ELECTRO HYDROSTATIC ACTUATORS

A NEW APROACH IN MOTION CONTROL

2nd Workshop on Innovative Engineering for Fluid Power
Sep 2-3 2014

Agenda

- Introduction - MOOG
- Actuation Technologies
- Electro Hydrostatic Actuators
- Applications

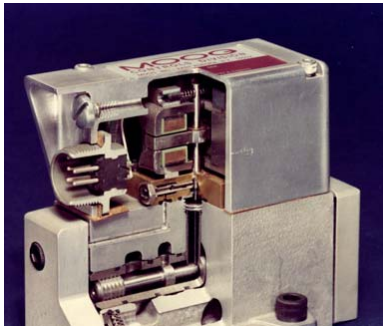
FOCUS IN HIGH PERFORMANCE MOTION CONTROL

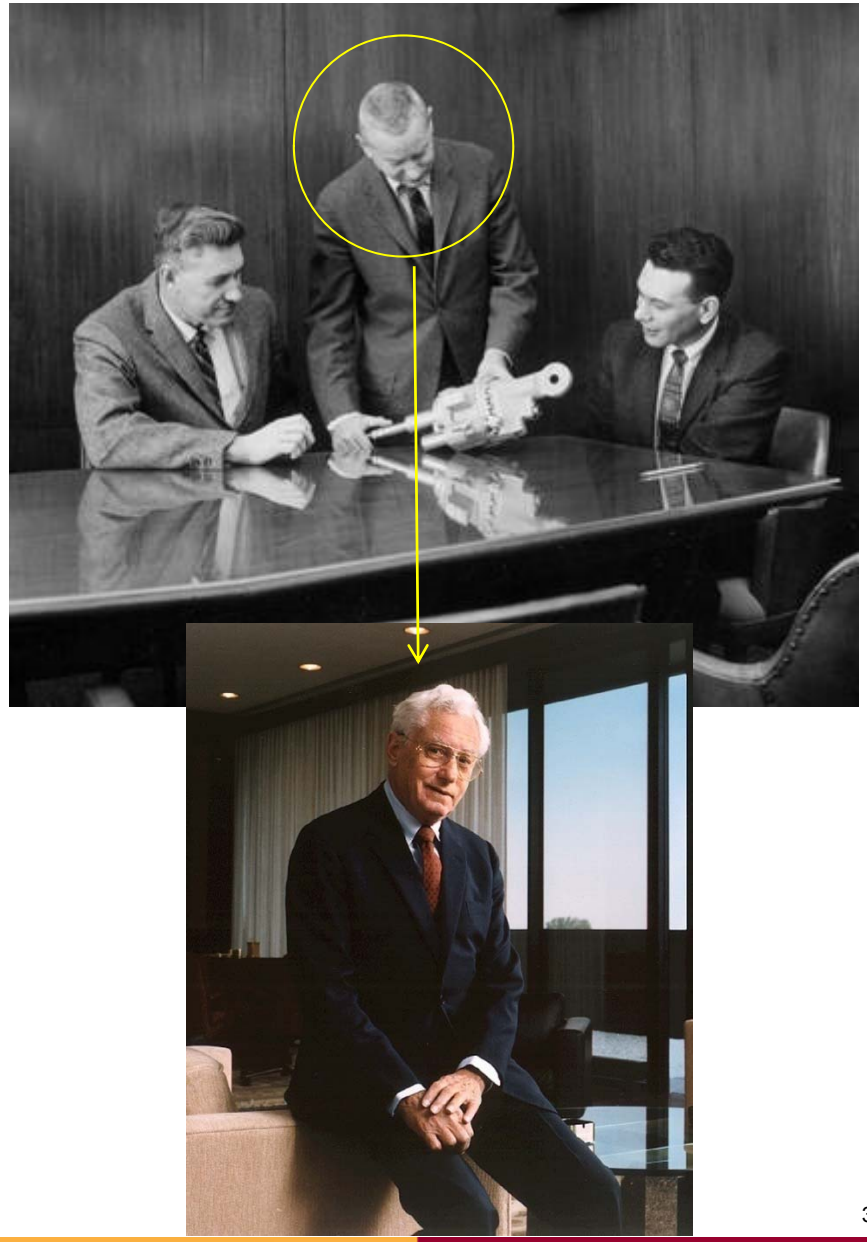
Established in 1951, by Bill Moog

HIGH PERFORMANCE MOTION CONTROL SOLUTIONS FOR INDUSTRIAL, MILITARY AND AEROSPACE APPLICATIONS.

Sales (2013) = US$ 2,6 Billion

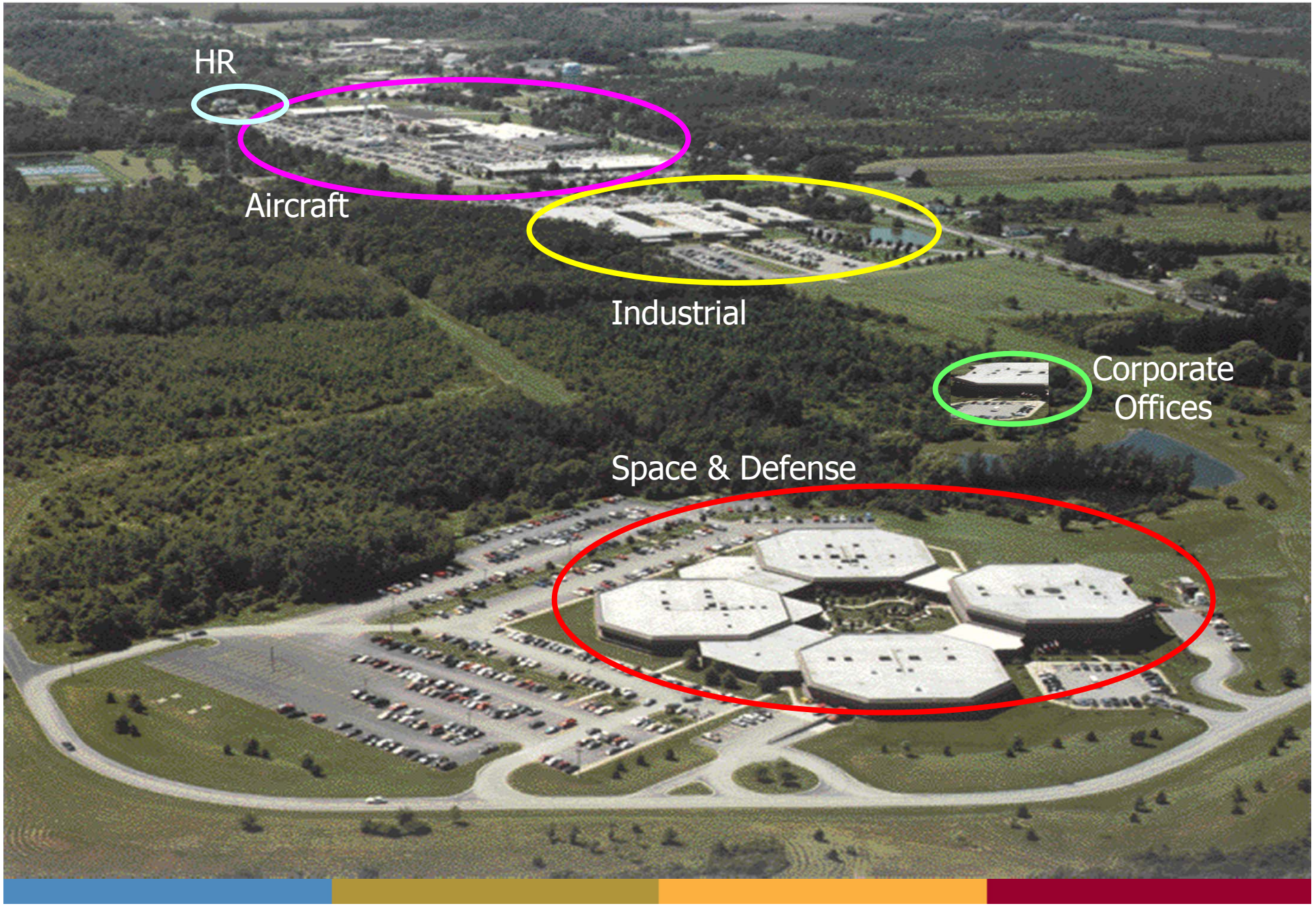
11.600 employees





EAST AURORA CAMPUS (BUFFALO-NY)

MOOG



MOOG do Brasil Controles Ltda

Rua Prof Campos Oliveira, 338
Rua Agostinho Togneri, 457 Sto Amaro, São Paulo Phone (11) 3572-0400

GROUPS

MOOG

Aircraft Group	Industrial Group	Space and Defense Group	Components Group
primary and secondary flight control, engine controls	high performance motion control for industrial applications, test (aerospace and automotive), simulation	missiles and launchers trajectory control, antenas and solar panels positioning, satelites atitude control	Slip rings, small motors, rotating joints, fiber optics interfaces, air cooling solutions











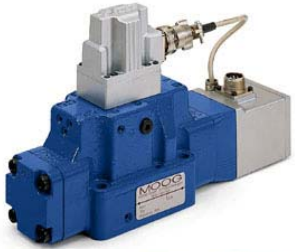


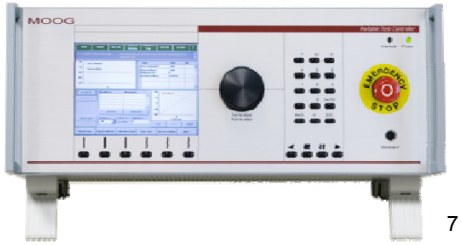


INDUSTRIAL GROUP - PRODUCTS

MOOG

Servovalves





INDUSTRIAL GROUP - MARKETS

MOOG

TURBINES

Wind

Gas, oil, hydro

SIMULATION

TEST

Aerospace

Automotive

HEAVY INDUSTRY

Steel mills

METAL FORMING

Presses

Oil & Gas

AFTERMARKET

Formula 1

Repairs

Agenda

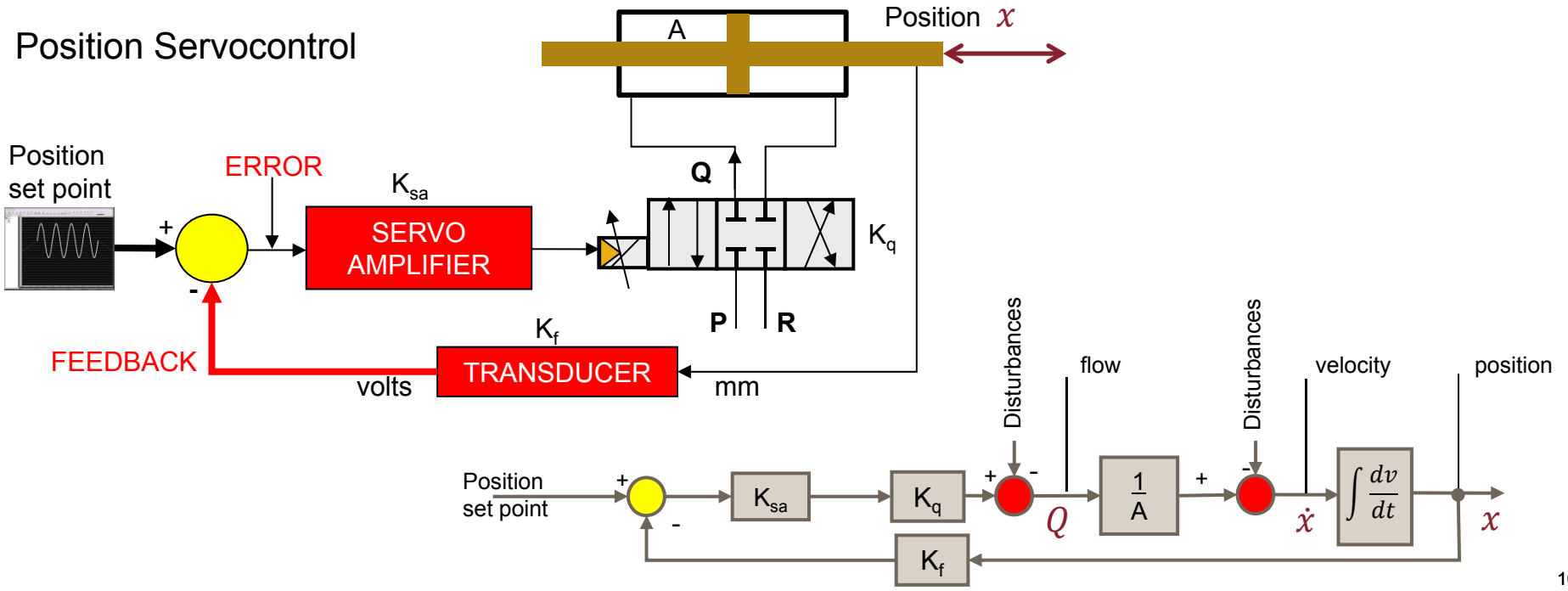
- Introduction - MOOG
- Actuation Technologies
- Electro Hydrostatic Actuators
- Applications

SERVOCONTROL = closed loop motion control

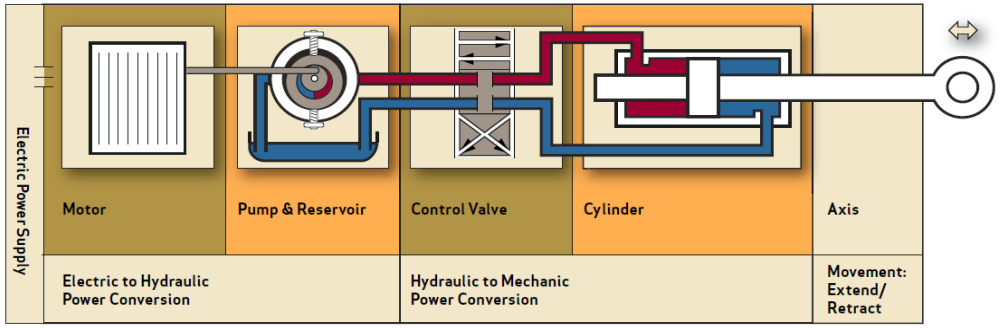
MOOG

LINEAR		ROTARY	
position	x	angular position	θ
velocity	$\dot{x} = \frac{dx}{dt} = v$	velocity	$\dot{\theta} = \frac{d\theta}{dt} = \omega$
acceleration	$\ddot{x} = \frac{dv}{dt} = a$	acceleration	$\ddot{\theta} = \frac{d\omega}{dt} = \alpha$
force	F	torque	T
pressure	p		

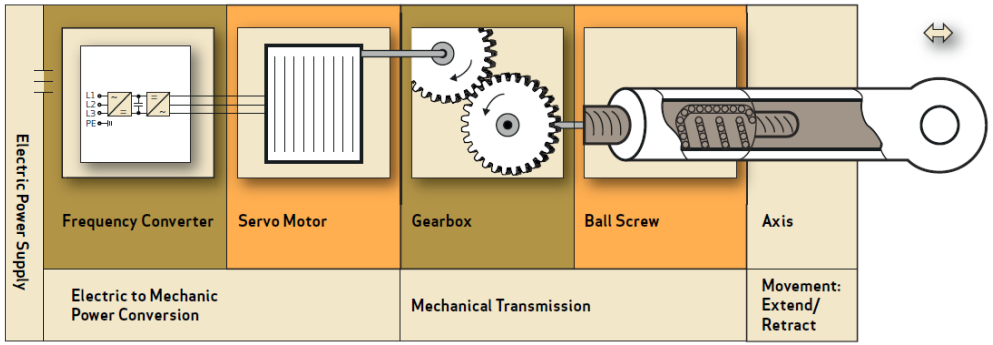
Position Servocontrol



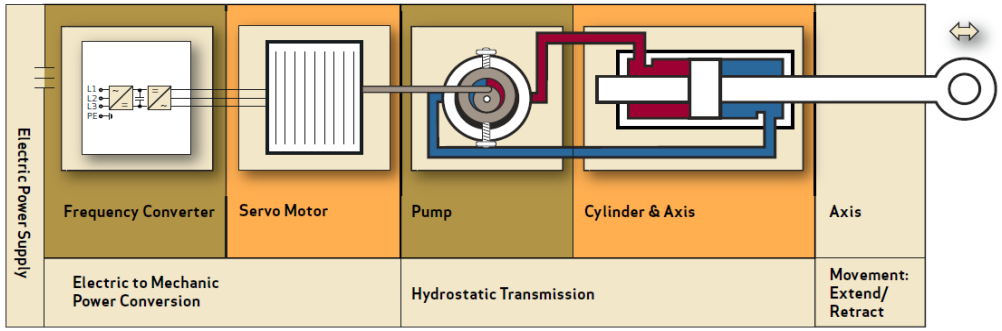
ACTUATION TECHNOLOGIES



Electro-hydraulic



Electro-mechanical

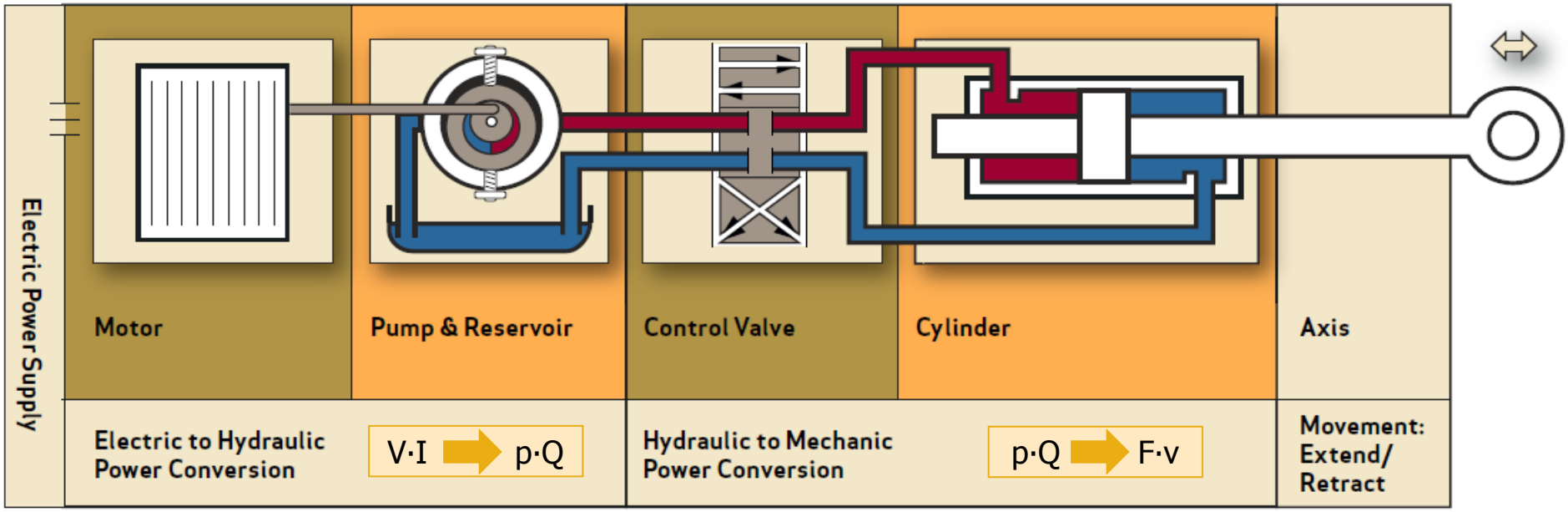


Electro-hydrostatic

ACTUATION TECHNOLOGIES

ELECTRO-HYDRAULIC

MOOG

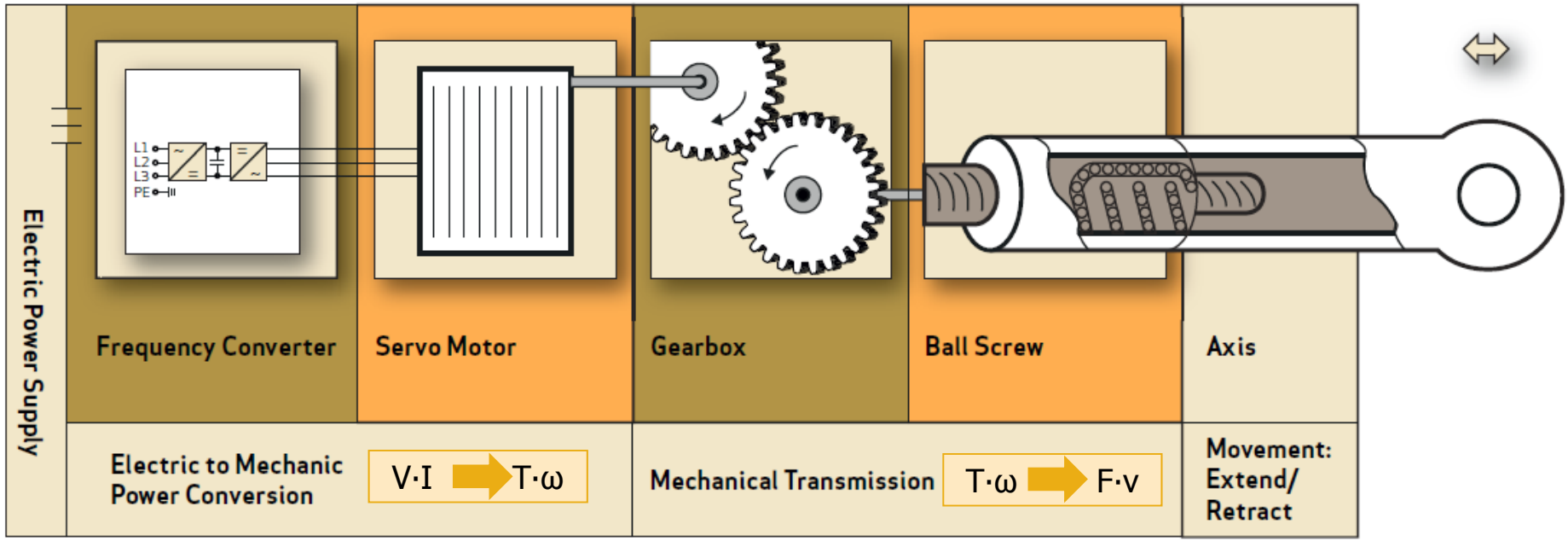


Elements: pump, servovalve, hydraulic cylinder.

Power is transmited by the fluid $P = Q \cdot p = (flow\ x\ pressure)$

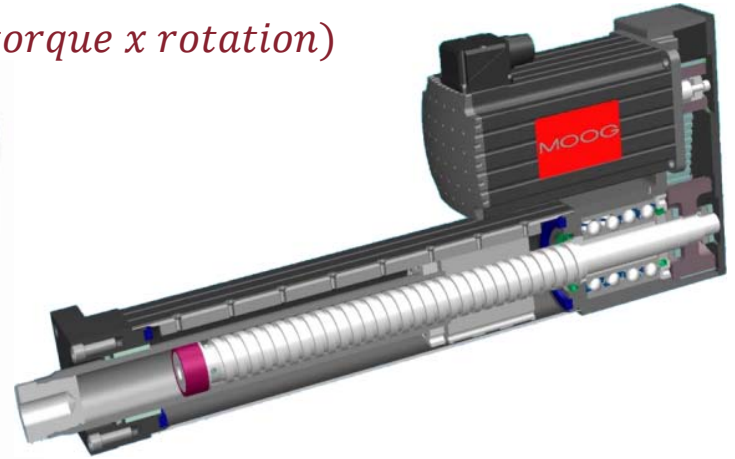
ACTUATION TECHNOLOGIES

ELECTRO-MECHANICAL

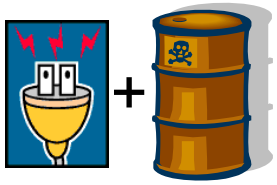


Elements: servomotor, gearbox, ball/roller screw

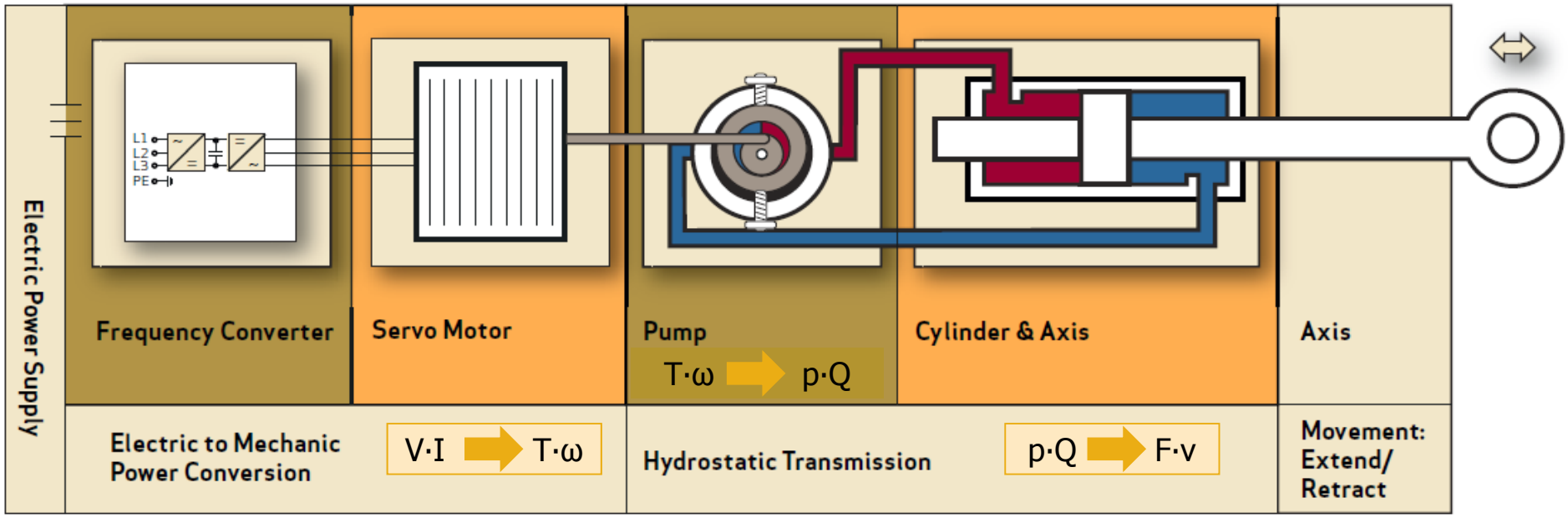
Power is transmited by the mechanics $P = T \cdot \omega = (torque\ x\ rotation)$



ACTUATION TECHNOLOGIES
ELECTRO-HIDROSTATIC



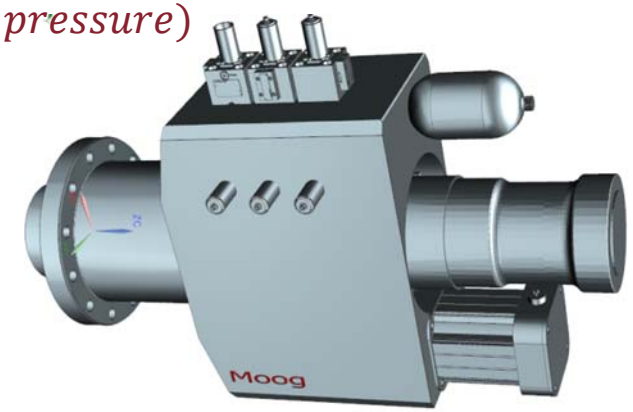
MOOG



Elements: servomotor, pump, hydraulic cylinder.

Power is transmited by the mechanics $P = T \cdot \omega = (torque\ x\ rotation)$

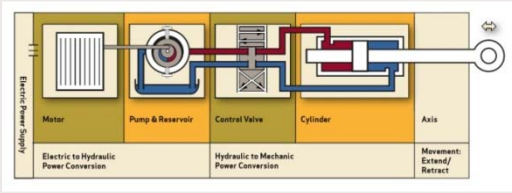
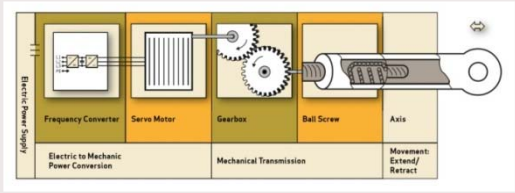
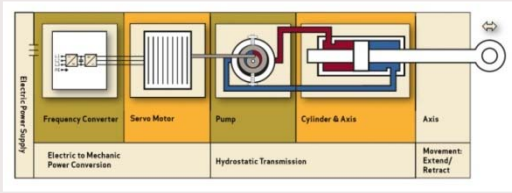
and by the fluid $P = Q \cdot p = (flow\ x\ pressure)$



ACTUATION TECHNOLOGIES

MOOG

Comparison

Electro-Hydraulic - EH	Electro-Mechanical - EMA	Electro-Hydrostatic - EHA
		
+ High robustness and reliability + Ideal for high & static forces + Fail-safe options + Easy redundancy (2+ actuators) + No backlash + Easy maintenance + High frequency operation + Compact size + Light weight	+ High energy efficiency + Powered by wire (no HPU) + Easy installation and commissioning + Environmental cleanliness + Well suited for rotary actuation + High stiffness	+ Good energy efficiency + Powered by wire (no HPU) + Easy installation and commissioning + High robustness and reliability + Fail-safe options + Easy redundancy (2+ actuators) + No backlash + Good for high & static forces + Unlimited hydraulic gearbox ratio
- Low energy efficiency - Requires HPU* & piping - Environment contamination	- Heavy weight - No fail safe (gearbox can block) - No redundancy (single actuator) - High power consumption to hold static load - Backlash - High maintenance effort ($) - Electrical noise	- Weight - Higher cost - Complexity - Electrical noise - Limited stiffness - Power consumption to hold static load

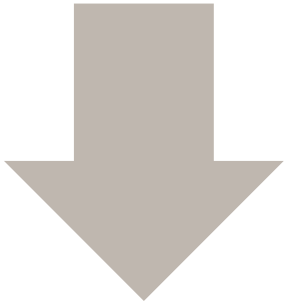
*HPU: hydraulic power unit = motor + pump + filtering + cooling

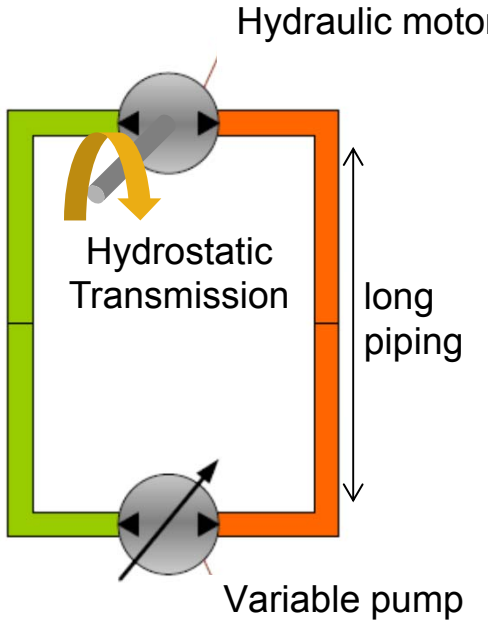
Agenda

- Introduction - MOOG
- Actuation Technologies
- Electro Hydrostatic Actuators
- Applications

EHA - AN OLD CONCEPT

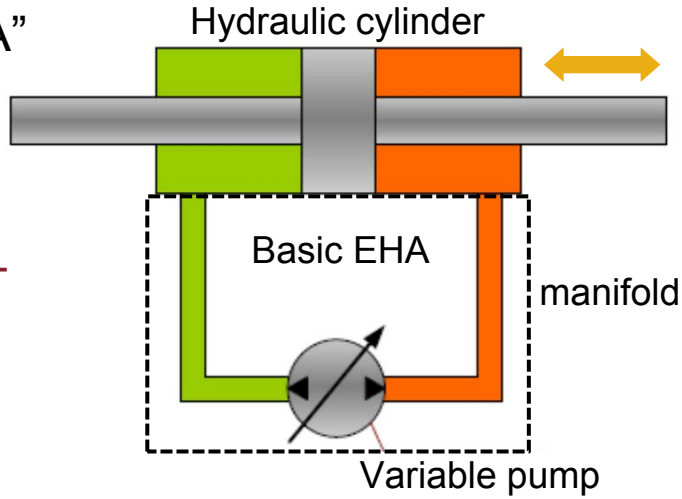
Hydrostatic transmissions have been used in a wide range of mobile applications





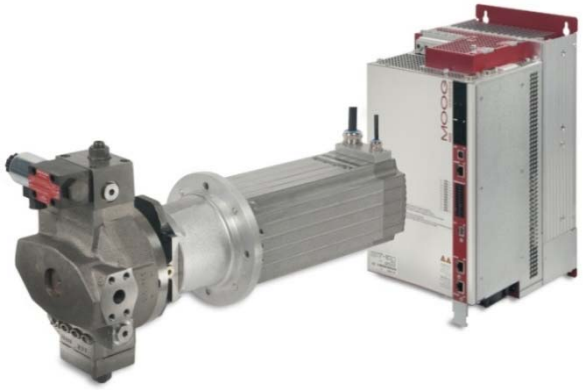
Same principles can be applied to get a “Basic EHA”

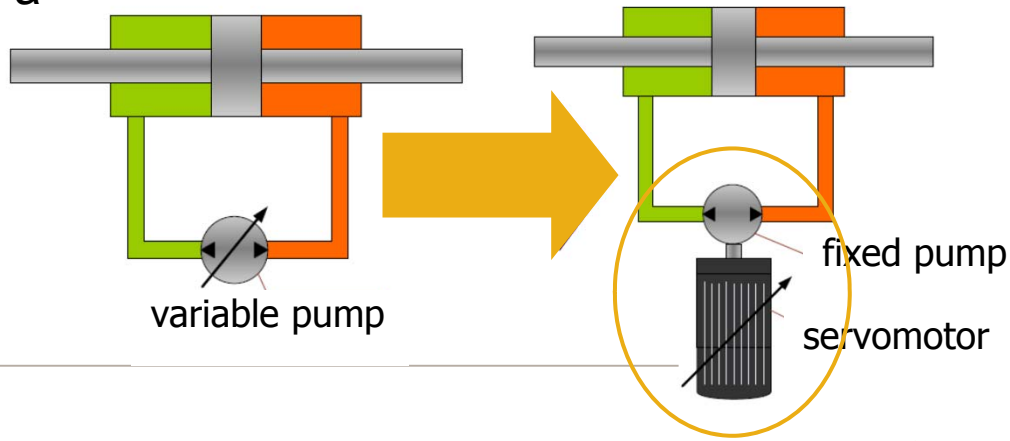
+ No need for a “separated” HPU
+ Self contained hydraulic system
- Low frequency response
- Requires auxiliary devices (cooling, filtration, anti-cavitation)



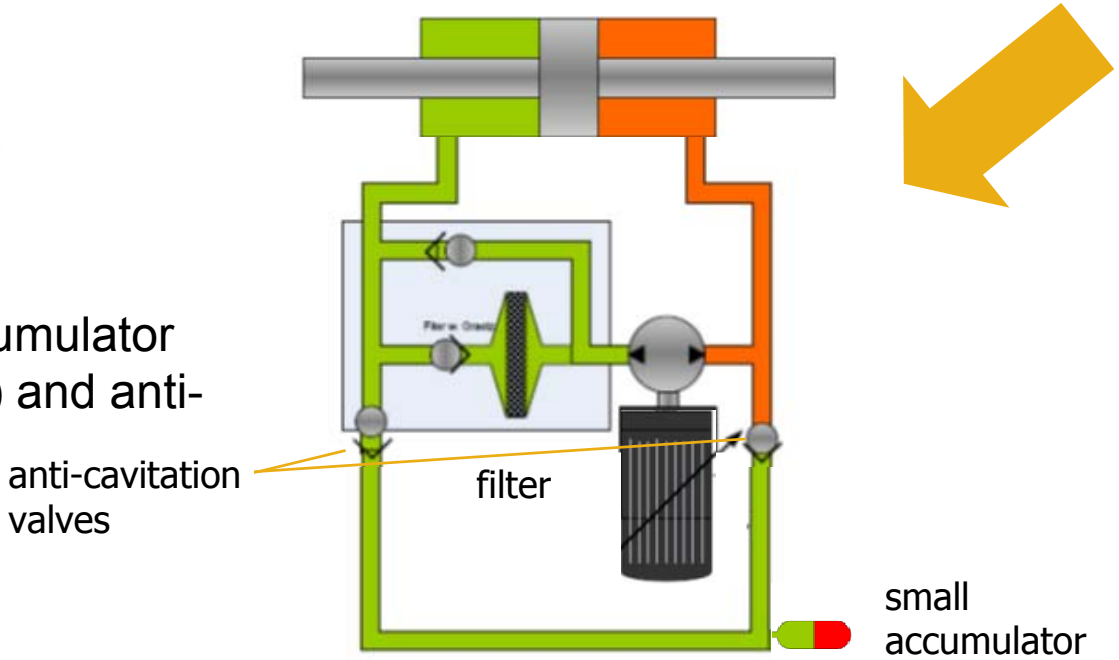
EHA - DEVELOPMENTS

1) Replacing the variable pump by a fixed pump + servo motor
   - Gear Pump:lower cost, loss of performance
   - Piston Pumps: higher cost, better efficiency

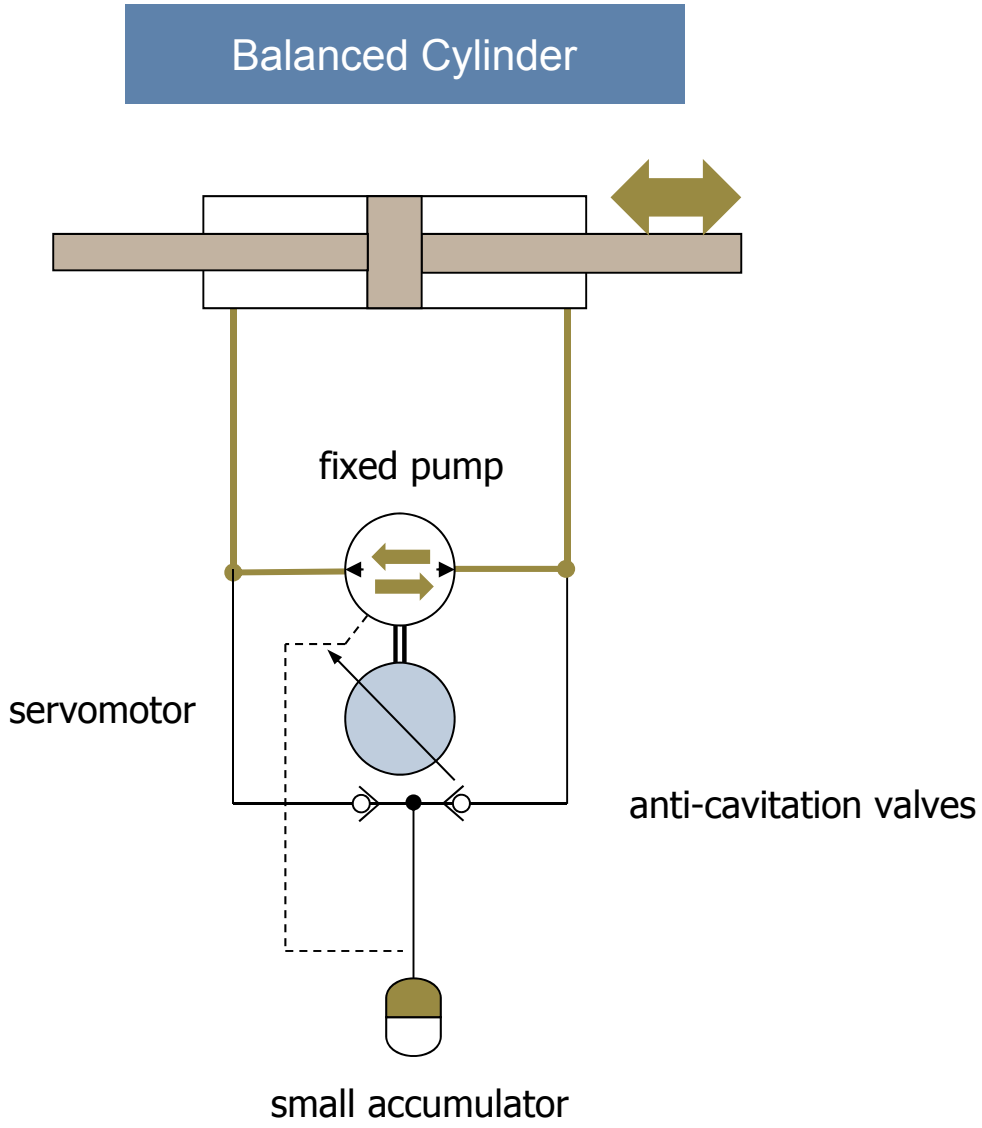




2) Adding filtering, small accumulator (to keep system pressurized) and anti-cavitation check valves.



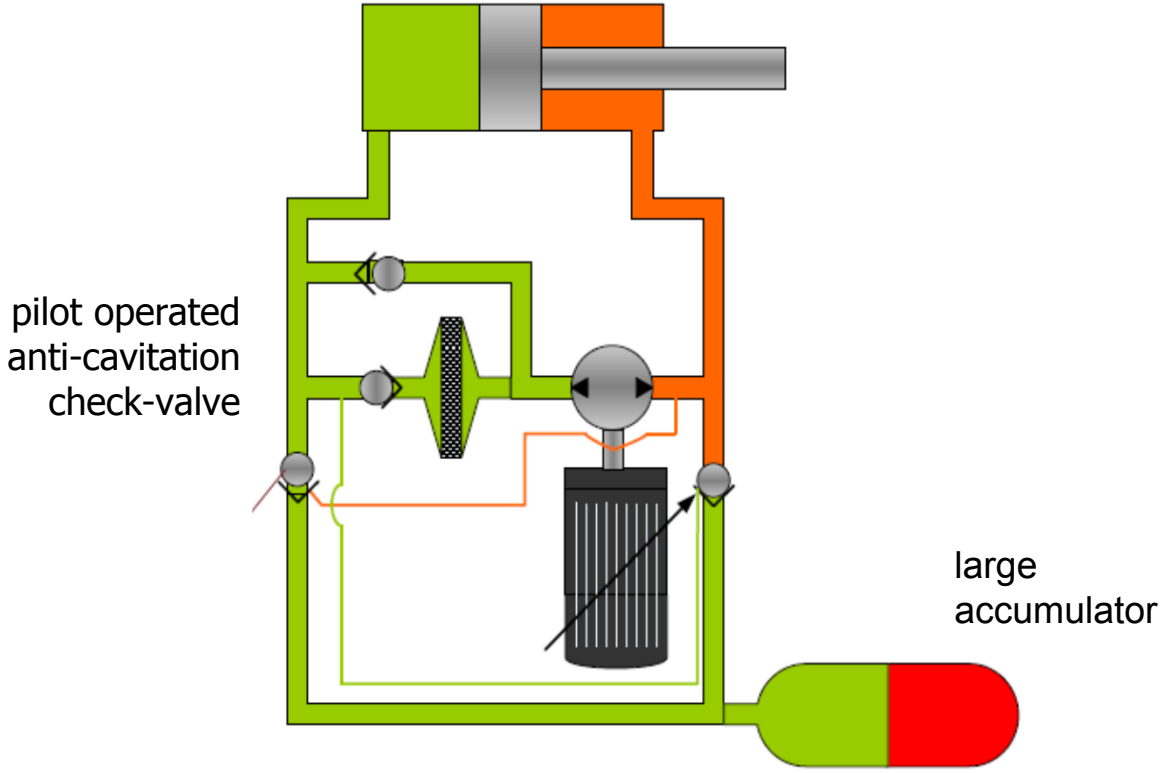
EHA – OPERATION



EHA – DEVELOPMENTS

3) Dealing with unbalanced cylinders
Requires:

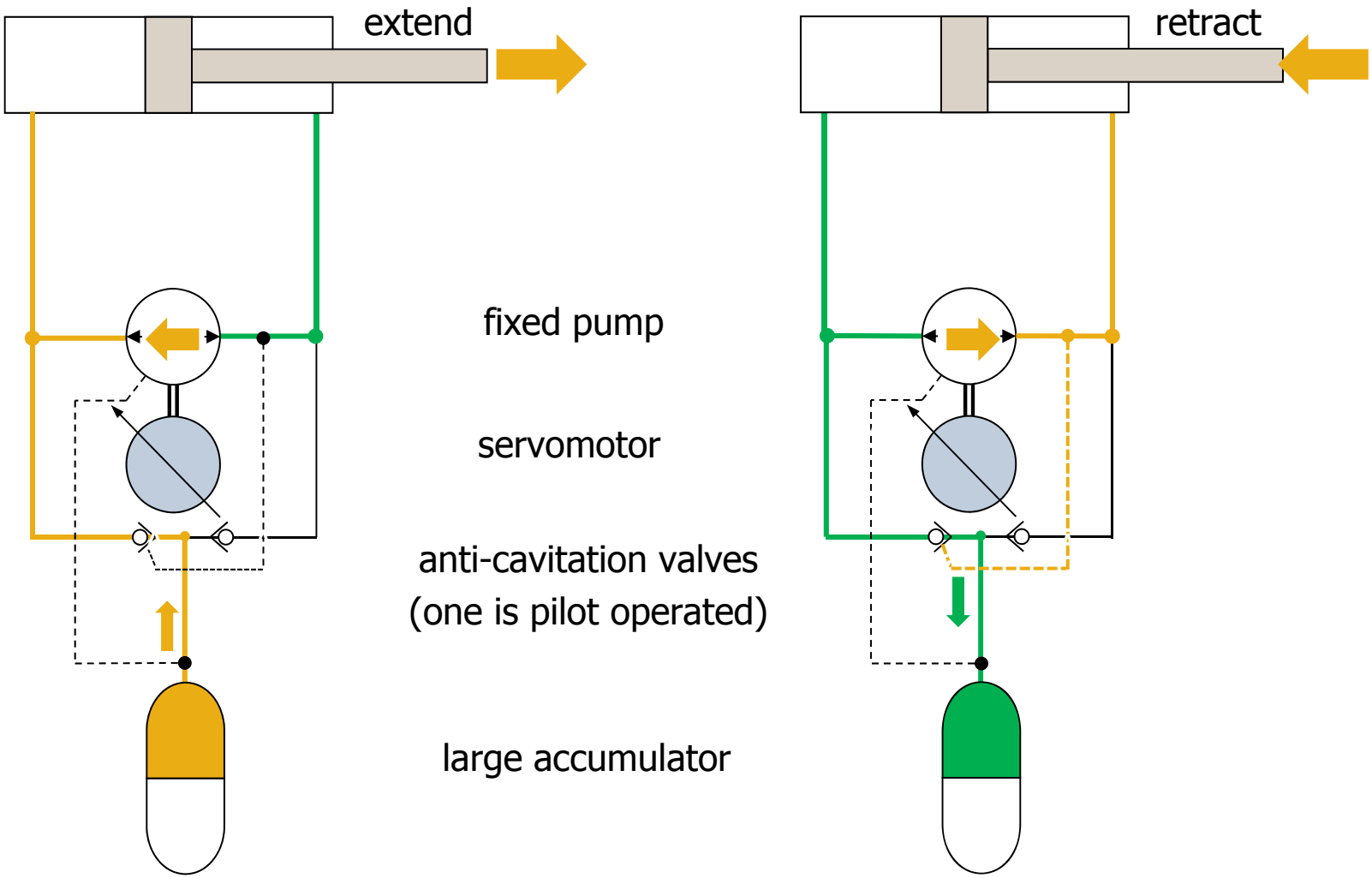
- large accumulator : to hold the differential oil volume
- pilot operated anti-cavitation check valves: to assure the pressurization of the pump port to avoid cavitation



EHA – OPERATION

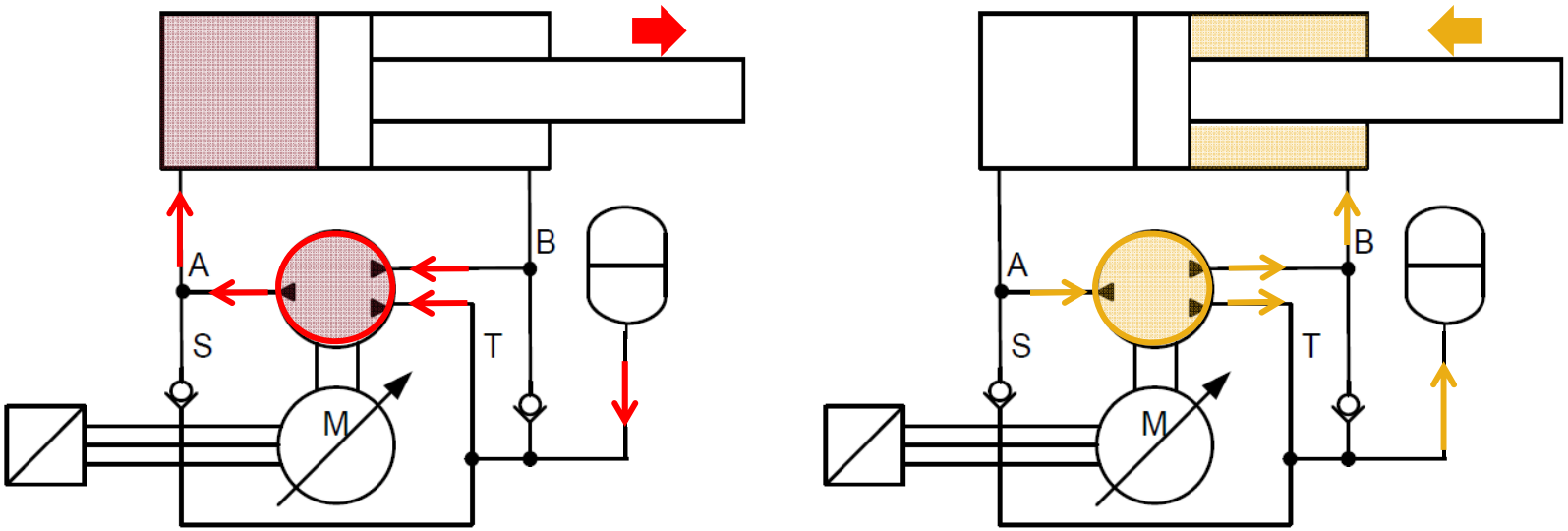
MOOG

Unbalanced Cylinder

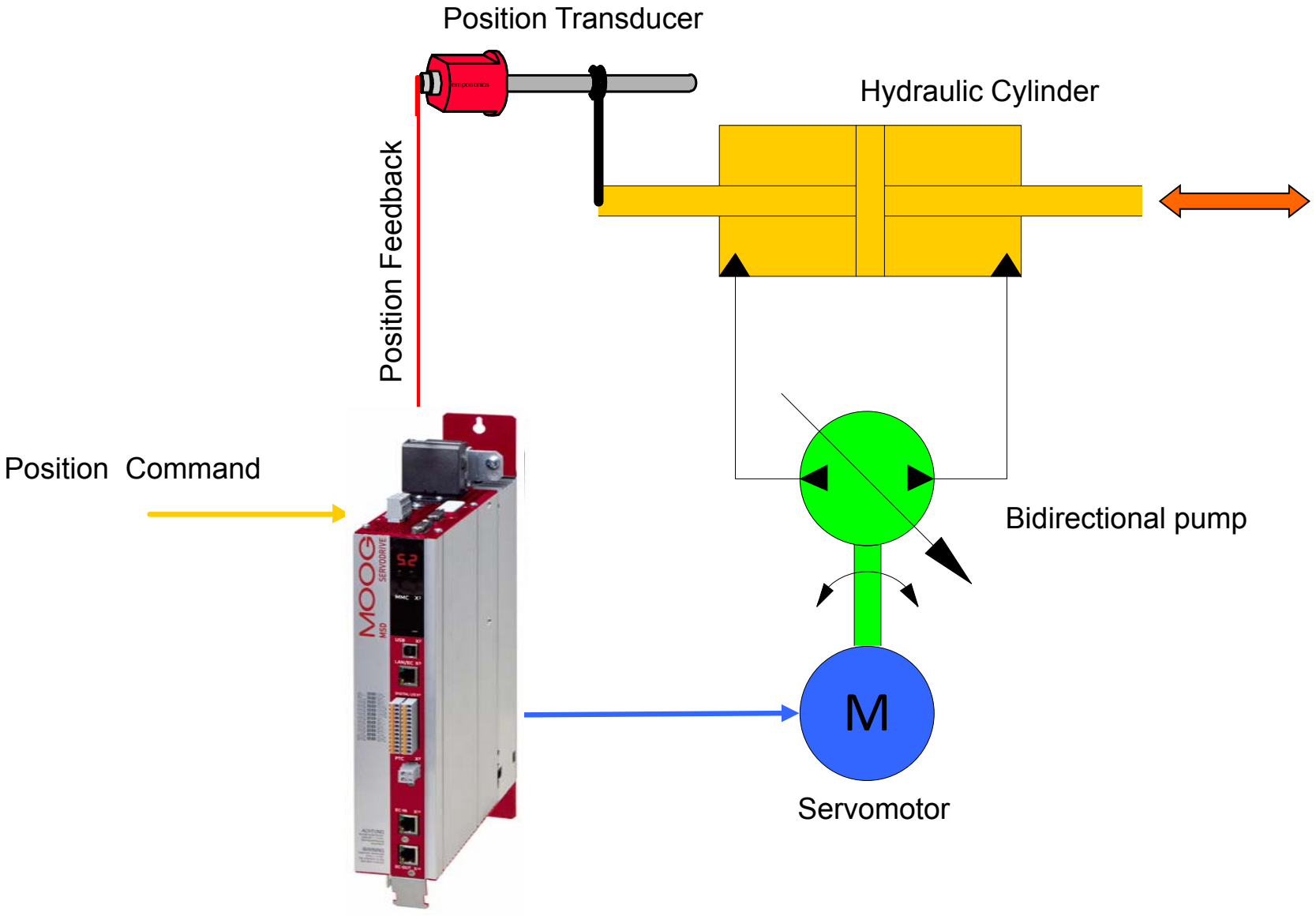


EHA – Dealing with unbalanced cylinders

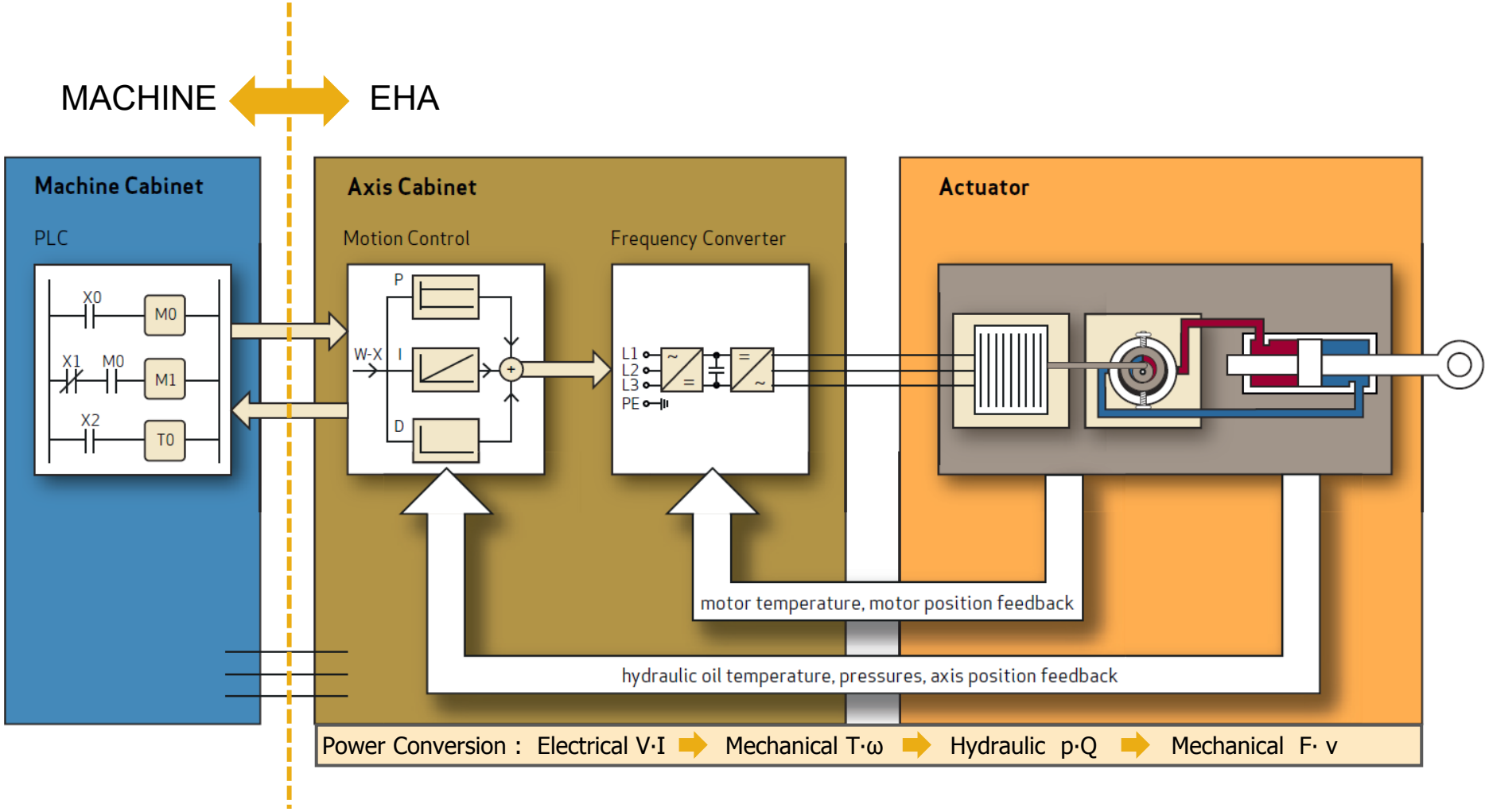
- 3 ports pump, for unbalanced flow control



EHA – CONTROL ARCHITETURE

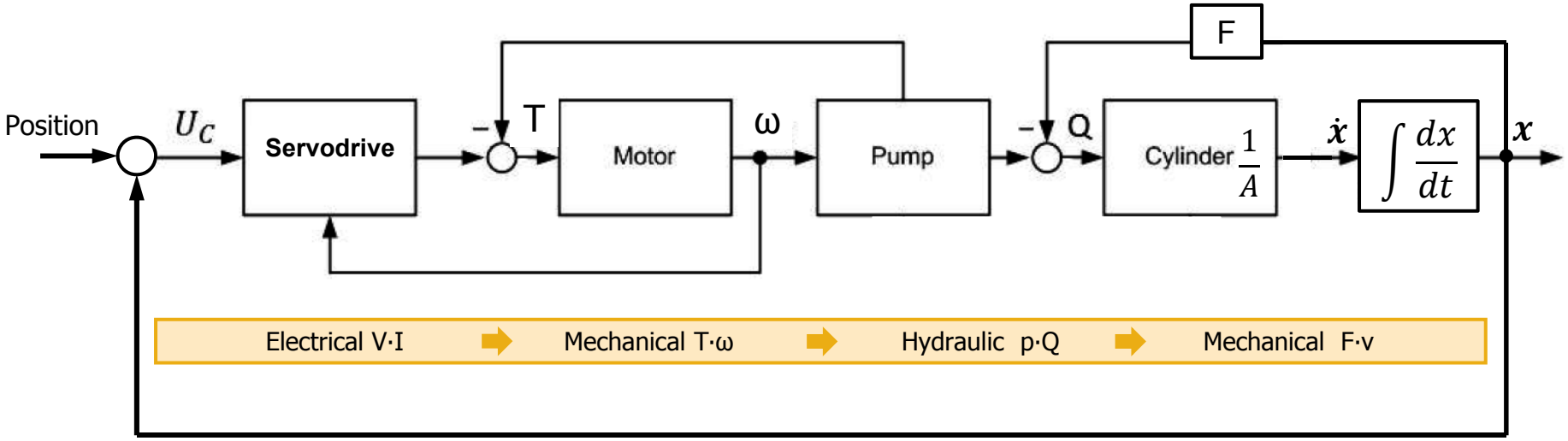


EHA – CONTROL ARCHITETURE



EHA – CONTROL ARCHITETURE

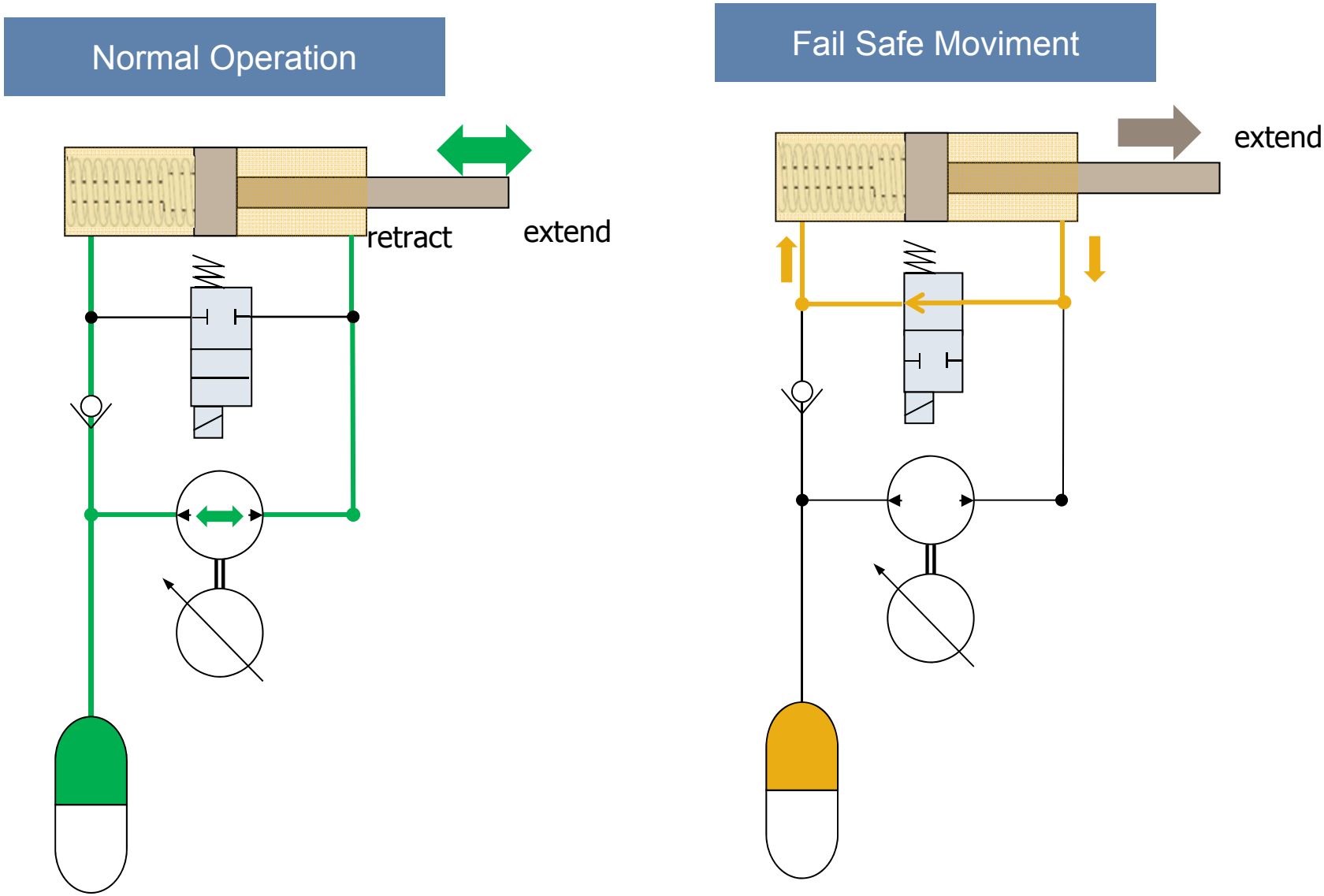
DYNAMIC BEHAVIOR



Large, low speed, high torque pump

Small, high speed, low torque pump

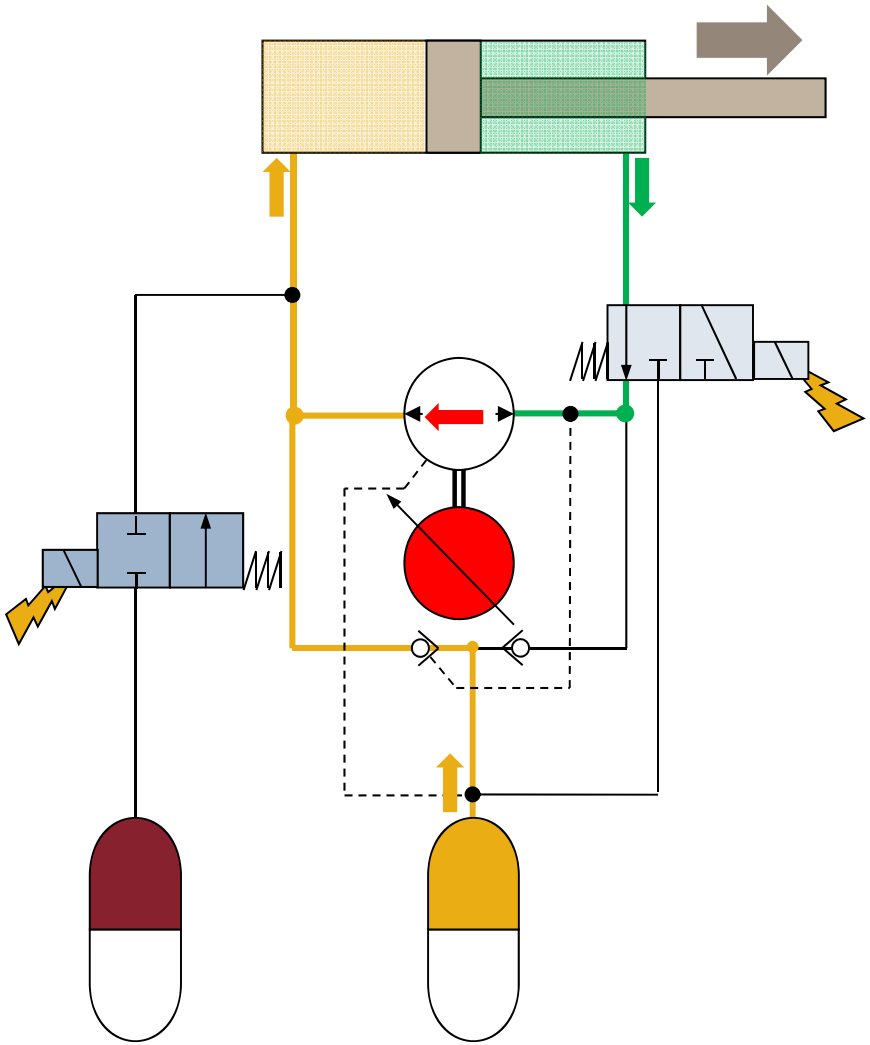
EHA – SAFETY based on spring



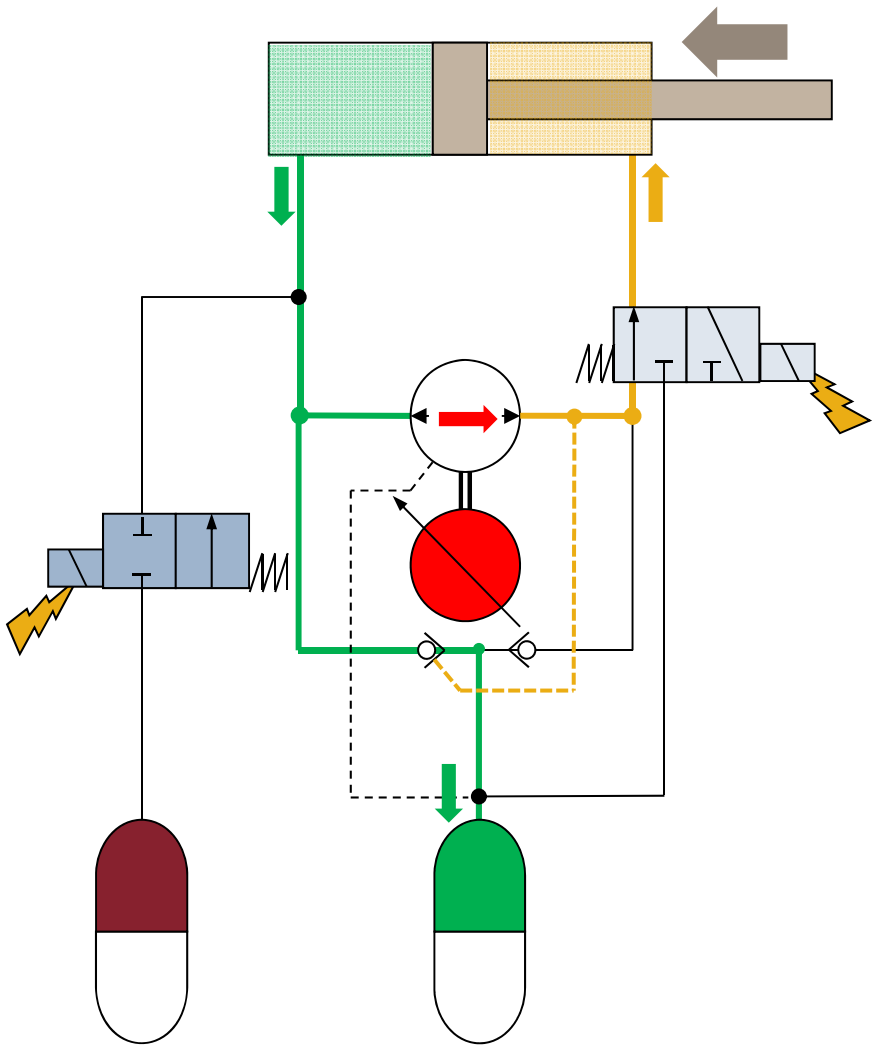
EHA – SAFETY based on accumulator

MOOG

Normal Operation -extend



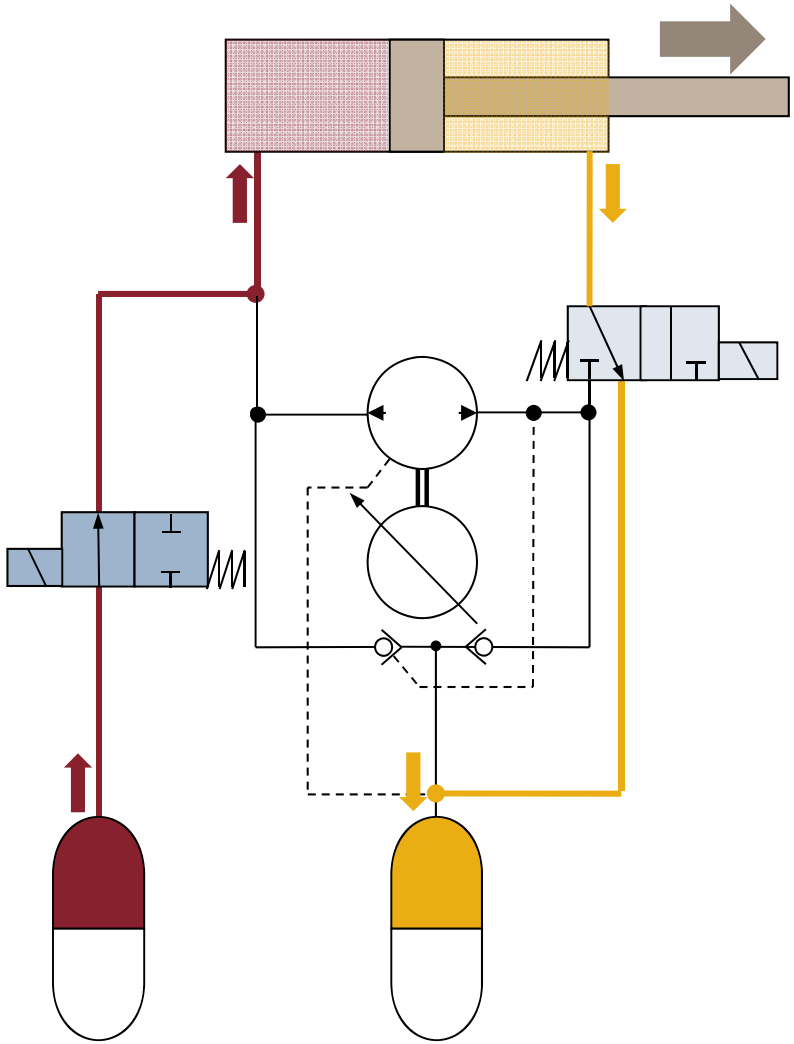
Normal Operation - retract



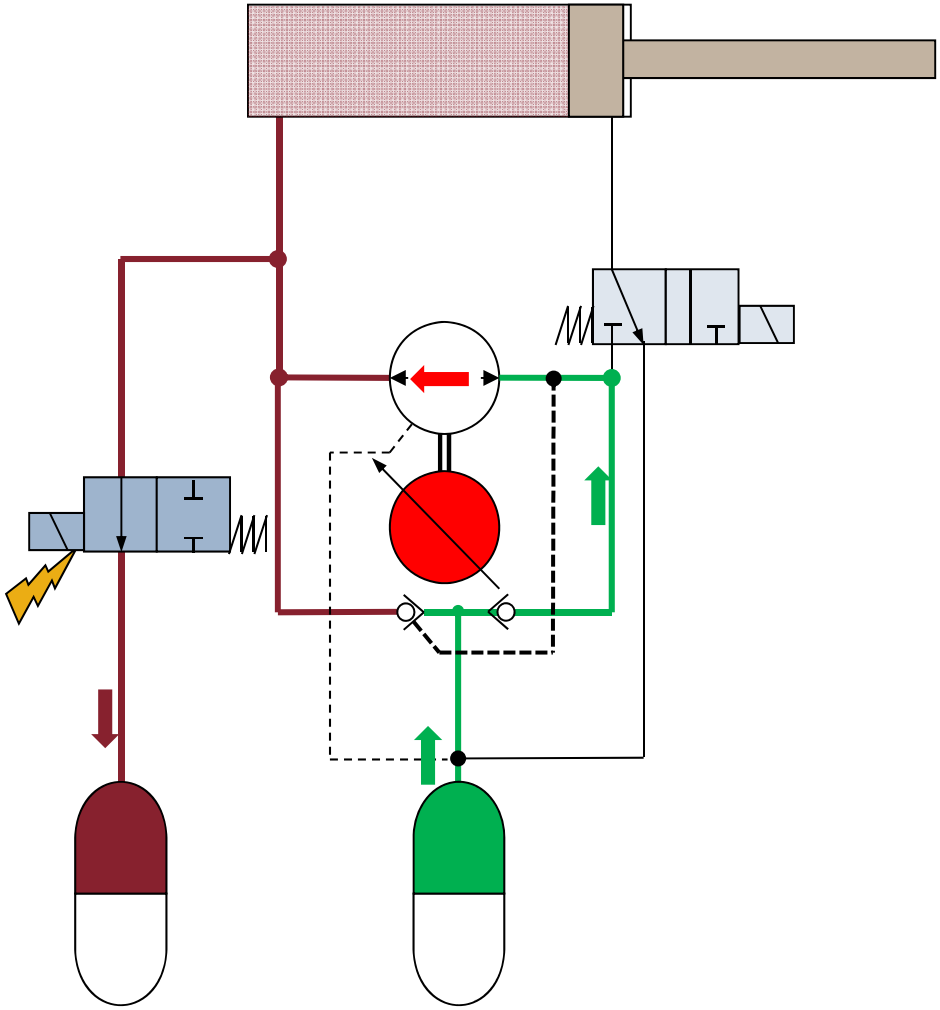
EHA – SAFETY based on accumulator

MOOG

Fail Safe Moviment - extend



Accumulator Recharge



Agenda

- Introduction - MOOG
- Actuation Technologies
- Electro Hydrostatic Actuators
- Applications

APPLICATIONS

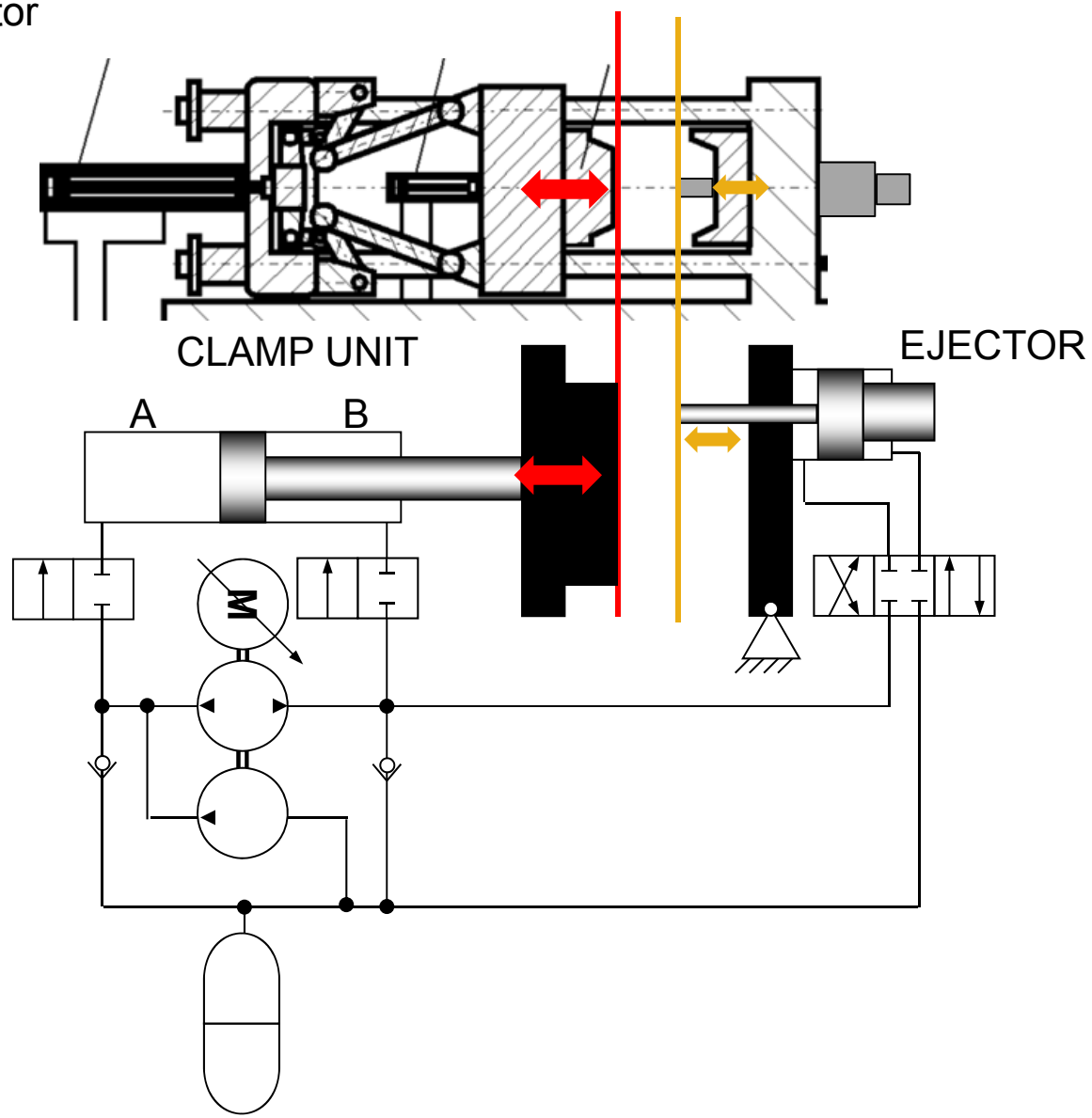
EHA applications

- Injection molding machines
- Metal Forming & Presses
- Flight Control
- Wind turbines pitch control

APPLICATION

INJECTION MOLDING AND DIE CASTING MACHINES

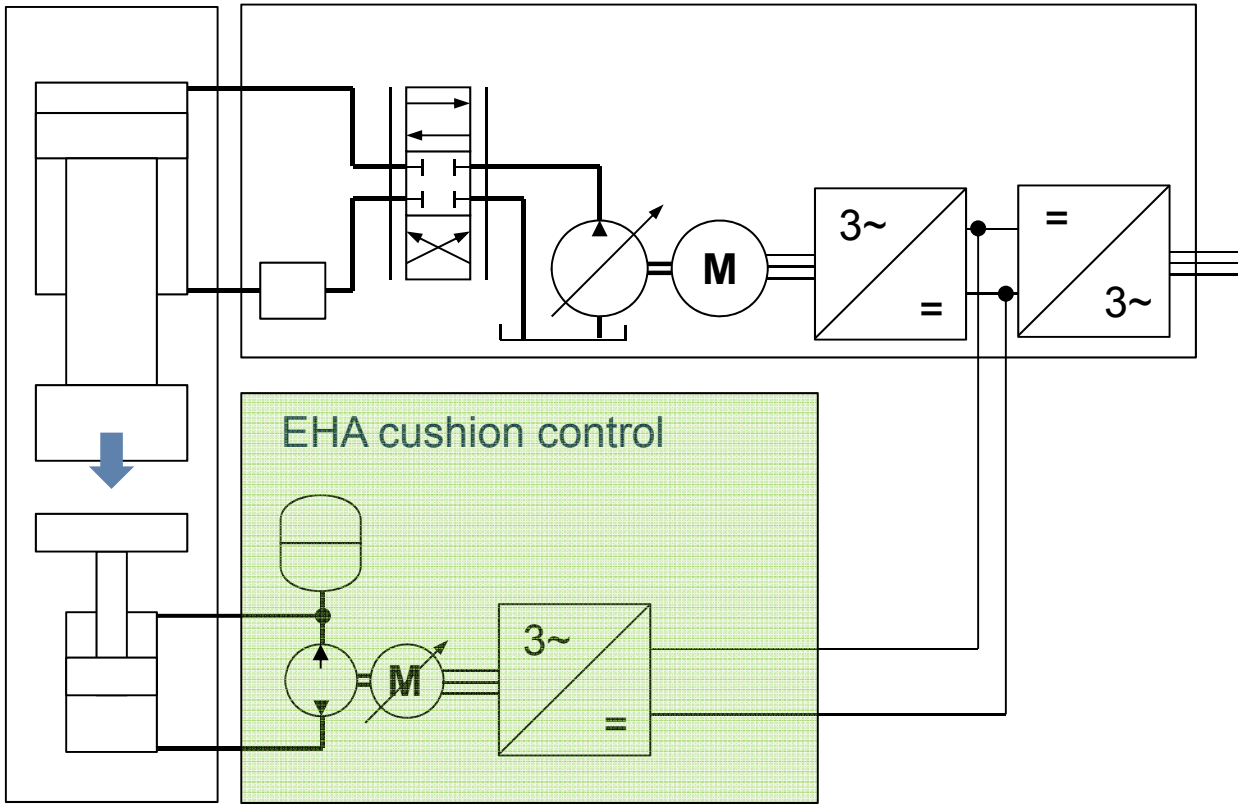
Clamp Unit & Ejector



APPLICATION

METAL FORMING & PRESSES

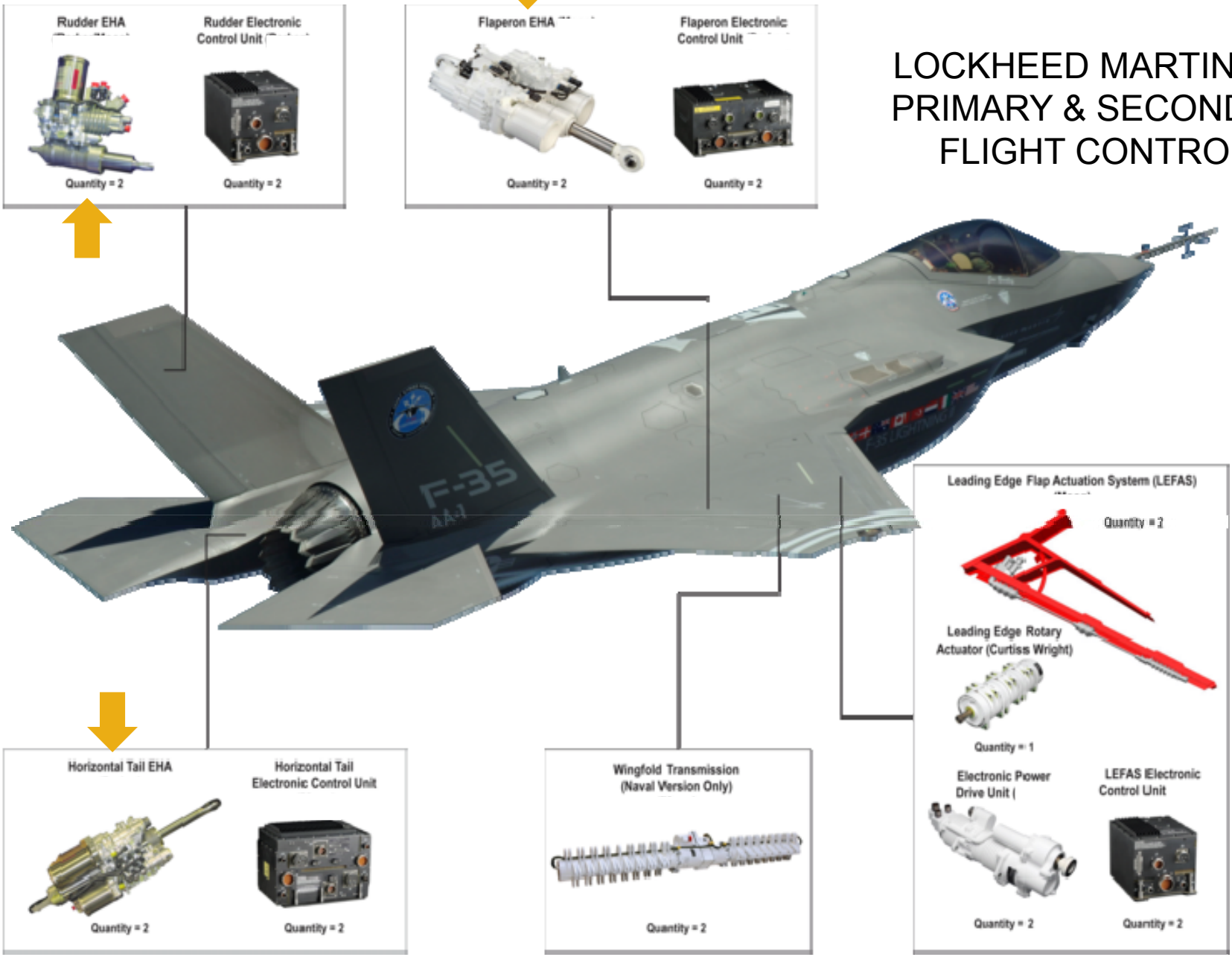
CUSHION CONTROL - velocity and pressure control



APPLICATION

MOOG

LOCKHEED MARTIN F-35 PRIMARY & SECONDARY FLIGHT CONTROLS



APPLICATION - FLIGH CONTROL

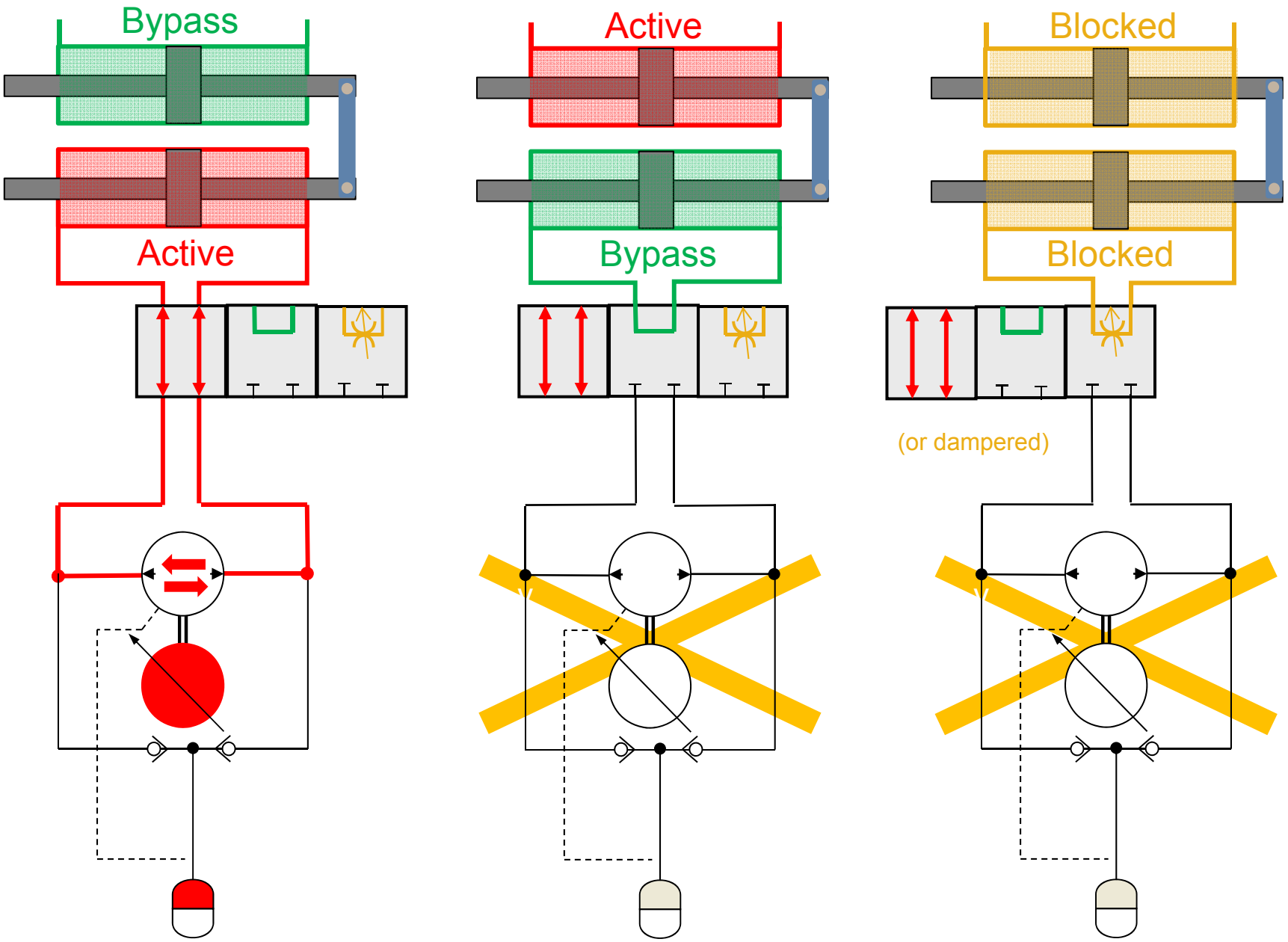
MOOG

Features

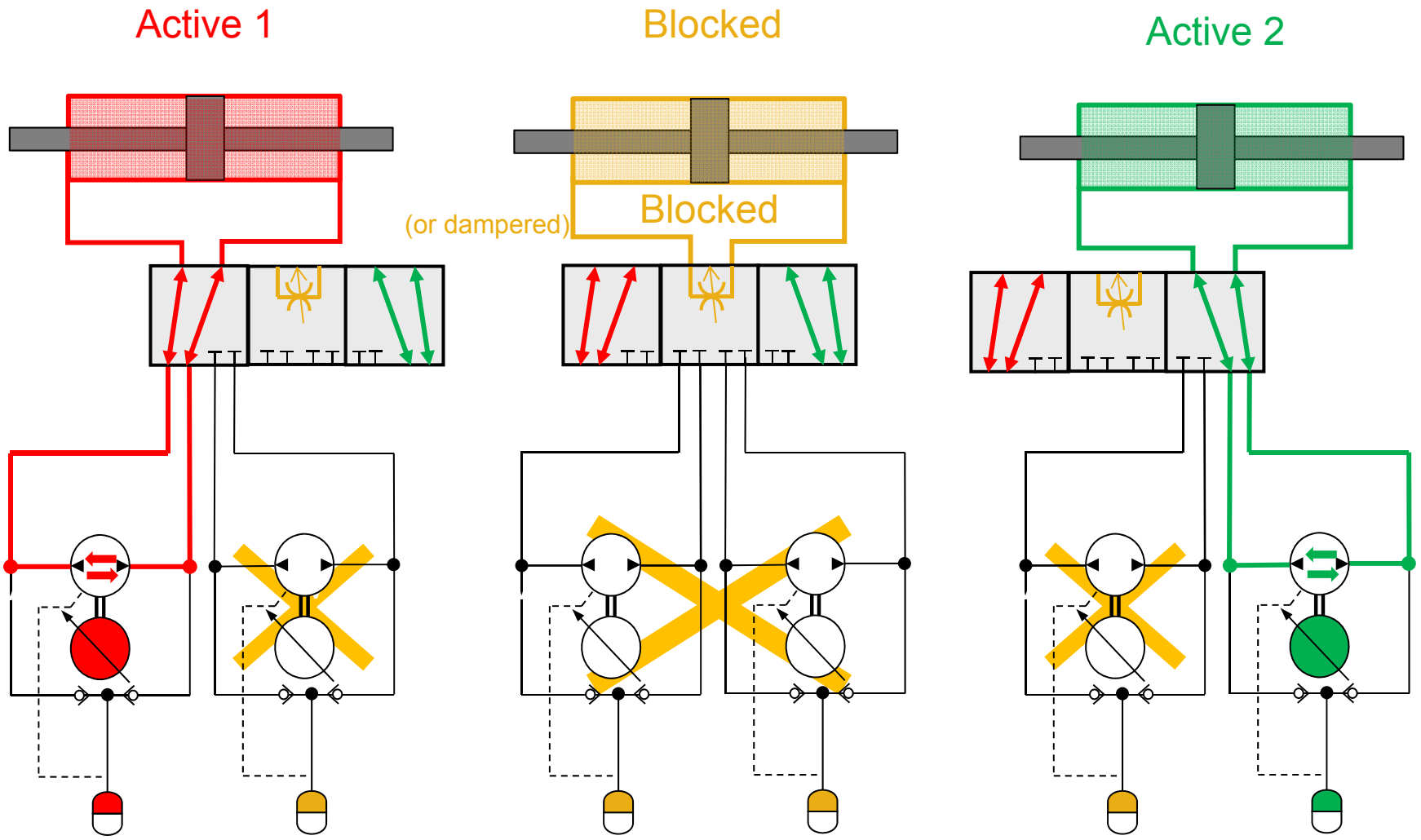
- Manageable failure modes
- Flexible packaging
- Multiple electrical channels possible
- High power consumption to hold load

- Overload relief
- Multiple failure modes:
  - ✓ Normal servocontrolled operation
  - ✓ Bypass (to allow other actuators to operate control surface)
  - ✓ Damped
  - ✓ Blocked
  - ✓ Damped - Blocked

APPLICATION – FLIGHT CONTROL - REDUNDANCY



APPLICATION – FLIGHT CONTROL -
REDUNDANCY

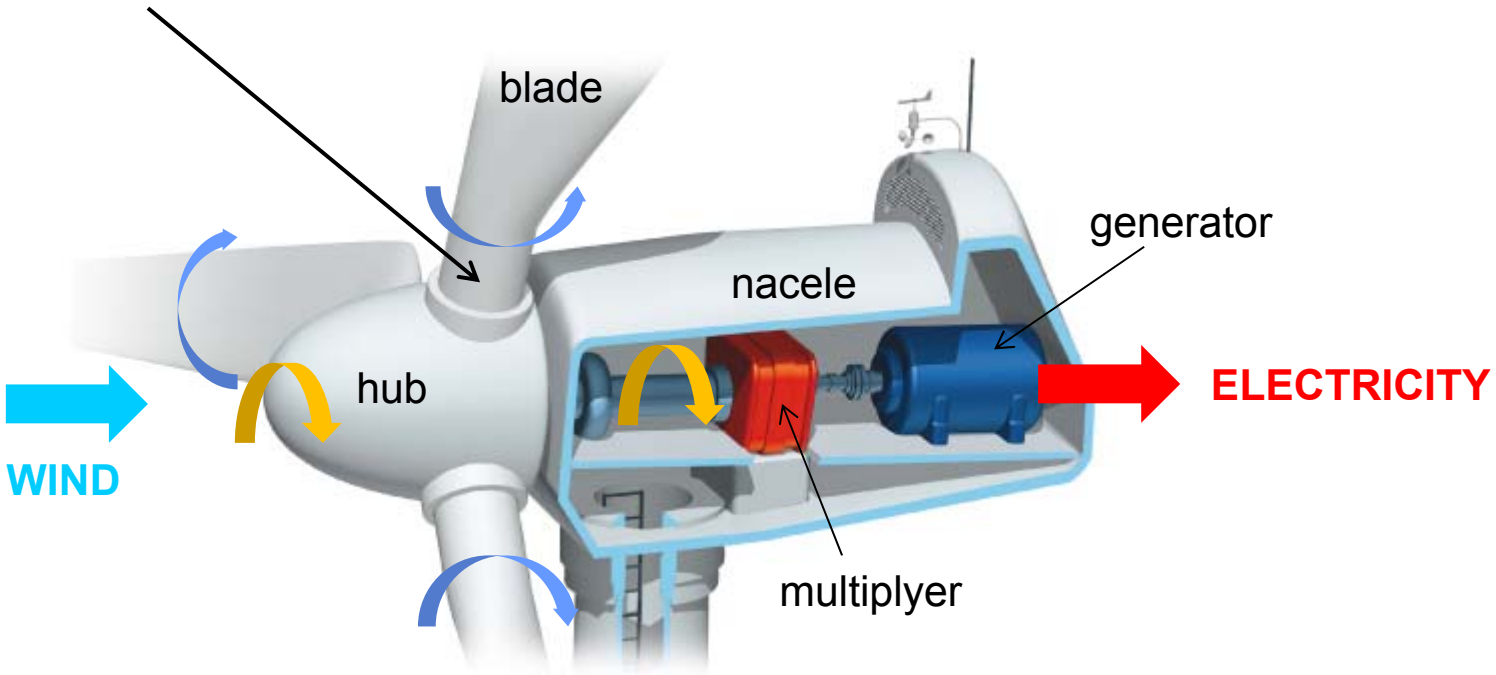


APLICATION - BLADE PITCH CONTROL

Wind Turbine

PITCH CONTROL SYSTEM :adjusts the pitch turbine blade angle.

- 3 blades follows the same command (syncronized)
- The turbine main controller sets blade pitch angle
- The pitch control system is assembled inside the blades and rotates with the turbine.



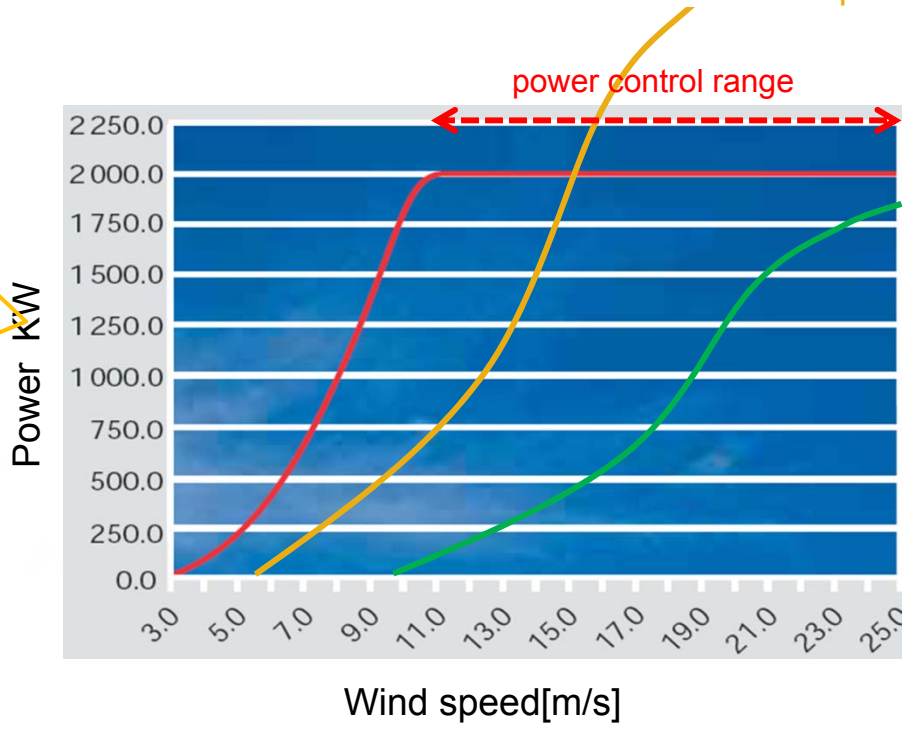
APLICATION - BLADE PITCH CONTROL

Wind Turbine

1. STOP the turbine in case of emergencies and failures
2. MAXIMIZE energy conversion in a large wind speed range

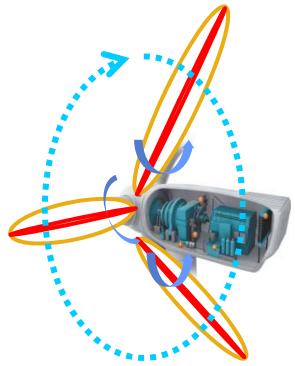
Power ≈ pitch angle · (wind speed)^3

CONFIABILITY is the main feature of a pitch control system



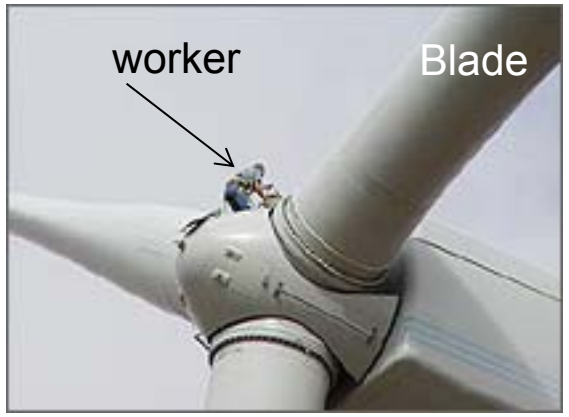
Turbine with pitch control

Fixed pitch angle = 10º



APLICATION - BLADE PITCH CONTROL

Wind Turbine

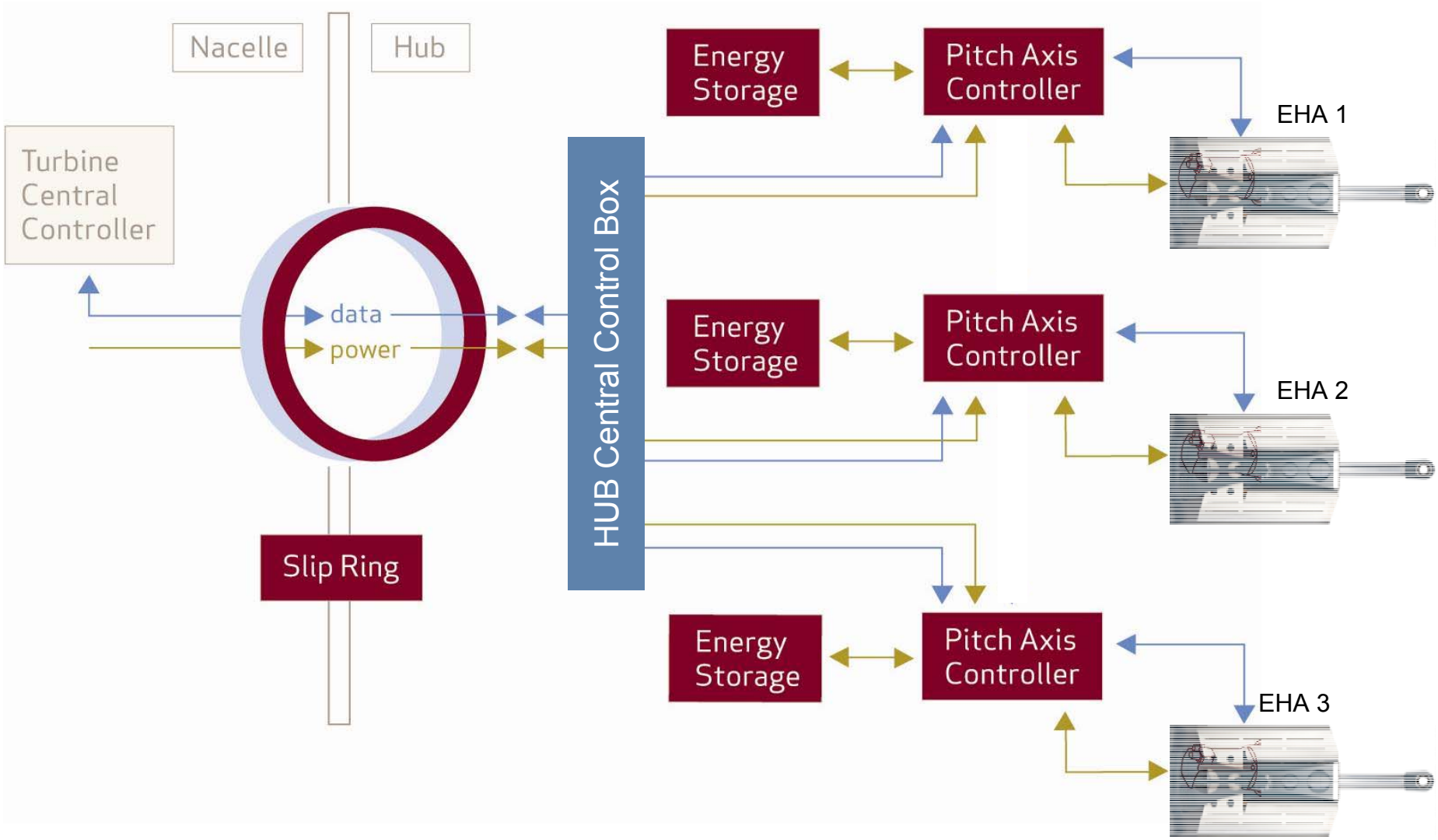


APLICATION - BLADE PITCH CONTROL

Wind Turbine

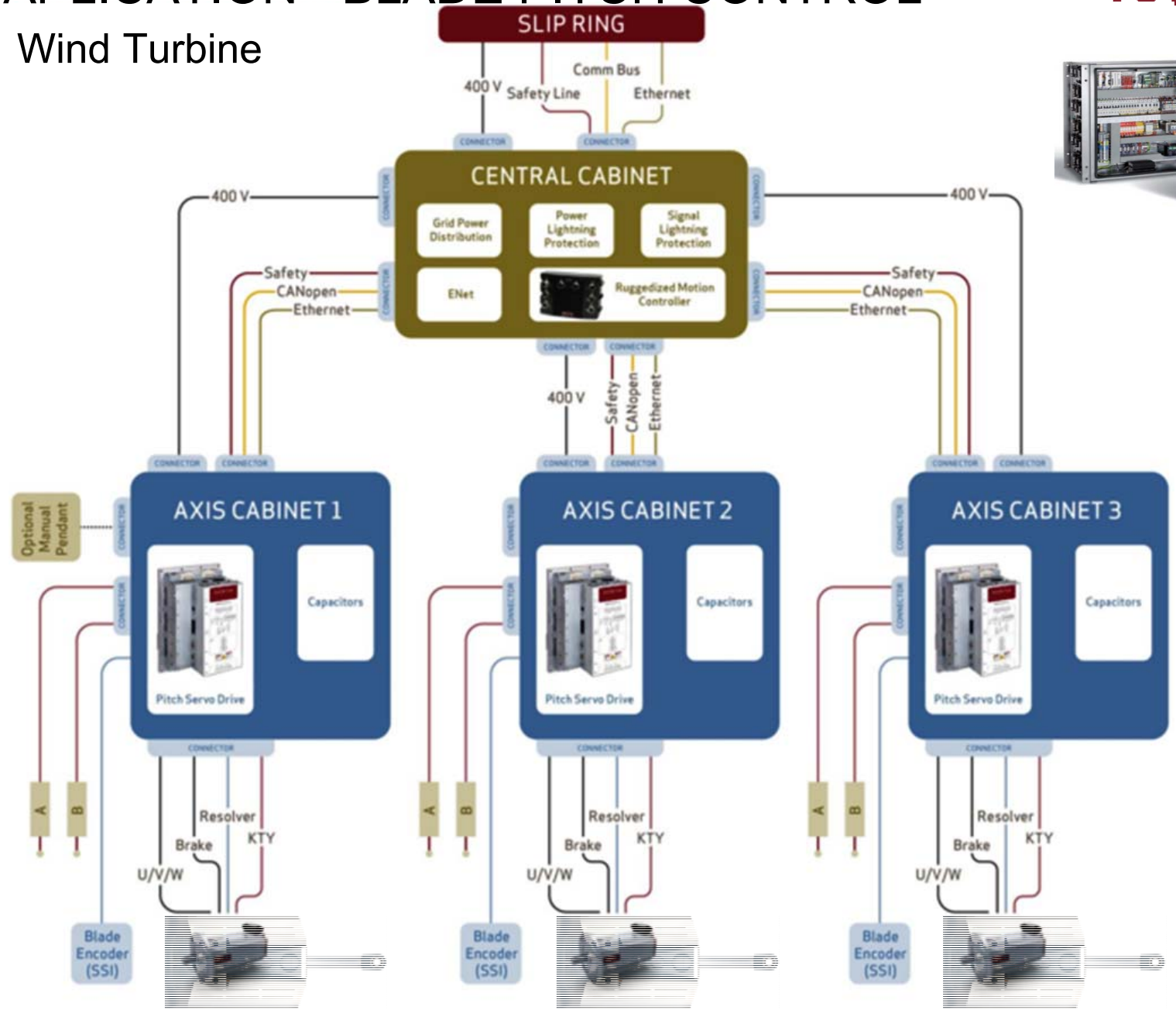
APLICATION - BLADE PITCH CONTROL

Wind Turbine



APLICATION - BLADE PITCH CONTROL

Wind Turbine



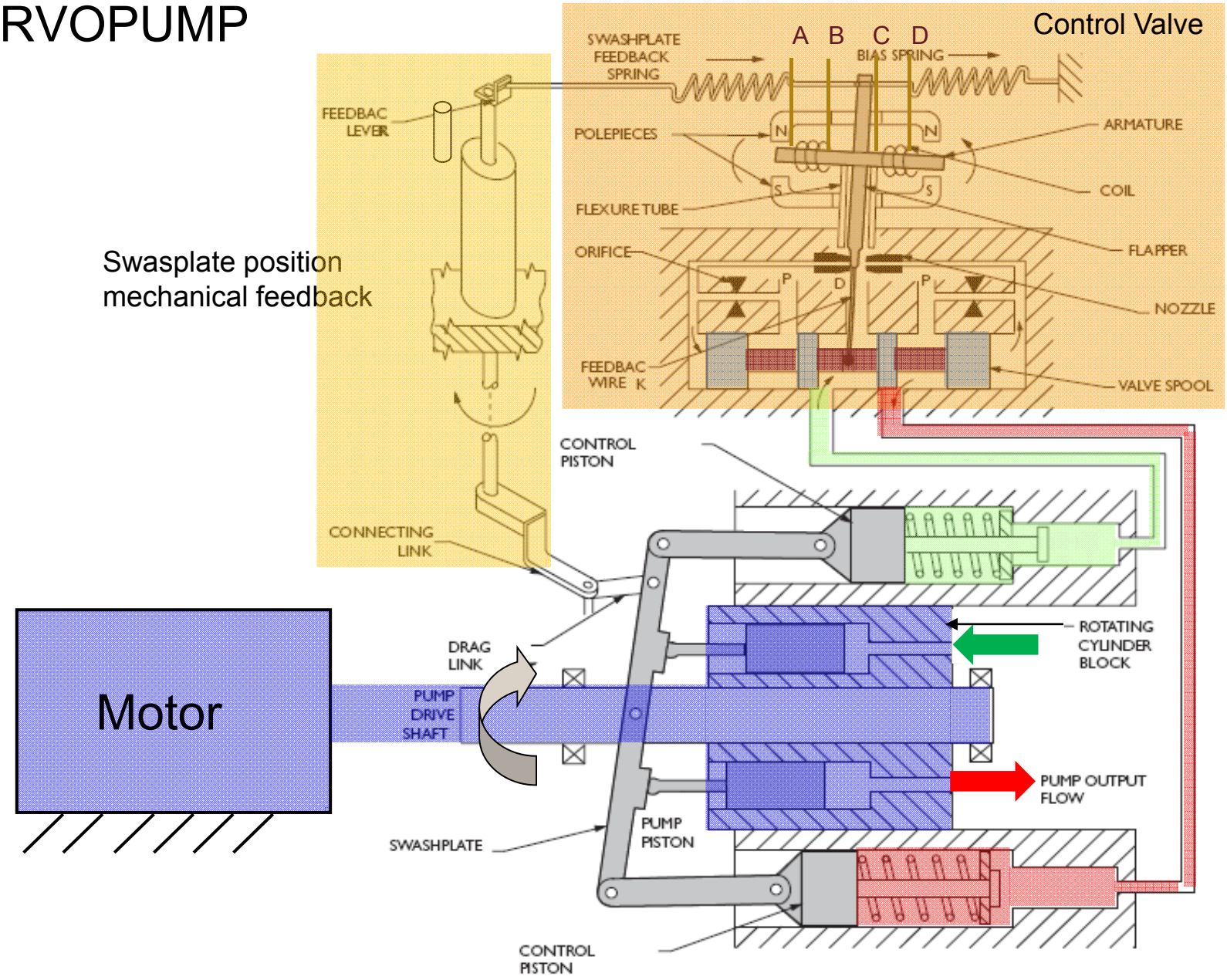
That’s all folks!

For additional info, please contact : Mario Valdo
mvaldo@moog.com
phone: +55 (11) 3572-0404

MOOG do Brasil Controles Ltda
Rua Prof Campos de Oliveira, 338
04675-100 São Paulo –SP
Phone :+55 (11) 3572-0400
info.brazil@moog.com
www.moog.com.br

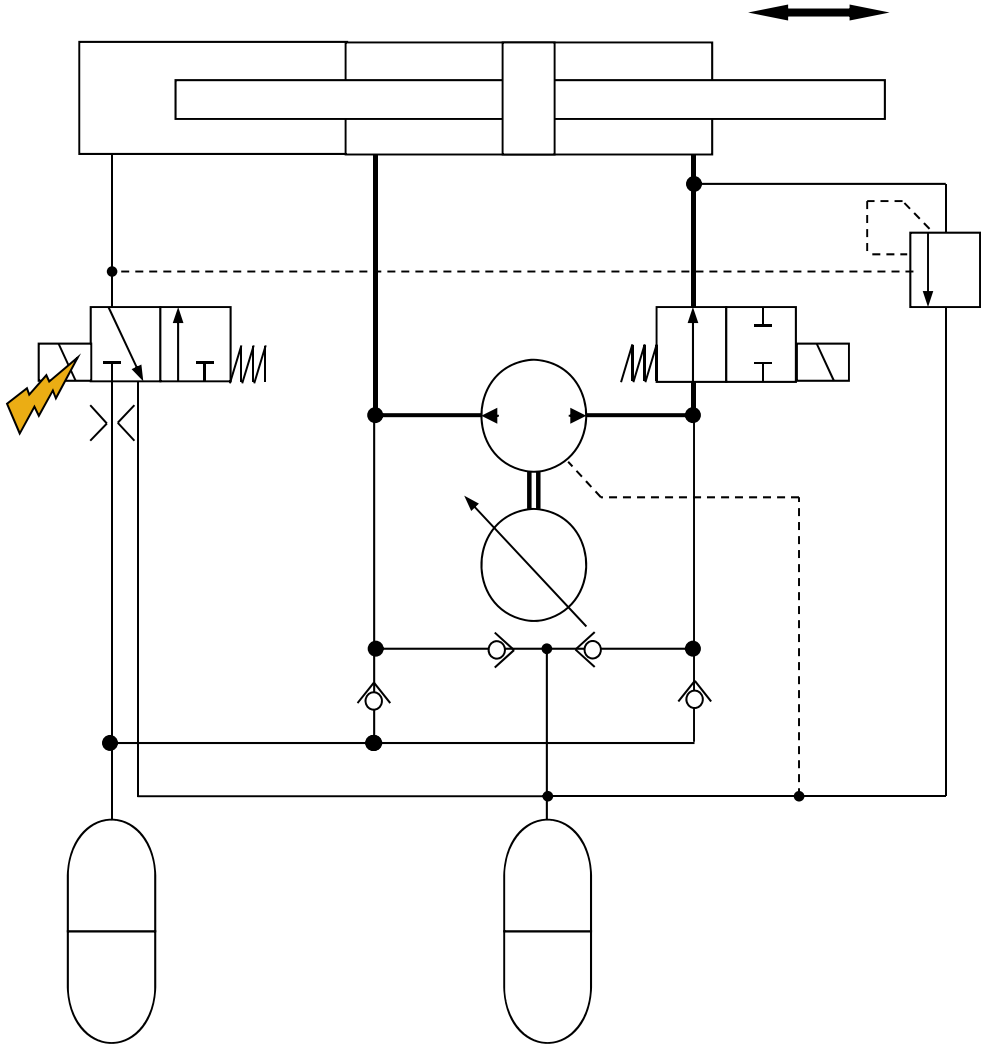
HYDROSTATIC TRANSMISSION SERVOPUMP

Swasplate position mechanical feedback



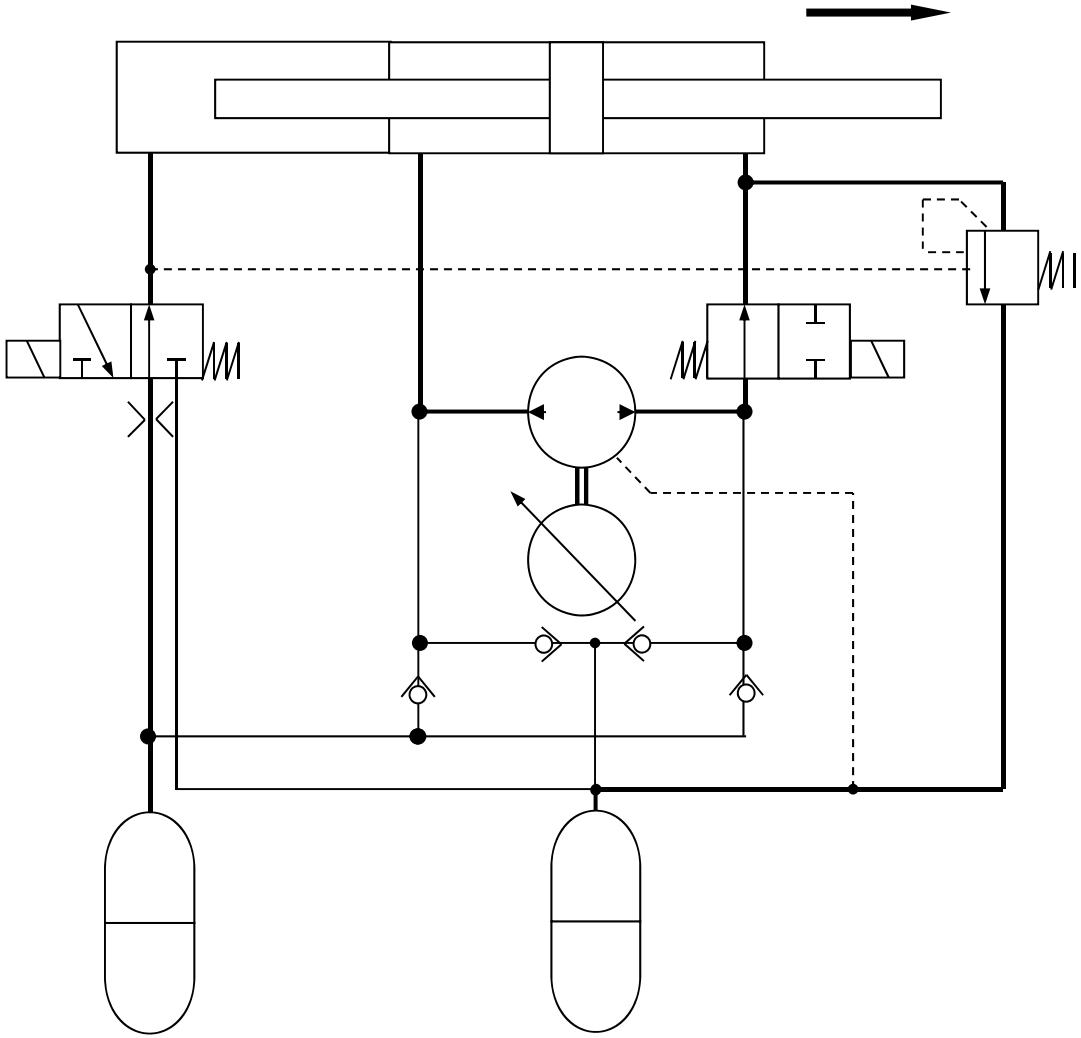
EHA – SAFETY BALANCED CYLINDER

Normal Operation



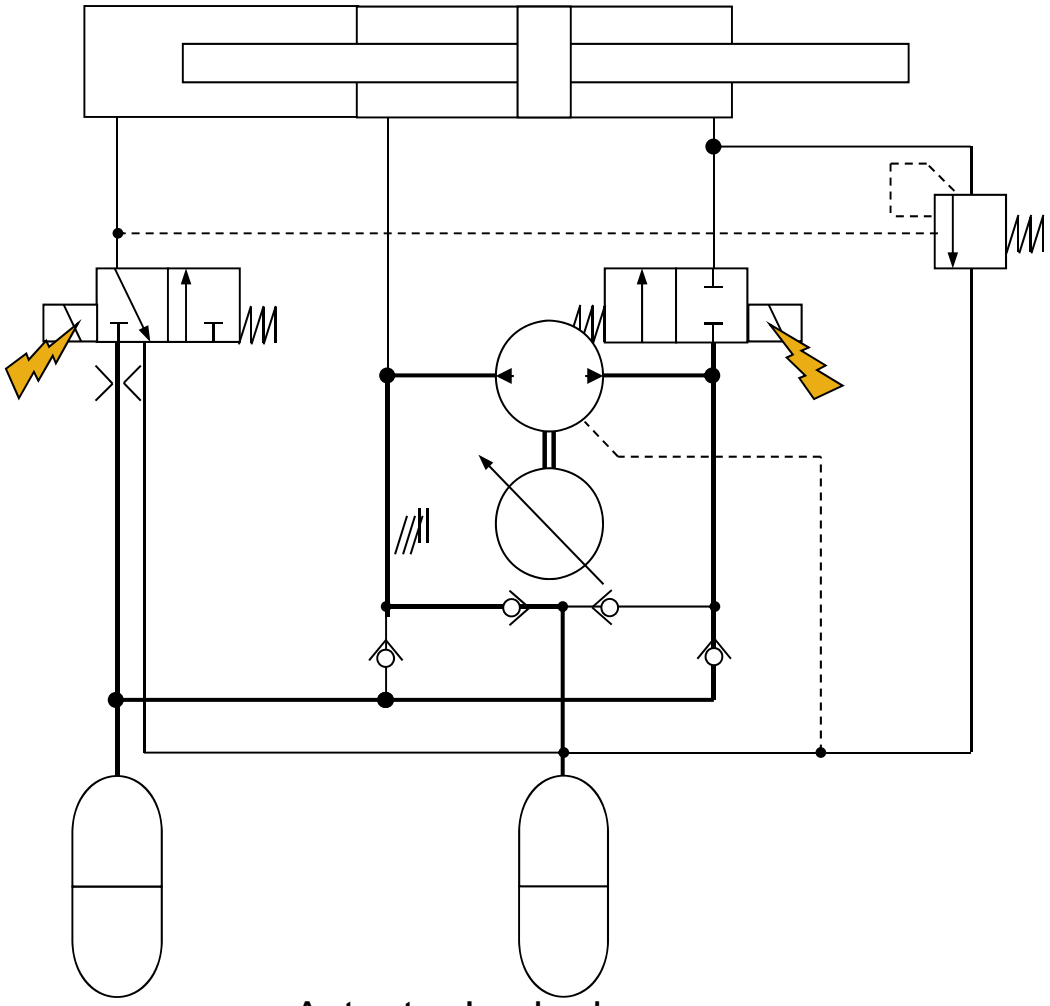
EHA – SAFETY BALANCED CYLINDER

Fail-Safe Movement

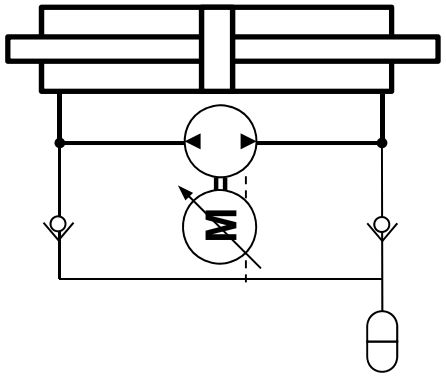


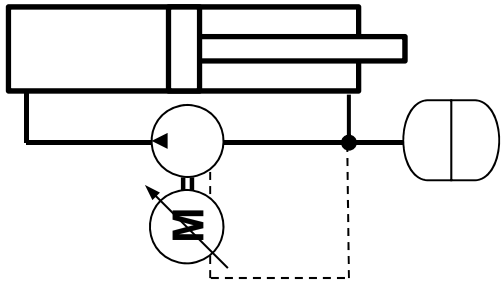
EHA – SAFETY BALANCED CYLINDER

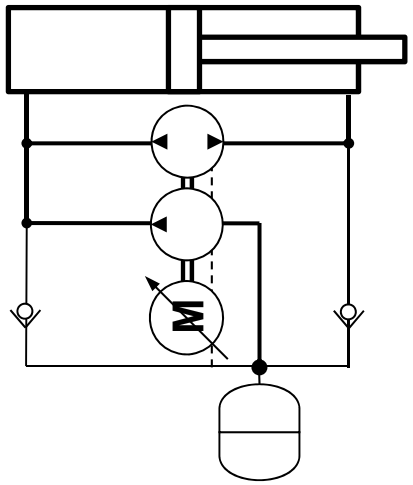
Accumulator Recharge



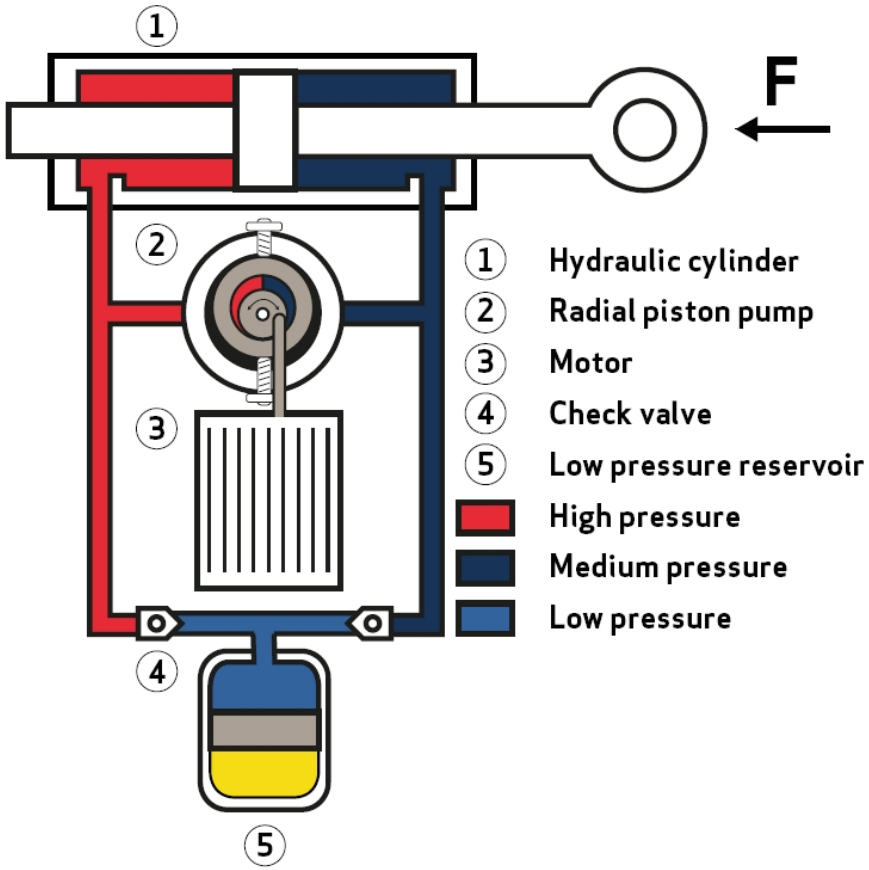
Actuator Locked


M


M


M

Electro-**H**ydrostatic **A**ctuation



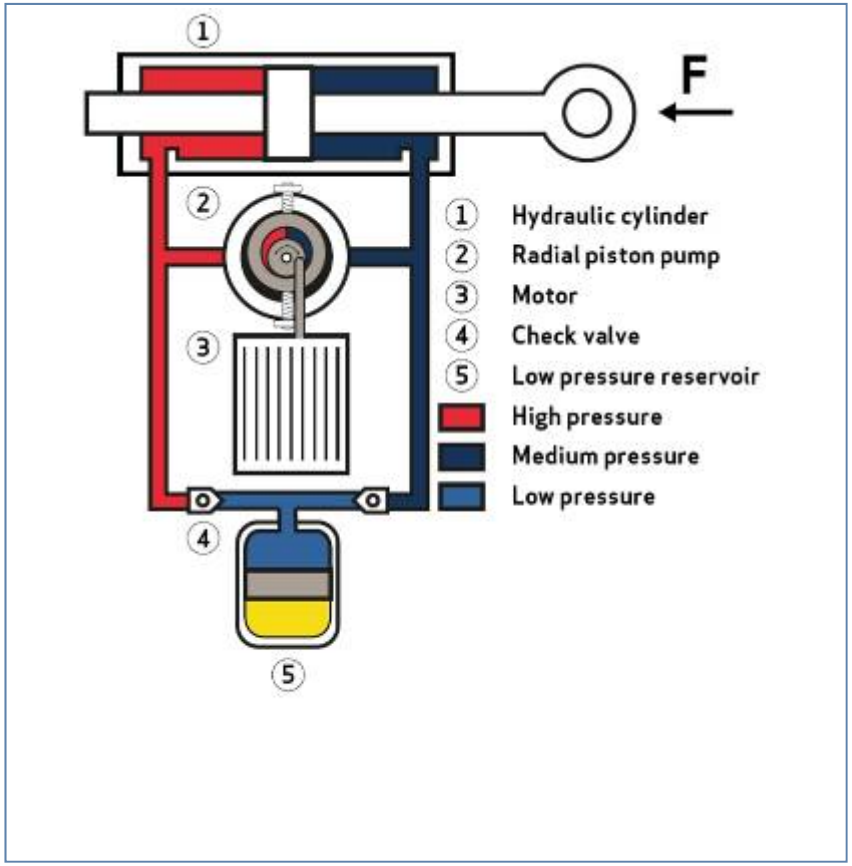
EHA characteristics

- Power on demand,
  Energy efficient,
  Energy recovery
- Powered by wire
  Self-contained
  No hydraulic piping
- Additional features
  e.g. fail safe
- Low noise
- High force capability

Electro-Hydrostatic Actuation

MOOG

Balanced EHA



Unbalanced EHA