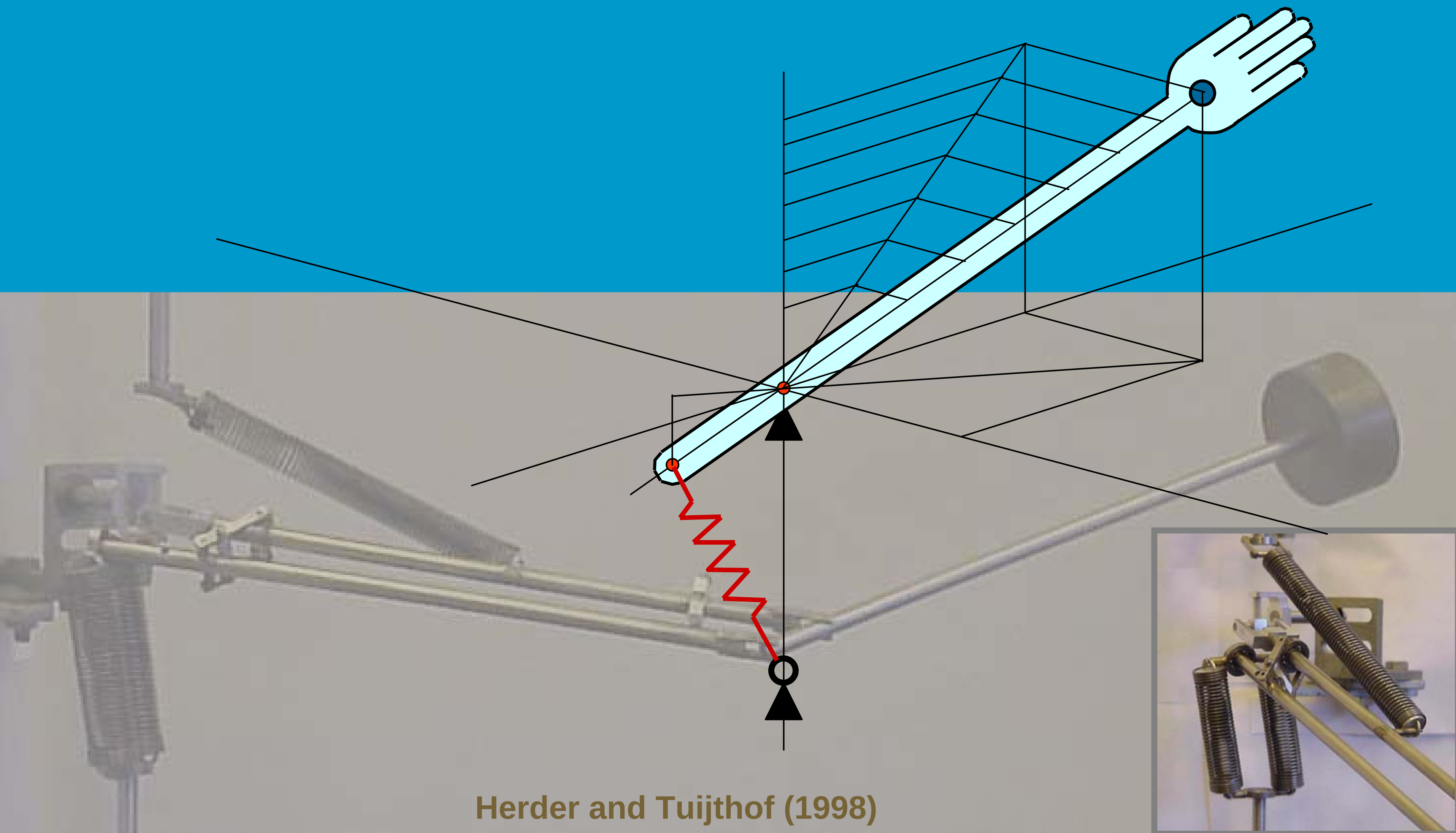


Anthropomobile balanced arm



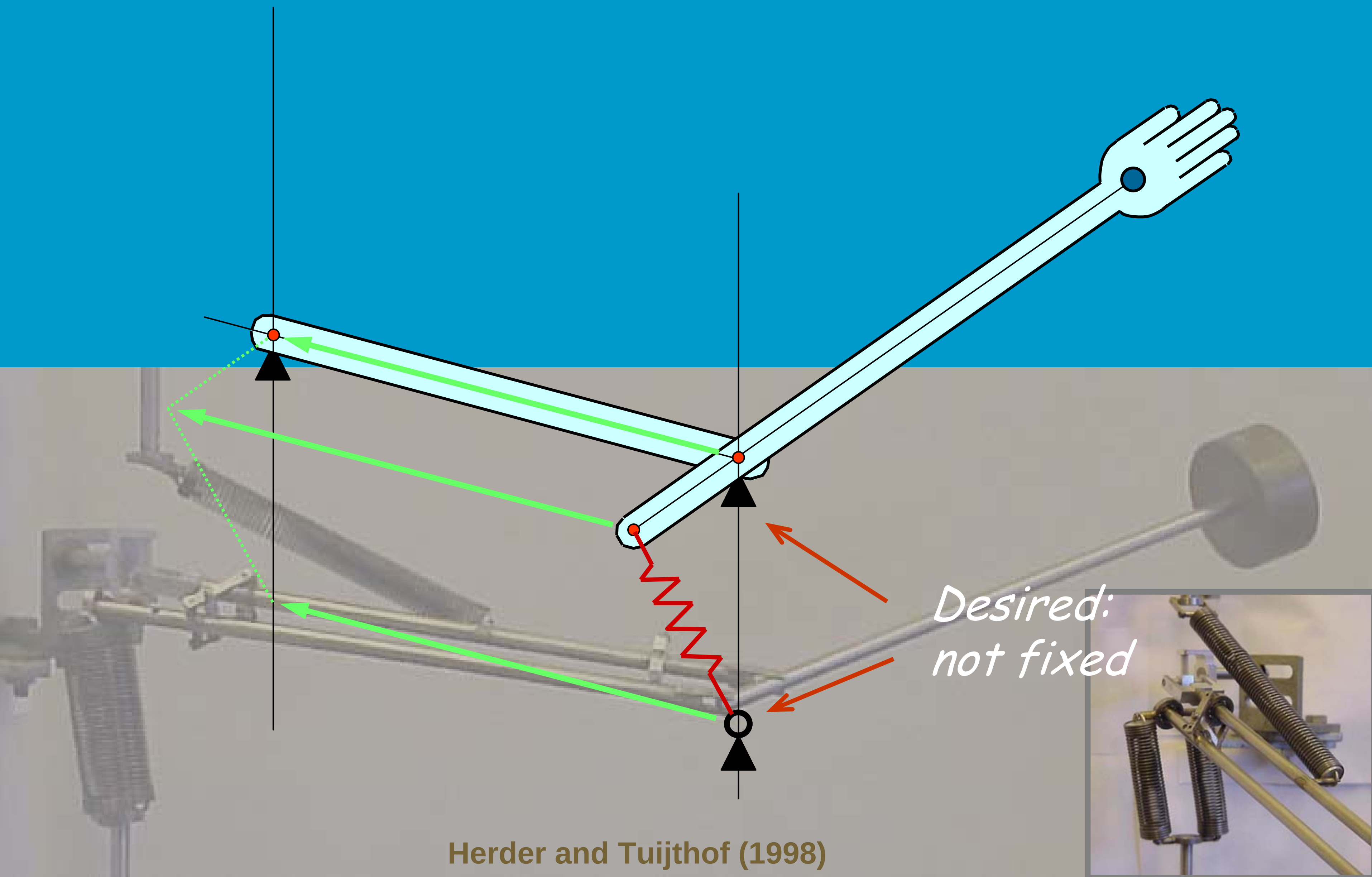
Herder and Tuijthof (1998)

Anthropomobile balanced arm



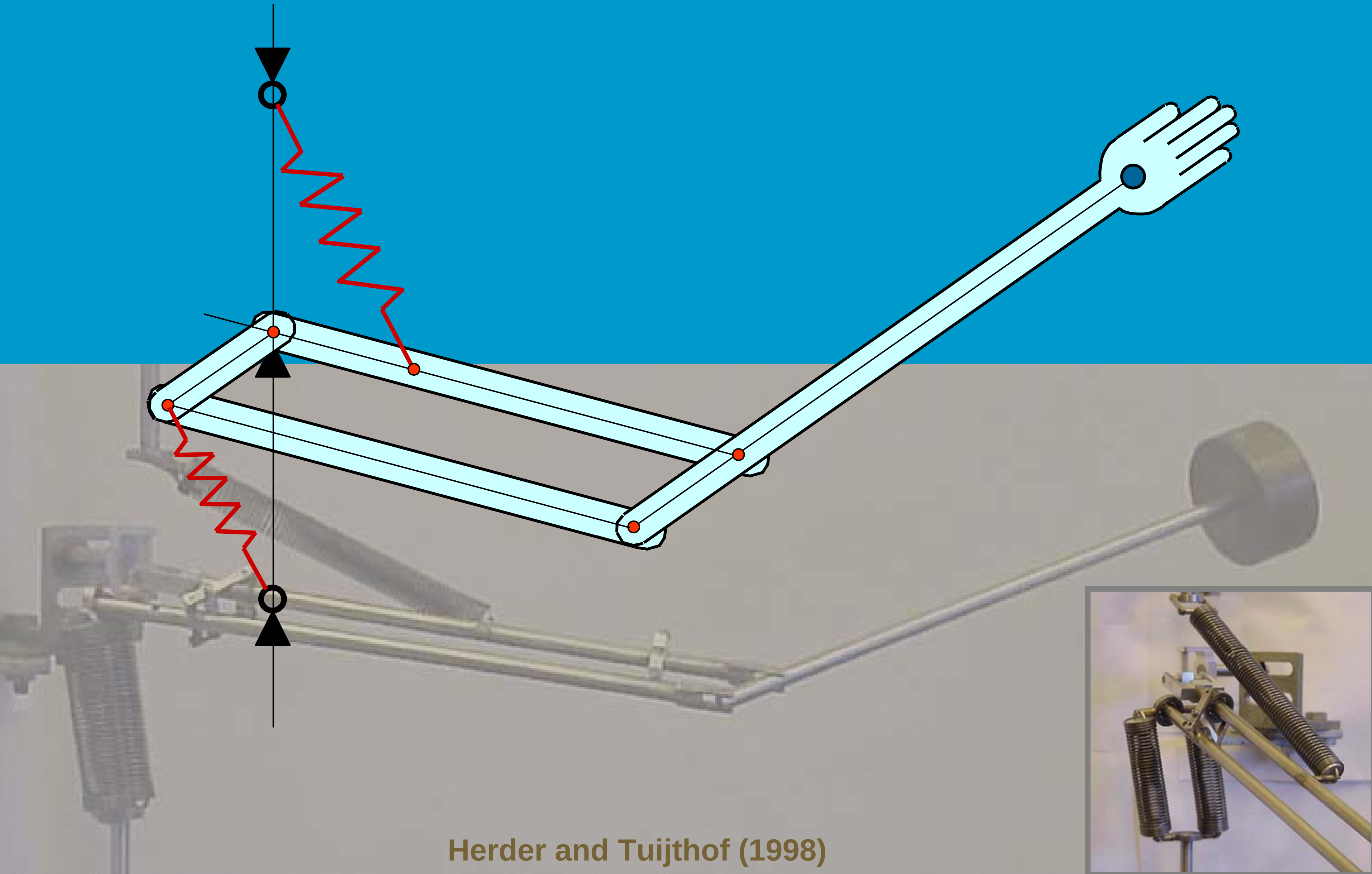
Herder and Tuijthof (1998)

Anthropomobile balanced arm



Herder and Tuijthof (1998)

Anthropomobile balanced arm



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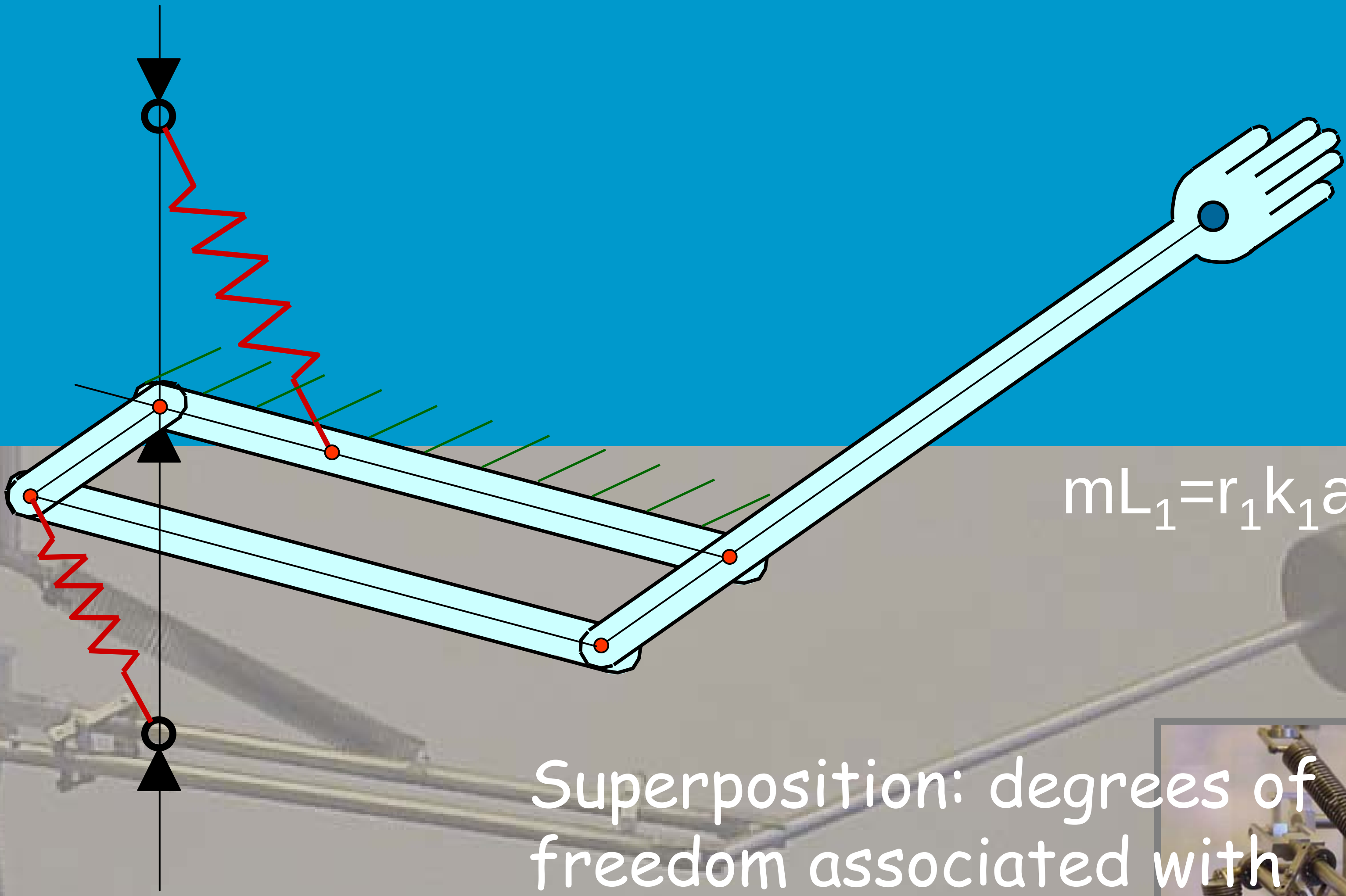
Anthropomobile balanced arm

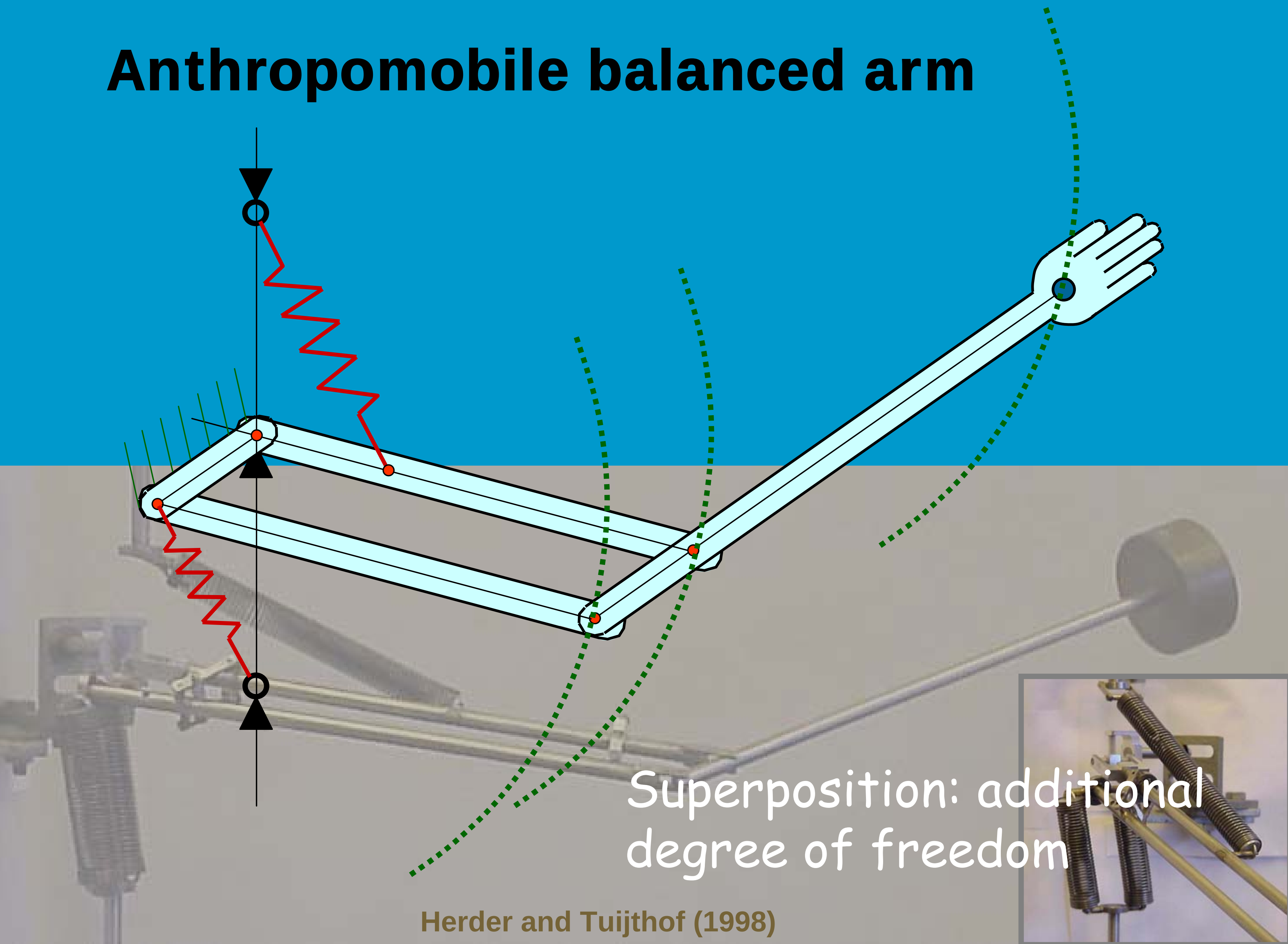


$mL_1 = r_1 k_1 a_1$

Superposition: degrees of freedom associated with lower spring are balanced

Herder and Tuijthof (1998)

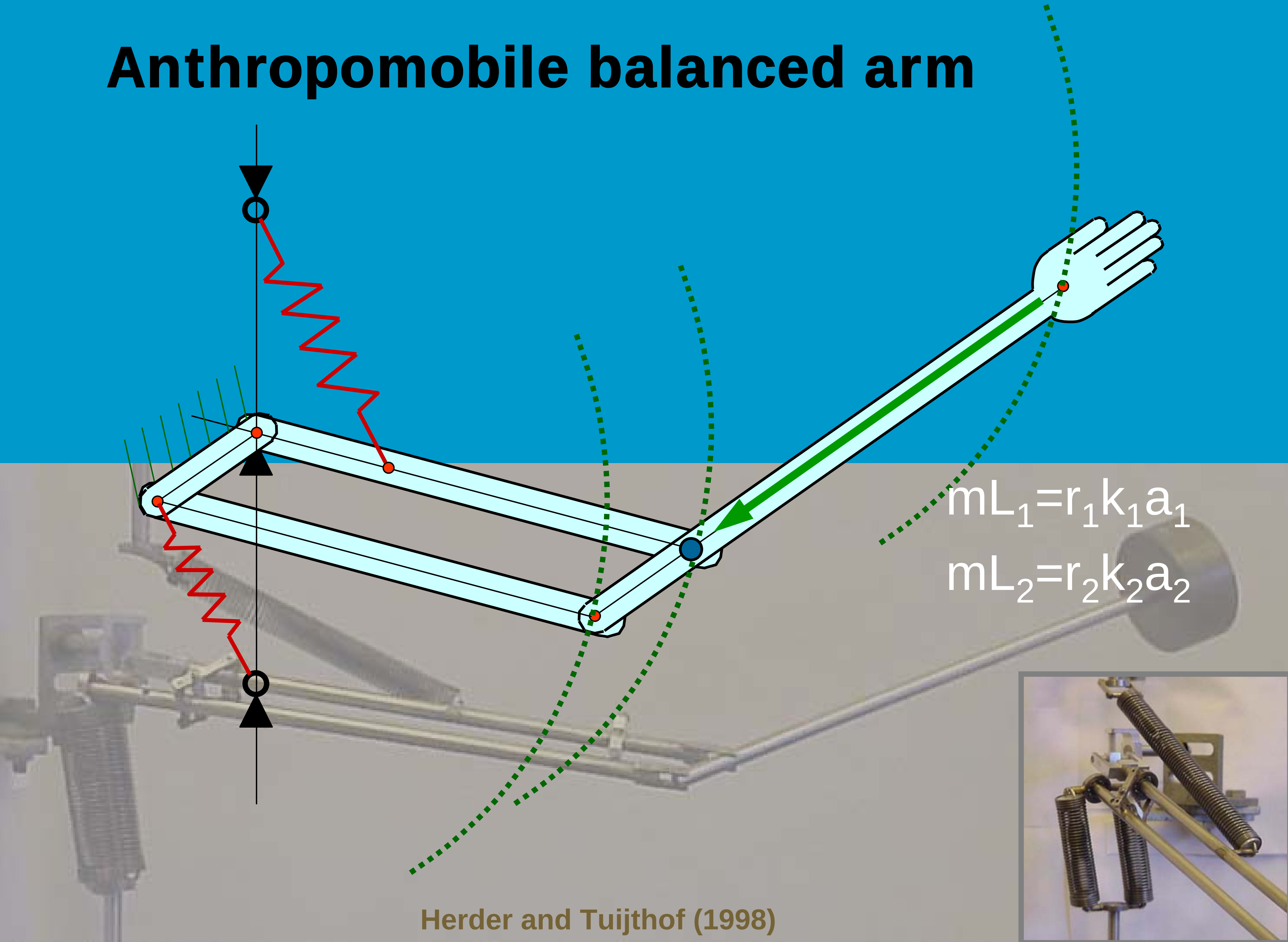
Anthropomobile balanced arm



Superposition: additional degree of freedom

Herder and Tuijthof (1998)

Anthropomobile balanced arm

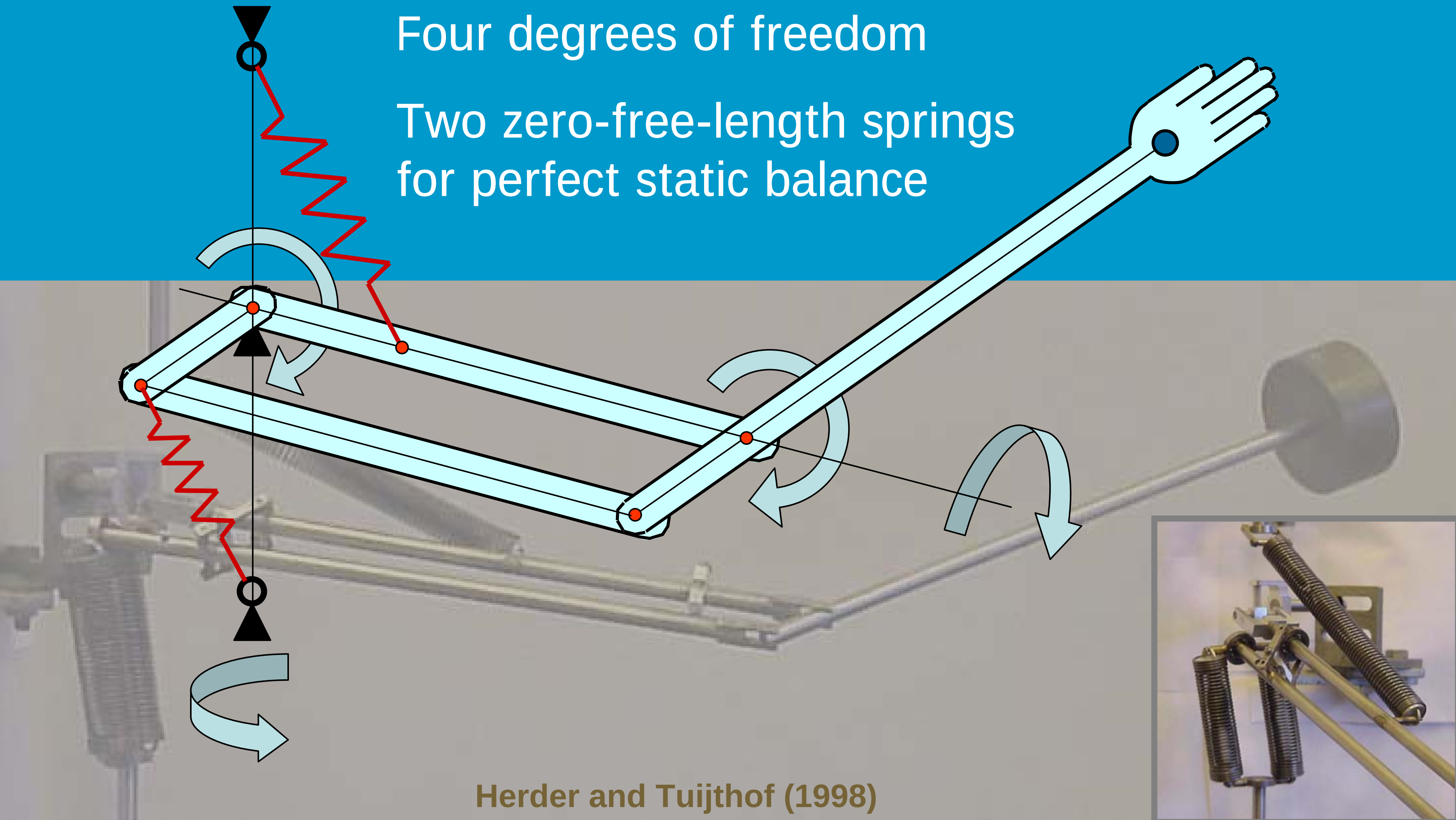


Herder and Tuijthof (1998)

Anthropomobile balanced arm

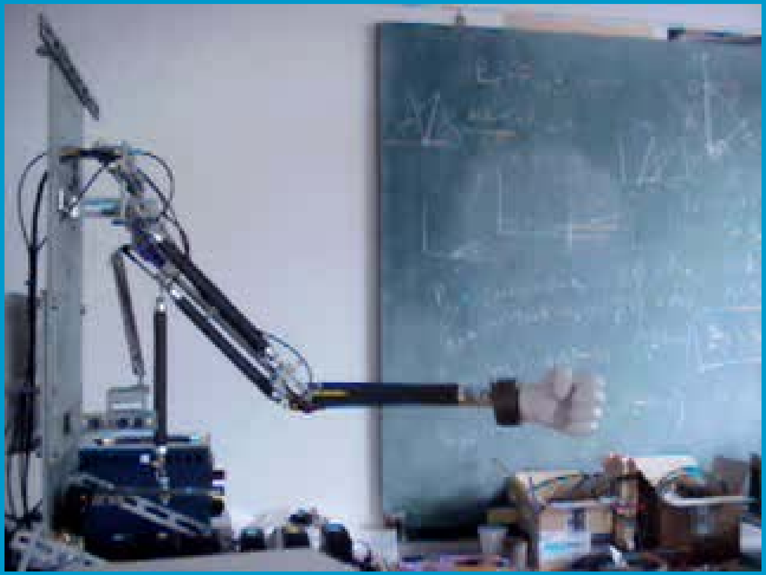
Four degrees of freedom

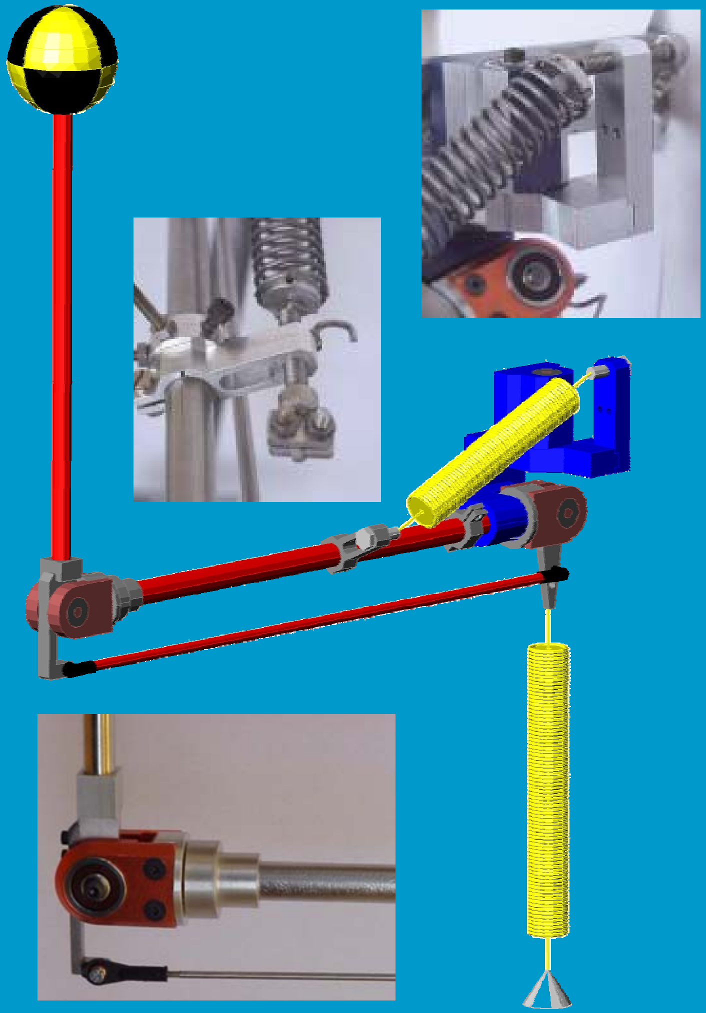
Two zero-free-length springs
for perfect static balance



Herder and Tuijthof (1998)

Anthropomobile balanced arm





Variable stiffness control

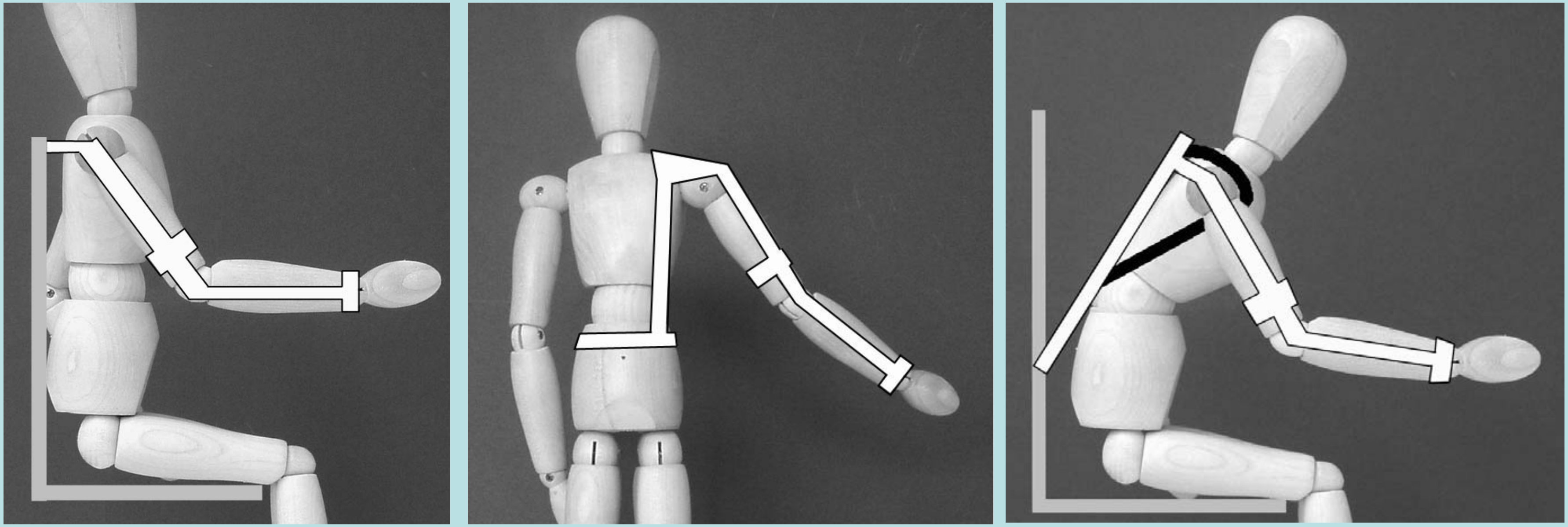
McKibben actuators

Statically balanced

Inherently safe

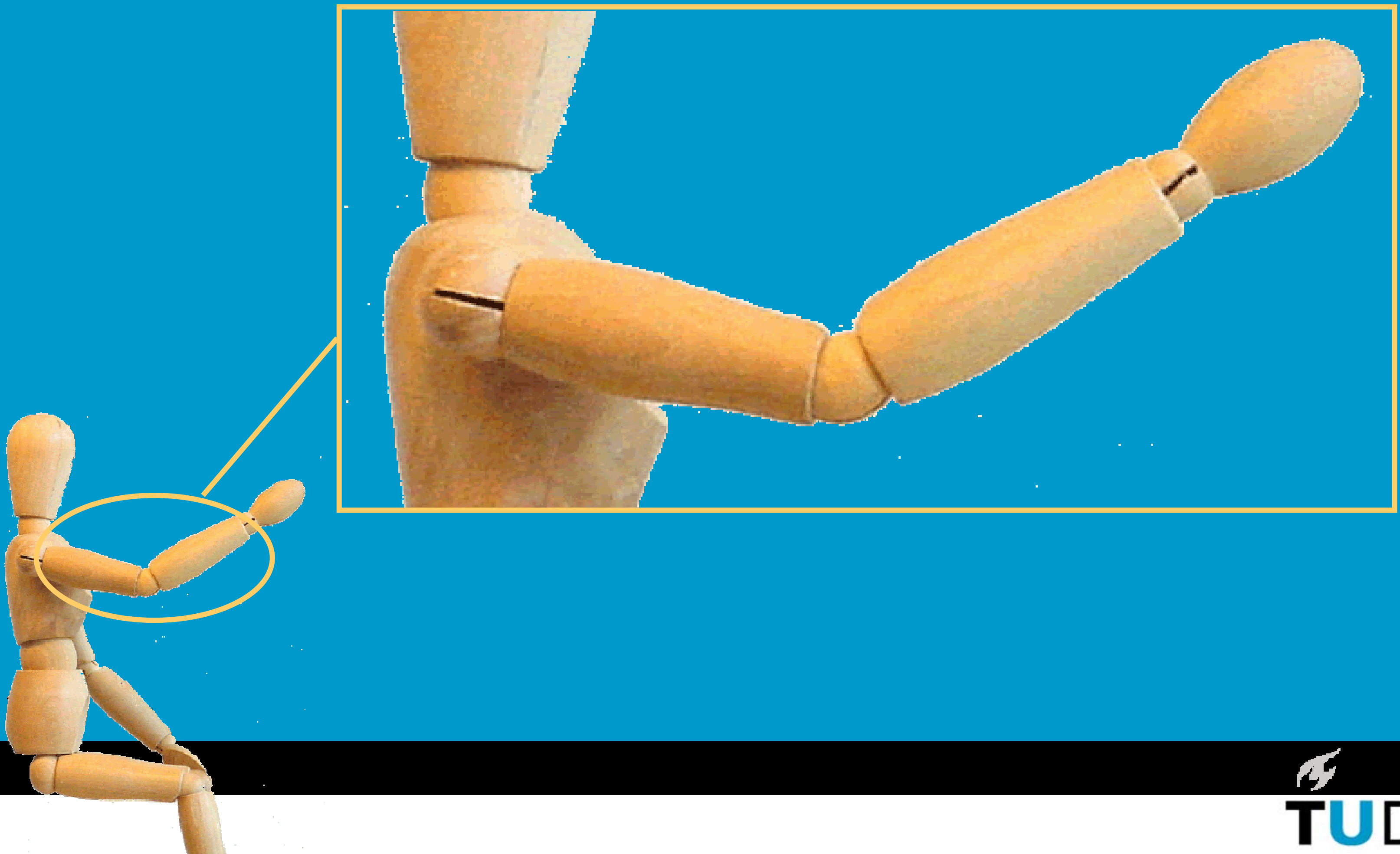
Conceptual design

Mechanism alongside the user's arm

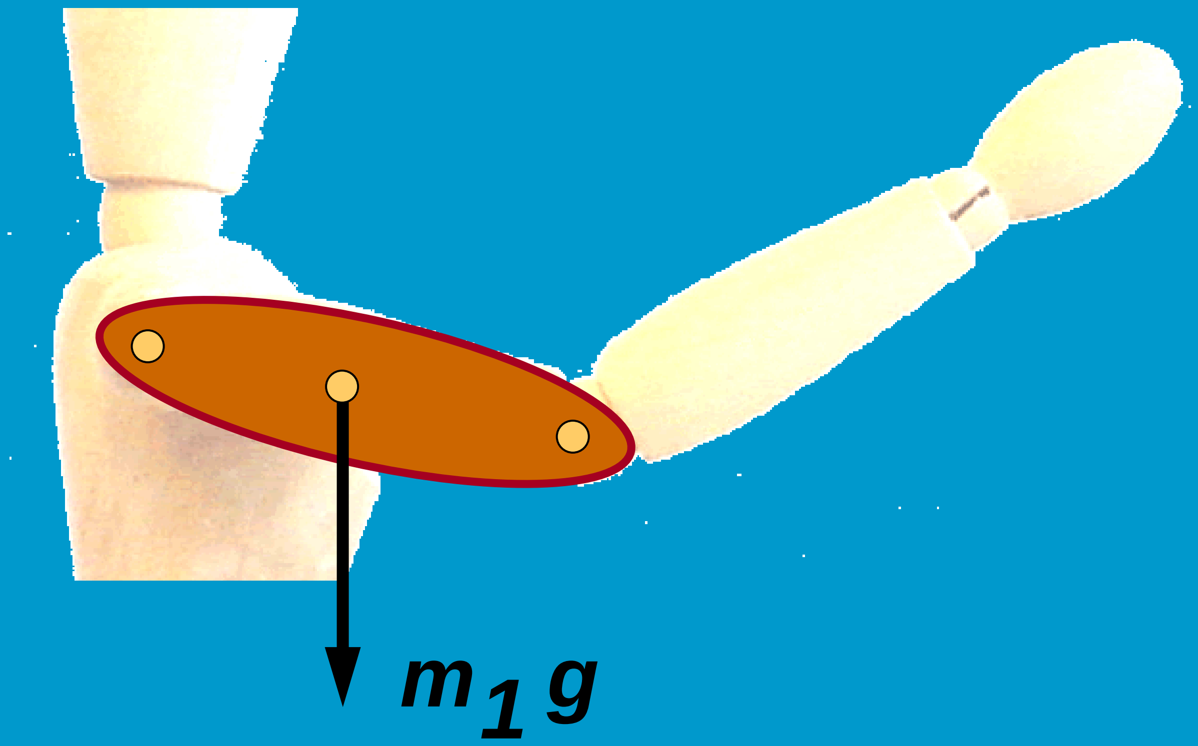


Attached to wheelchair	Attached to the user's trunk	Hybrid form with additional segment
Insufficient mobility	**Respitatory hamper**	**Excessive complexity**

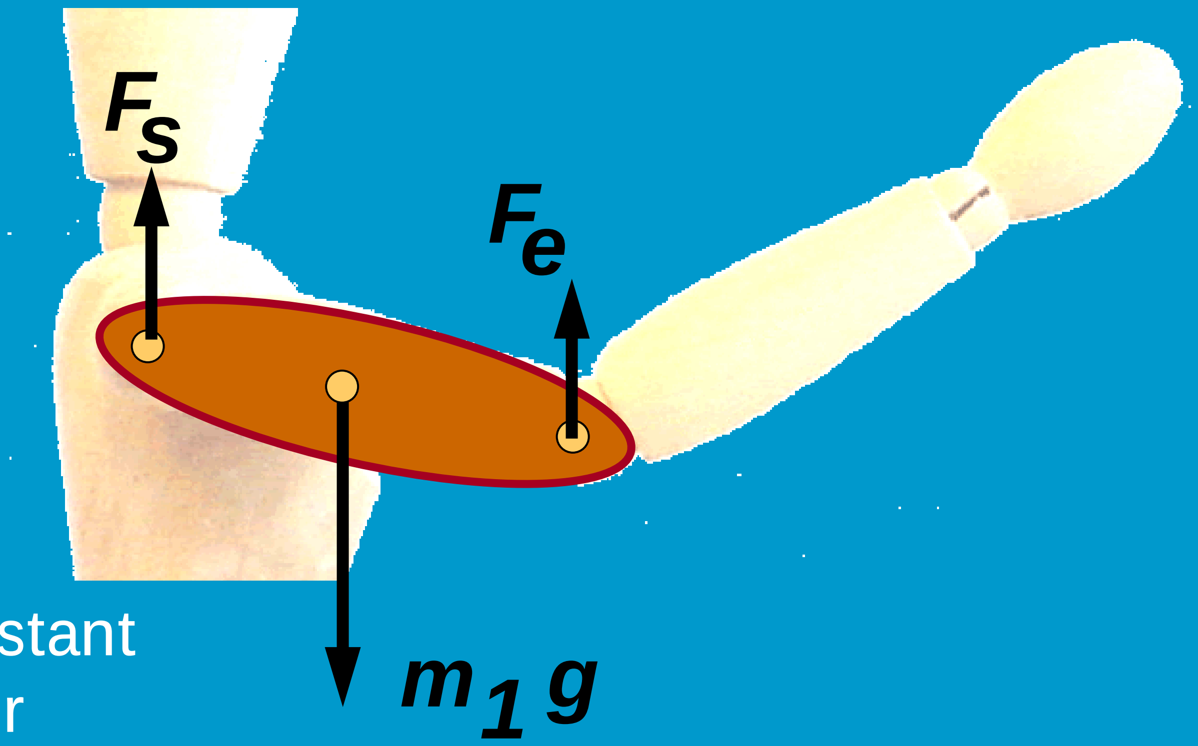
Conceptual design
Force analysis revisited



Conceptual design
Force analysis revisited

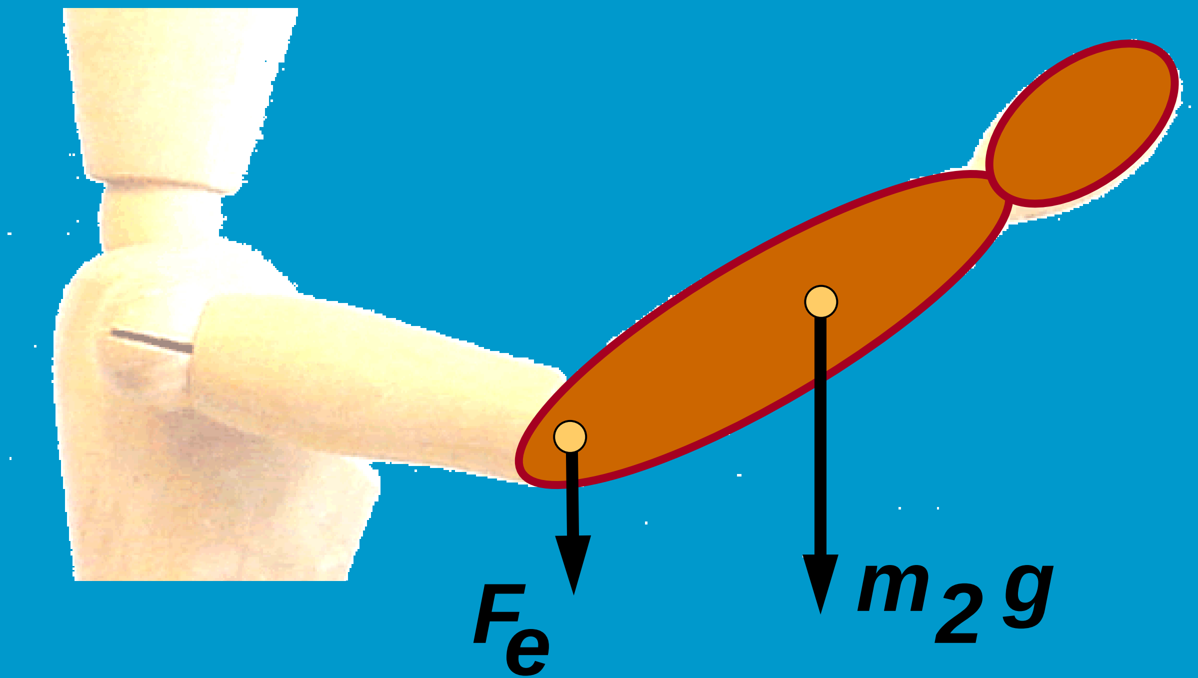


Conceptual design
Force analysis revisited



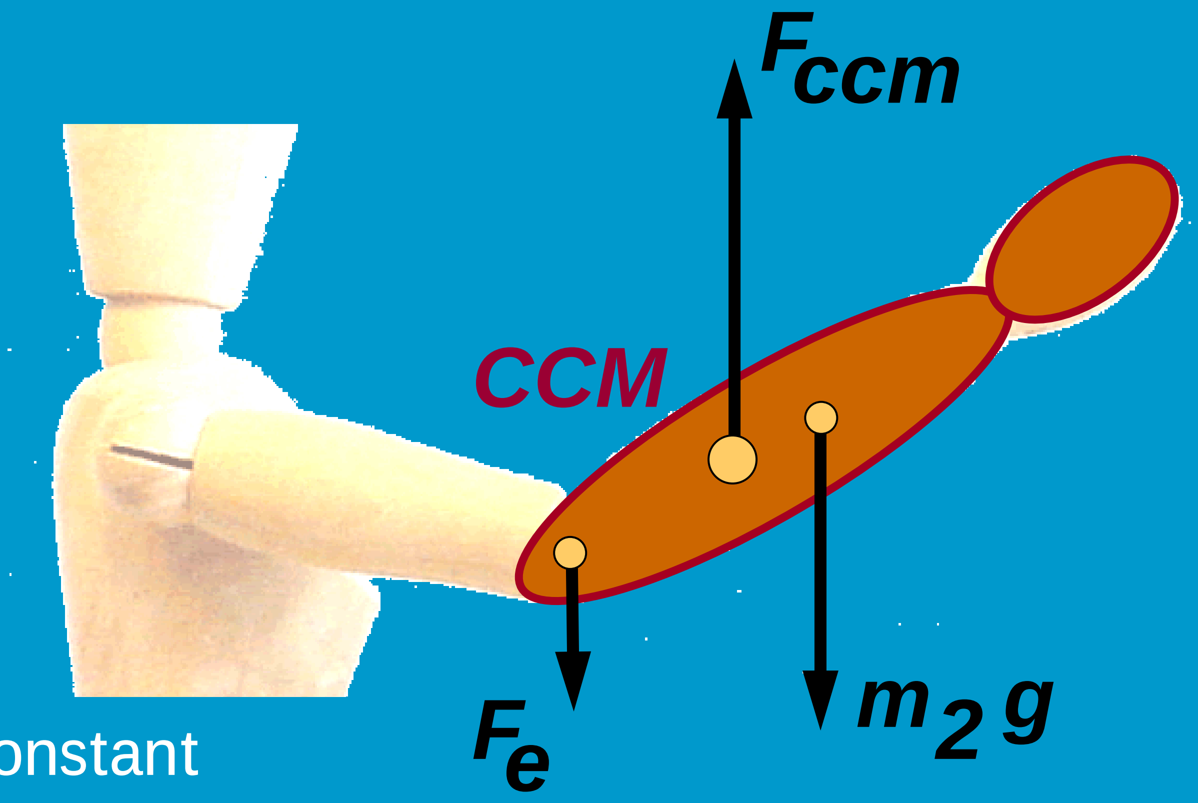
F_e and F_s constant
F_s by shoulder

Conceptual design
Force analysis revisited



Conceptual design

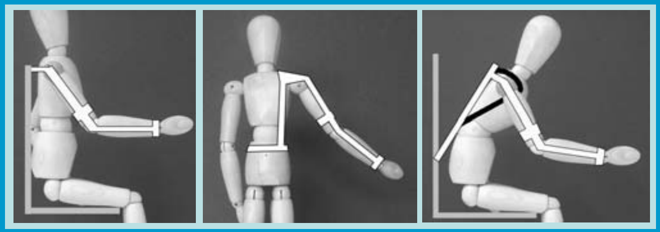
Force analysis revisited

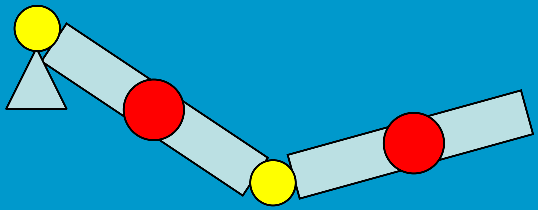


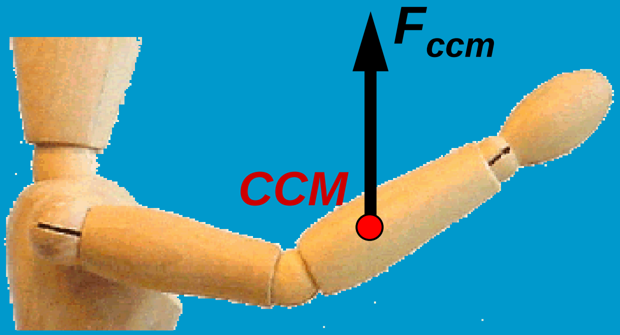
F_e and m_2g constant

F_{ccm} for complete arm

Biomechanics
Change of Design Paradigm







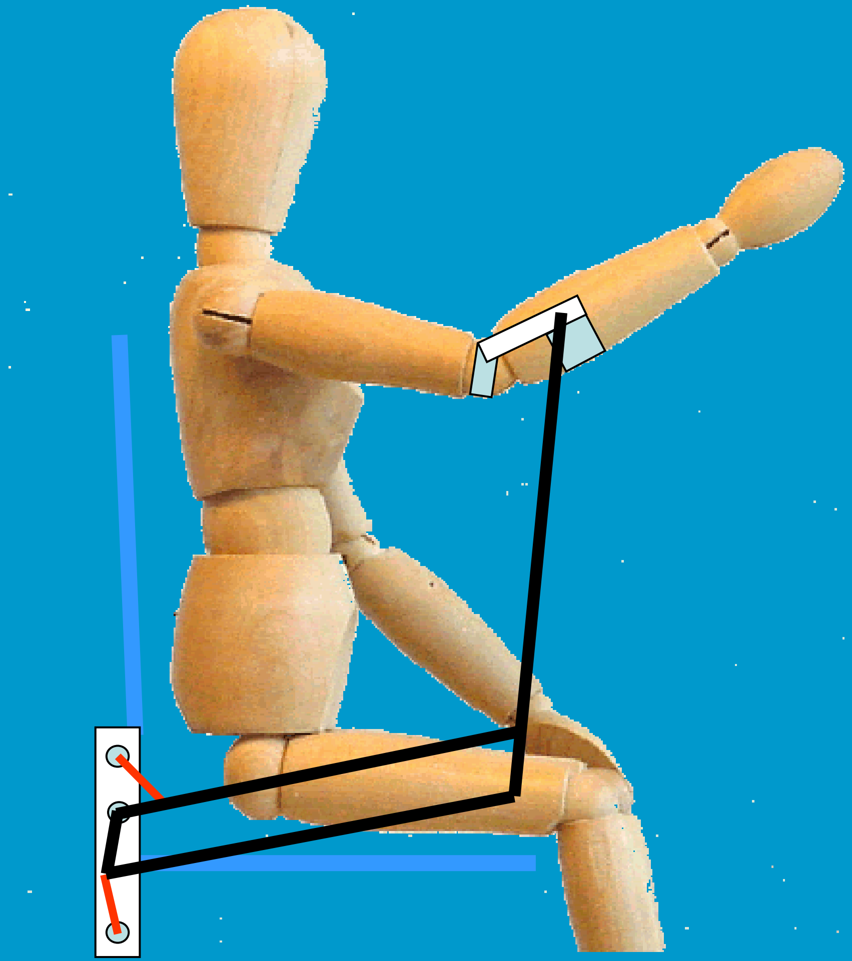
Balancing 2-link 4DoF arm

Balancing a point mass!

TUDelft

Conceptual design

Based on CCM principle

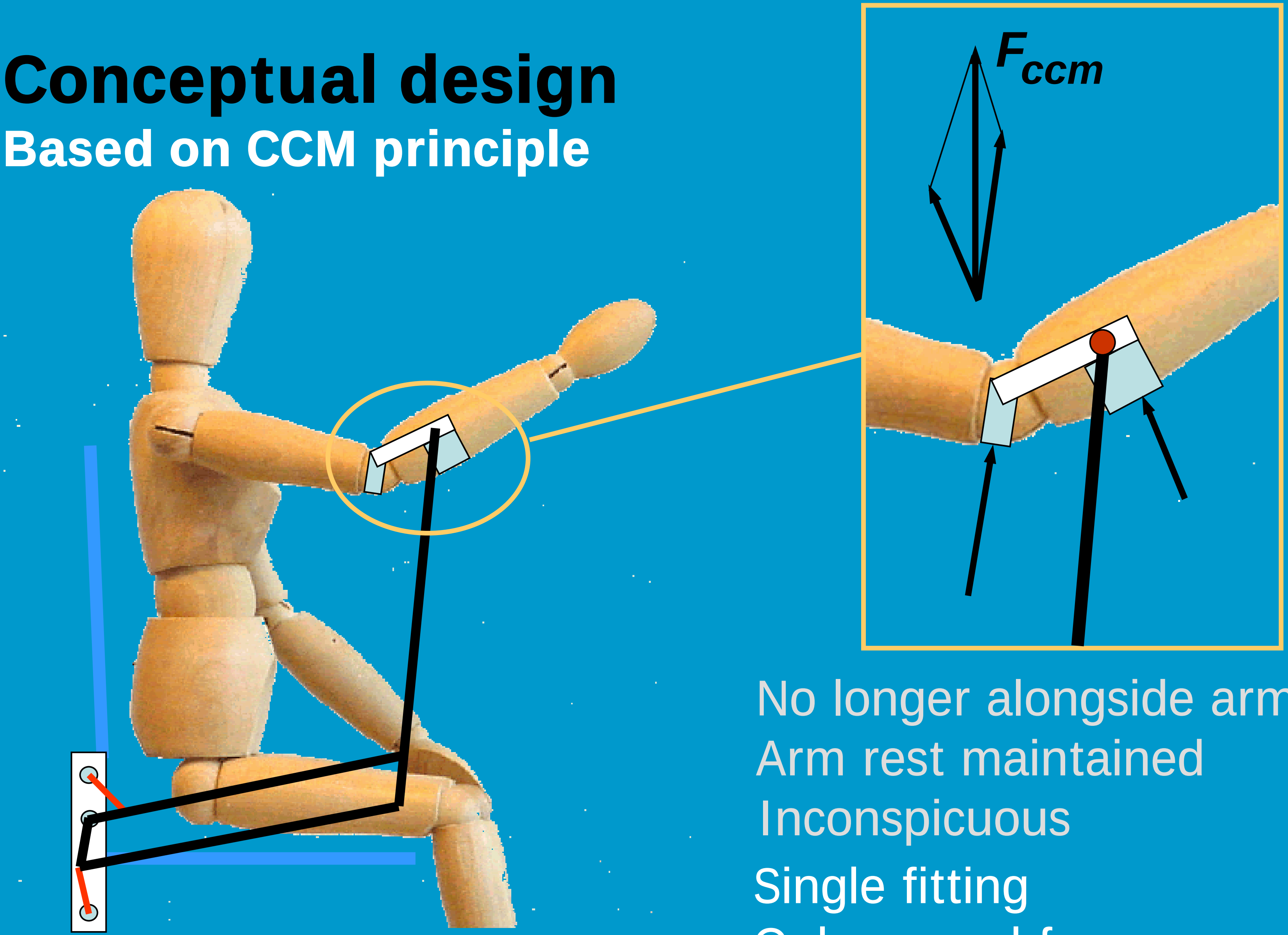


Anglepoise Desk Lamp (Carwardine, 1934)

No longer alongside arm
Arm rest maintained
Inconspicuous

Conceptual design

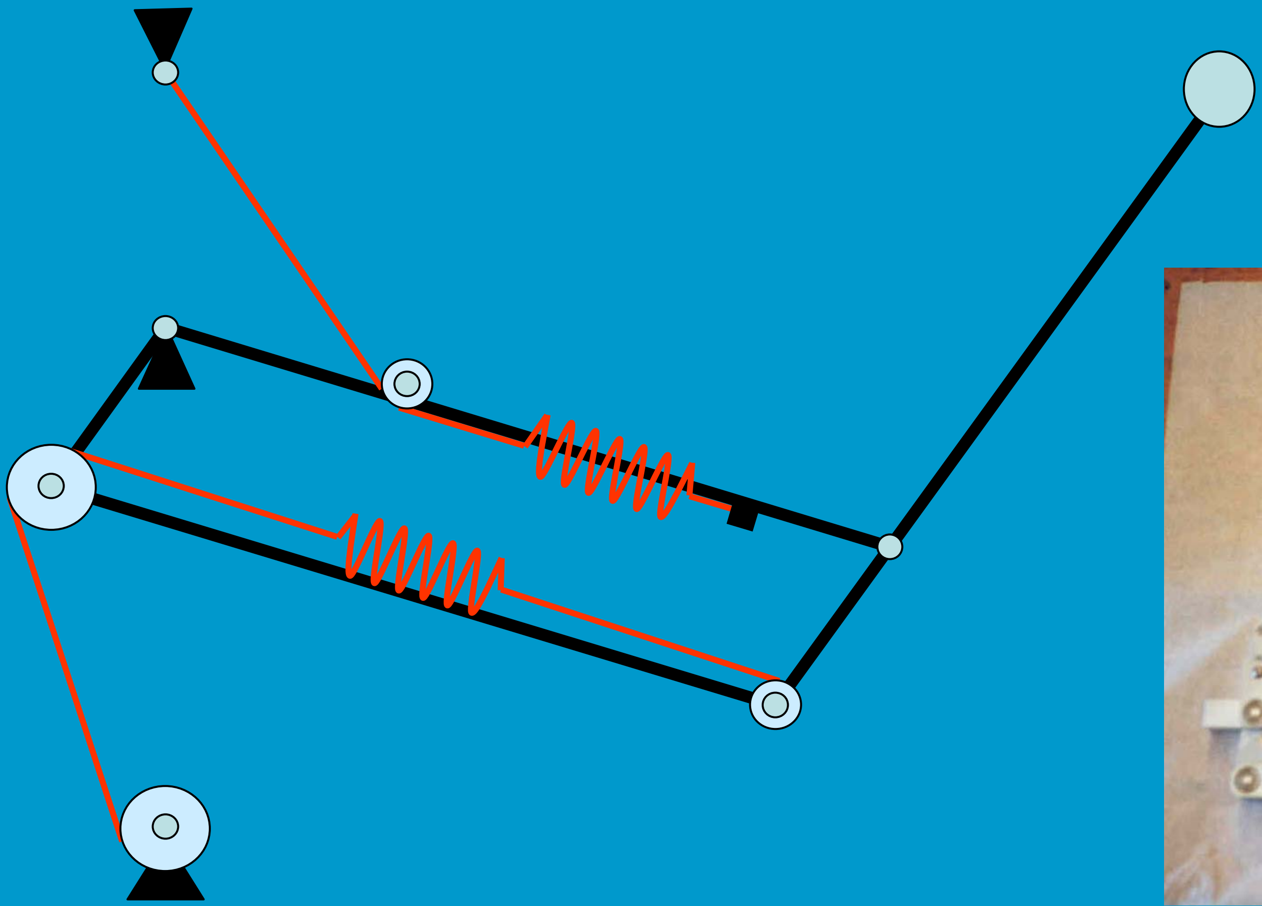
Based on CCM principle



No longer alongside arm
Arm rest maintained
Inconspicuous
Single fitting
Only normal forces

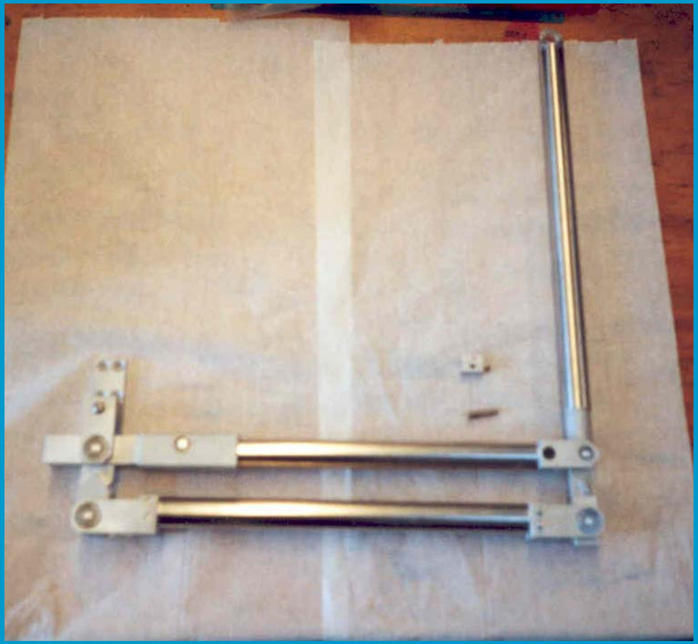
Conceptual design

Working principle

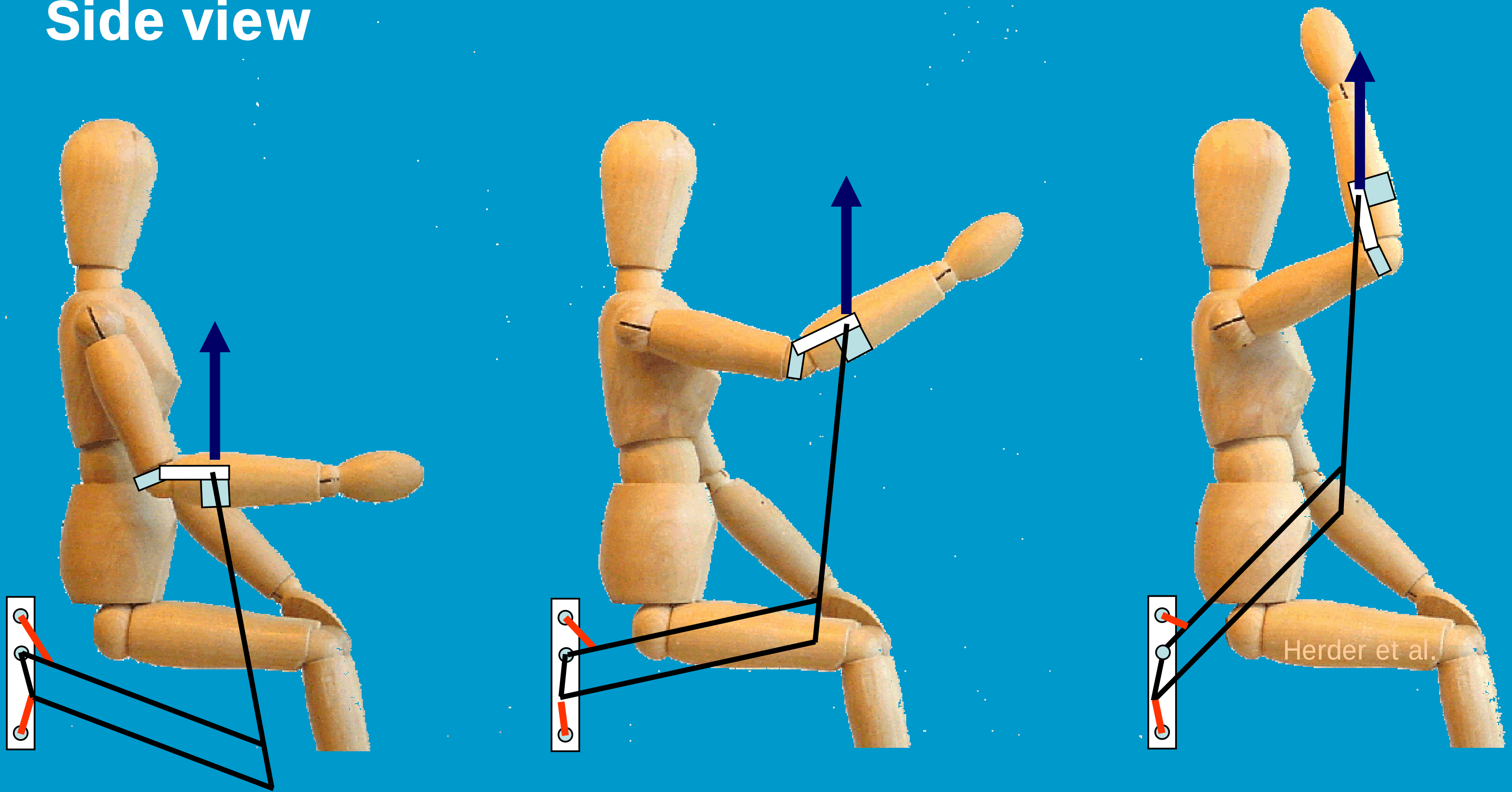


$$mL_1 = r_1 k_1 a_1$$

$$mL_2 = r_2 k_2 a_2$$



Conceptual design
Side view



Anti-gravity system rather than pick-and-place robot

ARMON (Mark I)

Preliminary clinical testing

Herder, Tomazio, Cardoso, Gil and Koopman, 2002

Patent pending

TUDelft

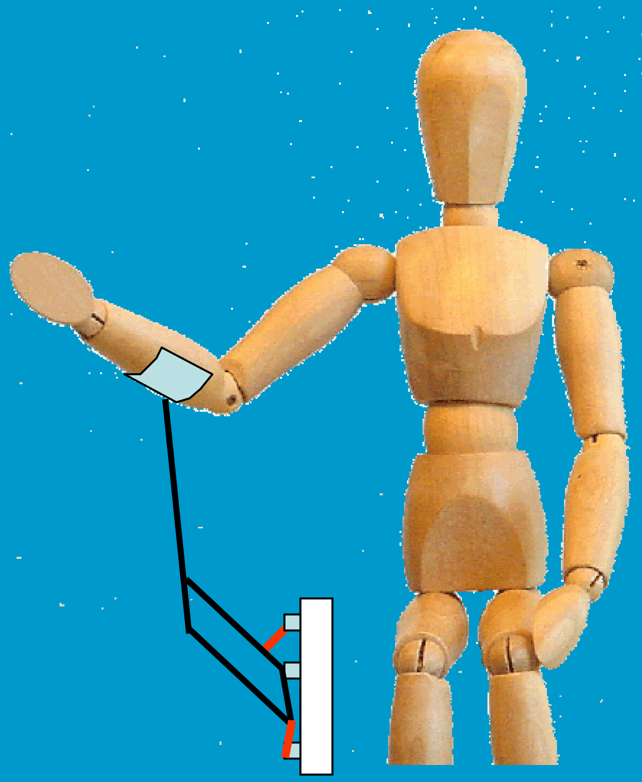
ARMON (Mark I)

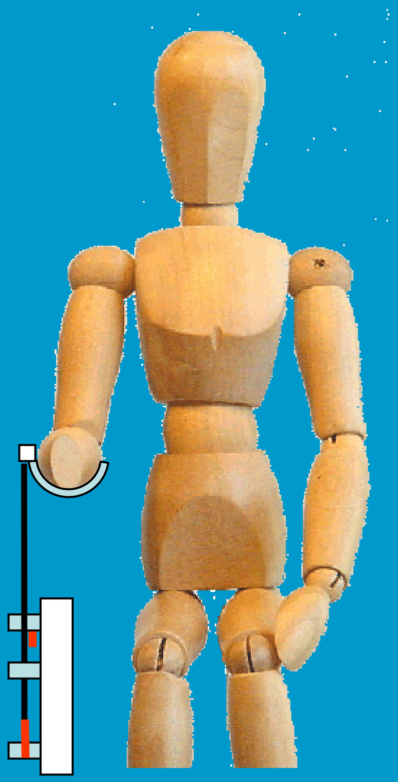
Patient performing important ADL with device

Sergio Tomazio and Luis Cardoso recieving the Premio Engenheiro Jaime Philipe award

Patent pending

Conceptual design
Frontal view





Preliminary clinical testing
Moving arm sideways

Herder, Tomazio, Cardoso, Gil and Koopman, 2002

Preliminary clinical testing
Moving arm sideways

Herder, Tomazio, Cardoso, Gil and Koopman, 2002

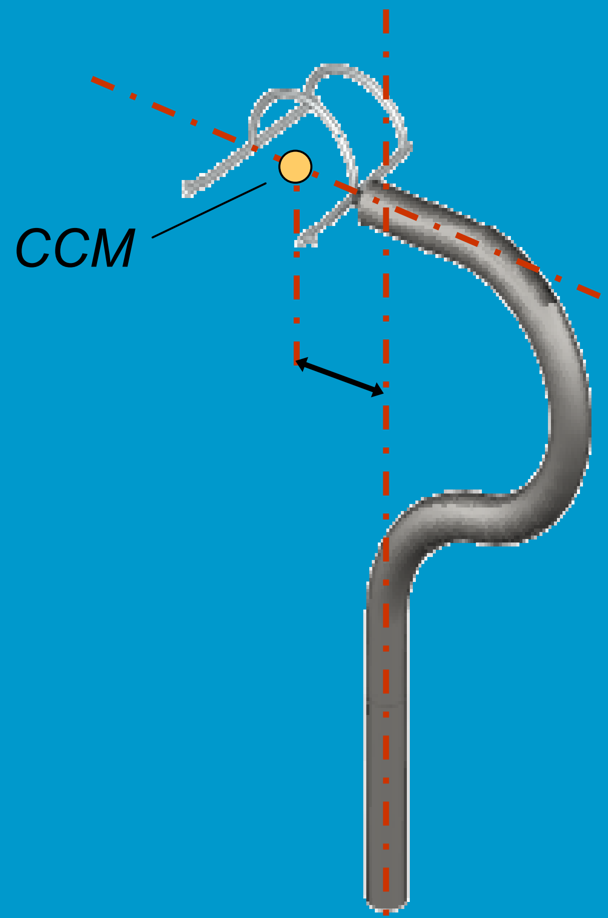
Preliminary clinical testing

Interference with fixed arm rest!

Herder, Tomazio, Cardoso, Gil and Koopman, 2002

Preliminary clinical testing

Fitting unbalance!



Herder, Tomazio, Cardoso, Gil and Koopman, 2002

Preliminary clinical testing

When very weak: friction!

Herder, Tomazio, Cardoso, Gil and Koopman, 2002

TU Delft

Conclusion Arm Support

Achievements:

- CCM principle works well
- Aesthetics and control highly appreciated

Problems to be solved:

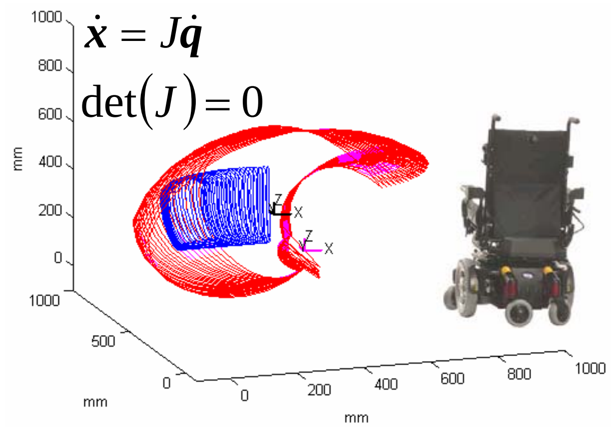
- Interference with fixed arm rest
- Fitting unbalance
- Friction

ARMON (Mark II)

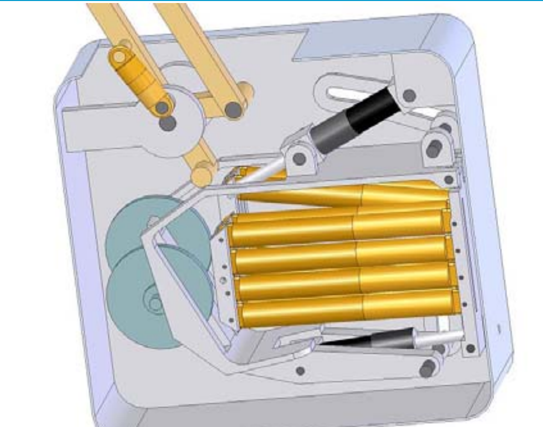
Team: 2 ME and 2 IDE students

Tonko Antonides (IDE)

Sabine Gal (IDE)



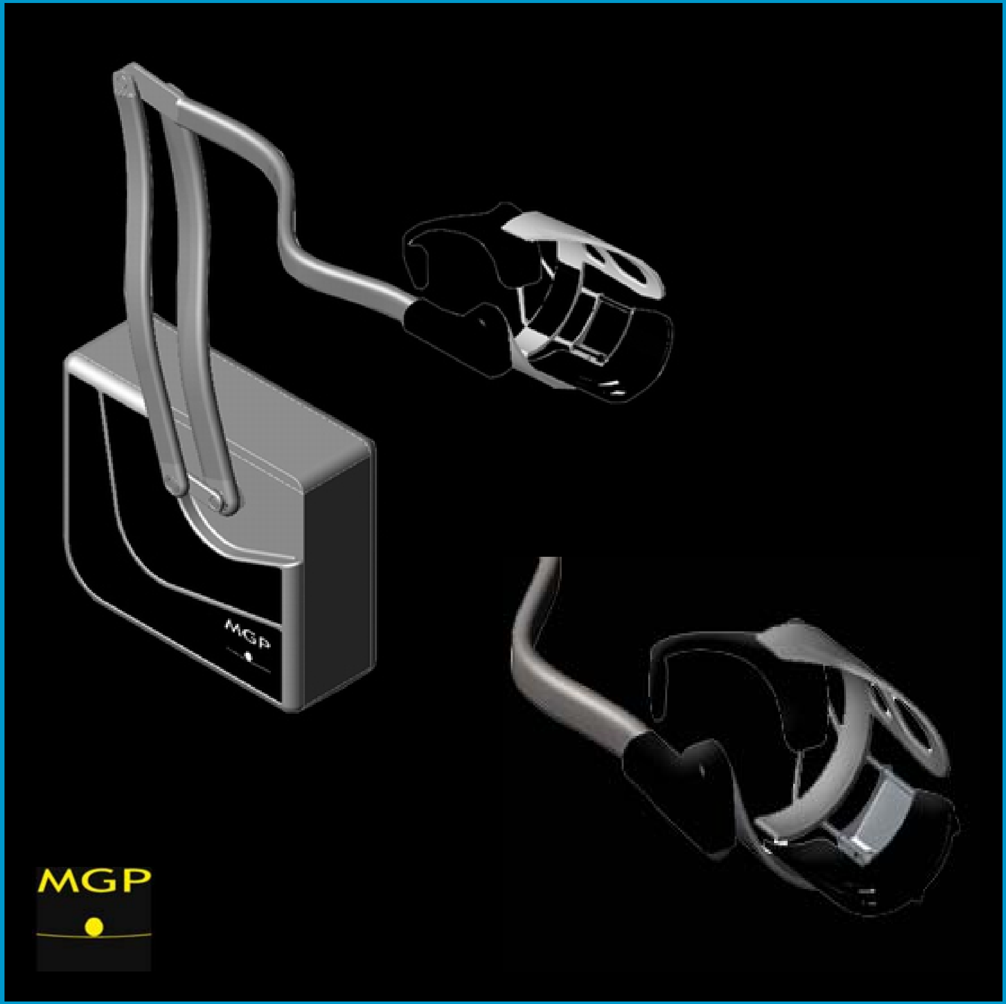
Wendy van Stralen (ME)



Pieter Lucieer (ME)

ARMON (Mark II)

Complete device and close up of fitting



Herder, Stralen, Lucieer, Gal and Antonides, 2004

Patent pending

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ARMON (Mark II)

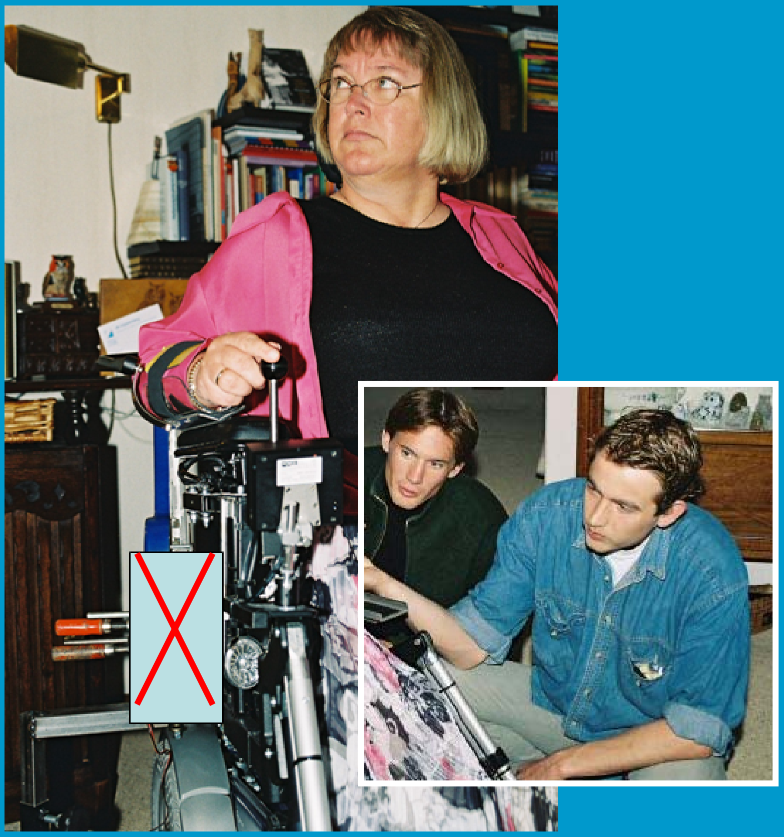
Patients with the device

Herder, Stralen, Lucieer, Gal and Antonides, 2004

Patent pending

TUDelft

ARMON (Mark III)
Testing of pre-production prototype



Niels Vrijlandt and Tonko Antonides at work

Patent pending

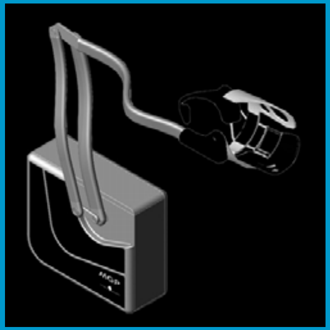
ARMON (Mark III)
First commercial product

Herder, Vrijlandt, Antonides, Cloosterman, 2005

Patent pending

www.microgravityproducts.com

Development of ARMON



- Mark I:
  - Proof of novel CCM balancing principle
  - Single fitting and aesthetics highly appreciated
- Mark II:
  - Improved range of motion, no interference
  - Actively adjustable gravity balancing
  - Improved appearance and fitting design
- Mark III:
  - Further improved balancing quality and reduced friction
  - Reduced box volume, general sophistication

Thank you for your attention

Eelke drinking a glass of water with ARMON Mark II

Acknowledgment

- MSc Students: Sergio Tomazio, Luis Cardoso, Jorine Koopman, Clara Gil Guerrero, Wendy van Stralen, Pieter Lucieer, Sabine Gal, Tonko Antonides
- Physician: Imelda de Groot MD
- Patients: In total over 12 patients tried the device
- Patient organization: Dutch Neuromuscular Disease Association (VSN)
- Company: Microgravity Products (MGP), Niels Vrijlandt, Tonko Antonides, Marijn Cloosterman, for manufacturing the prototypes and images.