R&D in Support of DARPA Applications of Molecular Electronics Program (MoleApps)

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DARPA/DSO

Project Data (internal use only)

- Project Number: 0705D070-ME
- Ceiling Source: DARPA
- Principal Investigator: James C. Ellenbogen
- DARPA Office: DSO
- Sponsor: DARPA
- FY05 Funding Level: $150K
- Technical Area: Electronics
- External Web URL: www.mitre.org/technology/nanotech

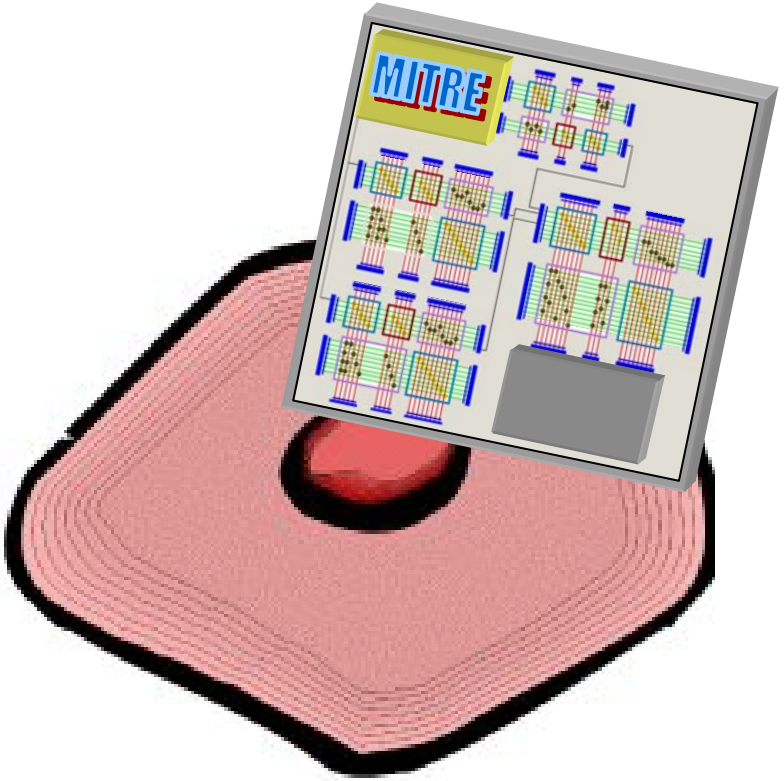
Problem

- Investigators under contract to DARPA are attempting to build molecular-scale computer and sensor systems – e.g., a nanoprocessor.
- These will be ultra-dense and very complex, and will incorporate new operating principles.
- Quantitative analysis and simulation tools are required to determine
  - How such circuits and their molecular-scale elements are likely to perform.
  - How best to combine these elements to perform computation and sensing.

Background

- DARPA is developing next-generation, ultra-dense computer and sensor systems integrated on the molecular scale.
- Challenges include:
  - improving understanding of molecular devices
  - interpreting experiments, while developing metrics and standards for such molecular-scale systems
  - performing simulations to ensure that prototypes can be scaled up to meet program milestones

Future nanoprocessors might occupy an area comparable to that of a human cell.



Example: design for nanowire-based nanoprocessor to control MITRE's millimeter-scale robot

Objectives

- Design, simulation, and analysis to assist DARPA in addressing major challenges facing development of molecular electronic nanocomputer and nanosensor systems
- New insights into the electrical properties of molecular-scale components that will make modeling and design easier and more reliable
- Adopt an approach that will assist in integrating diverse research efforts by other groups under contract to the DARPA Moletronics and MoleApps Programs

Activities

Developing:

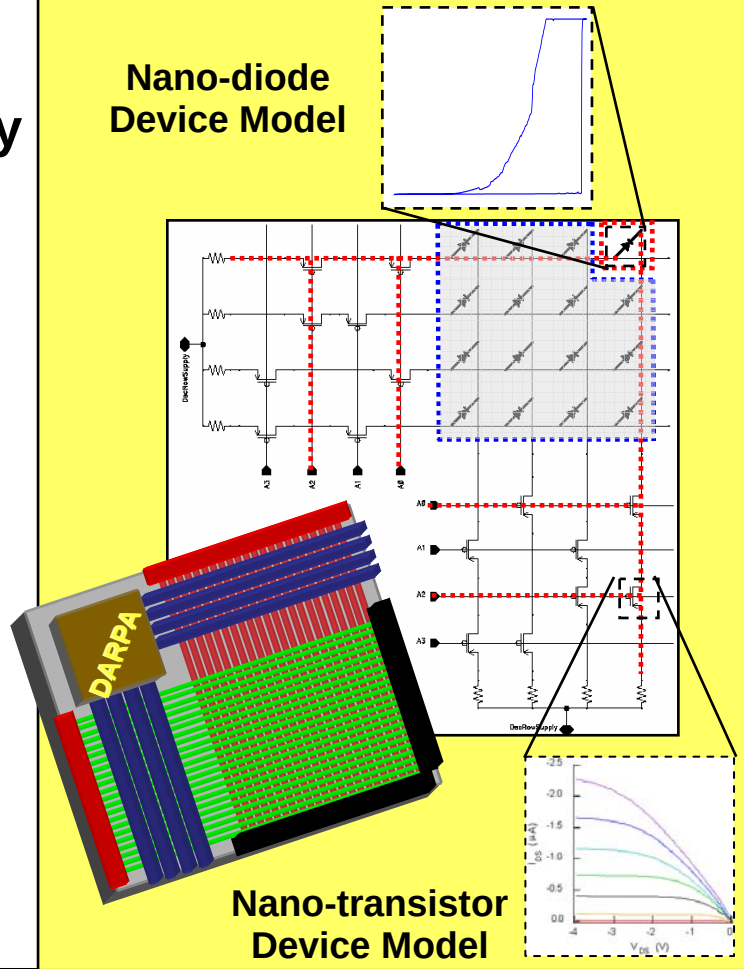
- **Scalability simulations for molecular-scale electronic memory and processor systems in collaboration with teams from:**
  - **Harvard**
  - **Caltech**
  - **Hewlett-Packard Corp.**
  - **Purdue University**
- **Architectures for future molecular-scale electronic processor and sensor systems**
- **Simpler models for electron transport in molecules and for molecular device analysis**

Highlight

NANOMEMORY

- Detailed MITRE simulations suggest 16-Kbit nanomemory array would operate if fabricated using present devices.
  - Analyzed both the Harvard-Caltech and the Hewlett-Packard systems
  - Demonstrated that scalable nanomemory systems function
  - Identified ways to further improve system performance and increase robustness
- Now assisting DARPA developers in integrating nanomemory arrays with memory addressing circuits

Nanomemory Simulations



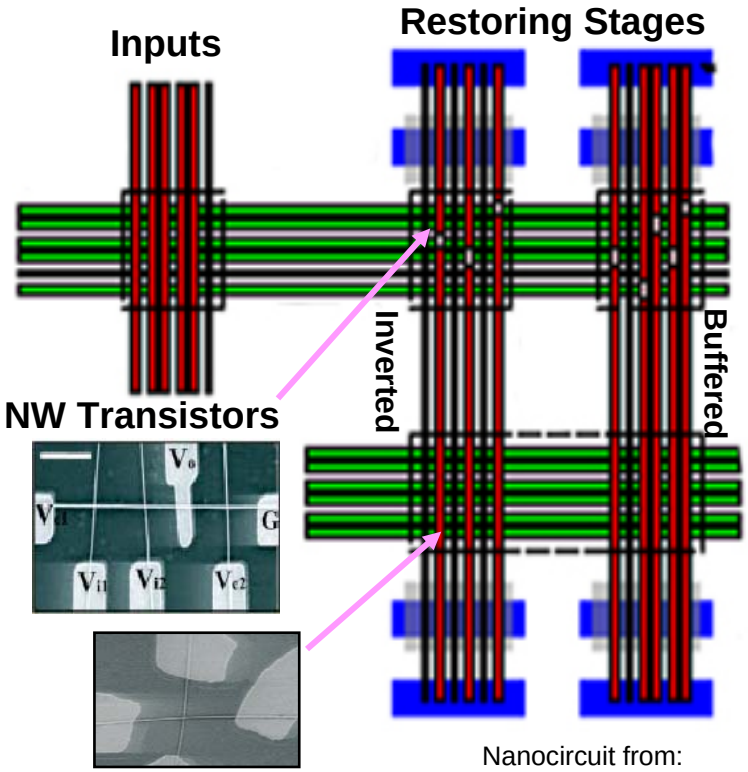
MITRE simulations show DARPA memory goal is achievable

Highlight

NANOPROCESSOR

- Initial, detailed, simulations indicate successful operation of essential circuits
  - Inverters and buffers
  - Programmable OR-planes
  - Combinations of these circuits
- System simulations for a 64-bit nanoprocessor suggest entire extended systems also will function
- Identified modifications that may improve system performance even more

PLA-Based Nanoprocessor Architecture

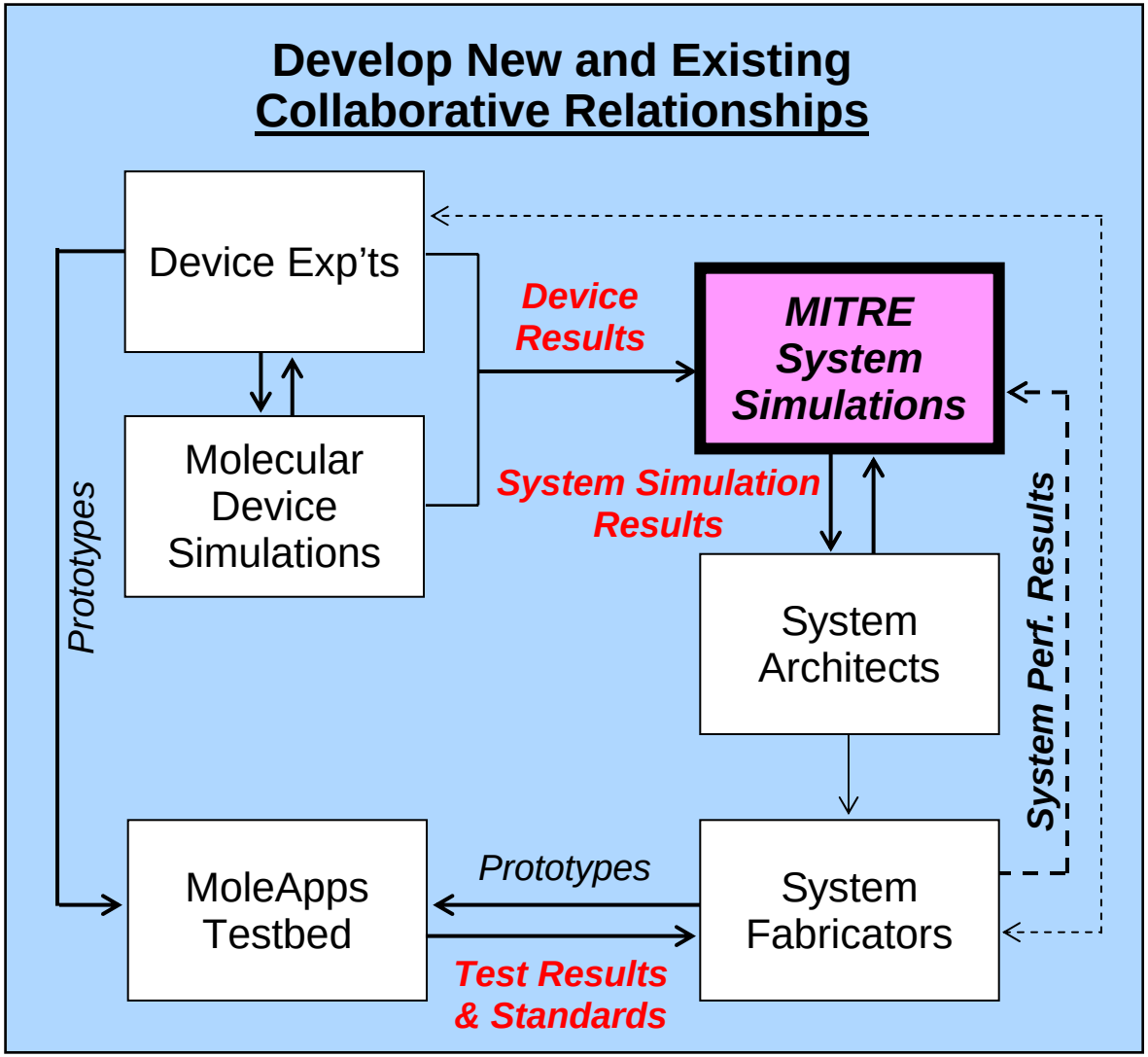


PLA = Programmable Logic Array
NW = Nanowire

Impacts

- MITRE simulations are assisting other groups under contract to DARPA to meet the nanomemory system goal in 2005.
- Simulations of extended nanoprocessor circuits confirm that architectures proposed in MoleApps Program can be made to operate for an entire nanoprocessor system.

Future Plans



- **Integrate into detailed simulations of extended nanocircuit systems**
  - **Results from detailed simulations of the electrical behaviors of molecules**
  - **Results from experiments on molecular-scale electronic devices**
- **Assist in developing standards for evaluating molecular electronic devices and systems**