

Streaming subtitled videos (including full-dome planetarium shows) via Zoom

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Abstract. We have been exploring ways to keep our planetarium shows in the public eye. With the closure of many planetariums due to the COVID-19 pandemic, during the summer of 2020 we streamed our shows online instead. We performed tests of streaming planetarium shows via Zoom using various formats. We use “[MediaShow](#)” as our streaming software, since it allows multilanguage subtitles on demand, and has excellent show control, invisible to the viewers. Developed under NASA cooperative agreement, it is available for a free 30-day trial from [ePlanetarium.com](#). We have now shown a series of shows, and have an established procedure for excellent quality at even modest download speeds, making an “immersive-like” feel to the viewers. Our user survey shows excellent satisfaction from a diverse audience. A test of streaming shows in Spanish was also successful.

Background

The power of a full-dome planetarium show is in the visitor’s peripheral vision, which brings the visitor into the action without using 3D glasses or VR headsets. A typical planetarium is a hemispherical dome (with a flat or tilted horizon, as desired) that the visitors sit under. Most pre-rendered planetarium shows are designed for “unidirectional seating”, which means that the action has a preferred look direction, and all the chairs are aligned theater style facing “forward” with the planetarium operator typically in the back. Virtually all new planetarium construction uses that orientation (as opposed to “in the round” for star-only shows). Visitors typically face forward, but sound and visual cues let them know that action may come from the side or from the back, and they turn their heads appropriately but are never required to look directly behind them. This kinetic action and use of peripheral vision is what makes planetariums unique as a teaching venue, and we have shown that it leads to better content retention [Zimmerman et al., 2010].

Making planetarium shows “accessible” includes providing closed captions for the hearing impaired (and ensuring the narration adequately explains the action for the blind). We now can provide multi-language subtitles for demand using our show display software “MediaShow”. Creating a second language subtitle file is far less trouble than translating and voicing a dubbed version of the shows. We have many dubbed and subtitled shows available: see our YouTube Channel <https://www.youtube.com/user/eplanetarium/playlists> for playlists in various languages.

Planetarium Show Formats

Fisheye Most planetarium shows are distributed in “fisheye” format to large theaters, and planetarium professionals are used to that format, called “dome masters”. The horizon maps to the outer circle and the zenith is in the center, with the front horizon at the bottom edge, the back horizon at the top edge, and the left and right horizons on the left and right edges, respectively. However, someone watching a show online gets confused by the format, since the

“sweet area” (the part directly in front of the visitors in the dome) is relatively small and is located at the bottom of the image, and the top part of the frame is upside down (Figure 1). The images shown in the following figures are all the same fisheye frame from the show [“Earth’s Wild Ride”](#) (2005), which not only was one of the first full-dome Earth Science shows, it was the first to feature a lunar colony at Shackleton Crater. All are shown at the same size (1080 pixels vertically).



Figure 1. Full-dome fisheye frame from the show [“Earth’s Wild Ride”](#). Altitude/azimuth lines at ten degree spacing are shown in white with the forward horizon on the bottom edge and the Zenith in the center. Planetarium visitors will be looking primarily at the “sweet area” (bottom center), concentrating on the grasshopper eating the leaf, and only with their peripheral vision will they see the bird approaching. This view is not ideal for showing on flatscreens, since it overemphasizes the part of the image behind the viewer.

Warped With the advent of inexpensive mirror-based projection systems [Bourke, 2005], a new format (“warped”) was developed to allow the image to be projected onto a hemispheric mirror which then fills the dome using the reflection. We distribute all of our planetarium shows in both fisheye and “Pre-warped” format, for ease of use in mirror systems (Figure 2). These can even be rented on demand [<http://www.fulldomeondemand.com>].

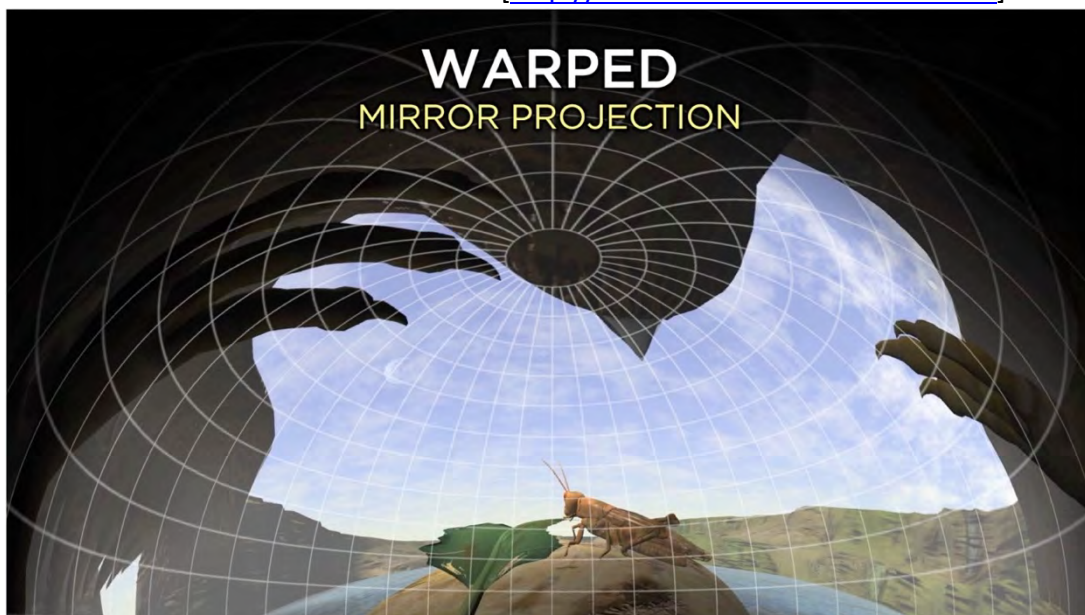


Figure 2. “Warped” version of the same frame as Figure 1, again with the altitude/azimuth lines at ten degree spacing shown. The sweet area is much more emphasized at the lower edge. The periphery is at the top and sides. This version would essentially fill the dome if bounced off a mirror, so again does overestimate the peripheral information.

This projection technique has many advantages in portable systems: 1. More pixels are projected: 1.4 Megapixels rather than a full 1080 circle (0.9 Megapixels). 2. The pixels are more concentrated in the “sweet area” (straight forward). 3. The “sweet area” is nearly flat so that the same setup can be used to project non-fulldome content in the lower central portion without needing distortion. Both of these standard formats fill (or in the case of the mirror, nearly fill) the dome, so can be a bit confusing for someone watching on a flatscreen. Since they include more information that is necessary, the “sweet area” is a smaller fraction of the total view.

VR Headset A VR headset has a much smaller field of view and relies on the user turning their heads in order to see the entire action. A typical field of view of a VR headset is only 110 degrees left to right (and is in a 16:9 ratio so about 60 degrees up and down). That gives better resolution to the “sweet area” but the peripheral information is completely invisible unless (and until) the users turn their heads. In the case of many planetarium shows, a VR user won’t know that action is approaching until it is “too late”. In this case, a VR field of view for that same frame (Figure 3) does not show the bird until the bird is upon the grasshopper, several frames later, unless the user just happens to be looking up.

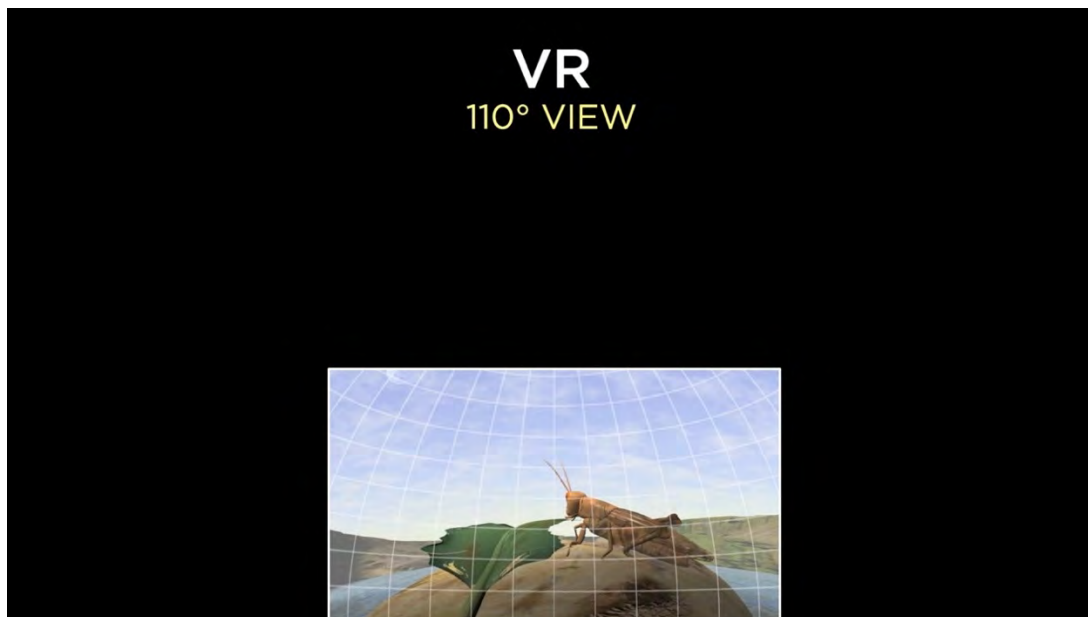


Figure 3. Field of view of a typical VR headset for the same frame as Figures 1 and 2. The viewer will be concentrating on the grasshopper eating the leaf and will have no peripheral vision to inform them that the bird is coming until it is too late.

After testing various options, we find that a “cropped warped” format (Figure 4) gives the best illusion of immersion in a flatscreen (e.g. Zoom or Youtube) platform. This takes a “warped” (for mirror) show, 1920x1080 pixels, and crops it to 1280x720, removing the highest distortions

at the top and sides. This gives a full 180 degree field of view along the horizon, and the compression allows even some of the vertical view to remain.

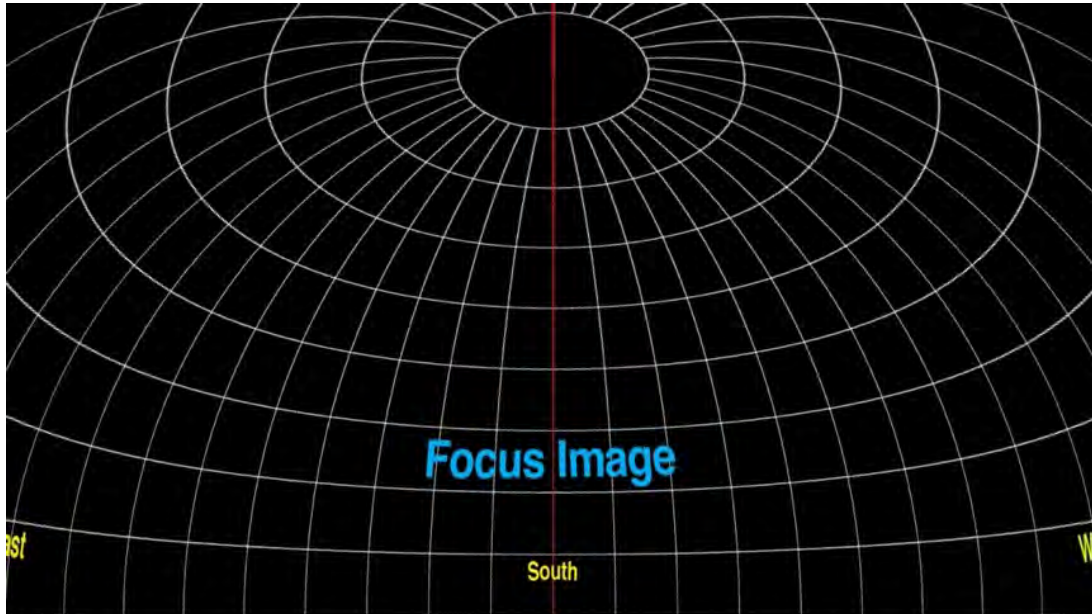


Figure 4. “Cropped warped” format showing the projected field of view (altitude / azimuth grid with ten degree lines). The “front bottom center” portion is almost not distorted at all, but the top edge allows a wide view of objects near the zenith, impossible in a normal wide screen video format. The effective max width is 180 degrees (along the bottom) and 111 degrees vertically (along the center line).

Note we have been using this “cropped warped” format for years. This is the format we use for the YouTube versions of our shows (<http://www.Youtube.com/user/eplanetarium>) and our DVDs. One of our DVDs (Figure 5) was taken on STS-123 by Takao Doi in 2008. Mark Petersen came to the same conclusion in his blog [Petersen, 2013].



Figure 5. Show DVD floating in the Space Shuttle STS123, taken into space by Takao Doi in 2008. (<http://www.eplanetarium.com/img/gallery/DVDinspace.jpg>)

The cropped warped format allows the viewer to be able to see peripherally the action coming from the back or over the top, as in this bird descending on the grasshopper (which always elicits a gasp from the users in a dome). Furthermore, it is not uncommon for planetarium shows to use the top of the dome as a vital part of the story, for example as an orrery in

“Amazing Astronomers of Antiquity” or a clock as in “Powers of Time”. Those effects are lost in normal flatscreen mode..

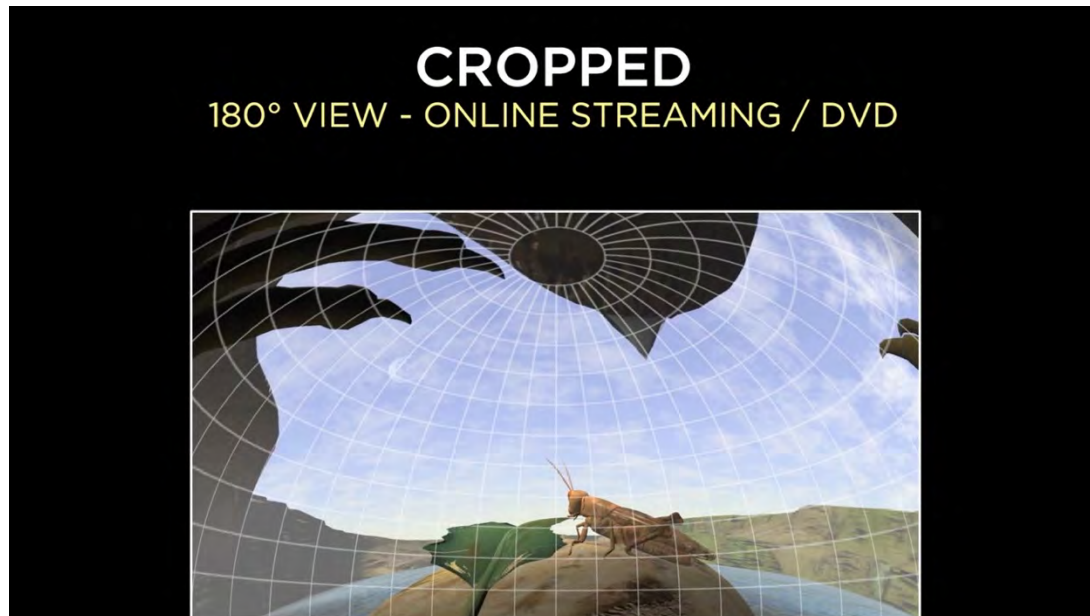


Figure 6. Same frame as (1, 2, 3 and 5) but now in the “cropped warped” format. This is a good compromise between the warped view and the VR view. The peripheral view is active but the visual emphasis is on the “sweet area” of the grasshopper. (Note each of these is shown at same 1080 pixel vertical scale but the images will be displayed expanded when projected).

For the second show, we did extensive testing, trying different pixel sizes of the show, different show quality, and various upstream servers and downstream “users”. We found the fastest serving was from Rice University (which has a much faster upload speed). We then found that the received quality was still jerky if the receiver’s internet was not fast. We then explored ways to reduce the sending rate to maximize quality.

We experimented with various options and found the best combination of quality and frame rate was this, which we used for the very successful showing of “Earth’s Wild Ride” on Weds April 29.

1. The show pixel size used to stream was 1280x720, but it was re-created at a lower data rate (3-5 MBs) so that the final show file size was about 650 MB (not 1.6 GB for 9 MBs)
2. MediaShow Pro was used to show the show so that subtitles could be used, especially important if the user’s audio was poor (and in fact, one user was not able get his audio to work).
3. MediaShow Pro was set up to project the show onto an 800x600 window. This means that the actual projected image was 800x450, better than the preview size of 640x360. This setup with this pixel rate showed smoothly on all kinds of receiving platforms, including smart phones. Using a Mac for the server, you can place the subtitles to be shown in the dark space below the show. On a Windows version of MediaShow, the

subtitles are actually on the video window so when the shared space is selected with Zoom, only the actual video will be shared (800x450).

4. Zoom was set up with “advanced options” to only show a portion of a screen, and to use “computer sound” and “optimize for video”.
5. The Rice University Zoom license was used so that up to 300 users could participate at once. (If we have more users, we can use YouTube Live to also simulcast the stream but we would not be able to capture metrics of users nor easily respond to their questions).
6. All incoming users went first to a “waiting room” and were admitted one at a time. All visitors were muted and could not unmute themselves until the Q&A. They were able to ask questions and make comments via the “chat” window during the event. We asked them to “Raise their hand” in the “participant” window to be called on for an audio question.

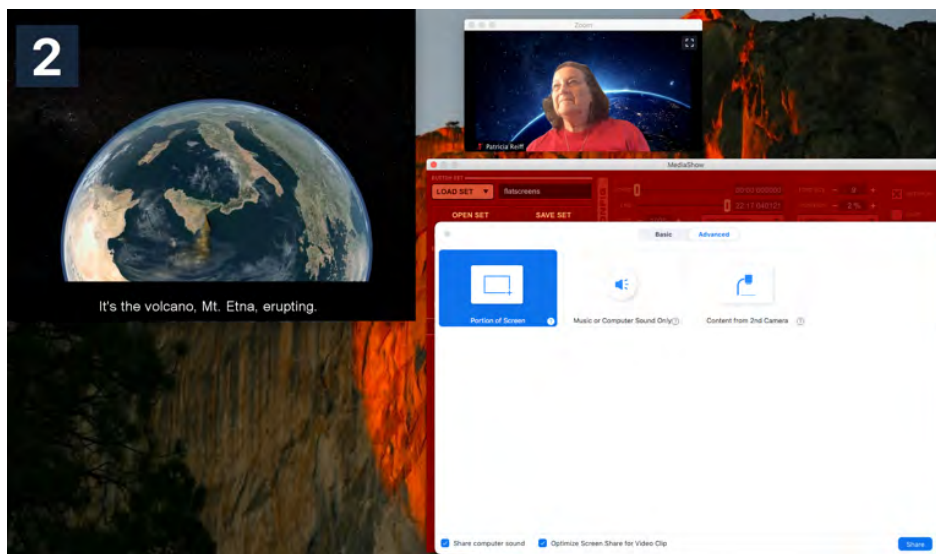


Figure 7. Screen shot of setting up advanced Zoom options



Figure 8. Zoom in progress using MediaShow Pro on a Mac with subtitles below the shared window (outlined in green)

For the second show using these setups (“Earth’s Wild Ride”), 166 people signed up.

The maximum users online at any given time, however, was 96. (Generally, if people don’t have to pay for a ticket, they often don’t show up. So we could safely allow 350-400 “tickets” and

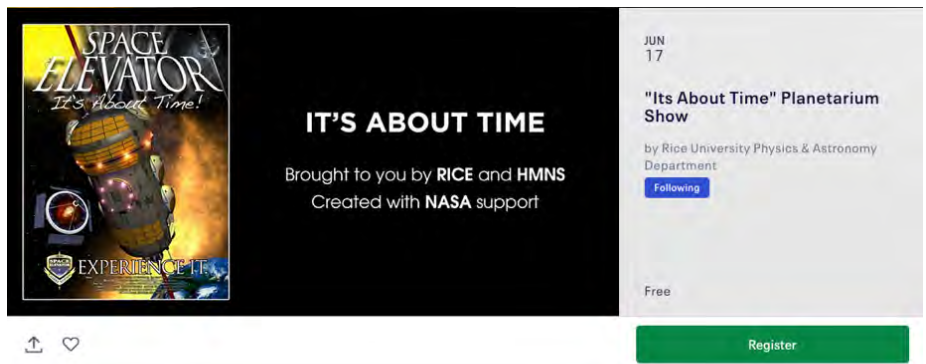
still keep the maximum users below 300). Many users made great comments (sic): “So far, everything is smooth. FiOS over WiFi”; “looks good on wifi and android phone”; “This is really cool”; “Wow. The distortion effect there was really cool.” “I can’t wait for the next show!” “I like this because we don’t just learn about one thing, we learn a lot of things” “Awesome! Would love to see it in the dome!” We found the best archiving method was to “spotlight” the speaker and record “in the cloud”, to allow later playback.

Ticketing and Advertising

Given that very successful second show, we continued weekly shows and posted a calendar show page: <http://space.rice.edu/nssec/shows.html>. In May we showed: “[Dinosaur Prophecy](#)”

May 6 (97 registrations); “[Impact!](#)” May 13 (170 registrations); “[We Choose](#)

Figure 9. Sample Eventbrite show listing.



“[Space](#)” May 20 (122 registrations); “[Great Planet Adventures](#)” May 27 (115 registrations) and streamed a watch party for the SpaceX mission (420 registrations). In June we showed “[Magnetism](#)” (111), “[Apollo and Beyond](#)” (66). We used [Eventbrite](#) to handle registrations so that we did not exceed the Zoom room limit, and so that we can manage users and create a cadre of “users”.

It's about Time is a planetarium show about using a space elevator to go to an amazing time telescope. Streamed with Q&A from the producers

Date And Time
Wed, June 17, 2020
6:00 PM – 7:15 PM CDT
[Add to Calendar](#)

About this Event

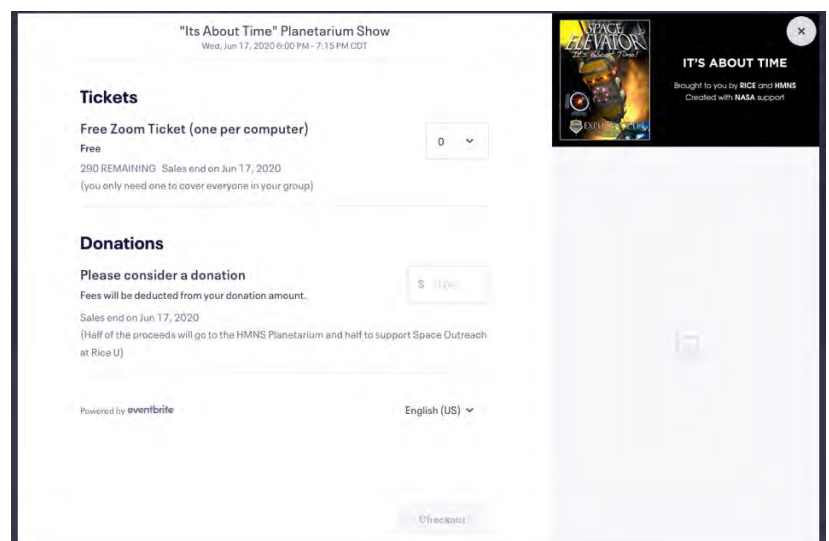
Journey into Space! Some day our children may travel to orbit in a Space Elevator. Some day we may use a Time Telescope to watch the Big Bang, the birth and death of a star, or an explosion on the Sun. Explore these wonderful inventions from the “science future” as you discover the many clocks that keep time in the Universe! Hosted by HMNS VP Carolyn Sumners and Rice Professor Patricia Reiff, this is a show for all ages, and children are especially invited to ask questions.

Location
Online Event

IT'S ABOUT TIME, created by the [Burke Baker Planetarium](#) at the Houston Museum of Natural Science and funded partially by NASA, takes you up from the top of Mt. Kilimanjaro to an orbiting geosynchronous space station. As the Earth gets smaller below you,

Now, when we post a new Eventbrite, we immediately get signups from previous users before we even advertise, because they have “followed” us via Eventbrite and get immediate notices of new events (Figure 9). In addition, using Eventbrite (as opposed to just Zoom “Registration”), allowed users to make a voluntary

Figure 10. Sample Eventbrite ticket sales page.



donation to help offset expenses. For our shows, tickets were free, but we added a “donate” option so that the participants can choose to donate any amount. So far, a reasonable fraction have chosen to donate, which helps us defray expenses (Figure 10). Eventbrite does allow paid tickets as well.

Watch Party

We also hosted a “Watch Party” for the SpaceX launch (twice, because the first was scrubbed because of weather). Because we were just sending the stream, we did not reduce the size of the viewing window. In both the first and second attempts, we had over 100 simultaneous computers

Figure 11. Visitors giving a “thumbs up” before the SpaceX launch.



connected, with each on average having about 1.5 children (Figure 11). Again, it worked very well. Most of the visitors kept their video stream off during the launch until we asked for a “group photo” which many happily joined (Figure 11). It was an unqualified success.

Spanish Language Versions

To attract a wider audience, we performed a test using Spanish audio shows with English subtitles. We had Spanish speaking translators to translate questions and answers after the shows. In all, ten shows were shown in Spanish, and in total, 93 people watched shows in Spanish. This included some who watched the English version and stayed on to watch the Spanish version. Since we did not actively promote the show in the Hispanic community, this was just a test but indicates that a market may be available.



Figure 12. Spanish team for events: (from top left): Carolyn Summers, HMNS; Patricia Reiff, Rice U; Luis Trumper, Argentina (who translated many of our shows); and Umbe Cantú, Rice U.

Summary and Repeat Customers

Streaming subtitled videos using MediaShow and Zoom

Over the course of the summer, we offered 18 planetarium shows; 14 sky shows; 3 launch parties; one live “solstice at the sundial” event and ten Spanish-only shows, for 46 total events (36 in English). Of the 2362 “tickets” that were “purchased” for the shows, the total number of unique emails is 1250. The total number of unique streams logged in and watching was 1253, but many had more than one person participating. The most sincere form of flattery is the number of repeat customers we have. So, on average, each person registered for about 1.92 events. More importantly, many began “following” us on Eventbrite and signed up within minutes of us posting a new show, before we sent out any notices to our email listservers. Having a consistent weekly time is helpful to keep a group of returning “customers”. Maximum number of events registered per person: 25 (mode=1).

Total of all Events (4/22 – 8/30/2020);

Total registered:	2362	(Spanish only: 29)
Maximum simultaneous streams:	1253	(Spanish only: 83)
Total estimated children (visible):	321	(Spanish only: 10)
Minimum actual users:	1574	(Spanish only: 93)

User Survey

We sent out a user survey (via Survey Monkey) to the participants and received 60 responses. Here is a summary of some of the results. (Note: some of the results are not shown here but are available on request.

Results:

Overall rating:

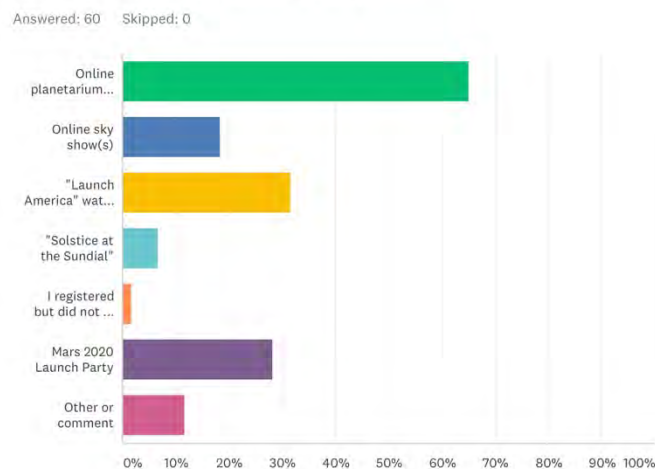
“Overall, how would you rate this event?” Excellent: 46%; Very good 42.3%; Good 5.8%.

Participation

Most of the respondents attended more than one type of event, and the statistics of the respondents approximately matched that of the persons who had registered (Figure 13).

Figure 13. Respondents attended each kind of our events this summer.

Which of our Zoom event(s) have you participated in?
(check as many as relevant)



Attitude questions
 Most agreed that it enhanced their knowledge of, and interest in, the subject matter (Figure 14).

Figure 14. Responses to attitude questions. Most strongly agreed.

	STRONGLY DISAGREE	SLIGHTLY DISAGREE	NEITHER AGREE NOR DISAGREE	SLIGHTLY AGREE	STRONGLY AGREE	N/A (I STRONGLY AGREED BEFORE THE SHOW)	TOTAL	WEIGHTED AVERAGE
I enjoyed the program	3.85% 2	0.00% 0	3.85% 2	13.46% 7	75.00% 39	3.85% 2	52	4.62
I learned something new	3.85% 2	0.00% 0	3.85% 2	13.46% 7	75.00% 39	3.85% 2	52	4.62
It enhanced my interest in the subject	3.85% 2	0.00% 0	5.77% 3	9.62% 5	76.92% 40	3.85% 2	52	4.62
I got my questions answered	5.77% 3	1.92% 1	19.23% 10	13.46% 7	48.08% 25	11.54% 6	52	4.09
I enjoyed interacting with a real scientist	3.85% 2	0.00% 0	7.69% 4	7.69% 4	75.00% 39	5.77% 3	52	4.59
I want to learn more about the subject now	5.77% 3	0.00% 0	13.46% 7	15.38% 8	59.62% 31	5.77% 3	52	4.31
I understand more now about how science (and scientists) work	1.92% 1	1.92% 1	11.54% 6	17.31% 9	59.62% 31	7.69% 4	52	4.42

Here are some comments:

Love both the show and the Q&A. Both cohosts are knowledgeable and handle the questions very well.

It was perfect! The mix of knowledge, entertainment, and interaction was well planned and made you want to join again and find out more about the topic!

Please provide more shows. Thank you

Listening to the scientific lectures as well as listening to the Professor(s) and scientists answer questions from the audience.

Word cloud for "things you liked": (figure 15)

loved interesting great shared hosts really events kids show
 details made time scientists live learn people fun questions
 watching information

Word cloud for "things you disliked": (figure 16)

looking Sometimes time N Nothing NA

Ethnicity of respondents (optional) (more than one response allowed):

Choice	Number	Percentage
Hispanic	6	12.77
African-American	4	8.5
White not Hispanic	29	61.7
Asian	10	21.2
Pacific Islander	1	2.1
Native American	0	0
Choose not to answer	3	6.3

Gender of respondents (optional)

Choice	Number	Percentage
Male	13	27.1
Female	4	70.8
Transgender	0	0
Non-binary	0	0
Prefer not to answer	1	2.1

Do you identify as disabled? (optional)

Choice	Number	Percentage
No	45	90
Yes	5	10

How often would you like these events?

Choice	Number	Percentage
Weekly	5	12.8
Twice a Month	6	15.4
Once a Month	19	48.7
I am not interested in participating at this time	0	0
I might participate if later in the evening	9	23.1

Conclusions

Zoom is an effective way to preview/stream a planetarium show. The participants all gave their thanks in the zoom chat (and their smiling faces). The repeat customers are a documented way that demonstrates the effectiveness of the shows. The surveys show that it attracts a diverse audience, and that most viewers gave “excellent” or “very good” responses when asked about the quality and effectiveness.

Acknowledgments

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