Slide 2: Welcome to the first of our three-part series on visual satellite observing. Today's webinar will cover the fundamentals of visual observing. Whether you're a regular user of STK or someone new to the topic of satellite tracking, I think you'll find today's webinar both interesting and informative. The goal of today's webinar is to show you how easy it is to visually observe satellites and my hope is that this will not only stimulate your curiosity, but that you will share what you learn with your friends and particularly your kids.

We've got a lot to cover so we should get started. Before we do, though, I want to point out that no special equipment is required for what we'll discuss today. It's not necessary to have a telescope or even binoculars to see any of the objects we'll discuss, so all you need are the tools to be able to predict when and where to look. And we'll provide you all the tools to do this—with or without STK—although those of you with access to STK will find the visual aspects of the STK-based tools will give you a much better grasp of the subject.

And, to best see what we're presenting, I'd encourage you to go to full-screen mode now.

Slide 3: So, let's get started. Today's webinar will start by discussing the fundamental constraints of visual satellite observing, paying particular attention to the satellite-observer geometry. We'll then discuss the visual magnitude scale, to give you an idea of what you can expect to see and how bright it might be. Then, the majority of the webinar will focus on a recent pass that I observed of the International Space Station—or ISS—and the tools I developed to be able to predict when it is visible.

Slide 4: [Pause] The basic constraints for visual observing are actually quite straightforward. The fundamental requirement is simply that the satellite must be brighter than the sky background. Typically, that means that the satellite must be in direct sunlight—not in the Earth's shadow. It also means that the observer must be in darkness.

There are actually several ways to define darkness for the observer, but I've found the best way to define it is to say that we want to observe after civil twilight. As defined by the US Naval Observatory, this is the period when the Sun is more than 6 degrees below the horizon. This is about the point when the brightest stars begin to appear visible. The time between sunrise/sunset and the end of civil twilight varies throughout the year, so you'll want to be sure to use this value rather than a simple time after sunset {Question: Why?}

Of course, the satellite must also be above the observer's horizon to be visible. In most locations, a simple plane can be used to define the horizon, but for those of you in mountainous locations—such as here in Colorado—STK's ability to use terrain can provide some extra capability, as we'll discuss later.

Finally, there are a number of satellite-observer considerations we must take into account in determining how easy it might be to see a particular satellite. Those include the size and/or distance of the satellite from the observer, the attitude of the satellite relative to the line of sight, the albedo—or intrinsic brightness—of the

satellite, and the sun-satellite-observer angle—or phase angle—at the time of observation. Let's take a look at each of these factors to develop a better understanding of how they affect the apparent brightness of a satellite.

Slide 5: [Pause] First, let's look at size and distance. [Build] If we have two satellites of different sizes at the same distance from the observer, the larger satellite—all other factors being equal—will appear brighter. Similarly, if we have two satellites of the same size but at different distances, the closer satellite will appear brighter. Calculation of the satellite-observer distance—or range—is straightforward.

[Build] Next, let's look at the attitude of the satellite relative to the observer. Many objects—such as rocket bodies, which are often large and easy to see—have long cylindrical shapes which are easier to see when viewed from the side but more difficult to see when viewed end-on. If the satellite is in a stable attitude—which typically only happens with operational satellites—the attitude relative to the line of sight will change slowly throughout the pass. If the satellite is tumbling—which is common with rocket bodies—the satellite's brightness may appear to vary more quickly and may even seem to flash. Unfortunately, it is usually difficult to determine the attitude of most satellites, other than some of the operational ones.

[Build] Our next panel shows the difference resulting from differences in a satellite's albedo—or its intrinsic brightness. For two satellites under the same observing conditions, the one which best reflects the Sun's light will appear the brightest. This factor really isn't due to the satellite-observer geometry, but by taking the geometry into consideration, it is possible to infer the albedo of the satellite.

[Build] Finally, we need to consider the satellite's phase angle relative to the observer. This is the angle—centered on the satellite—between the vector to the observer and the vector to the Sun. Just like with the phases of the Moon, when the phase angle is near zero, the phase is full and the satellite will appear brightest—all other factors being equal. At a quarter phase—as seen on the right side of the panel—less of the satellite is illuminated and those portions which are illuminated have larger reflection angles, which also reduce the brightness.

Slide 6: [Pause] Let's look at phase angle geometrically using STK. This figure shows the phase angles for two geostationary satellites relative to a hypothetical observer at the intersection of the equator and prime meridian. The green vector at each satellite points to the observer and the yellow vector points towards the Sun. You should note that the phase angle for different satellites is different at the same time. What is not quite so obvious here, is that the phase angle will also change for each satellite over time, as both the satellite moves in its orbit and the Earth rotates.

The best way to see this is using a tool which is relatively new to the STK family—AGI Viewer. AGI Viewer is a free product which allows anyone with a Windows computer to view an STK scenario. Just like with Adobe Acrobat, where the authoring software requires a license but the Adobe Reader is free, STK can

produce AGI Viewer files—also known as VDFs—which can then be viewed by anyone with the AGI Viewer software. You can find the free AGI Viewer on the AGI web site.

I have created a solar phase angle scenario in STK—which is how I generated this screen shot—and saved it as an AGI Viewer file that you can download and view after this webinar. Not only can you watch how the phase angles of the two satellites vary over the course of a full day, but AGI Viewer also allows you to animate forward or backward, pause the animation, and zoom or pan the view for a more complete understanding of the scenario. And, a nice plus is that the VDF is typically smaller than a single screen shot like the one we're looking at. In this case, the JPEG screen shot is 157 kB and the VDF is only 83 kB. I highly encourage you to check out this capability, as we will use it to illustrate other concepts in this series.

Slide 7: [Pause] Now, let's talk about the visual magnitude scale. As it turns out, this scale is a logarithmic scale, and is defined such that a positive difference of five magnitudes corresponds to an increased brightness of a factor of 100. So, for a difference of a single magnitude, the brightness changes by a factor of just over 2.5. This scale is based on the initial observations by the ancient Greeks, who measured the brightest stars as magnitude 1 and the dimmest visible to the naked eye as magnitude 6. A few exceptions, such as Sirius—the brightest star in our skies—are actually brighter. Sirius has a magnitude of -1.1. So, you should note that not only are smaller magnitudes brighter, but that they can also be negative. Venus—the brightest object in the sky, apart from the Sun and Moon—can reach a maximum brightness of -4.5—23 times brighter than Sirius. The Sun and Moon are obviously much brighter.

Of course, we're interested in satellites, many of which are visible at magnitudes of 5 or brighter. So, we'll have plenty of satellites to work with. But the easiest satellite to work with today is the ISS, due to its large size and low orbit.

Slide 8: [Pause] As can be seen from this picture—taken as the US space shuttle was leaving the ISS on September 17, after installing the P3/P4 truss segment with its large solar arrays, [Build] as seen on the left side of the picture—the ISS is huge. These new solar arrays are 73 meters or 240 feet end-to-end. A similar set of solar arrays will be installed on the other side of the ISS during STS 116, scheduled to launch next month. These changes have dramatically increased the brightness of the ISS, as I've seen on some recent passes—to the point where it is easily brighter than Sirius. So let's talk about how you can predict when to see the ISS yourself.

Slide 9: [Pause] I'd like to use a pass I observed last month as an example of what to expect, since I know from my own observations that they matched the predictions generated by STK quite nicely. This example will serve to introduce the basics of what can happen during any satellite pass, including not only rise and set of the satellite above the observer's horizon, but seeing the satellite disappear into the Earth's shadow.

Let's look at the basic geometry of this pass. I observed this pass from my front yard in Colorado Springs on the evening of October 18. My location is marked in

green and [Build] the circle around my location is the zero-degree horizon for an object at the altitude of the ISS—338 km or 210 mi. Basically, anything within this 2,100-km radius circle at the altitude of the ISS would be above the horizon at my location.

The ISS is positioned in this screen shot just as it rises above the horizon at 1925 local time. [Build] The blue circle around the ISS is the horizon, as seen from the ISS. That is, the portion within this circle is the portion of the Earth visible from the ISS at the time shown. As expected, Colorado Springs is on the edge of this circle as the ISS rises above the horizon.

[Build] The yellow-orange line which transects the Earth vertically is the Sun terminator, the point where the center of the Sun is on the observer's horizon. Basically, anyone to the left of this line can see the Sun and anyone to the right cannot. We'll see the significance of this portion of the geometry in just a bit.

[Build] The yellow line which goes from the lower left to the upper right across the Earth is the path of the ISS, starting at 1915 local time. As we'll see more clearly in just a minute, the orbit is color-coded to show whether the ISS is in sunlight or Earth shadow, with the yellow portion showing when it is in direct sunlight.

Slide 10: [Pause] We're going to switch our vantage point to observe this pass from the northwest, to have a better view of the three-dimensional aspects of what's happening. Here we again see the ISS as it rises above the horizon in Colorado Springs.

Slide 11: [Pause] Just over five minutes later, we see the ISS begin to rapidly fade as it begins to move into the Earth's shadow. Here we see the ISS as it enters the penumbra—the point when the Sun begins to slip below the horizon as seen from the ISS.

[Build] In fact, we can also see this by looking at the ISS horizon and the terminator on the Earth's surface. When these two curves are just touching, the center of the Sun is on the horizon as seen from the ISS. If you were at this point on the Earth's surface, you would be on a straight line between the ISS and the Sun. We show the portion of the ISS orbit as it passes through the penumbra, in gray.

[Build] In another 10 seconds, the ISS passes into the umbra and the Sun is completely below the horizon as seen from the ISS. We can no longer see the ISS from the ground and the orbit is now shown in black.

Slide 12: [Pause] The ISS doesn't actually set—or go below the horizon as seen from Colorado Springs—for almost another five minutes—as seen in this view. At this point, the ISS is on the horizon as seen from Colorado Springs and Colorado Springs is on the horizon as seen from the ISS.

Slide 13: [Pause] Now, let's take a moment to see how to build a scenario to predict ISS passes in STK. It's actually pretty straightforward, at least for a single satellite.

[Build] First, we want to create a scenario with our location—in this case Colorado Springs—and the satellite we want to observe—the ISS. Be sure to set your time horizon—through the Scenario properties—to look far enough ahead to see at least one observing period.

[Build] Then, we want to set the basic constraints for the observer to ensure that we only get passes where the Sun is 6 degrees or more below the horizon. Just open the properties for the observer, go to the Constraints section, [Build] and select the Sun constraints. Then, [Build] check the Max Sun Elevation Angle checkbox and set the value to -6 degrees. This will prevent us from getting any passes when the Sun is above this value. Be sure to save your changes.

[Build] Next, go into the properties for the satellite of interest and, again, go to the [Build] Sun Constraints tab. Here, all we need to do is set the [Build] Lighting for the satellite to Direct Sun. Now, save your changes and generate an access report from the observer to the satellite.

The basic process is fairly simple, especially for a single satellite, but with multiple satellites it can become increasingly easier to forget one or more of these steps. There should be an easier way—and there is. Let's look at a couple of them.

Slide 14: [Pause] I want to cover two ways to do this, so that nobody is left without a way to predict passes. First, we'll look at a very popular web site which is designed to make this process pretty easy—Heavens Above. I've provided the URL here for your reference. We'll take a quick look at what's available there and then describe a tool which will allow you to harvest the information found there to input directly into Microsoft Outlook, if you use that program to maintain your calendar. Then, we'll do the same thing with STK to show you how easy it can be to automate this type of task and integrate with other Windows applications.

Slide 15: [Pause] Once you've established an account on Heavens Above and set your default observing location, you'll see a main page that looks like this.

[Build] For today's presentation, we're particularly interested in the area that shows predictions for visible satellites. It includes individual predictions for some of the brighter satellites—such as the ISS, Genesis-1, Envisat, and the Hubble Space Telescope—as well as a whole host of satellites as dim as magnitude 4.5. If we click on the link for predictions for all satellites brighter than magnitude 3.5…

Slide 16: [Pause] …we get a screen that looks like this one, showing the basic time and observer conditions along with all of the visible passes for your location. You can easily print out this schedule for use at the appropriate time. However, if you find that you often get busy and might forget when to go look, you'll find this next application quite useful, particularly if you have a PDA that you sync with your calendar. In fact, I use it quite regularly to remind me when to go outside and look.

Last night, I almost missed the second pass listed here while working on this webinar since I forgot to sync my PDA. The application we're about to see will help us avoid this problem and will be provided with the rest of the materials for this webinar after we're done.

[Build] The Visual Satellite Scheduler is designed to allow you to automatically query Heavens Above, using your previously established and configured account, to find all the passes which meet the basic considerations you set for visual passes. You can decide whether you [Build] want to look for only morning or evening passes, [Build] set a minimum brightness, and [Build] look for passes which only get to a certain culmination or maximum elevation. Then, [Build] you tell the program how many days ahead to look and [Build] how much of a reminder you want in Outlook. [Build] Be sure you have your Heavens Above username and password entered and Outlook open and then click the Generate Schedule button. That's all there is to it! You can save all of your settings so that all you have to do the next time is open Outlook and click Generate Schedule when you run this application.

[Build] Once you're done, you'll see appointments for each satellite pass in Outlook that look like this. [Build] The subject field shows the satellite name and NORAD Catalog Number. [Build] The location field shows the maximum elevation and time of maximum elevation, along with the maximum brightness for the pass—which may not necessarily occur at maximum elevation. [Build] The note field has all the details on rise, set, and maximum elevation found in the Heavens Above report.

[Build] Just be careful when you start not to relax the conditions too much or you'll end up with a lot of reminders. For the passes brighter than magnitude 4.5 last evening, there were 17 visible passes culminating above 25 degrees. That's a lot of appointment reminders! Still, it's a great way to set up for an evening of visual satellite observing.

Slide 17: [Pause] Now let's look at how to do the same thing in STK. Let's start by building a basic application with your location. Don't worry about setting anything else right now, unless you want to add terrain to your scenario. Save your basic scenario in a folder and [Build] place the following files in that folder: visual.html, site.css, and Pass_Az_El.rst. These will be provided on the webinar web site when we're done and we'll talk about these as we go.

[Build] Next, let's open an HTML Viewer window by selecting it from the View pull-down menu.

[Build] Now, use the HTML toolbar to browse to the location of the Visual.html file.

That file, together with the site.css file which describes how this HTML page will look…

Slide 18: [Pause] …will pop up an HTML panel on the right side of your STK application. This simple HTML page, which consists of basic HTML and VBScript

available on all Windows computers, is only 18 kB, and you can go in and look at the source code and modify it, if desired. It will allow us to do everything we need to do to schedule visible satellite passes for as few as one or as many as dozens—or even hundreds—of satellites. We can do that to visually see what's happening in real time or schedule appointments in Outlook, as we've already done. Before we proceed, I would recommend saving your application again, so that it will automatically load with the HTML page already present.

The HTML page automatically sets the scenario time to the beginning of the current hour and looks one day ahead—actually, it uses the number of days at the bottom of the panel. That way you don't have to worry about forgetting to set the appropriate time interval. It also sets the animation time to real time and displays the time in STK as your local time.

The application is intended to be run in checklist fashion, to make it easy to make the process repeatable. [Build] First, we select the observer location. All facilities loaded into the scenario at startup will be shown in the combo box. If you add new facilities after startup, just be sure to refresh the list before selecting the observer you want to use.

[Build] Next, you'll want to select the set of satellites you want to use. [Build] You can add satellites as you normally would in STK from the Insert pull-down menu. If you plan to use the same satellites each time, I'd recommend setting them to auto update after loading the satellites, to ensure you have the latest data, and then saving the scenario.

[Build] The other way to load satellites is directly from the CelesTrak web site, using the combo box on the HTML panel. Here, you'll get the very latest TLE data and can access any of the already pre-defined lists, such as the one for the ISS or the 100—actually 124 at present—brightest satellites.

[Build] Once you click the Load Sats button,…

Slide 19: [Pause] …the list of satellites you've selected will be quickly loaded and configured in your STK scenario, as seen in the 3D window. You can even choose whether or not you want to show the orbits at this step.

[Build] Now, set your desired observing conditions.

[Build] Then select your satellite lighting condition…

[Build] And, finally, click the Apply Constraints button.

Slide 20: [Pause] All of your constraints will be shown in the 3D window, with visible portions of the orbit in green and invisible portions in red. If you wish, you can change the observer and satellite constraints and reapply the constraints to see the differences.

Now, you can either observe your scenario in real time—the default setting—or in animation mode to explore the scenario, as desired. You can also generate any reports you might normally want to use to get schedules of the visible passes.

[Build] You can, however, also generate Outlook appointments, just as we did earlier. This is where the Pass_Az_El.rst file comes in. It is a custom report style that will generate just the data we need to produce our Outlook appointments. It will be automatically loaded into your STK user directory the first time you generate a schedule.

Slide 21: [Pause] For those of you who might be curious about how we interface with Microsoft Outlook, let's take a quick look at the code needed to generate an Outlook appointment. Actually, it's not too hard to use, once you know how. This example uses VBScript and matches pretty closely to what's in the visual.html file that you can download when we're done.

You'll start by first creating an Outlook object. You need only do this once. Then, for each appointment, you'll create an Outlook appointment object, set all the relevant properties, and then save the appointment. After saving the appointment, you'll want to discard the appointment object. That's really all there is to it.

Slide 22: [Pause] With these tools in hand, you're all set to go out and do your own visual observing. To whet your appetite, here's a shot of the ISS as it passed over my house at the end of 2004. As you can see, it is quite readily visible compared to the star background and this was before the addition of the huge new solar arrays. If you haven't experienced seeing an ISS pass before, I'm sure you'll be quite impressed and you should find it's pretty easy to figure out when to look. Even if you have seen ISS passes before and haven't seen them recently, I think you'll be in for a bit of a surprise. Just be sure to share the experience with as many others as you can. Of course, if you run into problems—other than the weather, which nobody has any control over—please feel free to drop me a note explaining the difficulty or question.

Slide 23: [Build] That wraps up today's webinar. If you have any questions at this time, and haven't already entered them, please be sure to enter them now. If you'd rather send an e-mail question, you are more than welcome to do so via my CSSI or CelesTrak e-mail addresses.

While you're entering your questions, I'd like to take a moment to review some administrative items. First, I want to remind you that the original PowerPoint briefing used for today's presentation plus all the tools we discussed will be available with the other AGI webinar resources at www.agi.com/webinars. I will also be turning this webinar into a full-blown article, similar to the ones I used to do for Satellite Times, which will be available early next year on the CelesTrak web site. It will also include links to all the resources provided and will be updated, as needed.

Next, you'll notice that we have two more parts of the visual observing series scheduled for this month, the first set for a week from today. That webinar will focus on Iridium flares. If you don't know what an Iridium flare is or haven't

experienced one, you really don't know what you are missing. These are truly awesome and next week we will delve into what they are and why they happen and provide more tools you can use to go out and view them.

Then, two weeks from today, we'll cover a little more esoteric topic on solar and lunar transits. These can be a bit more of a challenge to observe but can provide some spectacular results—if you are prepared. We'll show you a hint of what's possible and then, again, provide you with the tools to go out and see them yourself. I hope you'll join me for both of these webinars.

Finally, our next AGI "How-To" webinar is scheduled for December 14 on how to "Accelerate Application Development by Embedding AGI Technology."

I want to thank you for joining us today and I hope you'll want to provide feedback on what you saw today via the feedback form after we're done. Now, on to the questions.