NWX-NASA-JPL AUDIO CORE (US)

Moderator: David Prosper
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David Prosper: Okay, thank you. So, hello everyone. This is David Prosper from the NASA Night Sky Network, as you heard, here at the Astronomical Society of the Pacific in San Francisco, California. I'm excited to present this really awesome teleconference with our guest speakers, Dr. Olivier Guyon and his two colleagues Josh Walawender and Mike Butterfield.

They've been hard at work on the Panoptic Astronomical Networked Optical Observatory for Transiting Exoplanets Survey, or as we'll call it from here on out, PANOPTES.

David Prosper: So hopefully your clubs are about to receive if not have already received updates for your educational toolkits for Planet Quest and for Shadows and Silhouettes. We also threw in a few extra goodies in there, so keep your eyes peels at your mailboxes.

So if this is your first teleconference with us, double welcome. Just follow along with the slides and there will be time for a brief Q&A at the end of the talk. And stick around for a minute after the presentation and Q&A, and we'll

be giving away a copy of the Cambridge Photographic Atlas of the Moon, from Cambridge University Press. And it's very pretty, and very awesome.

Now it's my great pleasure to introduce our speakers, Dr. Olivier Guyon, Josh Walawender and Mike Butterfield from PANOPTES. The goal of this, of Project PANOPTES is to build a network of low cost, reliable robotic cameras, which are - will be used to detect transiting exoplanets.

They are aiming to bring this in sort of an open source, open hardware sort of approach, and allow both amateurs and professionals to participate in the search for exoplanets. So PANOPTES team, if you would like to take it from here, I'm sure we all are very excited to hear what you have to say.

Olivier Guyon: Thank you very much, David, for the introduction. This is Olivier Guyon. I'm going to start giving the presentation, and then hand it over to Josh and Mike. We're all very excited for this opportunity that you are providing us to talk to amateur astronomers, for the simple reason that our main audience for this - or main goals for this project is to involve amateur astronomers, citizen scientists and also schools into the very exciting field of exoplanet discovery.

So without further ado, I'll - let's move to Slide 2, on the Project PANOPTES overview and goals. I think we already went over this in the introduction. Our goal is to have a worldwide network of small cameras that monitor a large fraction of the sky from multiple locations, to detect exoplanet transit.

And unlike previous projects that are doing this already, our goal is to have this project very much driven and run by amateur astronomers and citizen scientists, and also schools. So there is both a scientific and an outreach component to this project that merge together very nicely, as we'll explain.

The PANOPTES project is not meant to be very rigidly stuck to a single science goal, and it very much empowers amateur astronomers and citizen scientists, and also schools to explore other things once the network is built. So you are in the driving seat, you being the community of amateur astronomers, and the community at large, to come up with new ideas and new projects and test them.

So this is also a, we think, exciting scientific adventure that empowers the public to actually do science projects, come up with their own science projects. Slide 3. Just a visual reminder of a primary goal, which is to go after exoplanet transit, we're looking for the occurrence, as shown in this picture, where the planet passes in front of the star.

So this is a picture that some of us took for the Venus - transit of Venus in June last year. We're not going to see it like that if it's an exoplanet passing in front of the star. We're just going to see a small dip in the brightness of the star, and that's what we're after measuring.

To keep numbers in mind, a Jupiter size planet passing in front of the sun-like star will dim it by approximately 1%. So getting 1% level photometry, the ability to measure the brightness of stars to about 1% is a minimum requirement to start measuring and detecting exoplanets.

Slide 4. When we're thinking about a survey, a whole sky or nearly whole sky survey of this type, we need to monitor a very large number of stars, with good sensitivity. And the metric, the number that tells us how well we're doing is what we call etendue. It's basically the product of our total collecting area multiplied by field of view.

And so there's a simple equation here that we wrote. You can write it as the number of units we have multiplied by the collecting area for each unit, each camera for example, multiplied by the field of view of each camera. And the name of the game here is to maximize the etendue.

And PANOPTES uses a very low cost available technology to do that very efficiently. So we use DSLR cameras with wide field - actually intermediate field lenses. So our baseline is to use an 85 millimeter F1.4 lens. And as Josh will describe, when describing the baseline, that brings us at an etendue of about 2/10 of a square degree square meter per $1000 in hardware.

So this is - the hardware is not very expensive, but it's actually getting quite a bit of field of view and sensitivity. And if we compare this, on Slide 5, with other major astronomical projects - and here we have a list of the LSST, which is an 8.4 meter diameter telescope currently under construction with a 3-1/2 degree field of view, we find that actually we're very efficient, in terms of covering a large fraction of the sky with this sensitivity.

And this basically illustrates that most of the very heavy spending in astronomy is going after very high sensitivity over much smaller field of views than what amateur astronomers can do with reasonably cheap hardware. And so amateur astronomers have a very unique role that they can play for this particular science in monitoring efficiently, large parts of the sky.

So if we compare the cost per etendue between PANOPTES and LSST, we find out that we're actually 340 times more efficient than a project like LSST. Of course, for most scientific investigations, LSST is much better than PANOPTES, but for monitoring a very large number of stars, the type of hardware that we're advocating for is actually very high performance.

And there's another comparison with amateur astronomy hardware, which is intermediate field of view, so if you're a Celestron 14 with a Hyperstar wide field corrector and a 27 millimeter CCD, and a dome, would be actually better than LSST at monitoring a large piece of - field of view, but still about 20 times less efficient than PANOPTES. So we're really gearing toward the low cost but very wide field of view monitoring of the sky, which is not properly covered by current - other astronomical projects.

Slide 6. So what we really want to do is establish a network, a distributed network of such DSLR-based units, that are run by amateur astronomers, not only because it makes sense on the outreach and public involvement point of view, but as I showed in the previous slide, because it really makes sense, scientifically.

And having lots of small units is a very efficient way to carry out this type of survey. Geographical coverage is also very good, both to mitigate weather, to have continuity in time, but also to cover a large fraction of the sky. And so we really think that for this particular very ambitious type of all sky survey for exoplanet discovery, amateur astronomers are well positioned to play a key role.

And we also hope to involve citizen scientists and schools into joining this network and actively participating in it. So the challenges we have to solve, what keeps us busy is how to build such a network, and how to solve - how to make it easy for people to actually build such units and join them in the network.

Slide 7. Our approach to this survey is to have the whole project essentially driven and pushed forward by the community, by amateur astronomers and

motivated citizen scientists. We've no boundaries as to who can participate. So everything is open source, open hardware.

We are structuring the project from the start in a way that facilitates contribution by anyone. And this is very much driven by the public, and there is no such thing as a rigid boundary for membership. Anyone can participate. So our goal is to really make it easy for anyone to jump in.

Slide 8 gives us a little bit of history behind the project. We started in 2010. A few of us, as I'm sure many of you, were doing astrophotography with DSLRs, and started to notice that those cameras are a very interesting tradeoff between cost and performance. And we did some more analysis of the - quantitative analysis of the cameras, and found that they are potentially suitable for exoplanet transit.

In December, 2010, we actually deployed the first prototype, one robotic unit with one camera, at the Mauna Loa Observatory in Hawaii, and we started robotic operation a couple of months later, of that unit. Since then, that unit has been upgraded a couple of times, and it is now consisting of four cameras on the same mount.

We're trying different lenses. We tried also to remove the infrared filter versus keeping the camera untouched. And so we're basically, over the last 2-1/2 years, 3 years, we've basically been exploring the technical feasibility of such a network with this prototype.

And what we are doing right now, which Josh will talk about, is we are working on establishing what we call our baseline, which is an assembly instruction set of how to build a unit that is reliable yet low cost and high

performance, as easily as possible. And this is something that we need to do to facilitate involvement by public and schools and amateur astronomers.

Slide 9 shows our very first, first prototype, which was deployed in late 2010 on Mauna Loa. And what you can see is on the left there's a large wide (bile), for weather protection. Inside it there is a mount, and a camera attached at the end of the mount.

The white tape that you can see is weather sealing, so that when it rains on the system, the electronics don't get wet. And the camera is pointing down in this picture, because it's in sort of safe mode position, the position it assumes during daytime or during bad weather.

You can see there is no dome, and this is a choice we made to simplify the system and to reduce cost, and we'll talk a little bit more about that. And on the right, you can see our electronics. This is the very first prototype, so the electronics is a little bit messy, put together from things that we had lying around in our garage, essentially, and additional things we bought for the system, but not really having yet in mind something that's very standardized and clean and easy to duplicate.

Slide 10 shows an image, an example, a single frame of a few minute exposure with no processing, taken by this unit. And the first thing we see is that the image quality is actually pretty good. There are a lot of stars in this single image.

If you go to Slide 11, this is a zoom of the lower left corner of the full field image, and you can see that even in the corner of the field of view, the image quality is quite good, and in a single image, there are about 100,000 stars. So this type of setup is extremely efficient at monitoring a large number of stars.

Next slide, Slide 12, this is a bit of a quiz. When you build something that robotically measures the sky with a wide field of view, there are a lot of things you pick up that are somewhat surprising. One of them is shown in this (practical) image.

You can see two roughly vertical lines which are satellites, and you can see this diagonal line with the haze surrounding it, which actually is a meteorite that deposited a trail of iron - of sorry, sodium atoms in the atmosphere, that are then dragged by the wind and blow in this image. So this image is actually a difference between two consecutive frames.

The reason we show this is to also illustrate that there's a lot of projects that you can think of, once you build a robotic network of cameras like that, that you could run. You could photo a comet. You could try to process the images in a different way to do statistics on micrometeorite, anything you can think of.

Slide 13 shows another image. This time we actually co-added several frames with this first prototype, and you can see that the other thing that this type of hardware is very good at doing is pretty images, which we think is quite important also, for outreach. And because the detector is color, we don't have to do any fancy processing. The images come out already quite nice, right out of the camera.

And if you go to the next slide, Slide 14, we zoom in to one part of the image, showing that there are a lot of features in this image. We can see a globular cluster, a lot of dust (planes), so this is a field right next to Antares, in Scorpios.

Slide 15, if we think about what we've learned with this first prototype, and there's a picture of it here just after a snow storm, the first thing we learn is that we actually demonstrated that you can run a robotic DSLR system without a dome, and it's quite reliable and durable.

So this system ran for over two years until we upgraded it, and it survived quite well several storms. And the hardware never really - the camera never failed. It's actually still running. That camera is part of our Prototype Number 3, and we're still using the same mount.

What we - we learned a lot of things that we needed to improve also. Sealing cables is quite important. We had a couple of issues with that. Planning for a long power outage is something we hadn't done, and so this basically builds up a list of things we need to keep in mind so that the final baseline is taking advantage of all those lessons we've learned.

The next slide, Slide 16 goes into really what is at the core of the feasibility of this network, is can we do photometry, can we measure the brightness of stars with DSLR cameras, at least at the percent level. And so we actually developed software to do that, to demonstrate that we could do that.

The challenge is that the - and if you want to monitor a large number of stars, you don't want to defocus the image, and so from - and the PSF, the image of the star is going to be very small, maybe a few pixels, one to four pixels. As this image moves across different pixels, you get very large modulations in flux in - if you just count how many counts you have on, what the value of the pixel is.

So you have about 20% modulation from one frame to the next, just because the image of the star moves between pixels, which themselves have different

core sensitivity. So the next slide shows a demonstration of this, that we performed this on a star that's approximately 9 to 9-1/2.

So this is a - so Slide 17 shows the full frame image. There is a little green circle showing where the star that we used for this test is. If we zoom in, next slide, Slide 18, we can see that star starting to appear in a portion of the previous image.

And if we zoom in even more, so Slide 19, we can actually see that the star is small, the image of the star is only a few pixels, and we can start to see the individual pixels popping up, and we can start to see that they have different sensitivity, depending on their color. So one pixel out of four in this image is sensitive to blue, one pixel out of four to red, and half of the pixels are sensitive to green. And we can see that in that image.

So the next slide, Slide 20, shows a sequence of images looking - zooming in on that star. And it's moving across pixels, so it - the morphology of the image changes, but more importantly, Slide 21 shows that if we just measure how much total light we gather in those pixels, and we show this as a function of frame number, each frame being approximately one minute, we can see huge variations at the sort of 20% level.

So what this tells us is just measuring the total amount of light in the pixel will not work very well. So we developed an algorithm, which is described on Slide 32. The first thing we noticed is that there are a lot of stars in this image. So whatever happens to that star, for which we want to do the photometry, the same combination of things must happen to at least another star in the image.

So the first thing we do is we look for other stars which experience the same defect, and we look for stars that, for which the morphology of the image on

all the frames is the same. And then we use the combination of those stars as a reference against which we compare our target.

And this, two images shown on Slide 22, show that this actually works very well at figuring out the interaction between the image and the pixels. The image on the left is an actual image of our target. The image on the right is what we reconstructed from the reference stars, what we get that at that image should be if we removed it from the data set. And we can see that the two images look very similar.

So that reconstruction is working quite well. And when - Slide 23 shows that when we apply this algorithm on the same data set, we suddenly get into a very interesting regime where we have, on the time scale, which we integrate over the duration of a transit, with a single camera we are at or below 1% photometry level.

And here you can see the sequence of images. For each of them we measure the flux. And the distribution of flux is at the - depending on the color is around 2% to 3%. If you combine the three colors together, it's better than 2%. And that's just in one minute. So we have reached a sensitivity that demonstrates that we can calibrate quite well pixel effects, and also reach a sensitivity where we can actually look for transits around other stars.

So the Slide 24 shows the Prototype Number 2. We went - we changed two things. The first one is we went to a sturdier mount. So now we're actually mounting on a metal frame instead of the wooden panel on the side of the building. And we actually put two cameras in the system.

We wanted to test if we should - if we would gain a lot by removing the infrared blocking filter inside the camera. And what we found is that it doesn't

make a huge difference. So for the baseline, at least, we don't advise - we will not advise people to take apart their camera and remove the filter. The camera as you buy it is perfectly good for this type of work.

The next slide, Slide 25 shows our prototype, our third prototype. This is the one that is currently running. If you go on our Web site, and you click on Mauna Loa - on Units, Mauna Loa System, you would actually find live image of the Web cams that are monitoring this unit, and you will find the 100th image that was taken the night previous, the previous night, so as a sample image of what this unit acquires.

And the goal here was to compare our original choice of lens, which is a $2000 lens, very high-end Canon lens, F1.2, with a much cheaper alternative, which is a F1.4 85-millimeter lens, manual, and which costs significantly less, actually less than $300. The conclusion is that the cheaper lens is actually quite good, and almost as good as the much more expensive lens, and that's the one that we're going to adopt for the baseline, to keep the cost small.

And we also demonstrated that as an extension to the baseline, it is quite feasible to have four cameras on the same mount. So the type of mounts we're using, which is a typical amateur astronomy, between $1000 and $2000 mount, is well capable of supporting four cameras.

Next slide, Slide 26, shows that what we started doing, also, is improving the electronics, streamlining it, using more standard components, to move in the direction of establishing a baseline, something that's more reliable, easy to duplicate by others. And Josh will talk more about this ongoing effort.

Slide 27 shows an example image with the lens for the baseline, which is an 85 millimeter F1.4 lens. And on the top left, you can see a full frame image,

and there is a small box which shows the area that is zoomed on the rest of the slide. So the big image is actually a zoom on the lower left of the full frame.

And you can see that the image quality is actually quite outstanding, even on the lens that costs less than $300. So I will now hand the presentation over to Josh, who is going to talk about the baseline unit.

Josh Walawender: Thanks Ollie. As Ollie said, I want to talk a little bit about the baseline unit, which is where we're going, now that we've tested things out with the prototypes. But before I get into that, I just want to point out a couple of things.

One, all of the prototypes that Ollie has talked about so far have basically been his work on the weekends. This is, you know, a hobbyist building this on the weekends. This wasn't some big funded project by the NSF. This is really amateur science. And after seeing how well they performed, we think that there is real potential here, which is why we're building this PANOPTES project, and why we're trying to recruit more people to build units like this.

So in order to make that happen, we're going to build this baseline unit. And the idea of the baseline is, it's a new design using everything we've learned from the prototypes, and it'll be one which we will be documenting on the Web site, and it'll be sort of a common point of reference for all the future evolutions.

So different people can take it and evolve it and change this, or use a different mount, or try different cameras and lenses, whatever they might want to do, but the baseline is sort of that common point of reference. And so what I want to describe is how we see this project moving forward from today. Because basically we've got this prototype up, and now we want to build this baseline.

So we're hoping, over the next, you know, few months, to build the first baseline unit and document it, and put that on the Web page. And so what happens after that? How do we build this community? So that's the Phase 1, which I talk about on Slide 28.

If you look at Slide 29, Phase 2 is really once that baseline is done and described, what we're hoping to do is recruit a sort of core group of users - mostly professional and amateur astronomers is what we expect, to basically build their own versions of the baseline unit and, you know, try it out, basically figure out, you know, what did we do wrong, how can we improve this, and basically get a community discussion going about the baseline unit and how it works and how it should evolve.

And, you know, so these users are, you know, what we consider expert users, people who come in with at least a little bit of knowledge about astronomy, mounts, astrophotography, whatever it might be. Once we have that sort of core group of expert users, we then move on to Phase 3, which is on the next slide, where we begin to actively recruit a much, much larger pool of users.

And we're very interested in getting schools involved, because we think that building a unit, you know, a PANOPTES unit, makes for a very interesting and very exciting project for high school and middle school schools and students, because it involves a little bit of programming, if they want to try and modify things.

It involves electronics, things that are involved in, you know, robotics, which is a big thing, at least here in Hawaii. We're seeing a lot of schools doing robotics projects. And so - but one of the key things that we're going to run into is if we've got a lot of schools, and we're not expecting the students and

the teachers to necessarily come in with as much knowledge about astronomy and astrophotography as some of the amateur or professional astronomers that we recruited in Phase 2.

If it's just me and Ollie and, you know, half a dozen other people in sort of our core PANOPTES group, we're not going to be able to keep up with peoples' questions, with requests for help. And that's why we want that sort of core group from Phase 2, and basically this becomes the user community, where everybody's helping one another to build this, and especially helping out new users, people who are coming to this who have an interest but maybe not as much experience.

And so that's really going to be, you know, where PANOPTES succeeds or fails, is do we successfully build this user community. Because if we do that, then it'll take off and gain its own momentum, whereas, again if, you know, it's just the three or four of us trying to answer all the questions, it's going to be really tough. So we're really interested in getting, you know, a bunch of core users, and that's where you guys come in.

If we look at the next slide, what makes the baseline different than some of the prototypes that Ollie described? And so, you know, our goals in building this baseline unit really come down to how simple can we make this. And I've worked on other robotic telescopes in the past, and a good sort of core principle to embrace is keep it simple. Simple systems tend to be very reliable. They have fewer things to break, less thing to go wrong.

The other thing is, is that simple systems are easier for other people to build and understand and improve upon, which is core to how we want PANOPTES to evolve. And every time I give a talk about hardware for robotic systems, I

have to throw in this quote, because I think it really is a good guideline for how people should look at the design of systems like this.

And it's "Perfection is finally attained not when there is no longer anything to add, but when there is no longer anything to take away." So again, keep it simple, and that will be much more reliable. So we go to the next slide, one of the things we're doing is in the prototype, we use some custom digital input-output and analog input-output boards to handle sensing the weather, sensing limits, which is for the mount, things like that.

Well what we want to do is not get tied in to particular external boards. And so what we want to do is use Arduino prototyping platform. And for those of you who are not familiar, I put this quote that I pulled off the Arduino Web page. And what it says is, "Arduino is an open-source electronics prototyping platform based upon flexible, easy-to-use hardware and software."

And here's the key. "It's intended for artists, designers, hobbyists and anyone interested in creating interactive objects or environments." So the key is, you don't have to be a programmer or an electrical engineer to use this. And so as an example of that, on the next slide, this is actually a diagram that was put together by an undergraduate student who worked with me for a few weeks this past summer.

And this student was visiting Hawaii and working at our planetarium, but she wanted to do a small project working with one of the observatories. And so she only had a few weeks, and she got interested in PANOPTES, and so we decided that what she should do is basically write the code for this Arduino board to read a whole bunch of sensors that would basically, together add up to being a weather station.

And she came in with zero experience in electronics and very little experience in programming, and in about 2-1/2 weeks was able to assemble the circuit that you see here, this is her diagram, and then write the code that ran this. And this code, if you look carefully at this diagram, one of those LEDs was basically giving you a safe or unsafe signal that said either, you know, it's raining, or it's very humid, or it's very, you know, or it's very cloudy.

And it would tell you whether or not it was safe to operate your telescope. And all this happened within that little Arduino board which is, again, fits in the palm of your hand. So this is something that should be fairly easy for most people to just do a little bit of, you know, background research, and then they can get their hands on it and actually start making changes and improvements.

So if we look at the next slide, one of the features that we're going to try and add to the baseline unit is something we've debated a lot, but one of the difficult things with robotic telescopes is safety. You don't want the telescope physically crashing into things. And so if you look at really high-end telescope mounts, I mean, a Paramount or an Astro-Physics, they have limit switches built into the mount, or homing switches built into the mount.

But because we're trying to make PANOPTES accessible, and at a cost where, you know, schools and individuals can build it, we don't want to have a $10,000 mount be the basis for our design. So what we're going to try and do is get that same feature, but without actually modifying the mount. You don't have to build, you know, custom mounting brackets to put limit switches and home switches on the mount.

So what we're going to do is use an accelerometer. And what this idea is, at its root is that, you know, you look at a smart phone, and a smart phone knows

how it's oriented. It knows which way is up and down. So why shouldn't your telescope?

So we're hoping that by putting one of these accelerometers, or technically we can use another device called an IMU, an inertial measurement unit, in the, you know, box that holds the camera, and you read that information from that accelerometer with the Arduino board, it'll tell you what the orientation is.

Now, it's not as accurate as, you know, the encoders on the mount, but what it means is that you can never get truly lost with the mount. You can always figure out which way you're pointing. And so by using this, we're hoping to avoid using limit switches, home switches or absolute encoders, which are either very expensive or require you to physically go in and modify the mount to get them.

So this is something we're testing out. We're not 100% sure it works yet, but we think it will, and I'm kind of excited to see how this does. If we go to the next slide, I just wanted to give you this quick overview of what we sort of envision the baseline unit being.

We're going to take all the electronics, the computers, the power supplies, and just store them in a weatherproof box. And in this case, I think we're just going to use a commercial Pelican case. Some of you may be familiar with that. And once you build this case, basically you've just got power going in, and then a few cables going out to the mount and cameras. And all of the sort of complicated stuff is stored within this case.

Then you connect those up to your mount. And then on top of the mount - I don't have a picture of this, but we're going to build a similar case that just

holds the cameras and whatever little electronics needs to be in and around the cameras to trigger their shutters and what not.

So basically you end up with a modular system. You have three things. You've got your camera box, your electronics box and your mount. And that's an entire PANOPTES unit in these three modules. And so again, we're trying to keep this relatively simple. Once you sort of have each of these three modules built, it's really simple to understand what's going on with each of them.

So that's what we're hoping to do with the baseline unit. We're hoping to have that done sometime within the next three to four months. We'll see, you know, how well that does with that estimate. It always seems to take a little bit longer than we expect, but certainly early next year to have our baseline unit published.

And so with that, I'm going to hand it over for just a few minutes to Mike to talk a little bit about software.

Mike Butterfield: Thanks Josh. Well Josh talked about the hardware that we're going to use to construct the baseline unit. I'm going to chat briefly about the software that's going to control the system, and going to ultimately process the data that we take from all the participants' units. Now before I get too far, I should tell you that there are no slides for this part of the discussion, so stay on Slide 34 or go on to Slide 36.

We're going to build software that will robotically control the PANOPTES units. This has already been tested on the baseline unit, but we're going to expand the software and modularize it so that we accept additional data - or

sorry, additional hardware that hasn't already been incorporated. We want to be flexible and allow people to change the software.

Our plan is to ultimately create an open source control system that's going to be accessible to anyone who wants to participate in the PANOPTES project. The systems - the software itself is going to be relatively simple. It's going to do the minimum necessary to control the mount, accept a schedule, take data, manage the data, monitor the weather and protect the mount, provide a basic user interface so that participants can control the telescope, and then report the results.

Olivier talked a little bit about the algorithm that we're going to use to process the data for a single image. That brings us into a nice discussion of how much data we're going to actually capture. We're going to capture lots of images, almost 300 gigabytes of data per month for a two-unit - for a two-camera PANOPTES unit.

That's a lot of data. It's too much to be sent over the Internet easily, so we have to plan to retrieve the data every couple of months by exchanging hard drives. Processing that data's going to be a real challenge, and we're going to have to look at cloud computing type concepts, maybe a SETI-at-home style distributed data processing technique, and there's going to be a lot of opportunity for people to get involved in the data processing side.

Since this is ultimately an outreach program, we're looking at ways for people to participate and to help expand both the software for the unit and the data processing software. The baseline unit software is going to be open source and made available on GitHub or something similar, so that anyone who wants to participate can easily download, use and modify and improve the software.

And with that, I'm going to go ahead and turn the conversation back over to Olivier.

Olivier Guyon: Thank you Mike. And so we're now on the last slide, Slide 36. I think the most important, hopefully for many of you, is how do I participate to this project? Reminding everyone that participation is wide open to all, and we encourage participation at any level.

There are many ways you can participate. You can write code, help us figure out how to build the baseline, build a unit, process data, improve the hardware, start a new type of hardware. You can - if you have a telescope that's quite capable you can actually follow up interesting targets that we're going to find with those small cameras. You can also provide data storage.

So there's many ways you can participate. What I encourage you to do is to email us at info@projectpanoptes.org. If you want to join, drop us an email. We'll include you in the Google group that we have, and you'll see the trail of emails that is going back and forth, mostly on the baseline right now.

And another way you can help, of course, is to help us advertise the project, and make it widely known among the amateur astronomy community. Thank you very much.

David Prosper: Thank you very much, PANOPTES team. This is awesome. I'm sure there's going to be many questions out here from our very excellent clubs. Let's open up the lines to our listeners for Q&A. Operator?

Coordinator: If you'd like to ask a question, dial star 1 and record your name at the prompt.

Woman: While the questions are lining up, I want to jump in with a question. I wondered if you have any goals for the kinds of latitude distribution that you want with where these robotic telescopes will be placed. Do you have any particular goals there?

Olivier Guyon: So this is Olivier. We - this is really up to who joins the project. I think that the primary goals are to have as many members as possible, preferably distributed in longitude, I think more importantly than latitude, so that we can get 24-hour coverage of a field in the sky, which is quite useful for exoplanet transit discovery.

And then there's a whole question of the quality of the site. One thing that we are actively planning for is to accommodate groups that may not live in a place where they have access to a very dark sky, and link them with other groups that do have access to dark skies, so that we can enable, if groups wish to do so, that a group that builds a unit can deploy it at another location which is more favorable.

Woman: Well, I want the clubs who are calling in to have a chance to ask questions too.

Coordinator: Our first question comes from Patrick O'Brien. Your line is open.

Patrick O'Brien: Well thank you, sir. Good presentation, PANOPTES team. And my question is, I'm from - I'm Patrick O'Brien, and I'm a member of the Darien O'Brien Astronomy Club in Colorado, Lakewood Colorado. And my question is, when do you hope that Phase 3 will become activated, next school year or in the following school years? Because this school year has already begun.

Josh Walawender: I guess I'll take that. So I think, for us, like I said, early next year we want to have Phase 1 completed. And then we want to start Phase 2 which, while we're not necessarily restricting who gets involved, our expectation is that it will be mostly people who come in with a little bit of pre-knowledge.

Now, we expect that to be professional astronomers and amateur astronomers who have already received several expressions of interest. But that doesn't preclude a school from getting involved at that point, but there will be a little bit more of a learning curve on those first set of units that are built.

And how long before Phase 3? Well there's not an exact transition, but once we've got sort of that first generation of users who have experience and have built their own. And it's hard to judge how long that will take, but maybe by that following, say fall semester. But like I said, it's sort of a gray transition between Phase 2 and 3, I'd say.

Patrick O'Brien: Well hopefully you're correct. Good presentation, and good luck.

Josh Walawender: Thank you.

Coordinator: Our next question comes from (Stewart Myers). Your line is open.

(Stewart Myers): Well hello. I was wondering about how is this going to be coordinated? In other words, you know, who's going to decide what - who's going to look at what area of the sky?

Olivier Guyon: So this is Olivier. The policy for us is not to enforce any rules as to who should look at what. The primary driver for looking at a field in the sky is the interest of the group who actually built the unit. What we will advise, initially,

is that most units focus on a few areas of the sky, so that on those areas of the sky we do have as close as possible to 24-hour coverage with good sensitivity.

So what we will do is take probably three to four, maybe three to five fields, which are along the Milky Way where there are a lot of stars, and we will advise members to point their units at those field, so that when we put together data from a moderate number of units, let's say 10 to 20 units, we can have a quasi-continuous coverage on a few fields. And that's the way that, initially, we're going to start to get exoplanet discoveries.

As more units get built, we can then have more flexibility. We can have a larger number of high priority fields, eventually hopefully covering most of the Milky Way. And then if we think about a very large number of units, we can then extend away from the Milky Way to cover a larger fraction of the sky.

(Stewart Myers): What I was thinking, was concerned about was that they - you know, was afraid you'd get a situation where, say, half the members of the project are looking at the same part of the sky, leaving huge swaths uncovered.

Olivier Guyon: Yes, and I think we will be in that situation at the beginning, because we will not have enough units to cover the whole sky or even a significant fraction of the sky. And for exoplanet transit discovery, it pays off to have very continuous monitoring. So I think, until we have enough units to cover a large area of the sky, we will advise members to focus on a few areas.

And in our prototype unit, this is actually what we've done so far. We've identified four fields which are our high priority transit testing fields, and the camera, the system basically points at those fields almost exclusively.

(Stewart Myers): Oh, okay. That pretty much answers it. And I think you've already answered a question about the initial level of sensitivity that you'd be - that this thing is configured currently to find Jupiter and larger sized exoplanets.

Olivier Guyon: That's right. We've demonstrated that with one camera we have the sensitivity to detect Jupiters. And so we - averaging the signal from a few cameras, we can detect giant planets. And then taking it from there, having a larger number of units allows us to gain sensitivity by averaging signals between units, and go down in planet size, hopefully to, down to Neptune type planets.

(Stewart Myers): Oh, that's good. Well, I wish you luck with the project.

Olivier Guyon: Thank you.

Coordinator: Our next question comes from Joseph Martinez. Your line is open.

Joseph Martinez: Hello PANOPTES team. I'd like to thank you for this introduction to this project. I basically have two quick questions. We work with a lot of high schools here in New York City. I'm a member of the Amateur Astronomers Association of New York. And a lot of the schools that we work with tend to have robotics teams and astronomy clubs that we're trying to combine them together to develop things like this.

When would you foresee something, let's say, like the source code for the weather monitoring unit becoming available so that they could begin testing creation of an Arduino unit, which they're already familiar with creating Arduino units and programming, so this would be, you know, a stepping stone challenge for them to get involved in this project when it does hit Phase 3.

Josh Walawender: So this is Josh. I'll take that one. As far as the source code for the weather station, the only hurdle to that being publicly available is me taking a few minutes to put it on the Web page. If you go to our Web page, there is a section on the development of the weather station. There's a few, you know, blog entries on that. I need to put in the final stages, essentially the final report that this student wrote up for us.

But yes, it's just a matter of me getting organized and putting it on the Web page. That piece of it is ready. Now the rest of the Arduino code to handle the accelerometers, the - we're going to use an Arduino to actually trigger the cameras, the little TTL-level signals that trip the shutters on the cameras. That has yet to be written, and we're hoping to do that, like I said, over the next few months.

Joseph Martinez: Fantastic. And just one last question, with regards to the camera's protection, I know in the images we saw the camera within its safety mode, what protection are you using on the camera? Is it just like a skin or...

Josh Walawender: I guess I'll take that as well. So we've tried, I think, three different ways of protecting the cameras now, sort of those three prototype units that Ollie described, and they have all three been broadly successful. So what I first heard about this project, I thought the aspect of there being no dome, no enclosure, was going to be the most challenging part of it, and what we've learned from the prototypes is it's not as bad as we thought it would be.

What we're planning to do for the baseline is basically buy a commercial weather-proof box that you would put, you know, electronics in, that sort of thing. Mount all the cameras in that and basically just cut two holes in it, one for each lens to look out. And the lenses themselves, in our current design, are not protected. They're just open.

But when you park the system looking down, it tends to be good enough, even with blowing snow, rain - we get, you know, plenty of fog at our test site. So shockingly, they're pretty robust, and we don't have to go to extreme lengths to keep them protected.

Joseph Martinez: Great. Thank you once again.

Coordinator: Our next question comes from Alan Rossiter. Your line is open.

Alan Rossiter: Hello there, just a couple of very quick questions. How many - have you started recruiting people for your Phase 2 at this point? That was the first question, and the second one is, is this Webcast actually being recorded so I can pass it on to other people who might be interested?

David Prosper: So I can answer the Part 2 already, this is Dave. It is being recorded, and we'll have the transcript available, along with both audio and the actual text, in the next few days.

Alan Rossiter: Okay, so you'll email us with links for that or something?

David Prosper: I'll post an internal article up with links and everything. And also there'll be links in the e-newsletter, too. And...

Alan Rossiter: Thank you.

David Prosper: Yes, okay.

Josh Walawender: Ollie, do you want to take the first part of that?

Olivier Guyon: Can you repeat the question? I didn't catch the audio very well.

Alan Rossiter: So, yes. I was just asking, for Phase 2 of this project, have you started recruiting amateur astronomers to join in with you? Or are you just in Phase 1 at this point, in terms of personnel?

Olivier Guyon: We're mostly in Phase 1, but thinking seriously about Phase 2. So what we've done is basically two things. We've talked about this project whenever we had an occasion, and so we've gathered a few very motivated persons along the way. We've also started to talk to sites - the people, mostly professional astronomers who have very good sites and could host our next sort of generation of baselines.

So we want a few baseline units to be built fairly soon, and we want to deploy them, so we can start actually discovering exoplanets. And we've talked to a few observatories, and the response we get is generally quite enthusiastic, as long as we can make the baseline robust enough that the observatory staff doesn't have to actually work for it or maintain it.

And so that's what we have to do for the baseline, we have to make sure that things are reliable enough that we can install them at a few professional observatories with very good sites, and that they will run autonomously without us having to get people at the observatory to work for us.

Josh Walawender: And as far as, you know, signups for people interested in Phase 2, as you can probably tell, this isn't this very rigidly defined project. So if you're interested in being part of that Phase 2 or know someone who is, send us an email and welcome to the team.

Alan Rossiter: Thanks, okay.

David Prosper: And we have time for one more question, then we'll wrap up.

Coordinator: Our last question comes from David Furry. Your line is open.

David Furry: Hi. I also thank you very much for an excellent presentation. I have a question that may not be possible to answer, but back on Slide 4 you talked about the costs. And I wonder if you could clarify that a little bit. You said a few thousand dollars for a unit. And I realize you're still in a prototype phase, so I wonder if you could come up with a ballpark figure on what this would cost.

Olivier Guyon: Maybe Josh, you can take that one.

Josh Walawender: All right, yes, I mean, when we say a few thousand dollars, we're probably looking at $3000 to $4000 would be a good guess. The mount we're looking at right now is about $1500. We're considering some others. And that is the most expensive single piece.

I mean a, you know, typical, you know, Canon Rebel camera might be $600, the lens is $300, and then all of the, you know, computers, the boxes, the electronics, you know, those are relatively small individual items that might add up to $1000 to $2000. So you're looking at somewhere around $3500, $4000, give or take a little bit.

Mike Butterfield: And of course, all this is hardware, and it'd be volunteer time.

Josh Walawender: Right, yes. So labor not included.

David Furry: All right, thank you.

David Prosper: Okay. That's all the time we have for this evening. Dr. Guyon and the rest of the PANOPTES team, thank you so much for your time and excellent presentation. But before we sign off, there's one last thing. We have a drawing for a copy of the Cambridge Photographic Atlas of the Moon. Operator, can you let us know how to call in for this? We'll take the lucky seventh caller.

David Prosper: Now while we wait for our lucky winner, I'd just like to take the time to thank the Cambridge University Press and the Astronomical Society of the Pacific for donating this fine book tonight, and to thank everyone else, also, for joining us for this really awesome presentation. This could be potentially really great. I might even want to do it, though I'll have to make some time out and convince my girlfriend that I don't need to sleep.

Coordinator: And our seventh caller was (Roger Macklin) with the Orion Astronomy Club.

David Prosper: Awesome. Congratulations (Roger), that's great. And that's all for tonight. You can find this telecon along with many others on the Night Sky Network under the Astronomy Activities link. If you want to find this particular one as it updates over the next few days before we send out the notice, just search for PANOPTES, and for any other telecons you can just search for telecons.

Tonight's presentation with the full audio and written transcript will be posted by the end of this week. Good night everyone, and keep looking up.

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