Microtechnology in Space: NASA's Lab-on-a-Chip Applications Development Program

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NASA's Marshall Space Flight Center (MSFC) Lab on a Chip Application Development (LOCAD) team has worked with microfluidic technology for the past few years in an effort to support NASA's Mission. In that time, such microfluidic based Lab-on-a-Chip (LOC) systems have become common technology in clinical and diagnostic laboratories. The approach is most attractive due to its highly miniaturized platform and ability to perform reagent handling (i.e., dilution, mixing, separation) and diagnostics for multiple reactions in an integrated fashion. LOCAD, along with Caliper Life Sciences has successfully developed the first LOC device for macromolecular crystallization using a workstation acquired specifically for designing custom chips, the Caliper 42. LOCAD uses this, along with a novel MSFC-designed and built workstation for microfluidic development. The team has a cadre of LOC devices that can be used to perform initial feasibility testing to determine the efficacy of the LOC approach for a specific application. Once applicability has been established, the LOCAD team, along with the Army's Aviation and Missile Command microfabrication facility, can then begin to custom design and fabricate a device per the user's specifications. This presentation will highlight the LOCAD team's proven and unique expertise that has been utilized to provide end to end capabilities associated with applying microfluidics for applications that include robotic life detection instrumentation, crew health monitoring and microbial and environmental monitoring for human Exploration.

Classification and Rational

for

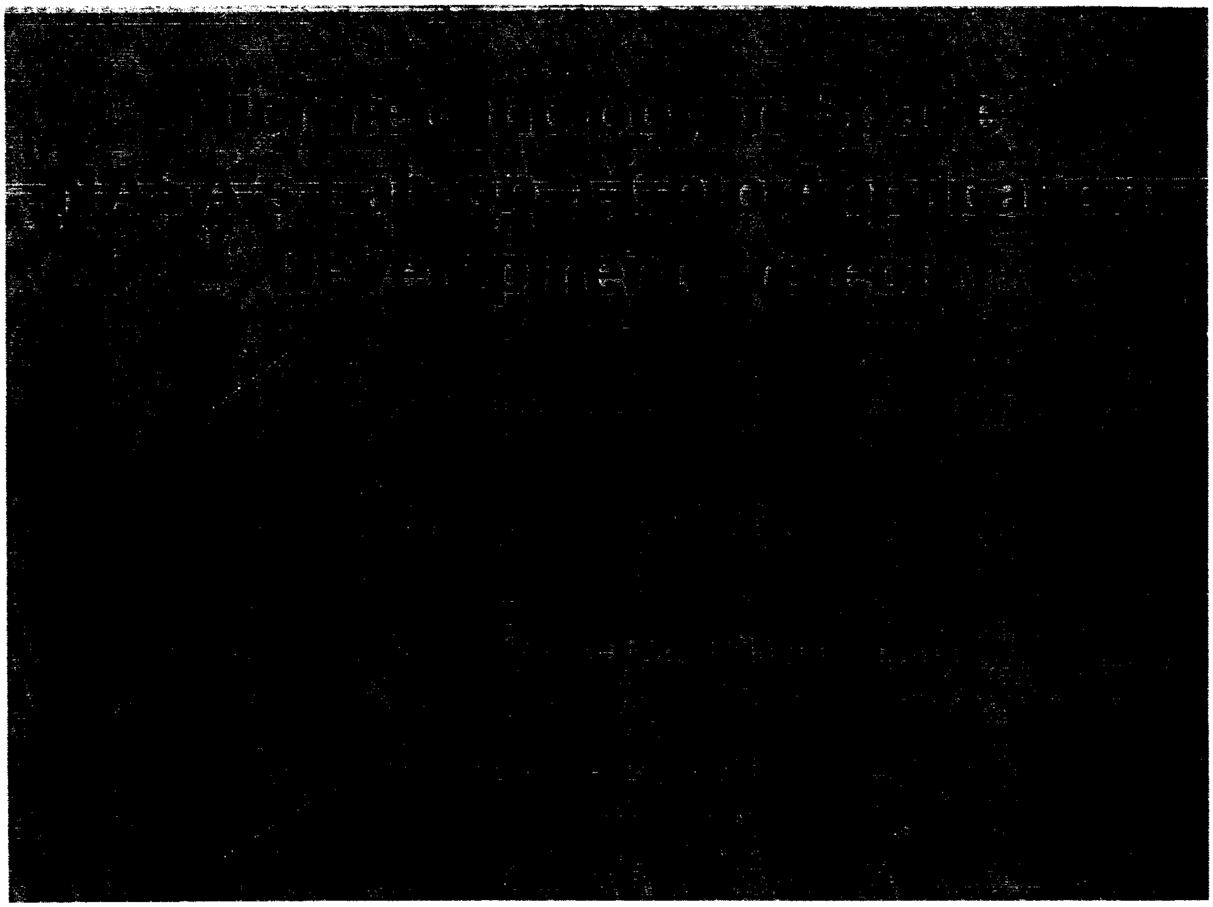
Microtechnology in Space, NASA's Lab on a Chip Application Development Project

After a review of the attached presentation, it has been determined that the technology described does not fall under the jurisdiction of the International Traffic in Arms Regulation (ITAR).

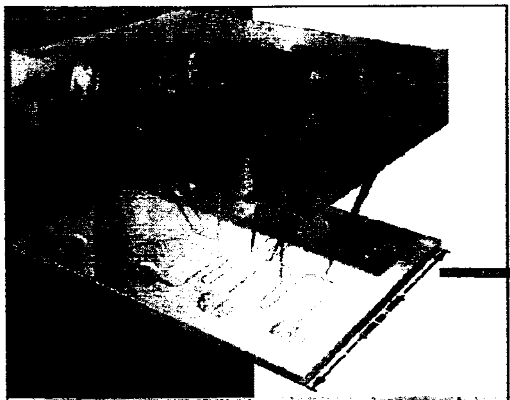
Per part 734 of the Export Administration Regulations (EAR) – If a technology is submitted without restriction for consideration for inclusion in an "open" conference then the technology is published and is not subject to the Export Administration Regulations.
Therefore the attached abstract may be considered publicly available.

Note: A conference or gathering is "open" if all technically qualified members of the public are eligible to attend and attendees are permitted to take notes or otherwise make a personal record (not necessarily a recording) of the proceedings and presentations.

Tom Dollman / Ron Koczar SD01



Technology Approach



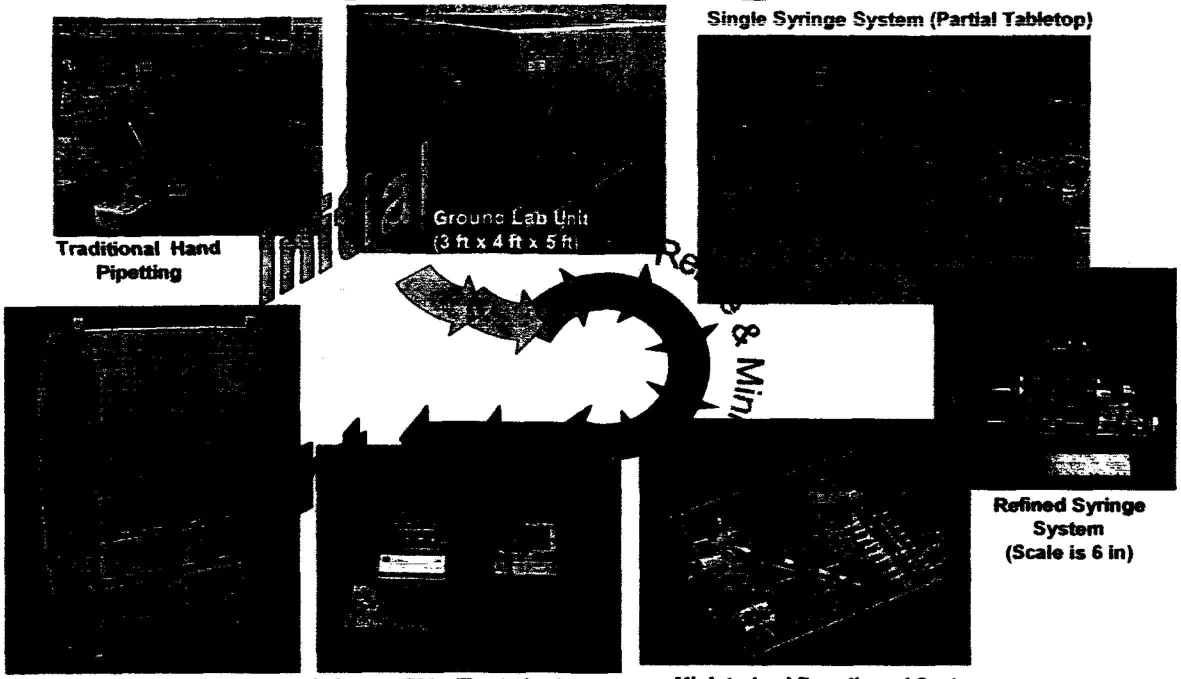
Lab-on-a-Chip Technology

Multiple pieces of laboratory equipment, and many labor intensive processes, are replaced by a glass chip and a chip control unit. NASA specific chips have developed in conjunction with Caliper Life Sciences

Sean O'Keefe, NASA Administrator, views the

ITERATIVE BIOLOGICAL CRYSTALLIZATION (IBC) O[redacted]

IBC Technology Approach (History)



Traditional Hand Pipetting

Single Syringe System (Partial Tabletop)

Refined Syringe System (Scale is 6 in)

EXPRESS Rack Flight Volume (Two @ 17 in x 20 in x 20 in)

Lab-on-a-Chip (Two) (Scale is 6 in)

Miniaturized Breadboard System

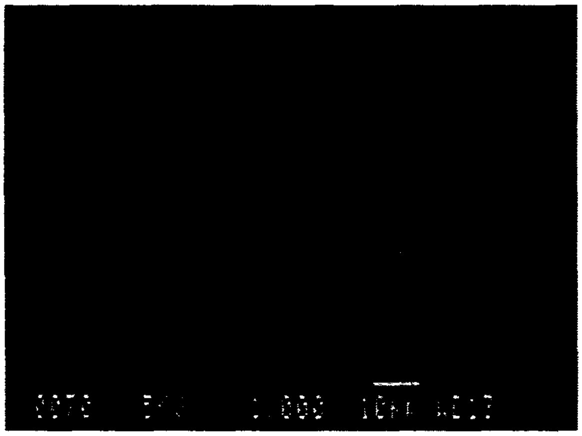
Microfluidic Channels

10-100 μm wide

1-100 μm deep

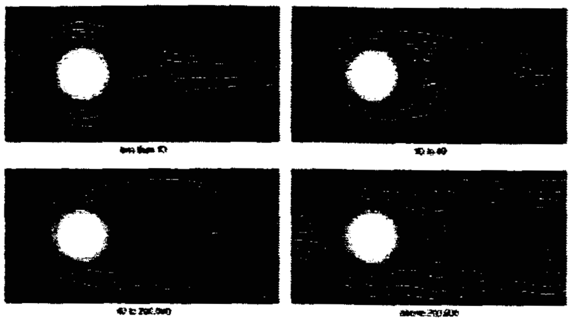
~ 1mm contains ~ 1nL fluid

- Flow rates 0.5-5 nL/sec
- Reactions occur within channels
- Flow control via pressure, or voltage



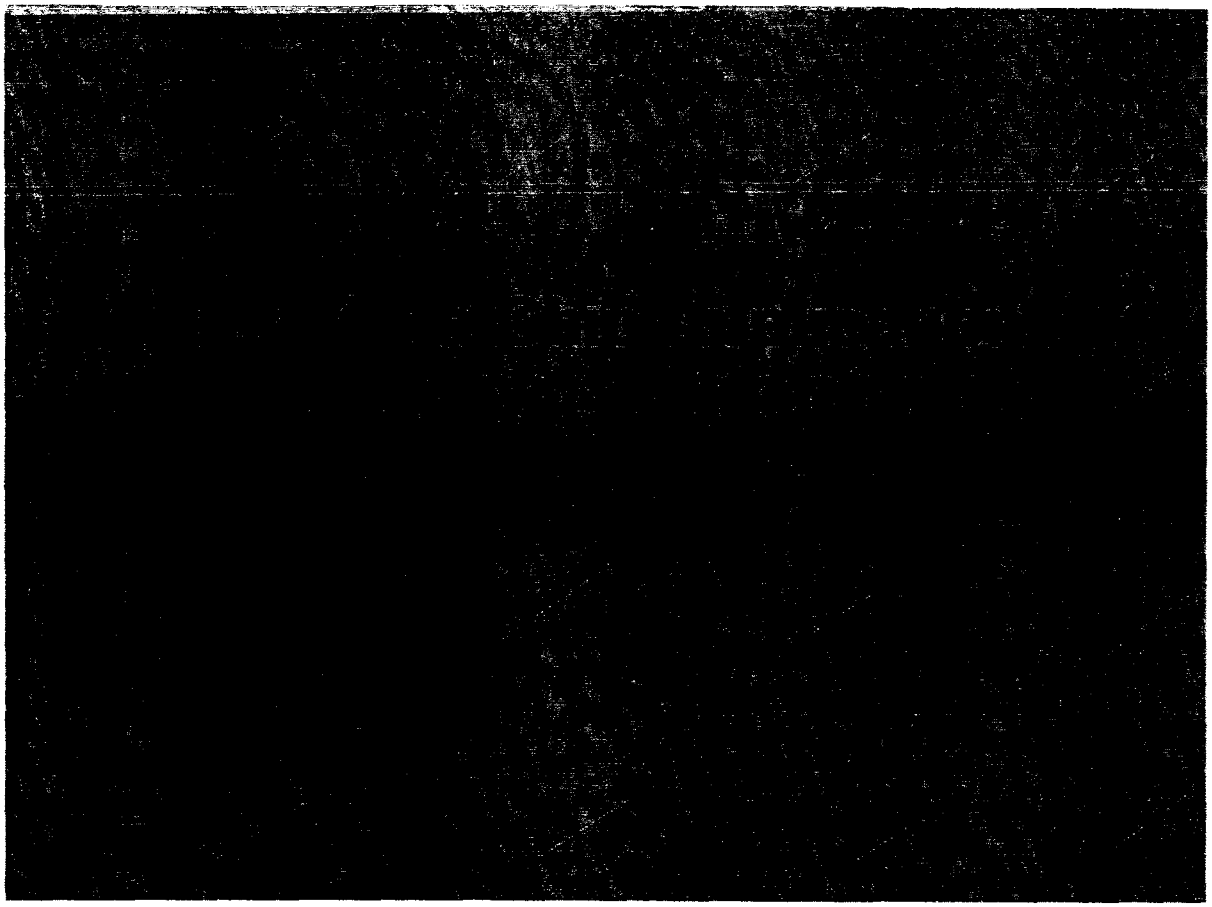
Turbulent vs. Laminar Flow

Nature of the flow is predicted by the Reynolds number, the ratio of inertial to viscous forces acting on the fluid.



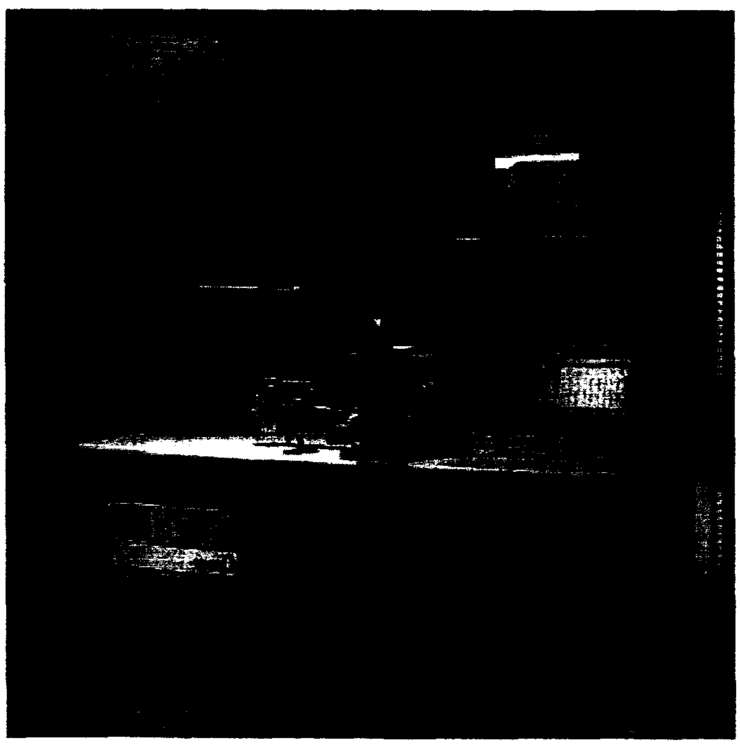
LOC Approach – Advantageous features

- Safety
- Contamination
- Volumes
- Accuracy of dispensing
- Accommodates a range of viscosities
- Environmental (minimize solution evaporation)
- Materials compatibility
- Optically compatible



Caliper 42 Research/Development Station

Basic Caliper 42 Unit



Caliper 42 at MSFC was acquired as part of the Applications Development Program (ADP) with Caliper Technologies.

The Caliper 42 can manipulate fluids on chips either by electrostatics or low pressure (± 5 psi).

This unit provides direct real time viewing and has fluorescence instrumentation.

Chip lighting can either be with a standard white light or with UV (several different wavelengths are possible).

Caliper 42 Research/Development Station

Chip Installation onto Caliper 42

Platform "head" contains eight separate interfaces for the unit to chip connection.

Each interface includes a pressure port and an electrode.

Platform "head" is self aligning to the chip.

Chip viewing instrumentation is located below the platform with diffused lighting from above.

Each well is externally isolated from all other wells and from the surrounding environment.

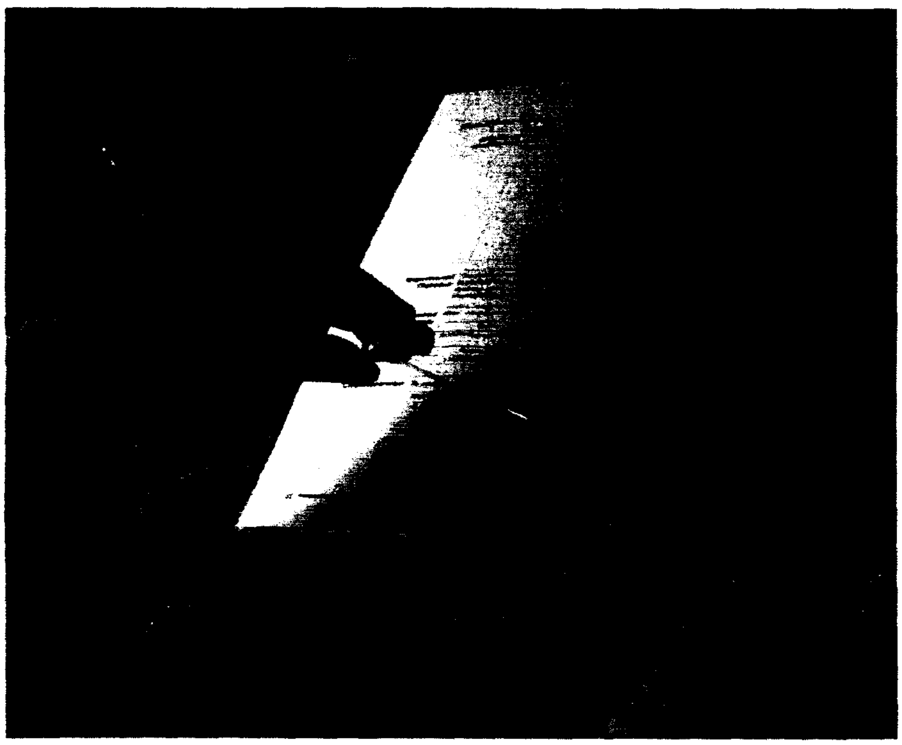
Caliper 42 Research/Development Station

Chip Loading

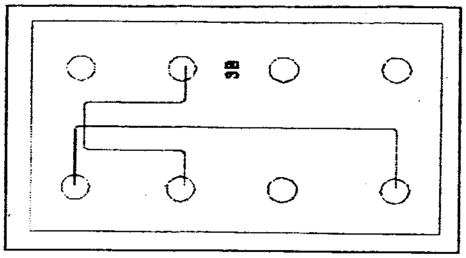
There are many existing standard chip configurations for use on the Caliper 42.

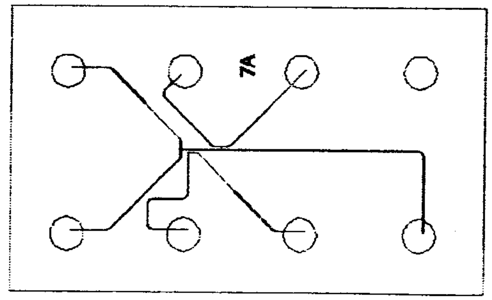
Fluid loading onto a chip is accomplished via simple pipetting.

Each standard chip has a set of existing protocols to be exercised on the Caliper 42.

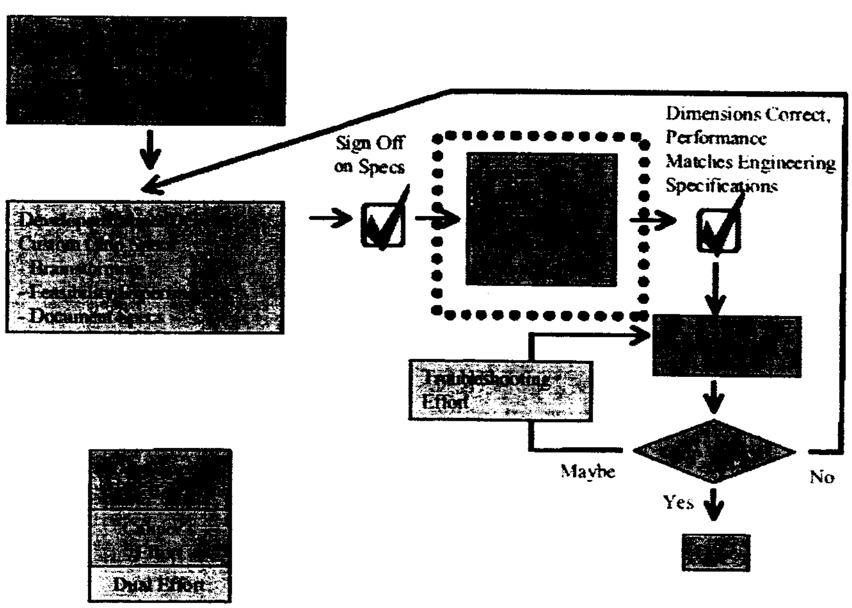


Standard Chip Set Examples

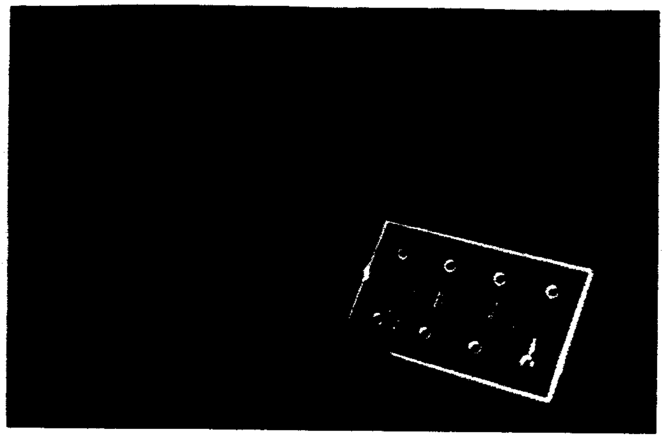




Chip Requirements and Design Process



MSFC Custom NS374 Chip



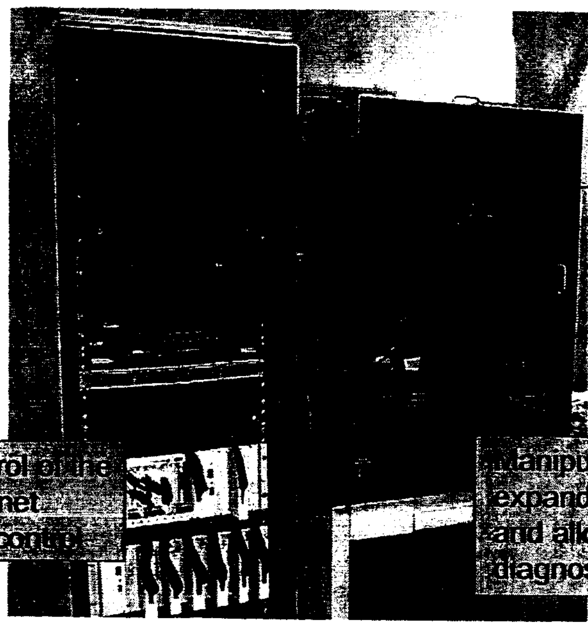
Lab-On-a-Chip Application Development

Application Development Unit (ADU-25)

ADU-25

Control/Interface Assembly

Provides direct control of the unit and allows internet access and remote control



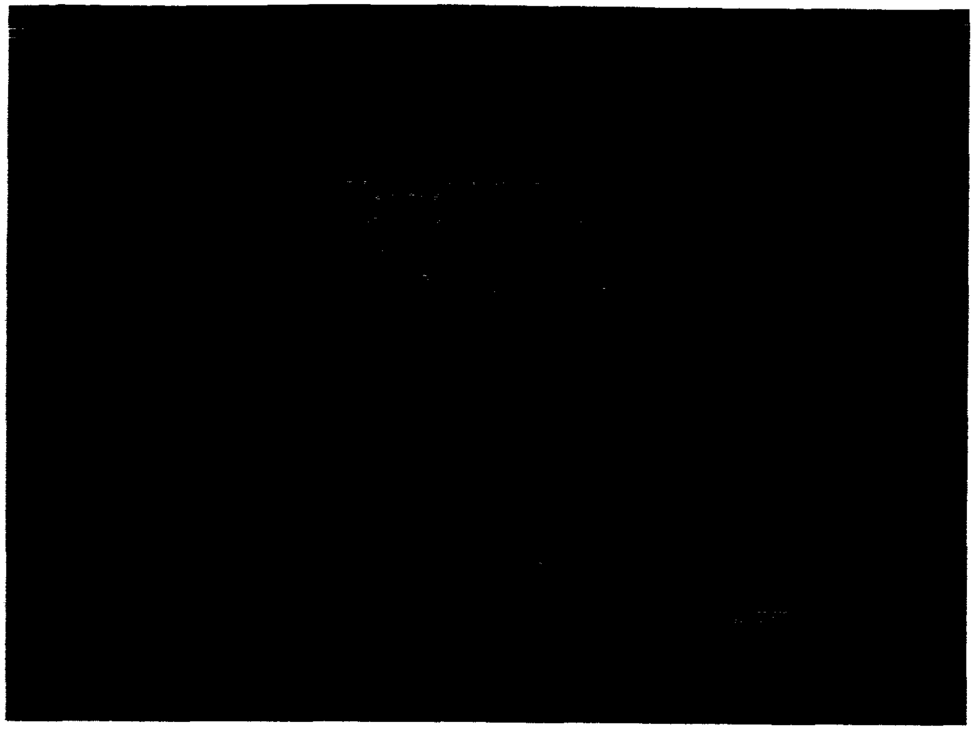
Process Assembly

25 Port test chip interface for integrated multi-step fluidic processes

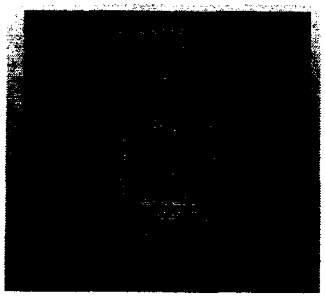
Manipulates fluids on expanded capacity chips and allows real-time diagnostics/images

Caliper 42 Research/Development Station

Fluidic Control on the Caliper 42



LOCAD Activities



Endosafe PTS
- Discriminate Gram -, Gram +, Yeast/Mold *; Confirm culturing methods, FY06
- ATP assay cartridge, FY07
- LAL ELISA specific target cartridges, FY07-08, i.e.
  - Salmonella
  - Listeria
  - E. Coli 0157

Create a microfluidic chip to consolidate and expand testing capabilities (e.g. LAL ELISA, protein, & DNA microarrays)
- Increase number of tests in a microarray format
- Increase sensitivity
- Decrease time to detection

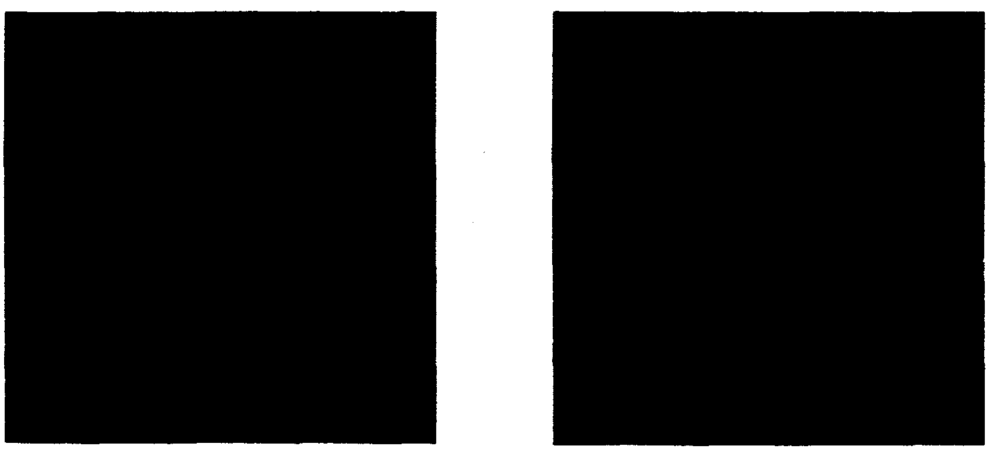
* Clinical trials underway

KC 135 Testing

LOCAD Activities

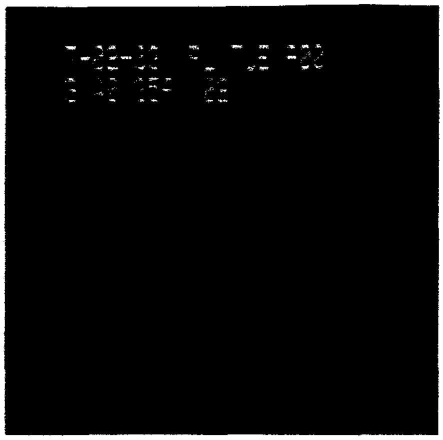
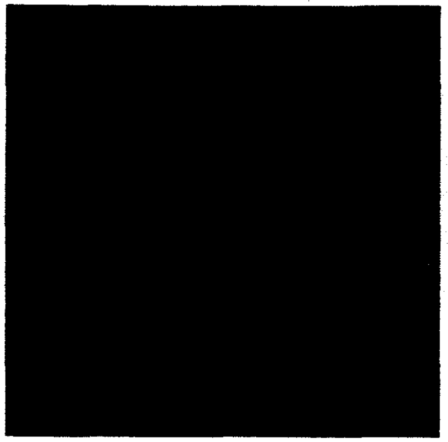
- Tested LAL assay on microfluidic chip
- Tested cell lysis and DNA/protein extraction on a chip
- Microfluidic chips to receive commercially available (or custom printed) DNA or protein microarray slides (test chips in development)
  - cell lysis, extraction, clean-up, labeling, and microarray inoculation
- Handheld unit for processing and reading microarrays in conceptual design
- Preliminary identification of target compounds complete
- Printing and testing protein microarrays

Cell Lysis on a Chip



Bacillus Megaterium

Cell Lysis on a Chip

Bacillus Megaterium

Acknowledgements

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