TELLURIDE SCIENCE
& INNOVATION CENTER
ELEVATING SCIENCE AND DISCOVERY

Q & A with
Jim Crutchfield

How long have you been involved with Telluride Science?
The first Telluride Science workshop that I attended was on molecular dynamics in 2014. A year later, I organized the Information Engines workshop with my colleagues Korana Burke (UC Davis) and Sebastian Deffner (UMBC) and we have been running it since 2015. Fabio Anza (UW) joined the organizers a couple of years ago. Southwestern Colorado is not new to me, though. I spent summers in high school herding cattle near Bayfield, Colorado on a family friend's ranch and had explored Telluride a bit during my high school days. We used to take the Durango Silverton Train and get dropped in Chicago Basin to backpack for a few weeks. It was like the old west, flagging down the train to return to civilization.

How is Telluride Science different from other scientific conferences and what makes it unique?
There are several distinctions that make Telluride Science meetings unique. The meetings are really workshops and are truly for getting work done. Usually, professional conferences serve as a networking function to catch up with colleagues. Telluride meetings are much more scientifically productive than that. There is a core group of Information Engine regulars that have a fondness for Telluride Science workshops since they get time off from busy personal and professional lives. You really get to focus on science and new ideas. The workshop format gives extra time to have spontaneous conversations outside of the seminar room. Afternoons are open and free; people convene in different subgroups and go hiking and that is when participants have had some of their best ideas. The informal time is crucial to the creative process. It is the ideas that come in through the interstices between established areas that are sometimes the most innovative. And, bridging different backgrounds takes time. Our workshop is quite long, ten days whereas most professional conferences are only several days.

The subject Information Engines is radically interdisciplinary; sometimes I say transdisciplinary to emphasize the collective exchange that develops. The workshop explores how natural and designed systems store and process information. This brings in people from very different backgrounds---biological physics, molecular science, chemistry, computer science, statistical physics, quantum physics, and thermodynamics. Telluride Science offers the ideal environment for a diverse group of people to come together and collaborate.

How has the organization impacted your career?
The Information Engines workshop led to an important rethinking of how systems use information and energy to support their function. One long-lived question in this field has been "What are the physical limitations of information processing and computing?" In the last 15 years, there has been a revolution that revealed how to adapt ideas from statistical physics and thermodynamics to describe complex systems that are far out of equilibrium. Equilibrium systems are death. Systems that are out of equilibrium are constantly in flux and adapting, buoyed by the flow of energy, materials, and information.

Our workshop leverages that new understanding of nonequilibrium systems. Unlike large-scale equilibrium systems, there is constant noise and fluctuation on small scales. Years ago, several of our workshop participants discovered that the way small systems respond to environmental fluctuations is lawful; that is, described by exact probability laws. This gave us a new picture of how to design efficient computer devices and logic gates. One concrete result is that we can now design logic gates that are 10,000x more energy efficient than current technologies. Today, huge server farms burn up megawatts of power. So, reducing that by a factor of 10,000 in 4 or 5 years will have a huge impact on energy consumption. With the exponential increases in the human use of computing this impact will only grow.

These new energy efficient logic gates will also have a huge impact on technological devices that we all use daily. Imagine only having to charge your cell phone once every 10,000 days. Charging batteries on an iPhone or an iWatch will become a thing of the past as batteries will last years. At that point, the watch or phone will simply be recycled/replaced.

I just received a research grant from the Army Research Office to working Caltech's Kavli Nanoscience to start a whole suite of experimental tests of these energy-efficient devices. So, the future is bright that we be able to thoroughly

validate the promise of these new design approaches.

What is your scientific field of study? How is the science you are studying applied outside of the lab?

I'm a Theoretical Physicist in condensed matter systems. Though, more precisely, my background is in the area of chaos and complexity---the mathematical field of dynamical systems. Some of the ideas there are being applied in weather forecasting and modeling. Hurricanes are heat engines that organize to convert high ocean surface temperatures to energetic motion in the atmosphere. We have developed new statistical inference methods to teach machines that analyze weather data to automatically recognize structures in the atmosphere like hurricanes, typhoons, atmospheric rivers, tornados, and cyclones. A few years ago, we were awarded a national prize in High Performance Computing because we could process petabytes of climate data and satellite imagery to discover and track hurricanes. All unaided by humans. This is called unsupervised machine learning, but it is founded on a more physics-based approach to analyze climate data. This is a markedly different approach from how weather is currently tracked and monitored. In several years, we believe weather forecasting methods will most likely adopt this approach. One of the benefits is that you will no longer need humans to identify ahead of time the atmospheric structures that control climate.

Is there a grand challenge that your field study could potentially solve?

Automated weather forecasting and super efficient computing will have a very big impact on our world. However, there are still even more important theoretical challenges that we need to solve. For example, and more me personally, adapting these ideas to understand biological systems and how they function is a grand challenge.

What do you think about Telluride Science finally having a permanent home?

The Depot is going to have a huge impact. It will change how scientists and the public sees Telluride Science. There is nothing like having a home. It will be a beautiful space and will give people a lot of pride. It's wonderful to connect to the town's history. The space will be designed in a creative way to maximize brainstorming, interaction, and discussion.