PROTEIN BASED NANO MACHINES FOR SPACE APPLICATIONS

Dr. Constantinos Mavroidis, Associate Professor

Department of Mechanical and Aerospace Engineering

Rutgers, The State University of New Jersey

NIAC Phase I Grant

THE TEAM

Dr. C. Mavroidis

Associate Professor Mechanical Engineering, Rutgers University

Dr. M. Yarmush

Chair, Biomedical Engineering, Rutgers University

Dr. M. S. Tomassone

Assistant Professor, Biochemical Engineering Rutgers University

Dr. F. Papadimitrakopoulos

Associate Professor Department of Chemistry University of Connecticut

Dr. B. Yurke

Researcher, Bell Laboratories, Lucent Technologies Inc.

Mr. Atul Dubey

Graduate Student Rutgers University

Ms. Angela Thornton

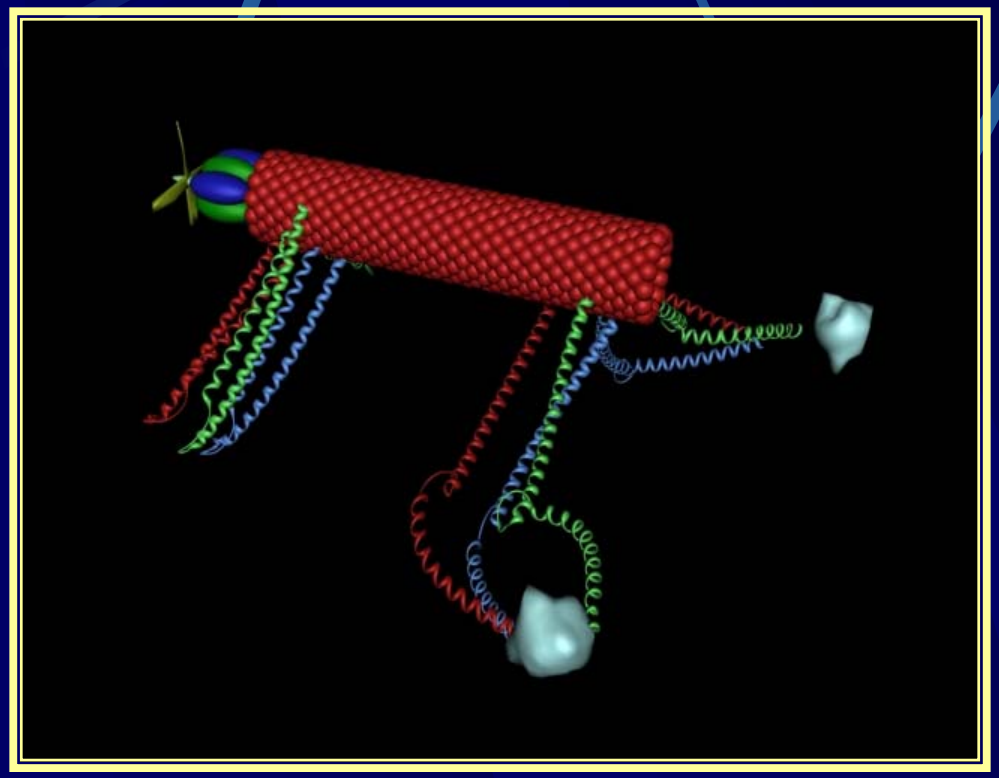
Graduate Student Rutgers University

Mr. Kevin Nikitczuk

Undergraduate Student Rutgers University

OUR VISION

To Develop Protein Based Nano Machines and Robots

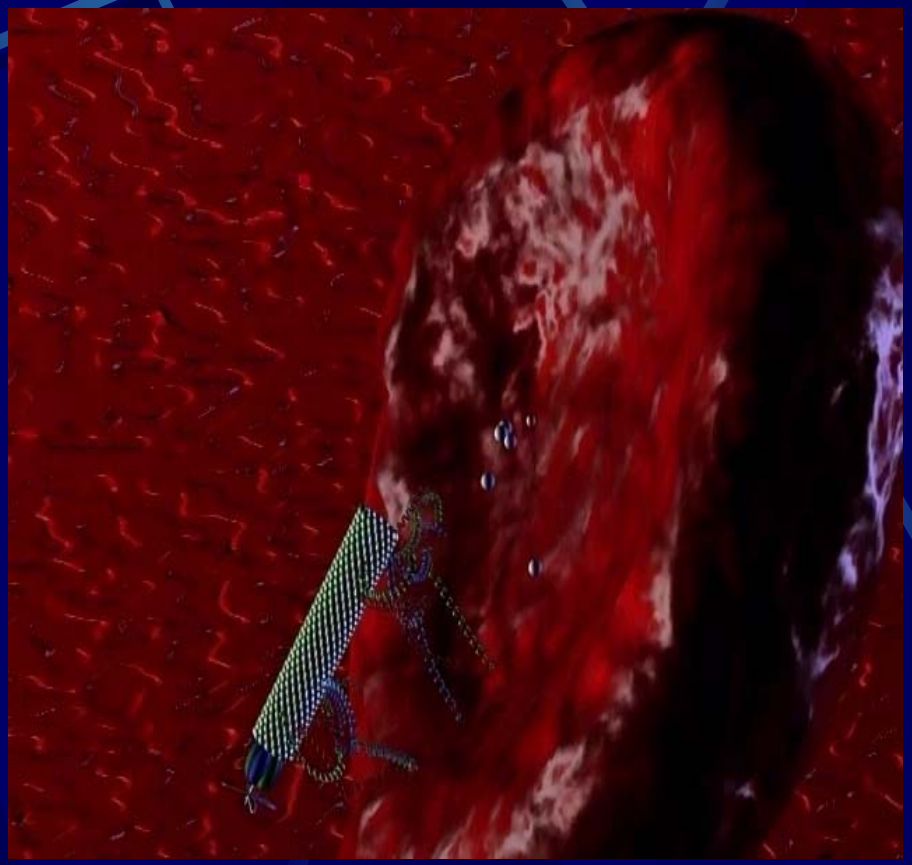


- Novel
- Biological
- Multi-Degree of Freedom
- Apply Forces
- Manipulate Objects
- Move From Nano to Macro
- Lightweight / Efficient
- Self-Assembling
- Self-Reproducing

APPLICATIONS

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

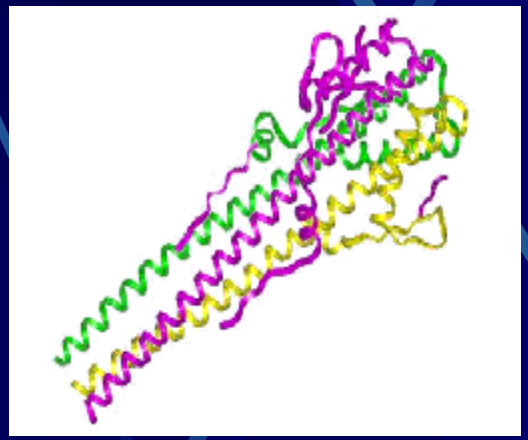
APPLICATIONS



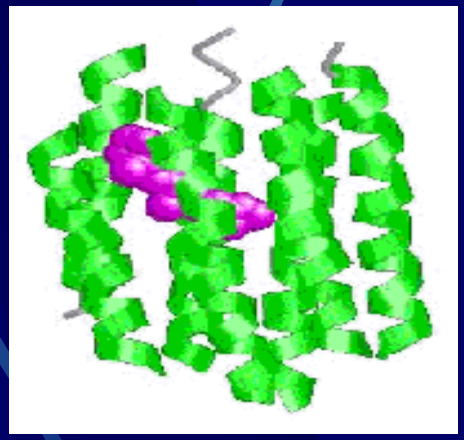
- Bio-Nano-Robot Repairing a Damaged Blood Cell

0-10 YEARS: DEVELOPMENT OF BIO NANO COMPONENTS

DNA



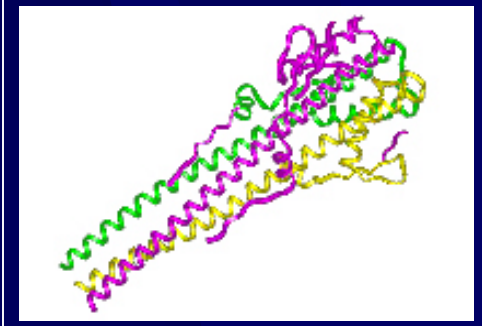
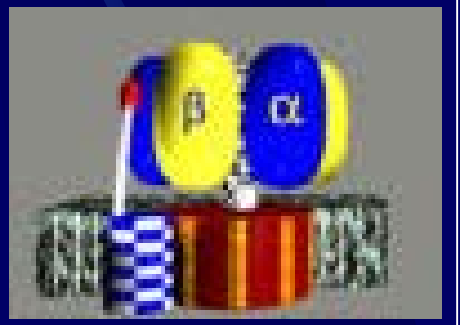
VPL Motor



Bacteriorhodopsin

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

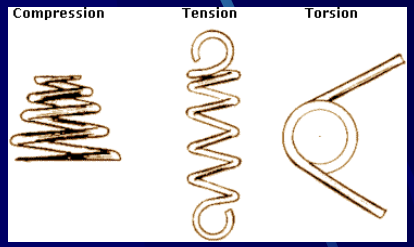
MACRO-NANO EQUIVALENCE

Structural Elements	
Metal, Plastic Polymer	DNA, Nanotubes  
Power Sources	
Electric Motors, Pneumatic Actuators, Smart Materials, Batteries, etc.	ATPase, VPL Motor, DNA  

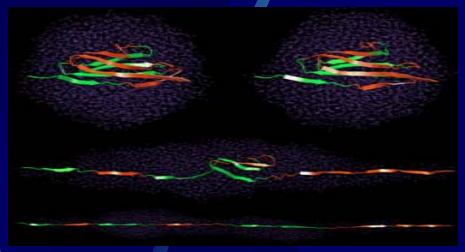
MACRO-NANO EQUIVALENCE

Compliance Devices

Springs

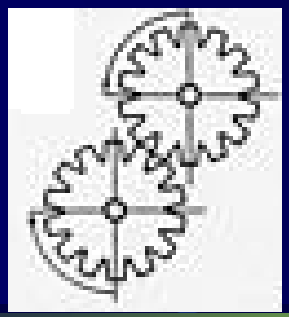


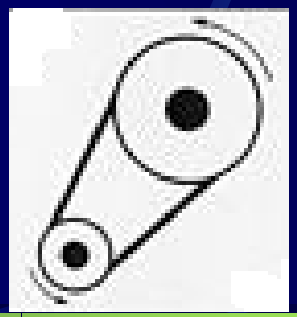
β-Sheets



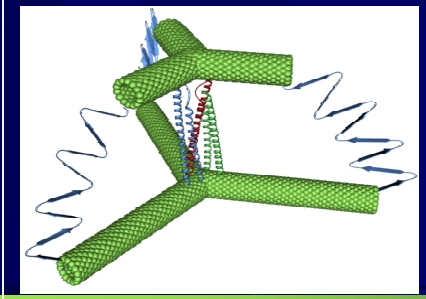
Transmission Elements

Various Types of Gears, Belts, Chains etc.

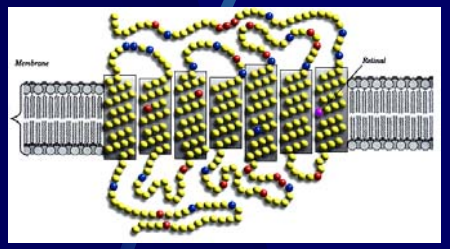
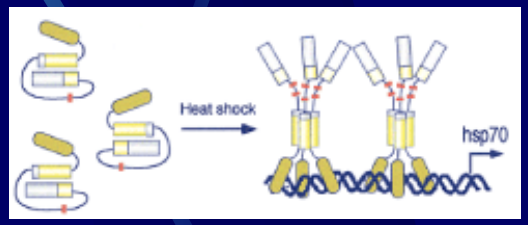
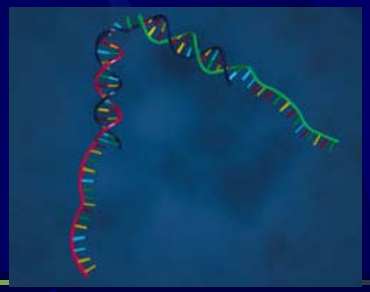




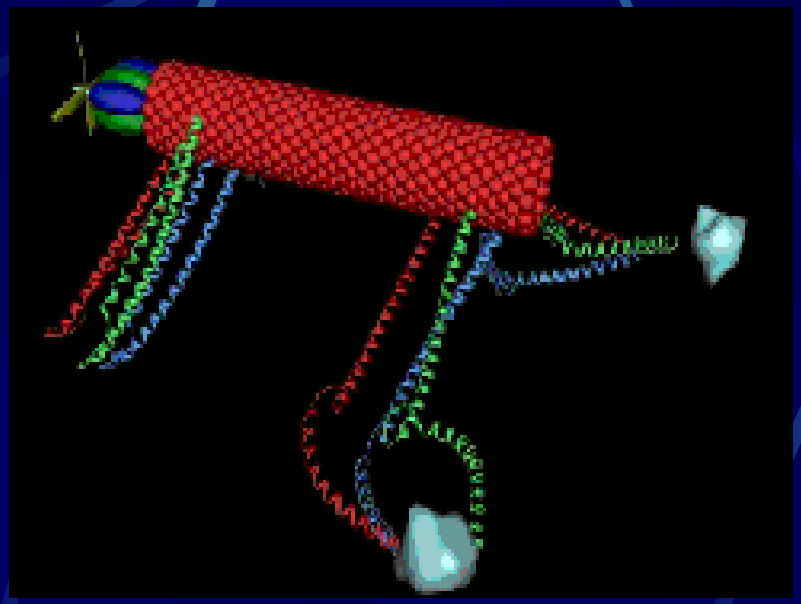
VPL Platforms, DNA Double Crossover Molecules



MACRO-NANO EQUIVALENCE

Sensors	
Light sensors, force sensors, position sensors, temperature sensors	Rhodopsin, Heat Shock Factor  
Actuated Joints	
Revolute, Prismatic, Spherical Joints etc.	DNA Nanodevices, Nanojoints 

10-20 YRS: NANOROBOTIC ASSEMBLIES



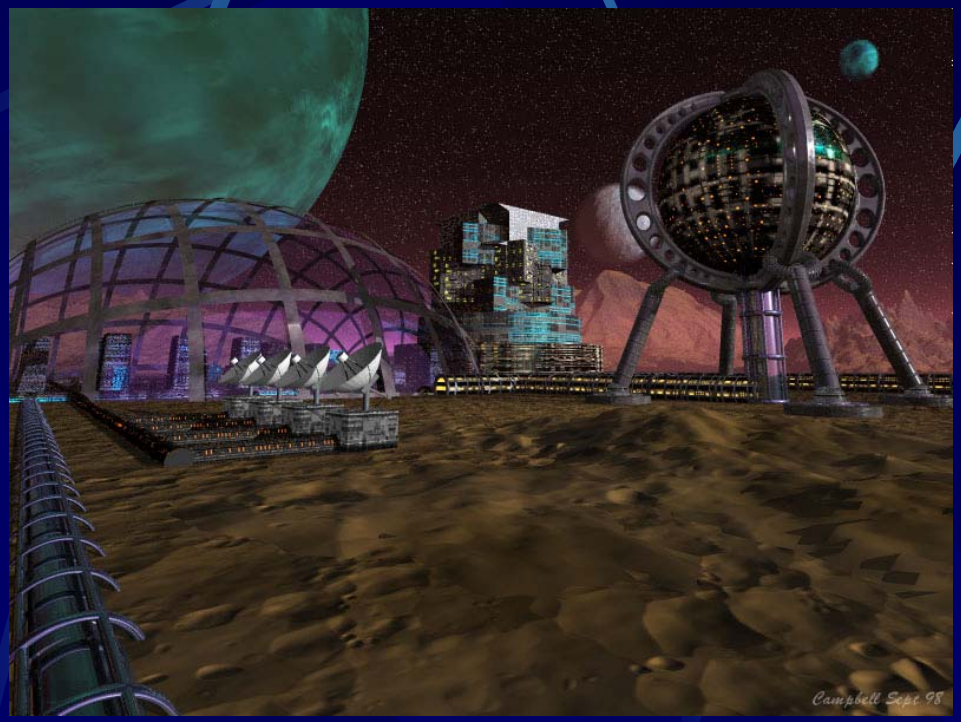
Vision of a Nano Robot

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

20-30 YRS – SELF SUSTAINMENT AND REPLICATION

- Self Replication
- Sustainment
- Swarm Intelligence
- Controllability

30-50 YRS – DEPLOYMENT FOR SPACE COLONIZATION



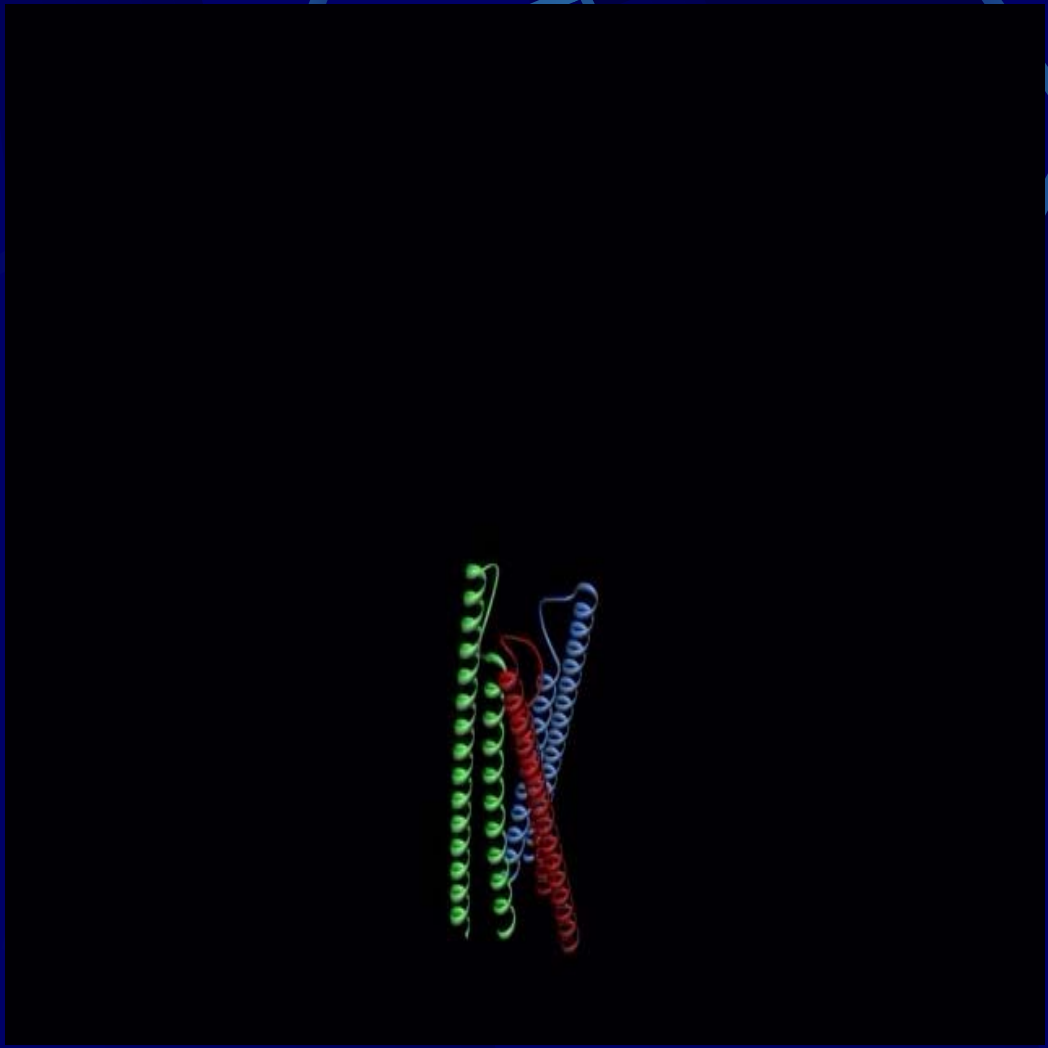
- Space Colonization
- Non-living Robots
- Bio Mimetic
- Remote Sensing
- Signal Transmission

Courtesy: http://members.cox.net/kableguy/bryceworks/

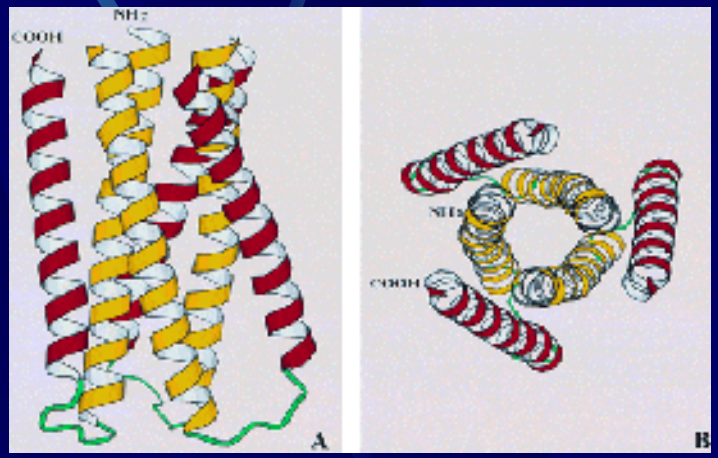
SPECIFIC AIMS FOR PHASE I

- 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

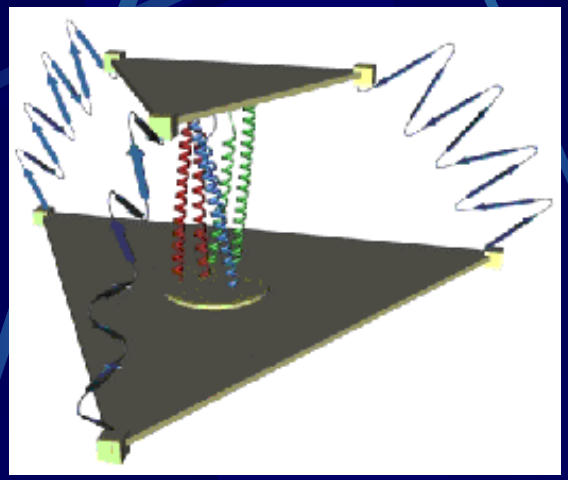
VPL MOTOR CONCEPT

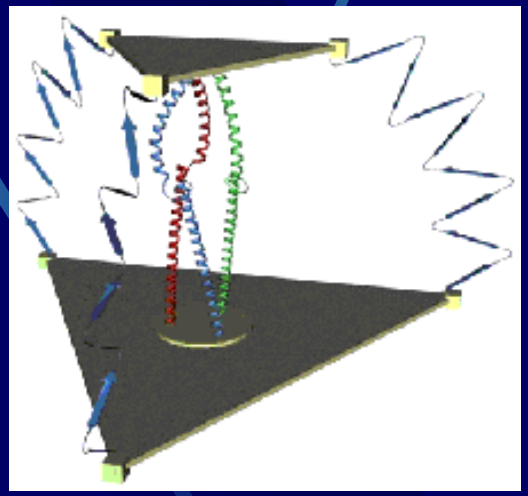


- Viral Membrane Peptides
- pH Dependent



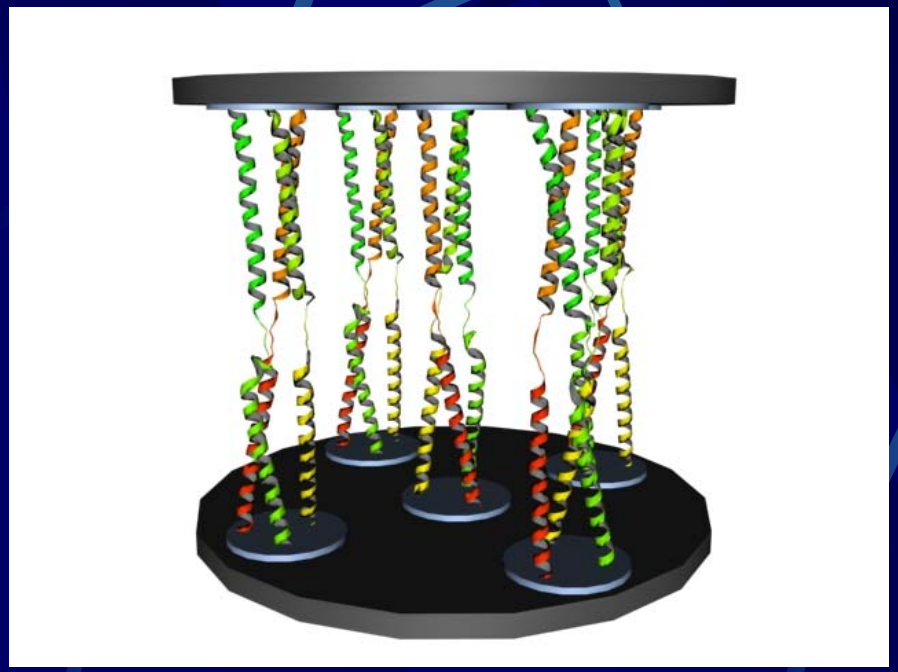
VPL ACTUATED PLATFORMS





Viral Protein Linear Motor Actuated Parallel Platforms with Controllable Motion

VPL OUTPUT MULTIPLICATION

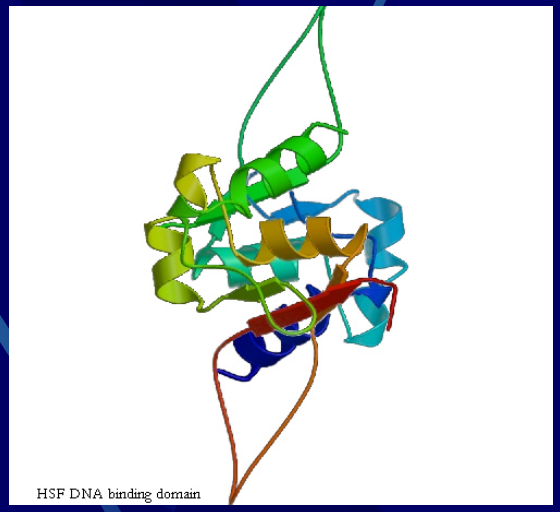


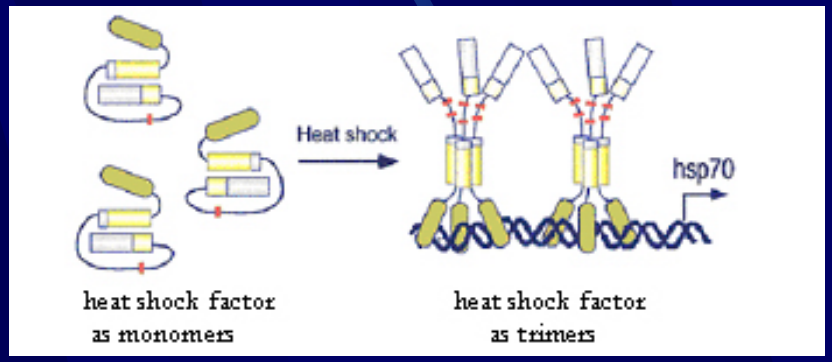
VPL Motors in Parallel – Force Multiplication

VPL Motors in Series – Displacement Multiplication

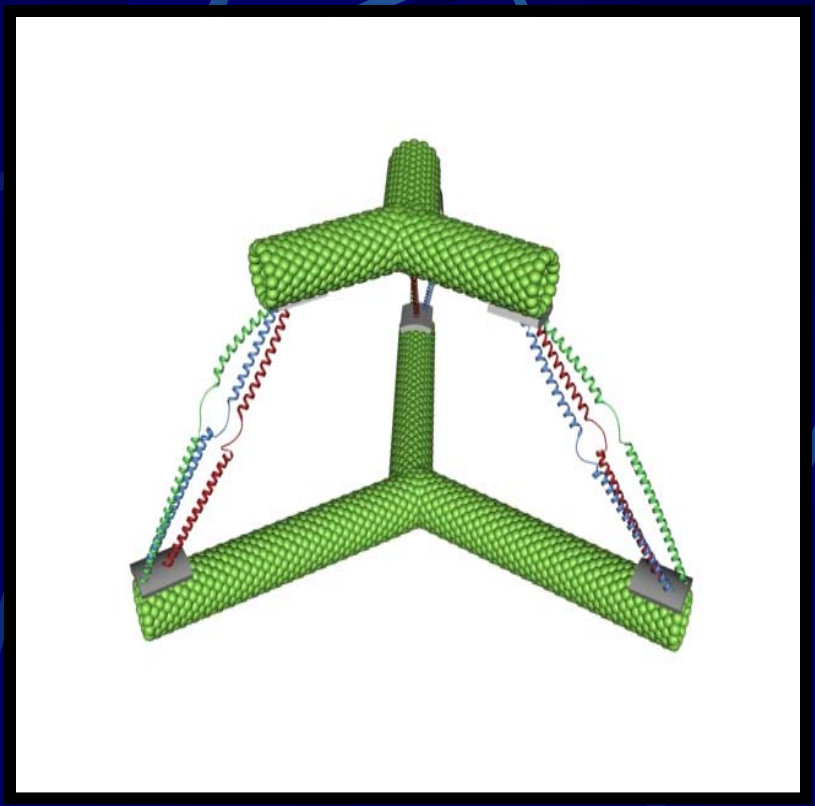
BIOSENSOR SYSTEM

- 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

Rutgers Bio Nano Robotics - Microsoft Internet Explorer

File Edit View Favorites Tools Help

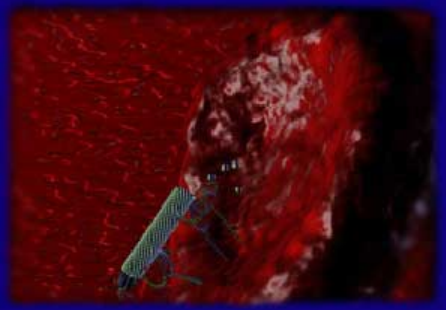
Back Search Favorites Media

Address http://www.rci.rutgers.edu/~dubey/nanorobotics/ Go Links

Google Search Web Search Site Page Info Up Highlight

Bio-Nano Robotics

Home Team Our Research Related Research Outside of Rutgers Multimedia from R.U. Multimedia Outside of R.U.



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..

Internet

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