Speaker 1: Welcome to CRR Radio from the Vision 2020 Project.

Ed Comeau: Welcome to CRR radio. My name's Ed Comeau with the Vision 2020 Project. We're going to be talking about using some high tech tools to help visualize how fires spread, whether it's a wild land or a structural fire. And joining us is Matt Hoehler and Matt, could you take a minute and just introduce yourself to our listeners?

Matt Hoehler: Sure. My name is Matt Hoehler. I am a Research Structural Engineer at the National Institute of Standards and Technology.

Ed Comeau: And, I came across a great article called, In the Eye of the Fire, that was written by Jennifer from NIST about the work that you're doing, trying to visualize fire using 360 cameras and other high tech solutions. So maybe you can just start right off by filling us in on what you guys are doing down there at NIST.

Matt Hoehler: So for the past 20 years or so, I've been involved in all kinds of large scale experimental structural research. So investigating how infrastructure, primarily buildings, respond to extreme events. A lot of that time was spent doing large scale earthquake testing and then, looking at terrorist threat. But the last couple of years while I've been at NIST, we've been looking at the response of buildings to large fires. So looking at the ways that real fires interact with buildings and how we can make these buildings better, either through improving the design codes or trying to improve the building codes, which help designers to design buildings to make buildings more fire safe.

We have a a very large indoor burn testing facility at NIST, the National Fire Research Laboratory where we can test multi-bay, multi-story structures under combined fire and structural load. And so, we run these large scale experiments and often these experiments require us to measure things that we've never measured before or are very difficult to measure, because of the environments that we're taking measurements in, and that's the case with the structural fire research. So we spend a lot of time trying to develop new measurement technologies and one of them is these video camera systems that we're talking about today.

Ed Comeau: And tell me a little bit more, how did you even come to be in the first place?

Matt Hoehler: The video systems that we developed were an evolution over time really, and came from a couple of different projects. When we expanded the National Fire Research Laboratory about three or four years ago to include this large test bay. In parallel to that we started looking for new ways to measure quantities of structural relevance and these are usually things like forces and displacements in buildings and that, what we were finding, there wasn't a lot of suitable technologies to do this in fire. And so, we started looking at a spectrum of different measurement technologies which are used in other applications and

trying to see which ones would be most applicable in fire. And we started a couple of different thrust areas. One, doing non-contact laser measurements of structural elements in fire, trying to look how they deform and how they move in fires.

We were also working with fiber optic systems and then, we had one development area where we are just looking to improve our ability to take video in fire. And we're looking at using techniques like digital image correlation and camera systems in a fire. So we had a couple of different projects running, all focused on trying to improve our ability to take measurements and also to quantify the uncertainty, these measurements that we're taking. Because this is important for researchers not only to understand what's happening with the structure, but we also use those measurements during testing and they're safety relevant for us. We need to know how far we can push an experiment and if we're not getting good measurement data, we don't know how far we can push the building and how we should be conducting the test. And so, we had a number of projects going on and really the camera systems that... The 360 camera system that we developed started in some of the work that we were doing on the laser based measurements.

And in those situations, what we were trying to do is use near ultraviolet spectrum lasers. So they're at about 405 nanometer light wavelength to take measurements through a burning room of objects. One of the big problems that you run into is even if you can keep the instrument cool, you have a lot of radiation from a fire up in the infrared spectrum that's very difficult to get rid of and it will, it'll melt your laser optics. And so, we spent a good deal of time trying to find ways to get rid of that infrared radiation. And a guy I was working with, at the time, name of Chris Smith, was I think at the time a postdoc from Stanford and then stayed on at NIST here, had the idea of using a sheet of water in front of the laser systems to absorb the infrared radiation.

So, we started using that on these laser systems. And basically what the water does, just when you go underwater, you know, water looks fluid, absorbs a lot of the red spectrum light and infrared spectrum light, but it passes the, a lot of the visible spectrum, while absorbing the infrared radiation. So by putting a layer of water in front of an instrument that, particularly one that's operating the visible spectrum, you can heat the water, move that heat away either with the heat exchanger or just flushing that water away and you can take measurement through that sheet of water. And so, we were doing that successfully with these laser-based systems back in I think 2016, 2017 so a couple of years ago. And, in parallel to that we were starting to run some larger experiments on the structural side of the lab. And then one of those experiments, I think I just decided, well if the water's working well for the lasers, it would probably work pretty well for our cameras as well. And so, we started using this water as an infrared filter for some simple 2D cameras in some large experiments.

Ed Comeau: And I understand your daughter a had a role in this.

Matt Hoehler: Yeah, so we had been, we had, I think we had done one smaller scale experiment putting a camera, this was just a 2D kind of an action camera, waterproof action camera, into some water. And we had run some smaller compartment fire tests, barely post flashover conditions. And then, we had a large scale set of experiments with cross laminated timber buildings. I think this was 2017 which we were doing at NIST together with the NRC Canada. And in those tests, we used some of these 2D cameras in these water-cooled systems and we put them in the doorway of the compartment fires and got some spectacular footage of how a compartment burned and particularly, how the cross laminated timber compartments interact with the fires and the ventilation conditions. And during those tests I was, you know, I was constantly thinking about how we could improve these video systems.

And one of the day, I think right in the middle of the testing, I was taking my daughter to gymnastics on a Saturday morning and had an hour-and-a-half to kill and was doodling around on paper and realized that we didn't need to be putting 2D cameras in the doorway, we could just move the cameras to a spherical camera or a 360 camera and put it right in the middle of the room. But basically using the same approach that we had started with the lasers and then, we had expanded out to the 2D camera systems. And so, that was kind of the origin of the idea. But at the time, we had a very large project running and I just didn't have the time to build a prototype system. So, we had to wait around for about a year before I finally had the opportunity to try to build one of these things.

Ed Comeau: And I liked the name you guys came up with, BOB. Can you kind of describe what it is that you've created there?

Matt Hoehler: Yeah, so basically, I mean in simple terms, it's a camera in a fish bowl. You have a spherical camera. Basically the spherical cameras, the ones we're using right now are monoscopic cameras. So they're basically two cameras with a 180 degree lens looking in two different directions. And then, you use software. Most of the commercial software does this automatically. Now, we'll stitch those two hemispherical videos together and give you a 360 view. There's also stereoscopic cameras, which have multiple lenses, but we're not working with those at the moment. But anyway, so you've got this camera. They're a fairly small camera and they make waterproof ones as well. And so, what we need to do is we need to, we needed to surround this camera with water and put it in a transparent enclosure. And so what we used is, they make commercially available, you can purchase high temperature glassware out of borosilicate glasses, which are fairly temperature resistant.

We've basically taken one of these systems and created a way of mounting it onto a piping system where we can flow water into this sphere and put the

camera in the middle of it. And as the fire surrounds the camera, it heats the water as the water absorbs the radiation from all sides in all directions, and when the water's heated, we then transport that hot water away through a piping system. And it's, the name BOB came about is, because some of the technicians, I think they were calling it a, calling it the bubble, go get the bubble. You know, we got to put the bubble in the room before we run the test. And I think then one of technicians has a grandchild that liked SpongeBob and pointed out that the bubble looked like the one that SpongeBob puts on his head when he goes up above the sea. He puts on a bubble with water on his head so he can be up on dry land. And so, the name kind of stuck and we just formed an acronym around BOB, then.

Ed Comeau: A Burn Observation Bubble, love it.

Matt Hoehler: Yep. Burn Observation Bubble. And that's really what it is. It's a, you know, it's a way of putting any type of camera really into a fire and allowing you to get some pretty unique views of what's going on inside of a compartment or really the stuff we've been doing recently, I think these systems really, really shine. They really do well when you put them in large open spaces, which is why we wanted to try it out in a wild land fire.

Ed Comeau: And it's pretty dramatic footage that you're getting from this. How is this helping you in terms of analyzing the fire, being able to see it in a 360 configuration?

Matt Hoehler: One reason this is valuable, is just the ability to allow somebody to experience a fire from a perspective that they would otherwise not be able to experience, allows people to understand what we do in fire research and also what, you know, fire protection experts and what firefighters do and the environments that they're working in. So, being able to just put cameras in this environment, there's value of that in that and the fact that you've moved from a 2D view into a 360 view, means that the viewer gets to decide what they want to look at, rather than having whoever's shooting a 2D photograph decide what you're going to be looking at. The viewer can, you know, either on their computer monitor or put on a virtual reality headset or even step into a CAVE environment.

So, a computer automated visualization environment. These are the big rooms where you have screens all around you and you can surround yourself with the fire environment. And really, the individual gets to decide what's important to them when they're viewing the fire. And so, that's one way that the 360 video on its own has been really powerful. It takes the experiment to the viewers perspective rather than the researchers perspective or the person shooting the video.

Ed Comeau: So it sounds like you're developing a real educational tool in addition to creating a research tool.

Matt Hoehler: Correct. So for, in that sense it's a great, I think it's a great educational tool. It's a way to communicate fire science. And also, as a training tool. So that's one reason that we do the work. The other reason is taking that video to the next step and doing data augmentation of that video. So, you've probably heard of virtual reality or augmented reality where you integrate technology with the real world in the case of augmented reality, so you can look out at the real world. One of the issues that we face in fire research is, we'll do a very large experiment and I might spend six months or two years developing a project and you get all into the details of the project and then, you write a report and it may be a very large several hundred page report and it takes a lot of work for somebody else to understand what happened in those experiments.

Because if you want to, let's say you're in a flashover room and you want to know what the ceiling temperature is, you need to look at images of the room and understand where the fuel is and what the room looked like. You then have to look at detailed schematics of where all the sensors are in the room and then, you have to look at the data itself and you have to be able to integrate the images of the room, the sensor locations and the data to understand, okay, I understand that 15 minutes into the fire, the ceiling temperature was a thousand degrees C and this is how it was changing in time. And, that's often something that people who are interested in this particular material just don't have the time to do.

With the 360 video and where we're going with it is, we can then take these videos as well as all the measurements that we take and experiment. And in experiment, we can put them into an augmented reality software where we project the video into a, onto a sphere onto surrounding the viewer. And then, we can take all that sensor data and we can put it onto those videos and just like the viewer can watch the video, they can then interact and say, Oh, I'm interested in knowing what the flow velocities, the gas flow velocities in the doorway are. And they can just simply reach out and touch that sensor and bring up the data stream there. So all of a sudden you don't have to think about where am I in the room? What's that sensor number? And then try to understand the data. You just look somewhere, you know, ask the question and turn on the data or turn off the data. And so, it's a powerful tool for doing data communication about fire research.

Ed Comeau: So what you're talking about is this reality now? Have you done this, or is this what you're planning on doing?

Matt Hoehler: We have successfully data augmented up to this point, we've done one video. It's very time consuming. Right now we're doing it on a commercial gaming engine, a software called Unity. And so, we currently, you can sit down at an

individual computer and throw on a headset and do this, but it's still at its infancy right now. What we're working on is to move that away from an individual experience for one person on the one, you know, PC I have sitting here in my office to a web based platform that we could push this out over a web browser or to somebody who wants to plug in their headset if they have one to a web based platform. And, that's just at it's start right now. We think it's doable but, it's not available yet. So it's still an individual viewing experience on that front with the data right now.

Ed Comeau: What kind of burns have you done using BOB?

Matt Hoehler: The first burn we did was a kitchen fire and it was actually the day after we finished the first prototype and we weren't intending to put it in that fire. This was the end of an experimental program last summer where we were looking at interaction between fires and light gauged metal structural walls. And, as kind of one of the culminating experience experiments, we built up the prototype kitchen that we had been simulating for several months with furnishings and we conducted that fire. And we took BOB, which had just been built up and just put it in the doorway of the fire and shot it. And we got video but it's, you can see it on, we posted that on our website, you can see that we didn't have the video settings dialed in. So when you, when the fire gets to the flashover stage, it's pretty over, overexposed and you don't see the flame structure very well.

And then, we learned pretty quick that we needed to switch some of the materials in the setup itself. We had some felt materials that started burning and it allowed some leakage at one of the seals. And, we started boiling the water inside of the bubble and after about five minutes of boiling, one of our cameras, we decided to pull it out of the fire. The camera was still fine and we had the footage, but after that, we went back and we redesigned those aspects of the camera for, to really be able to sit at a, you know, in a very severe post flashover fire for half an hour or an hour, without having to extract the camera.

So we shot the kitchen fire and then after that about a month or two later, we were doing some work with the Smithsonian Institutes there. They have curators who need to do artifact recovery after a fire event. And we hosted a workshop for them where we set up a mock-up of a museum storage facility and there was a bunch of dummy artifacts in there and we set a fire in the room. And then, we activated the sprinkler system and made a big mess of everything. And then, they sent their curator teams in there. There was about 40 participants that went in and learned how to recover artifacts from a room fire. And so, I think that was, I think that video is out there as well. And so there's, that was the second video we shot and then, we did some other documentation of smaller experiments in the lab before we took the thing out to the wild land fire in March.

Ed Comeau: And talk a little bit about that one. That's very impressive footage.

Matt Hoehler: NIST has a whole group here working on wild and urban interface fires. We do a lot of work here in house as well as sponsoring grants for others that do work in this area. And I was at a presentation, I think it was in the fall around the time we were doing the tests with the Smithsonian of a grantee that was doing some work up in the New Jersey Pine Barons with the U.S. Forest Service and the New Jersey Forest Fire Service doing prescribed burns. And I was looking at those burns and thinking, gosh that is the ideal environment for us to try out this camera system. Because, you could really get a view from horizon to horizon as a fire approaches the camera and passes by you and moves off into the distance. And so, I kind of, I spoke to the presenter after that and said, Hey, next time you guys are doing a prescribed burn with instrumentation, let me know.

And what we had to do to make the system work though, we had to make it portable. Up until that time, we had always been testing in the laboratory where we have an infinite supply of water and power. And so, we had built the system to deploy in the laboratory. So we had to figure out how do we make this Bob camera system self-contained so we can carry it. One person can carry it out into the middle of the woods, set it up, leave the woods and have it then activate and capture the fire. So we had a couple of technical problems to solve to make it portable for the forest fires.

Ed Comeau: Well, it's extremely impressive what you guys are pulling here and, and I think it's a great way to let people visualize the things that you see in the lab all the time, but that people just don't see the inside of a fire right from the start all the way through flashover like you mentioned. So, I think you're just doing a great job of bringing this out there, this kind of research out there for everybody to use. Not only the public but the fire service as well.

Matt Hoehler: Absolutely. You know, those are our stakeholders. It's really the, like you said, the general public and then the fire service. I think not only as you mentioned for education and training, but just to have a chance to experience fire scenarios maybe that they don't deal with every day and you know, just look at them and say, Oh yeah, I can relate to that. Or, that's something I hadn't thought about before. And being able to do that in an immersive environment is, it's pretty neat.

Ed Comeau: Well, we're going to have links to all in the show notes to the videos that Matt's talking about and some additional information about the research that they're doing and about Bob and all the other products coming out of the NIST lab there. So, we've been talking with Matt Hoehler, a Research Structural Engineer from the National Fire Research Lab at NIST and Matt, I really appreciate you taking the time to talk with us today and fill us in on what you're doing there.

Matt Hoehler: Thank you very much.

Ed Comeau: And if you aren't already subscribing to CRR radio, you can do it through your favorite podcast app, whether it's Apple podcast, Stitcher, Overcast, or any other app. Just search for CRR radio, hit the subscribe button and you will get CRR radio automatically downloaded whenever we come out with a new episode, which is about every two weeks. CRR radio is a production of the Vision 2020 Project. It's edited by Rich Palmer and produced by me, Ed Comeau. Thanks for listening and we'll see you next time.

Speaker 1: Thanks for joining us on CRR radio from the Vision 2020 Project. For more information on community risk reduction, please visit us @www.strategicfire.org.