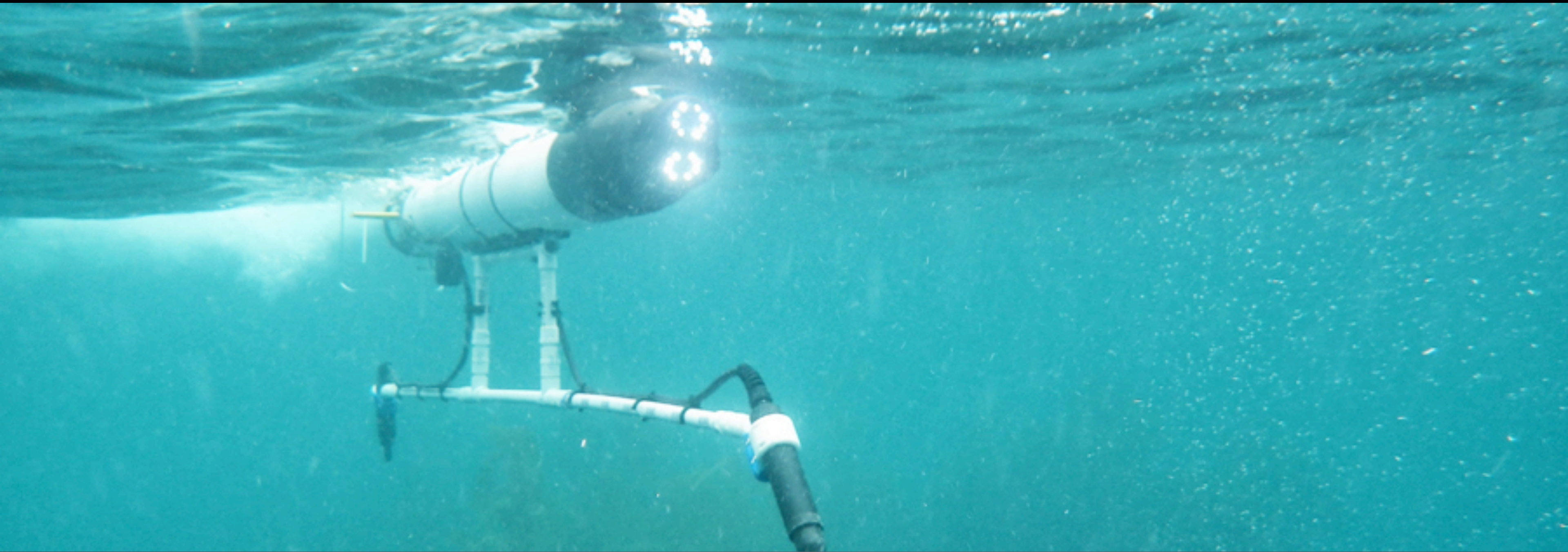
E11 - Autonomous Vehicles

Signals and Systems



Outline

- Mechanical Systems
- Electrical Systems
- Name that System

Mechanical Systems

- They are Everywhere!

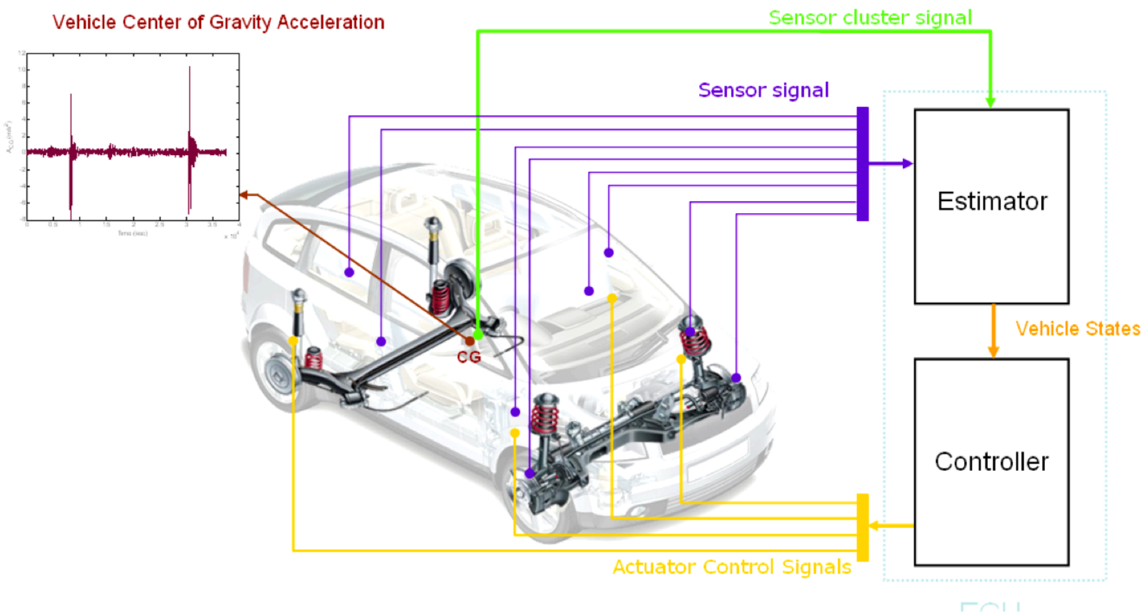
http://www.contitech.de/pages/produkte/luftfedersysteme/nfz-ersatz/anwendung-ers_en.html

Mechanical Systems

Where to start?

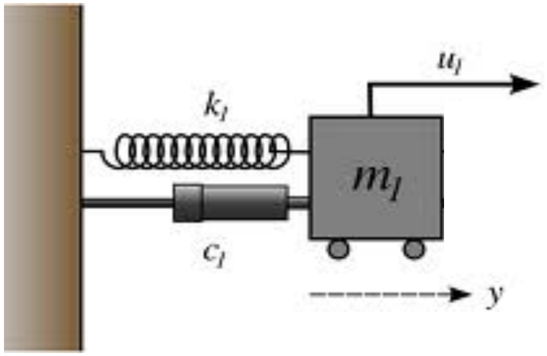
Mechanical Systems

- Model the System
  - Goal is to construct a mathematical model that characterizes the system dynamics
  - A model allows us to **control** a system!



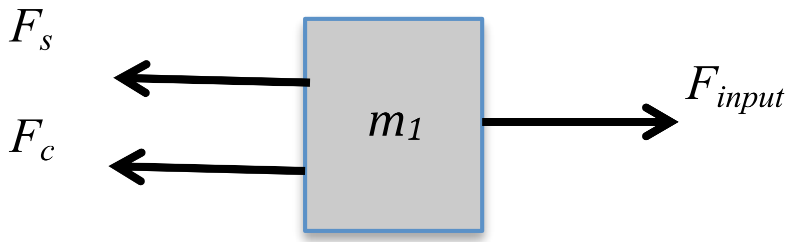
Mechanical Systems

- Step to Modeling
  1. Construct a Free body diagram
  2. Sum forces/Torques in each direction ($F = ma$)
  3. Derive the Differential Equations



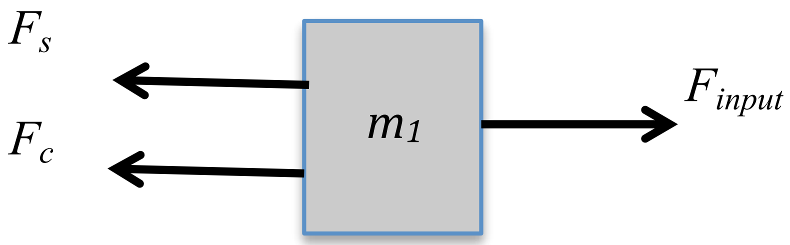
Mechanical Systems

- Free Body Diagram
  - Draw all forces acting on the system



Mechanical Systems

- $F = ma$
  - Sum forces/Torques in each direction



$$m_1\ddot{y}(t) = F_{input} - F_c - F_s$$

Mechanical Systems

- Derive the Differential Equations
  - Each direction will have its own equation

$$m_1 \ddot{y}(t) = F_{input} - F_c - F_s$$

$$m_1 \ddot{y}(t) = u_1(t) - c_1 \dot{y}(t) - k_1 y(t)$$

$$m_1 \ddot{y}(t) + c_1 \dot{y}(t) + k_1 y(t) = u_1(t)$$

Mechanical Systems

- What do we do with this equation?

$$m_1 \ddot{y}(t) + c_1 \dot{y}(t) + k_1 y(t) = u_1(t)$$

  - Analyze
  - Control

Mechanical Systems

- Analyze
  - Consider no input, i.e. $u_1(t)=0$

$$m_1\ddot{y}(t) + c_1\dot{y}(t) + k_1 y(t) = 0$$

  - Is there a solution to this equation, in other words, what is $y(t)$?

$$y(t) = Ae^{st}$$

Mechanical Systems

- Control
  - What if you can construct the input?
  - E.g.

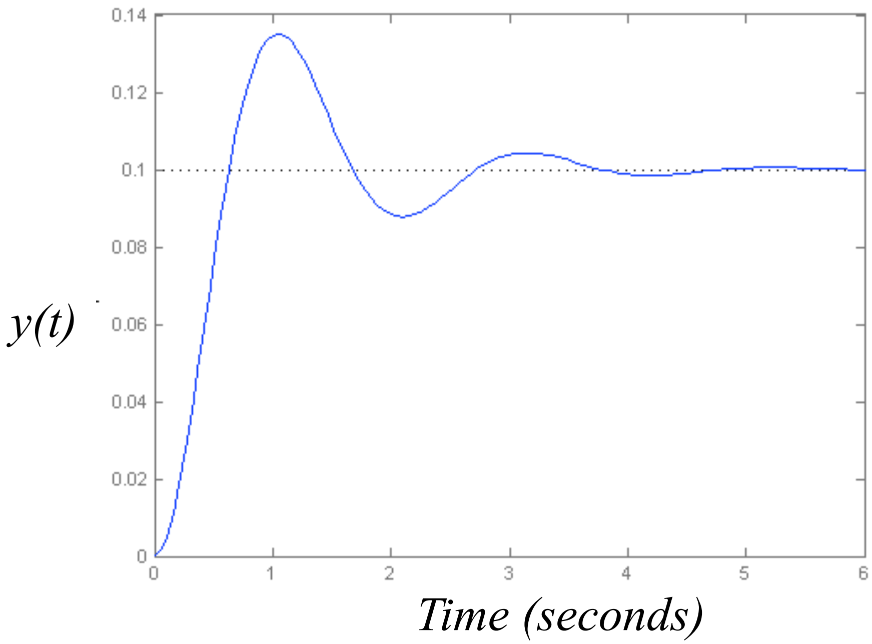
$$u_1(t) = K(y_{des} - y(t))$$

  - Now Analyse

$$m_1 \ddot{y}(t) + c_1 \dot{y}(t) + k_1 y(t) = K(y_{des} - y(t))$$

Mechanical Systems

- System Response

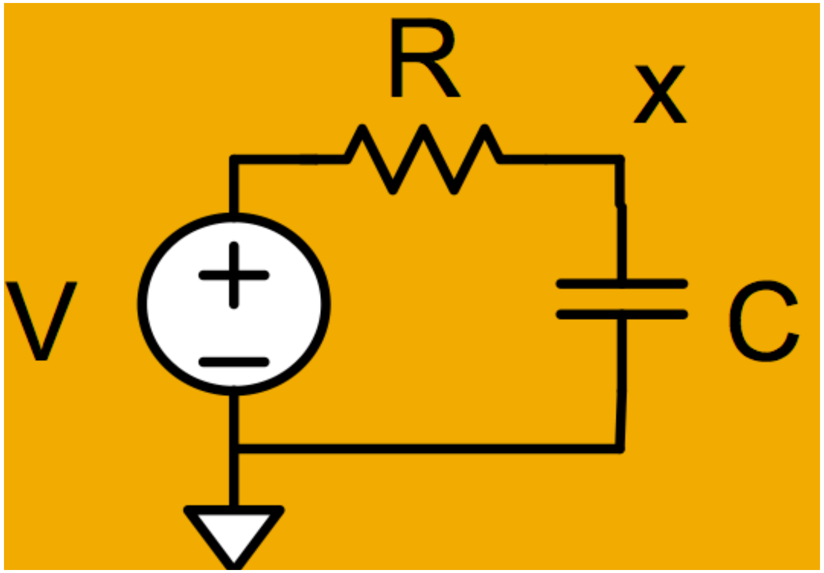


Outline

- Mechanical Systems
- Electrical Systems
- Name that System

Electrical Systems

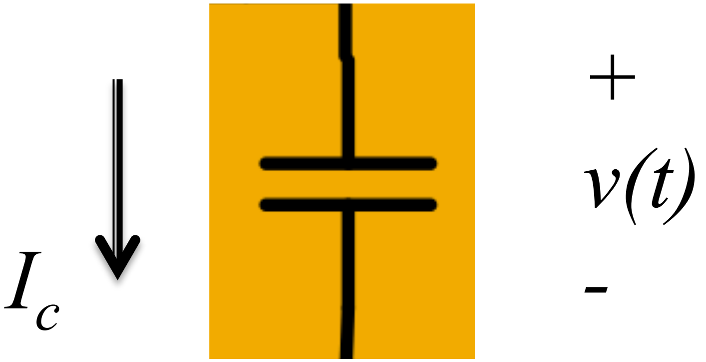
- Can we do something similar for circuits?



Electrical Systems

- Note: The current across a capacitor is

$$I_c = C\,\dot{v}(t)$$

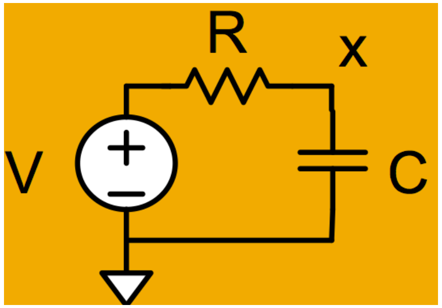


Electrical Systems

- Recall KCL and and apply it to x:

Current into x

$$I_{in} = (\, V(t) - x(t) \,) / R$$



Current out of x

$$I_{out} = C\,\dot{x}(t)$$

KCL

$$I_{in} = I_{out}$$

Electrical Systems

- Substituting

$$(V(t) - x(t)) /R = C \dot{x}(t)$$

$$(V(t) - x(t)) /RC = \dot{x}(t)$$

$$\dot{x}(t) + (RC)^{-1} x(t) = (RC)^{-1} V(t)$$

Mechanical & Electrical Systems

- Summary
  - We can derive mathematical models for both electrical and mechanical systems
  - Mathematically speaking, the electrical and mechanical systems can be the same
  - We can analyze the response of a systems using these models to predict system behavior

  - We can control these systems!

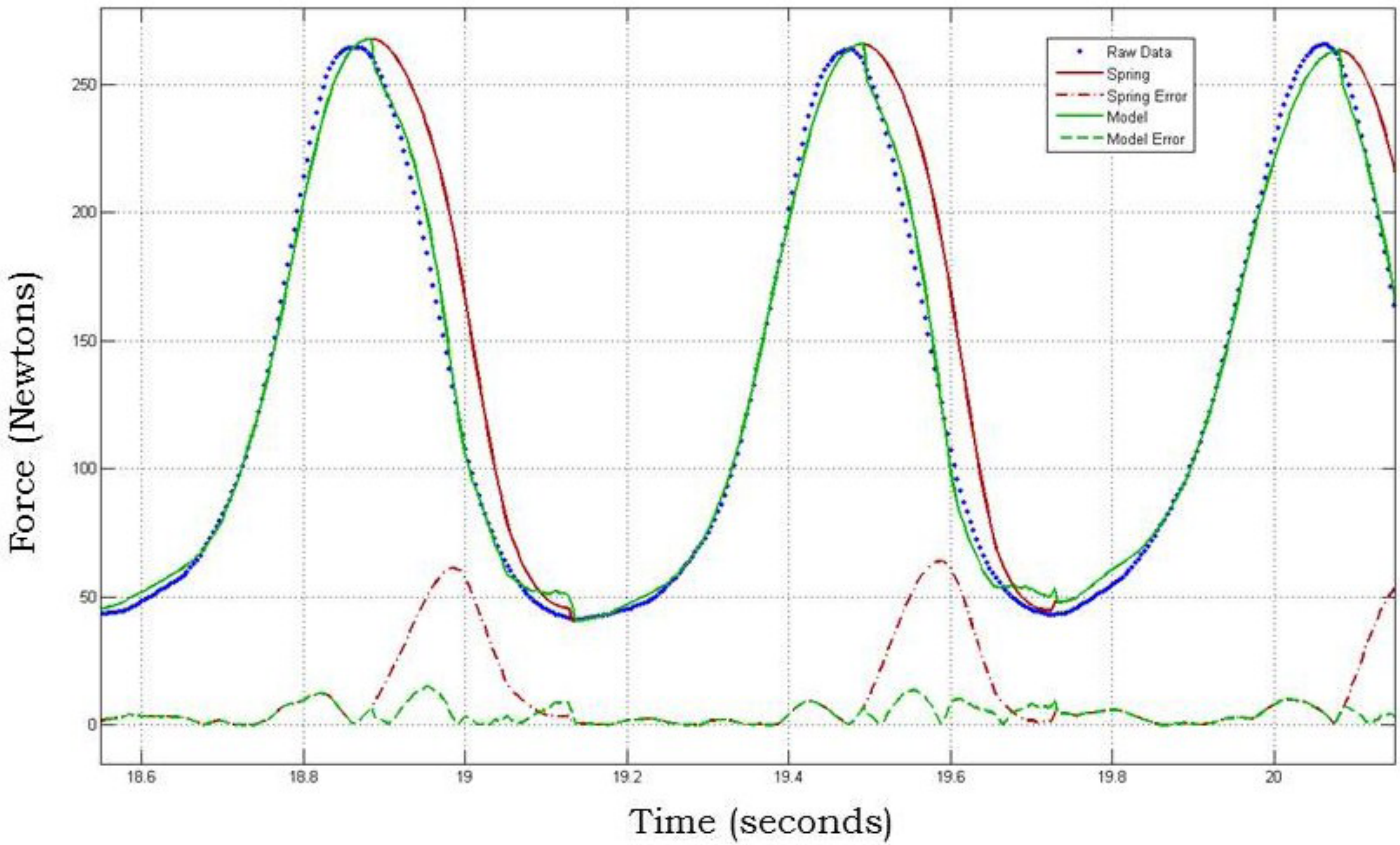
Mechanical & Electrical Systems

- Example 1
  - ROV Trajectory Tracking Control System

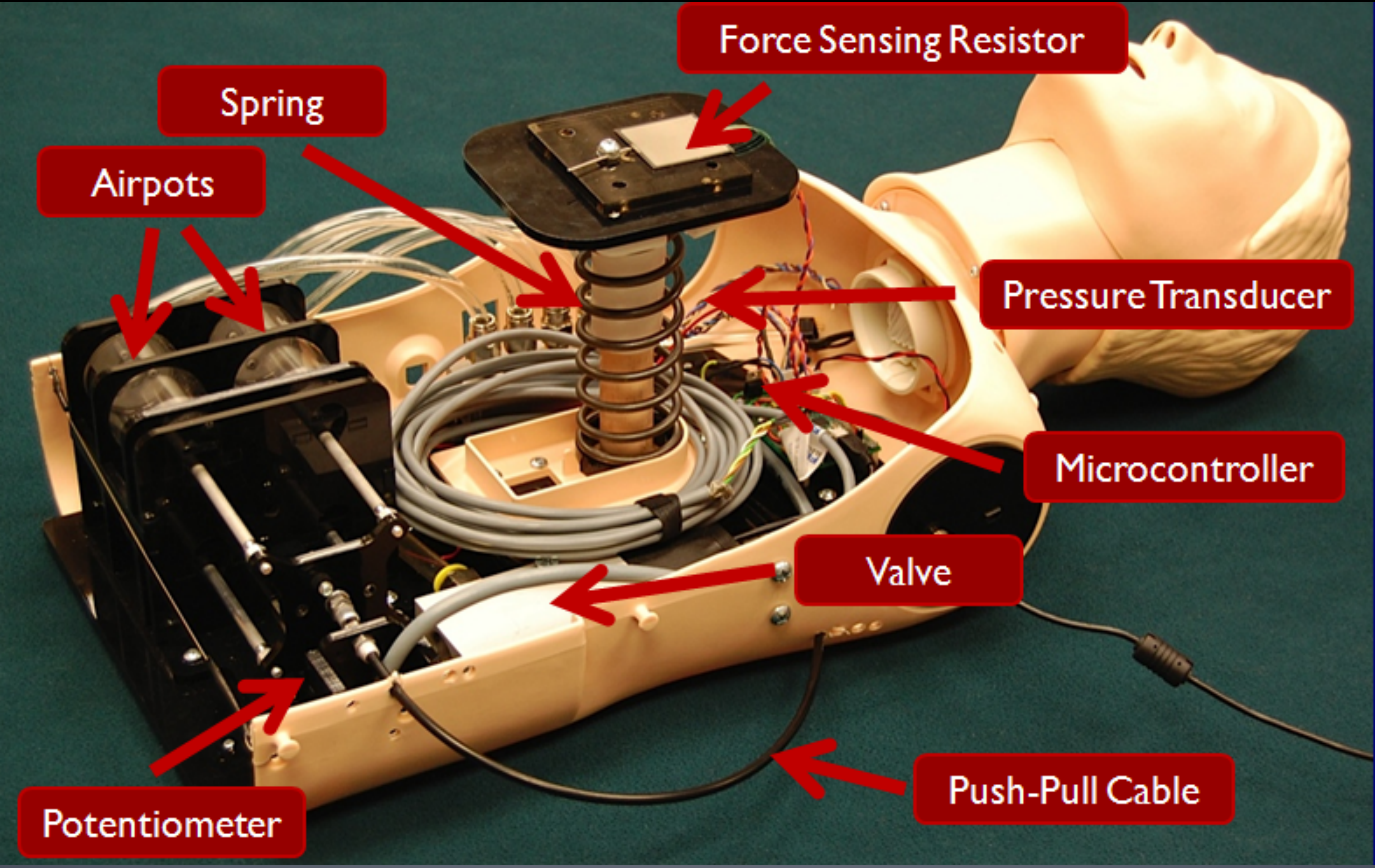
Mechanical & Electrical Systems

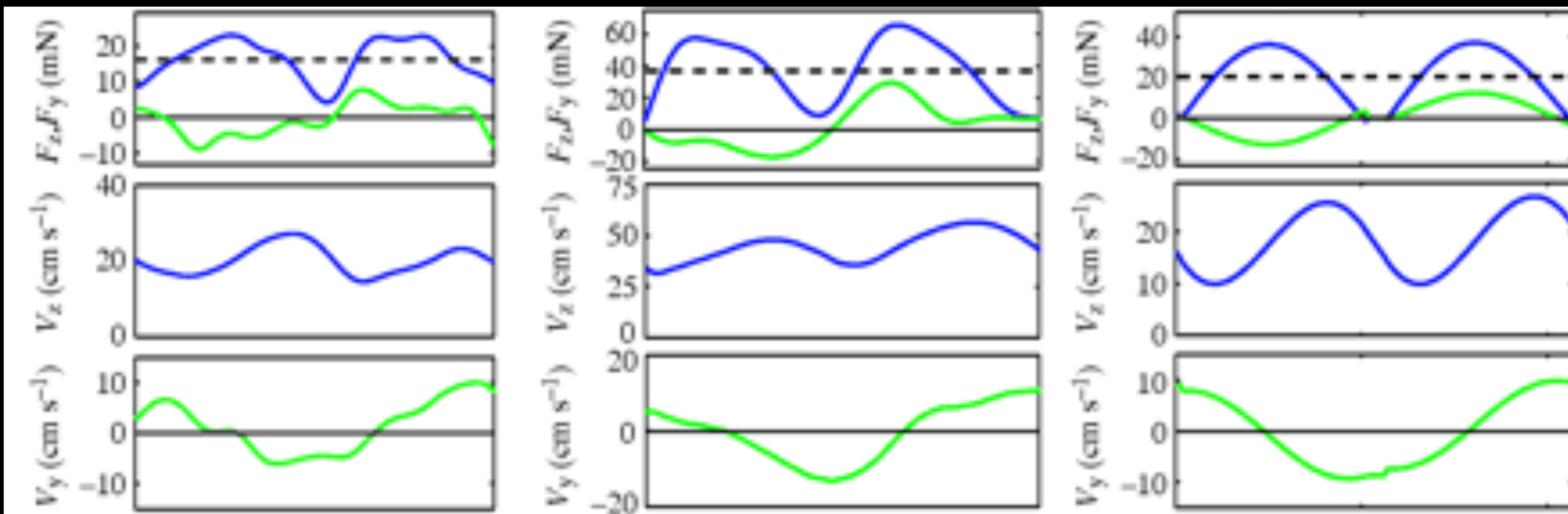
- Example 2
  - ROV Jelly Tracking Control System

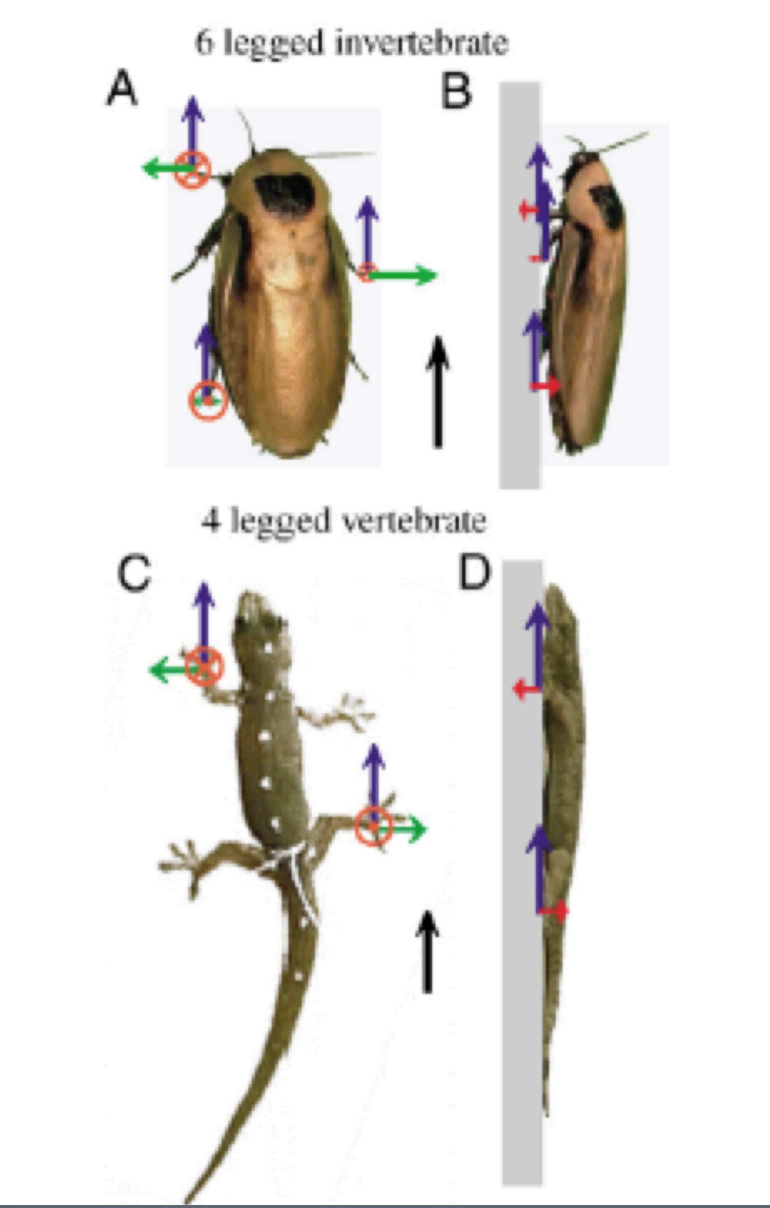
Name that Mass Spring System!

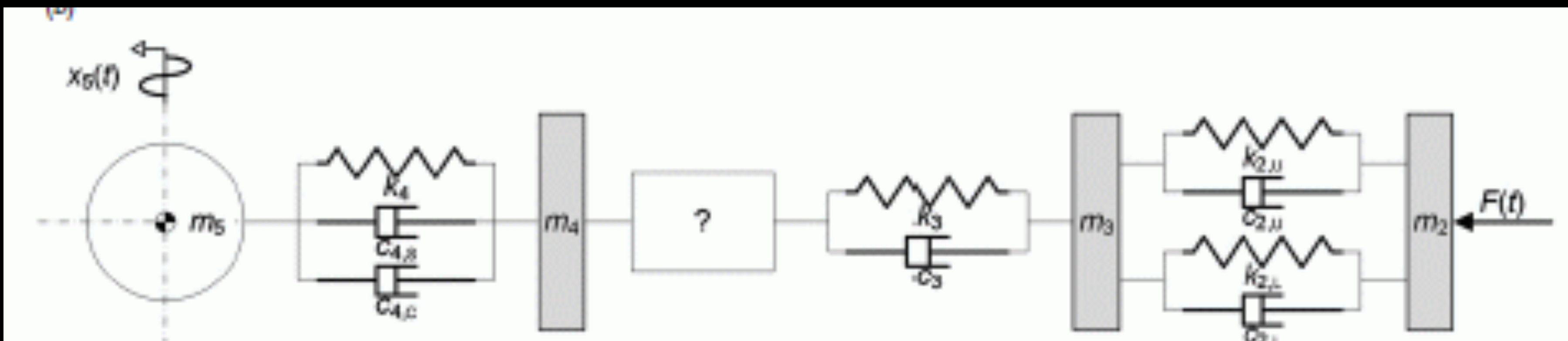


Raw Data
Spring
Spring Error
Model
Model Error
Force (Newtons)
Time (seconds)
0
50
100
150
200
250
18.6
18.8
19
19.2
19.4
19.6
19.8
20

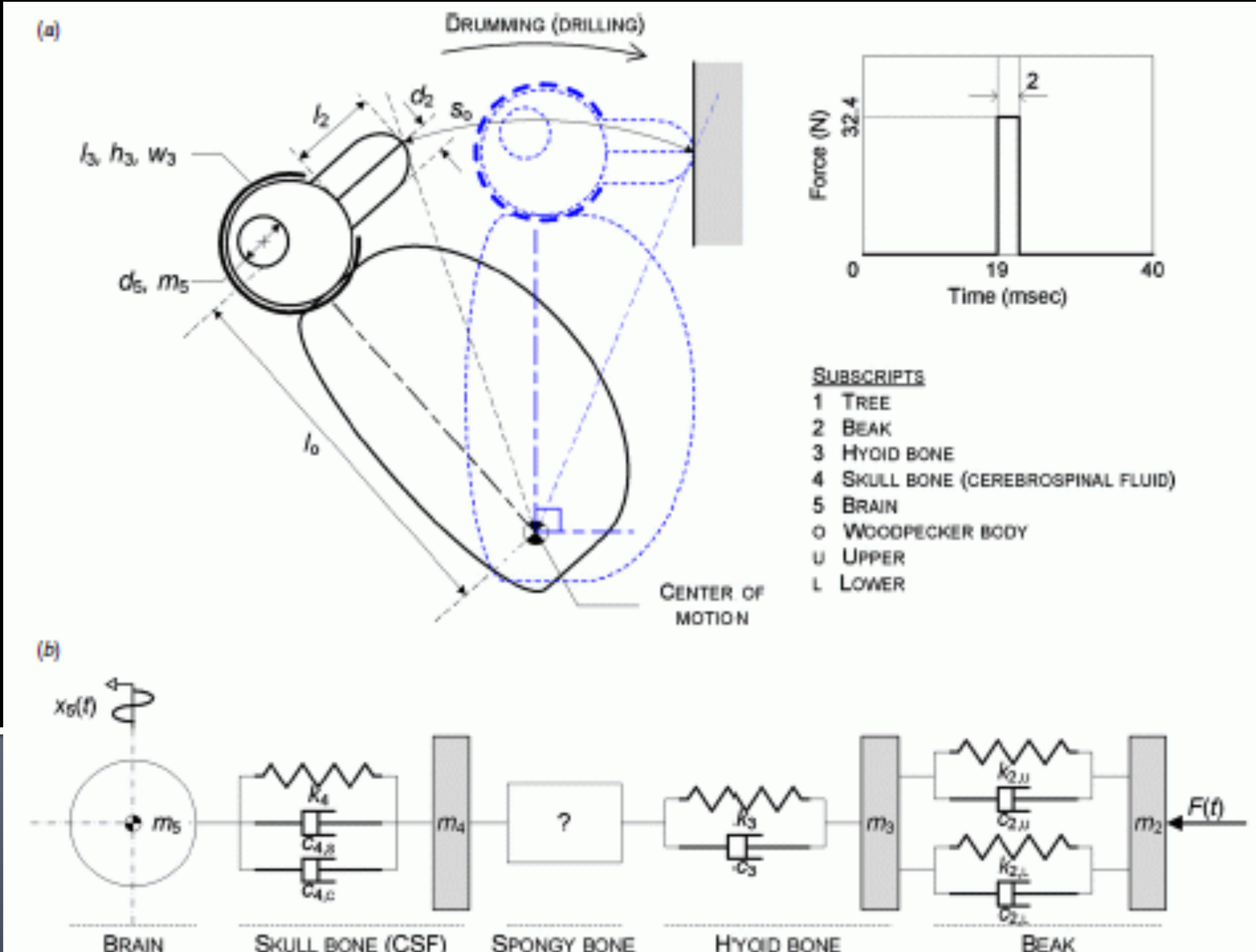

Force Sensing Resistor
Spring
Airpots
Pressure Transducer
Microcontroller
Valve
Push-Pull Cable
Potentiometer


F_z, F_y (mN)
V_z (cm s^{-1})
V_y (cm s^{-1})
F_z, F_y (mN)
V_z (cm s^{-1})
V_y (cm s^{-1})
F_z, F_y (mN)
V_z (cm s^{-1})
V_y (cm s^{-1})


6 legged invertebrate
A
B
4 legged vertebrate
C
D

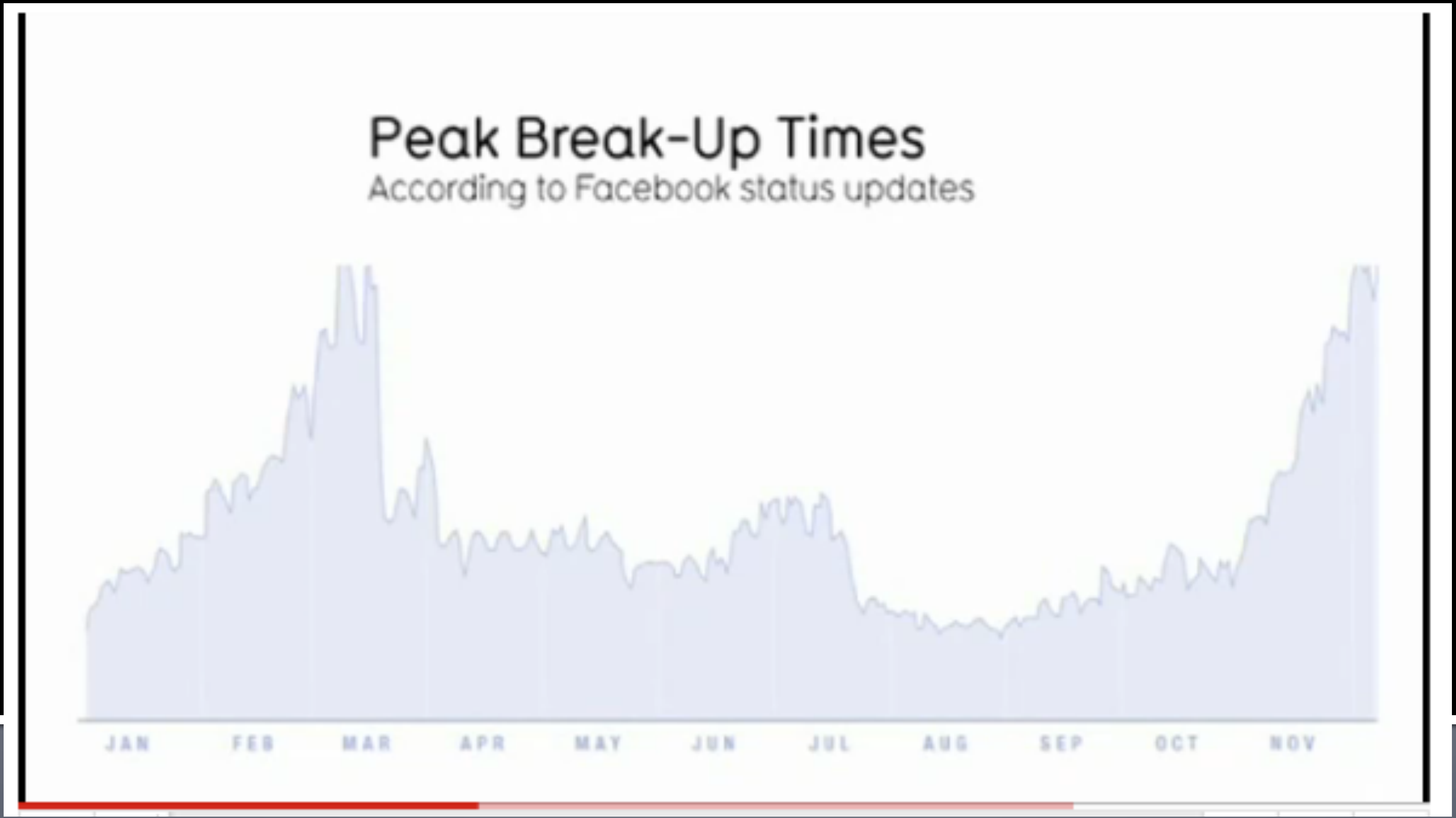


$x_5(t)$
m_5
k_4
$c_{4,B}$
$c_{4,C}$
m_4
?
k_3
c_3
m_3
$k_{2,u}$
$c_{2,u}$
$k_{2,L}$
m_2
$F(t)$



(a)
Drumming (drilling)
l_2
d_2
s_o
l_3, h_3, w_3
d_5, m_5
l_o
Center of motion
Force (N)
32.4
2
0
19
40
Time (msec)
Subscripts
1 Tree
2 Beak
3 Hyoid bone
4 Skull bone (cerebrospinal fluid)
5 Brain
o Woodpecker body
u Upper
l Lower
(b)
$x_5(t)$
m_5
k_4
$c_{4,s}$
$c_{4,c}$
m_4
?
k_3
c_3
m_3
$k_{2,u}$
$c_{2,u}$
$k_{2,l}$
$c_{2,l}$
m_2
$F(t)$
Brain
Skull bone (CSF)
Spongy bone
Hyoid bone
Beak


JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV


Peak Break-Up Times
According to Facebook status updates
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV