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**Edward McCue**

## **Acoustics of the Second Opera House at Eszterháza\***

It is not absolutely certain who was responsible for the architectural design of the second opera house at Eszterháza that opened on 25 February 1781 with the first performance of Haydn's "La fedeltà premiata", but Melchior Hefele (1716–1794), the architect of the palace expansion, is sometimes given the credit.<sup>1</sup> This new opera house was a freestanding building to the west of the formal gardens that stretched to the south of the main palace building occupied by Prince Nikolaus I Esterházy (1714–1790). The story of the destruction by fire of the first opera house, the transfer of the operatic and dramatic productions to the expanded marionette theatre, the rapid design and construction of the replacement theatre, and the eventual demise of that building is well told by Mátyás Horányi.<sup>2</sup>

This room acoustics examination of the second opera house attempts to describe the aural experience at Eszterháza. For the purposes of this discussion, the discipline of room acoustics describes the paths, in time and space, taken by musical sounds as they travel from the performers to the listeners.

Jürgen Meyer discusses only the "concert room" at Eszterháza,<sup>3</sup> but he claims that the 1769 (sic) opera house had an incredible volume of 9,500m<sup>3</sup>, similar to that of the audience chamber of the 1,900-seat Palais Garnier in Paris.<sup>4</sup> Meyer's data are repeated by Michael Forsyth.<sup>5</sup> Since few dimensional data for the first (1768) opera house exist, other than the observation that with

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\* Delivered 9 May 2003 in Budapest at the symposium "Eszterháza Opera House: Past and Future?" jointly organized by the Hungarian Haydn Society and the Hungarian Trust of Historic Buildings.

<sup>1</sup> Mihály Mócsényi, *Eszterháza fehér-feketén*, Budapest 1998.

<sup>2</sup> Mátyás Horányi, *The Magnificence of Eszterháza*, London 1962.

<sup>3</sup> Jürgen Meyer, *Raumakustik und Orchesterklang in den Konzertsälen Joseph Haydns*, in: *Acustica*, vol. 41/3 (1978), pp. 145–162.

<sup>4</sup> Jürgen Meyer, *Akustik und musikalische Aufführungspraxis*, Frankfurt am Main 1995, p. 185.

<sup>5</sup> Michael Forsyth, *Buildings for Music*, Cambridge 1985, p. 334.

the second “everything is larger,”<sup>6</sup> Meyer’s assertions require further investigation.

## ARCHITECTURAL DESCRIPTION

An anonymous “Beschreibung des Hochfürstlichen Schlosses Esterháß im Königreiche Ungern,” Pressburg 1784, describes many of the architectural features of the second opera house. A facsimile of the plate with engravings of the scaled drawings<sup>7</sup> by Jacob de Fernstein is provided by László Somfai<sup>8</sup>. The five engravings are reproduced individually in the appendix to this essay (see facsimiles 1/1 to 1/5). Additional information concerning the finishes and furnishings in the opera house is provided in other contemporary accounts.<sup>9</sup>

The opera house was about 19m wide and 61m long with a garden façade featuring a columned portico (see facsimile 1/1, “Façade vom Eingang”). The interior plan, from east to west, was divided into a foyer, audience chamber, stagehouse and costume storage. Staircases at either side of the small foyer led to the elliptical princely box elevated at the rear center of the audience chamber, also ovoid in shape. Two additional boxes at either side of the proscenium were connected to the central box via side galleries tiled with polished stone and fronted with brightly gilded balustrades. Adjacent to the boxes were lounges furnished with every amenity that might be required during the course of a three or four hour-long performance.

While the princely family and their most distinguished guests occupied these upper boxes and galleries, the majority of the audi-

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<sup>6</sup> *Literatur und Theaterzeitung*, No. IV (26 January 1782), see H. C. Robbins Landon, *Haydn at Eszterháza 1766–1790*, London 1978, p. 463.

<sup>7</sup> The scale is given in *Wiener Klafter*. One klafter equals 1.8965m.

<sup>8</sup> László Somfai, *Joseph Haydn: Sein Leben in zeitgenössischen Bildern*, Kassel 1966, pp. 46–47.

<sup>9</sup> Gottfried von Rotenstein, *Reise durch einen Theil vom Königreich Ungarn seit dem Jahre 1763. Eszterhâz*, in: Johann Bernoulli, *Sammlung kurzer Reisebeschreibungen und anderer zur Erweiterung der Länder- und Menschenkenntniß dienender Nachrichten*, vol. 9, Berlin 1783, pp. 250–288; Johann Matthias Korabinsky, *Geographisches, Historisches und Produkten Lexikon von Ungarn*, Pressburg (1786), pp. 163–72; and Anonymous, *Excursion à Esterhaz en Hongrie en Mai 1784*, Vienna 1784.

ence occupied the flat-floor parterre below. Access to the many rows of benches was either by a broad center aisle leading from the foyer or by multiple sets of double doors at the building exterior. These short paths of emergency egress to the out-of-doors surely promoted life safety, but by communicating directly with the building exterior, they readily admitted light and noise into the audience chamber when opened.

Tall, arched windows in vertical alignment with the parterre side doors dominated the upper volume of the audience chamber. Silvered on the inside, these windows, along with mirrors at the proscenium and princely boxes and galleries, repeatedly reflected the light of the many candles distributed throughout the audience chamber, thereby illuminating a frescoed ceiling portraying a classical allegory nearly 12m above the parterre floor. The gallery mirrors placed between the arched windows may have also served a second purpose. When properly adjusted, the reflected image of the prince in his box would have been visible to the occupants of the proscenium boxes, and vice versa.<sup>10</sup>

Analyses of the plan and sections indicate that the volume of the audience chamber was around 3,400m<sup>3</sup> and that the stagehouse volume measured about 2,750m<sup>3</sup>. Therefore, the total interior volume of the second opera house at Eszterháza was approximately 6,150m<sup>3</sup>.

Altogether, the opera house could accommodate an audience of at least four hundred persons. Some contemporary descriptions infer that the parterre alone could accommodate four hundred audience members, but if that were the case, the twenty-two benches illustrated in facsimile 1/2 ("Grundriss zu ebener Erde") would have provided significantly less than 300mm of seating per person. Other documents indicate that as many as thirty benches and twenty-four loose chairs were found in the parterre.<sup>11</sup>

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<sup>10</sup> For a discussion of the metaphor of mirrors in theatres, see: Martha Feldman, *Magic Mirrors and the Serial Stage: Thoughts Toward a Ritual View*, in: *Journal of the American Musicological Society*, vol. 48 (1995), pp. 423–84.

<sup>11</sup> Landon, *Haydn at Eszterháza*, p. 427.

## COMPARISON WITH OTHER OPERA HOUSES

Architectural comparison of a few extant court opera houses from the eighteenth century reveals which aspects of the geometry, construction materials, finishes and furnishings of the second opera house at Eszterháza might have defined its acoustical characteristics.

The castle theatre at Český Krumlov, Czech Republic, while smaller in geometrical volume than the opera house at Eszterháza, is also a "hall theatre" and therefore shares with it many features: an elevated princely box and a single gallery, upper sidewalls free of obstructions, a flat parterre with bench-type seating, a long desk and benches for the orchestra, a shaped proscenium arch, and complex stage machinery. The musicologist H. C. Robbins Landon recognized its resemblance to the opera house at Eszterháza.<sup>12</sup> Probably in accordance with a design by architect Andreas Altomonte (1699–1780), Prince Joseph Adam zu Schwarzenberg (1722–1782) had the theatre attached to his family castle in 1766.<sup>13</sup> It is conceivable that Prince Esterházy discussed the design of this theatre with Prince Schwarzenberg during a courtly sojourn in Vienna.

The interior of the theatre of Margrave Friedrich von Brandenburg (1711–1763) in Bayreuth was completed in 1748 by Giuseppe Galli-Bibiena (1696–1757) and his son Carlo (1728–1787) in the form of an Italian public opera house with multiple galleries.<sup>14</sup> Although larger in geometrical volume than the opera house at Eszterháza, it shares with Eszterháza certain features that are not found at Český Krumlov: heavy surface ornamentation, open balustrades at the box and balcony fronts, and proscenium boxes at either side of the orchestra. The proscenium boxes, however, differ from those at Eszterháza in one important detail: at Bayreuth they are heavily chamfered in plan so that they do not interrupt sightlines to the stage from the side galleries.

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<sup>12</sup> Landon, *Haydn at Eszterháza*, p. 29; *Haydn: a Documentary Study*, New York 1981, pp. 66–67.

<sup>13</sup> Pavel Slavko, *The Castle Theatre in Český Krumlov, Foundation of the Baroque Theatre at the Castle in Český Krumlov*, Český Krumlov 1999.

<sup>14</sup> Klaus-Dieter Reus, *Faszination der Bühne – Barockes Welttheater in Bayreuth*, Gymnasium Christian-Ernestinum, Bayreuth 1999.

The court theatre at Drottningholm, outside of Stockholm, departs from both the hall theatre and Italian public opera house typologies. Built in 1766 for the Swedish Queen Ulrika Lovisa (1720–1782), the architect Carl Fredrick Adelcrantz (1716–1796) created an idiosyncratic design free of galleries or a central royal box. Instead, a steeply raked rear parterre transitions immediately into a sizable balcony, and the royal party typically observes the performance from the front, rather than the rear, of the parterre.<sup>15</sup> Other noticeable departures from Eszterháza include the use of individual music stands in the orchestra, as opposed to a common desk, and the rendering of plastic detail with papier-mâché rather than plaster. Of greatest value to this study is that Drottningholm retains its original stage machinery and sets from the eighteenth century.

So as not to compromise the mystery surrounding stage productions at Eszterháza, details of the opera house stage machinery were not included in the widely-distributed *Beschreibung*. The upper heating plan of the Eszterháza stage (see facsimile 2), however, intended for internal use only, indicates a quick scene-change mechanism of sideways tracking wings and suspended backdrops. Other elements of theatre technology that were standard by the middle of the eighteenth century were a main curtain, vertically rigged borders and harnesses for flying actors, lifts for elevating actors and scenery from below the stage floor, machines for simulating the action of waves, and sound effects devices emulating rain, wind and thunder.

While both Český Krumlov and Drottningholm feature three or four wings per wing alley, facsimile 2 schematically indicates only two sets of wings per alley. Since Pietro Travaglia, the prince's stage designer, submitted an invoice for five sets of scenery for "La fedeltà premiata",<sup>16</sup> it is likely that at least three sets of wings per wing alley would have also been required at Eszterháza in order to affect the necessary scene changes (Act One: Sacred for-

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<sup>15</sup> Stig Fogelmarck, *The Drottningholm Court Theatre*, in: *Gustavian Opera*, Royal Swedish Academy of Music, Stockholm 1991, pp. 79–86. The earlier "Comedien-Haus" at Drottningholm, designed in 1754 by the Bavarian Georg Greggenhoffer (ca. 1719–1779), followed the same hall theatre pattern as Český Krumlov and Eszterháza.

<sup>16</sup> Landon, *Haydn at Eszterháza*, p. 428.

est, Garden, Grove; Act Two: Dark forest, Grove, Mountainous terrain, Mouth of a cave; Act Three: Atrium, Landscape including a lake, Small grotto, Magnificent temple).

Additional scenic elements, supernumeraries, properties, and special effects were in abundance on the Eszterháza stage. In the case of "La fedeltà premiata", altars strewn with flowers, sacred fires, an inscribed marble slab, nymphs, turtle doves in a basket, a seashell, shepherds with their sheep, an arrow, hunters and huntresses, hunting horns, weapons, wild animals, satyrs, a cart, white robes, garlands, lightning, a sea monster, followers of the goddess Diana, and a golden heart supported the main characters and helped create a sense of place.

### COMPUTER MODELING

Three-dimensional modeling of the second Eszterháza opera house enables us to study the interaction between musical sounds and the geometrical boundaries of the opera house interior.

In an effort to reproduce important details of the historical longitudinal section of the opera house (see facsimile 1/3, "Profil nach der Länge"), a computer model in section (see figure 1) depicts a sloped stage complete with scenic elements including a backdrop, borders and sliding wings. Moving from the stage to the princely box (left to right), the model indicates the projecting geometry of the proscenium soffit and outlines the proscenium boxes and door and windows openings in the sidewalls, the expanse of the audience chamber ceiling, and the elevated position of the princely box opposite the stage.

Based on the historical upper plan of the heating system (see facsimile 2), the plan view of the computer model (see figure 2) further clarifies the extent of the backdrop and wings onstage, the proscenium boxes at either side of the orchestra, the extent of the side galleries, the depth of door and window openings, the underlying curvilinear shape of the audience chamber, and the generosity of the princely box.

The modeling process was complicated by the fact that the Fernstein drawings do not include a reflected ceiling plan. As a result, discrepancies between the plan and sections, especially at the princely and proscenium boxes, could not be reconciled. Furthermore, the acoustical modeling technique required that curved

surfaces be approximated by a series of flat planes. Since many small planes would have increased computation time and would have compounded errors in the final result, this model did not investigate the multiple convexities of the ceiling and upper walls.

After the section and plan views are combined and rotated in space, we begin to develop a three-dimensional understanding of the geometry of the opera house. A perspective view<sup>17</sup> (see figure 3) enables us to trace paths of direct and reflected sound from an onstage singer to the princely box. Other views of the model allow us to see how sound moves through the opera house over time.

Figure 4 illustrates in section a sphere of sound energy radiating in all directions from the head of an onstage singer. Within 8ms after starting to sing, the stage floor is reflecting the singer's sound. After 22ms, the voice of the singer interacts with the proscenium soffit, and the scenic elements begin to create a complex pattern of reflections onstage (see figure 5). The direct sound of the singer reaches the prince within 56ms and is then followed with reflected sound from the audience chamber floor and ceiling, the stage floor, and, after 104ms, even from the upstage backdrop. 128ms after the sound has first left the singer's mouth, his sound has returned to him after making a roundtrip journey to the far reaches of the audience chamber and back. By 150ms, this reflected energy is behind him at the upstage backdrop.

But what does a time period of 150ms mean to a musician? In the case of a metronome tempo of MM 200, the quarter note has a length of 300ms and the eighth note a length of 150ms. That means that a singer at Eszterháza performing a series of eighth notes, even in "tempo presto", heard each note he had sung returning back to him from the room before singing the next. Such feedback would have reduced vocal fatigue and would have encouraged the performer to experiment with subtleties in dynamics, phrasing and inflection.

An examination of the reflections in plan view during the same 150ms time period indicates that the proscenium shaping helps compensate for the shadowing proscenium boxes by first sending

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<sup>17</sup> Edward McCue, *The Second Opera House at Eszterháza*, in: *Early Music Colorado Quarterly*, vol. 12/2 (2002), pp. 4–8.

energy onto the opposite sidewalls. That energy is subsequently reflected towards the princely box, resulting in a widening of the aural image and greater loudness at that location. Simultaneously, the singer onstage receives strong reflections from the stage sidewalls and backdrop (see figure 6).

The plan view of the model also demonstrates the tendency of the concave geometry at the rear of the audience chamber to focus sound into the princely box (see figure 7). In reverse, this same geometry would have enabled the prince's voice to be easily heard onstage.

### ABSORPTIVITY OF MATERIALS

Another dimension of this room acoustics investigation reveals how sounds are "colored" through interactions with the construction materials used to build the room envelope, room finishes and furnishings. Figure 8 displays the tendency of selected materials to absorb sound energy within the audible spectrum.

The modern piano keyboard at the bottom of figure 8 reminds the musician that a frequency of 440Hz corresponds to the pitch a' of our equally tempered scale. That pitch falls within the octave band centered at 500Hz. The lowest pitch that could be produced by the five-string contrabass used in Haydn's orchestra at Eszterháza<sup>18</sup> was at the bottom of the 63Hz octave band.

The legend at the top of figure 8 indicates that shades of gray represent five degrees to which materials can impact musical sounds. A solid black band indicates almost total absorption of sound in an octave band, and a light gray band denotes very little absorption, or nearly complete reflection, of sound by a material.

Although audible sound energy in the 8,000Hz and 16,000Hz octave bands is not depicted on this graph, the impact that a material has on energy in those octaves is usually similar to the effect it has on energy in the 4,000Hz octave band.

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<sup>18</sup> Adolf Meier, *Konzertante Musik für Kontrabass in der Wiener Klassik* (Schriften zur Musik, vol. 4), Munich and Salzburg 1979.

Therefore, as the lightest shade of gray throughout the spectrum indicates, masonry, or masonry with plaster applied directly to it, does not readily absorb musical sounds at any pitch.

At Český Krumlov, the rake of the stage is not so great that good sightlines to the stage can be maintained when chairs are set up on the flat-floor parterre. Instead, rows of benches are successively elevated so that all members of the audience can view the stage and, as a result, more clearly hear the singers. It is reasonable to assume that the rows of benches at Eszterháza were similarly elevated, but we do not have concrete evidence of such an arrangement.

When sound energy grazes across occupied banks of such seating, however, it is readily absorbed, especially in the higher octave bands.

The unoccupied benches at Český Krumlov are probably less absorptive than the ones at Eszterháza because those were upholstered with cowhair and fabric;<sup>19</sup> therefore, it is possible that the padded benches at Drottningholm display acoustical characteristics similar to the unoccupied ones at Eszterháza. In either case, though, when occupied, the benches at Český Krumlov and Drottningholm probably behave very similarly to the occupied benches at Eszterháza.

The princely box at Český Krumlov includes the kind of fabric hangings that would have attenuated high-frequency sound at the rear of the audience chamber at Eszterháza. On the other hand, the thin wood paneling that surrounds the princely box at Český Krumlov, which has an absorptive effect on the sounds produced by the bass voices and instruments, was absent at Eszterháza. Also, the gallery and box railings at Eszterháza were open balustrades, in contrast to the sound obstructing wooden barriers seen at Český Krumlov.

Situated at 48 degrees North latitude, Eszterháza saw sunsets around 8:00 p.m. during the summer. Since performances in the opera house typically began at 6:00 p.m., a dependable method of daylight control was required in order for the theatrical lighting systems to make magic; therefore, the blind windows,

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<sup>19</sup> Landon, Haydn at Eszterháza, p. 427.

possibly in conjunction with other light control devices, must have been capable of preventing the intrusion of daylight.

Contemporary descriptions of the opera house do not mention interior window coverings. At the palace at Eszterháza, French doors and windows are fitted with two independent, glazed sashes and two sets of shutters, one at the room interior and another at the building exterior. Similar assemblies may have been employed at the opera house to control the infiltration of light, air and noise. In any case, the doors and windows at the sides of the opera house would have absorbed a portion of low-frequency sounds and reflected high-frequency sounds.

The sliding wings at Eszterháza were probably constructed in a manner similar to the stretched canvas techniques employed at Český Krumlov and Drottningholm. Somewhat absorptive at low frequencies and highly reflective at high frequencies, the acoustical behavior of these scenic elements is completely different from the highly absorptive velour softgoods commonly used to mask stages today.

The stage ceiling grid at Český Krumlov, with wide gaps between the boards, suggests that much of the energy radiating upward from a singer at Eszterháza was lost to the attic volume above the stage.

Even paintings, mirrors, and furniture affect the timbre of musical sounds by absorbing sound energy to varying degrees. This causes us to recall the contemporary descriptions of the elaborate finishes and furnishings in the princely box at the rear of the Eszterháza opera house.

The view towards the princely box (see facsimile 1/4, "Profil gegen die Fürstl. Haupt-Loge") poses an important question to architecture historians: Was the ornate decoration at the ceiling cove rendered in three dimensions with molded plaster or as painted "trompe l'oeil," as at Český Krumlov and Drottningholm? From an acoustics point of view, applied plaster shaping that scattered high frequency sounds would have supplemented the tightly radiused cove in reducing the strength of reflections back to the stage from the upper rear corner of the audience chamber. Prima-

ry sources describing the extensive plasterwork, painting and gilding are identified by János Harich.<sup>20</sup>

The sound-reflecting characteristics of the audience chamber ceiling are also important when considering the view towards the stage (see facsimile 1/5, "Profil gegen das Theater"). Sound-diffusing ornamentation above the orchestra would have reduced the strength of ceiling reflections, thereby sparing the musicians the confusion of strong, late-arriving sound images of instruments arriving from overhead.

The view towards the stage also emphasizes that the architecture of the Eszterháza opera house favored the prince in every respect. With his eyes nearly level with the vanishing point defined by the raked stage and the progressively diminishing wings and borders, he enjoyed the ideal illusion of central perspective. Playing a scene far upstage would have upset the forced perspective unless proportionately shorter actors were employed. In the case of "La fedeltà premiata", however, intentional upstage placement of the lake in Act Three would have maximized the dramatic impact of the sea monster's entrance.

Simultaneously, a convergence of reflected sound energy paths from the raked stage, the broad central aisle between the parterre benches, the ceiling, and the audience chamber sidewalls followed the direct sound from the stage such that onstage voices were amplified in the princely box. The prince's theatrical experience was, therefore, much larger than life.

But then, from the point of view of Prince Esterházy's servants and guests, His Serene Highness's satisfaction was their reward. Should the prince have wished to speak or applaud during the course of the performance, his opinion would have been clearly audible onstage, in the orchestra, and throughout the audience chamber. Undoubtedly, the gallery and proscenium box occupants kept one eye on the stage and the other on the prince so that they, too, might reflect his level of satisfaction.

Thus, the prince presided over the opera house as a symbolic "conductor" of the performances. From the balcony of the palace, the prince commanded a view of his domain, not only the

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<sup>20</sup> János Harich, Haydn Documenta (II), in: Das Haydn Jahrbuch, vol. 3 (1965), pp. 122-152.

geometric patterns of the park, but also the church steeples of the neighboring villages, which were visible at the vanishing points of the allées. The princely theater box likewise provided a view of the stage, but rather than gazing at a landscape of cultivated nature, the prince could observe a cultured view of human nature.<sup>21</sup>

It is now time to turn our attention to the performers' points of view.

### THE ORCHESTRA

The orchestra at Eszterháza occupied the space between the proscenium boxes where the audience chamber met the stage. Seated on benches on either side of a long, two-sided music desk,<sup>22</sup> as at Český Krumlov, the musicians stretched across the width of the stage and were partially hidden from the parterre audience's view by a low wall.

The overture to "La fedeltà premiata" requires an orchestra consisting of a flute, two oboes, at least one bassoon, a pair of trumpets assisting a pair of horns, a pair of timpani, two sections of violins, an independent part for the violas, and according to the performance practice of the time, a continuo line to be shared among a contrabass, violoncelli, possibly a second bassoon, and a keyboard instrument. A harpsichord would normally be assumed to be the keyboard instrument from which Haydn led the orchestra and singers, but records show that Anton Walter (1752–1826), the Vienna fortepiano manufacturer, repaired both harpsichords and fortepianos at Eszterháza just before the opening of the second opera house.<sup>23</sup>

In order to determine how many musicians were available at Eszterháza to play each part, we consult the January 1781 orchestra payroll: nine violin and viola players, two violoncellists, one contrabassist, one flutist, three oboists, three bassoonists, and five

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<sup>21</sup> Rebecca Green, *Representing the Aristocracy: The Operatic Haydn and "Le pescatrici"*, in: *Haydn and His World*, Princeton 1997, p. 158.

<sup>22</sup> Landon, *Haydn at Eszterháza*, p. 427.

<sup>23</sup> Landon, *Haydn at Eszterháza*, p. 445.

hornists. The names of trumpeters and timpanists are not recorded.<sup>24</sup>

A proposal for the layout of this orchestra (see figure 9) collects the continuo instruments at one end of the desk so that several players can read off the keyboardist's score. The violin and viola sections play opposite each other across the desk. In order to enhance their audibility, the woodwinds and bells of the horns face the audience. Space constraints relegate the trumpets and timpani to the free end of the desk and the antechamber beyond. Such a layout would work well for an orchestra of instruments from Haydn's time, but another arrangement would probably need to be pursued if modern wind instruments were employed.

The raked stage floor and projecting proscenium geometry at Eszterháza encouraged visual and aural contact between the singers and orchestra musicians, especially the first violinist, the continuo violoncellist, and Haydn at the keyboard.

#### REVERBERATION

The room acoustical phenomenon known as "reverberation" refers to that portion of a musical sound, near the end of its "life," that has been reflected many times over. In spite of what musical notation might suggest, musical sounds in a room do not end abruptly. Instead, the acoustical environment, defined by the architecture of the room, causes the sounds to linger. Even after an orchestra has stopped playing, the architecture continues to repeatedly reflect the sound energy until it has been so thoroughly diminished through absorption that it is no longer audible. This is not to say, however, that reverberation occurs only at the end of a piece of music; reverberation is at work as soon as any sound is made in a room.

Reverberation varies with changes in the quantity and distribution of sound-absorbing surfaces in a room. Greater total absorption results in reduced reverberation. Reverberation is also a function of the geometrical volume of a room. A larger room with

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<sup>24</sup> Dénes Bartha and László Somfai, *Haydn als Opernkapellmeister*, Budapest 1960, pp. 48–49.

the same quantity of absorption as a smaller room is more reverberant than the smaller room.

When performing indoors, musicians must consider reverberation as it affects the clarity, loudness and “envelopment” of musical sounds.

## REVERBERATION TIMES

We have already seen that the geometry of a room defines the reflection sequence of sounds and that the timbres of musical sounds are altered with each reflection. As a result, reverberation is not constant across the audible spectrum. Musical sounds reverberate in a room according to their harmonic content and loudness in each octave band.

Reverberation in the various musical octaves is described by comparing their reverberation times. For the purposes of this investigation, we define “reverberation time” to be the time period required for a very loud sound to decay to inaudibility.

The computer model described earlier can also be used to calculate reverberation times. Figure 10 indicates the changes in reverberation times between the sparsely occupied and fully occupied states of the opera house at Eszterháza. With a larger audience, the reverberation times fell at higher frequencies, but the reverberation time in the 125Hz octave band remained constant.

Figure 8 describing the acoustical absorptivity of materials indicates that there is little change in the absorptivity of benches at low frequencies when they are occupied. Some wooden floors, however, become less absorptive when they are loaded by the weight of an audience. Therefore, the reverberation times at low frequencies at the Eszterháza opera house may have slightly increased when the benches were fully occupied if the parterre floor consisted of wooden floorboards on joists.

Figure 11 compares the sparsely occupied and fully occupied reverberation times at Eszterháza with the unoccupied conditions at Český Krumlov,<sup>25</sup> Bayreuth and Drottningholm.<sup>26</sup> Bayreuth

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<sup>25</sup> Studio D Acoustics Laboratory, Český Budějovice, Czech Republic. Measured 2 December 1998. Courtesy of Dr. Pavel Slavko.

and Drottningholm display “haystack” curves characterized by shorter unoccupied reverberation times at both the highest and lowest octave bands. Český Krumlov, however, departs from this trend in the 63Hz octave band. This rise is at least partially due to the replacement of the wooden floorboards with tiles during a twentieth century renovation. Another likely contributor to this phenomenon at Český Krumlov is the expanse of unencumbered upper sidewalls, although their absorptivity has not been adequately studied to be certain of their contribution to the boost in bass reverberation.

Unfortunately, our lack of specific knowledge concerning the nature of the parterre flooring at Eszterháza prevents us from calculating the reverberation time in the 63Hz octave band with certainty; however, the extensive low-frequency absorption provided by the sidewall doors and windows suggests that a rise in the contrabass octave was probably not a characteristic of the acoustics at Eszterháza.

What is certain, though, is that even the fully occupied opera house at Eszterháza was more reverberant than the unoccupied Drottningholm or Bayreuth opera houses at pitches below *c*” (500Hz). Therefore, the three historical theatres studied here should not be thought to be representative of the acoustical environment for which Haydn wrote his operas.

Longer reverberation times, however, can diminish the intelligibility of spoken and sung texts. Therefore, when the theatre at Eszterháza was only sparsely occupied, actors were likely to have reduced the speed of their delivery. Similarly, opera singers probably sang their recitatives more slowly during rehearsals than during fully occupied performances.

The computer model also indicates that the intelligibility of texts was maximized when the singers and actors stood downstage and addressed the audience head-on. Facing cross stage or upstage caused a loss of articulation in the consonants because the regularly spaced wings and borders interacted unfavorably among themselves and with the upstage backdrop. The timbre of vowel sounds was also affected when facing cross stage or upstage, but

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<sup>26</sup> Swedish Radio, Stockholm. See Meyer, *Akustik und musikalische Aufführungspraxis*, p. 185.

such timbre changes may have been useful when delivering an aside or when the illusion of great distance was desired.

#### COMPARISON WITH OTHER "HAYDN HALLS"

Those who have attended performances in the important Haydn halls still in existence can extrapolate those experiences into a preliminary understanding of the architecture and acoustics of the second opera house at Eszterháza.

The ground floor "sala terrena" and its antechamber in the palace at Eszterháza, as well as the similarly sized ceremonial hall (often referred to as the "Prunksaal") and dining room just above on the first floor, were regularly used for musical performances. While the rooms were significantly narrower than the opera house (see figure 12), their combined length, including the porch leading to the staircase down to the "cour d'honneur" and the balcony overlooking the garden, was similar to that of the audience chamber and the stagehouse of the opera house. The ceremonial hall can claim only a 10m ceiling height, as compared to the 12m height of the opera house, but the composition of three doors topped by three windows featured in the ceremonial hall was also found in the opera house.

Of even greater interest is the remarkable coincidence that the length, width and height of the Haydnsaal at the Esterházy palace in Eisenstadt are nearly identical with the same dimensions of the combined audience chamber and stagehouse of the second opera house at Eszterháza (see figure 13). One can use a photograph of the Haydnsaal (see appendix to this essay) to estimate the height of the side galleries of the opera house to be in line with the tops of the door openings along the Haydnsaal sidewall. As a result, the monumental height of the Eszterháza opera house can be easily imagined.

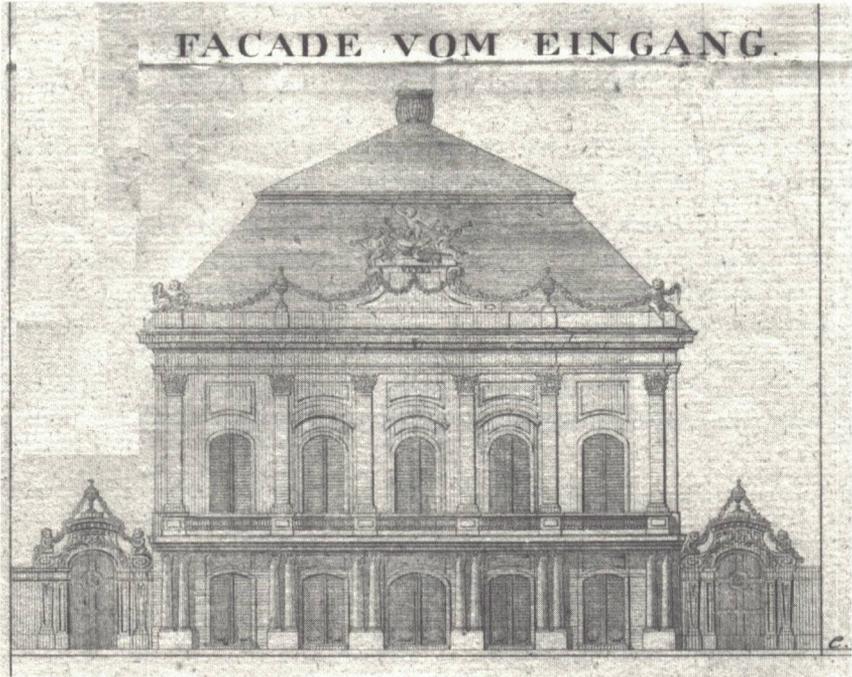
A comparison of the unoccupied reverberation times of the sparsely occupied opera house with the Haydnsaal and the ceremonial hall suggests more differences among the three spaces than similarities (see figure 14). Occupied reverberation times, however, better conform to theoretical expectations (see figure 15). The Haydnsaal, the largest of the three listening environments, shows a classic concert hall reverberation time curve with a steady increase in the octave bands below 500Hz. A proportionately larger occupiable floor area and dramatically smaller volume give

the ceremonial hall a different shape of reverberation time curve. It displays, in the 500Hz octave band and above, much shorter occupied reverberation times, and an even steeper rise in the lower octave bands, than the Haydnsaal.

The audience chamber and stagehouse of the opera house, with a combined volume similar to that of the Haydnsaal, were, on average, constructed from materials that were more sound absorbing than those used to build and furnish the Haydnsaal. As a result, the opera house reverberation times were far below those of the Haydnsaal; however, even when fully occupied, the opera house at Eszterháza featured some of the low-frequency “warmth” that today we associate with the acoustics of a good concert hall.

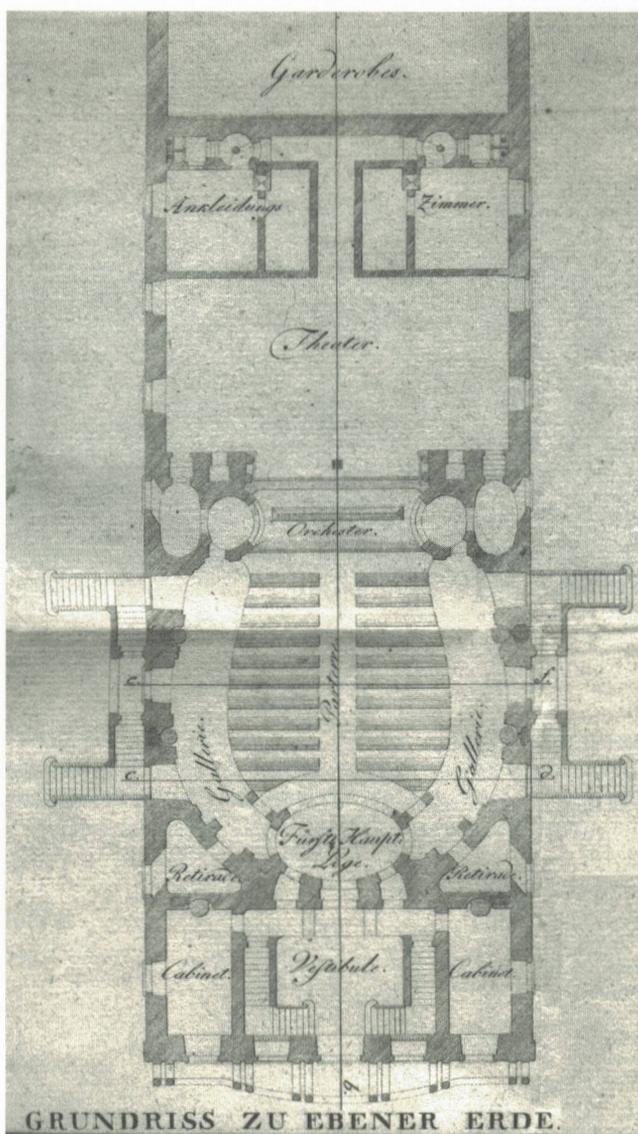
The relatively reverberant environment at the second opera house at Eszterháza expanded Haydn’s opportunities for dynamic contrast and spaciousness in his scoring, and, as a result, his small orchestra was capable of making great dramatic impact. Similarly, the acoustical response of the theatre provided a lively sense of room support for Haydn’s singers and thereby eased the physical strain of performing lengthy operas several times a week.

Facsimile 1/1:



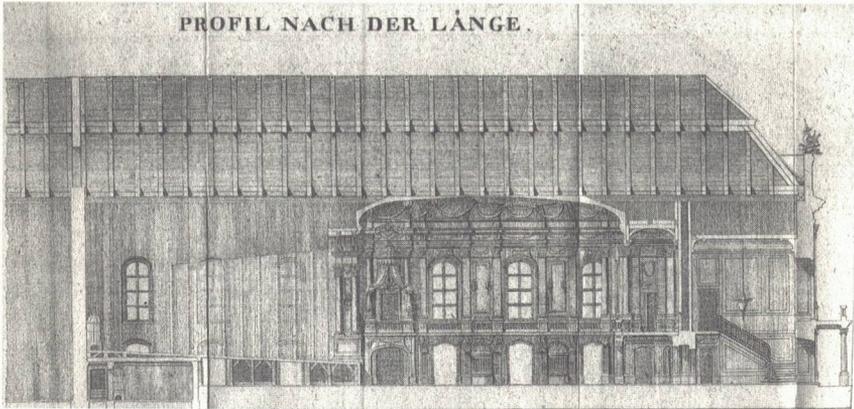
*Portion of engraving "Fürstl. Opernhaus zu Esterházy", in:  
Beschreibung des Hochfürstlichen Schlosses Esterházy im Königreiche  
Ungern, Pressburg 1784 (Eisenstadt, Burgenländisches  
Landesmuseum – Haydnhaus, BLM 58.185)*

Facsimile 1/2:



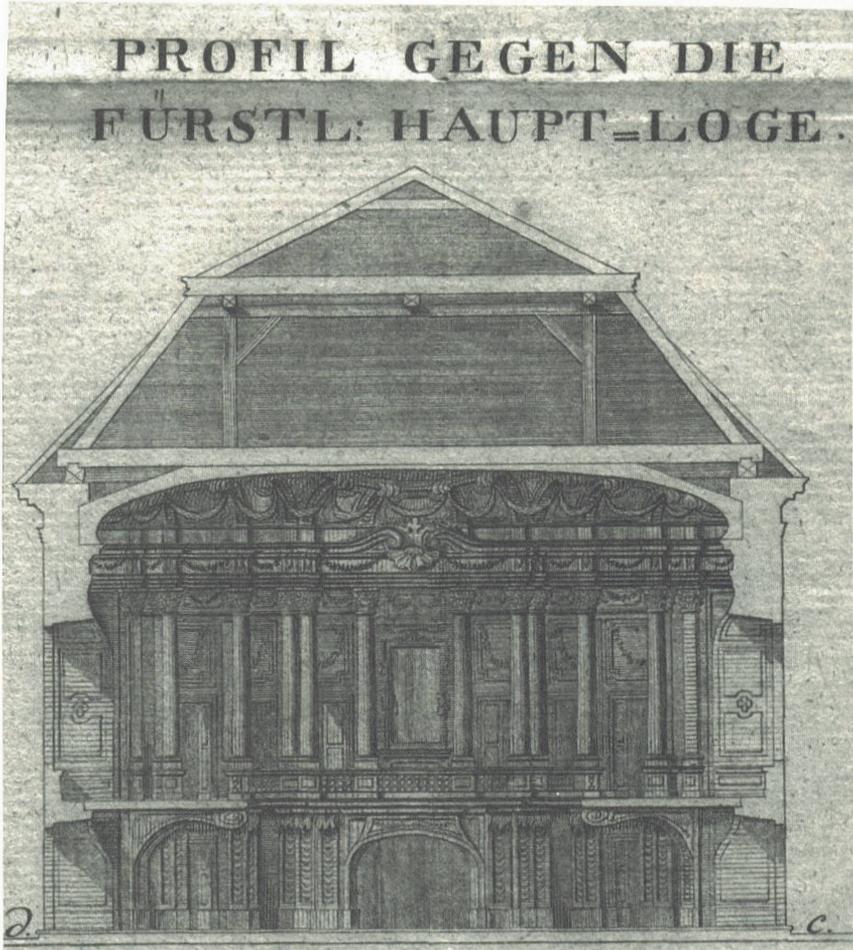
Portion of engraving "Fürstl. Opernhaus zu Esterházy", in:  
*Beschreibung des Hochfürstlichen Schlosses Esterházy im Königreiche  
Ungern, Pressburg 1784 (Eisenstadt, Burgenländisches  
Landesmuseum – Haydnhaus, BLM 58.185)*

Facsimile 1/3:



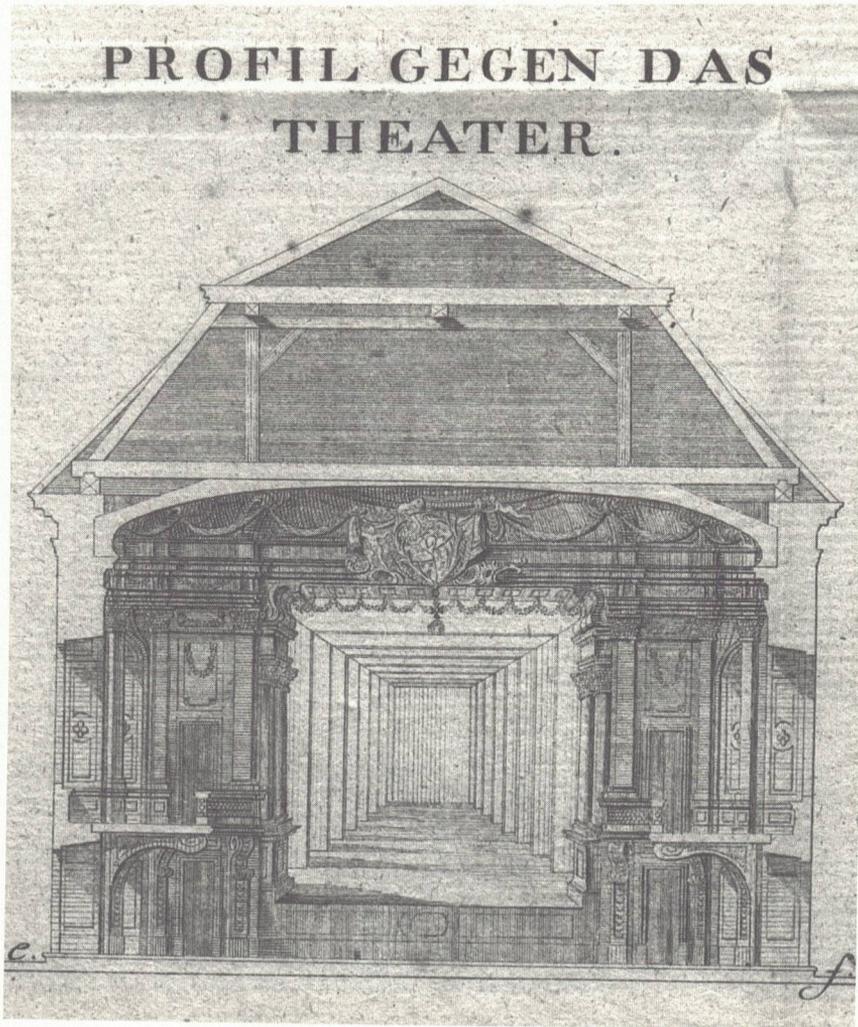
*Portion of engraving "Fürstl. Opernhaus zu Esterházy", in:  
Beschreibung des Hochfürstlichen Schlosses Esterházy im Königreiche  
Ungern, Pressburg 1784 (Eisenstadt, Burgenländisches  
Landesmuseum – Haydnhaus, BLM 58.185)*

Facsimile 1/4:



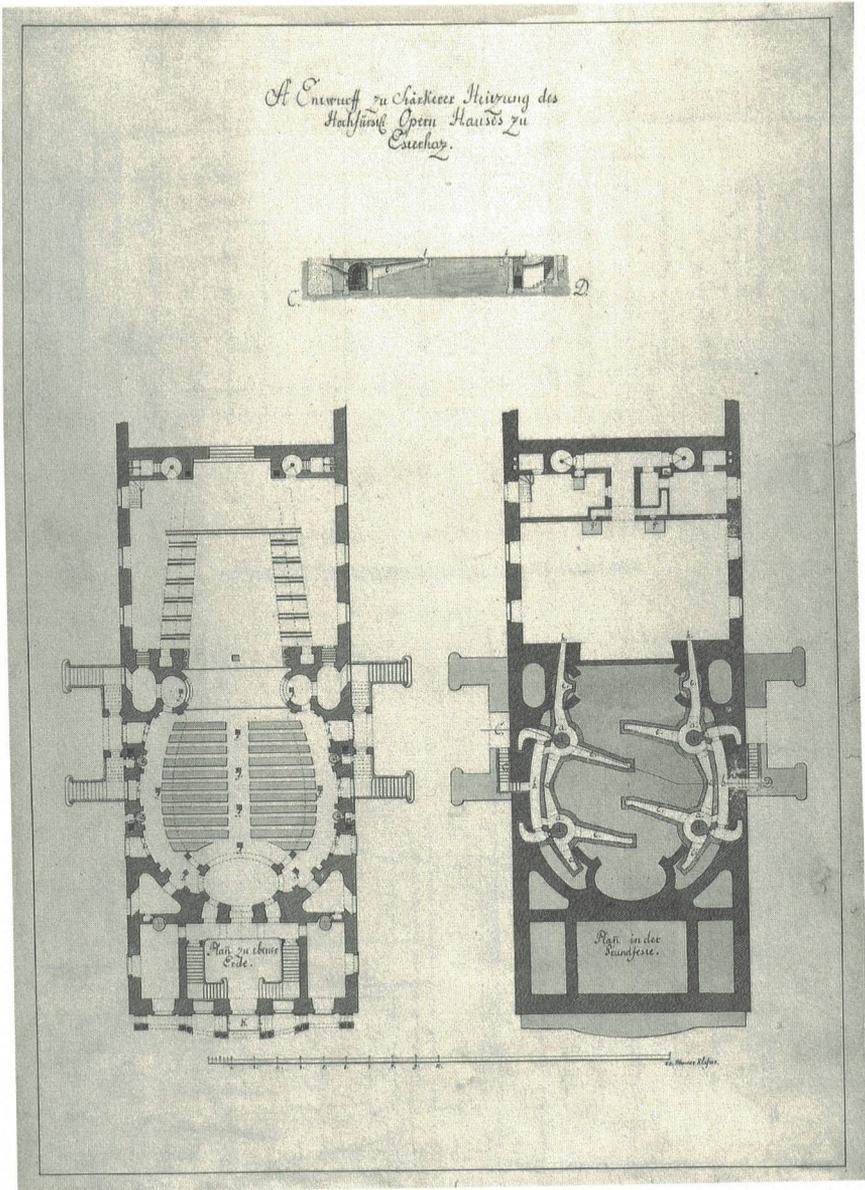
*Portion of engraving "Fürstl. Opernhaus zu Esterházy", in:  
Beschreibung des Hochfürstlichen Schlosses Esterházy im Königreiche  
Ungern, Pressburg 1784 (Eisenstadt, Burgenländisches  
Landesmuseum – Haydnhaus, BLM 58.185)*

Facsimile 1/5:



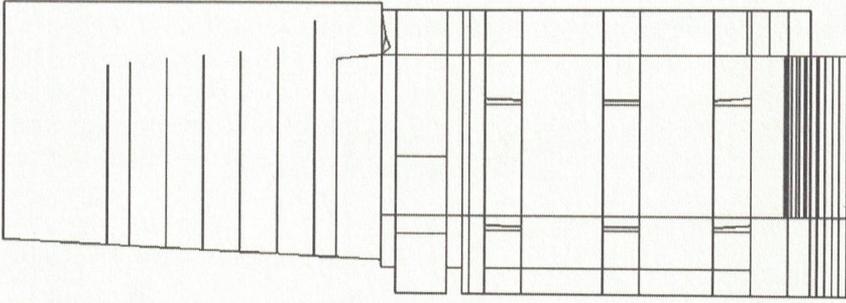
*Portion of engraving "Fürstl. Opernhaus zu Esterházy", in:  
Beschreibung des Hochfürstlichen Schlosses Esterházy im Königreiche  
Ungern, Pressburg 1784 (Eisenstadt, Burgenländisches  
Landesmuseum – Haydnhaus, BLM 58.185)*

Facsimile 2:



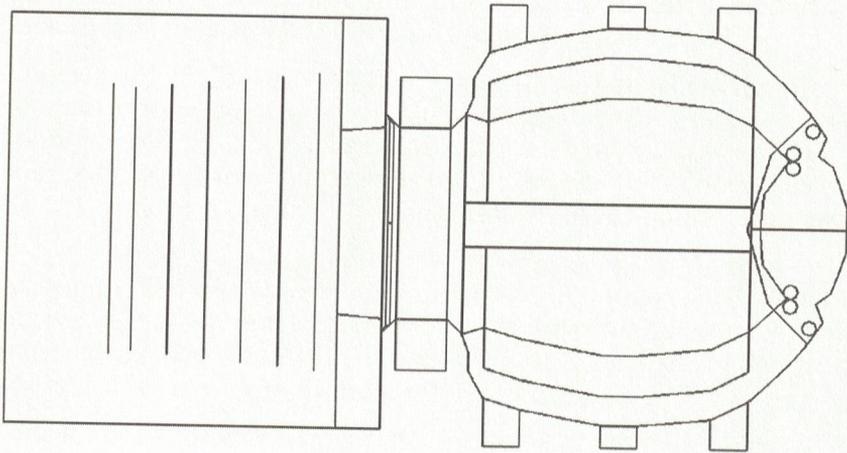
*"Entwurf zu stärkerer Heizung des Hochfürstl. Opern Hauses zu Eszterhaz". (Budapest, Hungarian National Archives, Collection of Maps and Plans, T 2, hg. Esterházy család, 1222; see Horányi, ill. 22) Courtesy of János Malina.*

Figure 1:



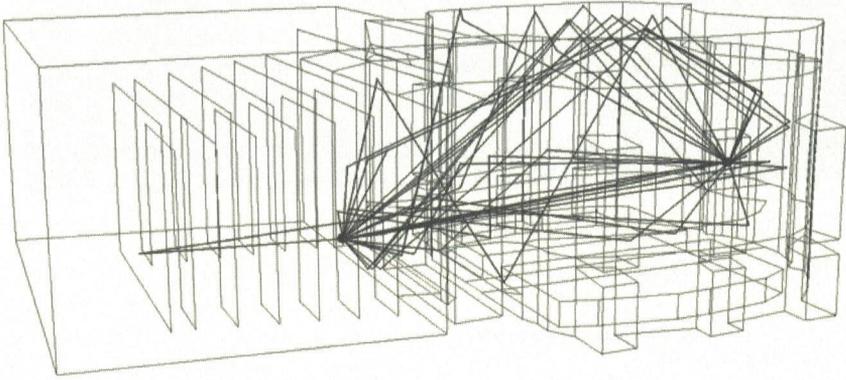
*Section view of a computer model.*

Figure 2:



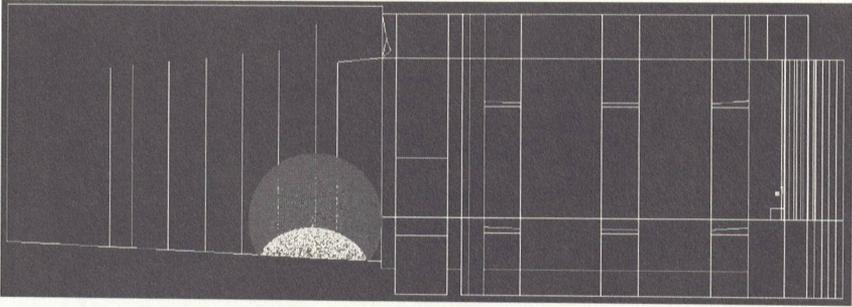
*Plan view of a computer model.*

Figure 3:



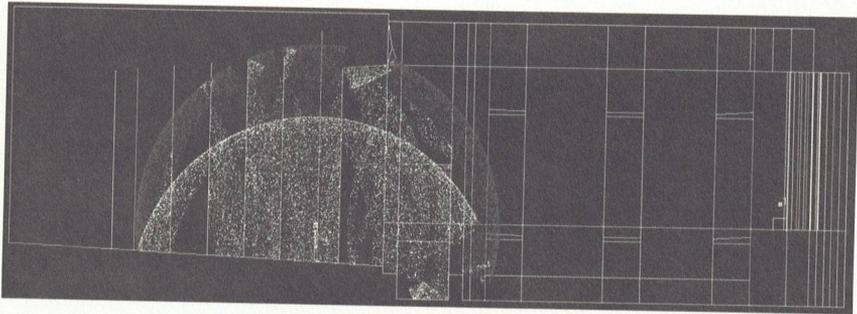
*Perspective view of a computer model including paths of direct and reflected sound energy.*

Figure 4:



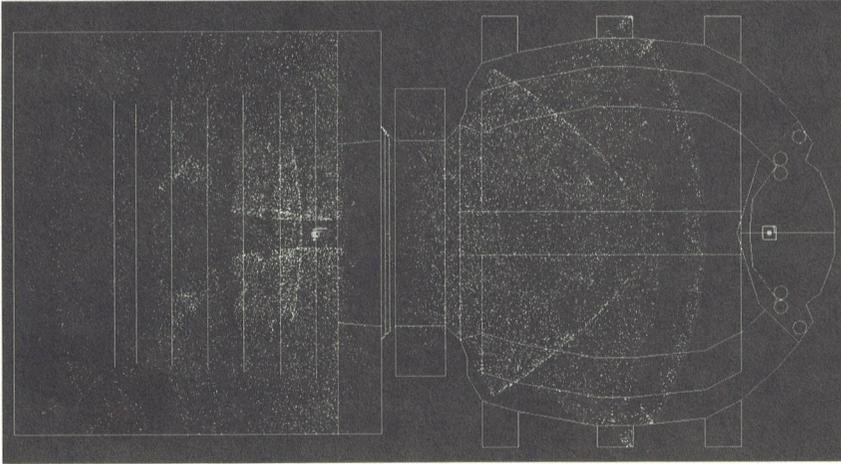
*Sound energy from a singer after 8ms.*

Figure 5:



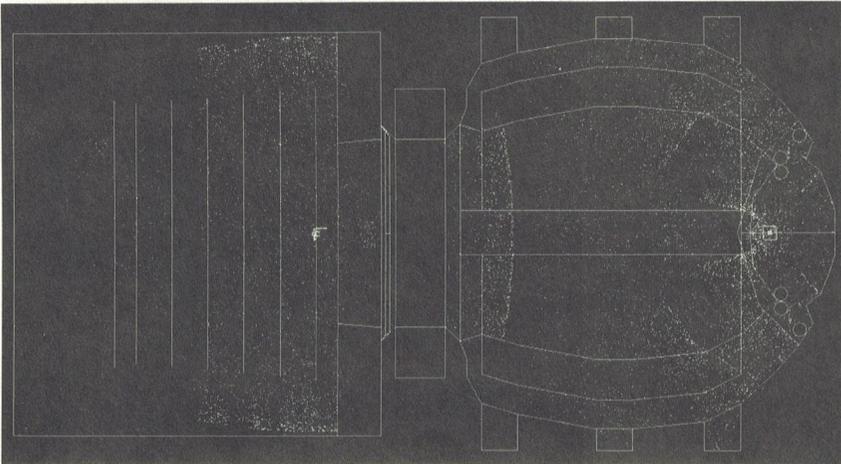
*Sound energy from a singer after 22ms.*

Figure 6:



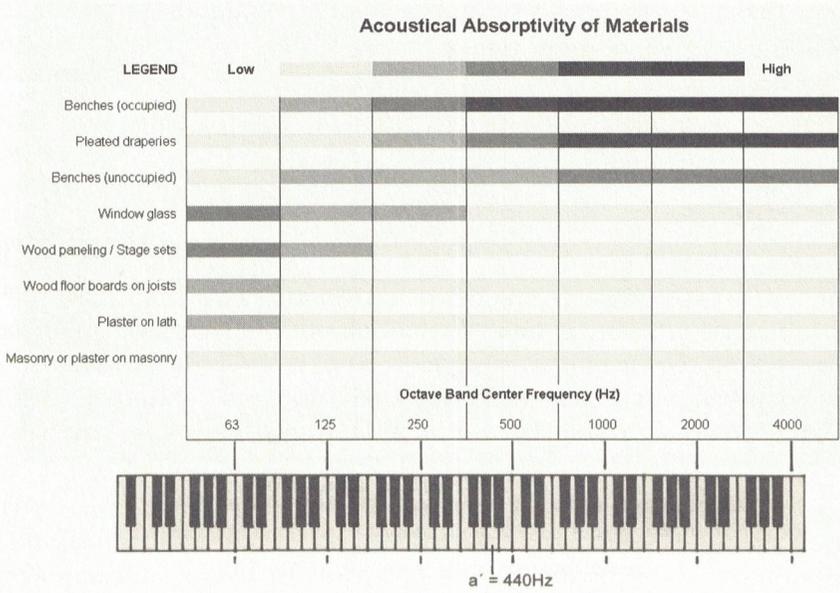
*Sound energy from a singer after 48ms.*

Figure 7:



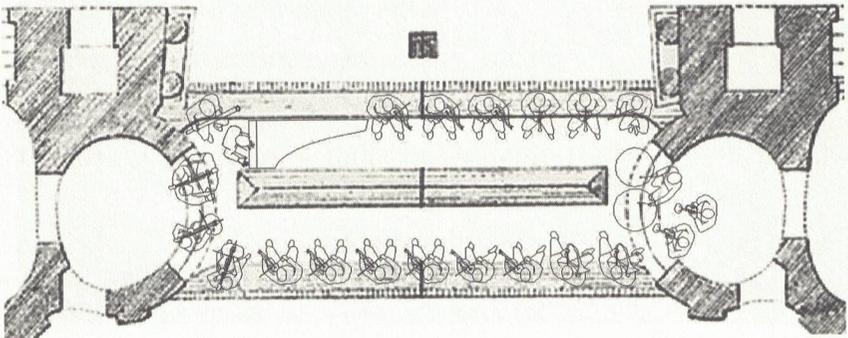
*Sound energy from a singer after 74ms.*

Figure 8:



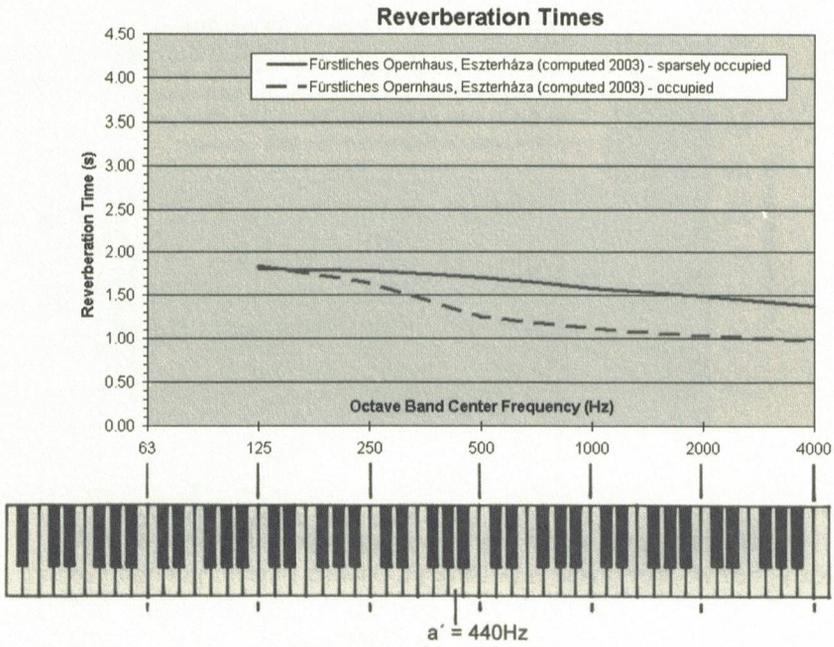
*Relative acoustical absorptivity of construction materials, room finishes and furnishings.*

Figure 9:



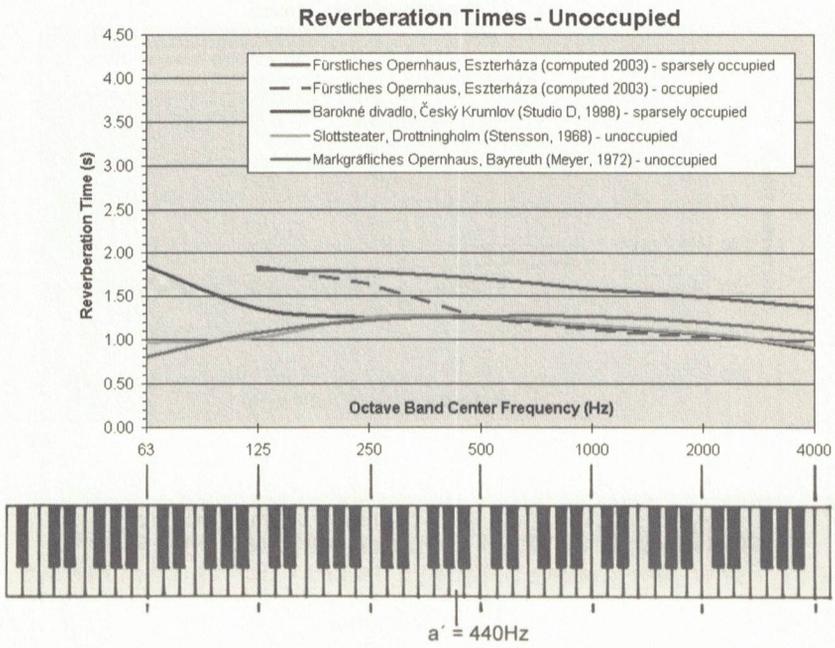
*Proposed layout for the orchestra for "La fedeltà premiata".*

Figure 10:



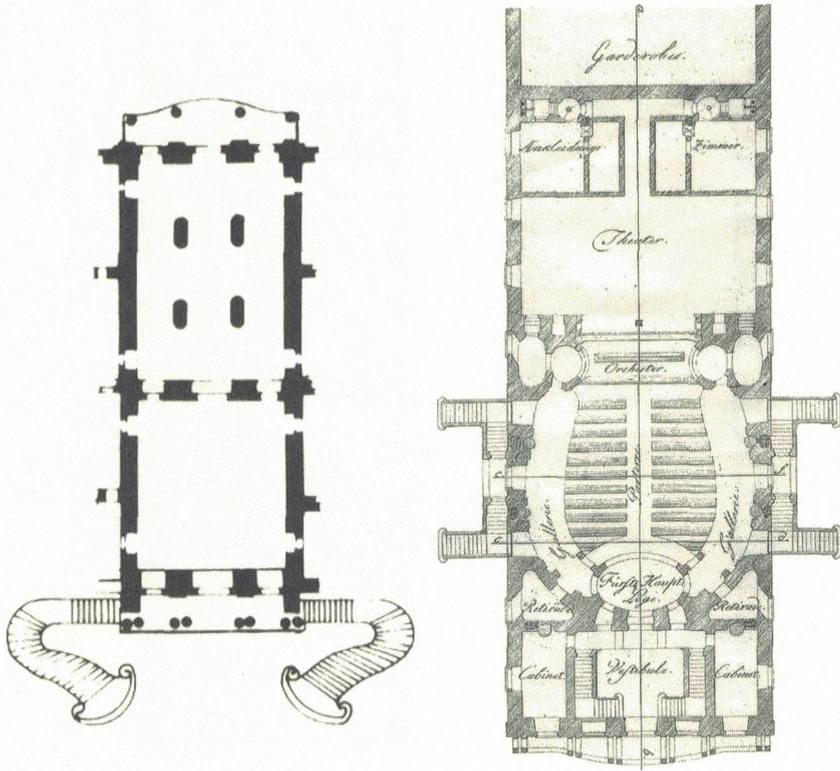
*Reverberation times of the sparsely and fully occupied opera house at Eszterháza.*

Figure 11:



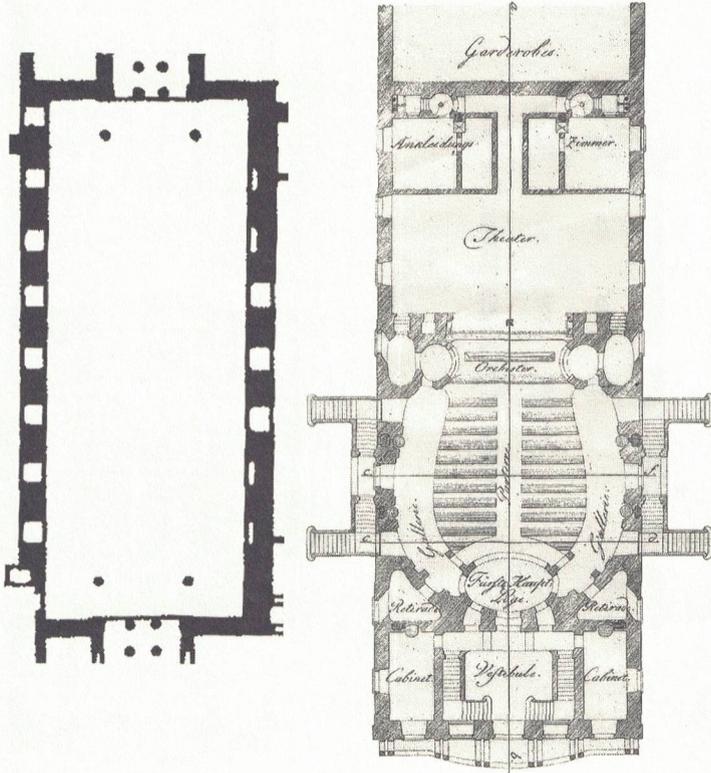
*Reverberation times of the opera house at Eszterháza compared with other opera houses.*

Figure 12:



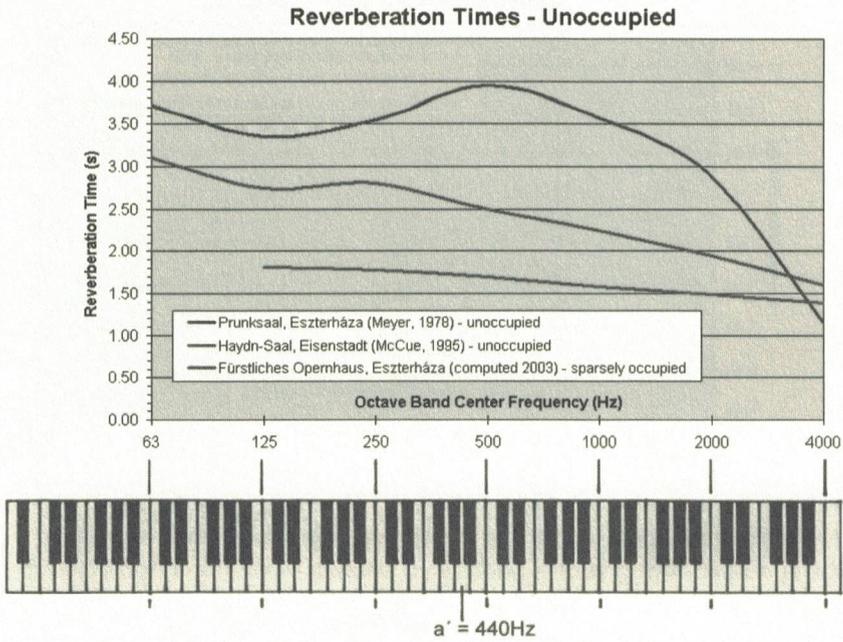
*Plan of the opera house compared with the  
"sala terrena" and its antechamber.*

Figure 13:



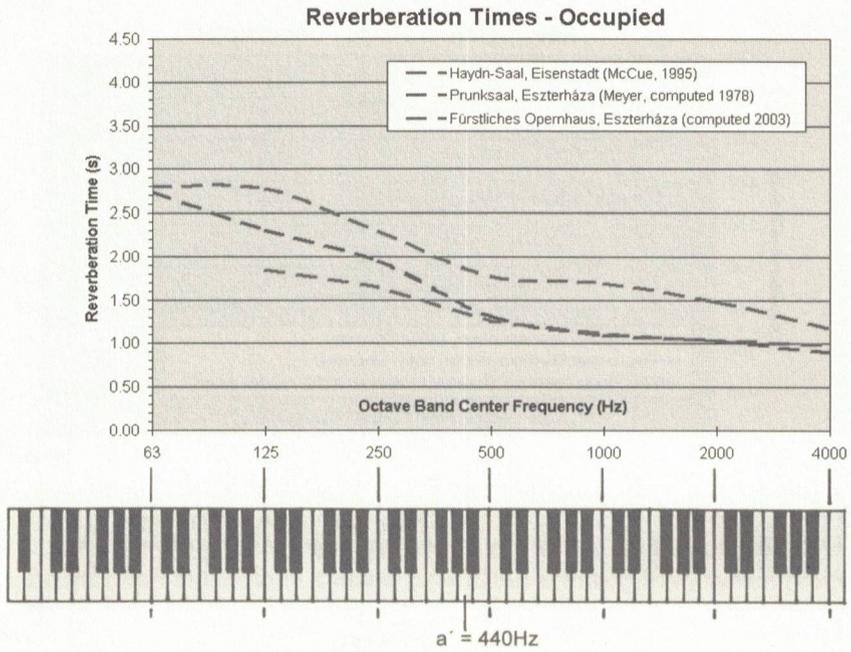
*Plan of the opera house compared with the Haydnssaal.*

Figure 14:



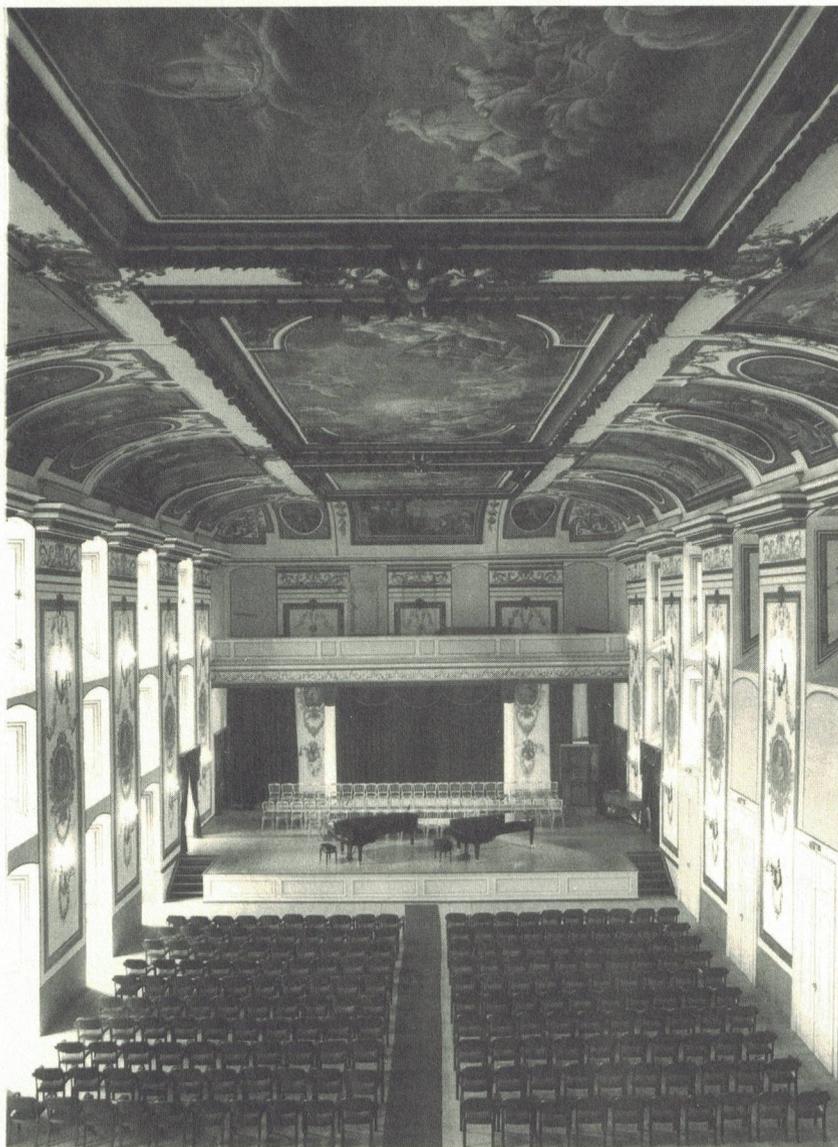
*Reverberation times of the sparsely occupied opera house compared with the unoccupied ceremonial hall and Haydn-saal.*

Figure 15:



*Reverberation times of the fully occupied opera house compared with the occupied ceremonial ball and Haydn-saal.*

Photograph:



*Haydnsaal at the Esterházy Palace in Eisenstadt.  
Courtesy of Haydn Festival Eisenstadt.*



## **Referenten**

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