Robonaut – 2
The First Humanoid in Space

[Advancements in Robotics Technology]

Robotics Technology

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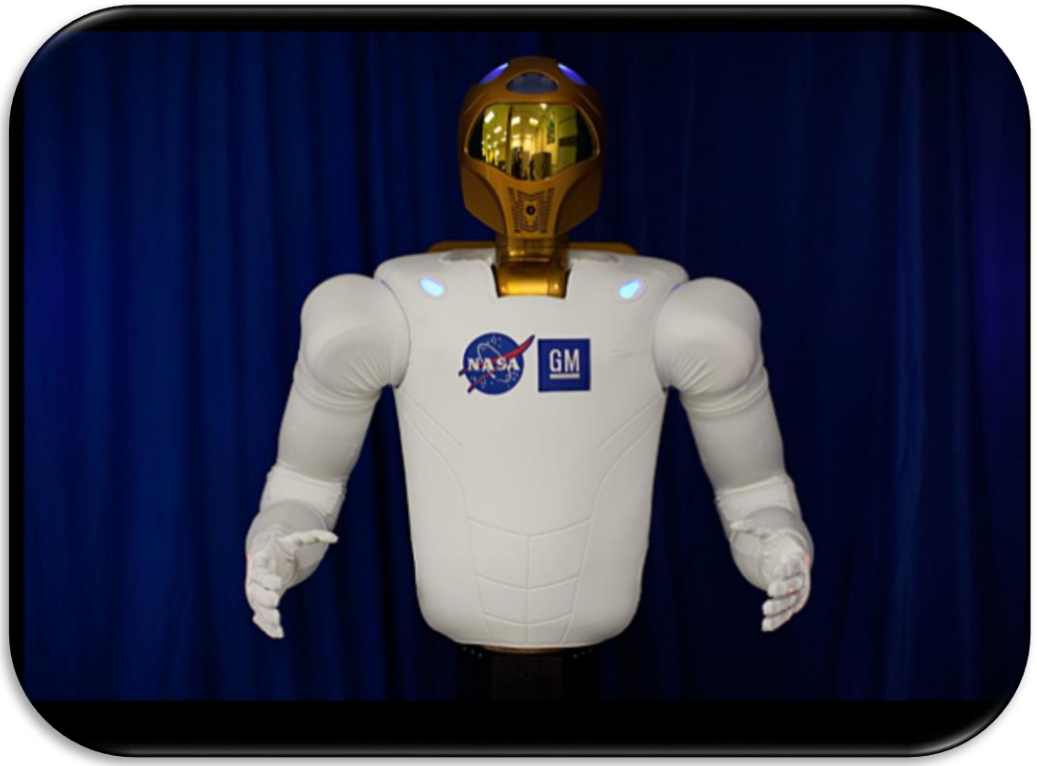
Who / What ?



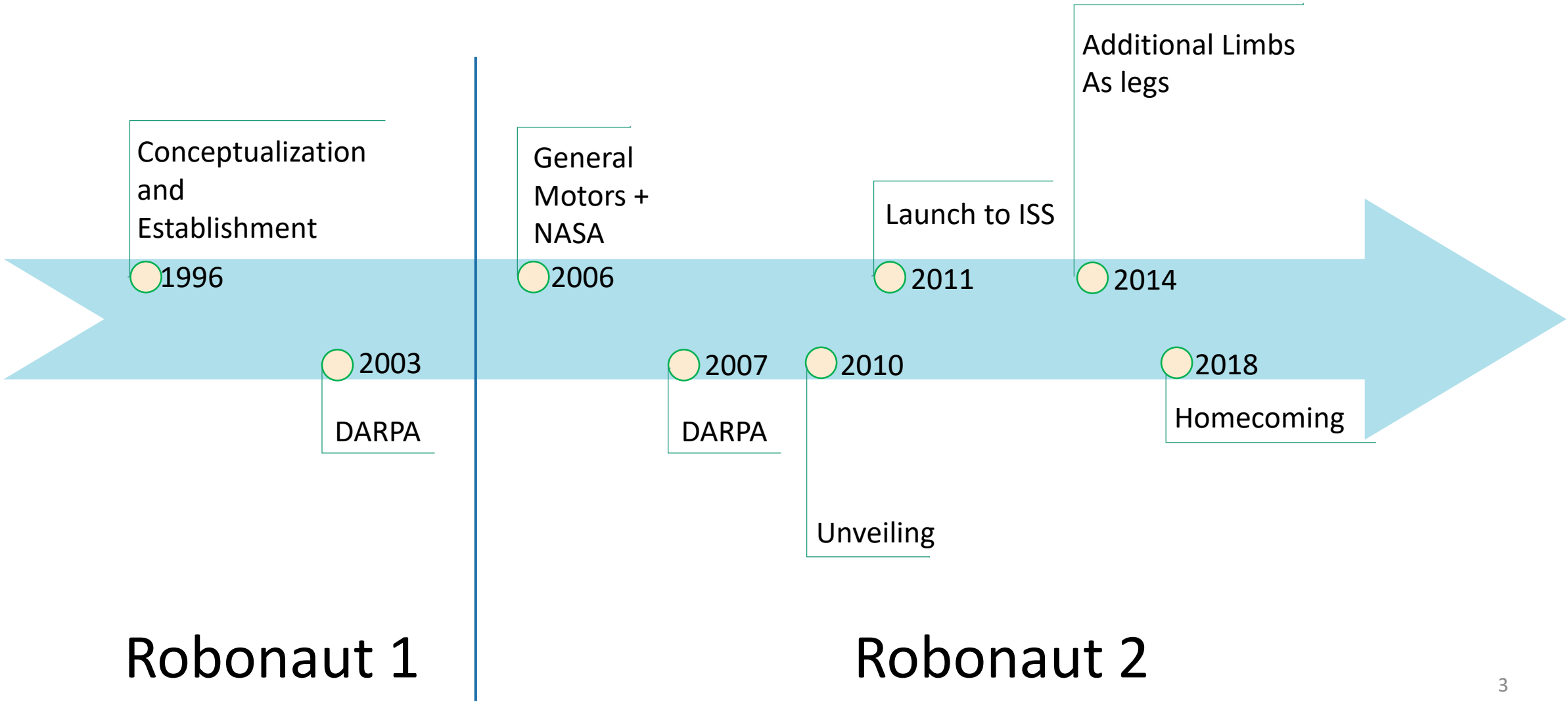
- 2 Armed Torso Humanoid Robot

- Collaboration between
  - General Motors
  - National Aeronautics and Space Administration

- Designed and Developed to aid Astronauts in space
  - Air System Monitoring
  - Cleaning Rails
  - Switching on and off Switches

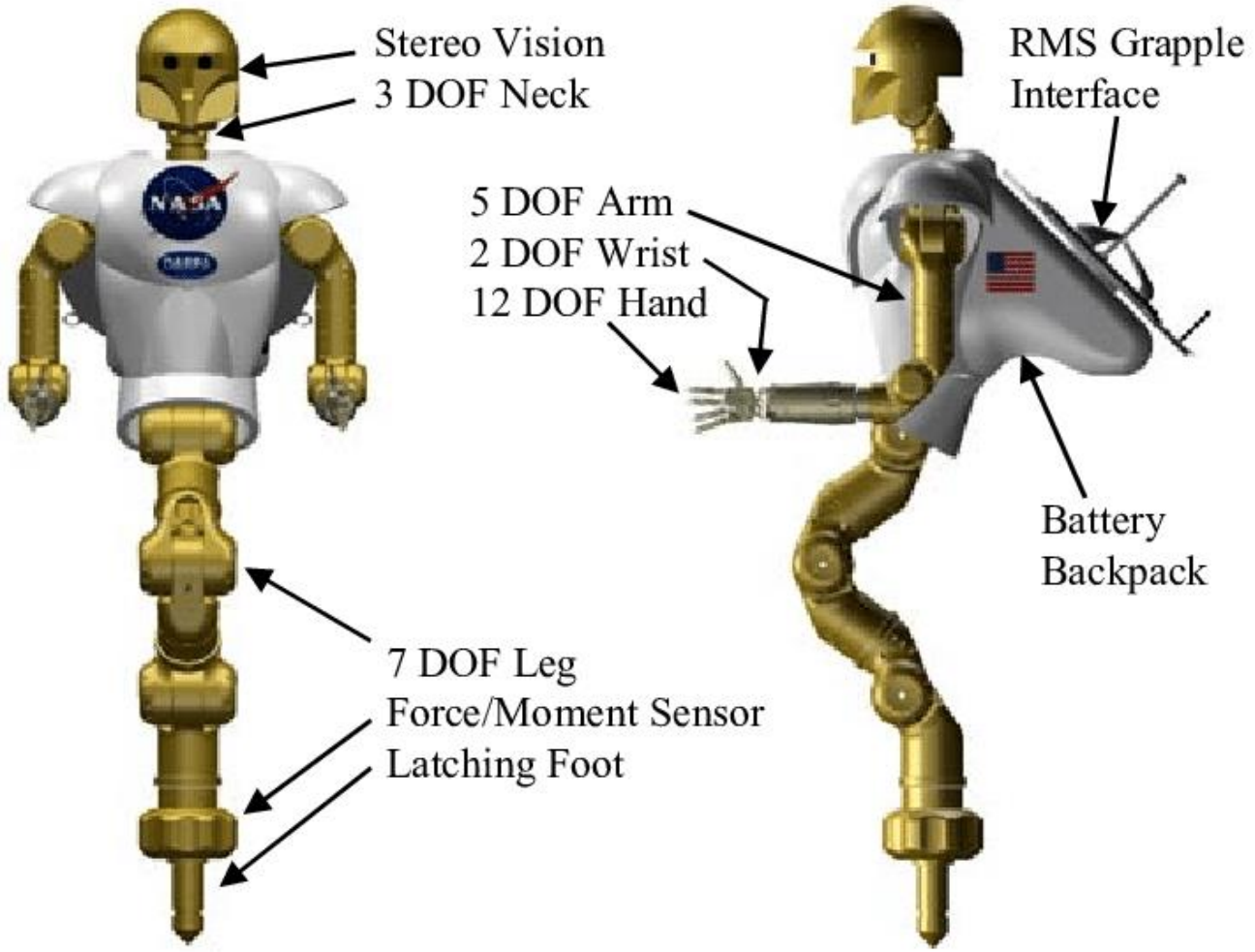
- Succeeds Robonaut 1; used as a painting and welding Robot

The Journey


Conceptualization and Establishment
1996
2003
DARPA
General Motors + NASA
2006
2007
DARPA
2010
Unveiling
Launch to ISS
2011
Additional Limbs As legs
2014
2018
Homecoming
Robonaut 1
Robonaut 2

Demographics

- Upper Body / Torso Humanoid
- Aluminum with steel
- Mostly Polymer Fiber
  - Height : 1.01m (Waist to head)
  - Weight : 150kgs
  - Shoulder width : 0.78m
- Independent Degrees of Freedom : 42
- Houses 350 Sensors
- 50 Actuators
- 38 On Board Processor
- 7 feet per sec



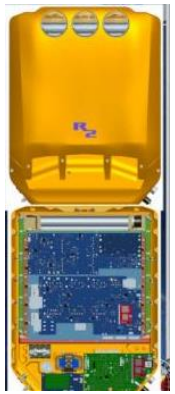
Mechatronics

- 3 Degrees of Freedom
- 4 Stereo Vision
- Infrared Camera

Fun Fact
Your Thumb is as long as your nose

- 12 Degrees of Freedom
  - thumb : 4
  - others : 3 each
- Cutosky's Grasp Taxonomy

- 5 DOF Arm
- 2 DOF Wrist
- Payload : 20pounds
- In any pose
- Brushless DC Motors
- Harmonic Drive Reducers
- EM brakes



- Battery Pack
- Battery Charger
- Power Converter
- Heat Shield
- Wifi & Radio

- 2 Degrees of Freedom
- On Board Commuter
- Intel Atom Processors
- Sensor Network Hub

Control Strategy

- High Level Processing for Sensor Network
- Speed and Torque Control of Motors
- Task Priority and Scheduling in the Kinematic Tree
- Ensure coordinated Motion among all DoF
- Dual Operating Modes
- Cutosky's Grasp Taxonomy

Control Equations

$$M\ddot{q} + c + g - \tau_e = \tau$$

Manipulator System

Joint Space Matrix

Coriolis and Centripetal forces

Actuated and External Torques

$$M_o\ddot{x} + B_o\dot{x} + K_o\Delta x = F_e$$

Closed Loop impedance

Operational Space Inertia

Damping and Stiffness Matrix

Error Correction

External Forces

$$M_j\ddot{q} + B_j\dot{q} + K_j\Delta q = \tau_e$$

Closed Loop impedance

Operational Space Inertia

Damping and Stiffness Matrix

Error Correction

External Torques

$$\tau = -J^T\left(B_o\dot{x} + K_o\Delta x\right) - N\left(B_j\dot{q} + K_j\Delta q\right) + g$$

Jacobian to map joint velocities And Operational Velocities

Torque Estimation

Feedback

Enhanced Dexterity and Control

User Interface : HCI

Robonaut 2 User Interface : VxWorks OS

What's / Who's Better ?

Robonaut 1 (R1)

- ✓ Point to Point RS485 Communication
- ✓ 8Mbits per second
- ✓ 32 Degrees of Freedom
- ✓ Can Run 50% of the Cutosky's Grasp
- ✓ Payload Carrying Capacity in 3 Directions

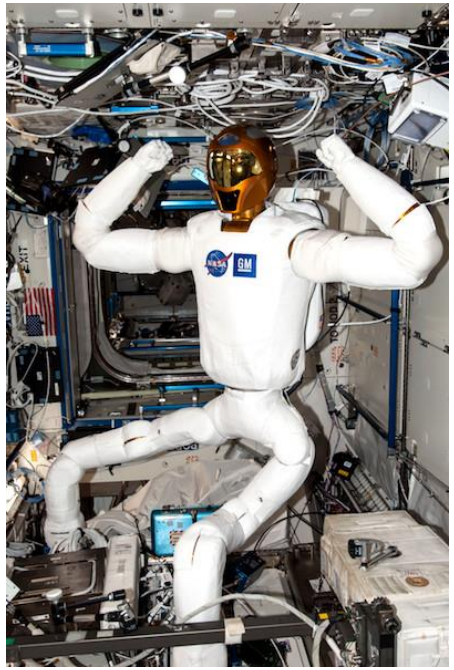
Robonaut 2 (R2)

- ✓ MultiDrop Low Voltage Differential Signal
- ✓ 50Mbits per second
- ✓ 42 Degrees of Freedom
- ✓ Can Run 90% of the Cutosky's Grasp
- ✓ Payload carrying capacity in any pose

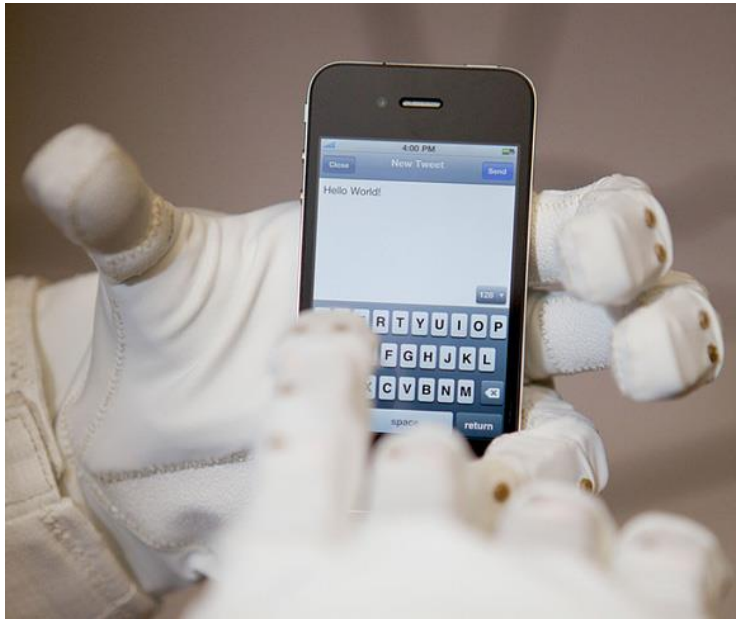
Homecoming

- The Limbs were not as modular as planned
- It took 45hours for the onboard astronauts to assemble and failed.
- Dexterity Mismatch
- Tried to resolve the issue for over an year
- Repacked : ready to be shipped

Unfortunate / Unfortunate ??

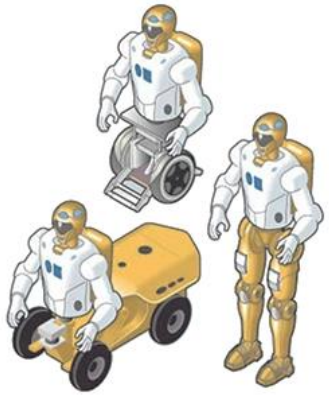


Infinity and Beyond .!



Twitter Post from ISS

Configure for
Extravehicular Activity (EVA)



Maneuverability

Research and Technologies
(RATs, Arizona, USA)

Valkyrie
The Next Gen Astronaut

References

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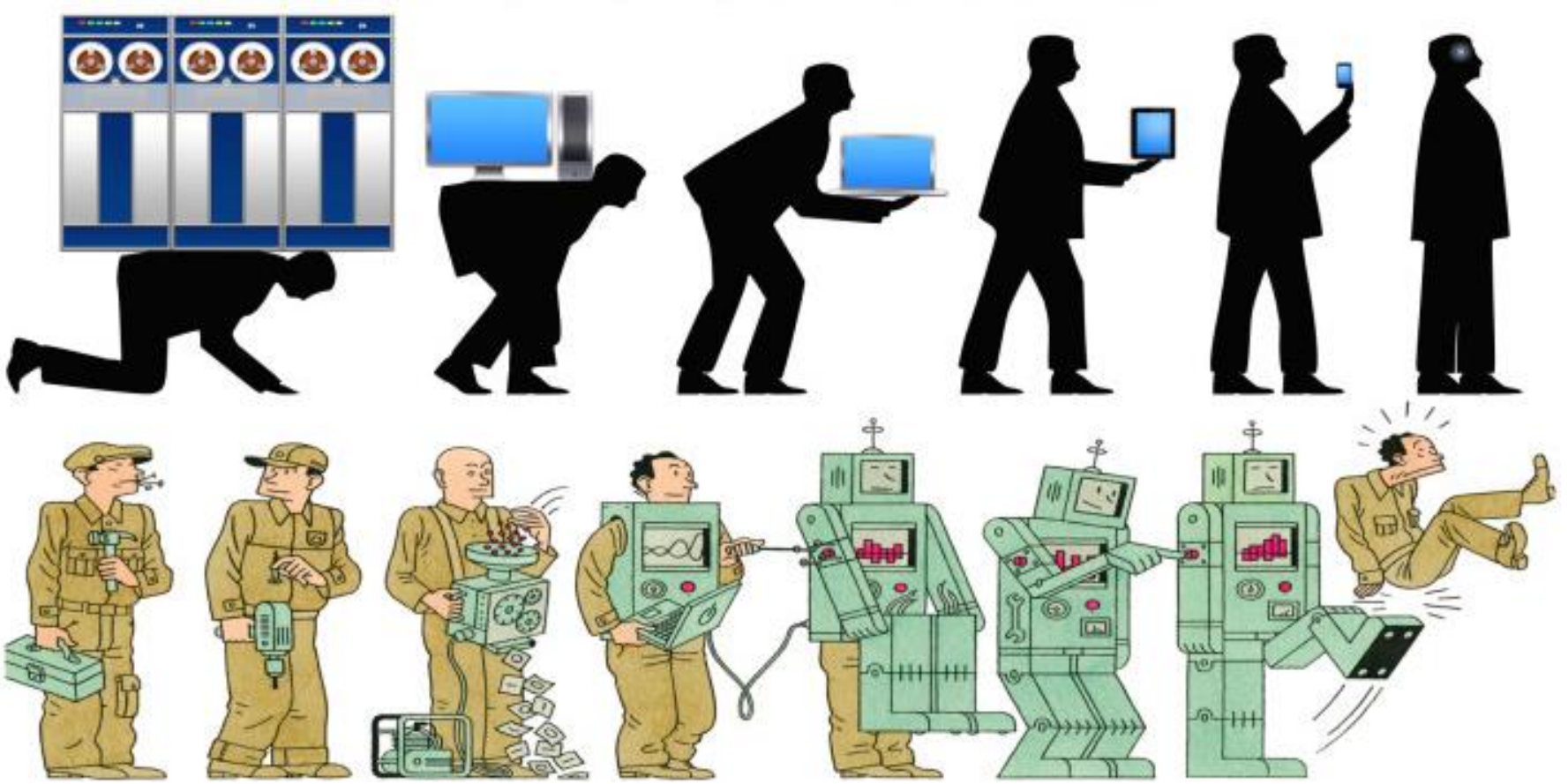
Food for Thought….



How Far Should We Take This ?

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01100001 01101110
01101011 01110011
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00100000 01111001
01101111 01110101
01110010 00100000
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