R.S.A. COSMOS

FULLDOME STANDARDS SUMMIT
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1. Introduction:

Today **R.S.A. Cosmos**, with ***In Space System™,*** is the only European manufacturer to provide a complete solution for digital planetarium including real-time 3D astronomical simulation and AllSky video playback.

AllSky video shows currently represent a growth market and it is urgent to propose a format meeting all requirements.

R.S.A. Cosmos, as a player in the AllSky video shows market and manufacturer of a playback solution, wishes to participate actively in this elaboration by defending some European specifications such as frames rate.

What specifications of the projection system should be taken into account in order to create a standard exchange of AllSky video shows ?

Fish-eye images have been already adopted as standard by the community, so it is important to define how to obtain them, their resolution as well as a working chain allowing the planetariums to use them.

The fish-eye images rendering method will have to meet the requirements of the planetarium producers according to their technical, temporal and financial means.

What method to use to produce fish-eyes ? What resolution to adopt for these images ? What method to use to adapt them to a particular planetarium theatre ?

Most of the shows currently produced take advantage of a spatial sound system. But each theatre is different, either in its architecture (titled or not) or in its sound installation (5+1, 6+1, 7+1, others…)

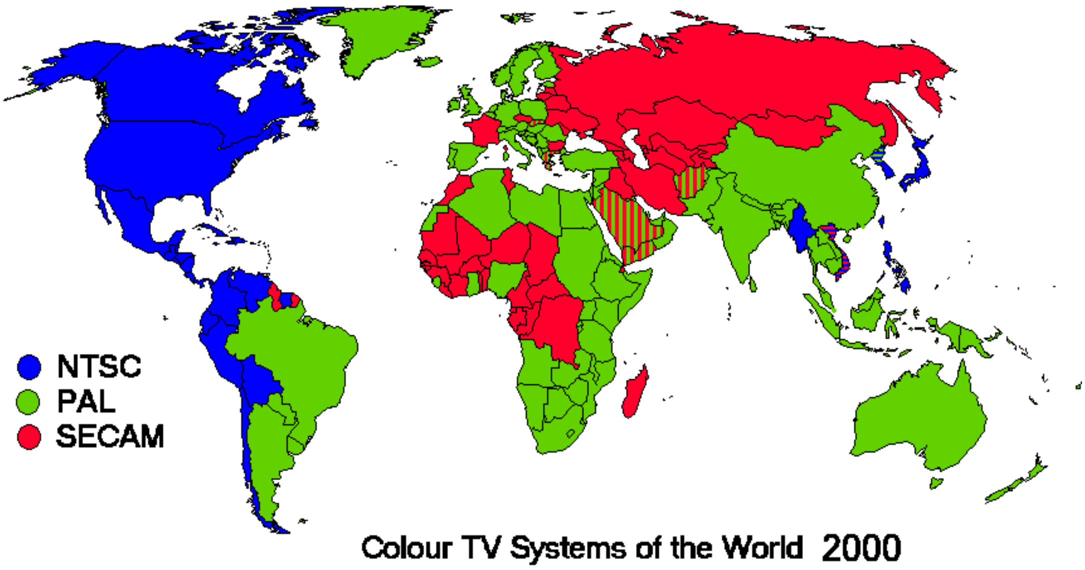
Which sound files to supply to planetariums and how do they have to treat them to optimize their installation ?

2. Projection system specifications

2.1 Video standards

We can often find two video broadcasting standards:

→ PAL/SECAM : 720*576 @ 25fps
→ NTSC : 720*480 @ 30fps



NTSC is used in North America (and in a part of South America) as well as in Japan.
PAL is used in the rest of the world (Europe, Australia…)

Historically, the choice of the image frequency is above all linked to the electrical network used: 50Hz in Europe : 25fps (or 50 for interlaced images) and 60Hz in the United States: 30 fps (or 60 for interlaced images).

Two parameters must be defined:

- Resolution
- Broadcasting frequency

Note about HDTV: resolution 1920*1080 (2073600 pixels): ratio of 16/9 not very adapted to our projection configuration 5/4 or 4/3. Computer resolutions 1024*768, 1280*1024, 1600*1200 (1920000 pixels) are adapted to our requirements and have only 8% fewer pixels.

2.2 Projection system resolution

A graphical channel includes a **graphical computer** and a **projector**.

2.2.1 Graphical computer resolution

The computer reproduces its images thanks to a graphical card with a maximum resolution of 2048*1536.

The computer generates 2 images sources:

- The graphical simulator
- Video flow

The power of the computers generally used in a planetarium can reach a resolution of 1600*1200 for the graphical simulator. Today video can also reach this resolution.

The ***In Space System™*** solution currently uses a resolution of 1600*1200 for video playback and real-time 3D. It sends this resolution to the projectors via the graphical card. It is a unique flow that requires only one source for the projector (no change of source to project video or real-time 3D and only one adjustment of the projectors).

2.2.2 Projector resolution

According to the type of projector, the maximum resolution is different (maximum of each technology) :

PROJECTOR	TECHNOLOGY	MAXI RESOLUTION
BARCO BR909	CRT	3200 * 2560
3D PERCEPTION SX 15	DLP	1280 * 1024
BARCO SIM 4	DLP	1280 * 1024
ZEISS ADLIP	LASER	1280 * 1024

2.2.3 Resolution and rendering time

In following is a small table, with the different resolutions, showing for each of them the percentage gained respect to the lower resolution and the percentage of rendering time lost with respect to the lower resolution (calculation times on a real planetarium show of 25 minutes).

Resolution	Number of pixels	% of pixels gained	Calculation time of a 25 minute All-Sky show	% calculation time lost
720*576	414 720		1 250 hours	
1024*768	786 432	+ 90%	1 650 hours	+ 32%
1280*1024	1 310 720	+ 67%	2 290 hours	+ 39%
1600*1200	1 920 000	+ 46%	2 940 hours	+ 28%

2.3 Projection system frequency

2.3.1 Projection frequency

Projection frequencies (scanning frequency of the projector) are generally 60Hz or 75Hz.

As we will see in the next point, the two video frequencies used (images frequency) are 25fps or 30fps.

The frequency of 75Hz is adapted to 25fps video (75 = 3 * 25)
The frequency of 60Hz is adapted to 30fps video (60 = 2 * 30)

On a 75Hz projection, 30fps video is acceptable (75 = 2 + 1/2 *30)
The images projection cycle is:
(*3*-**2**)-(*3*-**2**)-(*3*-**2**)- etc. so the jerky appearance is not very evident.

On a 60Hz projection, 25fps video is not acceptable (60 = 2 + 1/ 2,5 * 25)
(*3*-**2**-*3*-**2**-**2**)-(*3*-**2**-*3*-**2**-**2**) etc. a jerky appearance is very evident.

2.3.2 Computer video frequency

Unlike the PAL and NTSC standards where the resolution/frequency relationship was defined, with computer video technologies it is possible to choose any resolution and display it at any frequency.

We remind you that the frequency used for movies is 24fps. It is a very good quality which has been used for a long time !!

When using a higher frequency, associated with a higher number of images to calculate (to render one second of a movie, you have to render 24 images if you work at 24 fps, and 30 images if you work at 30 fps), is not necessary from a qualitative point of view and requires more time in the production because for a higher frequency you have to calculate more images.

If you pass from a 25fps frequency to a 30 fps frequency for a video with a same resolution, the rendering time will be 20% greater.

For example, a 25 minute video, with an AllSky rendering time of 3000 hours = 125 days on only one machine (Mono P4 2.4 GHz) (this is a realistic rendering time for a planetarium show playback on 6 channels 1600*1200). This same show rendered at 30 fps will require 3600 hours = 150 days : 25 more days of rendering !

Of course, the rendering will be done on several machines but it will not be done only once. When you create a show it is typical to have to re-render sequences (bad centering, detail improvement, color improvement…)

To render at 25fps instead of 30 fps allows a savings of 20% of time for the rendering of images and a gain 20% on the quantity of images stored.

So, according to the previous table, you can see that 28% additional time is necessary to render a video in 1600*1200, so:

If you render a 1600*1200 video @25fps instead of a 1280*1024 video @30fps, you reduce rendering time by 8% and you gain 46% in resolution, which allows you to play back video with the same resolution as the 3D simulator (and so to have a starry sky with the same quality !)

3. Fish-eye images production

3.1 Fish-eye images generation

We consider that the images to be played back are rendered from a 3D software (such as 3dsmax)

3.1.1 Orthographic vs Equidistant

There exist two types of Fish-eye images:

- Orthographic Fish-Eye
- Equidistant Fish-Eye

The Equidistant Fish-Eye offers a homogeneous distribution of the pixels on the 180° aperture whereas the Orthographic Fish-Eye compresses the edges and expands the zenith (important information loss on the horizon).

So, the better format is the Equidistant Fish-Eye.

3.1.2 Generation method

3.1.2.1 Direct Fish-Eye Rendering

The advantage of this method is to directly supply a Fish-Eye image which will be used to exchange the show and all the calculated pixels are useful (no pixel is calculated twice).

The disadvantage for the person who generates it, is that it is necessary to divide this image into multiple pieces before playing it back in the dome (additional time + image degradation).

3.1.2.2 Hemi-cubic rendering

The advantage of this method is that it is a simple and universal set of cameras. As for the Fish-Eye rendering, all the calculated pixels are useful (no pixel is calculated twice).

The disadvantage of this method is that it is necessary to recombine these images to obtain a Fish-Eye image (loss of time, image degradation compared to a direct rendering of the Fish-Eye image) and to again split the image into multiple pieces for playback on the projectors (loss of time and image degradation).

3.1.2.3 Camera rendering

The advantage of this method is that it directly supports obtaining images for playback on the projectors (gain of time to play back images and images are not degraded).

The disadvantage of this method is that it is necessary to recombine the images to obtain a Fish-Eye image (loss of time, image degradation compared with a direct rendering of the Fish-Eye image) and that the rendered image has soft-edge zones, so it is necessary to calculate pixels several times (around 20% of soft-edge and so 20% of time lost).

3.1.2.4 Conclusion

Used rendering	Time to obtain the Fish-Eye	Fish-Eye quality	Time to obtain images to broadcast	Quality of the images to broadcast
Fish-Eye	DIRECT	OPTIMAL	CUTTING	DETERIORATED
Hemi-cubic	COMBINED AGAIN	DETERIORATED	CUTTING	DETERIORATED
Camera	COMBINED AGAIN	DETERIORATED	DIRECT	OPTIMAL

A parameter is missing to finish this study: this is the average rendering time (rendering time of a real planetarium show) using the three methods.

3.2 Fish-eye images resolution

The mathematical method for defining the fish-eye image resolution for a given projection system is very complicated. In order to have an estimate of this resolution, we propose the following method:

3.2.1.1 Calculation of the number of effective pixels on the dome

Example of a 5+1 planetarium which can play back on each channel a resolution of 1600*1200.

1600 * 1200 * 6 = 11 520 000 pixels projected.

You have to subtract the pixels duplicated by the soft-edge zones (we take an average of 20% of soft-edge, obviously this value changes according to the site and the adjustment of the projectors).

11 520 000 * (100% - 20 %) = 9 216 000 effective pixels on the dome.

3.2.1.2 Calculation of the number of effective pixels of the Fish-Eye image

A Fish-Eye image is a circle in a rectangular composition. The image's diameter is the smallest side of the rectangle (of the side if it is a square).

Example of a square image of 2200*2200 in which there will be a Fish-Eye.
The number of effective pixels of the Fish-Eye image is:

PI * (2200 / 2)^2 = 3 801 336 effective pixels.

3.2.1.3 Comparison between the number of pixels available on the dome and the number of effective pixels of the Fish-Eye image

Ratio = (Number of effective pixels of the Fish-Eye image) / (Number of effective pixels on the dome) %

In the previous example, the ratio is 41% (<100%). The number of pixels of the Fish-Eye image is 2.4 times more little than the effective resolution of the dome and so, it is not enough to exploit the capacity of the projection system.

The Fish-Eye image must always have a resolution 10% better than the dome and so, the ration must always be superior to 110%.

3.2.1.4 Conclusion

Below is a table concerning the Fish-Eye image which must be used according to the number of projectors and the video resolution used. We used the previous method and a 20% soft-edge.

Video channel resolution	Number of channels	Minimum resolution of the Fish-Eye	Ratio
720 * 576	5 + 1	1700*1700	114 %
1024 * 768	5 + 1	2300*2300	110 %
1280 * 1024	5 + 1	3000*3000	112 %
1600 * 1200	5 + 1	3600*3600	110 %
720 * 576	6 + 1	1800*1800	110 %
1024 *768	6 + 1	2500*2500	111 %
1280 * 1024	6 + 1	3200*3200	110 %
1600 * 1200	6 + 1	3900*3900	111 %

3.3 Fish-Eye images compression

To compress Fish-Eye images for show transfer, there are several solutions. Generally, we work with Targa images allowing a lossless compression (RLE).

Here is a table showing the storage capacities of a 25 minute show.
If it is not compressed, the compression rate is 1.
In low compression (medium rate for images very difficult to compress by RLE), the rate is 1.15
In high compression (medium rate for images very easy to compress by RLE), the rate is 4.62.

In medium compression (medium rate given by the RLE using on a realistic planetarium show), the rate is 2.64.

Fish-Eye Resolution	25fps no compressed TGA	30 fps no compressed TGA	25 fps medium compression TGA	25 fps high compression TGA	25 fps low compression TGA
1800*1800	340 Gb	410 Gb	**129 Gb**	75 Gb	295 Gb
2500*2500	655 Gb	785Gb	**250 Gb**	145 Gb	570 Gb
3200*3200	1.05 Tb	1.26 Tb	**410 Gb**	235 Gb	935 Gb
3600*3600	1.33 Tb	1.59 Tb	**515 Gb**	295 Gb	1.15 Tb
3900*3900	1.56 Tb	1.87 Tb	**605 Gb**	345 Gb	1.35 Tb

3.4 Fish-Eye images splitting

To convert from a Fish-Eye view to several views which can be played back on multiple projectors, you have to split the Fish-Eye. The software ***O.R.I.ON™*** can do this step. This software can be adapted to any camera configuration and can also be used to recombine images. All these operations can be done for all the theatre configurations. Still, you have to know the parameters of the projectors.

These parameters currently depend on each installation. At first it is necessary to standardize all the possible configurations of the projectors (number + camera parameters) in order to supply a software covering all the installations without entering new parameters.

4. AUDIO REPRODUCTION

4.1 Playback system

Now, most of planetarium theatres have chosen 5+1 sound systems.

We prefer a 7+1 configuration because the spatial sound is better especially at the zenith of the planetarium.

On the other hand, the classical 5+1 configurations offer different qualities of loudspeakers:

- Centre forward (Voice)
- Right forward, left forward (Music + Effects)
- Right Back, left back (Effects)

We propose to use the same loudspeakers whatever their position in order to have the same sound quality everywhere in the dome. The spatial sound effect is more important than in a cinema because the projected image is 360° azimuth and 180° elevation.

4.2 File Format Used

Unlike the image files where there are frequency incompatibilities, the sound can be easily adapted to a playback frequency different from the one used in the encoding. Only the total duration of the file must be kept during the applied treatments. We propose to supply a soundtrack with a show as uncompressed PCM files with a 48 KHz frequency. The sound file size is very small respect to the images (around 10Mb per minute).

4.3 File Formats

For sound reproduction, it is best to have one discrete file per loudspeaker. Nevertheless it is true that to have the best quality, performing the mix in the theatre on the final configuration is essential.

An other element to consider for the show exchange is the translation of the show, which is rarely done by the company who supplies the show (planetarium or specialised company). The "Voice" track must be separated to be changed.

In any case, it is more practical to receive individual channel files for processing rather than only one AC3 file which will be totally closed and impossible to modify.

We propose the following elements:

- 7+1 sound system with voice (OV): 8 PCM 48 KHz mono files
- 5+1 sound system with voice (OV): 6 PCM 48 KHz mono files
- 7+1 sound system without voice: 8 PCM 48 KHz mono files
- 5+1 sound system without voice: 6 PCM 48 KHz mono files
- Stereo voice (OV): 1 PCM 48 KHz stereo file

5. CONCLUSION

It is important to think about a standard taking into account all the market and not only the American market.

It is important that this standard does not exclude the future technical solutions. Indeed, a planetarium which has chosen a technology different from this standard must have access to the standard shows (unlike the old planetariums with the Levels standardization)

Manufacturers must adapt themselves to the market requirements and not the inverse.
Manufacturers must not impose their standards on the market but, on the contrary, the standard must adapt itself to the market.