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LAWRENCE LIVERMORE NATIONAL LABORATORY

# Report to DHS on Summer Internship 2006

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**Lawrence Livermore National Laboratory**
**David Camp, mentor**

## Projects

This summer I worked at Lawrence Livermore National Laboratory in a bioforensics collection and extraction research group under David Camp. The group is involved with researching efficiencies of various methods for collecting bioforensic evidence from crime scenes. The different methods under examination are a wipe, swab, HVAC filter and a vacuum. The vacuum is something that has particularly gone uncharacterized. My time was spent mostly on modeling and calculations work, but at the end of the summer I completed my internship with a few experiments to supplement my calculations.

### *Fluid Modeling*

I had two major projects this summer. My first major project this summer involved fluid mechanics modeling of collection and extraction situations. This work examines different fluid dynamic models for the case of a micron spore attached to a fiber. The application is one where a biological spore is located in carpet or another fibrous material, and it is either being collected for forensic analysis with the use of a vacuum, or it is being extracted from a fibrous material. Extraction practices currently place contaminated fibrous materials in a liquid solution and then shake the sample in the liquid for a given period of time at a specific RPM. As of now, the actual forces imposed on the spore by either the agitating fluid or the flow created from the sampling vacuum have not been theoretically explored.

My study tries to obtain an estimate for forces exerted on spores in specific situations in order to understand how effectively these spores are being removed from their substrate. These values are then compared with a range of values deemed adequate to remove a spore from a surface that it is adhered to. In attempting to determine average forces imposed on micron size spores in either the presence of a collection vacuum or in an agitated liquid for extraction cases, a variety of approaches and techniques were used. First, the physical situation was broken down into three separate cases. The first case looked at different models for a vacuum nozzle held 1 mm above a surface, the second examined models for a vacuum held tight against a porous surface, like carpet, and the last case looked at the extraction process of a substrate in the lab.

The second part to the fluids modeling project was performing an experiment to see if extraction agitation speed actually did make a large impact on extraction efficiency. An extraction experiment was run with agitation speed as the independent variable. Wipes were used as the substrate, which have fibers with diameters of 12 μm. Calculations were made for forces on spores in both perpendicular flow and parallel flow (with respect to the long axis of the carpet fibers) situations for RPMS of 60 and 300. On average, modeled forces for the 300 RPM case are on the upper end of the sensitive range of forces. Average modeled forces for the 60 RPM case are on the lower end of the spectrum. Consequently, it was expected that the extraction conducted with the agitating speed set to 300 RPM would remove a higher percentage of spores than the extraction with the agitation shaker set at 60 RPM. The extraction process shakes the substrates for ½ an hour.

Results from the experiment show that shaking the wipes at 300 RPM was twice as effective at removing the spores than shaking at 60 RPM. The surprising part of the result is the fact that shaking the samples at 60 RPM resulted in removing as many as half those removed by the 300 RPM shake. Visual inspection shows that 60 RPM (on rotation per second) barely moved the liquid, and velocities were probably comparable to those imposed by moving containers from table to table. The fluid wasn't even disturbed enough during the low speed shake to ensure that the entire wipe was soaked in the fluid or to move the wipe itself much at all. Whereas, shaking the wipes at 300 RPM results in a violent shake where the wipe is completely submerged and shaken along with the fluid. However, expected forces were still within the required range to remove a spore, so it was expected that some spores would be removed.

## *Statistical Study*

The second project I was involved with was a statistical analysis of the different sampling techniques. The most important metric of the integrated process of field collection and laboratory extraction is whether or not any microbial evidence is made available for analysis. If the target microbe or DNA signature is collected, extracted, and made available for analysis, then the analyses may proceed. If none is produced, the investigating team is left to wonder if none was there in the first place, or if it was there and they missed it, and how much might have been there.

Suppose there is a large surface of interest in an investigation that may contain some small amount of microbial evidence. How many samples of what size should be taken?

Lots of small ones or a few big ones? What method should be used to sample? Given that method, how should they be extracted in the laboratory? My study looks at how the probability of obtaining microbial evidence from a large area of interest depends upon these choices.

Other important metrics were not considered, for instance the total cost of the integrated process includes planning, warrants, intrusions/disturbances, collection labor, materials and equipment, documentation, transportation, storage, handling and extraction labor, materials and equipment, archiving, documentation, data analysis, and reporting.

The quality of the obtained evidence may be affected by the collection and extraction processes. For example a dry procedure will preserve physical and chemical characteristics of spores better than a wet procedure. A procedure that uses culture growth loses the opportunity to examine the original individual organisms.

Situational factors such as the number of similar collection targets, the importance of the case and resources that may be allotted to it, the goals of the investigation, and many other subjective factors must be weighed in. What is the cost of missing trace evidence that might have been present? These are also outside of the scope of my work, although the model and results presented should be part of the decision making process.

A very important factor that will enter into decision making is the suspected quantity and spatial distribution of microbial evidence. This is explicitly included in the model presented for two limiting spatial distributions.

The model and calculated results show how the probability of obtaining some microbial evidence to analyze depends upon the quantity of target present per area and its spatial distribution, the area per sample and number of samples, the sampling, handling, and extraction efficiencies, and the volume of the concentrated extraction product. Sample plots are shown below in Figure 1 and Figure 2. The chosen graphs plot detection probabilities for samples collected with a wipe. Figure 1 shows probabilities for a uniform distribution of spores across the area, while Figure 2 shows the spot distribution case. In each plot, probability is plotted against the ratio of spores, *S*, per total contaminated area, $A_t$. Parameters relevant to the wipe are defined beneath the graph titles, such as the area sampled with one wipe, $A_{collect}$, the volume of concentrated extract, $V_{conc}$, and the total efficiency of the wipe collection and extraction method, $\eta_{total}$.

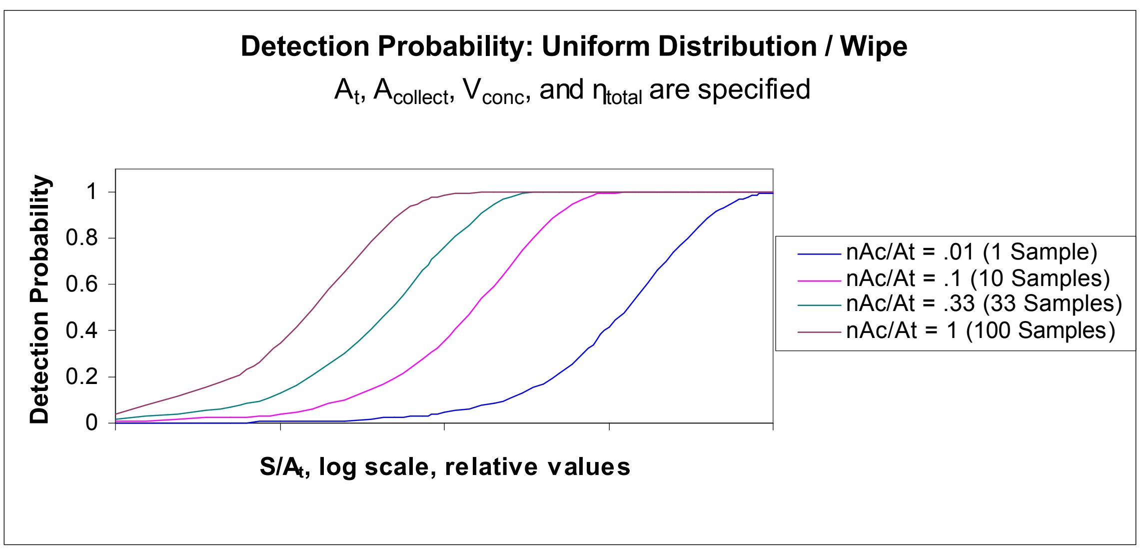


**Figure 1 Uniform Detection Probability**

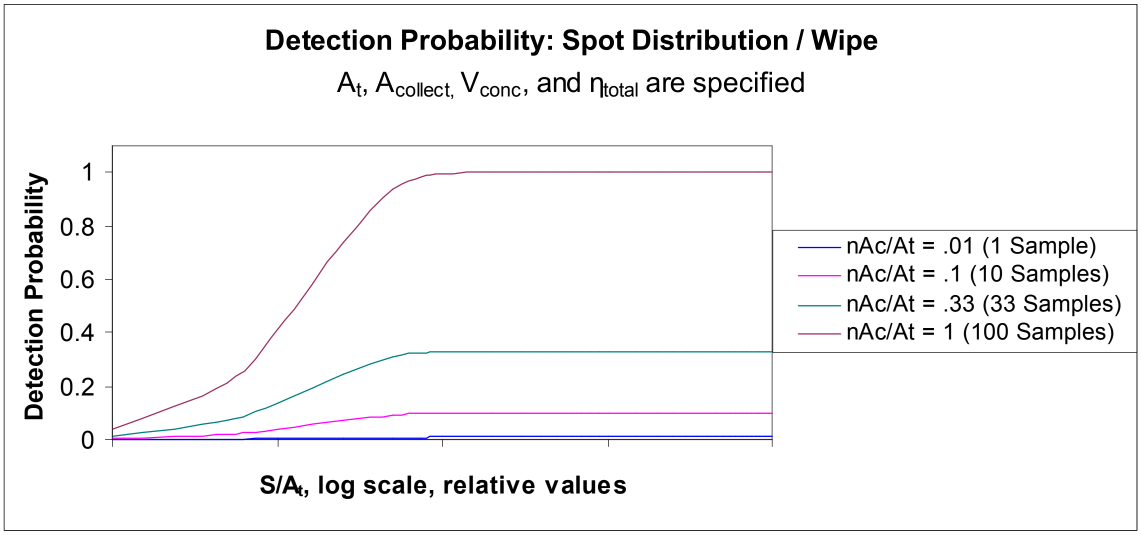


**Figure 2 Spot Detection Probability**

## Contribution to Milestones

During the summer I performed two technical studies and wrote two corresponding technical papers. A draft of the first paper concerning the statistical study, was submitted to DHS as part of my group's FY05 deliverable packet, and my final report on this will meet an FY06 deliverable. In addition to the statistical study, my fluids modeling gave rise to a series of experiments concerning agitation speed and the affect it has on extraction efficiency. I participated in these experiments as well, contributing to the physical results. Both the fluid modeling calculations and the experimental results will comprise part of a major FY05-06 deliverable.

## Internship Impact

This summer I took advantage of the wide range of talks hosted at the lab. Aside from the DHS summer lecture series, lectures were held by the IEC (Institutional Education Committee) as well as the Engineering department. I attended talks on subjects from border protection to explosive materials. These talks helped me understand all the different aspects of Homeland protection. I learned that border patrol is not a simple problem, it is extremely difficult and the opponent is organized. I have also realized how much of a challenge airport security and the technology involved with this sector of society is. While so many technological advances have been made over the years, there is still so much potential for growth. The talks I have attended this summer helped open my eyes to the different areas of research available for my career. This will help me narrow my focus as I look for a graduate program in the coming year.

Finally, I was exposed during my internship to office work, mathematical modeling and biology lab work in small doses. This variety of exposure helped me to evaluate what I want out of my career. I determined that I am looking for a job that is more research related than bureaucratic: I would rather perform research than write progress reports, and the ideal work situation is one where experimental work in the lab is balanced by theoretical research and modeling.

## DHS Mission and Goals

The majority of research at Lawrence Livermore pertaining to DHS that I have seen is Biology related. I would think that there is potential to integrate materials science and more fluid dynamics projects. For example, it seems like much could be done with a project to protect the US border by developing an unmanned aircraft to monitor traffic across the border. This sort of project would call for a variety of work, from materials to mechanical and aeronautical engineering to physics work on different monitoring devices.

One presentation I saw here at the lab was on the technologies used to scan luggage at airport security. This seems like an area that is advancing rapidly, with a lot of work being done by companies to create better technologies. I do not know if DHS is currently funding any research in this area, but probably more could be done in terms of integrating new technologies and streamlining the airport security process.

Finally, a large area of work that keeps springing up is the process of taking technology developed in a lab setting like Lawrence Livermore, and transforming it into something useful and practical for work done in the field. Amazing technology is worthless if operators find it too difficult to use and therefore ignore it. Research devoted solely to adapting technology to user-friendly devices would go a long way in serving the mission statement of DHS