Challenges in Legged Robots Design

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Main technology categories

Surveillance and perception technologies

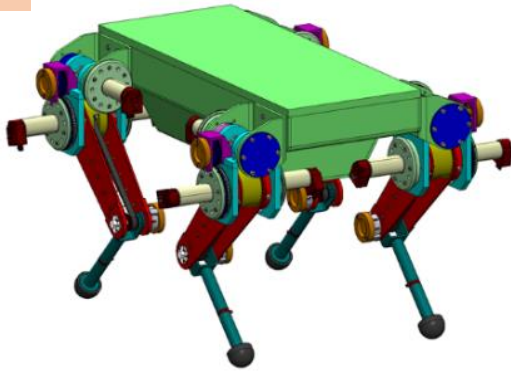
Autonomous navigation technologies

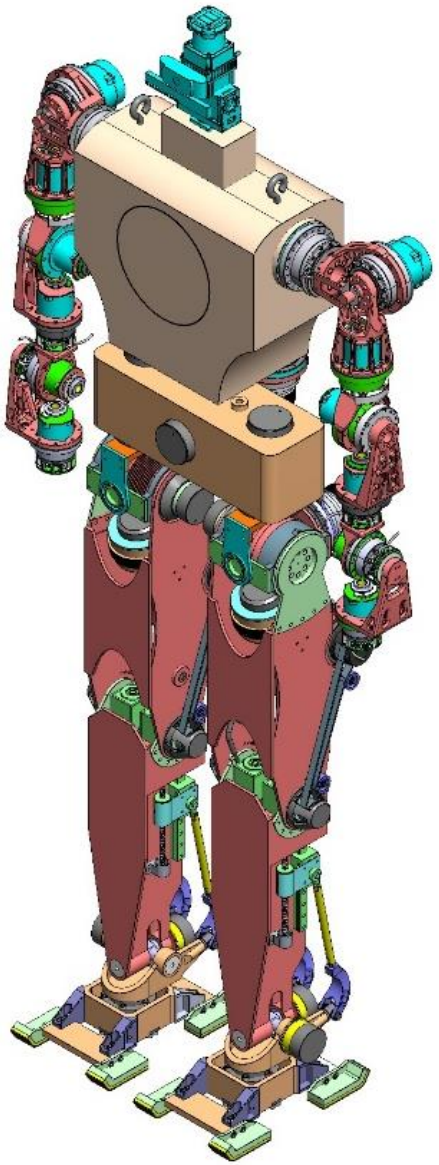
Collaborative dual arm manipulation technologies

Combat support technologies

Quadruped locomotion technologies

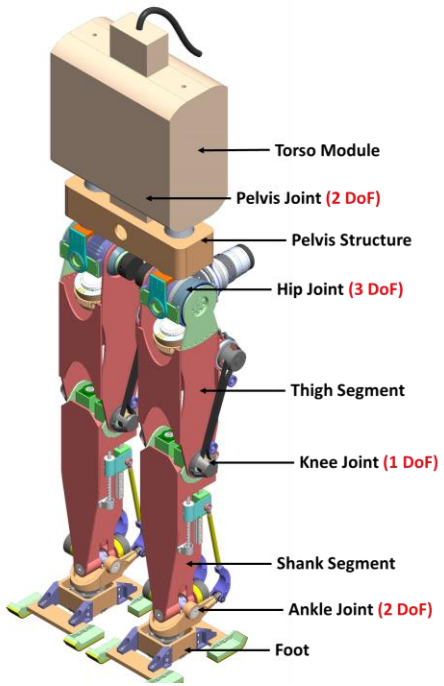
Biped locomotion technologies

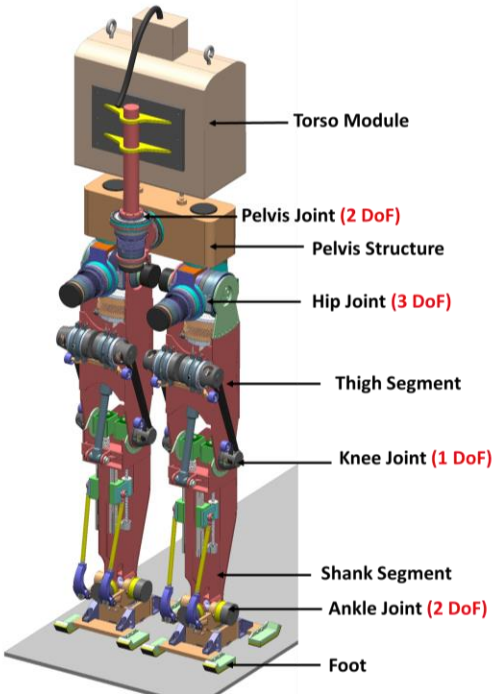


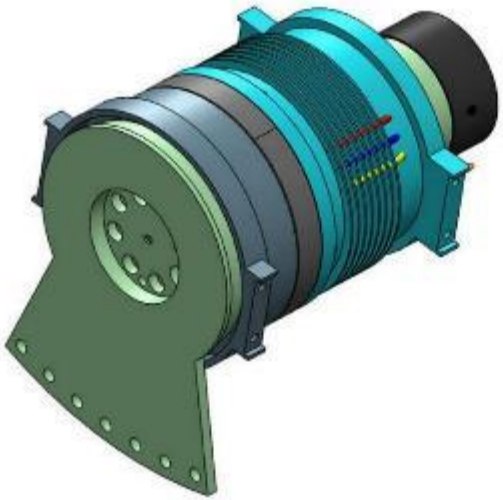


Biped rotary actuators

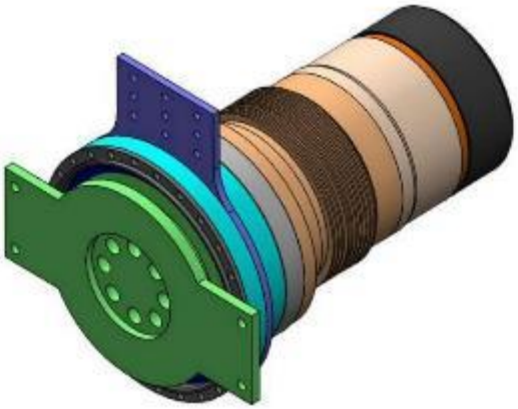
- Multistage planetary vs Harmonic
- Compact at matching gear ratios
- Complexity, cost
- Current and speed
- Efficiency, responsiveness
- Back-drivability, backlash







(a) Hip Flexion/Extension (Pitch)

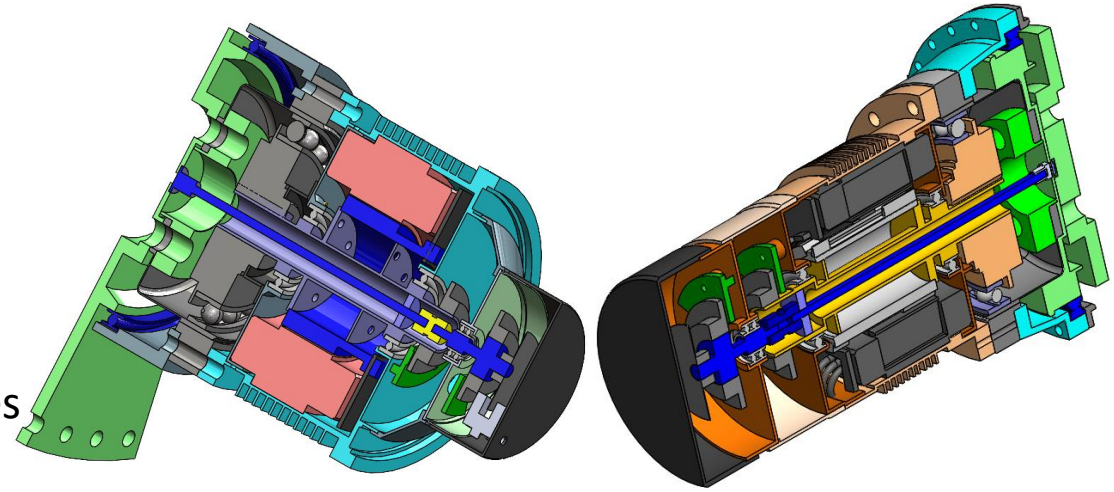


(b) Hip Adduction/Abduction (Roll)

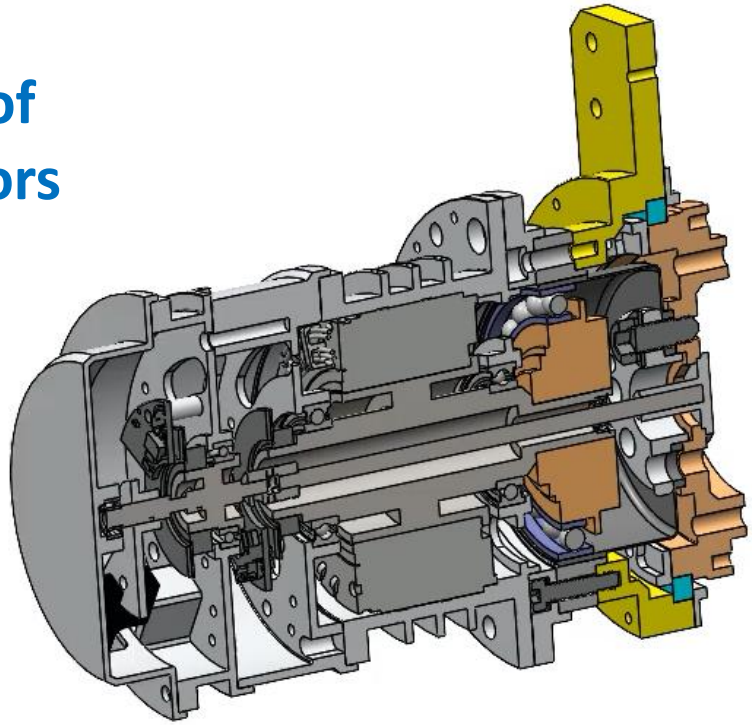
(c) Hip Internal/Ext. Rotation (Yaw)

Actuators assembly

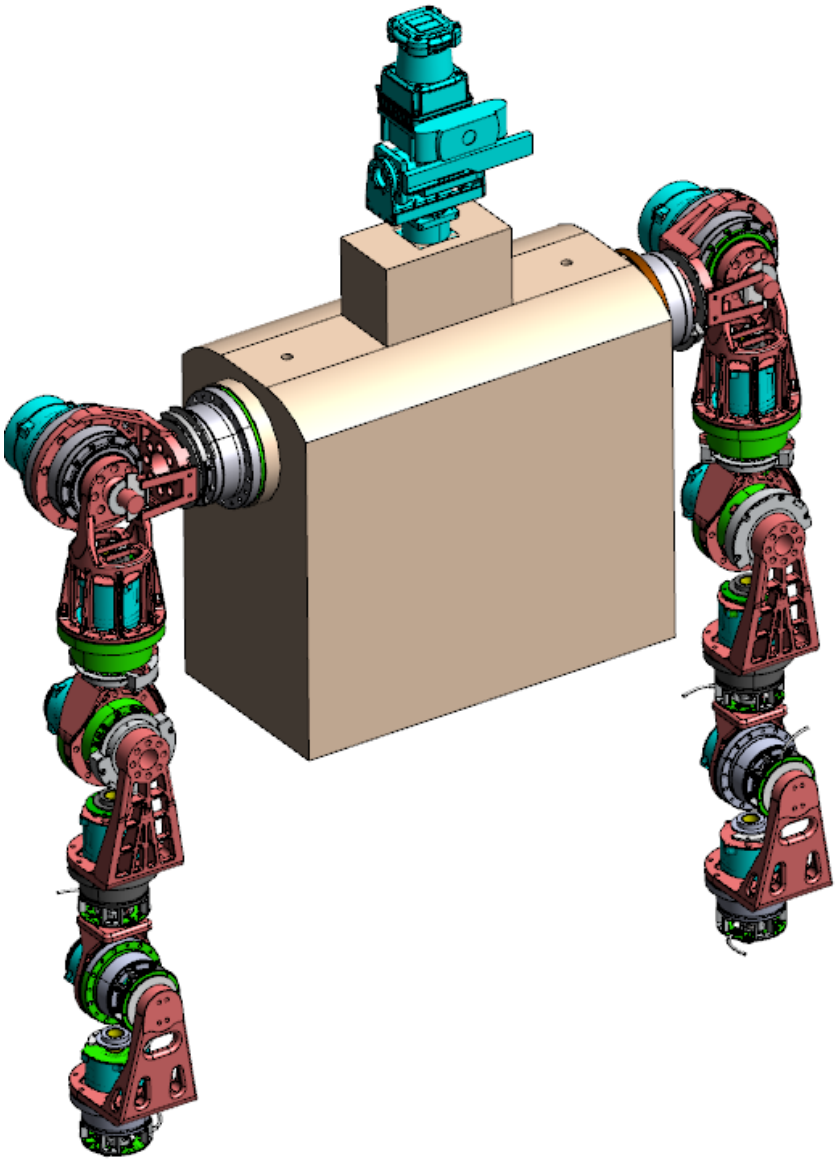
- Frameless motors
- Harmonic drive component sets
- Two bearing less open encoders
- Torque sensors, Brakes
- Component, assembly tolerances
- Assembly fixtures
- Thermal management



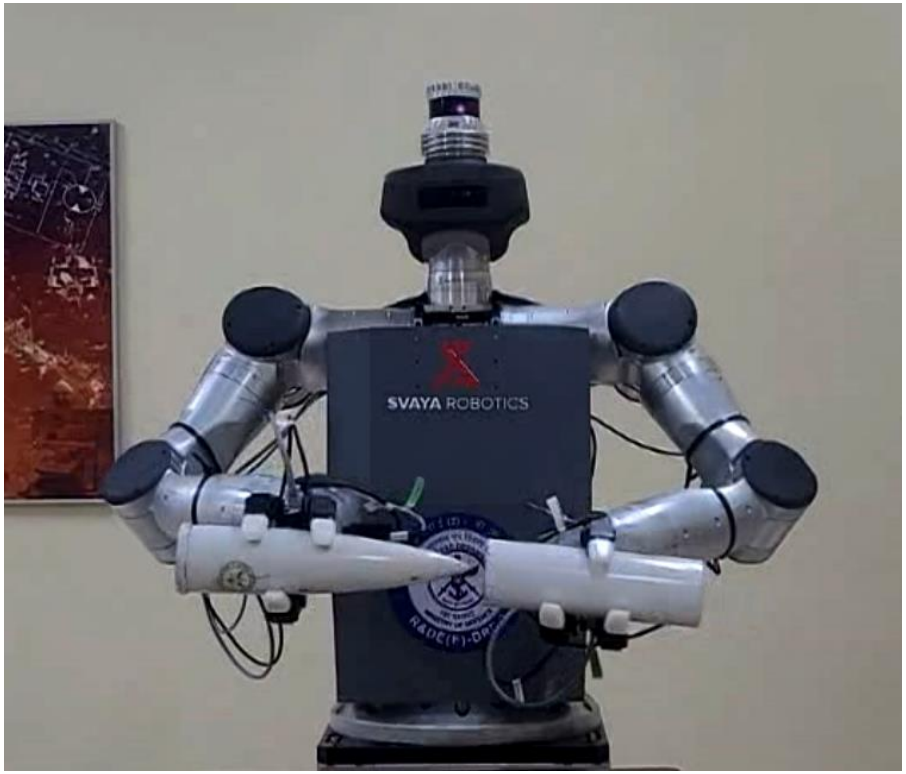
Advantages and pitfalls of custom designed actuators



Humanoid upper-body



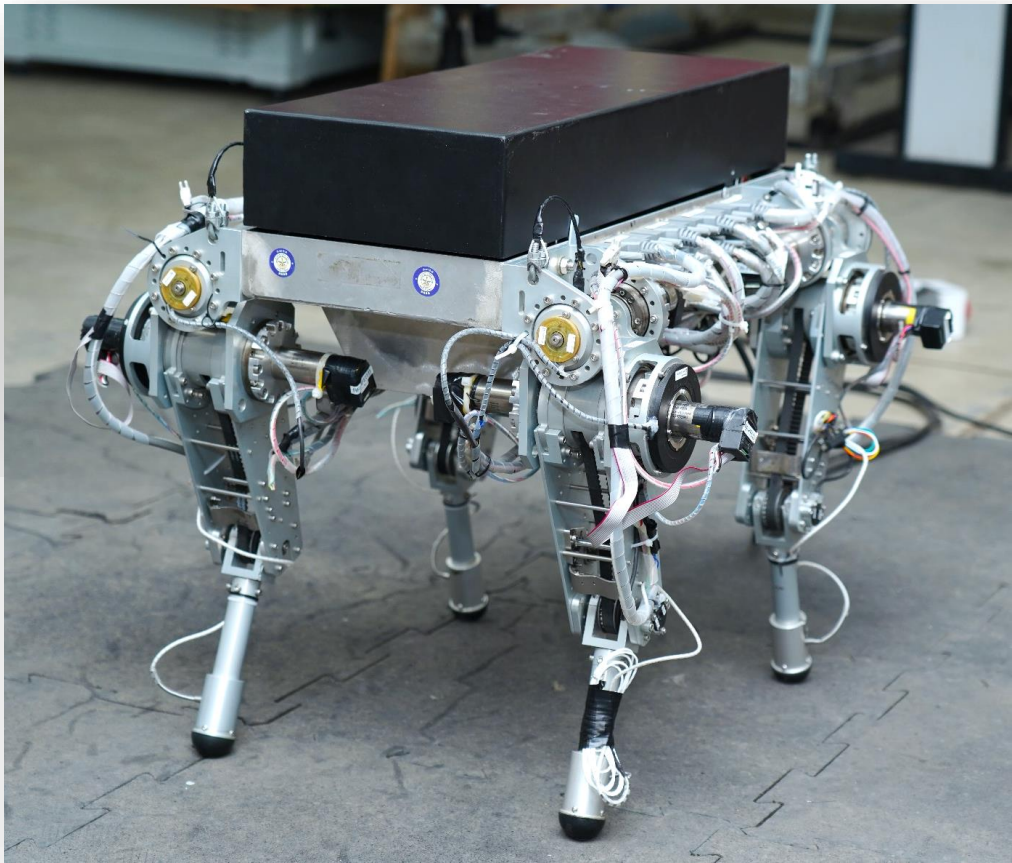
Dual arm manipulation test bench



Quadruped for logistics support

Quadruped with frameless motor + harmonic drive

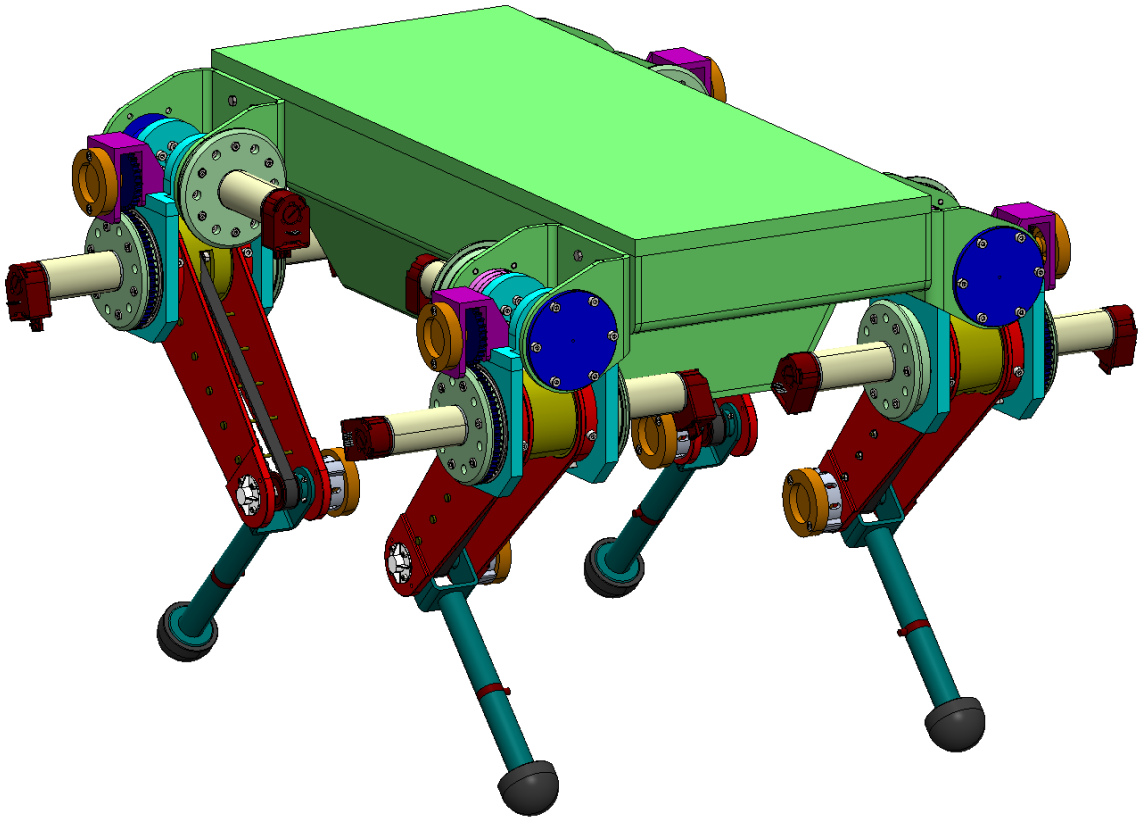
Scalable for higher payloads and endurance

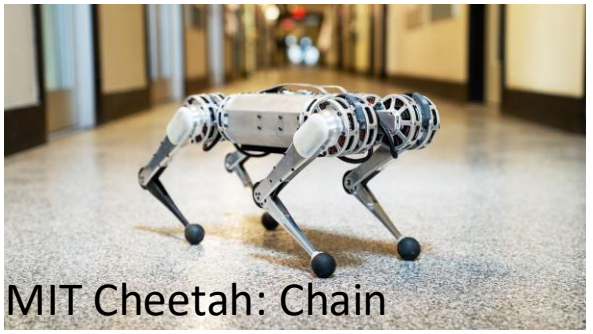


Quadruped leg mechanism

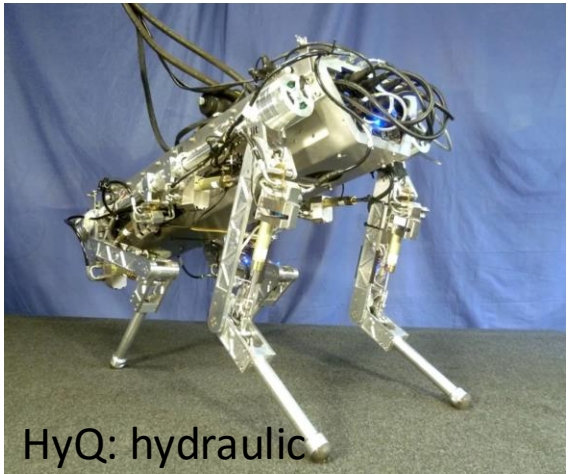
Belt vs chain vs four-bar
X vs M configuration

Parallel mechanism

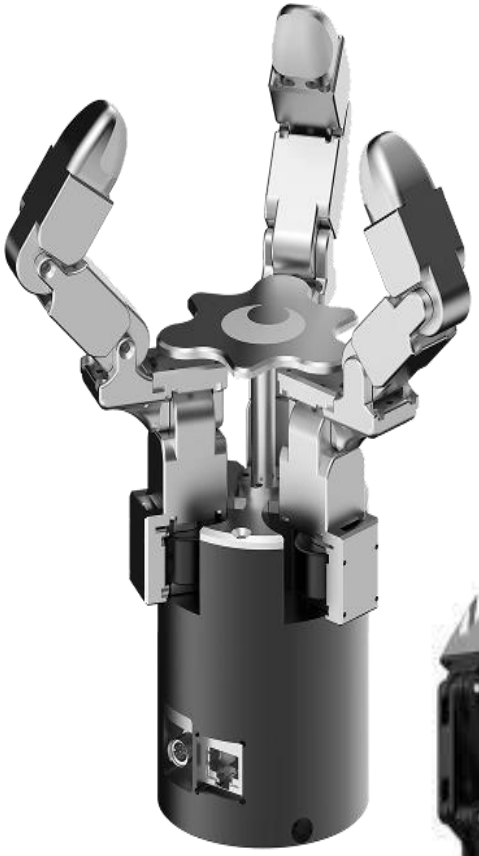


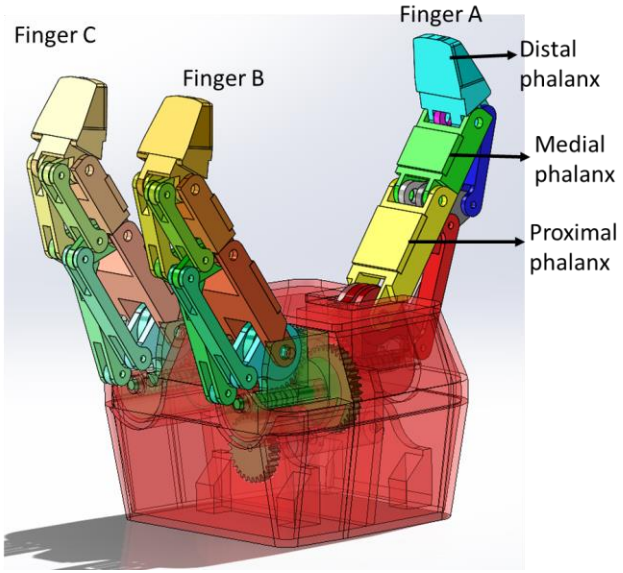


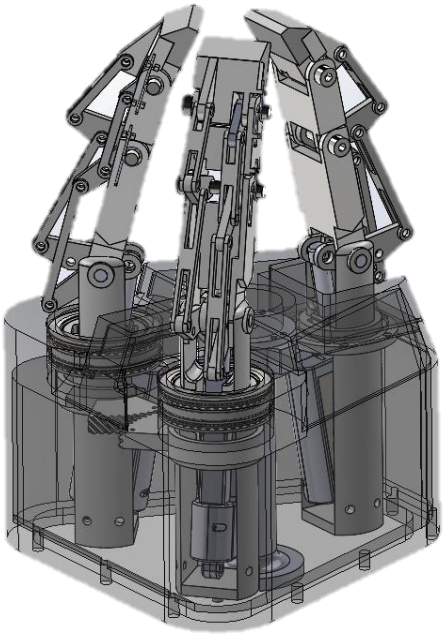
Unitree:
four bar
linkage



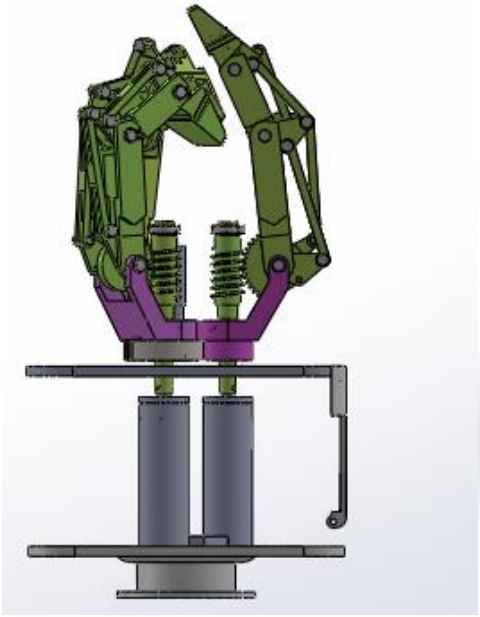
Gripper

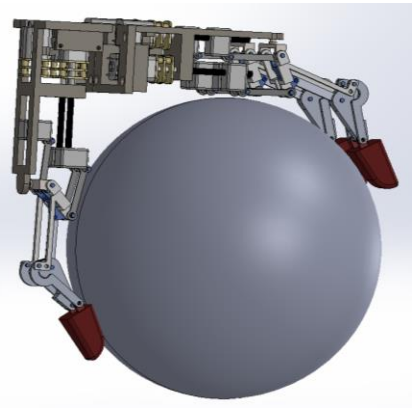



Finger A
Finger C
Finger B
Distal phalanx
Medial phalanx
Proximal phalanx

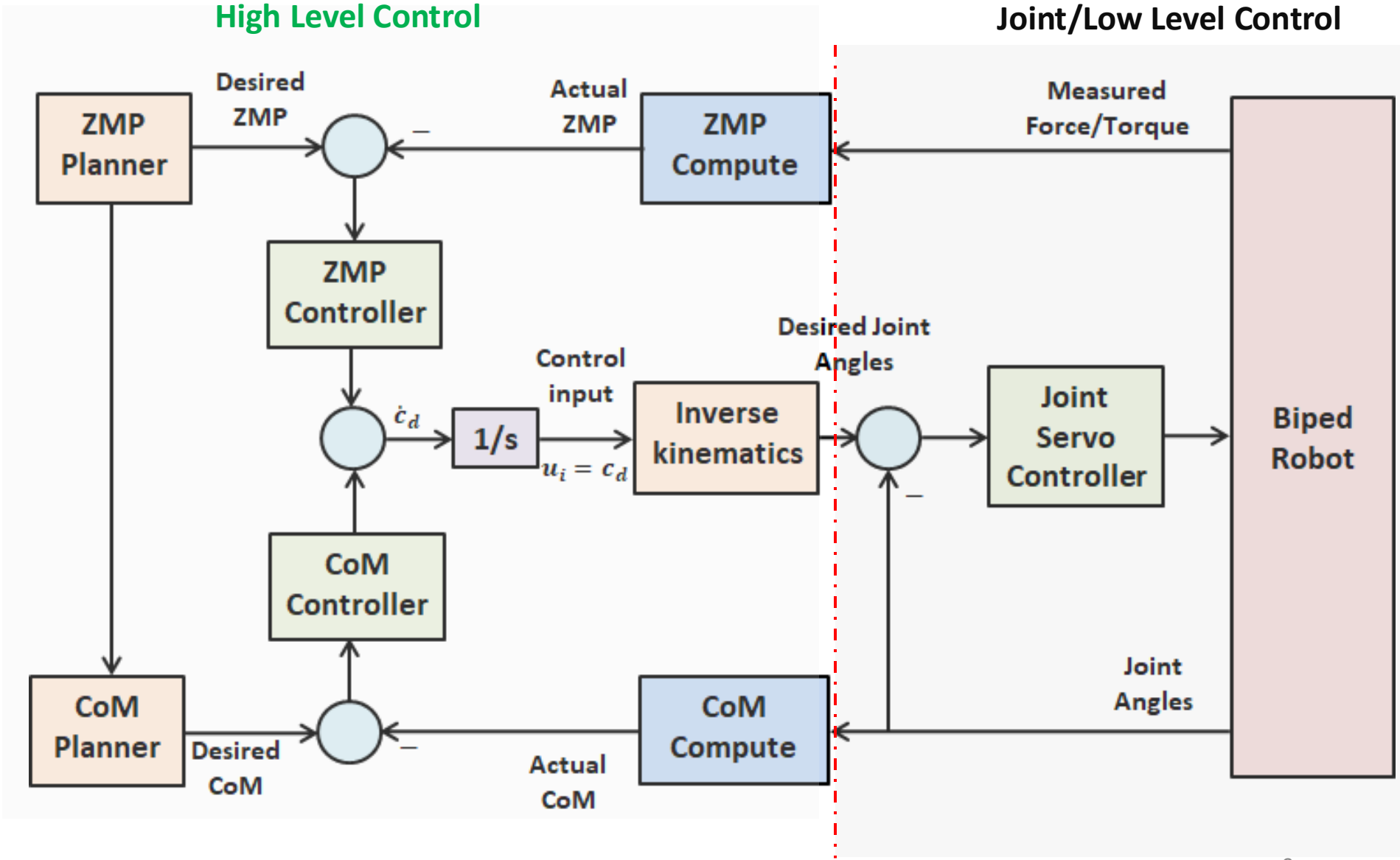



ROBOTIQ

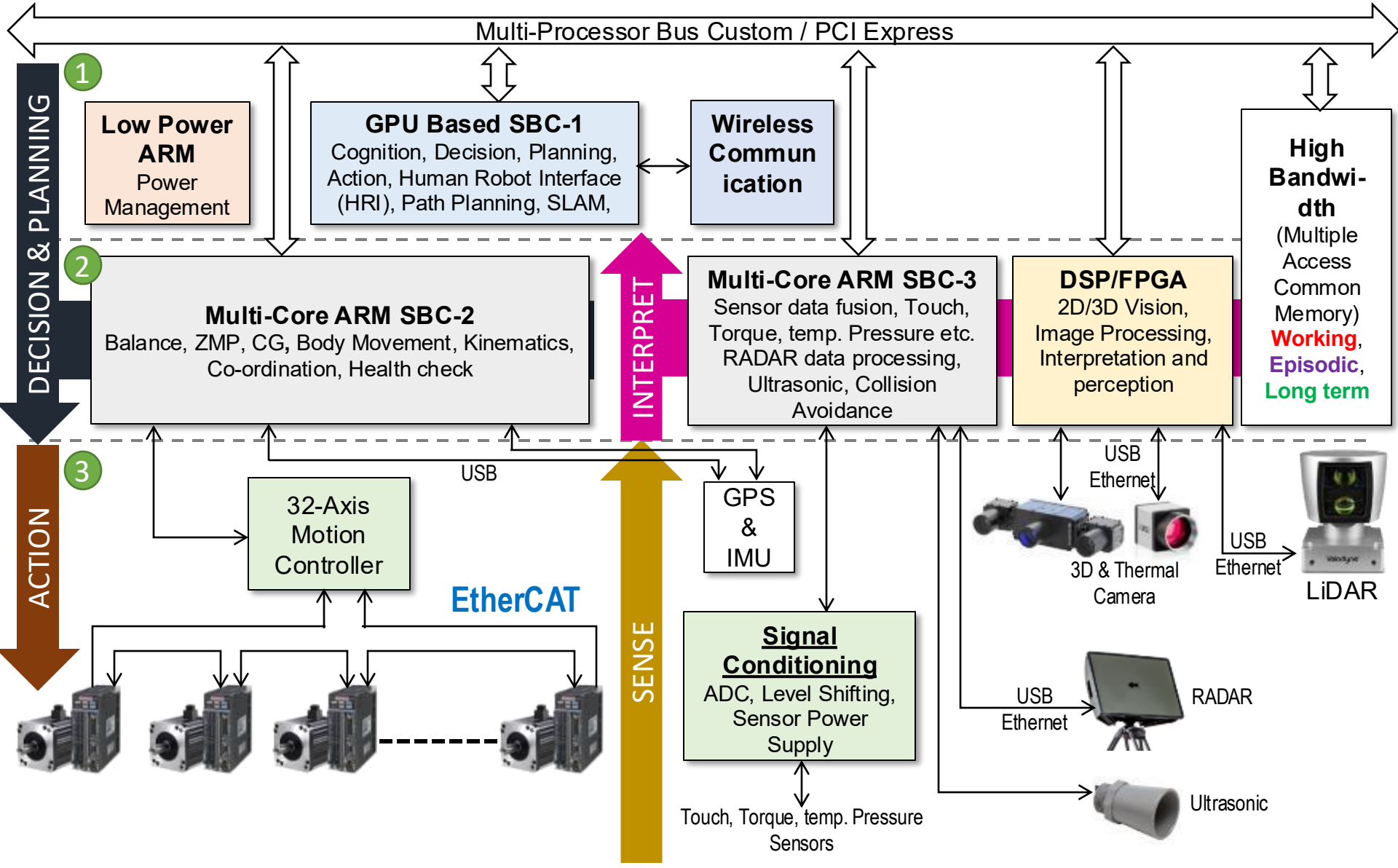




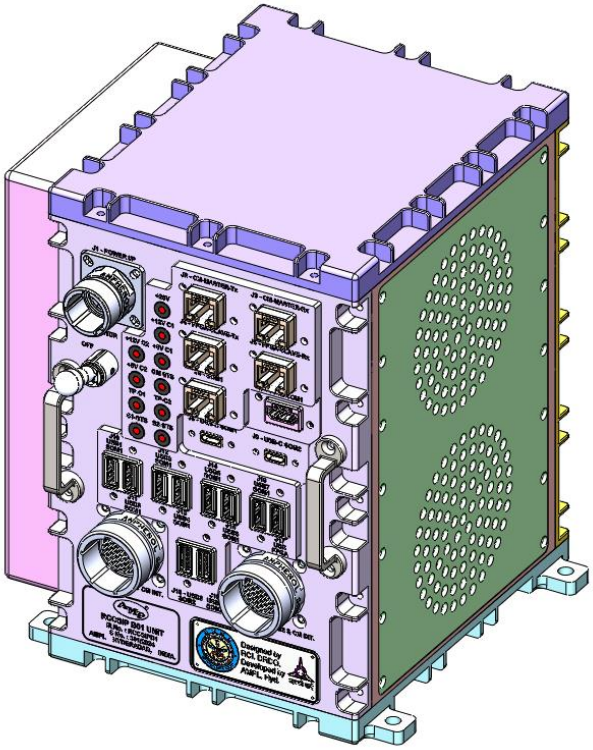
Balance and walking control scheme

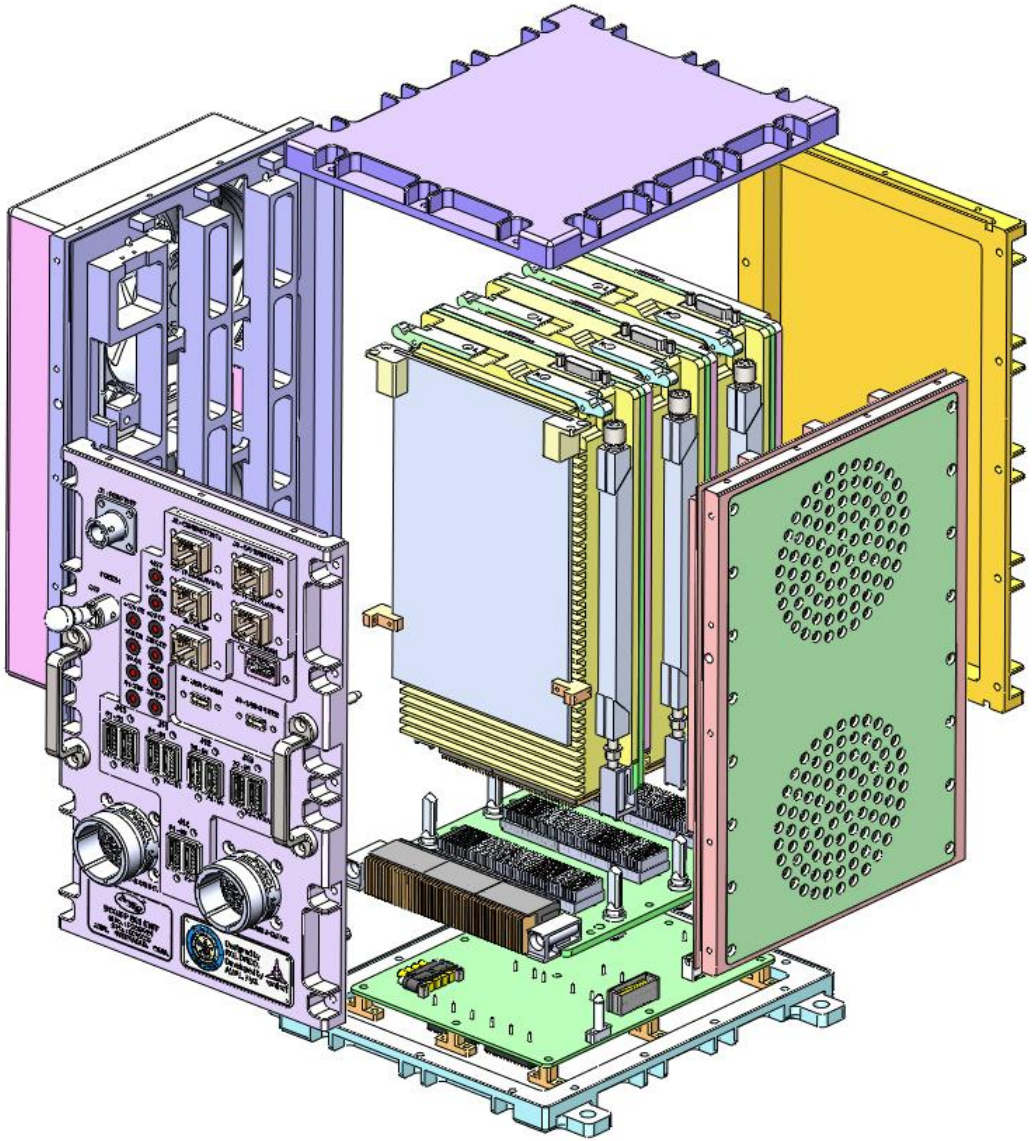


Electronics hardware

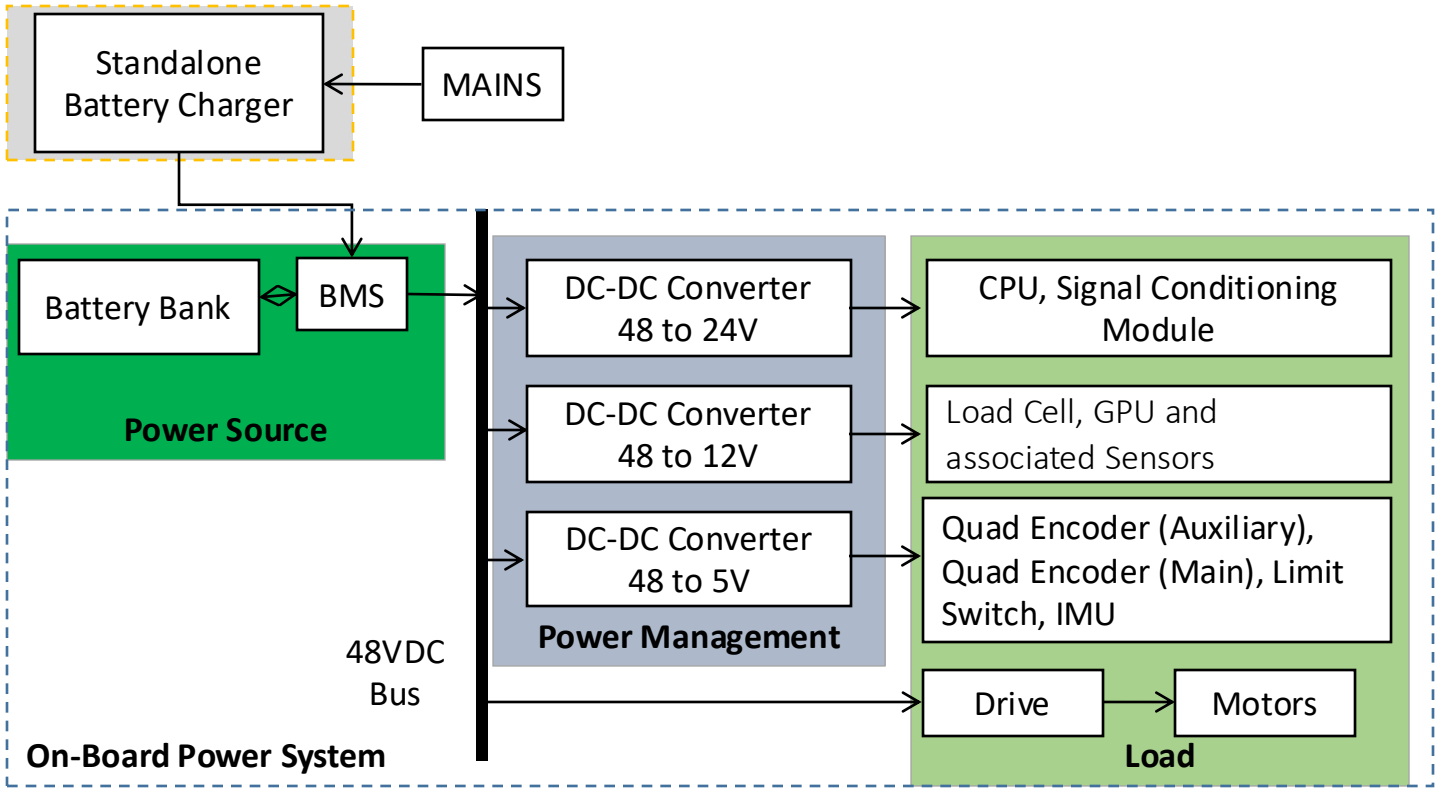


Computational platform





Power supply



- **Battery Bank sizing for QRS-1 and BRS-1: 48V, 15Ah (One hour endurance)**
- **DC-DC converters & Standalone battery charger selected**

Sensors

Key sensors common across all systems as much as possible

Stereo cameras

LiDAR

IMU

Audio sensors…

Other sensors

Encoders

Force torque sensors

Tactile sensors…

Proprioceptive and exteroceptive sensors as required

Summary: Collaborations and initiatives

9 Industries as lead system integrators and many others

Indigenous harmonic drives

Indigenous motors

Audio-video data generation

Over 10 partners for actuators, sensors, hydraulics, other components

Technology development fund (TDF) on actuators

Academic collaborations

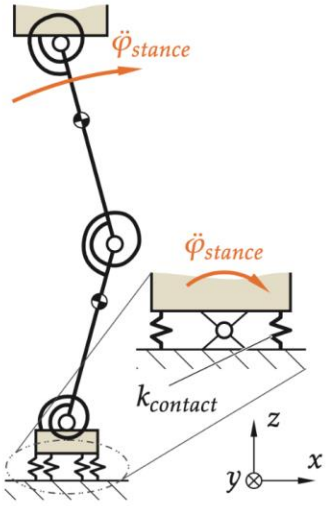
Biped walking balance and control
Walking control design for legged robots
Quadruped robot control
Collaborative dual arm manipulation, control
Grasping, manipulation with 3-finger gripper
Tactile sensor arrays for grippers
Strain wave gears
Audio-visual perception
Learning based locomotion

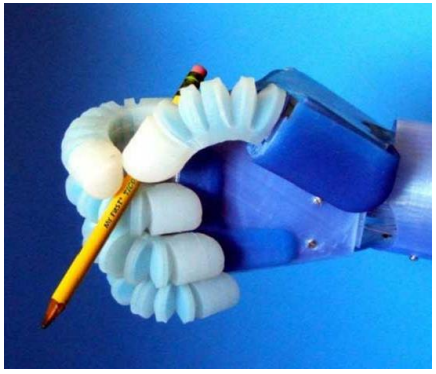
Many in pipeline: grippers, LLMs, HMI etc.

7 academic collaborations + 3 RCI, 1 CAIR, 1 DIACOE, 4 being explored (Total 16) and many more

Technologies and Challenges

1. **Compliant** and flexible robots
2. Advanced **control** strategies; compliance control; control of flexible systems
3. Efficient, responsive, lighter **actuators**
4. **Design** strategies; topology optimisation
5. Low energy **locomotion** strategies
6. New multifunctional **materials**
7. New **fabrication** schemes – multi-material 3D printing; structures and actuators with integrated sensors and communication
8. Tactile sensors arrays – artificial **skin**
9. Advanced **sensors** for day-night and difficult environment operations
10. Advanced **computational** systems
11. **Energy** storage and management
12. **Gripping**, grasping
13. Collaborative **dual arm** manipulation
14. Software, learning, AI and **cognition**
15. **Bioinspired** and soft robotics

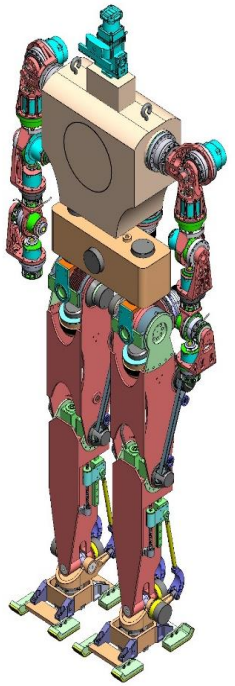




Significant gap between technology and expectations

- Trying our best to create an ecosystem and a comprehensive approach to reach a level where we can meet the expectations

- Build basic building blocks to perform meaningful tasks with usable endurance in a dynamic, unstructured and difficult environment



Thank you