NIST Summer Institute for Middle School Science Teachers
Day 1: July 9, 2012

Teachers from MA, CT, NC, SC, UT, and other states arrived early on the first day and spent time getting to know each other. How interesting to compare teaching in vastly different situations and conditions but all with students in 6th, 7th, and 8th grades!

After an icebreaker in which teachers shared successes that they had experienced in the classroom the previous year, Mary Satterfield gave an overview of the NIST Summer Institute. With the rapid advances in science, science teachers must keep up with what's going on in order to remain relevant in the classroom.

Willie May, Associate Director for Laboratory Programs, gave an overview of NIST based in part on his experiences at NIST over the past 40 years. Since his work in Alaska in the '70s developing sampling protocols and measurement methods for a pollution baseline assessment along the trans Alaskan pipeline, which led to specimen banking of marine mammals today, Willie has been involved in measurement science in many different areas. In his current position Willie oversees research as diverse as that of the redefinition of the kilogram, the only remaining SI unit that is based on a physical artifact to health IT record comparability, which will allow health care practitioners to reliably compare records across space and time. As Willie said, "If NIST is doing it's job right, the public won't realize we exist."

Keith Martin, NIST Librarian and Museum Tour Guide, shows teachers around the many exhibits of NIST work, starting with the nation's first metrologist, Ferdinand Rudolph Hassler, who was appointed the first Superintendent of the Survey of the Coast by President Madison in 1816.

A NIST exhibit at the Louisiana Purchase Exhibition in 1904 included modified laboratory instruments (glass tubing) containing neon gas. When electricity was applied, the glass tubing lit up with a colored glow. Today, the neon sign industry is worth more than $1 billion. Who knows how the measurement science advances that NIST is currently working on will be used?

For example, Bill Phillips of NIST received the Nobel Prize for his method trapping and cooling atoms, cooling them to almost absolute zero. At that low temperature odd properties are observed. However, just like the neon gas work, who knows how radical discoveries like this will be used?

Then teachers headed out to the courtyard to see the Newton's apple tree. The tree is a Flower of Kent variety, a direct descendant of the fabled Woolthorpe, England, apple tree that inspired Sir Isaac Newton's theory on gravitational forces.

While half of the teachers were having a tour of the museum the other half were having a NIST in Your Community Tour with Jennifer Huergo.

At the Keeping Time with Atoms exhibit, this replica of NIST's fountain clock (NIST-F1) shows how atoms are used to determine the duration of one second. One of the two most accurate clocks in the world, NIST-F1 subdivides the second into more than 9 billion equal parts. It will neither gain nor lose a second in more than 100 million years. NIST's ultra-accurate time services help navigate spacecraft through the solar system, synchronize telecommunications and computer operations, and measure fundamental processes like the speed of chemical reactions.

As a non-regulatory part of the federal government, NIST works with industry to meet their measurement needs. For example, manufacturing a car requires more than 15,000 parts and accessories. These parts must fit and work together perfectly even if made by many different companies, in different countries. NIST provides U.S. automakers with the tools to ensure that a centimeter in Milwaukee is the same as a centimeter in Malaysia.

After lunch teachers headed to the Weights and Measures Training Lab. Prior to playing the Metric Estimation Game, in which participants earn points by guessing the mass or dimensions of everyday objects in metric units, Elizabeth Gentry leads the teachers in investigating the tools in the measurement kit and selecting their team name.

Teachers hustle to estimate the length of a crayon in centimeters. Don't forget to include the units!

Using reference points such as a liter of water, which has a mass of 1 kg, helps participants estimate the mass or volume of other objects, such as the five rolls of nickels. Do five rolls of nickels weigh about the same as a liter of water? Hard to tell in this case because the density confuses the issue.

"Oh, gosh, it's going to be hard!" One of the teachers was heard to exclaim when someone selected volume for 1000 points. A container of ice cream actually held 1 L – and all four teams estimated as 1.25 or 1.5 L. More metric estimation work needed!

Afterwards teachers wrote down one thing they learned from this activity.

Just remember, Elizabeth said, “Every second of every day you’re using the metric system.” That’s because the second is the SI unit of time!

And it was on to Measurement in the Marketplace with Tina Butcher, an overlap between science and old-fashioned home economics in which measurements are related to everyday life. Congress established the United States Office of Weights and Measures in 1836 to provide consistency and accuracy in the marketplace. Now we know that a gallon of milk in Maryland is the same as a gallon of milk all across the country. Weights and Measures Inspectors verify the accuracy of measurements made in advance of purchases, such as packaged materials like candy or cereal, or measurements made in front of you such as the purchase of gasoline or apples.

The mass of the package is not to be included in the cost of the product, according to the federal, local, and labeling laws and regulations. And how accurate is the mass of M&Ms in the package? Turns out that more of the packages are overweight than underweight, which keeps the consumer satisfied and the inspectors happy.

Of course, it's really all about equity in the marketplace and being a savvy consumer.

NIST Summer Institute for Middle School Science Teachers
Day 2: July 10, 2012

The day began with a visit from NIST statisticians, Hung-kung Liu and Dennis Leber, out to prove that statistics is not boring and difficult to understand through an activity in which teachers measured the circumference and diameter of several round objects with different tools. Of course, receiving *A Cartoon Guide to Statistics* helped, too!

Dennis Leber asks Eric to measure the length of the table. After several people have measured the table, how do you know which one is right?

Hung-kung demonstrates how to use a caliper to measure an object.

Cherry carefully uses a measuring tape (metric of course!) to measure the circumference of a bicycle tire.

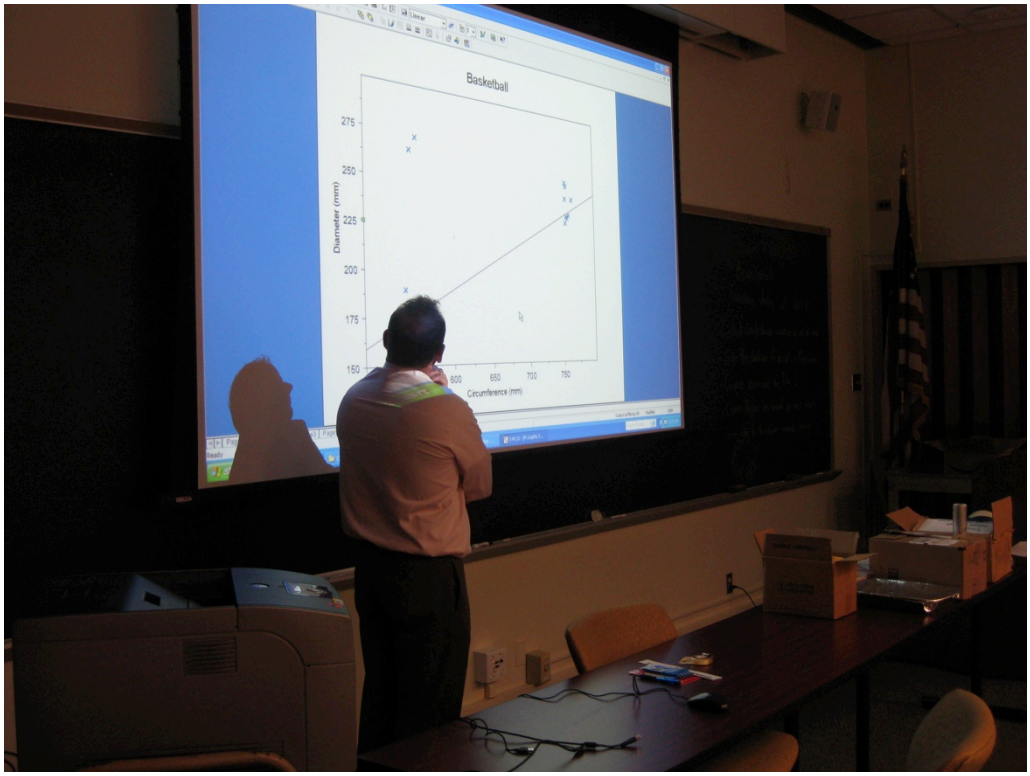
Kelly works to measure the diameter of a bicycle tire without being biased by the protruding axle. Is she is measuring the circumference at the same time?

Laura carefully aligns the copper ring at the start of the specially designed measuring device.

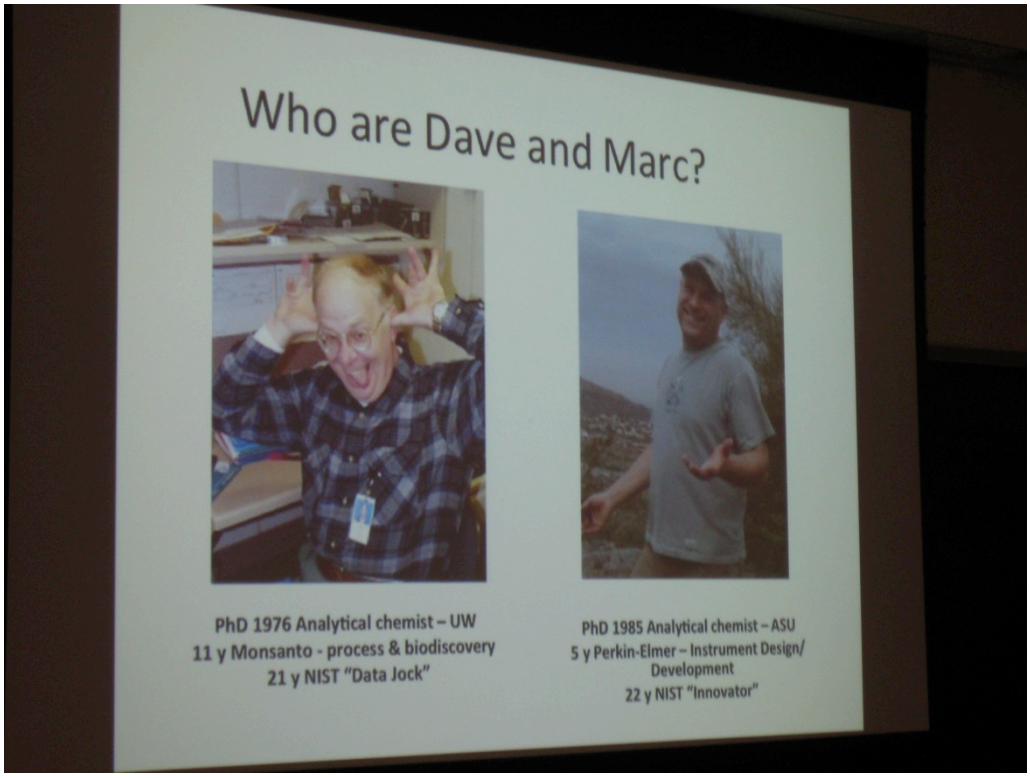
After Hung-kung's lesson, Loryn has no trouble using the calipers to accurately measure the diameter of the copper ring.

Martha and Mandy figure out an innovative method to more accurately measure the diameter of the ball. First align the chair backs so that the ball fits between them, then measure across the chair backs!

After analysis of the data and calculation of pi, Dennis presents each teacher with a certificate announcing that each teacher is now an honorary NIST metrologist. The certificates include the calculations of pi based on each teachers' measurements and prove that measurement is not easy.



Hmm, what could have caused those outliers? Did someone measure and report the radius instead of the diameter



As a follow-up, Dave Duewer presents a short lesson on metrology. Least the teachers think that he and his co-author Marc Salit are stuffy and boring, Dave shows evidence otherwise.

The four components of metrology are traceability, uncertainty, validation, and a quality system, and to illustrate them, Dave has three sets of teachers pace out the room, each using a pace as their measuring unit.

Frank paces off one side of the room while everyone counts – independently, please!

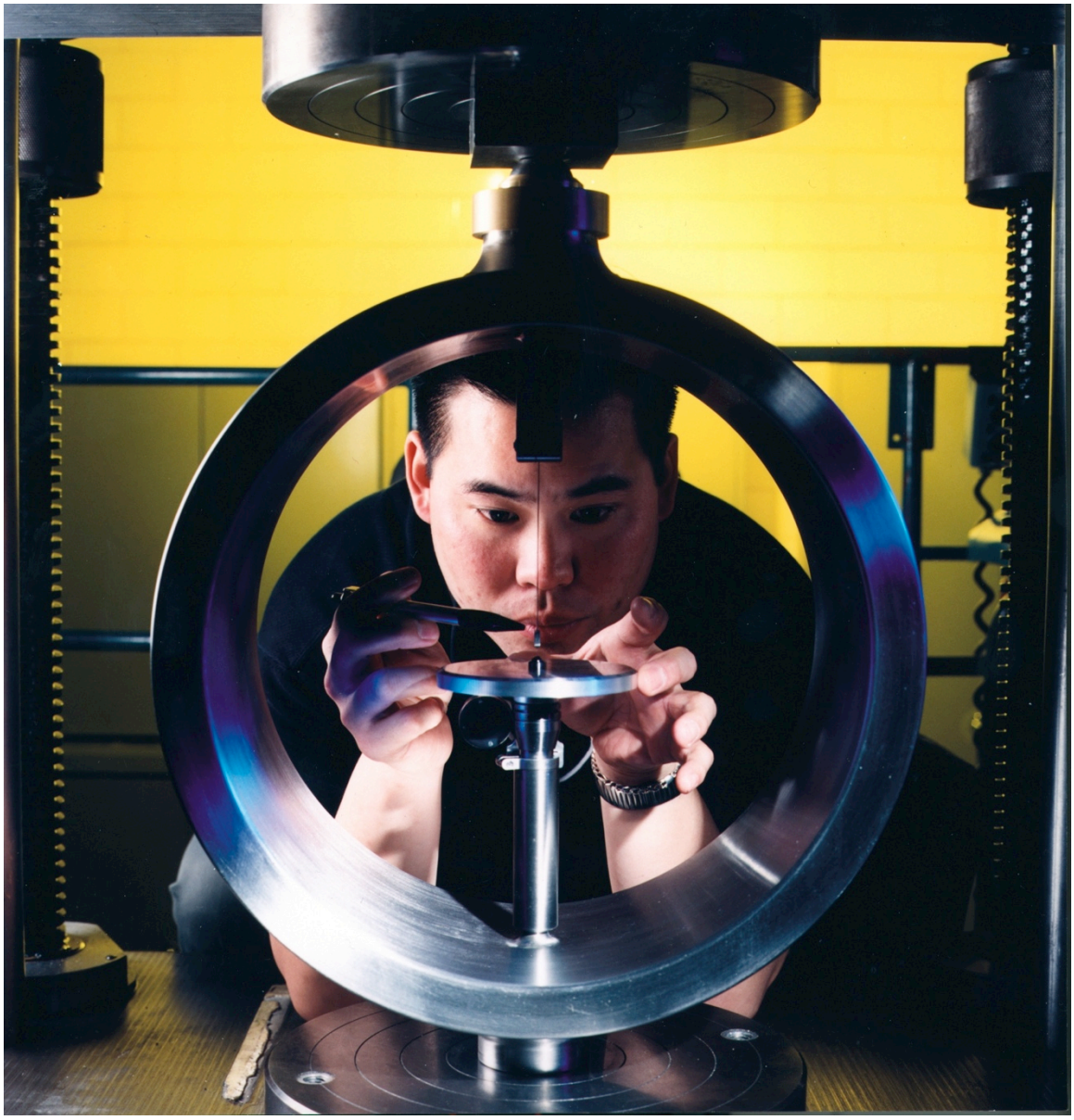
Mo and Dave confer about the pace data from her group.

Since every group used a different pace for measurement, Dave and Damisha measure out what will be the standard unit, the height of Mary. From transfer standards, pieces of string cut to the height of Mary, teachers will determine how many paces are in each Mary and convert their measurements to the standard unit of Mary's. Will this bring the measurements of the sides of the room closer together? Yes - or at least better than when three different measuring units were used!

Discussing how best to determine how many paces are in a Mary.

After lunch, teachers headed out for tours of the Million Pound Force Deadweight Testing Facility or the Ballistics Testing Facility. The Force Deadweight Facility is part of the Mass and Force Group which provides high-accuracy physical measurement test and calibration services, and access to the top of the traceability chain for the units of mass, force, and related quantities (e.g., torque) to meet the needs and demands of U.S. industry, government, and the scientific community and to improve public health and welfare. It houses the 1000000 lbf (4.4 MN) dead weight machine which is the largest in the world. Some of the instruments that teachers learned about were used in the design of rockets used to carry astronauts into orbit and then to the moon! The NIST Force Group played an important role in measuring the force provided by the rocket engines. Today the machines are still being used to generate forces and hence calibrate standards that are used in all types of industry and research.

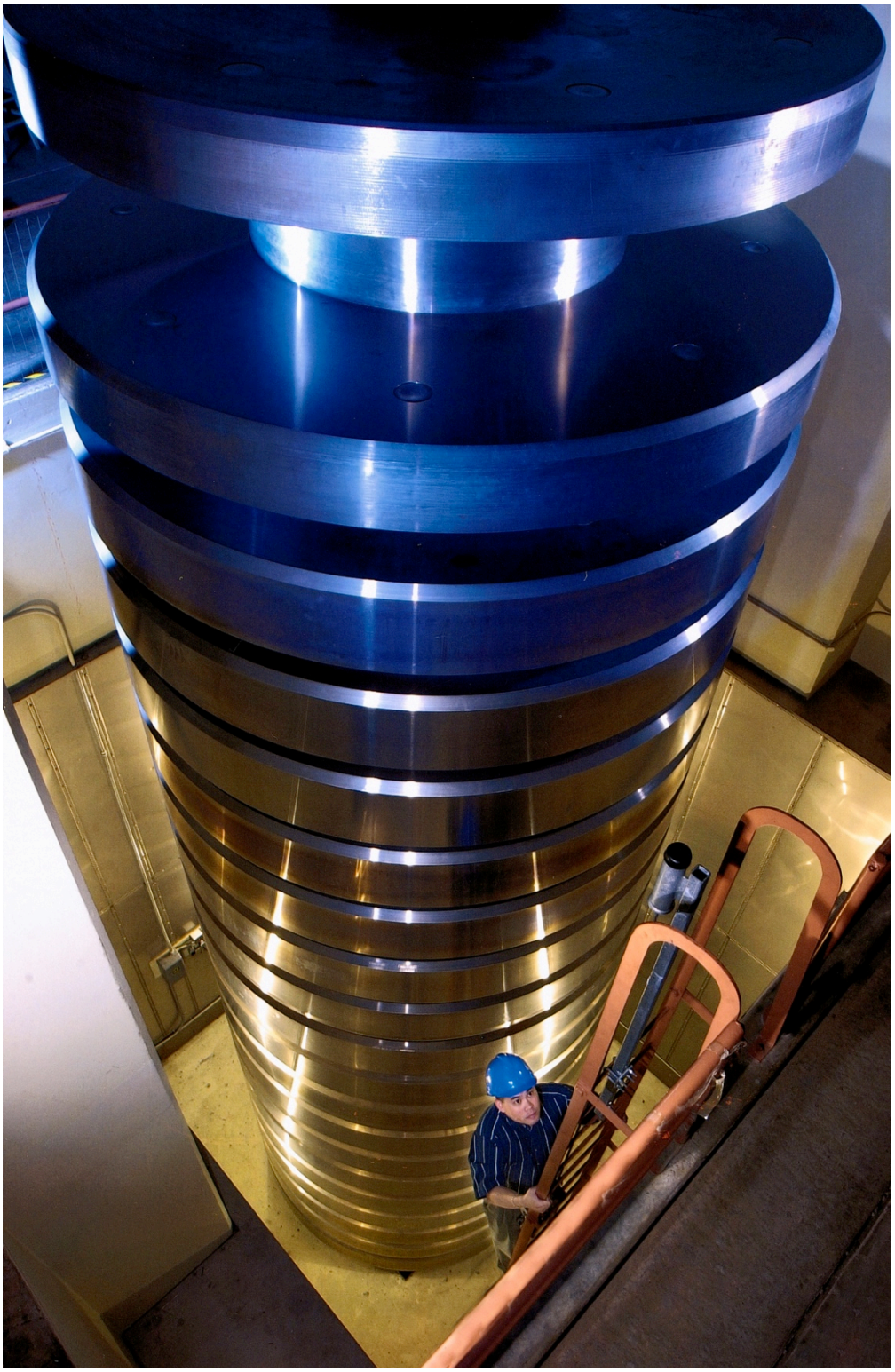
Kevin Chesnutwood, a mechanical engineer, describes a proving ring, a device used to calibrate machines used to measure force. It's a transfer standard, just like the string used to measure standard lengths of Mary's height!



Here's a picture of Sam Ho, also a mechanical engineer and the tour guide for the second group of teachers, in the process of calibrating a proving ring.

A group shot in front of the 1,000,000 (that's a million) lbf (4.4 MN) Deadweight Testing Machine.

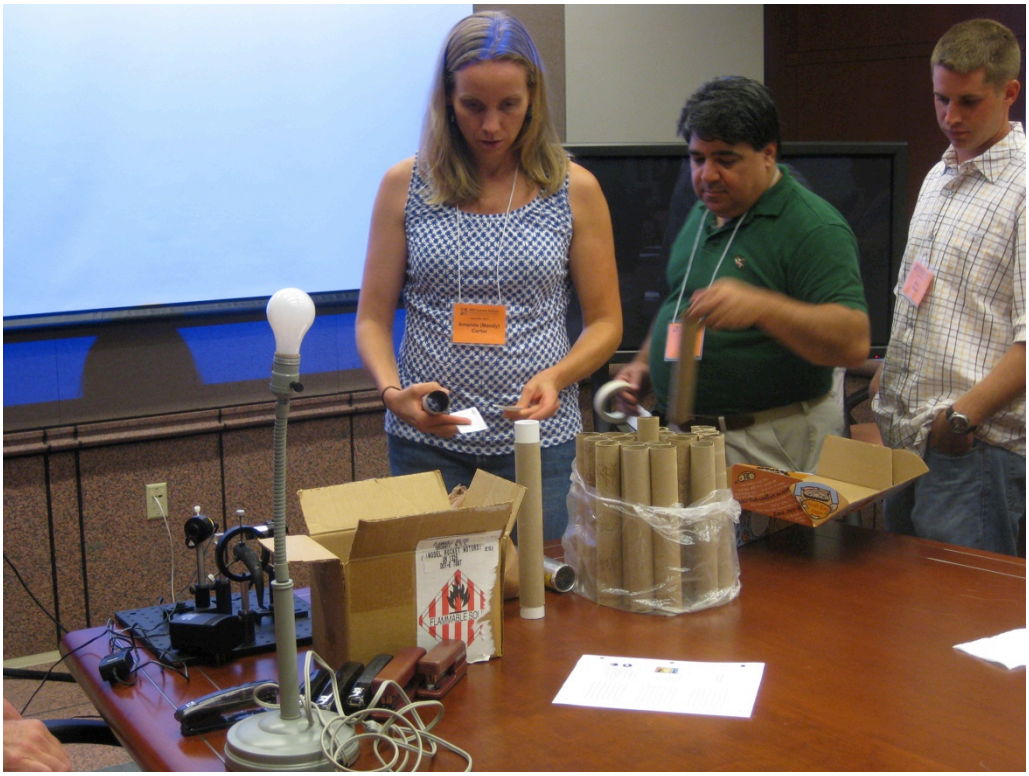
On the next level down of the 1,000,000 lbf (4.4 MN) Deadweight Test Machine are the million pounds worth of weights, an impressive sight. This is the only machine in the world with a million pounds worth of dead weight.



This shows a picture of the weights, each capable of generating 50,000 lbf (or 222.4 kN). In the previous picture the teachers were standing on the outer side of the orange railing that is visible in both pictures. Questions arose as to why the metric system wasn't being used for units of force; i.e. why isn't this called the 4.4 MN Force Deadweight Test Machine? The answer: The original nominal weight denominations were chosen in the 1960s when the English system was more widely used. All generated forces are now reported in Newtons (a simple conversion from lbf).

Then it's off to another lesson – this time on spectroscopy, what it is, how it's used at NIST, and how it fits in the middle school science classroom. But first, cake to celebrate Laura's birthday – even though it was last month! The cake was really an excuse to light candles that burn a variety of colors and to see if the spectrometers the teachers make can be used to separate the light.

Steve Choquette, a chemist, talks about how the use of spectroscopy has replaced wet chemistry, which required large amounts of expensive chemicals with lots of waste produced, for measuring non-destructively the amount of economically important components such as protein, oil, and water in grain and other foods. In fact, Steve predicts that our cell phones will enable us to do these measurements ourselves – based on flavor and ripeness, probably - within the next ten years!



Then it's on to build paper towel roll spectrometers with a simple diffraction grating used to separate the light. First to collect all the parts…

And then to build! (This is serious work so teachers pay close attention to the instructions ☺)

And then the spectrometers are used to look at different light sources. How does a fluorescent light differ from an incandescent source when examined with a spectrometer? The incandescent lamp produces a continuous spectrum, while the fluorescent lights produce a spectrum with some colors missing – and you can tell with this simple spectrometer!

Teachers look at the incandescent light source, an old fashioned light bulb.

Steve instructs teachers on calibrating their HASIII (High Accuracy Spectrometer III; HASII is in this same building just down the hall).

Teachers use their spectrometers to see how two colors of lasers that are one-on-top-of-the-other can be separated.

And then, after looking at several tubes of gases that show distinct spectra of just a few colors, teachers gather up the materials so they can do these experiments in their own classroom. So much to carry – but it's worth it!

NIST Summer Institute for Middle School Science Teachers
Day 3: July 11, 2012

The day was devoted to learning how to use the LabQuest, a hand-held device with multiple different probes that is used to simplify measurements so that students can concentrate on the experiment and what the measurements are trying to teach.

Teachers were very pleased to receive the LabQuest and probes …

… and even more pleased to be able to spend time learning how to use them.

Lisa sets up the first experiment with the light monitor and temperature probe. What's the difference between using black and white paper?

Chris goes several steps further and uses multiple different colors of paper – look at that data!

After everyone had a chance to do a simple experiment just to get to know the basics, teachers were given the opportunity to try out different experiments from different disciplines, all available from the Middle School Lab Manual, which teachers also received. Here Laura and other use the motion detector to track the motion of a car down an incline.

Laurie and Jill measure the pH of different soil and water mixtures. Does it make a difference if the soil comes from under a pine tree, or from the flowerbed, or from the grass?

Are we having fun yet? Oh, yes, so fun to learn how to use this new device and to envision possibilities for use in the classroom!

A group confers on how to do something with the LabQuest – many heads are better than one.

Although none of these teachers knew each other before this past Monday, working together on science experiments builds teams – and besides it's fun! Here Mandy and Karen are distracted long enough from the LabQuest to smile for the camera.

After lunch Nus Hisim talked about the advantages of the wireless capabilities of the LabQuest II and led the teachers through various classroom scenarios.

Loryn and Lisa pursue the yeasty beasties with the pressure sensor. Notice the use of safety glasses in case of an unexpected – and messy – explosion.

Fortunately, they're not too busy to look at the camera and smile!

Kelly and Monica prepare to track the temperature at different places on the earth as the seasons change. Beware of putting the “sun” too close to the globe!

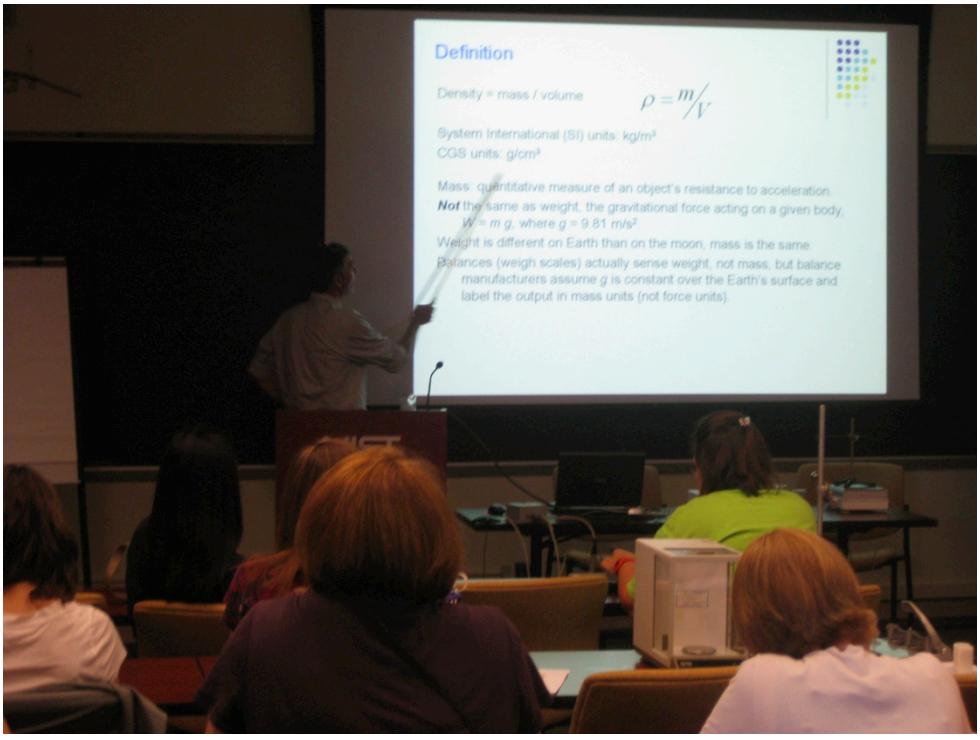
You may wonder why Dave is on the floor in this odd pose, but it’s all in the interest of science…

…. as teachers examine the profile of the "ocean floor" observed by moving the USS NIST (a cart with the motion detector mounted on it) over Dave's body and various boxes.

All in all a fun and productive day. I wonder what other experiments using the LabQuest NIST has in store for the teachers?

NIST Summer Institute for Middle School Science Teachers
Day 4: July 12, 2012

The morning began with Frank demonstrating the use of the hand-boiler as an introduction to the use of toys in the classroom. They're fun and they make kids think!



Then it was off to learn about density with John Wright and his student, Chris Crowley.

Questions quickly arose over the difference between mass and weight and a new-to-many definition of mass as a quantitative measure of an object's resistance to acceleration. Chris related mass to inertia, the resistance of an object to a change in its motion. Mass, an intensive property, doesn't change based on location. In any case, we're all familiar with the concept of density as mass/volume. But how is the mass affected when the object you're trying to find the mass of is suspended in a beaker of water? The buoyancy of the water pushes up on the mass and so the apparent mass decreases. And turns out that the decrease in mass is related to the density of the liquid in which the mass is suspended. For example, the mass changes less when a less dense liquid, such as methanol, is used.

John and Chris turned this around to see how closely teachers could calculate the density of water taking into account it's buoyant effects:

Martha and Jessica work to measure the diameter of the steel ball with calipers. (The cardboard box is a shield over the balance, designed to protect the balance from drafts, a source of uncertainty.)

Kelly, Lisa, and Monica prepare the setup according to configuration A with the beaker on top of the balance.

Cherry and Jerrin work together to read the calipers.

Teachers are tasked with building an apparatus to suspend the steel ball in the liquid. Karen and Loryn build a wire holder for the ball.

John provides guidance in use of the calipers.

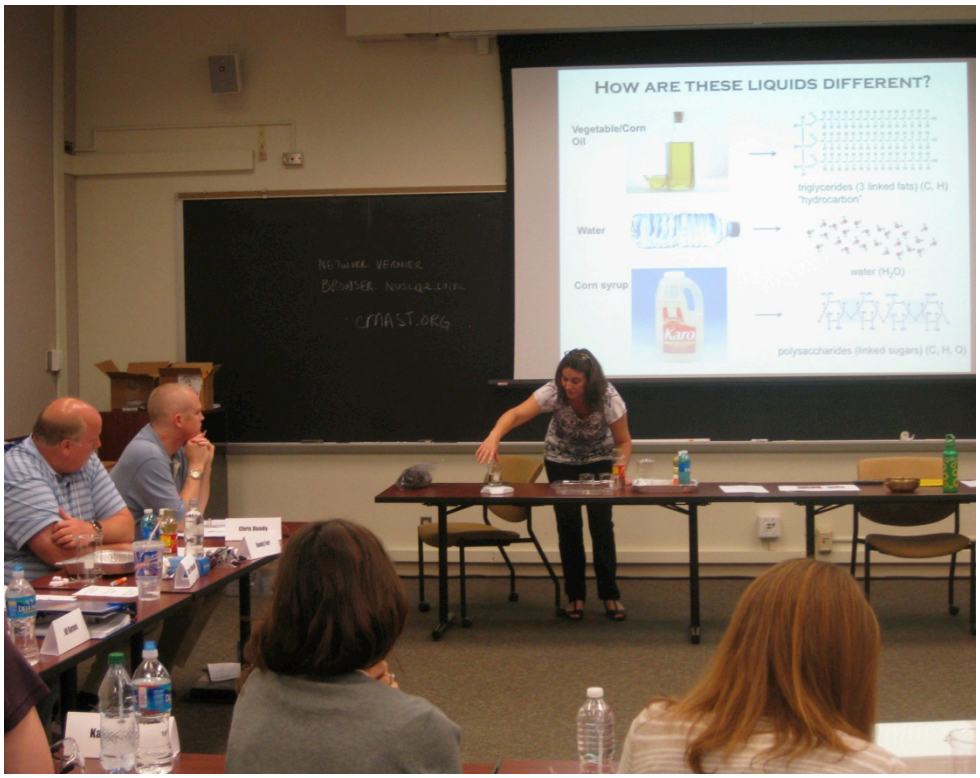
Eric measures the apparent mass of the steel ball suspended in water.

John and Lisa confer about her data.

John and Laurie discuss the meaning of mass and how a balance works. Turns out that manufacturers take into account the acceleration due to gravity plus buoyancy due to air and report mass – even though the balance is really measuring weight!

Then after teachers have submitted their data Chris displays their results – and most teachers are close to the right answer for the density of water! In a discussion of the possible sources of uncertainty in this experiment teachers come up with temperature of the water, thermal expansion of the ball, loss of water during the experiment, etc. Most of the factors introduce minimal error and are dwarfed by larger sources of error such as the effect of the hanger touching the box.

Then it's back to Lecture Room A for Cartesian divers – so fun and simple and can be used to teach basic concepts. Remember that the smallest water bottles don't work since the disposable pipettes are just too long! Note how strong Kelly is – she can control that pipette! Monica, on the other hand, has more subtle control.



Katrice Lippa, a chemist from the Analytical Chemistry Division, guides the teachers in making density columns and provides a different perspective, encouraging teachers to think about the composition of the materials they are using in the column.

Mandy, Laura, and Frank begin by making a layer of corn syrup.

Once the three layers of corn syrup, colored water, and corn oil are in place, where would you predict a grape would end up? Which layer is the grape most like?

Sometimes it helps to see by slouching down in the chair as Jessica and Lisa point out to Kelly. (They're actually discussing how the grape ended up at the bottom of the water and the top of the corn syrup.)

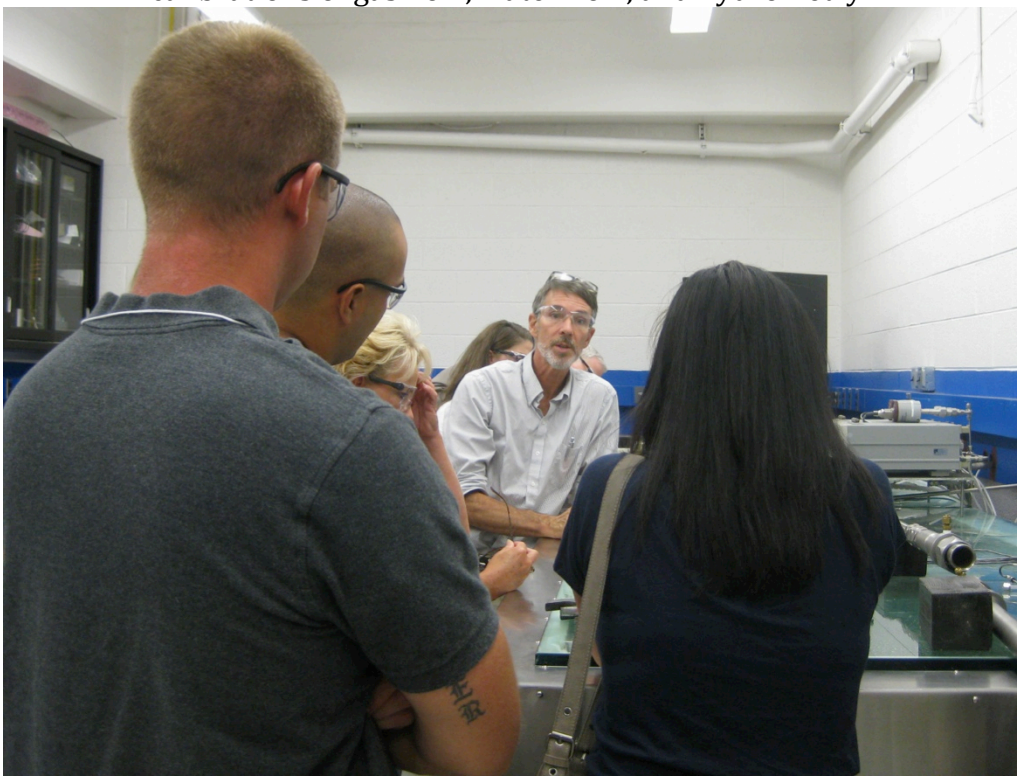
Damisha points out a phenomenon her group noticed when Dave chunked the grape in at a great height. As the grape fell through the layer above it, oil and perhaps air stuck to the grape. Once the grape was in the water layer the oil/air slowly peeled off the grape and rose to the proper layer.

What about the Lego? What does the Lego do? (And how in the world can they be cleaned afterwards? The sacrifices we make for the sake of science!)

Frank tries to push the Styrofoam peanut down to another level to get rid of the air stuck to it.

And finally: mixing it up to see what happens next. Will everything separate?

Then it's off to a tour of John Wright's labs, where he and his colleagues maintain the capability for calibrations of gas flow, water flow, and hydrometry.



John explains how the apparatus in the water bath is used to measure gas flow. The water bath is used to maintain the desired temperature thus decreasing the uncertainty associated with the measurement.

At another larger capacity tank, John explains how gas flow meters are calibrated. Turns out that different materials require different calibrations; what's inside the pipe makes a difference!

The white tanks are filled with purified water and are used to calibrate liquid flow meters used in the petrochemical industry, for aircraft engine manufacturers, the biotech industry, the semiconductor industry, and others.

Thanks to John and Chris for giving up their lunch to give us a tour!

Carolyn Holcomb, NIST Summer Institute and Research Experience for Teachers participant, talked about the use of NIST materials in the classroom. After the 2010 NIST Summer Institute Carolyn was determined to use every single activity and material that she received. Carolyn has certainly taken advantage of the resources NIST has to offer for the benefit of her students – and besides it's always fun to learn more science!

Then it's time for a one-on-one visit with a scientist. Jill starts early by visiting with Fatima Sequeira, a postdoc in the Biochemical Science Division. Postdocs are NIST staff members with Ph.D.s here on a two-year postdoctoral fellowship.

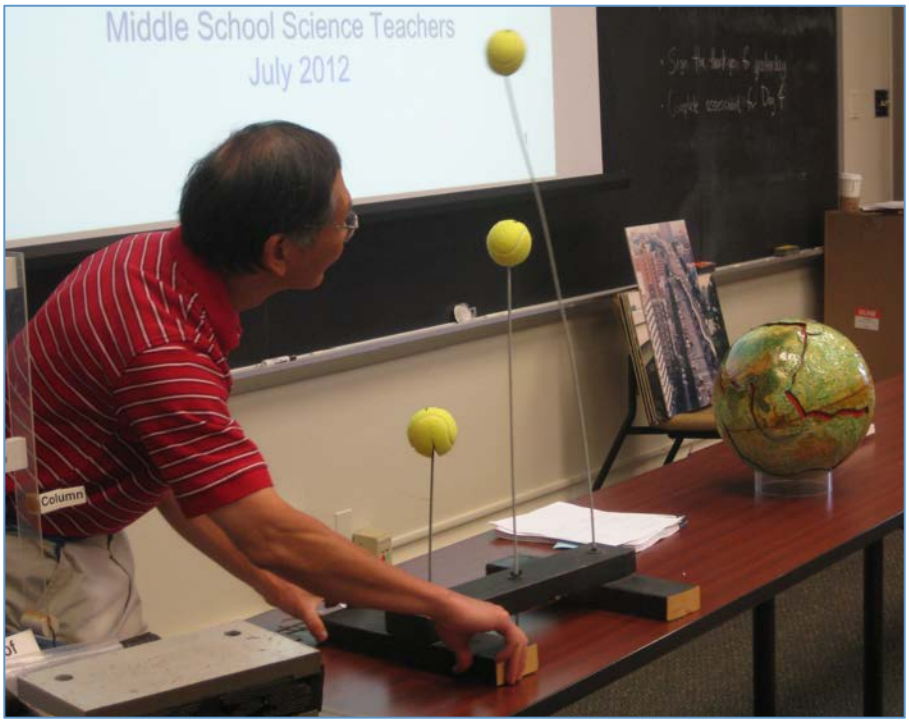
I'm not sure exactly what's going on here….

…. but if Lisa's involved, it must be fun!

NIST Summer Institute for Middle School Science Teachers
Day 5: July 13, 2013

Friday the 13th, what horrors are in store? The only catastrophe was the fact that the microphones didn't work with the LabQuest II – yet, turns out that the LabQuest II has sampling capabilities well in excess of its predecessor so measuring the speed of sound is possible with the built-in microphone. But more about that later…

The day started with the use of fortune fish as a learning tool – does the way the fish curls in your hand really indicate how passionate you are? No, but it does indicate how moist your palm is – and Monica discovered that the fish are infused with sodium polyacrylate, the same ingredient used in disposable diapers! In this picture Mo uses the fish to determine how the rest of her day will go.



Dat Duthinh, a mechanical engineer, talked about earthquakes and building earthquake-proof buildings. He started by using props he had designed to illustrate concepts such as the motion buildings of different heights experience when an earthquake occurs. Turns out that no matter the height, earthquakes can damage any building if it resonates at the same frequency as the earthquake waves.

Teachers work together to build a wall assembly. If the builder relies upon gravity connections with no actual physical connections then lateral movement of the earth can result in parts of the structure sliding off. In the case of the wall assembly, tightening the connections, providing rotation-resisting connections, and stabilizing with diagonal braces or sheer walls will stabilize the entire building.

Mandy and Francis work together to construct reverse pendulum props…

… while another group of Monica, Kelly, Jessica, and Eric work together towards the same goal on the table.

Martha and physicist Mark Bailey talk while Martha constructs.

The Redskins fans, Martha, Damisha, and Eric. Why today? Because it's Friday!

And then it's back to the lecture and demos with Dat, who illustrates the effect of an earthquake on buildings built on unstable soil – or in this case soft jello! Remember to make the jello with twice as much powder as usual so the jello isn't too soft.

Jessica and Martha want to know more and engage with Dat after the lesson is over.

After lunch John Jendzurski of the Office of Law Enforcement Standards comes by to talk about his work at NIST which has included figuring out a way to calibrate radar detectors. And along the way he designed a circuit to measure the speed of sound which has gradually morphed into today's lesson of using the LabQuest for that purpose. (John's holding a tuning fork because that's what's used to calibrate the radar detectors!)

Alas and alack, Friday the 13th strikes (at least it's not a horror show) and the microphones don't work with the LabQuest II. As an alternative lesson, John demonstrates the activity using the LabQuest I and then goes through the uncertainty calculations involved. Interesting that the largest uncertainty – not the error since we really don't know the true answer – is due to the time, not the distance. Use of the LabQuest II with its increased sampling rate will reduce that component.

Chris shares with John an experiment to measure the speed of sound he and a group of fellow science teachers came up with.

Jessica, Betsy Steel (previous NIST Summer Institute participant and at NIST doing research this summer), and Martha work together on measuring the speed of sound using a tube and the built-in microphone in the LabQuest.

Jerrin and Laurie prepare to measure the speed of sound once they figure out the correct setting on the LabQuest.

Those Horry County teachers (don't pronounce the "H"); gotta love 'em! I just enjoy hearing them talk, and they work together so well and have so much fun, "Oh, Law!" one of them often says.

Those Texas teachers; gotta love 'em! They're the two who so wanted to understand the uncertainty calculation that they had the guts to ask questions – and turns out they were right and John had made a math mistake! Loryn and Mo work together in the relative silence of the hallway.

Dave, Damisha, and Eric work together to figure out the LabQuest – they've got it down – now to get the timing right on the experiment.

Chris shares with the teachers the work he and another group of science teachers did – and put on the web at acoustics.nacase.org. What great resources teachers have to share with each other!

Friday ends in a strange way – with fireworks delayed from the 4th of July due to the big storm and visible from the NIST grounds. Actually, a wonderful way to celebrate a great week of learning and new friendships!