Honeywell

LDART

A Large Scale Network of Embedded Systems for Laser Detection and Reciprocal Targeting

Jathan Manley, Robert DeMers, Jan Jelinek, Michael Rhodes, Jay Schwichtenberg, Vicraj Thomas, Brian VanVoorst, Phil Zumsteg

This work is funded by the DARPA/IXO NEST program under contract number F33615-02-C-1175

Points of Contact

- Honeywell
  - Vic Thomas (vic.thomas@honeywell.com)
  - Jathan Manley (jathan.manley@honeywell.com)
- DARPA
  - Dr. Vijay Raghavan, Program Manager (IXO)

Outline

- LDART Application and Concept of Operations
- LDART Technology – MEMS Implementation
- LDART Development Efforts – A Macro Platform
- Current Status

LDART: Laser Detection & Reciprocal Targeting

- A lightweight, easy-to-deploy technology for improved battlefield situation awareness
- Implemented as a "patch" attached to a soldier or vehicle
- Combines capabilities provided by multiple systems into one small package
  - Detect if soldier/vehicle has been painted by laser
  - Accurate location of source of laser (new capability)
  - Friend-or-foe identification
  - Reciprocal targeting (new capability)
- Functions are easily separable
- Can interface with existing systems
  - Situation awareness systems
    - e.g., Objective Force Warrior displays and vehicle cockpit display systems
  - Target designators

DARPA Honeywell

LDART: Laser Detection Capabilities

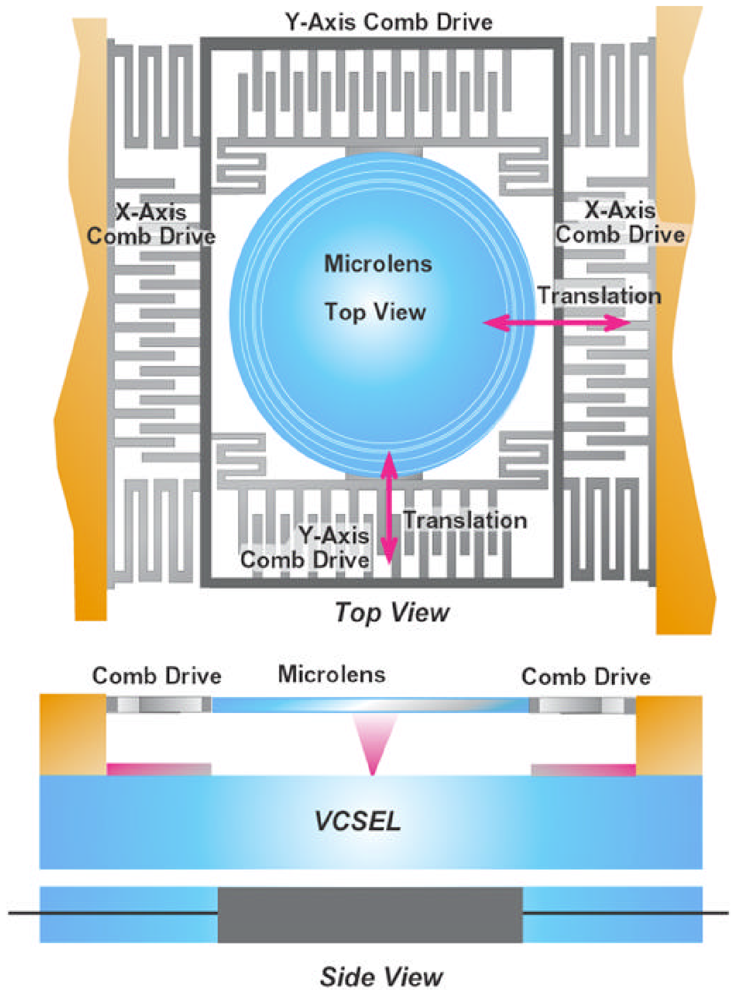
- Detect when soldier/vehicle has been painted by laser
  - Range finder
  - Target designator
  - Beam rider
  - Spotting Beam
  - Battlefield illuminator
- Can identify direction of laser source
  - Within ? 0.06 degrees (?1m for source at 1km)
- Can estimate distance of laser source
  - Accuracy depends of distance of source and size of patch
  - 1m^2 patch can estimate distance of target at 1km within ? 30m
  - Greater accuracy for closer sources
- Continues to track direction and distance of source even as source and target move relative to each other

Target Designator

Range Finder

LDART: Hardware Technology

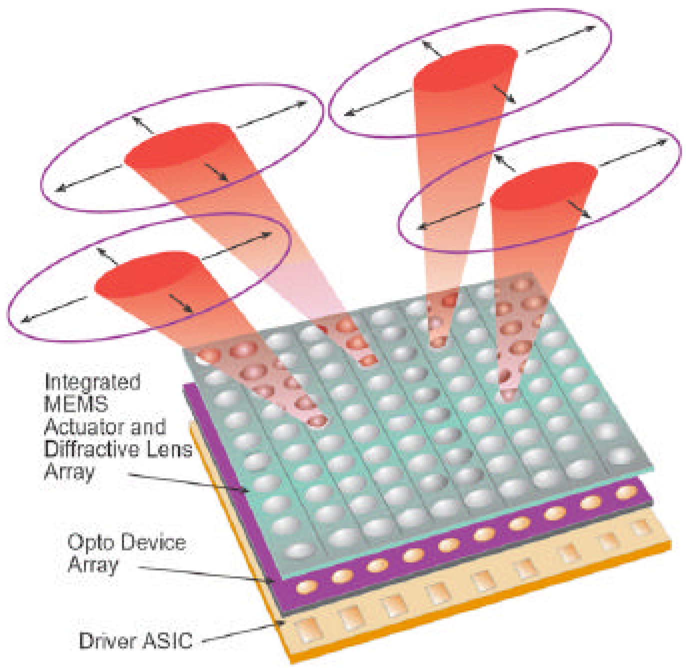
- Hardware based on MEMS technology being developed by Honeywell
  - Sponsored by the DARPA/MTO STAB program
- The LDART "fabric" consists of a large number of cells
  - Cell size: 1 mm^2 (~40,000 cells in 8inX8in area)
- Each cell consists of
  - A micro-lens (0.1mm diameter)
  - Drives to move lens in x and y directions
  - Detector or laser under the lens at its optical axis
  - Compute element to control cell
  - Communication links to neighboring cells



Top and Side View of a Single Cell

LDART: Hardware Technology

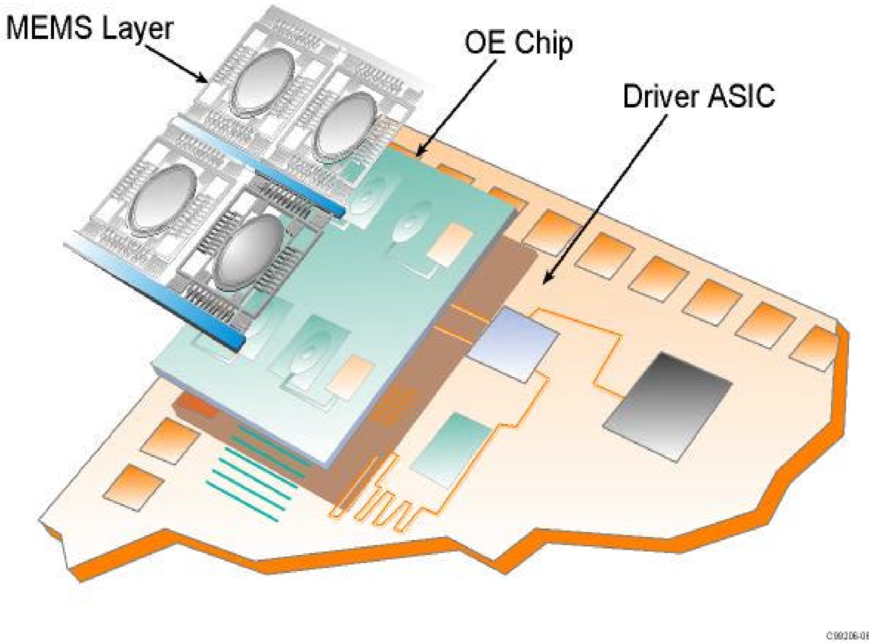
- Incoming laser beam can be steered onto detector by moving lens
  - Lens position used to determine incident angle of beam
  - Lens positioning accuracy: 0.0005mm
- Outgoing (paintback) laser beam can be steered by moving lens



LDART "Fabric" with Large Number of Cells

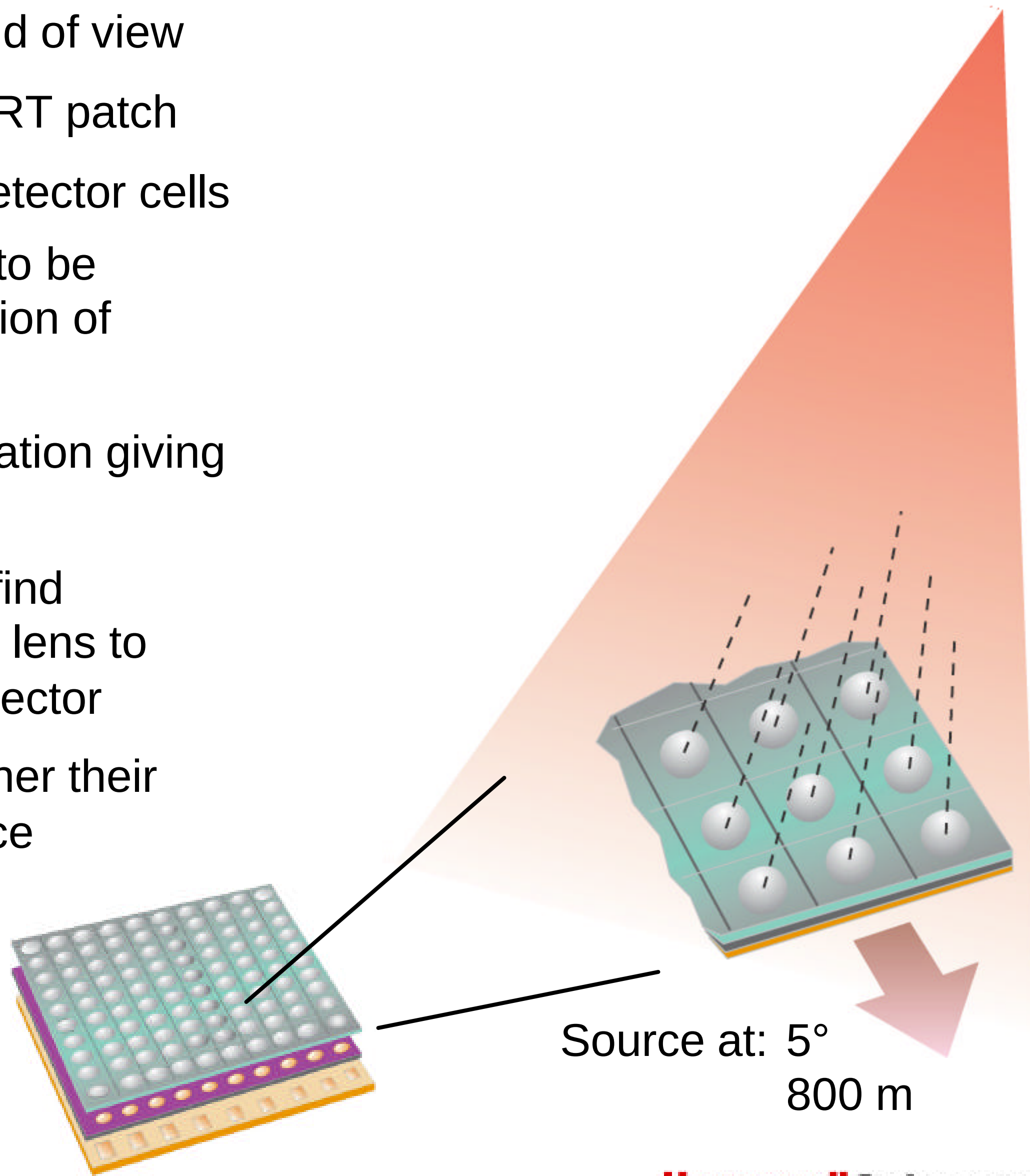
MEMS Details

- **Lens/sensor/actuator assembly**
  - **Size: <1 sq. mm**
- **Lens**
  - **Diameter: ~0.1 mm**
  - **Travel: ~0.05 mm in X & Y**
  - **Resolution: ~0.0005 mm (0.5 µm)**
  - **Speed: 5-10 KHz**
  - **Focal length: 0.12/0.32 mm**
  - **Refractive index: 3.4**



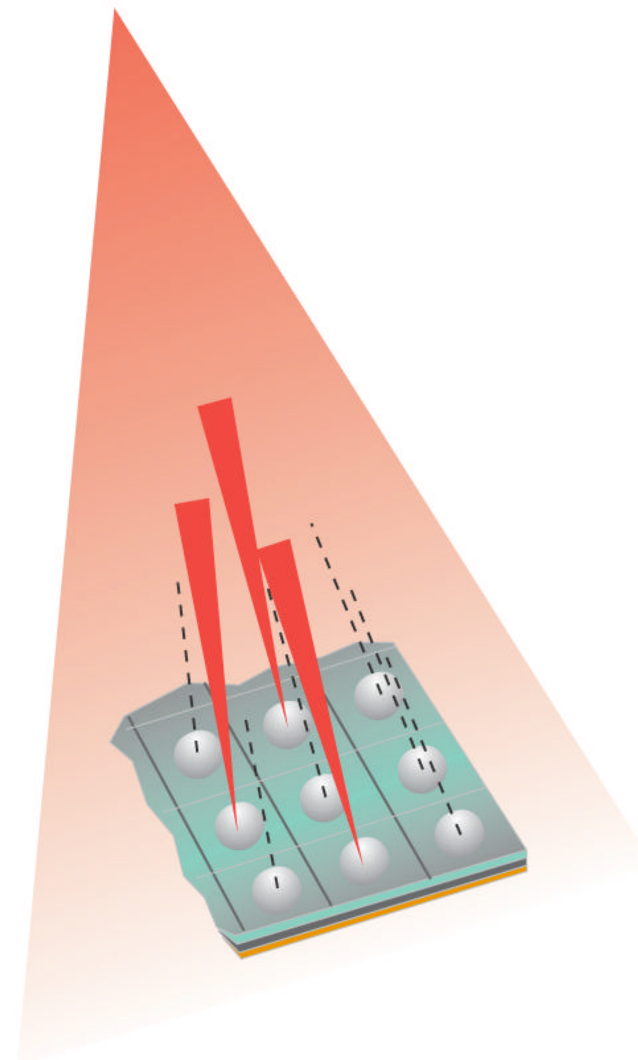
LDART: Laser Detection Overview

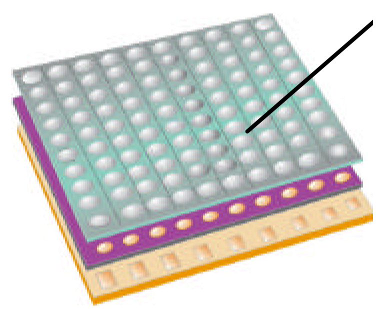
- Cells oriented to cover entire field of view
- Light from laser illuminates LDART patch
- Illumination detected by some detector cells
  - Cells whose lens happened to be pointing in the general direction of source
- Cells inform neighbors of illumination giving general direction of source
- Each cell independently tries to find direction of source by moving its lens to maximize energy seen by its detector
- Cells communicate with each other their estimate of the direction of source
- Cells estimate distance to source using triangulation



LDART: Reciprocal Targeting Overview

- After laser source is detected, set of cells is selected to do paintback
- Cells coordinate to determine code to be pulsed during paintback
- Cells paint back in a coordinated fashion
- Cells track target as it moves relative to LDART



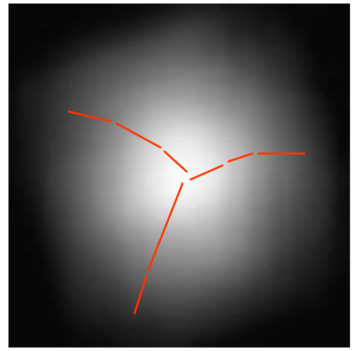


LDART: Features

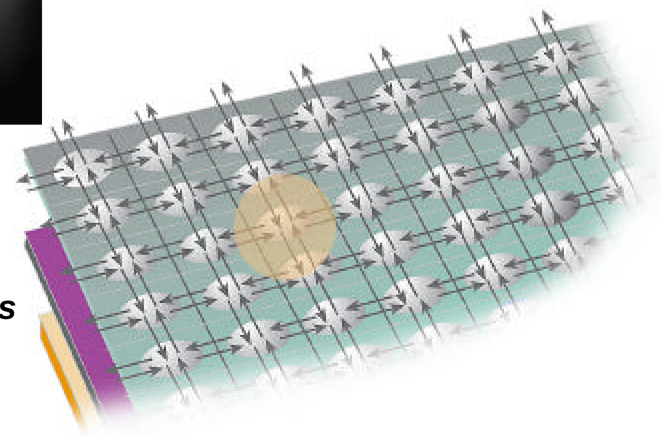
- Light weight
  - 8in X 8in patch: approx. 90 grams for MEMS hardware + approx. 250 grams for packaging
- Low power
  - Idle state (all lenses holding position): ?5mW for 8in X 8in patch
  - If all lenses are moving (unlikely): ? 5W for 8in X 8in patch
  - Paintback energy: ? 5mW per laser
- Accurate
  - Can locate source at 1km within ±1m (tangential) and ±30m (radial)
- Low cost
  - Estimate few hundred dollars for each patch
- Easy to deploy
  - Attached as patch of soldier/vehicle/asset
  - One system performs multiple functions

LDART: Software Technology

- **LDART control distributed over the tens of thousands of cells**
- **Cells collect their own observations and use data from other cells**
- **Advantages of distributed control**
  - Much greater accuracy as errors are averaged
  - Greater fault tolerance
- **Cells collaborate by exchanging data**
  - Their own data on energies detected, location computed, etc.
  - By passing on data from other cells
- **Each cell creates a table of observations from which it calculates where to move**
  - For finding a moving laser
  - For painting back its own laser



Paths taken to find strongest energy. Each node takes four samples to compute a vector towards center.



Information Exchanged Between Nodes

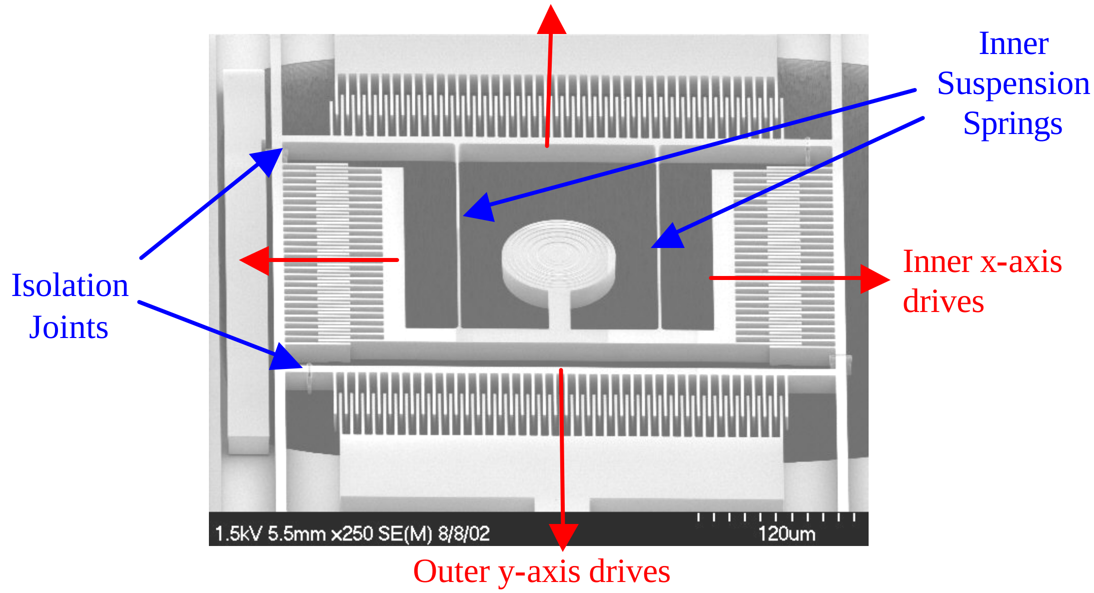
Table of Observations

Node	Energy Seen	Location	When
425	1020	45.367 º 121.24 M	12:00 01.0035
431	1044	45.380 º 121.25 M	12:00 01.0102
418	989	45.388 º 121.24 M	12:00 01.0199
• • •	• • •	• • •	• • •

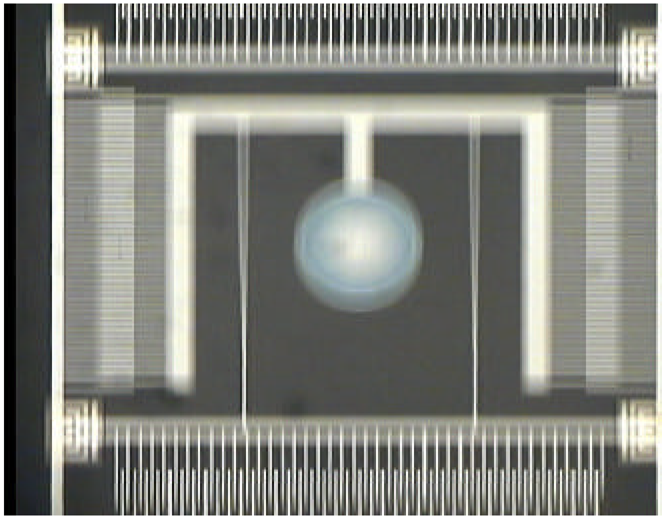
DARPA Honeywell

LDART Technology Status: Hardware

- MEMS hardware currently under development
- 2nd round of prototypes of the micro-lens array being fabricated and tested



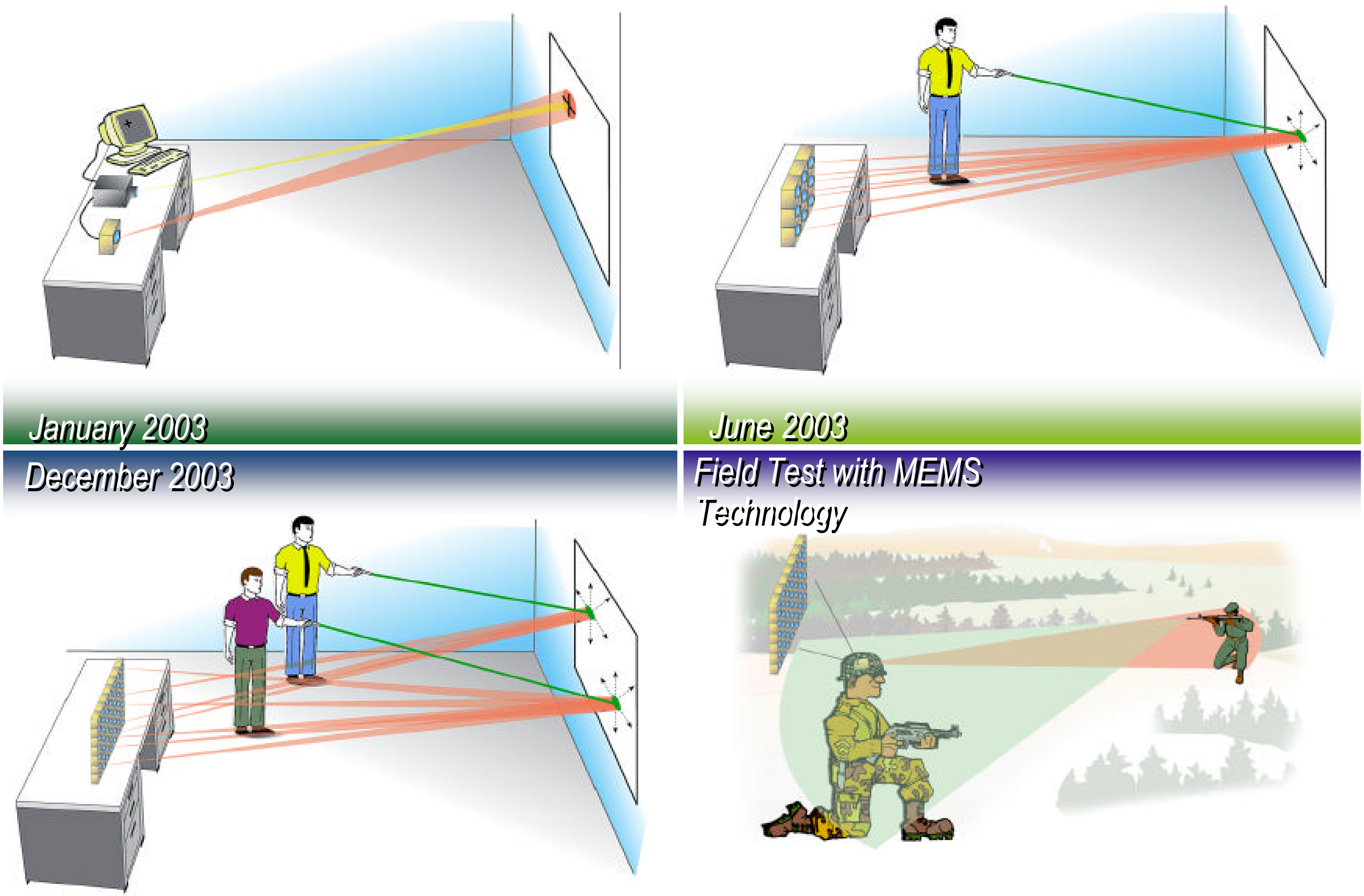
Microactuator structure



Microlens driven in resonance simultaneously in x and y-axes.

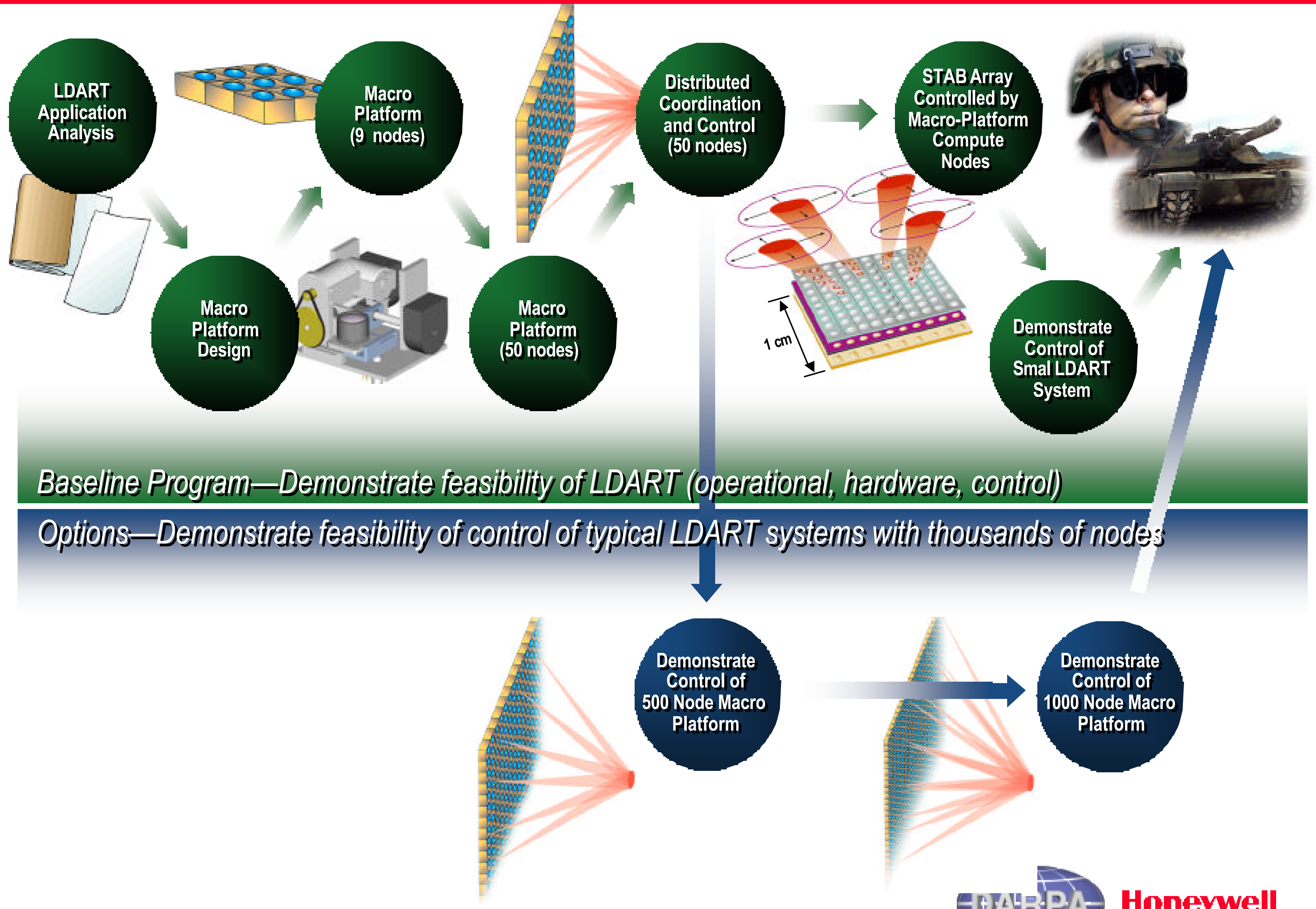
DARPA Honeywell

From Research to Product



Honeywell

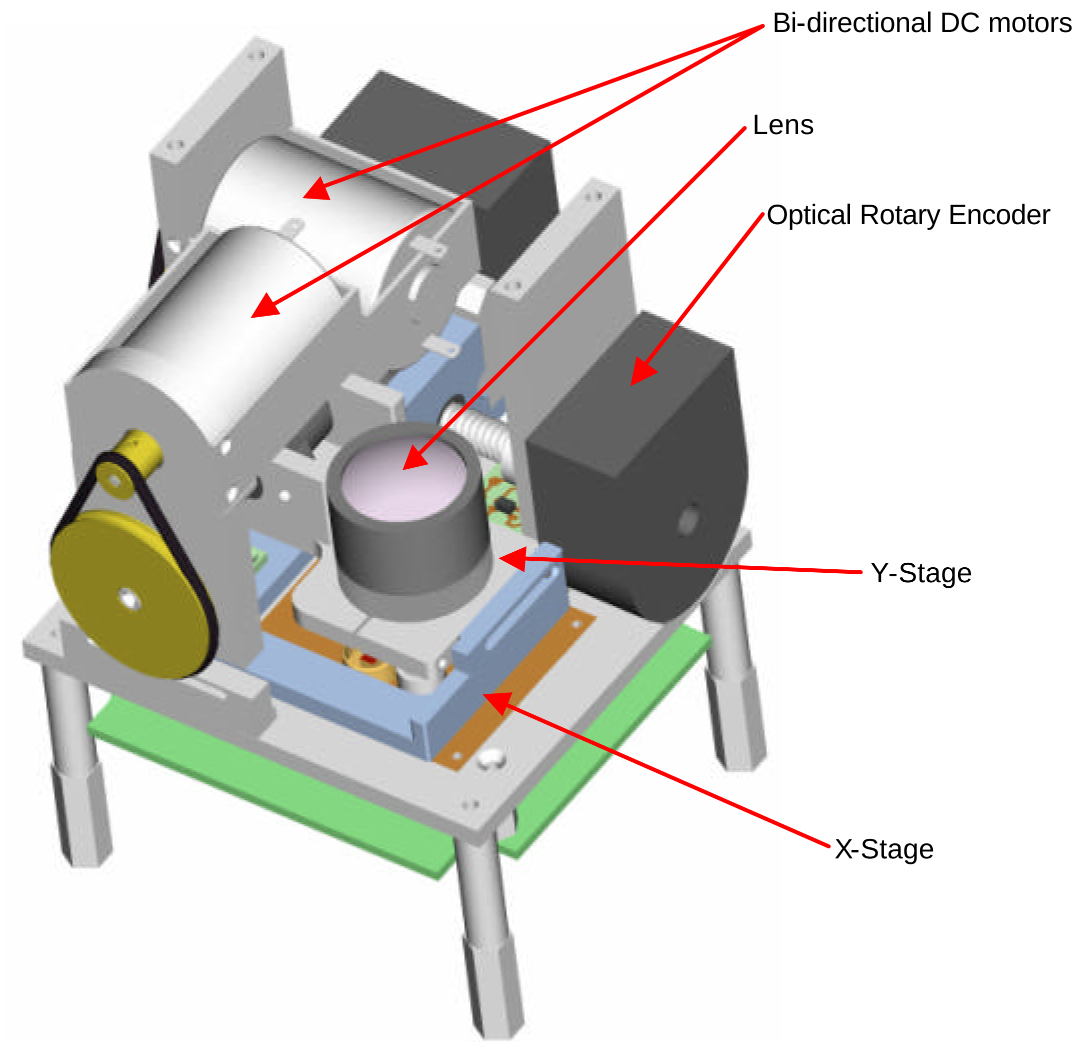
From Research to Product



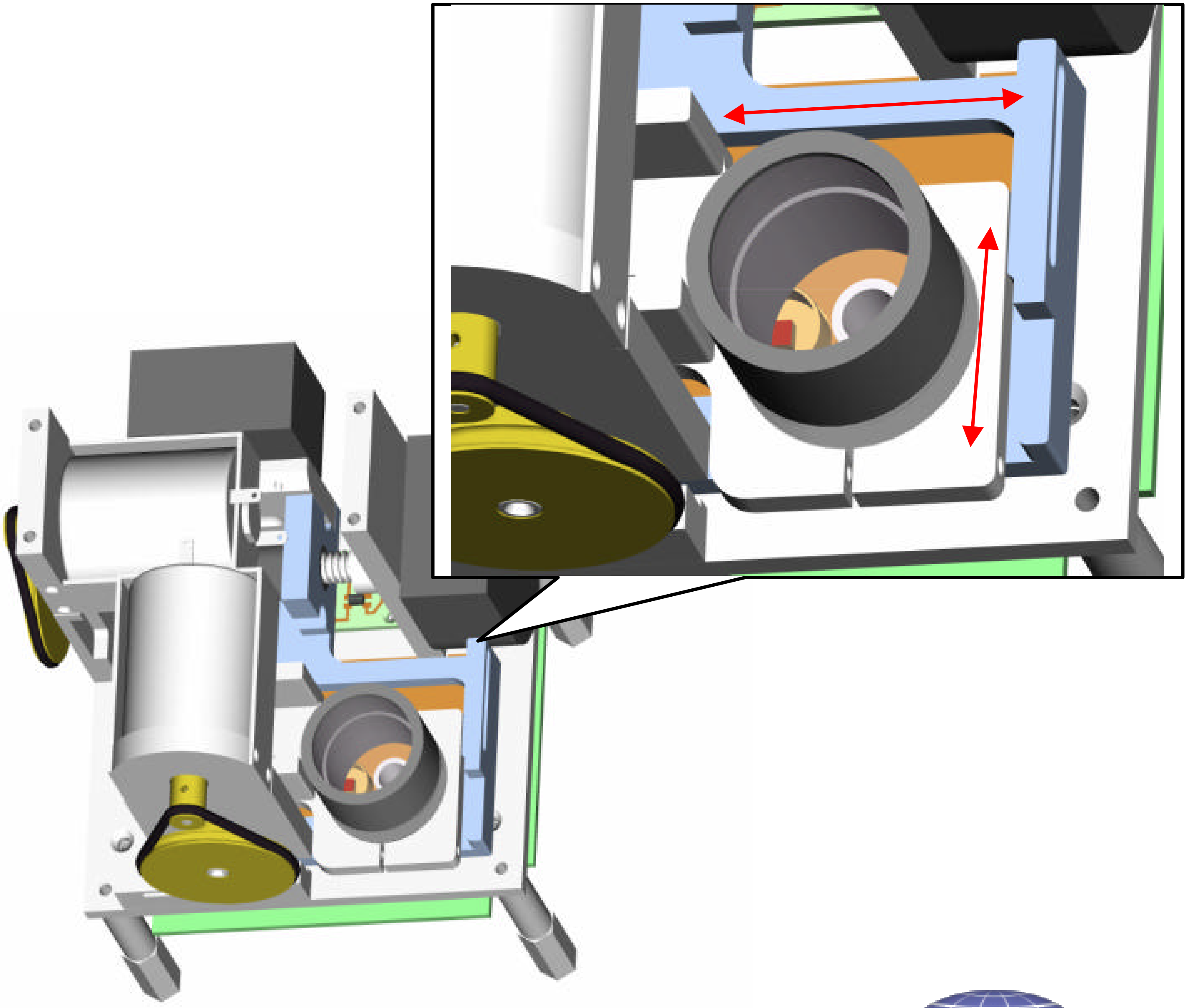
DARPA Honeywell

Macro Platform: X-Y Lens Stage

- The NEST optical stage employs a 2-axis stage to move a lens above an emitter (laser diode) and a detector (photo-diode).
- The Y-Stage is mounted on top of the X-Stage.
- Each stage is controlled independently by an inexpensive DC motor that drives a lead-screw. Each stage is translated as its lead-screw turns.
- Position feedback is accomplished by optical rotary encoders on the opposite end of the lead screw.

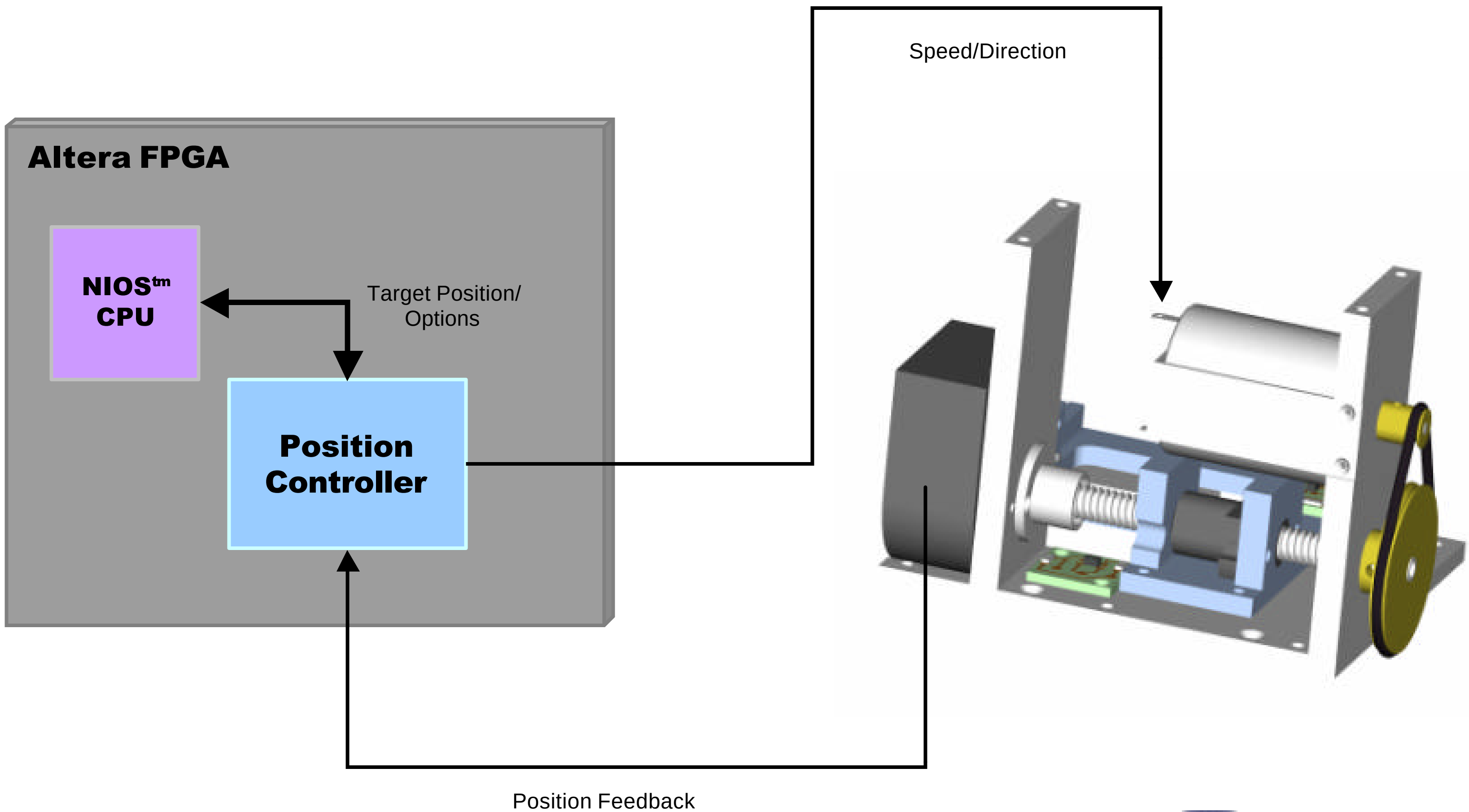


Macro Platform -- A closer look

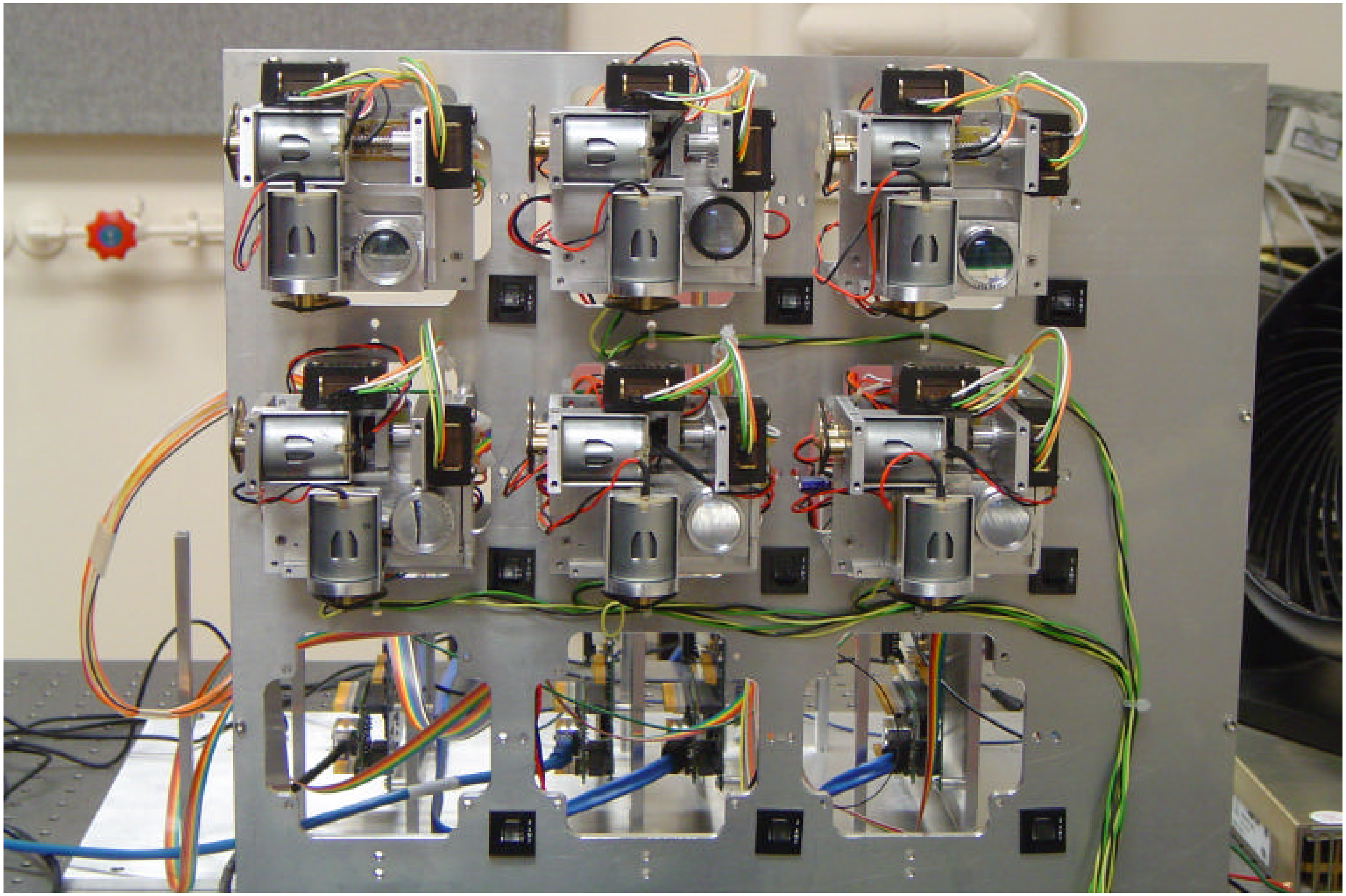


Position Control

- **Each axis has a complete control circuit that looks like the following:**



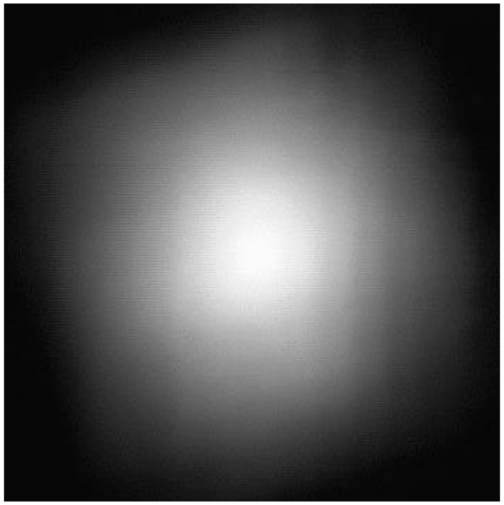
Macro Platform

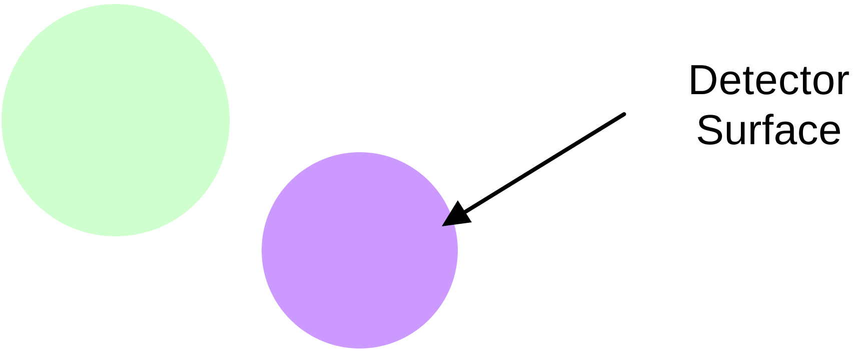


Compute Element

- **Altera/NIOS 32-bit CPU (Rev. 2.1), CPU core in Altera 20K200E FPGA**
- **Running µCLinux**
- **Hill Climb is performed by taking samples from four points and computing the gradient.**
- **When all four points have equal intenisty then we have found the top of the hill**

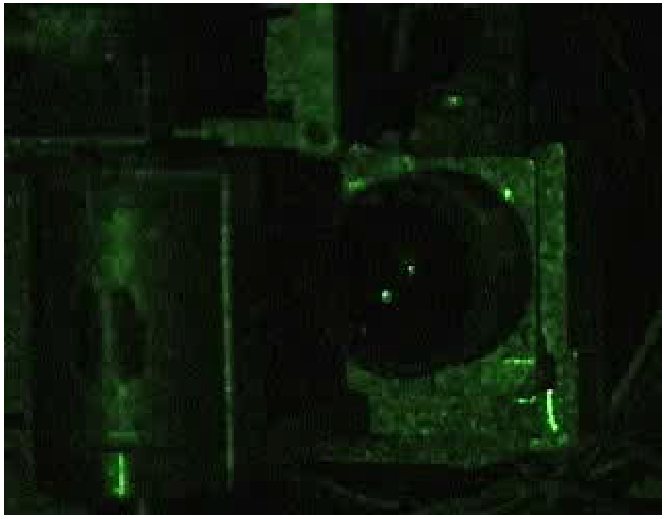
Image formed by scanning the lens and reading intensity





LDART Technology Status: Macro Platform

- Distributed control software being developed in parallel with MEMS hardware
- Control being developed and tested using a “macro-platform”
  - Macro-scale representation of MEMS platform
  - Designed to be a faithful representation of MEMS platform
    - ✍lens positioning accuracy: 0.03175 mm
    - ✍positioning speed: 128.8 mm/sec
    - ✍detector sensitivity: ? 6 nW



Movie clip of macro cell locating laser source

Summary

- MEMS-based laser detection and reciprocal targeting (LDART) shows promise in speed, accuracy, weight, and power consumption
- Macro platform has allowed first proof of concept in the development of LDART
- Plan moving forward will test MEMS design in the field at Fort Benning