Slide 2: Welcome to the second of our three-part series on visual satellite observing. I'm T.S. Kelso from the Center for Space Standards & Innovation. Today's webinar will cover a special topic of visual observing: Iridium flares. Whether you're a regular user of STK or someone new to this topic, 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 Iridium flares and how spectacular they can be 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 again, 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 these Iridium flares, 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 this subject.

We'll be following the same format as we did in Part 1 of our series, so those of you that joined us for that one should be pretty familiar with how we'll proceed. So, I'd encourage you to go to full-screen mode now, to best see what we'll be presenting.

Slide 3: So, let's get started. Today's webinar will begin by discussing the basics of what an Iridium flare is and what it looks like. Then, we'll look at the current constellation to get an idea what kind of opportunities we'll have to see Iridium flares. We'll focus the majority of the webinar on what's going on during an Iridium flare, using a flare I observed as an example. Then, we'll close by talking about some resources for predicting Iridium flares.

Slide 4: [Pause] The Iridium constellation is a constellation of low-Earth orbiting communications satellites. There have been 92 of them launched since 1997 and 66 of them are currently operational, with 11 spares on orbit. They operate in 86-degree inclination, 790-km altitude, 100-minute period circular orbits in six equally spaced orbital planes.

The flares occur when the Sun reflects off the Iridium satellites' Main Mission Antennas—or MMAs. While flares can occur with just about any satellite which has large reflective surfaces—such as solar arrays—what makes the Iridium satellite's MMAs unique is that they are fixed relative to the body frame of the satellite. Plus, since the operational Iridium satellites have well-defined, precisely maintained attitudes, it is reasonably easy to predict when and where these reflections will occur. We'll see more about what the satellite looks like and how these flares occur in just a minute.

But before we get too much further, you might be wondering, "So what's the big deal with Iridium flares?" "Can I really expect to be able to see one?" "What do they actually look like?"

Slide 5: [Pause] Well, here's a shot I took of one which occurred on January 3 of last year. The bright streak in the center of the picture is an Iridium flare [Build].

Even though the Sun is just starting to come up, this flare is easily visible and is the brightest object in the morning sky. In fact, this flare had a magnitude of -3.5, almost ten times brighter than the brightest star, Sirius. As you can imagine, something this bright is pretty hard to miss. And, as hard as it might be to believe, they can actually be up to 60 times brighter than this one—with a visual magnitude of -8!

The best way I can think of to describe the experience, if you haven't seen one before, is that it looks something like seeing the Star Ship Enterprise going into warp! Typically, the satellite will go from being barely visible to maximum brightness in 10-15 seconds and then dim just as quickly. Iridium flares are truly spectacular!

[Build] And, they are easy to photograph, too. For this picture, once I knew when and where to look, I set up a standard digital camera—in this case an Olympus D40Z—on a tripod and pointed it in the right direction. I set the camera to do a manual exposure of 8 seconds at ISO-400 and 4 seconds before the predicted maximum brightness, clicked the shutter release. With a 40-degree field of view, it's hard to go wrong. All you really need is a good watch.

So, you may be thinking, "Okay, if they're so easy to see, how come I haven't seen one before?" Well, there are certainly lots of opportunities, but if you're not looking in the right direction at the right time, you just won't see them.

Slide 6: [Pause] As we discussed earlier, there are 92 Iridium satellites in Earth orbit today, but only the operational ones will generate predictable flares. As seen in this screen shot of the current Iridium constellation, the operational satellites are shown in green, the decommissioned satellites are in red, and the spares are in blue. The constellation is designed to have at least one satellite over every point on the Earth's surface, to allow continuous communication through the network. That means, there are Iridium flares going on all around you every day! We'll get a better sense for this in just a bit.

Slide 7: [Pause] But let's look at an Iridium satellite to get a better idea of what they look like and how flares are generated. This shot shows the Iridium 94 satellite which we saw flaring in the photograph a few slides back at the time of maximum flare.

The satellite is oriented so that the bottom of the satellite—as seen in this shot—is pointed toward nadir. The solar arrays can be seen at the top of the satellite and the Main Mission Antennas—or MMAs—are shown at the bottom of the satellite. I have taken the convention of identifying the MMAs as 1, 2, and 3, [Build] defining the one aligned with the satellite's velocity as MMA 1, [Build] the one 120 degrees clockwise from MMA—or on the right side of the satellite—as MMA 2, and [Build] the remaining panel as MMA 3. I've also taken the convention of color-coding these panels in order as RGB—or red-green-blue—to make it easy to remember which panel is generating a flare. You'll see why this important a little later.

Slide 8: [Pause] The body frame of the satellite has the x axis pointing in the velocity direction for the satellite and the z axis pointing at nadir.

Slide 9: [Pause] One of the key pieces of information we need to know is where the normal vectors to each MMA point. As it turns out, this is pretty simple to set in STK, since each MMA is tilted 40 degrees down from vertical and, as we saw before are spaced at 0, 120, and 240 degrees in azimuth relative to the satellite's body frame. As before, we've color-coded these vectors to make it easier to remember which MMA we're looking at.

Slide 10: [Pause] Now, let's look at MMA 1 to get a better idea of the geometry of a flare. As seen in this shot, the Sun is to the front left of Iridium 94.

Slide 11: [Pause] From basic physics, we know that the reflection vector will point in the direction such that the angle of reflection is equal to the angle of incidence of the sunlight—which is in the opposite direction of the Sun vector. These angles are measured relative to the normal vector for the reflecting surface and all three vectors lie in the same plane. This screen shot shows the direction of the Sun reflection vector off MMA 1.

Slide 12: [Pause] Interestingly enough, I did not observe the flare off MMA 1 at this time, but a second flare which was coming off of MMA 3. As it turns out, it is possible to get two flares off a single Iridium satellite at any given time.

Slide 13: [Pause] If we add a flare cone to the reflection vector off MMA 3, we can see that my location was near the center of that cone—only 0.37 degrees off the reflection vector. For illustration purposes, I've defined the angle of the flare cone to be about where the magnitude of the flare would appear to be magnitude zero. It turns out that the primary contribution to estimating the visual magnitude of an Iridium flare is based on the mirror angle—the angle between a vector from the satellite to the observer and the reflection vector. The flare magnitude also depends on the range of the satellite and the solar phase angle, but for simplicity, we will just use the mirror angle today.

Slide 14: [Pause] If we move our vantage point around Iridium 94 toward its MMA 3, we can see the same basic reflection geometry that we saw with MMA 1.

Slide 15: [Pause] Now, let's look at the flare from above Iridium 94. Here, we can see that Iridium 94 is quite a distance from Colorado Springs—actually over 1,600 km. The long slant angle results in a long elliptical area as a footprint of the flare. While the footprint is smaller than what we saw for the ISS during our last webinar, it is still quite large. That means you really don't have to travel to see them, unless you absolutely must see them at their brightest.

Slide 16: [Pause] And, with as many as two flares sweeping along—on 66 satellites—your chances of being near the center line of the flare are actually better than you might think. It's not unusual to have a -7 or -8 magnitude flare once every week or so at any given location.

Before we get into the details of how to build an Iridium flare scenario in STK, I'd like to introduce you to a tool which should give you an even better grasp of the geometry of an Iridium flare. Up to this point, we've only looked at static views of

what happens during a flare. While these are better than anything I was able to find currently on the Internet, these are dynamic events, and having an interactive animation of what's happening will give you a much better sense for what's going on.

So, what I've done is generated an AGI Viewer file—or VDF—which shows the Iridium flare event we've been discussing from a variety of viewpoints. You can fly along underneath the satellite and watch it as it comes out of the Earth's shadow and see how the reflection cones move throughout the pass. You can fly overhead and watch the flares as they sweep over the Earth's surface or beam out into space. You can even view the event from Colorado Springs and watch as the flare sweeps over you.

If you weren't able to join us for our last webinar, you may not know what AGI Viewer is, so I'll take a moment to explain it. AGI Viewer is relatively new to the STK family. 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.

Once you've downloaded and installed AGI Viewer, you can get the VDF showing the Iridium 94 flare event and watch it unfold in detail. Not only can you watch the event from any of eight pre-defined views, you can animate forward or backward, pause the animation, and zoom or pan any of the views for a more complete understanding of the event. You'll be able to watch an Iridium flare in ways most people could only dream of. But don't just take my word for it—check it out yourself. You can find this VDF with the rest of the webinar materials after we're done.

Slide 17: [Pause] Now, let's take a look at what's involved if you want to build your own Iridium scenario in STK. While STK is very powerful, an Iridium flare is a much more complicated event than what we examined in our last webinar. First, you'll have to create a scenario with your observer location and load the Iridium satellite or satellites you want to examine. Then, for each satellite, you'll need to make sure the attitude is set to "Nadir alignment with ECI velocity constraint" rather than the default "Nadir alignment with ECF velocity constraint."

Then, you'll need to use Vector Geometry Tool to create the three normal vectors for the three MMAs on each satellite. Next, you'll create reflection vectors for each MMA, using the sunlight vector. One of the nice features of the sunlight vector is that its magnitude is based on the amount of sunlight incident on the satellite, going from zero when the satellite is in Earth umbra to one when it is in direct sunglight. This prevents us from having 'flares' when the satellite is in Earth shadow. Then, you'll need to set up three coordinate axes, aligned with each MMA reflection vector, as the coordinate frame for our reflection cones.

Slide 18: [Pause] Now, you'll create a sensor for each MMA, which points along the z axis of the coordinate frame you just created. I recommend setting the sensor cone to have a halfwidth of 2.3 degrees to allow for flares of magnitude zero or brighter. Finally, be sure to constrain the observer lighting, as we discussed in our last webinar, to make sure the sky is darker than the flare. I recommend using civil twilight, although the very brightest Iridium flares are actually bright enough to be seen in daylight—if you know just where to look. Now, you can run Access reports to see when you will have an opportunity to see an Iridium flare.

Wow! It's pretty amazing that we can do all of that within STK, but it's easy to miss a step or misconfigure something, if you're not careful. Even if you are careful, it would take a very long time to do this for all 66 operational Iridium satellites. You're probably thinking this is too hard to do, but if you are, you're about to see otherwise.

Slide 19: [Pause] As we did last time, I want to cover two ways to do this, so that nobody is left without a way to predict Iridium flares. 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 20: [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 Iridium flares. It includes predictions for the next 24 hours, the previous 48 hours, and the next 7 days. You can even get predictions for daytime flares. [Build] If we click on the link for predictions for the next seven days…

Slide 21: [Pause] …we get a screen that looks like this one, showing the basic time and observer conditions along with all of the Iridium flares for your location for the next week. 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. The application we're about to see will be provided with the rest of the materials for this webinar after we're done.

[Build] The Iridium Flare Scheduler is designed to allow you to automatically query Heavens Above, using your previously established and configured account, to find all the Iridium flares in the coming week. You can decide whether you [Build] want to look for only morning or evening passes and [Build] set a minimum brightness. Then, [Build] you tell the program 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 [Build] 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 Iridium flare in Outlook that look like this. [Build] The subject field shows the satellite name and NORAD Catalog Number. [Build] The location field shows the elevation, azimuth, magnitude, and time of maximum flare. [Build] The note field is used to show the time when this appointment was generated.

[Build] As you can see, this appointment matches the information in the last row of the Heavens Above report.

Slide 22: [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: Flares.html, site.css, Off-Boresight.rst, and iridium2.mdl. 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 Flares.html file.

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

Slide 23: [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 23 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 build an Iridium flare scenario for the entire Iridium constellation. 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 which Iridium satellites you want to use. Remember, only the operational satellites are known to have their attitudes maintained, although the spares may, as well. We're going to load this data

directly from CelesTrak—which means you'll need an active Internet connection—to ensure we not only get the very latest TLE data, but to take advantage of the operational status codes contained in the Iridium TLE file. Unfortunately, STK doesn't allow us to differentiate between operational and spare satellites, since it only uses Active or Inactive as status codes. This capability will be added into a future version, though.

Before loading the satellites, you can choose to use the ops colors—as we discussed before—whether you want to show orbits, and whether you want to load all the vectors we showed in discussing the theory earlier. These last two options tend to add a lot of overhead that really isn't needed in most cases, unless you're looking to build a detailed scenario such as the Iridium 94 flare event. Still, the fact that we can generate all those vectors automatically hints at the true flexibility and power of STK in this type of application.

[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. Now, instead of visualizing just one Iridium flare, we can see dozens of them!

[Build] As before, flares from MMA 1 are shown in red, and…

[Build] …flares from MMA 2 are in green. Flares from MMA 3—of which none are visible in this view—are in blue.

Slide 25: [Pause] If you're using STK Basic—AGI's free version of STK—you won't be able to see the 3D window, but can still see flare footprints on the 2D map, although it is hard to tell which satellite is generating which flare.

Slide 26: [Pause] If we change our vantage point to look on the night side of the globe over Africa, we can see how the nature of the Iridium flares change with the local time and see grazing flares and flares which just shoot off into space.

Of course, once again, we're looking at static views of the constellation. If you have access to STK, you can explore the dynamic nature of the Iridium constellation—in real time or animation time—in great detail. For those of you that don't have access to STK, I've created another VDF file that you can download and view when we're done. This one shows a day in the life of the Iridium constellation with all of the flares. It's a sure way to stay excited about Iridium flares when there aren't any predicted or the weather won't cooperate. I'm still awed at being able to see this and the fact that I can generate a current scenario in about 15 seconds with STK is pretty amazing.

Okay, but we're supposed to be generating a schedule of Iridium flares, so we can go out and watch them.

[Build] So, at this point, set your desired observing conditions.

[Build] And, then set your Outlook conditions for how far ahead to schedule and how much of a reminder you want. If you change the look-ahead value, remember that STK will have to re-propagate all the satellites in your scenario, so it may take 10-15 seconds.

[Build] Now, click Generate Schedule to create Outlook appointments for Iridium flares which meet your selected criteria, just as we did earlier. This is where the Off-Boresight.rst file comes in. It is a custom report style that will give us the minimum mirror angle—otherwise known as the off-boresight angle—for our reflection cone. We'll use that information to calculate the maximum magnitude of the flares at our designated location. It will be automatically loaded into your STK user directory the first time you generate a schedule.

[Build] As before, we'll get an Outlook appointment that looks like this, with [Build] subject and [Build] location fields as we defined earlier. [Build] The notes section now also includes when the flare is predicted to be brighter than magnitude zero, so that you can get an idea of how long the flare will last.

[Build] Sync this information with your PDA and you won't have any excuses for missing the next Iridium flare—okay, there's still the weather to deal with.

Slide 27: [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 Flares.html file that you can download when we're done.

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

Slide 28: [Pause] With these tools in hand, you're all set to go out and watch some Iridium flares yourself. I'm confident that you'll be just as awed as I am every time I see one. Once you've seen a magnitude -7 or -8 flare, you'll never forget it. Plus, with everything you've learned today, you can impress all your neighbors with how you can predict these magical events! They'll definitely think you're a rocket scientist!

Slide 29: [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 still have one more part of the visual observing series scheduled for this month, set for a week from today. That webinar will cover the somewhat esoteric topic of solar and lunar transits. These can be a bit more of a challenge to observe than basic visual observing or Iridium flares, 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 that webinar, as well.

Finally, our next two AGI "How-To" webinars will cover how to "Accelerate Application Development by Embedding AGI Technology" on December 14 and how to "Distribute Your Analysis Among Situational Awareness Users" on January 11.

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.