**Advanced Visualization using ViSit**

Alright, Colleen, are we ready to begin right off?

We are. I think we've, Yeah, let's go ahead and go and share your screen. And I will introduce you while you're setting that up since our talks are back to back. So this is Dr. Tom Jenkins. He's actually one of Tech-X's senior research scientists. He's been with the company for nearly 12 years following his doctoral work at Princeton University, and postdoctoral work at the University of Wisconsin Madison. He is a fusion energy scientist whose research focuses include both the theory and the simulation of magnetically confined plasma heating using radio frequency waves, as well as the development of novel particle in cell algorithms for faster kinetic simulation. Dr. Jenkins is also an expert on data visualization using VisIt software. And that is going to be the focus of his talk today. Thank you. Welcome, Tom.

Thank you. As Colleen mentioned, I am going to be talking today about visualization. We're going to use this piece of software called VisIt, we'll explain how that fix, fits into the Vorpal or VSim ecosystem. And show you some of the different features that we can exercise and looking at VSim data that you might generate from whatever applications you're running. Now, my emphasis, as Colleen mentioned, is infusion theory, and specifically RF heating of plasma. So I'll be showing some RF antennas and plasma waves that get excited from those. I hope that what I say will be more generally applicable though I've tried to make it fairly generic as far as the kinds of things you might want to do and visualize. So let's start off this is the kind of work that I produce with this visualization software. This is a experiment that's done at MIT. They have this complicated antenna structure, and then a plasma that sits in this doughnut here. And they're going to launch waves in from the periphery from those antennas that propagate inward to the core of the plasma and heat it. So you can see you get these very complicated wave effects you get, as I click over to the wrong part of the next slide accidentally. So you can see you're starting with this very complicated antenna structure here. And then as you evolve the simulation, this is all done using VSim, then you can get these complex wave structures that propagate and hopefully produce the physics that you want to heat your core plasma and teach you something about what's going on in the experiment.

And this is all done with the VisIt software, VisIt is something you've actually seen already that you might not have known that specifically. VisIt is this free visualization software tool that's developed by Lawrence Livermore National Laboratory. They have it on their website here, https://visit.llnl.gov. They've actually I think, moved to a GitHub repo in the past couple of months, but this will redirect you just fine. And when we do VSim, we've essentially taken VisIt and we've packaged it underneath so that this window that you see here is actually a VisIt window. And we have controls over here that we've customized for users of VSim that do the common operations that you might want to do. But it's also possible in this window to access other features of the VisIt software that we maybe don't have an easy one click button over here for and I will show you how that's done. Let's see. I suppose I can live demo this too. But we're gonna be doing a live demo of a number of other things. So I'll just explain how it's done. If you go into your preferences box on VSim. Yeah, I'm on a Mac, but on Windows, it's basically the same kind of thing that there's the tools and settings menu and on the Mac, there's a Preferences window. And then there's this different settings. And there are these different settings you can adjust. There's one for visualization options and if you come in and click this box here called the Enable VisIt context menu. That will basically turn on all of the extra features of the VisIt software over and above the ones that we've included as defaults and is easy buttons that you might want to click analyze your data. So then you have to click Apply because when you make a change, you have to apply the change, then we click OK. And I want to call a quick attention to this warning here, what we're going to do is essentially to from within VSim, we're also going to open a window that will control VisIt. And the two pieces of software both want to be able to do things. And so if we close one window, then it will close the other one by default, because it's because they're linked together in that way so, that's just a thing to be aware of. If you are going to do, if you're going to run VisIt from within VSim, then you need to make sure to keep all of your windows open.

So having done that, if you then come into your VSim window, and you right click on it right here in the plot, there will be these extra options, one of them will be open GUI and that is actually the GUI for the VisIt software. So if I click on that, it will pop me up the window the launches VisIt. And then I can control the plot from both the simple controls in VSim composer and from the more complex controls in the VisIt window. And I feel like I should probably show you this because it's, well I think at this point, I will open the VisIt window itself and show that to you. This is the main VisIt window. And if I go over into composer which I have put somewhere, okay. And I should go in and visualize this data, and then show you how this looks. So I'll just put up a plot of a potential in this particular example that I've run. And if I right click on the window, then I can get the option to open the VisIt GUI. I've got it open already. So what I'll do is I'll close it, then I will reopen it again from within composer. And it will said it will wait for a GUI to launch on my host machine. And I am not certain why that's taking as long as it is,

You know we sometimes have this problem on some of the newer Mac installations. But I'm understand, I understand that a fix has been put in this week for dealing with that. In the interest of the talk, I'm going to just cancel this out. And we will assume that it worked and popped us up a VisIt window that

looks like this. And then we have a window which controls, we have a control window and then we have a plot window.

For the rest of this talk because I don't want to be hopping back and forth between competing competing windows, I'm just going to use the VisIt interface directly. You know, close these out. One of the things that we've worked really hard on in VSim is to make our data accessible to VisIt so that even if you run VisIt separately, you will be able to look at any data that VSim generates and use all the VisIt features to examine it. So I'm going to come back to my PowerPoint here and see if I've left anything out.

Now I basically talked about that. Now let me just show you the kinds of things that VisIt can do.

Ranging from very basic to very complicated and we'll kind of come up the learning curve in a hurry. I mentioned before that my work is in antenna modeling, and I have a particular model of an antenna on the ITER experiment which is being built in France that I will show you. If I can find it; Okay. All right. So this is the VisIt window that lets you open files, and there's a couple things I want to call attention to here. One of them is that VisIt knows how to open lots and lots and lots of kinds of files can do ADIOS files. We can do Chombo. We can, Basically, we have this whole list of various things from various science projects all around the country that people have wanted to use this for. And so the VisIt team has built interfaces to achieve those particular formats, at Tech-X, we use a particular format called Vischema, or Vs is the abbreviation in the list. And VisIt should auto detect that if you're looking at data that's generated by VSim, but you can put it specifically to look for files of that type if you like. Now, the thing I want to call out is that after a VSim run, there's lots of different data files that appear in your directory and VisIt will group them. Now you can see here that I've got, let me give you a good physics example. I have a sheath potential that sits on the surface of the antenna. And I have that measured at each time step. And so at every dump file, I have a particular data set. VisIt will group these together so that if I want to open all of the sheath potential data at once, and then watch it as a movie, I can just click on the database collection and say open that collection. And then I can look at all those files sequentially. Not going to do that just yet. Right now what I want to show you is the geometry of my simulation. And I got to find where that lives. Okay, lives in a file called ITER Antenna. So I will open that up. So this is now open, I haven't made any plots with it yet. But you can see that it will be the default source that we look to to make plots from. And there are different kinds of plots that I can add, some of them make sense for this data. And some of them don't, the form of this data is basically a bunch of ones or zeros that say, is there metal in this place? Or is there vacuum in this place? So wouldn't necessarily make sense to make a histogram of that or anything like that. But what I'll do for now is I'll make a contour plot, I want to look at the nodes of the simulation grid and say, is there metal at that node or is there vacuum at that node. So I will choose this file, you choose the data set. And it's turned green, which means that it's set up to draw but it hasn't drawn it yet. And if I click the draw button, then

my antenna appears. And there's some funny things about this now this is, uh,

showing me carefully 10 different contours of my antenna, which in a data set with only ones or zeros doesn't make a whole lot of sense. So I can change the number of contours. going to click on the contour window here. And there's a number of different controls, you can change the color of the contours, you contain how many there are, I'm going to change it so that there's only one and I can hit Apply. There is our one contour that marks the difference between vacuum and metal. Since it is metal, I can make it look like metal. Just change the color. And then I can zoom in and I can look at the different geometric features of this antenna structure, and it's still a little bit weird. There's going to be an inside and an outside. And if I'm over here, I can clearly see that this is the outside and that there's these solid bits of metal over here. I come back to the coax. I want it to look like a coax, and it's not entirely clear. This is probably inside and this is probably outside but I'm not seeing that right away. So there's another kind of plot we can make here, which is a volume plot. I'll turn that around again. And I can add that volume plot right on top of this contour plot that we have. So come down to volume plot, choose the same variable and I will click draw. Immediately everything goes wrong. Because the default settings for the volume plot are not necessarily what you want. But I can come down here and explore those. And what we want is essentially to look at the transfer function. This is basically how the different volume, uh, how the different numbers in the data set are mapped on to the visualization. I'm going to reverse this. Now we've put the solid metal in the solid metal part instead of in the vacuum. And I'm going to chop off some of this top color. And I'm going to change the color map to a gray scale so that it also looks like metal. And if you then come back over here and look down my coax, you can see that I filled in all the middle bits, and I've left all the vacuum bits alone. So that's a little bit easier of a way to visualize this antenna structure that we've got. And if I turn off my contour plot, still is not looking so great. So I can make some more adjustments down here. And some of this is a bit of an art form as to what makes it look good. Seems like I should probably put more material in here, when it starts to fill in and match the contours that we saw in the contour plots. And I'm just gonna let this go for now and have that be good enough, I'll turn this back on, can see that it's basically doing the right thing. So that's my geometry. I am now going to do physics with that. And let's think about what we might want to see there, I'm going to first clear off some of these plot legends because I know the geometry is there. And I don't want to look at it. And there's a setting in here for so the legend, unclick that and in this contour plot, same story, and unclick the legend box. And then this legend up here will go away. What I want to look at is going to be currents and fields and particles and such that interact with this antenna. And that's going to be hard to do if I have this antenna structure sitting in front. So what I can do is put a clip operator on this antenna structure, there's different kinds of operators that you can apply to data sets, there's dozens of them. Some of them are more useful than others in certain contexts. But

now I can know one of the ones that we use in VSim is the fast Fourier transform, that you can move from time space to frequency space, or from position space to wave number space. Or you can scale things, you can convert from centimeters to inches, or you can project 3d things down into 2d. There are lots of different things you can do. But the thing that I will do right now is the clip operator. Come in here and choose clip. And then I have to redraw my picture, and it went away. Because the default clip settings are not necessarily what I want either. What I do want here, I'm going to take a slice that goes through the plane kind of like this, which is the XZ plane. So I will choose the Y, the plane two is the xz plane because y is the ignored coordinate. I'm going to move the origin over to 0.2 where it sits in my box right here. And I'm going to change the normal direction so that it orients the surface in a way that points the metallic structure away from me. If I were to change the sign of the normal then

that puts it in the foreground, but I want it in the background. So now I have half an antenna sitting here and I can look at the physics that goes on inside the antenna cavity as well as outside. I can look at the physics coming down the coaxial cable at the back, etc.

Now it may be that I want to look at the fields in this hole region and not just in this half space that I've cut out and VisIt will let you choose whether you want to, this clip operator I applied, VisIt will let you choose whether you want that to apply to all the plots or to just some of them, I'm going to uncheck the box here. And that means that if I put in some physical quantity like an electric field that will appear in the whole domain, instead of just the half that I've cut out to show the geometry. Let's look at some physics now. I'm going to open a new data file that has the electric field; so go to open, going to click the electric field on the nodes. No, actually no. Okay. And then I will make another contour plot of the field in the x direction, which is in this direction that comes outward from the antenna. I'll click draw. And there's nothing there because this is the beginning of the simulation. But if I run the movie, you may have noticed I opened the entire data set of electric fields. And so I can advance that forward in time. And I can see different electric field structures forming in the antenna, these are kind of jumping all over the place from one amplitude to another. And there's lots of contours and it's kind of tough to keep track of what's going on there. So I'm going to go in and fiddle with that. Let's just choose two contours, negative 1.0 ten to the 4 (-1.0e4), and 1.0 ten to the 4 (1.0e4). Apply. And then those contours sit at some fixed value. And if I go back and watch the movie again, I can see what the electric fields are at those particular values. You can see the fields in the coax and then the field being driven in front of the antenna but behind the strap. And if I were to run this longer than you would see fields being driven out in this vacuum region as well.

There are different variables I can look at, I looked at the x component of the vector but VisIt lets me very conveniently change quickly to look at other components, you can look at easy. And I'm going to set my contour levels a little differently to show you the wave that I get. So I'll just drop them down by a power of 10 (1.0e3). All right, it's a little more noisy in there, but can see that as I start to send power through my coax that I get these wave of structures that form red and green here. And those will eventually make it out and into the main body of the plasma as well. I don't think I've run this particular discharge long enough for it to do that, since it's just a demonstration. But then you can see if I turn it that I put that clip operator on the antenna so some of this is hiding in the geometry but you can also see what's happening on the near side with waves filling the cavity that the the antenna is, that constitutes the antenna. VisIt lets me add very nearly as many plots as I want on top of this window. I can also look at what is the density of the plasma out here that I'm propagating my wave into. So I'm going to open up that file, what is that called, density, Okay. Now in this particular case, I know that the density does not change. This is not a self consistently, evolving density that I've got. So I'm going to turn off my file grouping here and then it just shows me all the files individually so that instead of Opening a data set that contains all of the density files, and they're all kind of, they're all the same. I can just choose one of them. And the list is now very long, a little bit of a chore here, but so I'll choose the initial electron density. Another plot that you can make is called pseudo color, I'm going to do that. And this is basically an entire brick of three dimensional data. And it's going to have the predictable result that if I make that plot, it covers over everything that we've got. But just like with the other with the antenna, I can apply clip operators or other kinds of operators to make this a more useful plot. I'm going to put a clip operator on again here. And I will open it up, choose plane two, as we did, change the normal as we did, and here, we'll put the origin point three nine and send it to the back of the domain that we're visualizing. We'll draw it. then you can see how I've got this nice density gradient. But as I move away from the antenna, the density rises up from zero, I guess zero further back up into the 10 to the 17th range. Higher densities that I expect in front of a fusion antenna. There are different annotations that you can make on this plot, I have these big XYZ labels sitting on there. And if I'm going to send this plot off to a journal, I don't necessarily want that. If I go under my plot controls. There's this notation menu, where I can adjust various things like that. I can get rid of my username in here. Or I can change the font size for these or I can remove the bounding box or things like that. I'm going to just take the bounding box away and the axes away. And then I've got this plot that's got nothing but physics on it hopefully.

So there's different controls you can adjust, in order to make your plot look, the way you want. VisIt is very good at that; if there's a thing you can envision VisIt can probably do it.

Of course, none of this is very useful if you can't save and print and regenerate the plot as you would hope to do. If you were going to run this antenna discharge with lots of different density profiles, and then compare the wave patterns that you get in one and the other. Then you want to have some kind of reproducible workflow. And the way that, VisIt also gives you a way to do that. If I like this plot that I've got, I can go into file -> save window and then it will save it as a PNG file. There are different Save Settings, I can choose different file formats and different places that I can, that I would want to save those files and not going to get into the details there. But along with saving the window I'm also able to save the entire session, which is to say if my VisIt window suddenly crashes right now I've got to go back and I've got to redo all this stuff again with the contour plot and with the volume plot and with the electric field and such. But what I can do is to save this entire VisIt session, so we'll say Save Session. And then I'm going to give it another name because I've already got a couple of these. So VisIt002 dot session. And then we'll do the thing you never do during a live demo which is to close it up. We'll opn it up again and we'll open that session file and we'll hopefully get back everything that we had. Go into file, we're going into restore session, we'll click on 002, like we had, and everything comes back. So, okay, looking at my notes here, so we can get things back, and that's great. But how did we get here in the first place? Could I reproduce all these steps to produce this exact plot? Probably not, I could get it mostly looking like that. I might get one or two the details wrong. To what I'll do now is to show you the way to record your commands that you're issuing to VisIt and to make them reproducible and able to be transferred over between different runs that you might do with the same geometry and things like that. Gonna go into the command window up here. Control, sorry, the controls window. And then there is a command window.

And this has all kinds of information in it, I think, because I restored the session, I didn't expect that usually these are blank, they look like this, then what I can do is, if I'm changing something about a particular plot, I can hit record,

then I make a change, maybe I zoom in a little bit, and I change the angle. Then I'll come in here and hit stop. And it will tell me all of the VisIt commands that I issued in order to change it from where I was to where I am now, a lot of these are very detailed and technical. And they may not make a lot of sense. But there's a new view normal basically the orientation of my viewing plan, a new place that the center of the window is focused on things of that sort. These are all documented in the VisIt documentation on the website, visit.llnl.gov. And so I can zoom in, I can change my plot angle, so on and so forth. And if I go back over to my first window where all this data was generated, you can see the kinds of things that I did to get this plot in the first place, I opened up a database with my antenna file, I added a contour plot. I fiddled around with the contours. Told it how many contours there were going to be and so on. And then I drew the plots. Now what I can do with all this, now this is just a set of commands right now. But if I can copy it all, I can then paste it into a Python script, I can come over here and get this other thing that I did with the zooming in and they reorienting of the view and I can copy that and I can append it to the end of the Python script. And then I can use VisIt to execute the Python script to produce this file and to save it to a file if I want. Or I can use loops and I can produce many plots like this with my different values for electric field and you can watch the movie of the field propagating through the antenna out into the plasma and such. I'm going to go back to my PowerPoint now wherever that's got to.

And I, you can see here I've got yeah, start my slide show and you can see here I've just given an overview in these slides of the things that I did to get to the command window and the kinds of things that you can do there. This is what we just did, we hit record, we do all the plot changes that we want, we hit stop, and then we get all these commands, we can copy, we can can re-execute those commands, if we want to, we can clear things off and start over. If we don't like the way it looked, we can create a macro, which says do all those things we did and make it a callable function so that even if I shut down VisIt and start again, I can call that function that says turn this thing and zoom in, that may or may not be quite as useful as you need it to, but it's very customizable. So it can, you can do a lot with it. And as I mentioned, you can bundle all those commands into a Python script, and then just invoke it from a terminal line or something, you call the VisIt app and run the script dash s, and the name of whatever script you did, I have, Sorry, I haven't done this on a Windows machine. But I imagine it's kind of the same thing where you invoke some VisIt executable, and you point it at the script you want it to look at. And it's even possible to if you know what your script is doing, and you have it saving your images somewhere, it's even possible to do with, do this without the window at all. And just run it in the background while you're doing other stuff that you want to do. A couple of years back, I gave a talk at TWSS that went into much more detail on this process. I have sample scripts in that talk that talk about the different Python commands and how they work and how to do loops and how to make file exports and such. I can make that talk available to you as well. And I've also got it on my website right now. But I'll put that in the notes for this talk in the notes from this year's TWSS.

Another thing that VisIt is able to do, which I'm not going to demonstrate, but I'll just comment on briefly. You can run VisIt on remote machines. The movie that I started at the beginning of this talk was generated on a very large grid had 1.2 billion cells. And it's not the kind of thing that fits on my laptop in any meaningful sense. And so if I'm going to do visualization on that data, I need some powerful cluster or set up to do the rendering. Turns out that VisIt if you have the same version of VisIt on your laptop that exists on whatever remote local supercomputer cluster you've got, you can get the VisIt on your laptop to talk to that version of VisIt; can have the cluster do all of the rendering for you and then put the images to your screen and save them to your computer. Which is very convenient, because now all the computational firepower lives off somewhere else, and you just get the good visualization results. Have them accessible to you on your local machine. There's a bit of a learning curve to get the machines configured right but the main thing is if you have the same version of VisIt on the cluster that you're computing on, and on the laptop that you're visualizing on, then you should be able to get it to work. And this website visitusers.org has a bunch of useful hints for when things aren't working and how to get the configuration set up properly. That's a very powerful capability, And if you have access to a cluster that is doing your computation, you can make use of that to make good visualizations even with your local desktop or laptop machine.

So why am I talking about VisIt. Yes, the main point I want to bring out here is that we've built the VSim Composer on top of VisIt in some sense that everything that you generate with your VSim runs can be looked at with VisIt. If you want to do some complicated visualization that the VSim composer tool doesn't permit, you still can and this is how to do it. And there's been a very conscientious effort to make sure that that data that we generate in VSim is accessible to VisIt. And you can move Very complicated things with Python scripting, you can build new expressions. I didn't talk about that in this talk. But you can. For instance, if I have electric field data and magnetic field data, I can take my electric field and I can project it onto the magnetic field and pick off the parallel component of the field. There are ways to set up new meshes within VisIt, that read both the electric field data that lives in one grid and the magnetic data that lives on another grid. And then to merge those into a expression that makes use of both data set. Basically, any neat visualization you can envision is probably possible in VisIt. And it makes your program managers happy to see these kinds of pretty pictures that they can go show to their boss and say, Look, at the neat stuff these guys are doing. Um a lot of science, in my experience, now you can be as technical as you want. But if you got a pretty picture to back it up and convincing movie to show then it gets people's attention in a way that words on a page just doesn't do. And you know, VisIt is free. It's kind of steep to come up the learning curve for, but you know having your data within VSim formatted in a way that VisIt can read will be very helpful along that, in that process. And there's also lots of documentation on the web telling you how to make use of it, troubleshooting and such. So I guess at this point, I'd be happy to take any questions on VisIt or VSim and its interaction with VisIt or whatever you think of my movies, or anything else you'd like to ask. Thank you, if

you have any questions for Tom, you can type them in the q&a box on the bottom of your screen, and we will answer them. So I do have a couple. The first question is, what are some good resources for people who would like to learn more about VisIt?

Okay, this website visit.users.org that I've got linked here is one. And then I'll go back to the beginning of my talk.

If you go to visit.llnl.gov, that will redirect you to the GitHub page where you can both download the software, you can link to various user forums to email Q&A lists. All kinds of resources are made available there. And their goal there is to just make it easy for people to get into the boat and start working.

Do you do you have any experience with how VisIt works with very large data sets? I mean, what is your, has been your experience with that?

Yes, so for these, the movie that I showed here, as I mentioned, this is 1.2 billion cells. And I've got a couple of hundred images in this movie, I can render a movie with one point, from a grid that large, I can render a single frame of that movie within a minute or two on a 32 core computing cluster. So it's able to handle very, very large data sets and to do pretty well with them overall. I generated all the frames for this movie within I think a day and a half. Okay, I got a couple in the chat here.

Is there a calculator in VisIt for post processing the data like an integration of field along the line?

I believe that can be done I have not done it myself. But I know there are streamline operator, you can like trace a vector field. And, that is a good question actually, I have, I have not done that specifically. But I know that their operate, like you can build different expressions within VisIt that will let you for instance, integrate data along the line or sample data along a particular trajectory. So I'll give a tentative Yes. But if he asked me to do it in a live demo, I would have to go look at the wiki

Any other questions before we take a brief break and let Tom get out of here? So if anyone would like, Oh, we have another one?

Yeah, can I? Can I export figures to different file formats? For publications? Yes, there's lots of formats you can export to. And there's a there's a whole settings menu for what kind of files, you want to export file types, file resolutions, and so on and so forth. It's very, it's meant to be very accessible that way. Now, coming out of a DOE lab, they're conscientious about the fact that people want to publish their work and make figures that are publishable.

Sure, sure. So while we're waiting to see if there's any last questions, if you would like to request an evaluation of the latest version of any of our software products, you can go to the Tech-X website at txcorp.com. And there's a request evaluation button at the upper right part of the screen. And we will get you a 30 day evaluation of the latest versions and that works for all of our products, not just VSim, we can do that for you. Well I think we are finished now, with you, Tom.

Thank you. Yeah,

Thank you so much. Our next talk coming up in about 15 minutes, it will be our final presentation of this series. And that's actually going to be from Dr. Dave Alexander, as well as Dr. John Cary, the CEO of Tech-X, and it's going to be talking about some really exciting things that we have coming very soon about cloud resources for VSim.