INTRODUCTION

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CONTROL ENGINEERING WITH PYTHON

- 📖 Course Materials
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- 🏛️ ITN, Mines Paris - PSL University

SYMBOLS

	Code		Worked Example
	Graph		Exercise
	Definition		Numerical Method
	Theorem		Analytical Method
	Remark		Theory
	Information		Hint
	Warning		Solution

🏷️ CONTROL THEORY

A field of Mathematics that deals with the

- **modelling**,
- **analysis** and
- **control**.

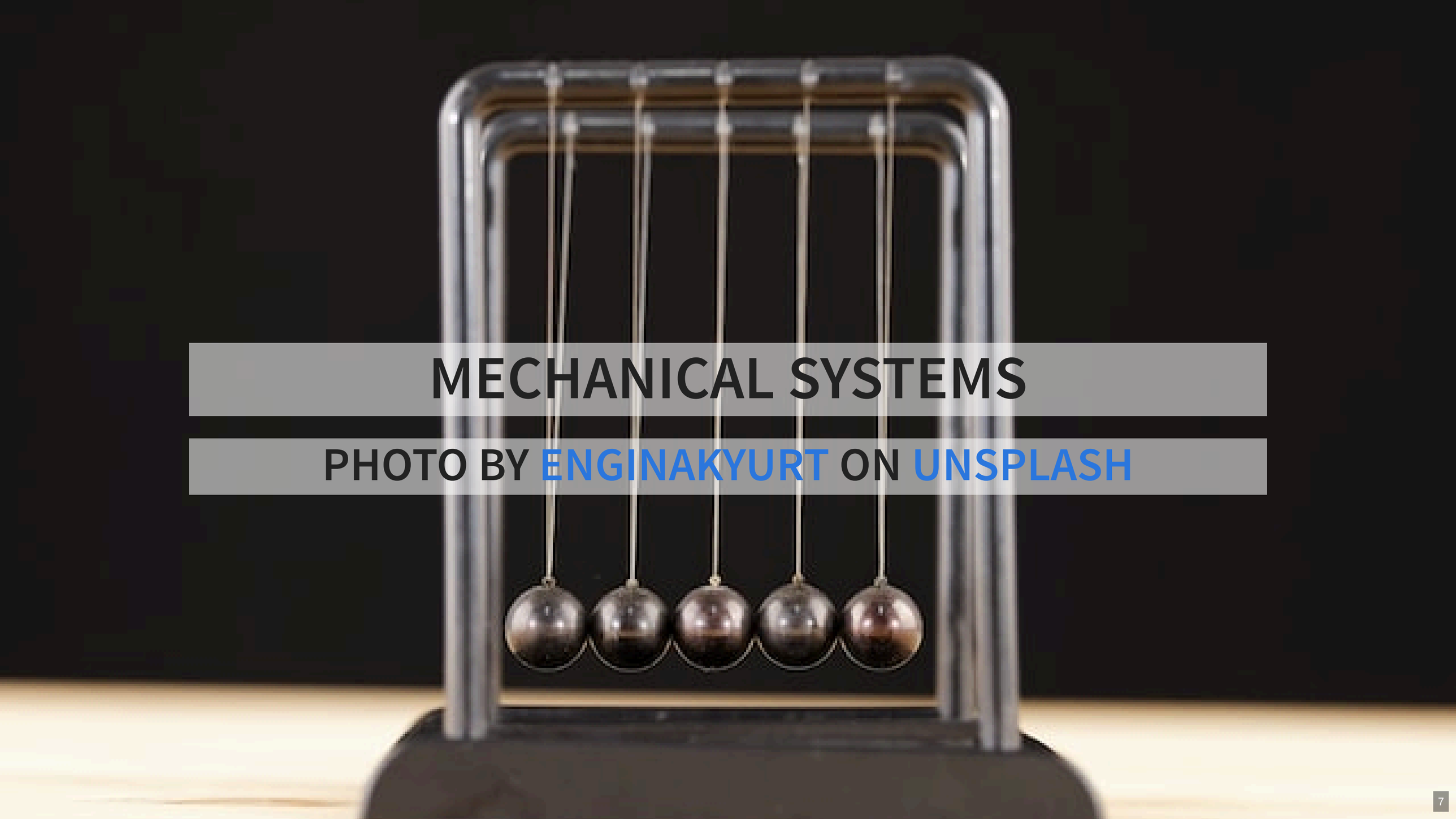
of abstract **dynamical systems**.

🇺🇸 Control Theory $\longrightarrow$ 🇫🇷 **Automatique**.

🏷️ DYNAMICAL SYSTEMS (ABSTRACT)

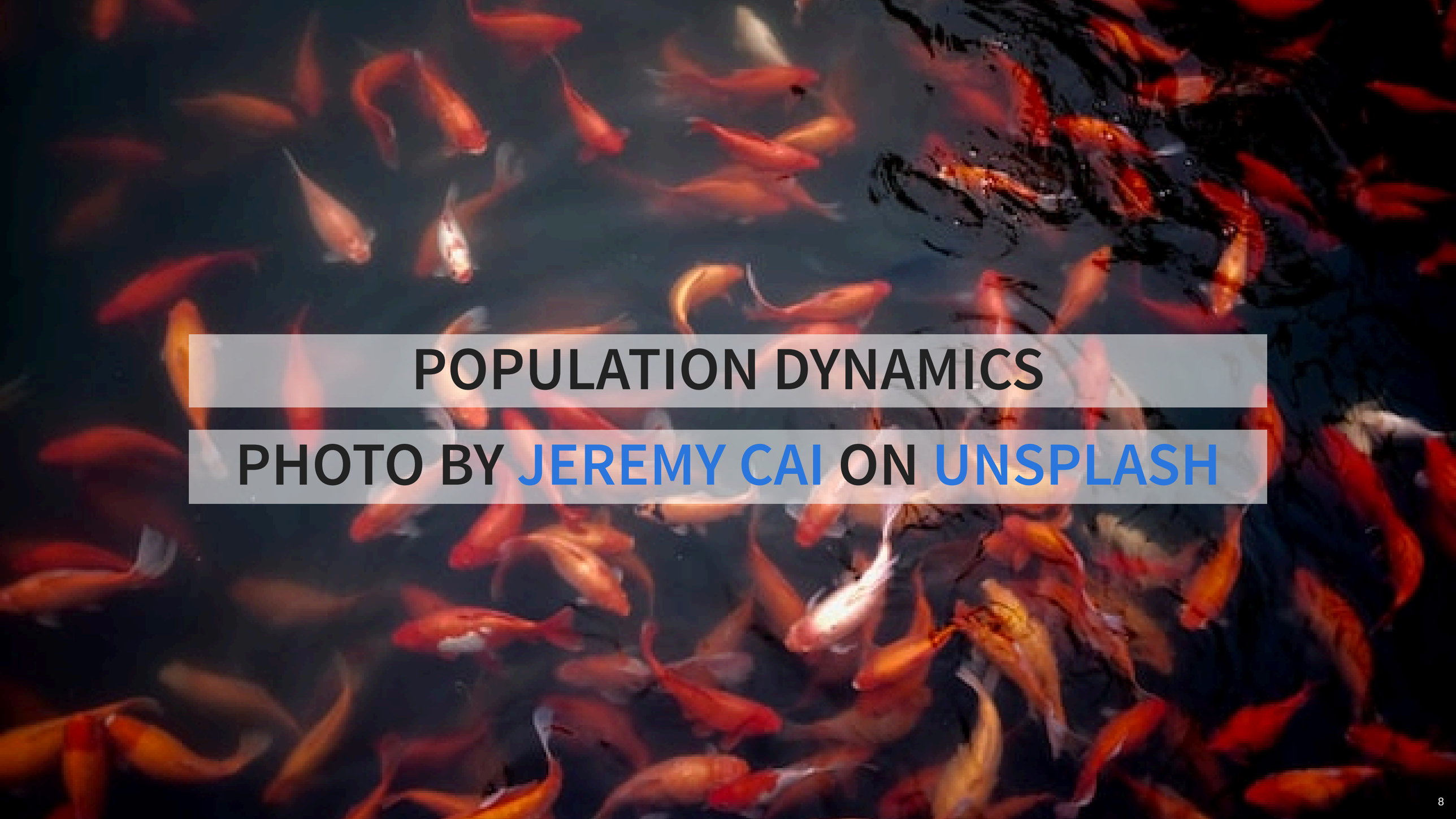
- Described by a set of time-dependent variables,
- which are governed by mathematical equations,
- that connects the system past, present and future.

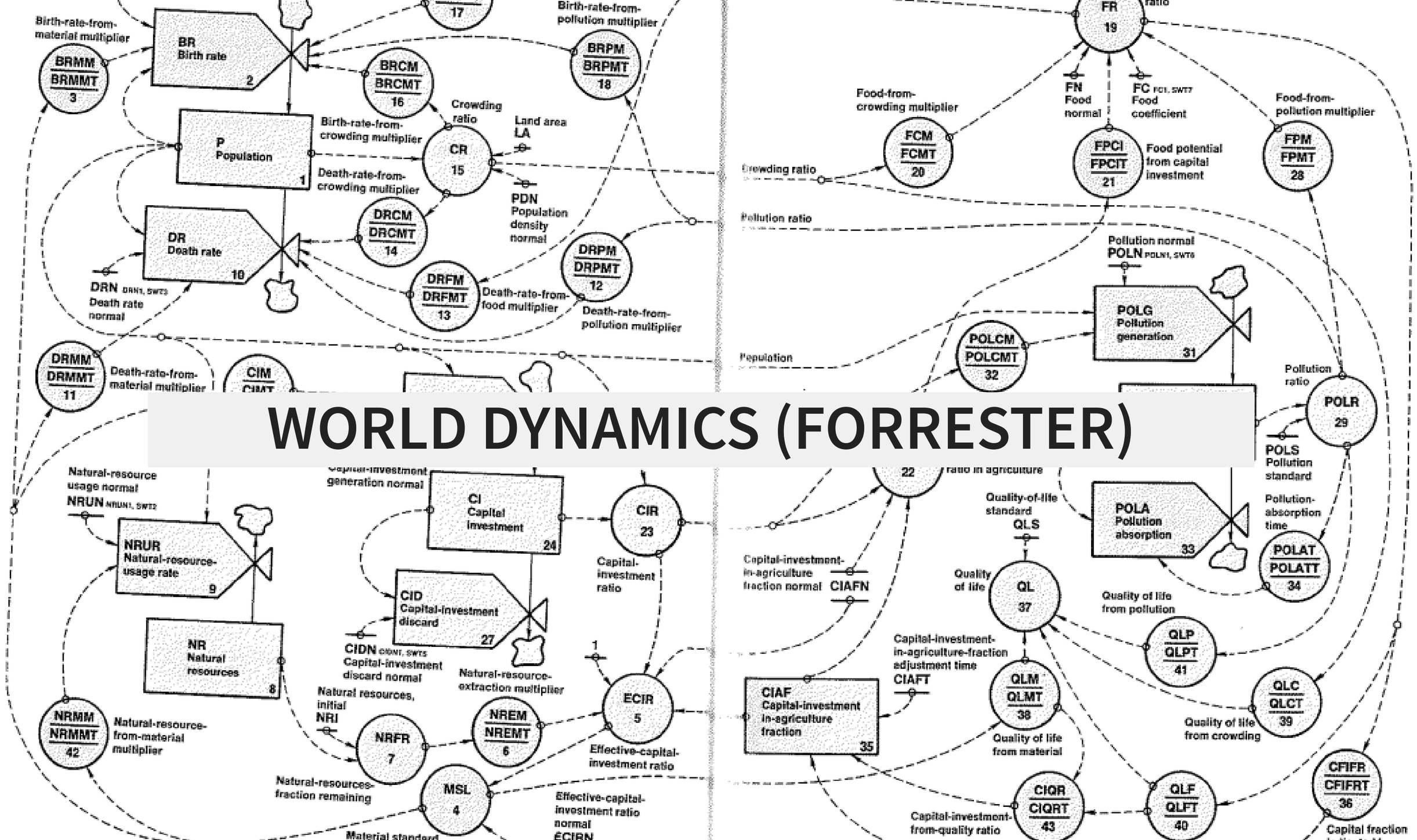
EXAMPLES

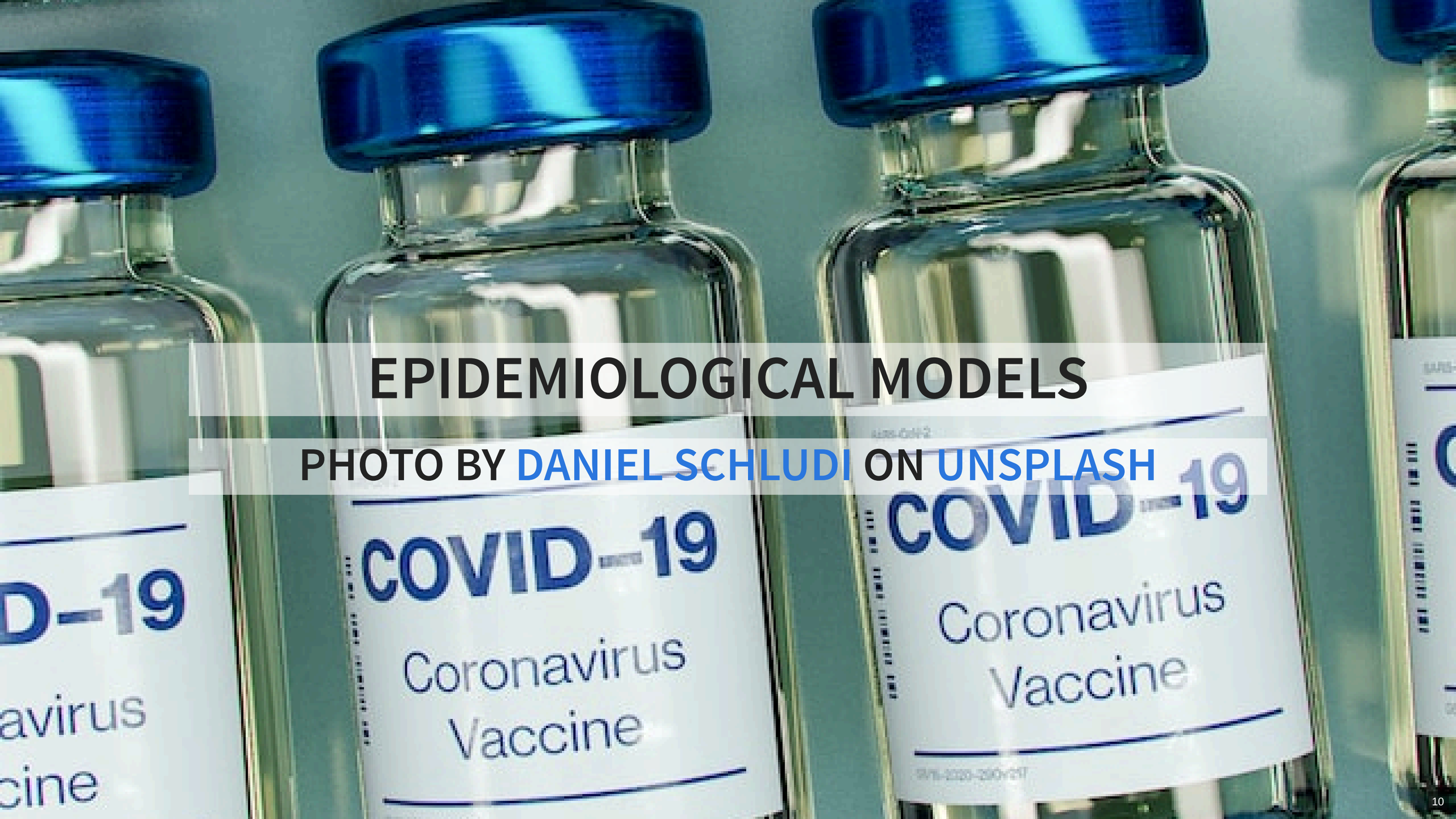


MECHANICAL SYSTEMS

PHOTO BY ENGINAKYURT ON UNSPLASH


POPULATION DYNAMICS
PHOTO BY JEREMY CAI ON UNSPLASH


WORLD DYNAMICS (FORRESTER)
Birth-rate-from-material multiplier
BRMM BRMMT 3
BR Birth rate 2
BRCM BRCMT 16
BRPM BRPMT 18
Birth-rate-from-pollution multiplier
Crowding ratio
Land area LA
P Population 1
Birth-rate-from-crowding multiplier
CR 15
Death-rate-from-crowding multiplier
PDN Population density normal
DRCM DRCMT 14
DR Death rate 10
DRN DRN1, SWT3 Death rate normal
DRFM DRFMT 13
Death-rate-from-food multiplier
DRPM DRPMT 12
Death-rate-from-pollution multiplier
DRMM DRMMT 11
Death-rate-from-material multiplier
Food-from-crowding multiplier
FCM FCMT 20
FN Food normal
FC FC1, SWT7 Food coefficient
FR 19
Food-from-pollution multiplier
FPM FPMT 28
Crowding ratio
FPCI FPCIT 21
Food potential from capital investment
Pollution ratio
Pollution normal POLN POLN1, SWT6
POLG Pollution generation 31
POLCM POLCMT 32
Population
Pollution ratio
POLR 29
POLS Pollution standard
Natural-resource usage normal NRUN NRUN1, SWT2
NRUR Natural-resource-usage rate 9
NR Natural resources 8
Capital-investment generation normal
CI Capital investment 24
CIR 23
Capital-investment ratio
CID Capital-investment discard 27
CIDN CIDN1, SWT5 Capital-investment discard normal
Natural-resource-extraction multiplier
Natural resources, initial NRI
NRFR 7
NREM NREMT 6
ECIR 5
Effective-capital-investment ratio
Natural-resources-fraction remaining
MSL 4
Effective-capital-investment ratio normal ECIRN
Material standard
NRMM NRMMT 42
Natural-resource-from-material multiplier
22
ratio in agriculture
Quality-of-life standard QLS
POLA Pollution absorption 33
Pollution-absorption time
POLAT POLATT 34
Capital-investment-in-agriculture fraction normal CIAFN
Quality of life
QL 37
Quality of life from pollution
QLP QLPT 41
Capital-investment-in-agriculture-fraction adjustment time CIAFT
CIAF Capital-investment in-agriculture fraction 35
QLM QLMT 38
QLC QLCT 39
Quality of life from material
Quality of life from crowding
CFIFR CFIFRT 36
Capital-investment-from-quality ratio
CIQR CIQRT 43
QLF QLFT 40
Capital fraction



EPIDEMIOLOGICAL MODELS

PHOTO BY DANIEL SCHLUDI ON UNSPLASH

🏷️ CONTROL ENGINEERING

Apply Control Theory to **design & build** concrete dynamical systems with specified behaviors.

Overlaps with and complements:

- 🔌 Electrical Engineering
- 🔧 Mechanical Engineering
- 🖥️ Software Engineering
- …

APPLICATIONS

ROBOTICS

POSSESSED PHOTOGRAPHY ON UNSPLASH

🤖 OR 🧑?

Consider:

- 💸 Cost analysis
- 🎨 Creative/complex work?
- 🦾 Strength, speed, precision
- 🏜️ Hostile work environment

MANUFACTURING

EUROFIGHTER TYPHOON

PHOTO BY RAY HARRINGTON ON UNSPLASH

- twin-engine, canard delta wing, multirole fighter
- air superiority fighter / agile / dogfighter
- ⚠️ **aerodynamically unstable in subsonic flight!**

“The design of the Typhoon is such that without input to any control surfaces the aircraft will pitch up during flight extremely quickly.”

“Although this improves the agility of the aircraft it also requires a system to enable controlled flight to be maintained.”

“This is achieved through the Fly By Wire 🏷️ **Flight Control System** […].”

“With this system the pilot has no direct link to any of the aircraft’s control surfaces.”

“Instead, **all movements of the throttle, stick or pedals are interpreted by the FCS and an appropriate control response taken.**”

LEARN MORE

- 📖 Negative Stability (Aerodynamics)
- 📖 Eurofighter Typhoon FCS
- 🖼️ Eurofighter Typhoon Photos

BOEING 737 MAX

PHOTO BY JUSTIN HU ON UNSPLASH

BOEING 737 MAX

4th generation of Boeing 737.

Larger and more powerful engines.

→ ⛽ fuel consumption reduced by 14%

→ 💸 profit!

→ ⚠️ engines located further forward and higher

→ ⚠️ pitch-up tendency that needs to be controlled

→ 🏷️ **Maneuvering Characteristics Augmentation System (MCAS)**

FATAL CRASHES

✈️ **Lion Air Flight 610** (2018, Indonesia)

“MCAS pushing the aircraft into a dive due to data from a faulty angle-of-attack sensor.”

✈️ **Ethiopian Airlines Flight 302** (2019, Ethiopia)

“Evidence suggests, that […] the aircraft was configured to dive, similar to Lion Air Flight 610.”

→ 🛑 **global 737 MAX groundings.**

LEARN MORE

- 📖 Boeing 737 Max (Wikipedia)
- 📖 Boeing MCAS
- 📰 Boeing 737 Max Plane Crashes
- 📰 What is the Boeing 737 Max MACS?
- 📰 Boeing 737 Max adjustable stabilizer

ROCKET BOOSTER LANDING

🚀 SPACEX'S STARSHIP

ADAS & SELF-DRIVING CARS

- 🏷️ **ADAS:** Advanced Driver-Assistance Systems
- 🏢 Tesla, Mercedes-Benz, Waymo, Comma, etc. 🎬
- 📅 **2026:**
  - We’re coming close to fully autonomous cars! 📰
  - Cars can be far safer when autonomous 📰

SAE AUTOMATION LEVELS

🏷️ **SAE** : Society of Automobile Engineers

- **Level 0:** 👨 No automation: warnings, alerts, etc.
- **Level 1:** 👨/🤖 single-task assist (e.g. speed control)
- **Level 2:** 👨/🤖 many-task assist ← Telsa Autopilot
- **Level 3:** 🤖/👨 ← Mercedes Drive Pilot (2021)
- **Level 4:** 🤖 ← Waymo (2022), Mercedes (2024 🔧)
- **Level 5:** 🤖 fully self-driving ← 🚀 Not achieved yet

- ADAS Level 3-5 system design is mostly Machine Learning (see for example the official Waymo's blog)
- ADAS Level 0-2 system design is mostly Control Engineering.

LEVEL 1 ADAS

Single feature automation.

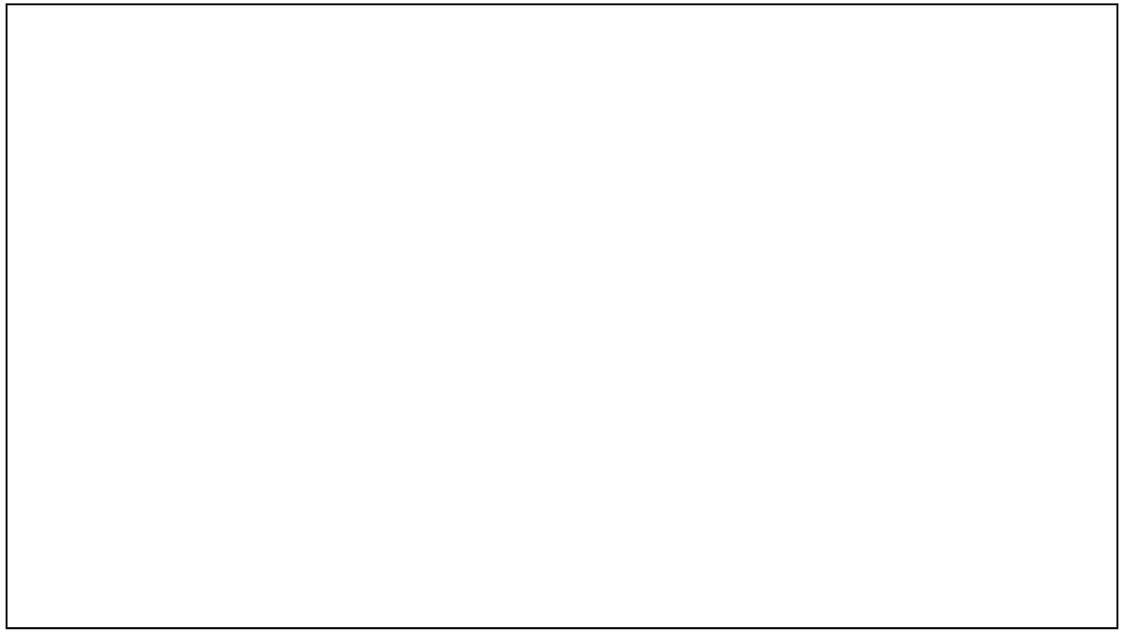
- 🏷️**CAS: Collision avoidance systems**
- 🏷️ **CC: Cruise control**

🏷️ ACC: CAS + CC

ADAPTATIVE CRUISE CONTROL

🏷️ ESC/ESP

ELECTRONIC STABILITY CONTROL



LEARN MORE

- 📰 Tesla’s self-driving technology fails to detect children […]
- 📰 Mercedes Drive Pilot Beats Tesla Autopilot By Taking Legal Responsibility
- 📰 Mercedes-Benz Wins World’s First Approval For Level 3 Autonomous Cars
- 📖 ADAS, CAS, CC, ACC, ESC/ESP.