NASA Institute for Advanced Concepts

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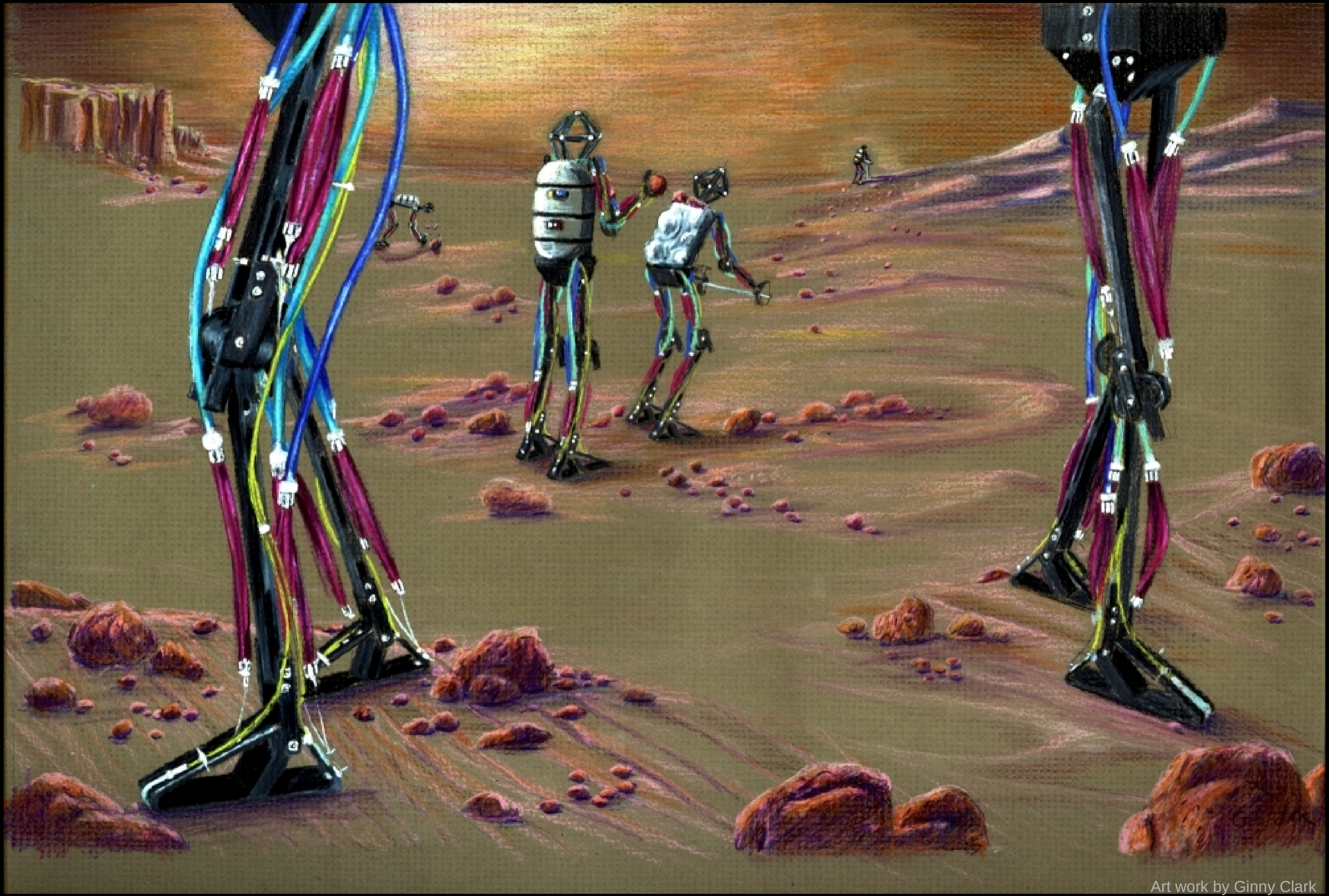
Intelligent Inference Systems Corp.

Biologically-Inspired Robot for Space Operations

Ron Jacobs, Ph.D.

A NIAC Supported Research Project



Art work by Ginny Clark

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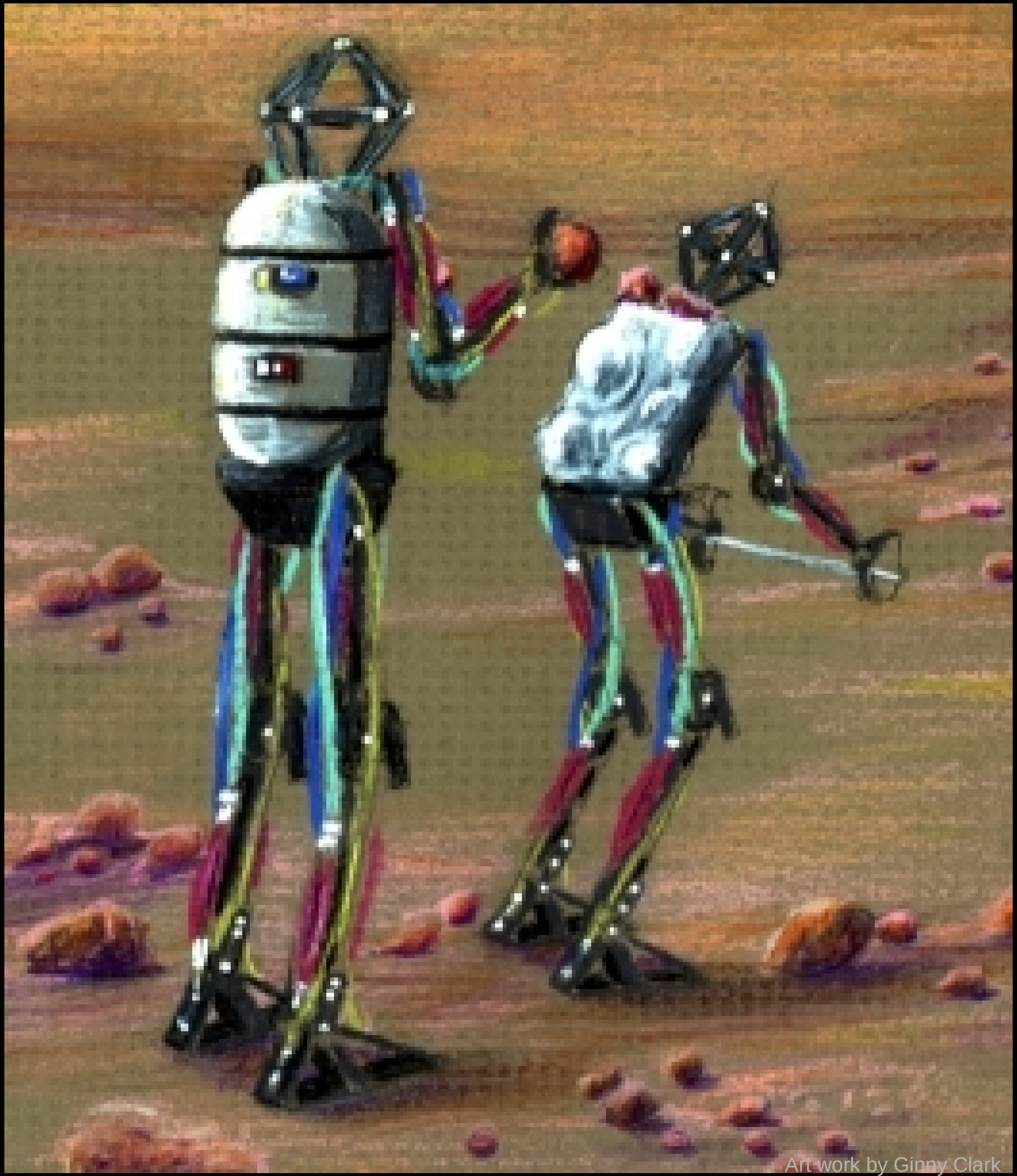
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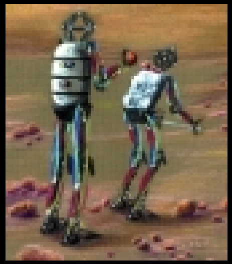
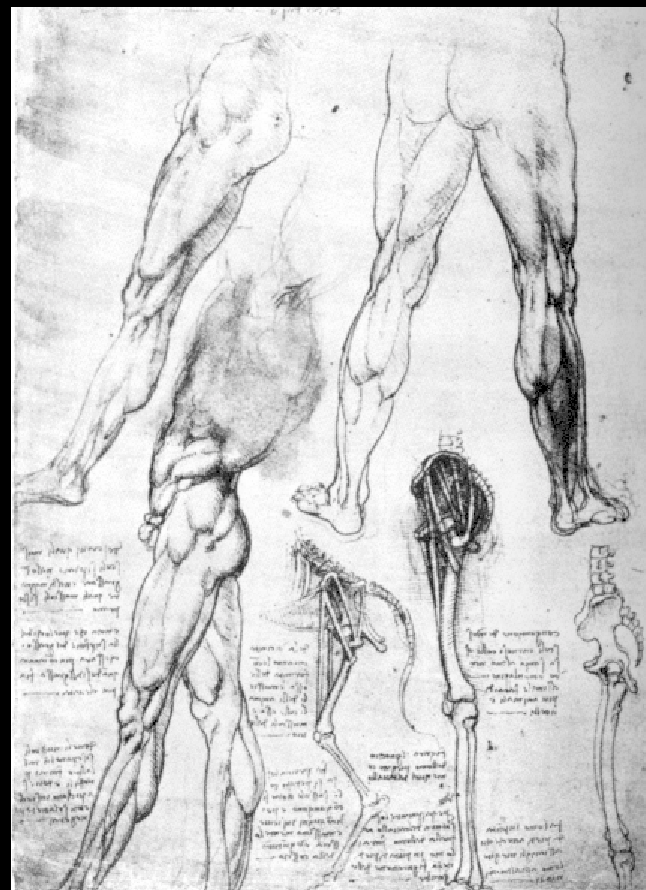


Biologically-Inspired Approach

- Provides for flexible and versatile systems
  - Subtle and huge forces dependent on task requirements
  - Multiple yet stable joints due to intrinsic mechanical features
  - High functionality of limbs with low mass and inertia
- Employs intelligent behavior
  - Use of *if-then* rules in control and decision making
  - Able to reason and interact
  - Adapts to changes in task demands and environment

Leonardo da Vinci

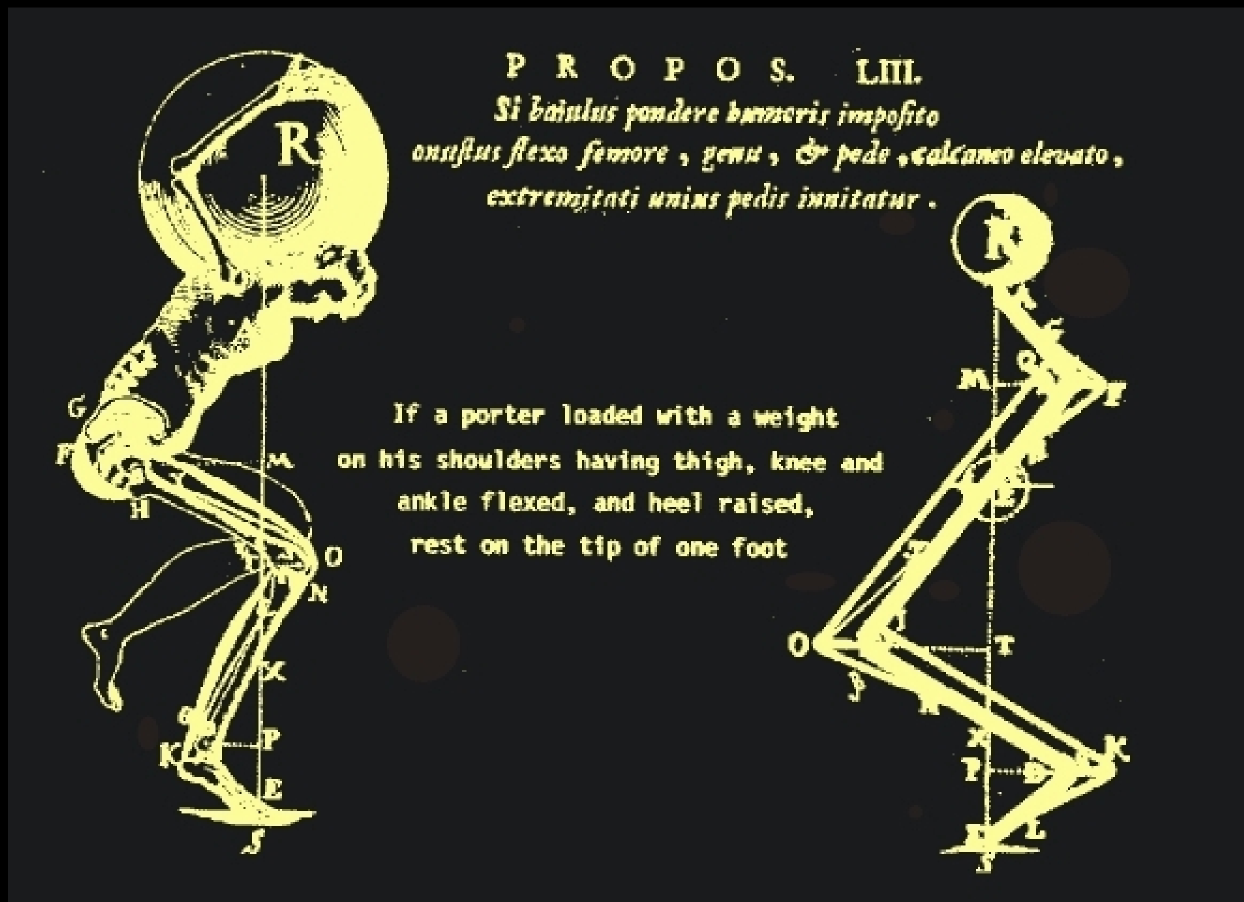
Integration of Biology and Physical Science



From: The drawings of Leonardo da Vinci, AE Popham, London 1994

Johannes Borelli

Integration of Biology and Physical Science



From: De Motu Animalium, F Mosca, Napels 1734

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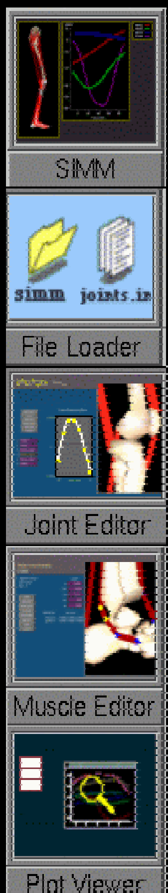
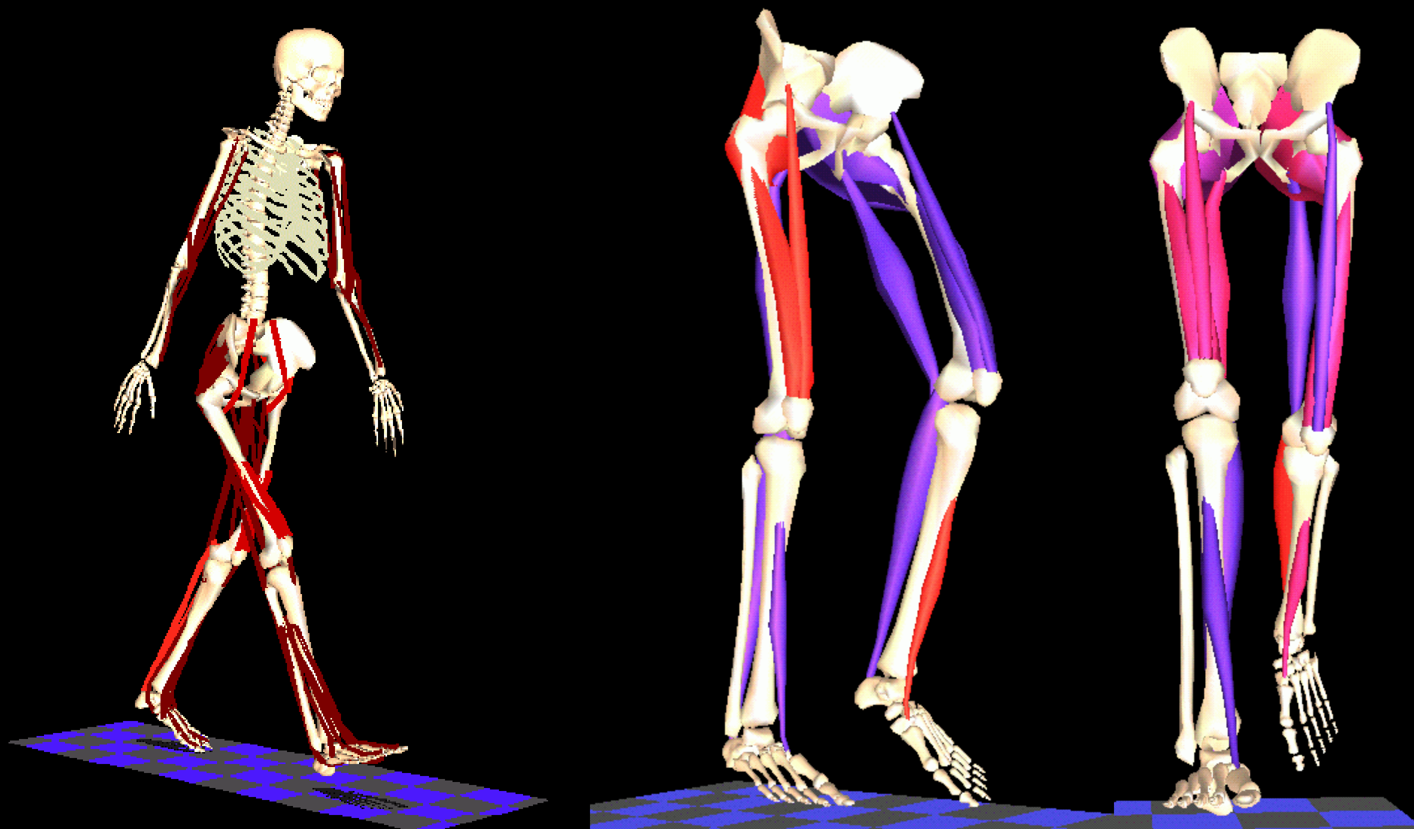
Implementation of Biologically-Inspired Approach

- Employs anatomical and physiological constraints
  - Force-length and force-velocity characteristics of muscles
  - Self-limiting joints
- Takes advantage of control features that enhance performance of biological systems
  - Focuses on *if-then* rules for intelligent control and behavior
  - Utilizes *functional muscle groupings* for required force and position control
- Requires a relatively small computational load

Analysis and Simulation of Biological Movements and Control





Courtesy of Musculographics Inc. and Dr. Rick Neptune, VA Hospital Palo Alto, CA

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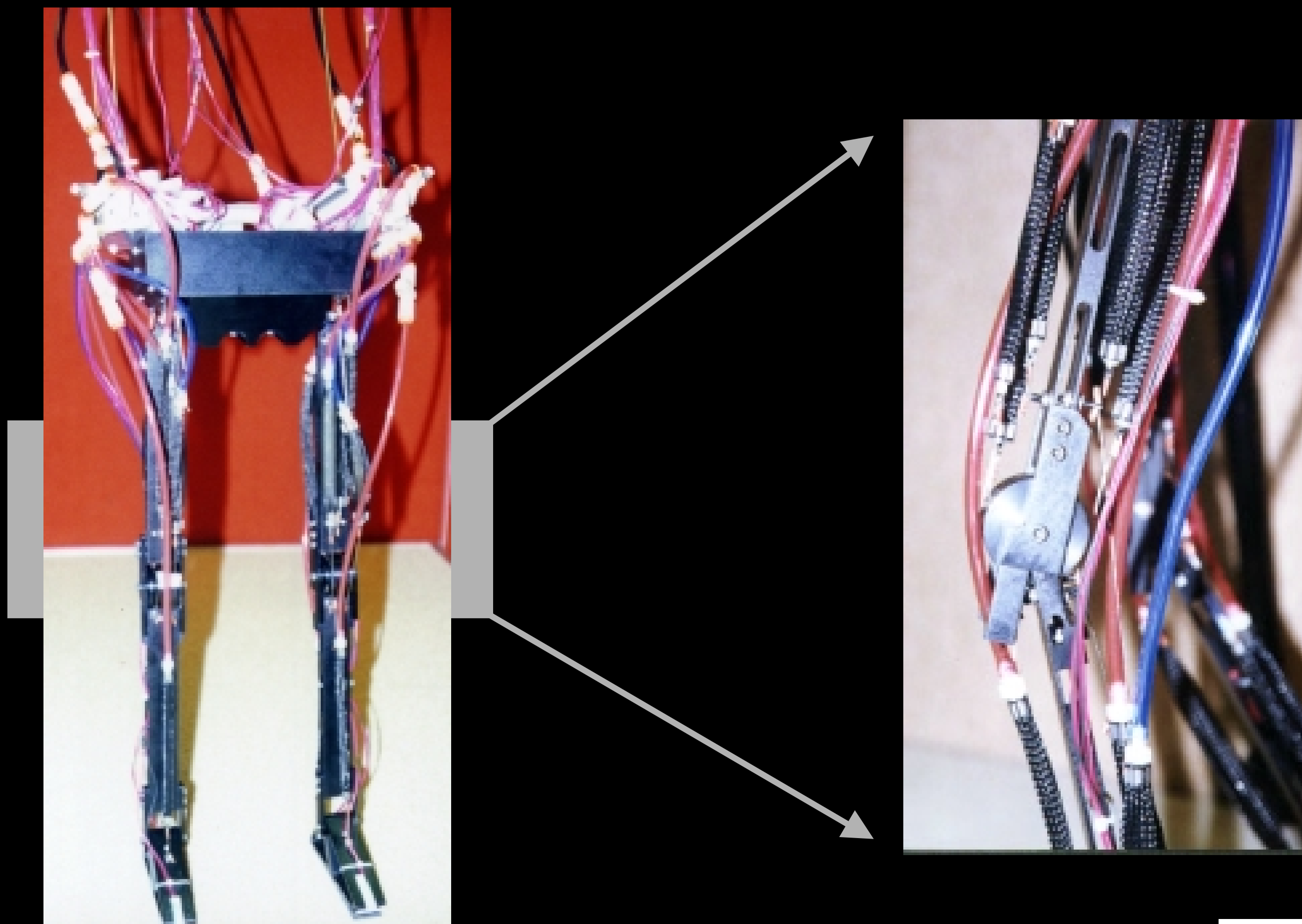
Hardware implementation

First prototype of legged robot



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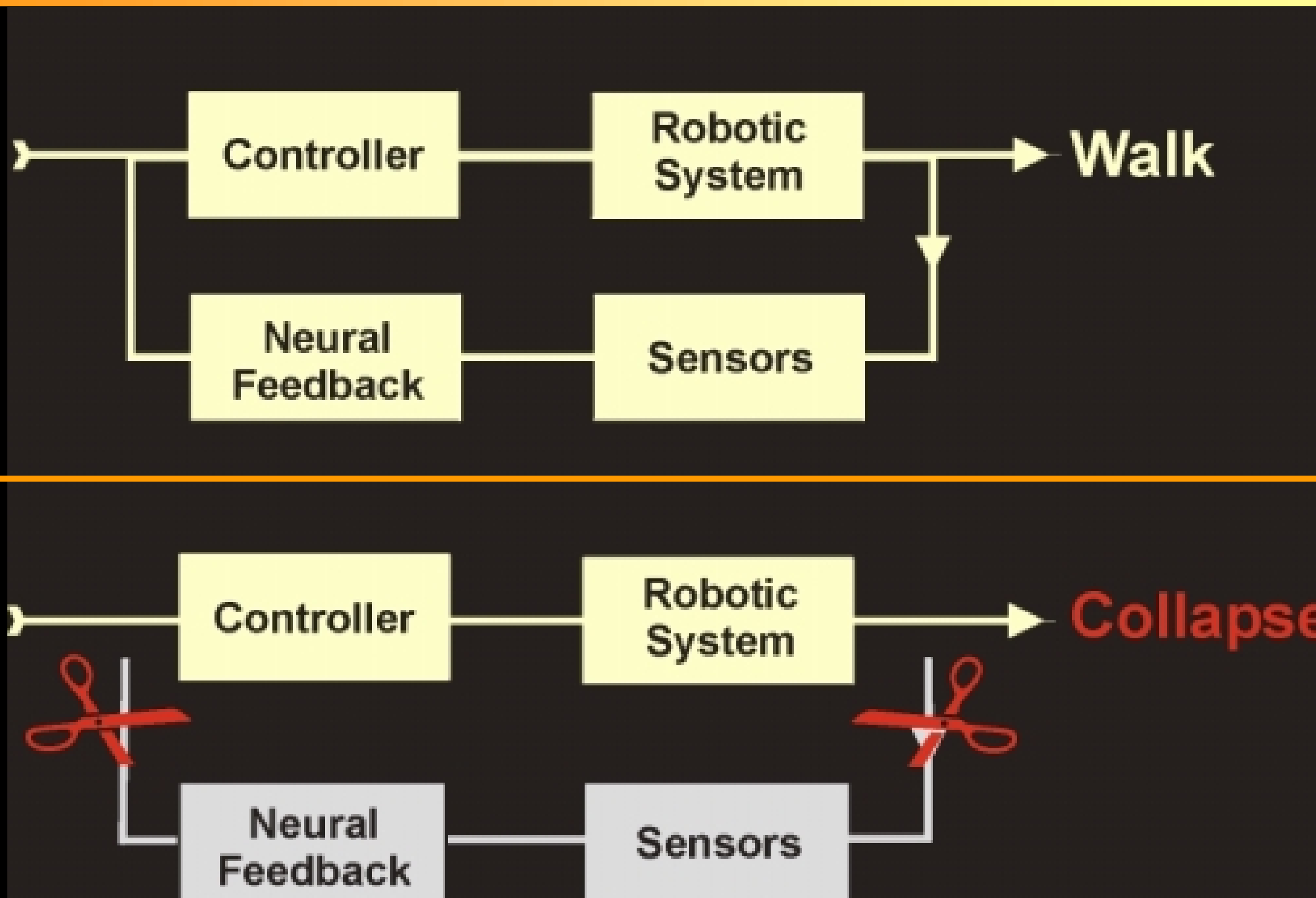
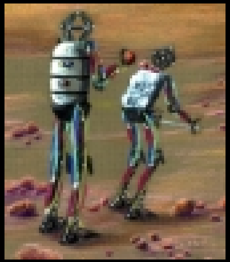
Conventional Robotic Design

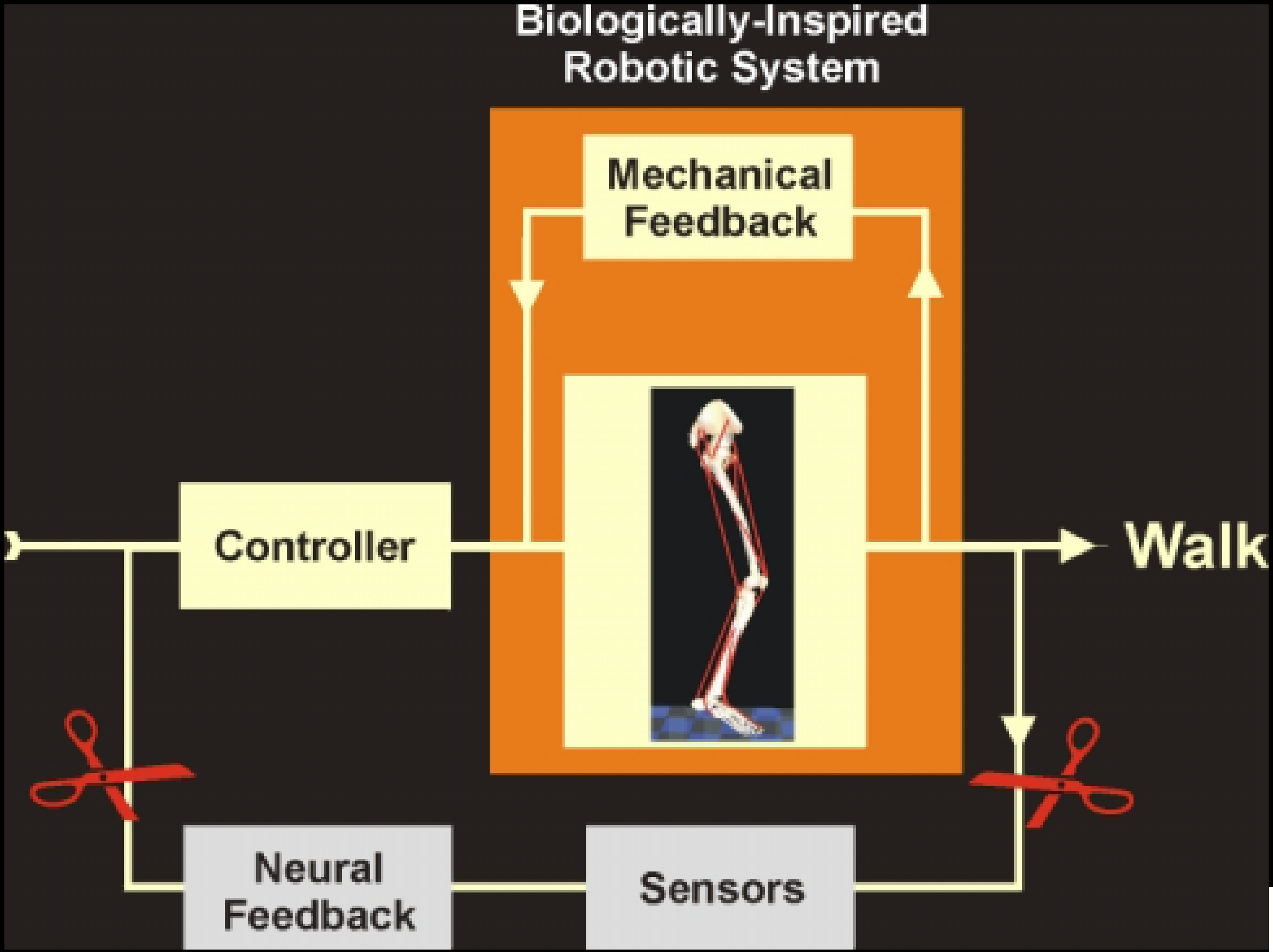
Heavily Dependent on Control





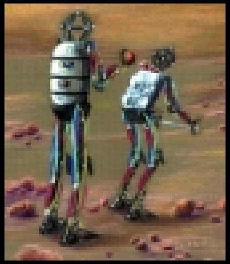
Biologically-Inspired Design

Intrinsic Mechanical Feedback Control



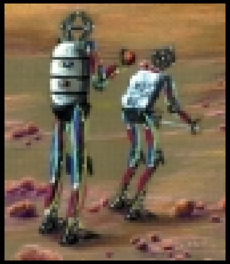
Technical Feasibility - Video

- First prototype
  - Legged robot with 18 artificial muscles
- NIAC Phase I
  - Project started in November 1998
- Abilities to date (after four months)
  - Standing (open loop)
  - Disturbance rejection while standing (open loop)
  - Walking movements (open loop)



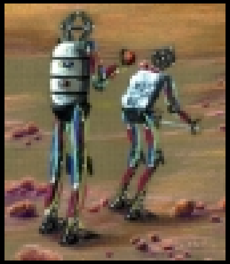
Benefits of Biologically-Inspired Approach

- Allows for intelligent control in a flexible yet stable system
- Facilitates travel and operation in rough terrains and difficult conditions
- Facilitates high functionality and versatility in a low mass system



State of the Art

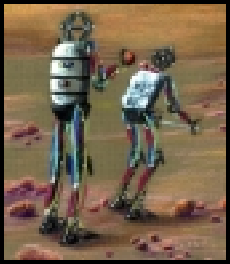
- First prototype demonstrates the power of the biologically-inspired approach
  - Implementation of artificial muscles
  - Utilization of intrinsic mechanical properties for local stability
  - Implementation of relatively simple control rules
  - Control of flexible multi-joint system
  - Implementation of *if-then* rules for functional muscle groupings
  - Provision of required force and position control



Design and Development Issues

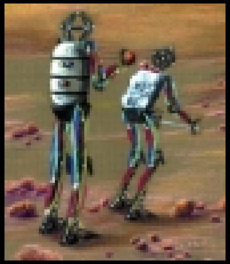
The Next 10 years

- Technical issues
  - Artificial muscles
  - Sensors
  - Self-contained power
  - Intelligent control
- Mobility and operation issues
  - Travel on even terrains
  - Travel on rough terrains and difficult conditions
  - Transformation and versatility
  - Maneuverability
  - Object manipulation



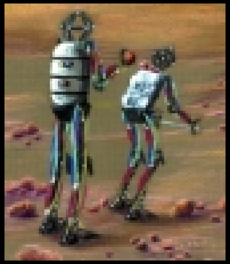
Design and Development Issues
The Next 10 years

- Intelligent agent issues
  - Autonomous nature
  - Problem solving and reasoning - especially in novel situations
  - Specialization of agent's performance
- Community of intelligent agent issues
  - Communication and reasoning among agents
  - Interaction and reasoning with remote scientist - *human extension*
  - Cooperation and problem solving

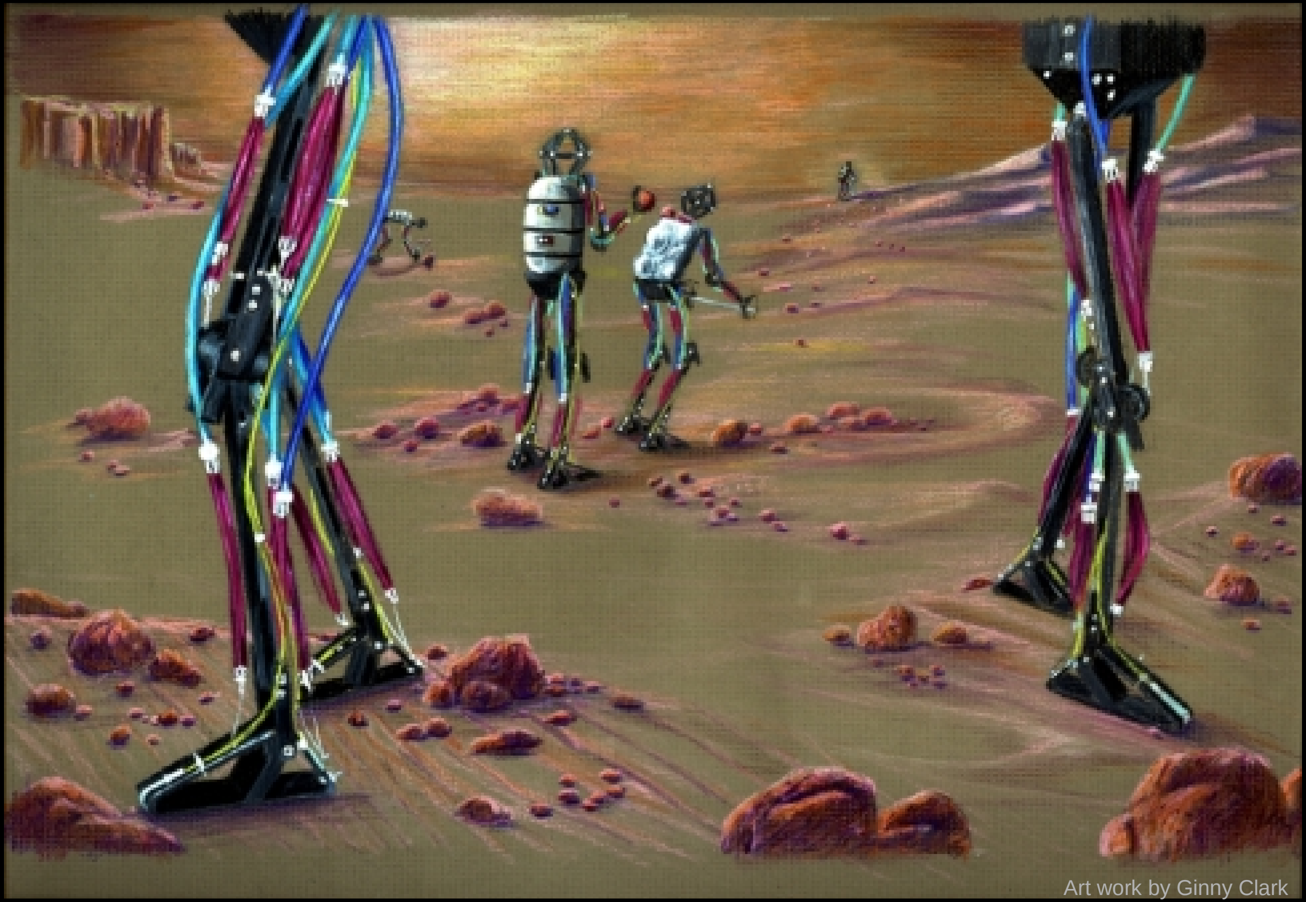


NASA Benefits of Biologically-Inspired Approach

- Provides community of intelligent agents
  - Travel and operate in rough terrains and difficult conditions
  - Focus on intelligent control, interaction and cooperation
  - Ideal for exploration beyond the solar system
  - Ability to explore novel opportunities
- Provides flexible and versatile systems
  - High functionality in a relatively low mass system
  - Human-like features ideal for remote human interaction



Community of Agents



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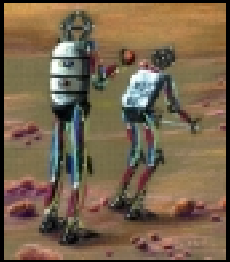
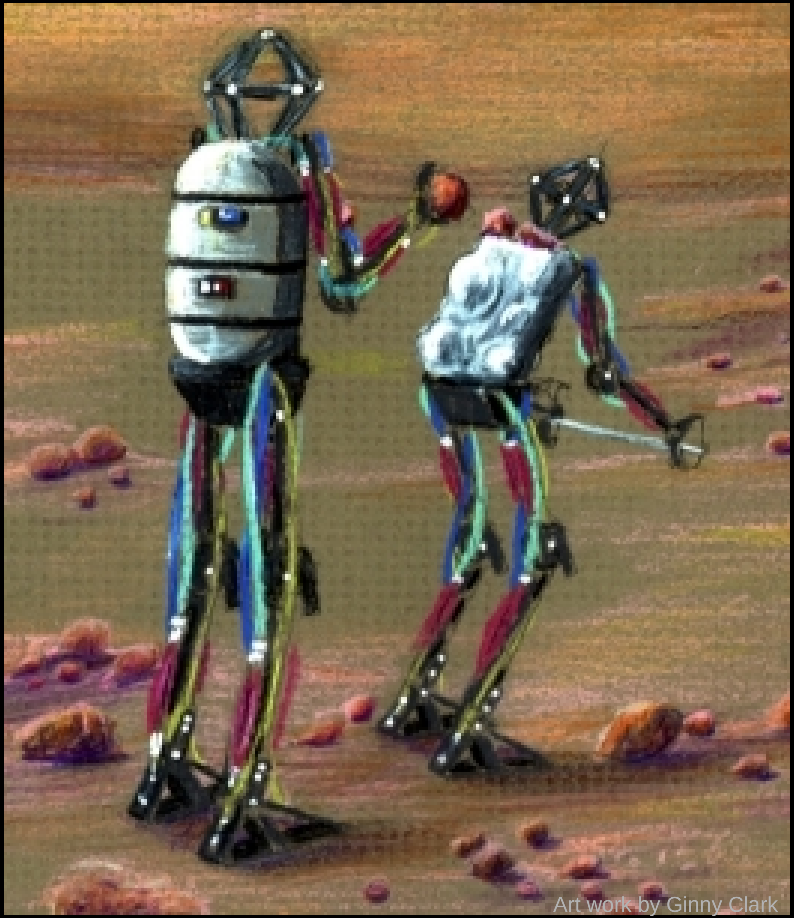


Futuristic Vision of Biologically-Inspired Approach



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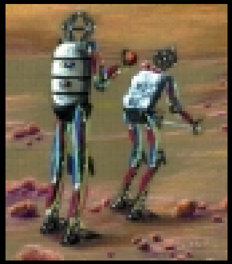
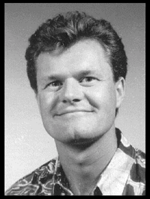


NIAC Supported Project Team



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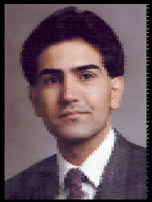

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