PROTEIN BASED NANO MACHINES FOR SPACE APPLICATIONS

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OUR VISION

To Develop Protein Based Nano Machines and Robots

- Novel
- Biological
- Multi-Degree of Freedom
- Apply Forces
- Manipulate Objects
- Move From Nano to Macro
- Lightweight / Efficient
- Self-Assembling
- Self-Reproducing
APPLICATIONS

- Outer Space and Planetary Missions
  - Colonization
  - Workstations
- Manufacturing
- Military
- Medical
APPLICATIONS

Bio-Nano-Robot Repairing a Damaged Blood Cell
0-10 YEARS: DEVELOPMENT OF BIO NANO COMPONENTS

- DNA – Structural Member, Power Source
- VPL – Protein Based Actuator
- Bacteriorhodopsin, HSF – Nano Sensors
## MACRO-NANO EQUIVALENCE

<table>
<thead>
<tr>
<th>Structural Elements</th>
<th>Power Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal, Plastic Polymer</td>
<td>Electric Motors, Pneumatic Actuators, Smart Materials, Batteries, etc.</td>
</tr>
<tr>
<td>DNA, Nanotubes</td>
<td>ATPase, VPL Motor, DNA</td>
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</tbody>
</table>

- **Structural Elements**
  - Metal, Plastic Polymer
  - DNA, Nanotubes

- **Power Sources**
  - Electric Motors, Pneumatic Actuators, Smart Materials, Batteries, etc.
  - ATPase, VPL Motor, DNA
## MACRO-NANO EQUIVALENCE

<table>
<thead>
<tr>
<th>Compliance Devices</th>
<th>Transmission Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Springs</td>
<td>Various Types of Gears, Belts, Chains etc.</td>
</tr>
<tr>
<td>β-Sheets</td>
<td>VPL Platforms, DNA Double Crossover Molecules</td>
</tr>
</tbody>
</table>
### MACRO-NANO EQUIVALENCE

<table>
<thead>
<tr>
<th>Sensors</th>
<th>Actuated Joints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light sensors, force sensors,</td>
<td>Revolute, Prismatic, Spherical Joints</td>
</tr>
<tr>
<td>position sensors, temperature</td>
<td>etc.</td>
</tr>
<tr>
<td>sensors</td>
<td>DNA</td>
</tr>
<tr>
<td></td>
<td>Nanodevices, Nanojoints</td>
</tr>
<tr>
<td></td>
<td>Rhodopsin, Heat Shock Factor</td>
</tr>
</tbody>
</table>
10-20 YRS: NANOROBOTIC ASSEMBLIES

- ATPase Motor Propelled
- Structure – Nanotubes
- Legs – Helical Proteins

Vision of a Nano Robot
20-30 YRS – SELF SUSTAINMENT AND REPLICATION

- Self Replication
- Sustainment
- Swarm Intelligence
- Controllability
30-50 YRS – DEPLOYMENT FOR SPACE COLONIZATION

- Space Colonization
- Non-living Robots
- Bio Mimetic
- Remote Sensing
- Signal Transmission

Courtesy: http://members.cox.net/kableguy/bryceworks/
SPECIFIC AIMS FOR PHASE I

- Identify Proteins for Use in Nanoscale Mechanisms
- Develop Concepts for Bio Nano Machine components
- Develop Dynamic Models and Realistic Simulations
- Perform a Series of Biomolecular Experiments
- Assembly and Interface Nano Machine Components
VPL MOTOR CONCEPT

- Viral Membrane Peptides
- pH Dependent
Viral Protein Linear Motor Actuated Parallel Platforms with Controllable Motion
VPL OUTPUT MULTIPLICATION

VPL Motors in Parallel – Force Multiplication

VPL Motors in Series – Displacement Multiplication
BIOSENSOR SYSTEM

- HSF Protein in Organisms
- Responds to Stimuli – Trimerises
- Binds to DNA
- Color Change
- Signal Transmission
MULTI-DOF DEVICES

- 3 VPL Actuators
- Nanotubes
- DNA Joints
- Response to pH Changes
COMPUTATIONAL STUDIES

- Model Reversible Folding of VPL Motor Protein
- Estimate Forces, Displacements etc. Through Energy
- Software Usage - CHARMM
- Input – Structure Files in .pdb Format
- Output – Simulated Energy and Displacements
- Microsecond Modeling – Assumptions, Targeted MD
- Parallel Processing Facilities at CAIP (Teal)
- Comparison with Experimental Observations
EXPERIMENTAL WORK

- Peptide Selection
- Protein Expression
- Protein Purification
- Protein Conformation as a Function of pH
- Calculate Force Expended upon Extension
- Reversibility
- Different Sequence - Different Designs
WEBPAGE

http://bionano.rutgers.edu
Welcome to the Rutgers' Bio-Nano Robotics web page. Using the tool bar above you will be able to navigate through the world of Bio-Nano Robotics. You will be able to see not only our work but also the works of the entire Nano Robotic community. If you are unaware of what our group’s goal is then perhaps you should begin your venture here by visiting the Our Research page and see what our main objective is. Perhaps you would like to see our hypothesis or those of others in action, in that case visiting the Multimedia pages is recommended. Maybe you would like to see whom it is here at Rutgers that’s working on the project, in that case then you should visit the Team page. I hope you enjoy the site and we wish you a pleasant learning experience.
OUTREACH ACTIVITIES

- High School Students in Research
- Minority Students in Research
- Undergraduate Students Employed
- Technology Transfer
- International and Industry Collaboration
- Colloquiums, Symposia and Journal Clubs
- Interdepartmental Course on Bio Nano Technology
ACKNOWLEDGEMENTS

- NASA Institute of Advanced Concepts (NIAC)
- SROA Program and Rutgers University, NJ
- NSF Nanomanufacturing Program