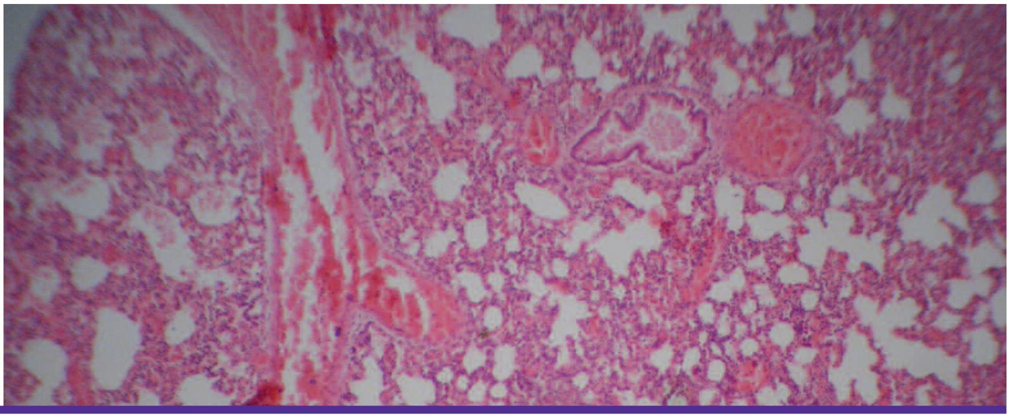
Success Story

Complex CFD Research at Dstl



Histological section of mouse lung, Crown Copyright

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– Dr. Steve Preston, Team Leader Aerosol Collection & Fluid Dynamics Detection Department

Dstl: Countering a New Era of Hostilities with Help from SGI® Altix® Servers

At Porton Down, Important Work Is in the Air

In this picturesque spot in southern England, not far from a 13th Century cathedral that watches over the town of Salisbury, is one arm of the Defence Science and Technology Laboratory (Dstl), the center of scientific excellence for the UK Ministry of Defence. Despite its image in the popular press, Porton contains some of the finest toxic handling facilities in the world, and is renowned worldwide for the quality of its research.

When researchers first established a laboratory here in 1916, British armed forces faced attacks by the most terrible weapons of World War I: chlorine, and later phosgene and mustard gas. That, understandably, made chemical weapons and chemical defense research the focus at Porton Down. The scope of study expanded during World War II and the Cold War, as UK scientists blazed new trails in the science of detecting and counteracting the effect of biological and chemical weapons on humans.

Today, however, the potential threats are even more numerous, and their effects potentially more menacing. Sarin. Smallpox. Anthrax. VX. Plague.

Dr. Steve Preston knows how these chemical and biological agents can be used against soldiers and/or civilians. As leader of the Dstl Detection Department's Aerosol Collection and Fluid Dynamics team, Preston makes it his business to learn how each of these potential weapons behaves when sprayed as aerosols, where they are suspended in the air until they are inhaled or fall to the ground.

Working with volatile compounds and live infectious agents comes with a mountain

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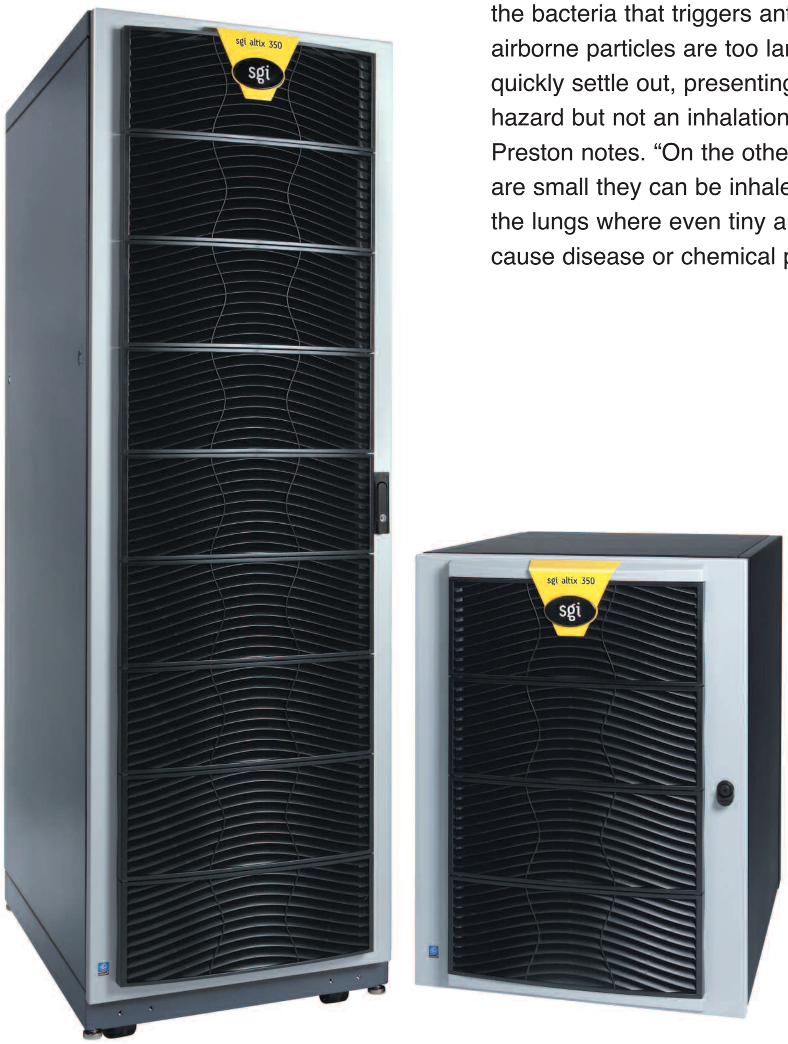


of challenges. "We have to look at how this airborne matter is carried," says Preston. "We look at the speed it can travel, how it can be inhaled, and what effect it may have on the lungs."

Preston's team runs complex computational fluid dynamics (CFD) problems for a wide range of studies, and shares its resources with other departments at Dstl. "With each new project, the file sizes grow significantly larger," he says. "We continue to see a tremendous increase in the need for memory availability with these large CFD problems."

Simulating the behavior of aerosol weapons is just that kind of complex problem. One reason is that aerosol VX nerve gas behaves differently than, say, the bacteria that triggers anthrax. "If the airborne particles are too large they will quickly settle out, presenting a contact hazard but not an inhalation hazard," Preston notes. "On the other hand, if they are small they can be inhaled deep into the lungs where even tiny amounts can cause disease or chemical poisoning.

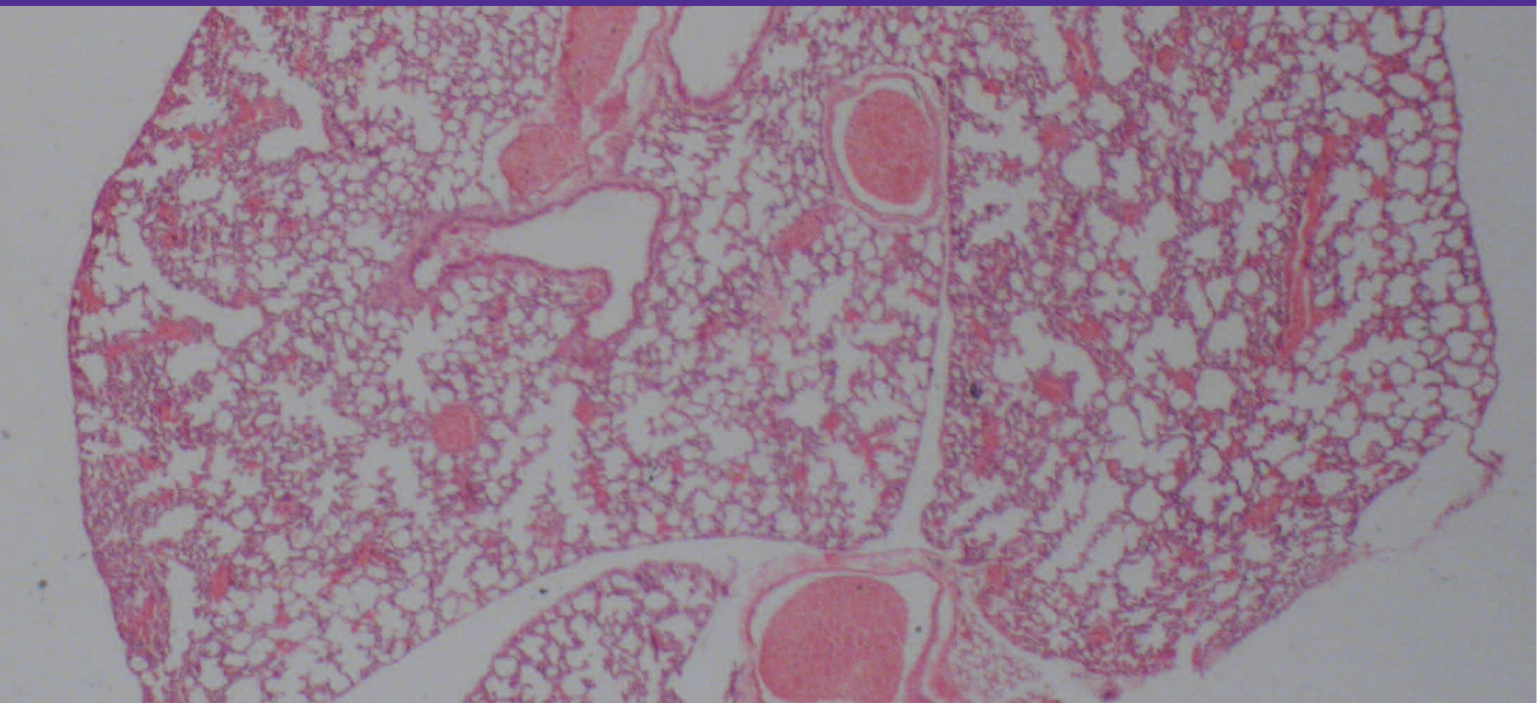
Some biological aerosols cannot live for long, but others, such as anthrax, can live on for many years and are therefore extremely dangerous."

In the field of toxicology—a specialty at Porton Down—creating a detailed working model of human physiology has historically stayed out of reach. With its practical approach to studying aerosols, the team has made great strides through what Preston characterizes as classical means. Yet those efforts, he says, have always been effectively reigned in by computing capabilities.

But new generations of shared-memory, 64-bit servers and supercomputers have opened an opportunity for Dstl's research to take a decidedly different course, one in which researchers can feasibly create an accurate, virtual model of working lungs. And in conjunction with Dstl's Biomedical Sciences Department, that's precisely what Preston's team aims to do.

Modeling a Working Lung

To grasp the deadly dynamics of potential aerosol weapons, Preston's ten-member team is using SGI resources and technology to build an interactive, fully articulated 3D model of a working set of lungs. By coupling the 3D model with CFD studies of how particles enter and are deposited in the lungs, they plan to study how infectious agents may be inhaled. Eventually, these studies may lead to measures that could minimize or prevent infections from airborne agents. They may even lead to designs for more effective inhalants—either to counteract the effects of airborne weapons, or to provide better delivery mechanisms for asthma medications or possibly insulin.



Histological section of mouse lung, Crown Copyright

Lung modeling is particularly difficult, explains Preston, because of the complexity of the lung's structure. For instance, an adult lung's tiny air sacs—called alveoli—are so numerous that if laid flat, they would cover an entire soccer field, suggesting plenty of opportunity for airborne chemical or biological weapons to enter the body. Infection or chemical poisons can then spread from the lungs to the rest of the body.

So enormous is the job, in fact, that the Dstl team is focusing first on creating a model of a mouse's lungs. "Human lungs are so large and complex that modeling them would take years, and right now, we don't have that much time," Preston concedes. "So we're starting with a fully functional model of a mouse lung, which is much smaller."

Preston's team concluded that a highly articulated model of a mouse lung, which is validated for humans, particularly in the microbiological area, would be highly valuable as it could then be extrapolated from mouse to human with some degree of confidence.

To create a CFD model of the airways of the lung, Preston's team is taking two different approaches.

The first is to carefully take histological sections of the mouse lungs, each measuring about 10 microns in thickness. Researchers then stitch the flat 2D images together, correcting any warping or stretching that occurred during the scan. Even with tiny mouse lungs, the project is substantial. "The modeling process is incredibly complex," says Preston, who estimates a single 2D image measures about 10MB in size, and engineers are stitching together thousands upon thousands of images. "It replaces the traditional method, which is to do a post-mortem or autoradiography study of deposition which are time consuming and require experiments of living animals. But with an interactive, 3D model, we can show how the particles are inhaled, and how deeply, and avoid using animals."

To power the project, Dstl purchased two SGI® Altix® 350 servers: one driven by four Intel® Itanium® 2 processors and packed with 60GB of memory, and another with five processors and 64GB of memory, along with 2TB of direct-attached storage devoted to supporting the modeling solution. The components are networked via gigabit Ethernet connections, and results are viewed remotely on PCs.

The systems were installed in February 2005, after which Preston set to work with SGI Professional Services to identify and develop the geometry of the model. "This is really pushing the boundaries of CFD model detail," he says. "Some of the CFD models used in Formula One racing are huge, some reaching ten million cells. But in modeling a lung, you'll be looking at a billion cells at least."

Countering a New Era of Hostilities with Help from SGI® Altix® Servers

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>
> *– Dr. Steve Preston, Team Leader*
> *Aerosol Collection & Fluid Dynamics Detection Department*

In the second approach, Dstl is working with Fluent Europe Ltd. For Dstl, Fluent created a series of lung CAT scans, from which a 3D model will be built. After comparing results from the two approaches, Preston's team will build its working model.

Hungry for Memory

While the Dstl team's current focus is on establishing the "mechanisms of the geometry," Preston says the end goal is to create a comprehensive computational model based on Fluent software. All stages of the project are highly memory-dependent—a primary reason Dstl selected Altix systems.

With its unique global shared-memory architecture, the SGI Altix server allows users to hold entire data sets completely in memory. This streamlines productivity by enabling scientists and engineers to avoid having to process large data sets in pieces. As a result, they can run more calculations against their data to reach conclusions faster.

The flexibility of the Altix platform, which supports independent scaling of processors, memory, and I/O, was important to Dstl. So was the system's support for industry-standard, 64-bit Linux® implementations and Intel Itanium 2 processors. "We can scale the Altix components independently, so if we need more CPUs, we can grow those, or if we need more memory, we can scale that as well," Preston says. "A 64-bit platform that supports major codes used in government and commercial fields was a vital criterion. This allows us to take the longer-term view for this research project and will give even more projects access to the system as needed."

With its important work underway, the Aerosol Collection and Fluid Dynamics team at Dstl are taking the long view indeed.

"The biggest benefit is that we can look at lots of different scenarios much more quickly," Preston notes, "and this should help us pinpoint solutions faster. That could yield very important discoveries that could save lives—not just in terms of aerosol weapon attacks, but perhaps even new medicines for everyday conditions."

And that, Preston says, may help all of us breathe a little easier.

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