Criteria for the design of the theater

1) Geometrical criteria:

- The theater should have between 400 and 600 seats. The width of a seat is 0,55m and the (horizontal) distance between rows should be 0,95m.

- The ratio of the total room volume V and the number of seats N should be in the range of V/N = 4 to 6 m^3/seat.

- The total length of the room (not including the stage) should not be more than 25m.

- The stage does not have to be included in the design. Instead, the mouth of the stage is defined as a rectangular surface in the corresponding wall, with a width between 14m and 16m and a height between 7m and 9m.

- Access to the seats should be ensured by pathways with a minimum width of 1,5m.

- The space containing the seats is modeled by way of rectangular blocks covering all the space between pathways, with a height of 0,5m.

- At least one reflector panel should be either hung from the roof just in front of the stage or integrated into the profile of the roof. This reflector will serve to direct early reflections towards the public in the farthest rows. The reflector(s) can be as wide as the width of the room, but the ***minimum length*** and the ***orientation*** ***must be carefully computed according to the theory presented in Module II, section 2.3.5.***

2) Acoustic criteria

- All the surfaces in contact with the inside of the room have to be assigned materials with corresponding frequency dependent absorption coefficients. EASE has a large database of materials and many more can be found on the internet (search for 'absorption coefficients of materials'). The choice of materials is guided by the desired Reverberation Time (see next point) but should also be based on 'common sense'. The EASE wall material databases are located in: EASE40Data\Global Materials40

- The finished room should have an RT according to Sabine in the range of 0,8s to 1,2s for all the frequency bands from 125Hz to 4 KHz. The RT is computed in the Main EASE window / View / Room Info / Data. Do not forget to change from Eyring to Sabine!

- If the reflector panel is hung from the roof, it will be a 'free-floating' surface inside the room. This means a material must be assigned to it on both sides of the surface (option 'two-fold' in surface properties). The absorption coefficients in the database are not valid for free-floating surfaces so appropriate coefficients must be found by an internet-search for commercial reflector panels that provide measured absorption values.

- The rectangular blocks representing the seats (with public) should be covered on all sides with one of the materials from the EASE database representing ‘public’.

- The surface representing the mouth of the stage must be covered with a self-defined material with linearly growing absorption coefficients from 0,3 at 125Hz to 0,55 at 4 KHz. New materials can be defined in the Main EASE window / File / Main databases. Use interpolation (in the Edit menu)!

- Echograms should be computed (see below) for 4 or more representative listening positions in the room, for the frequency bands from 500Hz to 2000Hz. If any echogram shows serious deficiencies (reflections in region ‘D’ of the Haas diagram) the room should be adapted to suppress them (without compromising the RT).

- A map of the STI should be computed (see below) for the entire audience. The STI should be at least ***0,6*** everywhere.

- When the design is completed an auralization (see below) should be generated for a listener seat near the center of the audience and a subjective evaluation of the result should be formulated in the final report.

<u>Creating an echogram in EASE</u>

Before computing echograms make sure the room is closed and the internal volume is computed correctly. To check this, go to the main EASE window / View / Room info / Data, uncheck ‘room open’ and press ‘Recompute’.

Now we need to insert a source (Edit project window / Insert) centered at about 1,60m above the stage, just inside the room (not touching the wall!). The default spherical source is okay for this purpose. Next we insert a number of listener seats (Edit project window / Insert) and adjust their position such that the receiver point is located at 1,20m above the floor.

For computing the echograms, we go to the main EASE window / Calculations / Ray Tracing. This opens the EASE Rays windows. We choose Mirror Image Impacts from the Rays menu. We select the desired source and seat, set the parameters to:

Order: 4,

Delay: 100 ms,

Loss: 40 dB,

and select the option ‘Make impact file’. Upon execution we are prompted to choose where to save the impact file. It can be saved in the project folder. Subsequently we are prompted ‘View File Now?’ After choosing ‘Yes’, a window with control buttons opens up. We choose ‘Invoke probe’ and a window appears with the calculated echogram. We can change the frequency band in the View menu.

We can now investigate the echogram by comparing it with the Haas diagram. If any reflections are in region 'D' of the Haas diagram (see Fig. 1 further down) we can visualize the path of the corresponding rays by changing the cursor to 'pencil', clicking on the reflection of interest (it will turn yellow) and bring forward the 'View Project' window. This will display the path of the selected ray in the room.

Creating an STI map in EASE

In order to create maps of acoustical parameters we first have to define audience areas above all the seats. To this aim, we right-click the superior surfaces of the seat-blocks and choose 'area above face'. This will create a surface (in green) at 1,2m above the block. However, the audience area should be at 1,2m above the floor (approximate level of the ears of a sitting person), so we have to lower it by 0,5m.

Next we must set the background noise level in the 'main EASE window / View / Room info / Data' window. We shall use the values of the Noise-Criterion curve that corresponds with the maximum 'recommended noise level for theaters', NC-25. The values are given in the table below (noise can be set to zero outside the given range)

NC-25 interpolated to 1/3 octave bands:

1/3oct	63			125			250			500	
dB SPL	49.2	47.7	45.2	39.2	37.9	35.9	32.2	31.0	29.2	26.2	25.3

1/3oct		1k			2k			4k			8k
dB SPL	24.0	22.2	21.4	20.5	19.2	18.7	18.0	17.2	16.9	16.6	16.2

Now we have to add a natural speaker source, centered at about 1,60m above the stage, just inside the room (not coincident with the wall!). We insert the source, and change it (right click the speaker and: 'Change Speaker Model') into MAN NORM NEW in the EASE Speaker database (EASE40Data\Global Speakers40). Then we right-click 'speaker properties' and adapt the SPL(1m) levels such that the 1 KHz level equals 54 dB SPL conform the ANSI S3.79 international standard. Finally, if necessary, point the source towards the center of the room using 'Loudspeaker Aiming' in the speaker right-click menu.

We are now ready to do the mapping. From the Main EASE Window, choose the menu Calculations / Area Mapping. A new window opens up. In the menu 'Mapping' choose 'Standard'. This opens a 'Calculation Parameters' window. Leave all parameters as they are, just select the active loudspeaker. Press Ok.

In the results window, the default result is 'Direct SPL'. Change to STI. Go to Options and select 'consider noise'.

Click on the large colored button to refresh the map. At the top of the color-bar you can read the minimum STI value found inside the room.

Auralization in EASE

Auralization of a room model consists in creating an audio file that allows listening to how a chosen acoustic source would sound to a listener at a given position in the room. To do this, we must first create an Impulse Response for a chosen source position and listener seat. This is similar to an echogram, and we can also use ray-tracing to obtain it.

As before, we go to the main EASE window / Calculations / Ray Tracing. This time we choose 'Local ray tracing'. We select the source and the listener seat we want to use and we adapt the parameters to:

Order: 6,

Delay: 200 ms,

Impact chance > 90% (Adjust the number of rays until this is fulfilled).

Execute. This may take some time, depending on the size and complexity of the model. When the calculation is finished, an echogram window opens with the title: 'probe on seat X', where X is the label of our chosen seat. We choose 'Edit / add random tail' and apply the random tail with the default parameters. Then: 'Tools / Invoke ears'. This prompts 'Save file?' We choose 'Yes' and save the .RSP file with our project under a name of our choice.

Now, in the 'EASE 4.4 ears' window, we choose 'Edit / Make binaural response'. Save the .BIR output file with the project. When prompted 'Show filter info?', we say 'Yes'. The binaural response is visualized. This is a 'stereo' Impulse response for the given seat. Observe how the signal is slightly different for the two ears.

Next, again from the 'EASE 4.4 ears' window, we choose 'Tools / Auralization'. This opens the 'Auralization' window. This is where the actual auralization is done; the binaural file is convolved with a source-file, which contains a piece of speech or music recorded in an anechoic chamber.

In the Auralization window we define:

Input file: H:/Material-Practica-AEII/anecoics/Texto_voz_masculina_grabacion_anecoica.wav

Output file: the path of our project folder and a chosen name, eg. 'MaleTextOut'.

Now we click the large 'Ears' button to select the Ears convolver.

Finally we press: 'Eject'. An audio player opens up and we press: 'Play' (Preferably use ear-plugs. If you do not have any, the professor will provide some)

Listen carefully to the result. Is there any hearable echo? Is the voice understandable word-by-word?

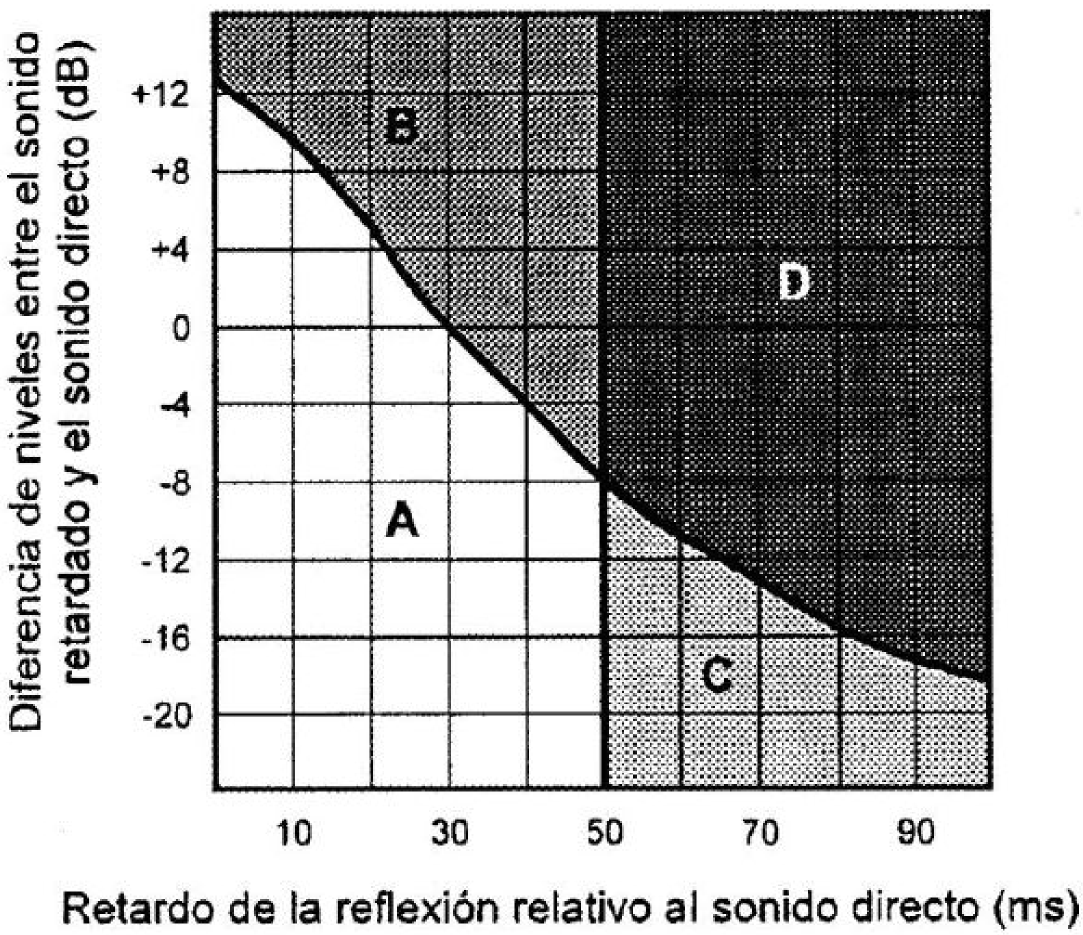

Figure 1: Haas Diagram