



# LabRAT

## (Laboratory Rapid Automation Toolkit)

*A flexible and robust peer-to-peer architecture with XML based open communication for Laboratory Automation*

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# Outline of Presentation

- Introduction:**  
**Choices for Automation Design & Integration**
- Background & Motivation for Our Work**
- System Design Overview**
- System Architecture**
- System in Action**
- Future Directions**
- Conclusions**

# Choices for Automation Design & Integration

- Outsource (Proprietary Solution)**

...

- Custom (Specific to Hardware Components)**

...

- Open Platform Solution**

...

## Choices for Automation

# Outsource (Proprietary Solution)

Turnkey system supplied by a full service automation company

Advantages	Disadvantages
One Stop Shopping	Vendor Lock-in
Offloading of Development and Support	High up-front cost
Rapid Implementation of off-the-shelf solution	Speed of customizations (slow)
Market Tested Systems	Low Flexibility

## Choices for Automation

# Custom (Hardware Specific)

Specialized Solution Built for the Specific Application and Components

Advantages	Disadvantages
Exact Tailoring to the Application	High Development Cost
Full Control over Specs	Slow to Implement
Full Ownership – no Licensing Costs	Reliability may take Several Development Cycles
	High Support Costs

## Choices for Automation

# Open Platform Solution

General Platform Designed for a  
Broad Range of Applications

<b>Advantages</b>	<b>Disadvantages</b>
<i>Same as for Custom System</i>	Slow Initial Implementation
Rapid Implementation of Systems Based on the Platform	High Initial Development Cost
Reliability Assured by a Stable, Tested Platform	High Initial Support Costs
Facilitates Open Sharing of Work with Other Groups	

# Background and Motivation

- ❑ **Amersham Biosciences – Background & Products**
  - **DNA Sequencer Analyzers**
  - **InCell Analyzer**
  - **Proteomics Instrumentation**
  - **Sample Prep, Sample Prep, Sample Prep!**
- ❑ **Automation Requirements**

...

## Background & Motivation

# Automation Requirements

- ❑ **Need for automation system on which to base our grant funded sample prep system (genomic sequencing)**
- ❑ **Existing instrument control software must be “wrapped” with minimal modifications (C++, LabView, VB, ...)**
- ❑ **Desire to create a reusable framework to avoid reinventing the same wheel on future projects**
- ❑ **Need for a common instrument command & control standard for the company to facilitate interoperability**

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# Automation Requirements (*cont.*)

⋮

- ❑ **Desire to create a flexible logic distribution model via Peer-to-Peer architecture**
- ❑ **Desire for a simple, convenient central controller operable from a web browser**
- ❑ **Desire for HTTP / web services based communication protocol to allow development flexibility**

# System Design Overview

- ❑ **Core concepts borrowed from LECIS  
(Laboratory Equipment Control Interface Specification)**

...

- ❑ **Why not just adopt LECIS?**

...

- ❑ **Advantages of Peer-to-Peer (P2P) Model**

...

- ❑ **XML-RPC based message transport**

...

## System Design Overview

# Core concepts borrowed from LECIS

- ❑ **Instrument State Model**
- ❑ **Key Command/Response Definitions**
- ❑ **Abstraction of Instrument Behavior**
- ❑ **Standardization of Interfaces**

# Why not just adopt LECIS?

- ❑ **LECIS is a little too “complete” for our needs (more interactions & states than we need)**
- ❑ **LECIS is a little too “incomplete” for our needs (no reference implementation, no definition of communication medium)**
- ❑ **LECIS (hierarchical model) not as flexible in terms of distributed logic as a P2P model**
- ❑ **Market adoption low, so few incentives to adopt**
- ❑ **OMG LECIS defined around CORBA**

# Advantages of Peer-to-Peer Model

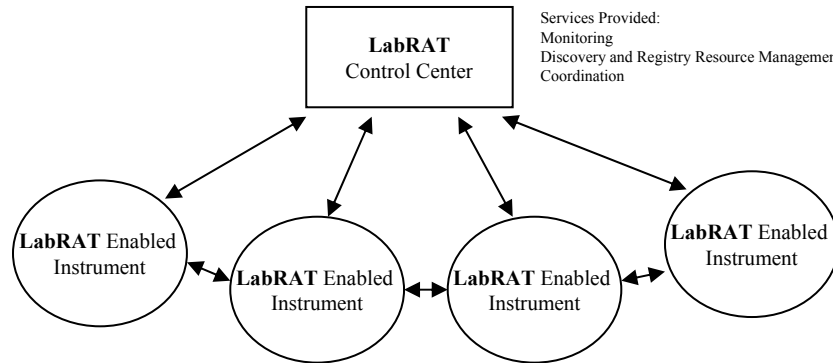
- ❑ **Flexibility in Distributing System Logic**
- ❑ **Scalability is largely “Automatic”**
- ❑ **Easier Development**
- ❑ **Fits well with Communication Model**
- ❑ **Best Model for Dynamic, “Ad Hoc” networks**

## System Design Overview

# XML-RPC based message transport

- ❑ Simple, easy to understand & use mechanism
- ❑ Runs over HTTP – extremely convenient
- ❑ Small & efficient
- ❑ Open source implementations available for all popular programming languages
- ❑ Easy path to SOAP

# System Architecture



## Communication Layer

...

## Instrument Peer Server

...

## Control Center

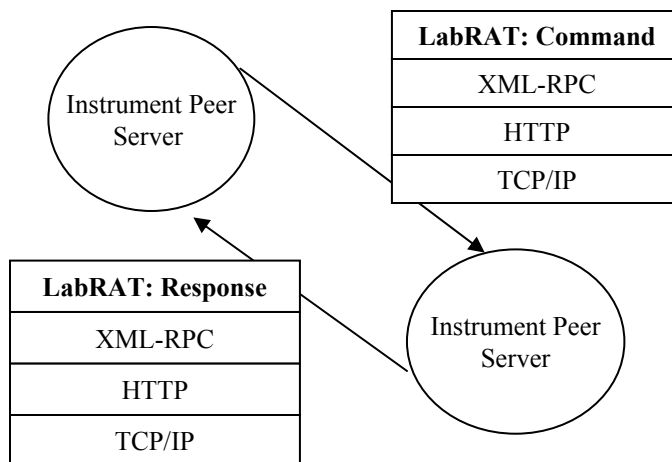
...

# Communication Layer

- ❑ **Based upon XML-RPC**
- ❑ **Encodes the LECIS inspired LabRAT command & control protocol**
- ❑ **Inheritable code provides interface to existing control software**
- ❑ **Communication Protocol Highlights**  
...
- ❑ **Communication Protocol Performance**  
...

# Communication Protocol Highlights

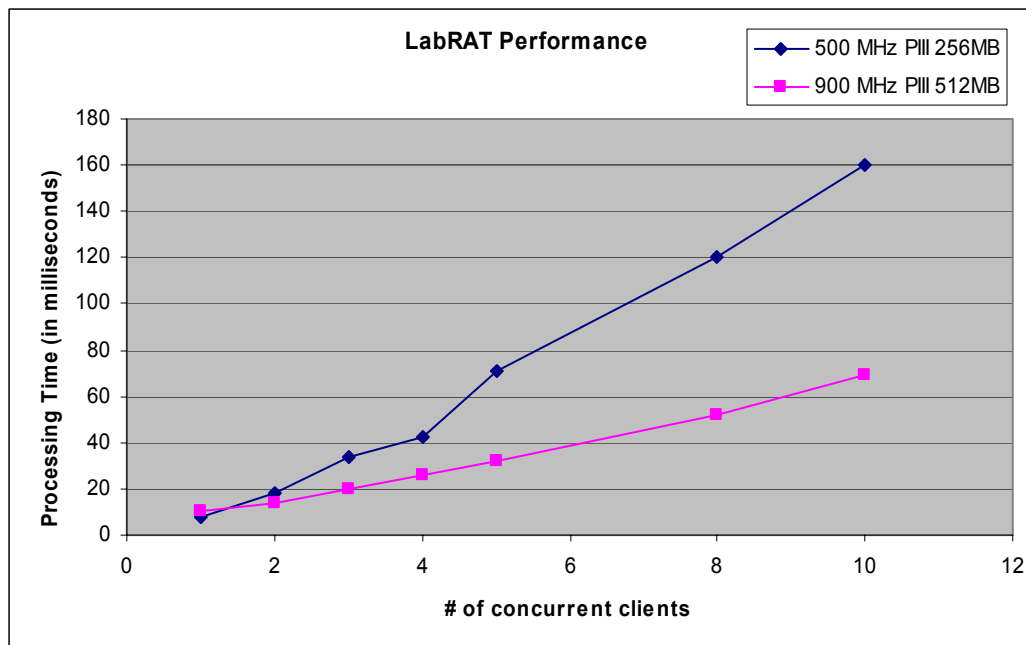
- ❑ Provides P2P messaging between Instrument Servers and to the Control Center
- ❑ Protocol Stack based approach
- ❑ Request / Response Format with a standard set of Instrument Requests & Responses



System Architecture → Communication Layer

# Communication Protocol Performance

❑ Quick, with Excellent Scalability



# Instrument Peer Server

- ❑ Provides an external interface or “wrapper” for instrument control software
- ❑ Receives and processes XML-RPC requests and issues requests to other servers
- ❑ Behavior is governed by a set of definition files and a standard state model
- ❑ “PreMethod” & “PostMethod” files specify actions to be performed by peers before & after local method runs
- ❑ “Synch” message (& state) allows peers to interactively cooperate to perform mutually dependent tasks
- ❑ Peers can interact to perform arbitrarily complex behaviors without intervention of the control center

# Control Center

- Provides interface for the human operator (process design, control, and monitoring)
- Provides essential, centralized services for peer instrument servers (registry, resource allocation, instrument monitoring, message broadcast, ...)
- Performs global error handling
- Performs scheduling and coordination of multiple high level tasks
- Logs all operations
- Web based interface, accessible via standard web browser (Internet Explorer, etc.)

# System in Action

- ❑ **Lab Protocol to be Automated**

...

- ❑ **Protocol Translation to  
Control Center Process**

...

- ❑ **Physical Implementation**

...

## System in Action

# Lab Protocol to be Automated

- 1. Aspirate raw material from a stored microtiter plate into a capillary cassette.**
- 2. Bind and denature DNA via thermocycling.**
- 3. Wash to remove extraneous material (leaving bound DNA behind).**
- 4. Aspirate sequencing cocktail from a microtiter plate.**
- 5. Execute terminator reaction via thermocycling.**
- 6. Transfer product to a fresh microtiter plate by centrifugation.**
- 7. Transfer final product microtiter plate to refrigerated storage.**

# Protocol Translation

- Specify Storage method to perform sample aspiration.
- Specify Thermocycler method to perform binding/denaturation.
- Specify Washer method to perform ethanol wash.
- Specify Storage method to perform cocktail aspiration.
- Specify Thermocycler method to perform terminator reaction.
- Specify Centrifuge method to perform capillary-to-plate transfer.
- Specify Storage method to perform plate storage.

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# System in Action (Control Center Process Definition)

LabRAT V1.0a - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Forward Stop Home Search Favorites Media Print Mail News RSS Chat

Address http://10.146.31.65:8080/processflow-action.do?ID=p1037056053531&OP=EDIT&page-num=0 Go Links >>

Amersham Biosciences LabRAT V1.0a

Instruments **Processes** Executions Alerts Preferences [Help](#) [Logout](#)

[Home](#) > [Processes](#) > Process

Process Details

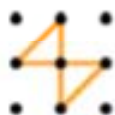
■ Name (\*required):

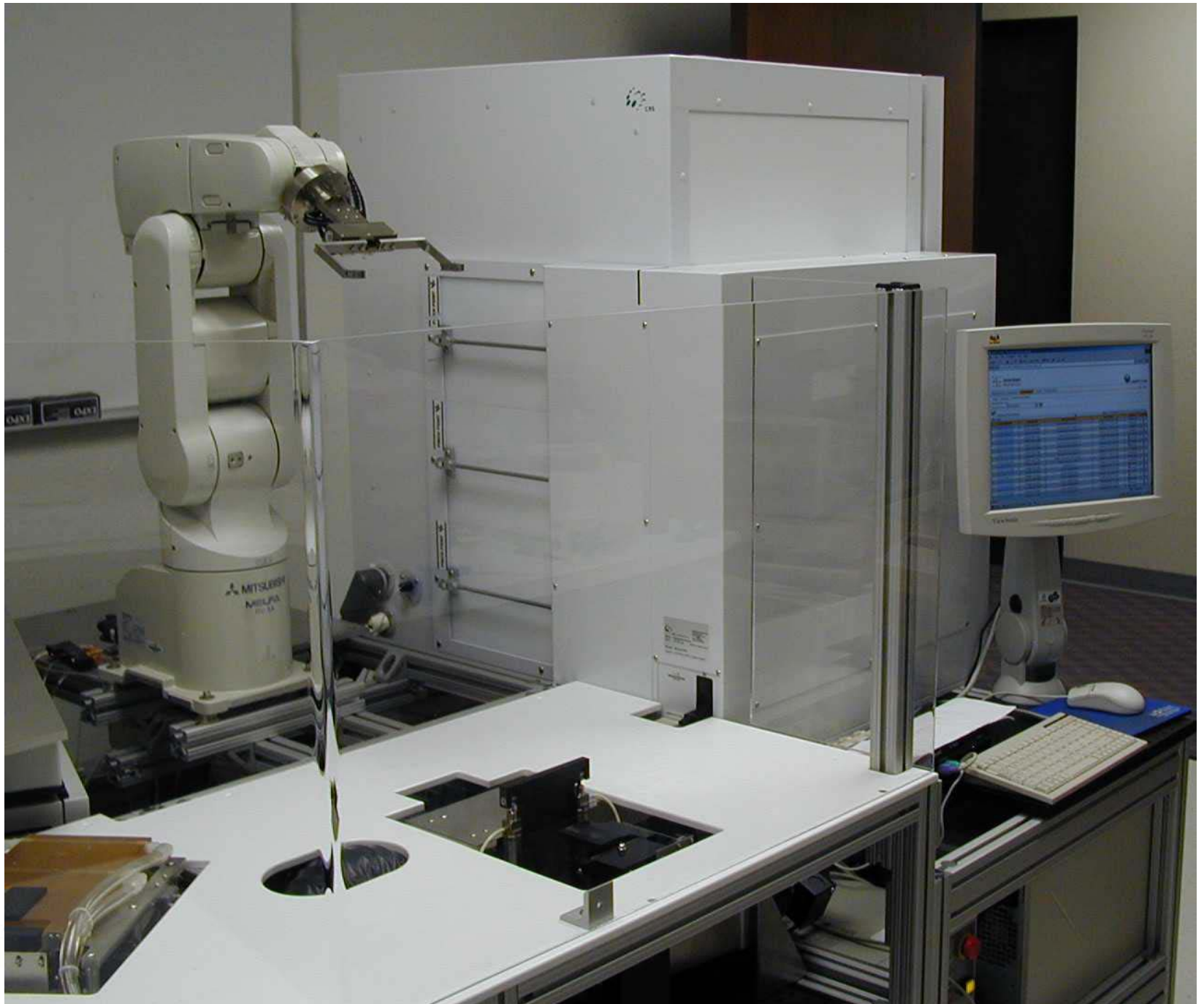
■ Description:

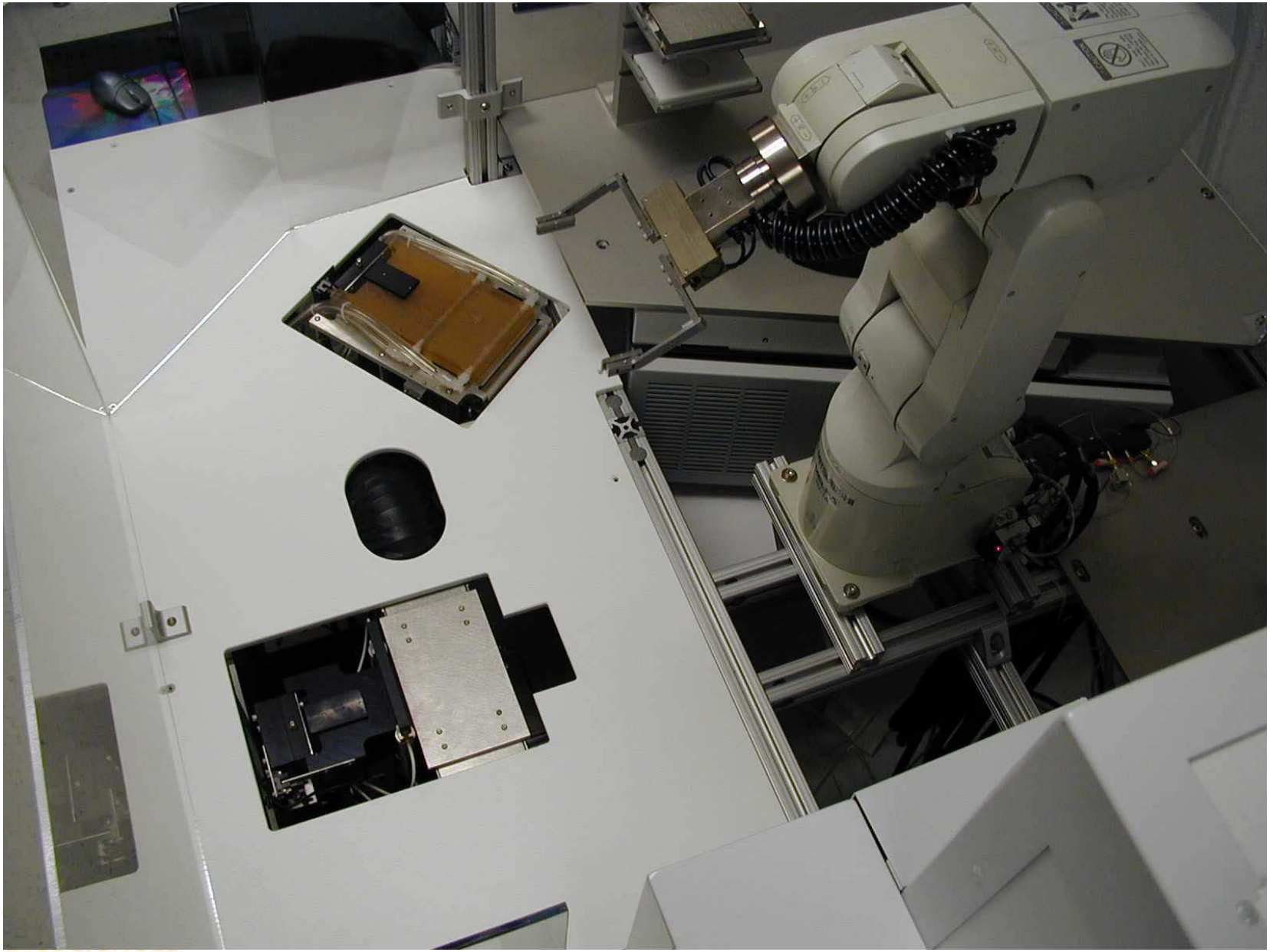
■ Sample Required:

■ Steps:

Seq #	Description	Instrument	Method Name	Params	Up	Down	Copy	Edit	Delete
0	Aspirate Sample into capillaries	serial	Aspirate123	AspTime:5;Speed:33;RotPos:1;ServoOn:-1;HotelShelf:1;Hotel:"MTPHotel2";CassShelf:1;LidPos:5		▼			
1	Binding & denaturing step.	cycler	95CDen		▲	▼			
2	wait for 5 minutes	_directive	wait	time:300	▲	▼			
3	Ethanol wash.	washer	80percentETOH		▲	▼			
4	Aspirate master mix into capillaries	serial	Aspirate123	AspTime:10;RotPos:2;Speed:33;Hotel:"MTPHotel2";HotelShelf:1;CassShelf:1;LidPos:6	▲	▼			







# Future Directions

- ❑ **Improved scheduler (optimizing, dynamic)**
- ❑ **“Intelligent Agent” technology to allow peers to negotiate to achieve best outcome**
- ❑ **Exchange & synchronization of method and Process files across different installations**
- ❑ **Support for additional transport protocols, including SOAP**

# Conclusions

- ❑ **Built peer-to-peer, XML-RPC based rapid automation framework for laboratory instrumentation**
- ❑ **Viable alternative to adopting proprietary technologies from a single automation supplier and developing a custom set of components for a specific application**
- ❑ **LabRAT protocol is a balance between simplicity & ease of use on the one hand and flexibility & adaptability on the other**
- ❑ **Proven in execution of real world sample prep for genomic sequencing**

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