

02 CADoP Papers

Computer Aided
Deconstruction of Perspectives

Las Meninas, Velázquez and the camera obscura



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Summary

This research follows a suggestion by John Moffit: to analyse *Las Meninas* with computer-assisted drawing. This analysis has led to a new interpretation of the process of creating the painting. This article presents graphic and geometric evidence that Velázquez used a camera obscura to paint *Las Meninas*. We also clarify here the relationship between *Las Meninas* in the Prado and the Kingston Lacy painting in Dorset. The perspective and general lines of the latter painting were drawn by Velázquez using a camera obscura of the cabin type. Later, after some modification and reversing the operation of the camera - lighting the interior and darkening the room - Velázquez projected the small painting onto the blank canvas of the large one and traced the general lines of that painting following the projection. He then completed the large painting. Finally, he commissioned his son-in-law, Juan Bautista Martínez del Mazo, to copy the figures of the large painting onto the small one, and they sold it. In this painting, the kings are not reflected in the mirror in the background.

Key words

Computer-assisted perspective deconstruction, perspective restitution, camera obscura, Velázquez, *Las Meninas*.

Credits

(WARNING: At some points, this writing inevitably becomes complex and abstruse. We have taken care to footnote these passages - with others that are not essential to a general understanding of the text. People not interested in the technical issues of perspective deconstruction can dispense with reading the footnotes and be guided by the images).

Las Meninas, Velázquez and the camera obscura.

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Text and drawings by the author

As in the traditional indications for staging: left and right, those of the spectator.

It's impossible to remember when it happened, it's already ten years of work... On the other hand, I'm sure it was a sudden discovery: something we had never seen before and that, after seeing it, we can't stop seeing it.

We made the discovery by looking at a reproduction of the painting entitled *Las Meninas* (**Fig. 1**), which is kept in Kingston Lacy (Dorset County, UK), and which is generally considered to be a copy of the original by Velázquez, (**Fig. 2**) in the Prado Museum.

It is a straight vertical line of eight centimeters, finished off at the bottom with an arrowhead, which until now has gone unnoticed, a very small detail, almost nothing; but it is a crucial detail for understanding how Velázquez painted *Las Meninas*.

If we compare the two versions of *Las Meninas* ⁽¹⁾, we only see this line in Kingston Lacy's painting at the lower right, between Nicolasito Pertusato's legs (**Fig. 1, 3 and 4**). In *Las Meninas* del Prado it does not exist, it is hidden. We will call the lower end of this line G.

All the experts on Velázquez's work - except Matías Díaz Padrón - and also the present owners of the painting maintain that Kingston Lacy's *Las Meninas* (we will call it the small painting) is a copy - by Juan Bautista Martínez del Mazo - of the original by Velázquez (the large painting) in the Prado Museum.

Matías Díaz Padrón (2013), on the other hand, states that the small painting is an original by Velázquez, prior to the painting of the large one, a sketch or *modeletto* to be approved by the king before starting to paint the large painting. There is no other painting like it in Velázquez's entire oeuvre. And we can imagine neither Velázquez so servile, repeating exactly in the large painting what he had already painted in the small one, nor the king so distrustful, demanding that he do so. As if he still did not know that, whatever Velázquez did, it would be magnificent. And accepting, moreover, not to appear in the painting, not even diminutive and reflected in a mirror... Because in the mirror in the background of the small painting the kings do not appear.

When we compared our tracings of the two versions of the painting we found that, while the perspectives and the straight lines defining the general outlines of the space of the painting were, apart from the difference in size, practically identical, (**Fig. 4** and **6**) the figures were quite different from one painting to the other ⁽²⁾. (**Fig. 5**).

Such a precise copy from one painting to the other cannot be achieved with the naked eye, but it can be achieved using a camera obscura ⁽³⁾. The comparison between the two perspectives shows the trihedron we have already referred to, with vertex at G and formed by the floor, the window jamb and the wall on the right with the windows or glazed doors (**Fig. 4**).

This trihedron - hence its importance - allows us to state two things with certainty: that the small painting is not a copy of the large one, because a copyist does not invent; he cannot paint anything that he does not see in the original. And also that the figures were painted a posteriori at least in the small painting and, in our opinion, also in the large one.

Kingston Lacy's painting is not a copy, nor is it a sketch of the great one. It is not only by Velázquez, nor only by Mazo: it is by both. And it is, specifically, what we might call, by analogy with the language of photography, the "pictorial negative" of the large painting. Let us try to justify these statements.



Fig. 1 *Las Meninas* by Kingston Lacy.
Our decal, in dark cyan blue.

John Moffit: Perspective deconstruction of *Las Meninas*

The historian John Moffit, with the help as draughtsman of the engineer Terry Fox, has been the one who has most carefully and thoroughly attempted the restitution or deconstruction of the perspective of *Las Meninas* ⁽⁴⁾. He published this work in different versions between 1983 and 1991 (**Fig. 7**).

Our work follows what Moffit proposed in one of these publications, a 1987 article entitled "*Las Meninas*: reality, science and architecture":

"To ensure greater (or perhaps absolute) accuracy I should work from a life-size, high-contrast photograph of "*Las Meninas*"; this image could then be programmed into a new system of computer graphics [sic], to which the outline and dimensions of the image would have to be added.



Fig. 2 Las Meninas del Prado.
Our decalco, in old gold colour.

taken from a larger reproduction of the *Lower Room of the Prince of the Alcázar* from the drawing by Gómez de Mora". ⁽⁵⁾

This quotation makes it clear not only that Moffit and Fox worked with pencil and paper, without using computers, but also that *Computer Aided Design* (CAD) was still, in 1987, something unknown and futuristic, like science fiction, for art historians. In response to Moffit's suggestion, we analysed photographic reproductions of *Las Meninas*, and specifically the geometry of its perspective, using CAD.

We have traced these digital photographs so that they can be superimposed and compared. We may have made some mistakes, but one of the advantages of computer drawing - and, consequently, also of the method of computer-assisted perspective deconstruction (DPACO) - is that anyone who doubts the results can repeat any drawing and check it.

As also recommended by Moffit, we have used in this work the drawings of the ground and ground floor of the Alcázar of Madrid, made by Juan Gómez de Mora in 1626 (**Fig. 8** and **9**). We consider them to be the most reliable of the available drawings and the most coherent in the relationships between the distribution, enclosures and load-bearing structure of the building. We have also traced this drawing in CAD and superimposed it on Moffit's perspective deconstruction in order to study its coincidence (**Fig. 10**).

Moffit and Fox's perspectival deconstruction is, for all that we have come to distrust it, quite correct. But it contains three blunders which we will consider separately:

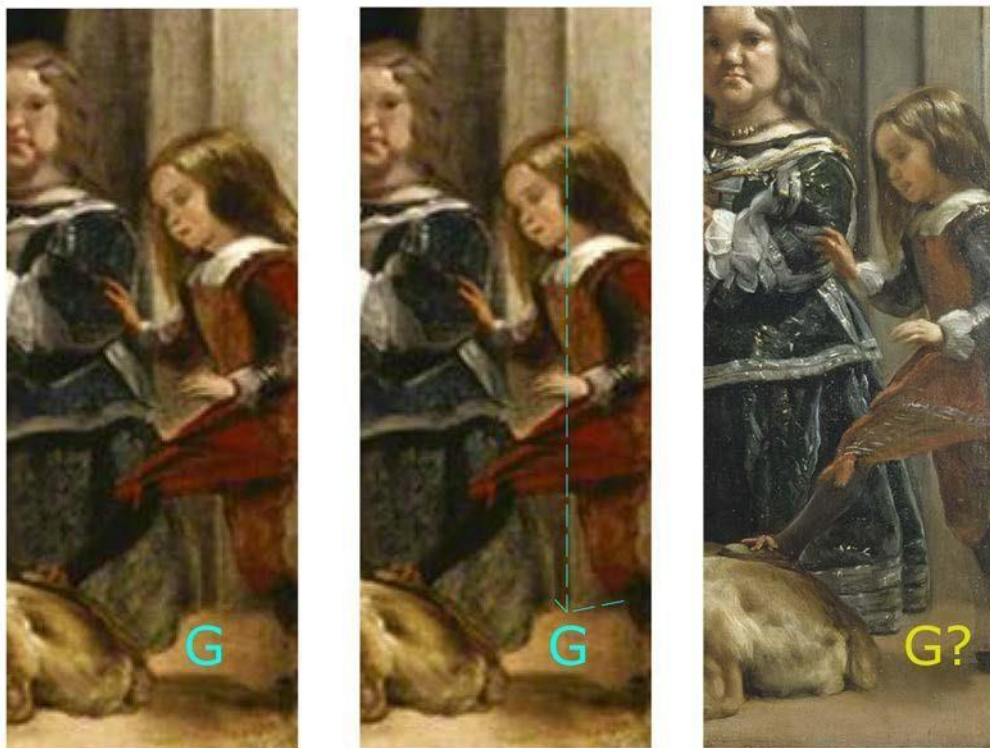


Fig. 3 A crucial detail.

On the left: Detail of *Las Meninas* by Kingston Lacy. Centre: The same detail, showing point G and the continuity of the vertical edge that starts from it above Nicolasito Pertusato's head. Right: The same detail, in *Las Meninas* del Prado.

(a) The door at the back existed where it is painted

This is impossible. Moffit, following Jonathan Brown (1978), assumes that Velázquez did not repair the Rubinejo Staircase, but had it built from scratch. In Gómez de Mora's plan of 1626, the staircase starts on the left side of the back wall, and not on the right, as it is painted in *Las Meninas* (**Fig. 1**).

Brown and Moffit claim that the *Bastimento Tower* had been demolished. However, Gómez de Mora's plans clearly show that the *Gallery* extending the Alcazar to the south had been erected on the base of the tower on the ground floor (**Fig. 8**) and that, from the first floor, where the tower narrowed considerably, the *Gallery* enclosed the tower. (**Fig. 9**) Writes Brown (1978):

"Velázquez's architectural career officially began on 6 June 1643 [...] In his new capacity, Velázquez was involved in the reconstruction and remodeling of certain state chambers on the main floor of the Alcázar. The fundamental part of the task included the creation of two magnificent salons: the *Ochavada Piece* and the *Hall of Mirrors*".

By 1648, the year of Juan Gómez de Mora's death, all these works on the main or first floor of the Alcazar had been completed (Brown, 1978). The *Bastimento Tower* was an Arab construction, made of masonry or directly of wall. The demolition of its ground floor would have been a costly, difficult and lengthy job that was either done before 1643, demolishing and rebuilding the newly built *Gallery*, or it was done after 1648, demolishing the newly refurbished parts of the main floor... neither of these two possibilities is plausible.

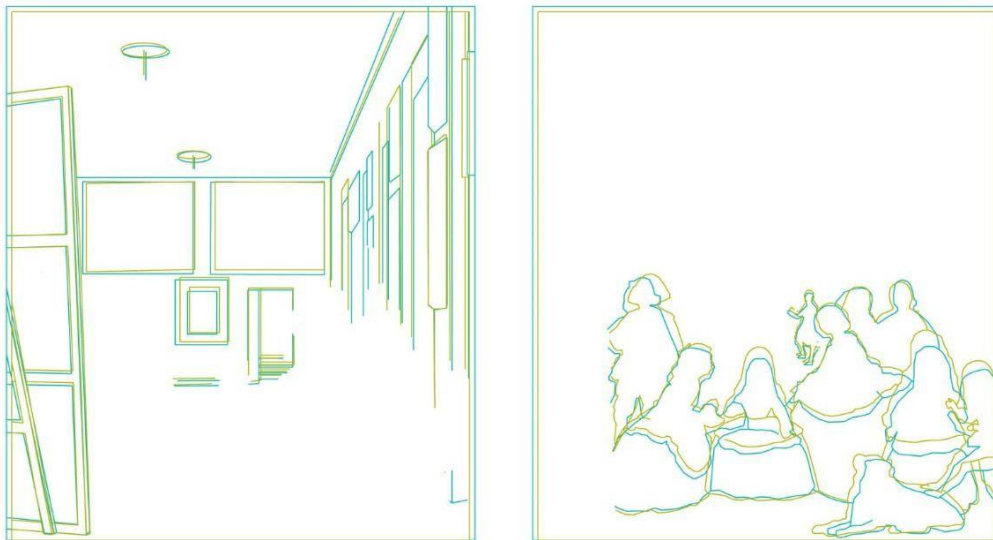


Fig. 4 and 5 Comparison of the two tables.

Fig. 4: Perspectives. Note the striking coincidence between the two. At the bottom right, the three edges that coincide at point G can be seen in the small box.

Fig.5: The figures are quite different in the two pictures, as can also be seen with the naked eye in Fig. 1 and 2.

Moffit and Brown give dates and references for the demolition of the partition wall that previously separated the *Gallery of the Prince's Lower Room* into two distinct rooms, ordered by Velázquez in 1645 to create the space depicting *Las Meninas*:

"It was probably at this time that the thin partition separating the two rooms was removed and a new door opened on the east side, giving access to a new staircase under construction in the space vacated by the demolition [sic] of a medieval tower." (Brown, 1978)

The demolition of a partition wall is a minor work. On the other hand, of the much larger work of demolishing the base of a tower and building a new staircase, we have no news, reference or date.

Finally, the painting of the door at the back in *Las Meninas* is frankly strange: (**Fig. 11**) The door leaf seems to continue above the lintel, of which we do not see the bulk - nor that of the right jamb - despite the fact that the vanishing point of the lines of depth is located in the doorway. If at the top the door certainly opens towards the bottom, at the bottom it might appear to open forwards, because the door leaf is below the dihedral formed by the floor and the back wall, in both the large and small pictures.

a) The picture that Velázquez appears to be painting in *Las Meninas* is a portrait of the kings

Moffit and many other authors are right in asserting that, as the background mirror and the vanishing point of the depth lines are situated, what that mirror would reflect (the angles of incidence and reflection are equal) (**Fig. 7**) would be further to the left, and could be on the canvas whose back we see (we will call it the hidden picture). But George Kubler (1985) is also right in his objections to this assumption.

If the kings were reflected in the mirror, the queen would have to be in the portrait and in reality on the king's left, which is not possible because of a rule of protocol, and because of the *raison d'être* of that rule: the left side is the side to carry and draw the sword.



Fig. 6 Details of Fig. 5.

Detail of the right upright of the hidden frame. ⁽²⁾ Left: deformed details increasing its width. Centre: details by dimensioning the angles between the edges of the two frames. Right: general view by dimensioning the angle between lines b1b4 and B1B4.

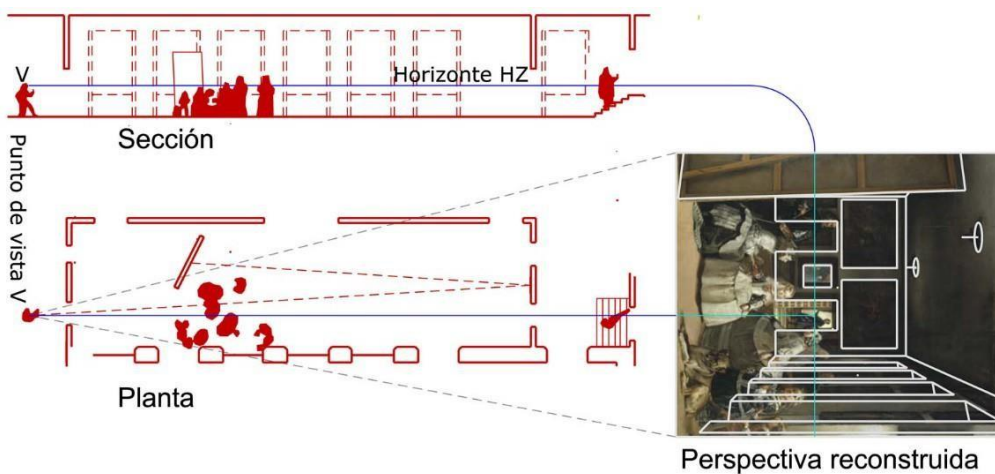


Fig. 7 Moffit and Fox's perspective deconstruction.

Note the location of the point of view they set for the perspective: it is not in the *Gallery*, but in the *Golden Tower*. The reconstruction of the perspective is our own.

If we draw the reflection of the background mirror on the canvas that is supposed to produce it with the precision that allows the computer, (**Fig. 12**) we see that in their portrait the kings would appear close to an angle, off-centre, and that (given the normal proportion of the height of the body equal to eight heads) they would not be shown full-length, but cut off above the ankles, which is not congruent with their dignity.

Moreover: a mirror never reflects anything by illuminating it more than the figures seen through the mirror are illuminated. The kings in *Las Meninas* do not appear to be reflected in a mirror but seen through glass in an adjoining, more brightly lit room than the one in *Las Meninas*.

the *Gallery of the Prince's Lower Room*. Like goldfish in a fishbowl.

Finally, let us remember that in the small painting, which precedes the large one, the kings do not appear in this mirror.

b) Velázquez painted *Las Meninas* in the Golden Tower

Moffit locates the perspective point of view of *Las Meninas* in an apparently absurd place: in a room - the *Golden Tower Piece* - adjacent to but distinct from the one depicted in the painting, the *Main Piece* or *Gallery of the Prince's Lower Room*. (**Fig. 7** and **10**).

In his perspectival deconstruction, Moffit situates Velázquez very precisely: seated on a high stool so that his eye is at eye level with the viewpoint and looking through a door about two metres high into the *Gallery*. (**Fig. 13**).

Very good; but, on the other hand, it does not situate the painting that Velázquez is supposed to have been painting from there: *Las Meninas* in the Prado. A painting almost three metres wide by more than three metres high, which Velázquez had to paint not only seated as Moffit depicts it, but also standing, crouching or climbing a ladder: with the eye - the point of view - in positions, at very different distances and heights... It cannot be; a perspective can only be drawn by seeing it or projecting it (geometrically or with an optical machine) from a point of view.

Climbing a ladder, with his eye almost three metres in the air, Can we believe that Velázquez painted the perspective of the fleurons on the ceiling with absolute precision? No. It is impossible. He couldn't even see them, they were obscured by a wall. A perspective of the dimensions of the of *Las Meninas* cannot be drawn directly from visual perception and even less so from the next room.

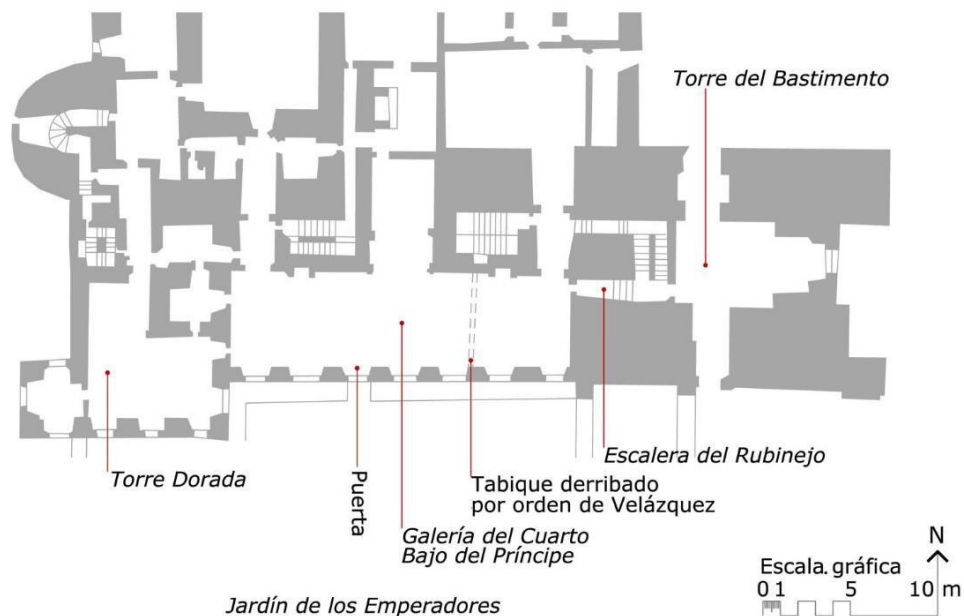


Fig. 8 Ground floor of the Alcazar.

Our tracing of a reproduction of the original drawing by Juan Gómez de Mora (1626). Detail of the rooms in the southwest corner of the building, where Velázquez painted *Las Meninas*. The third opening of the *Gallery*, counting from left to right, is marked as a doorway, with the exterior paving reaching the exterior plane of the south façade, and interrupting the flowerbed in front of the south façade for this passage. This implies that, as early as 1626, the floor of the *Gallery* coincided in height with that of the *Garden of the Emperors*, and explains the name *Gallery of the Lower Room of the Prince*.

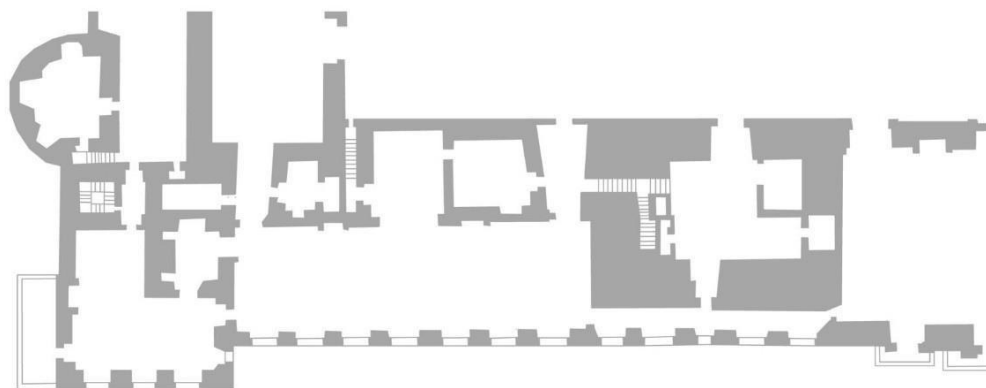


Fig. 9 First floor of the Alcazar

On the ground floor, the outer face of the *Gallery* forms a single plane with the outer face of the *Bastimento Tower*. On the first floor, on the other hand, the tower has been set back, reducing its section, so that the façade of the *Gallery* passes in front of the tower, enclosing it. The *Mirror Room* and the *Ochavada Piece* were fitted out on this floor between 1643 and 1648 under Velázquez's direction. The latter, in the space freed up by the demolition, from the floor of the first floor upwards, of the *Bastimento Tower*. This demolition did not affect other important constructive elements and could be carried out without touching the *Gallery*.

We will see later what more DPACO's analysis reveals about Moffit's three misunderstandings. But to begin that analysis we have to fix the position of the horizon and the point of view of the perspective of *Las Meninas*.

Situation of the point of view of the perspective of *Las Meninas*.

We take the back wall of the painting - and of the floor plan of the *Lower Room of the Prince's Gallery* according to Gómez de Mora's plan - as the plan of the perspective painting. This allows us to measure precisely because we know the measurements of the painting hanging above the door, at the back, which measures 223 by 181 centimetres (Moffit, 1983). We can see that the height-width ratio of the painted picture is compatible with these dimensions.

To locate the point of view - and the horizon that contains it - we traced the lines of depth: the axis of the two fleurons on the ceiling and the horizontal lines of the lintels and frames on the wall on the right, including the dihedral that this wall forms with the ceiling. In doing this we saw that these lines are in both paintings - more so in the large one, which confirms the idea that the perspective of the large painting is the copy, because it is easy to obscure a copy, but impossible to clarify it - difficult to locate exactly.

These lines, due to inaccuracies in their layout or in our tracing, do not converge at a single point. They intersect at several points in an area at the door in the background. Locating the horizon would allow us to reduce this area to a single line, that of the horizon (and to locate the midpoint between the different vanishing points, which we will take as the vanishing point of the depth lines, C). To obtain this information we decided to look for the vanishing point of the crossbars of the frame that we see in the foreground on the left.

Checking the vanishing point of the three lower horizontal crosspieces ⁽⁶⁾ (**Fig. 14** and **15**) shows that this is a geometrically very precise perspective, and in which the coincidence of the large square with the small one is almost absolute. We leave for now the problem of the highest crossbar. The midpoint between all the vanishing points of these three crosspieces, A, allows us to locate the height of the horizon HZ and to draw our own perspective (**Fig. 16**).

We use the middle lines between those of the small frame and those of the large frame, correcting the leaks of the horizontal crossbars of the painting is hidden from point A in order to maintain geometric coherence. We leave the south façade, the right wall, for later (**Fig. 19**).



Fig. 10 Superimposition of Moffit's deconstruction on Gómez de Mora's plan.

Note that the construction of a new staircase would have required the demolition of the southwest pillar of *the Bastimento Tower* on the ground floor. And, therefore (Fig. 9), of the eastern section of the *Gallery on the first floor*. The point of view of the perspective is, as we have already noted, in the *Torre Dorada*.

Finally, in order to specify the situation of the point of view of the perspective of the small painting, we have four points A, B, C and G, which define two lines: AB, the line closest to us from the base of the frame of the hidden painting, and CG, the edge of the dihedral formed by the floor and the inside face of the south façade. (Fig. 17) Note that point G, whose importance we have already mentioned in order to affirm that the small painting is prior to the large one, is also fundamental to fix the perspective and its point of view, and to allow its deconstruction.

With this knowledge we can locate point of view V ⁽⁷⁾ on the ground plan. (Fig. 17) In doing so, we can see that Moffit was right: the point of view of *Las Meninas*, V, is in the *Golden Tower*, in a room next to the one depicted in the painting. But how is that possible?

Deconstruction of the perspective of *Las Meninas*

Before answering this question, and given that there is hardly any detail left, we can finish the deconstruction of the perspective. We start with the location and measurements of the back wall. We already know, as part of the process of locating the point of view, where the hidden painting must be on the ground floor. We still have to deconstruct the wall on the right, the south façade with the windows.

The openings on the right wall appear (through the shadow they cast, for example, between Nicolasito Pertusato's legs) to be windows from the ground. On the other hand, in Gómez de Mora's plan, only one of these openings is depicted as a door, even interrupting the flower bed that follows the south façade. The others would be high windows (**Fig. 9**).

The jambs of the windows we see in *Las Meninas* are different from the way they appear in Gómez de Mora's plan. The trapezoid-shaped machones have been converted into pillars with the inner face is octagonal, truncated at 45 degrees. This is compatible with the modification of opening the windows to the floor, which would have required a reform of the jambs. They are also represented in this way in other perspective deconstructions (Moffit, 1983; Snyder, 1985).

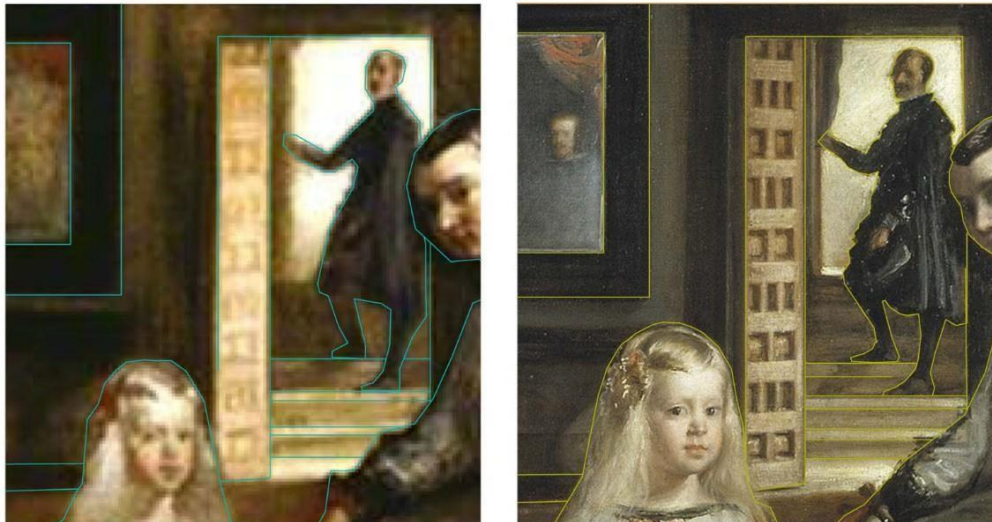


Fig. 11 The door at the back.

Anomalies in the painting of the door at the back, in the two paintings: the lintel and the right jamb seem to have no thickness; to the right of the left jamb we see the thickness of the door leaf. Considering that the hinges have to be on the vertical line between the door leaf and the jamb, and that the door leaf continues above the lintel, how does it close? Such a door could only close if the lintel were a vertical plane with no thickness. Moreover, if it were to close, the uppermost panels would be cut off by the lintel. Above the line - which would have to be horizontal - What is the darker stripe between the two lines that we have drawn, doubting which one should be the one where the floor meets the wall?

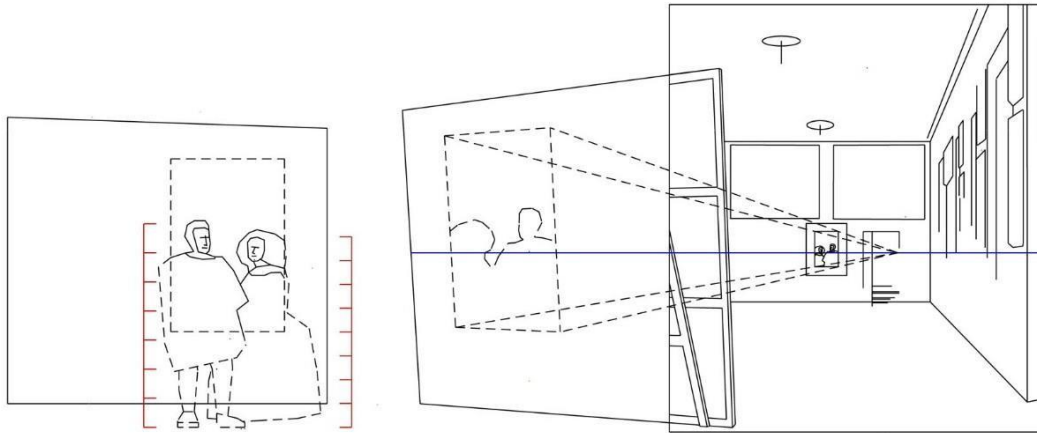


Fig. 12 A portrait of the kings?

On the left, a frontal elevation of this supposed portrait. The eight tall heads of the king and queen are off-centre and cut off at the ankles. We have drawn the upper frame of the painting tilted because that is how it appears to be in perspective. On the right, projection of the reflection of the mirror on the back of the hidden painting.

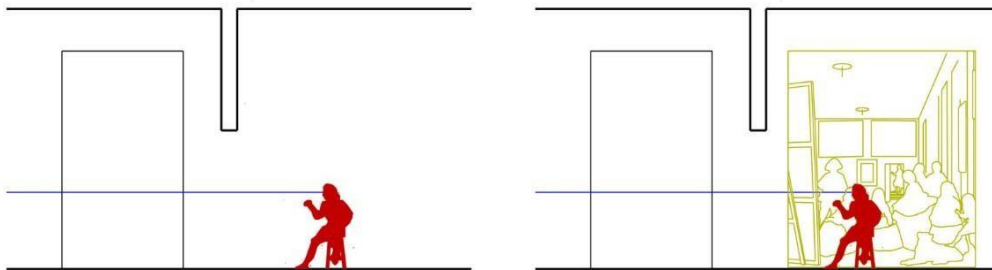


Fig. 13 According to Moffit: Velázquez painting *Las Meninas* from the *Golden Tower*.

If Velázquez had worked without using a camera obscura, the perspective point of view would be in his one open eye, and would move with it. When he climbed a ladder to paint the fleurons on the ceiling, it is not that he could not see them from the point of view of perspective. It is simply that he would not be able to see them. They would be covered by a wall. By the way: it is impossible to fit *Las Meninas* in that room. The doors are too small.

Pedro Teixeira's plan of Madrid in perspective, which is strictly contemporary with *Las Meninas*, from 1656 (**Fig. 18**), confirms our hypothesis about the arrangement of the openings in the *Gallery of the Lower Room of the Prince* towards the south: windows starting from the floor and opening onto the *Emperors' Garden*, which had been renovated by Velázquez between 1655 and 1656 (Brown, 1978).

The deconstruction of the windows seems easy, but it is not easy at all for two reasons: because the inside face of the wall is in shadow and with several closed windows and also because it is, in plan, parallel to the VC line, which joins the point of view with the vanishing point of the depth lines, and is very close to it: just over a metre away. (**Fig. 19**).

All this means that the angles between the projection lines of the window jambs are very small and that the slightest errors in perspective can produce large deformations in the deconstruction of the floor plan ⁽⁸⁾.

After many unsuccessful efforts to deconstruct the perspective of the openings on the south façade, we decided not to give importance to the exact location of the windows. We started from point G (the only one where the start of a vertical edge is visible) and placed the windows at regular intervals (**Fig. 19**). The superimposition of our deconstruction on Gómez de Mora's plan shows minor, unimportant differences ⁽⁹⁾.

Having concluded our perspectival deconstruction, we can return to the question we posed earlier: How is it possible that the point of view of the perspective of *Las Meninas* is outside the *Lower Room of the Prince*? With the answer to this question, we begin with a review of the successive stages in the process of creating *Las Meninas*.

What procedure did Velázquez follow to paint *Las Meninas*?

1. The small picture.

As we have already explained, Velázquez was unable to paint the large painting in the *Torre Dorada*. He could, however, have drawn the perspective and general lines of the small painting enclosed in a cabin-like camera obscura, located in the Piece of the *Golden Tower* and focused -perhaps through a hole in the door- towards the *Prince's Lower Room*. We are convinced that he did so ⁽¹⁰⁾.

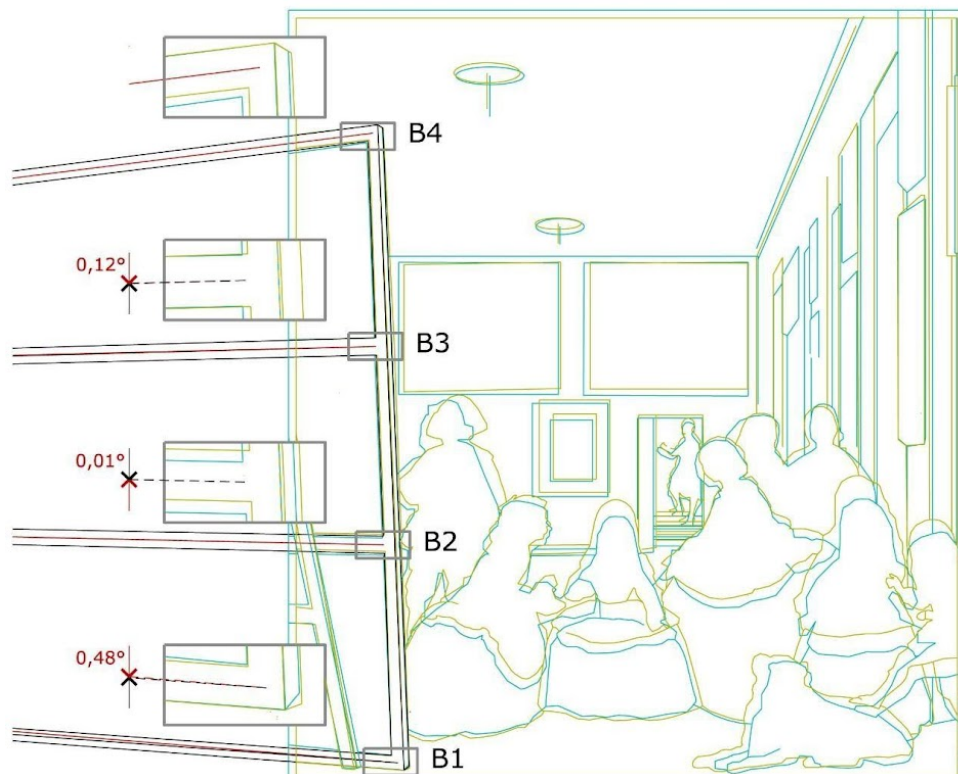
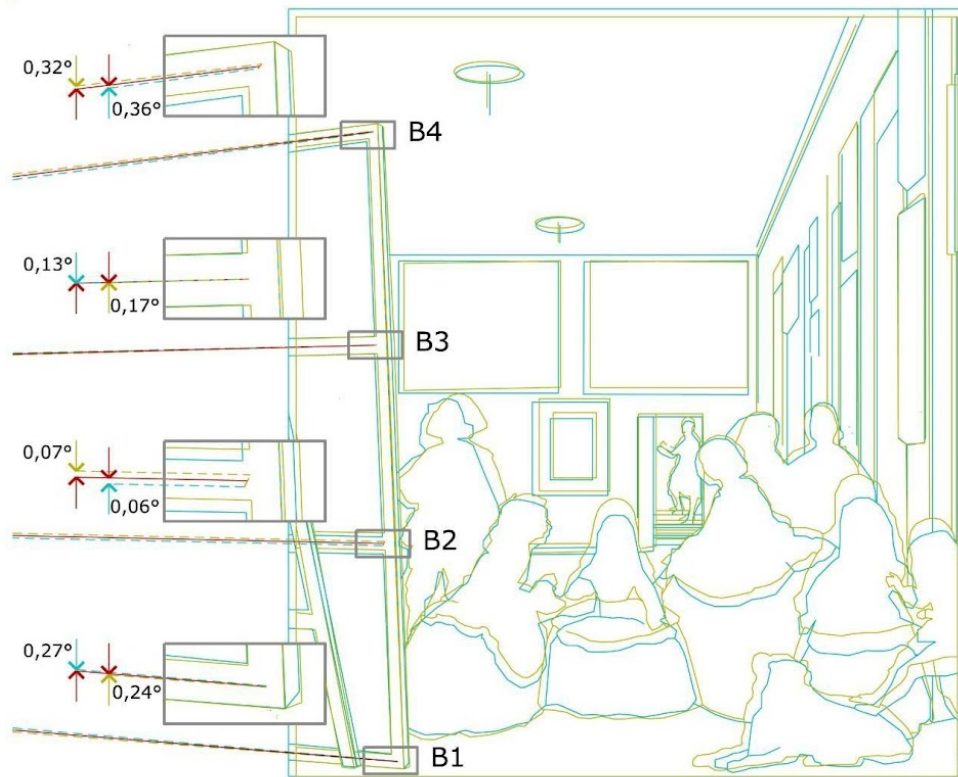
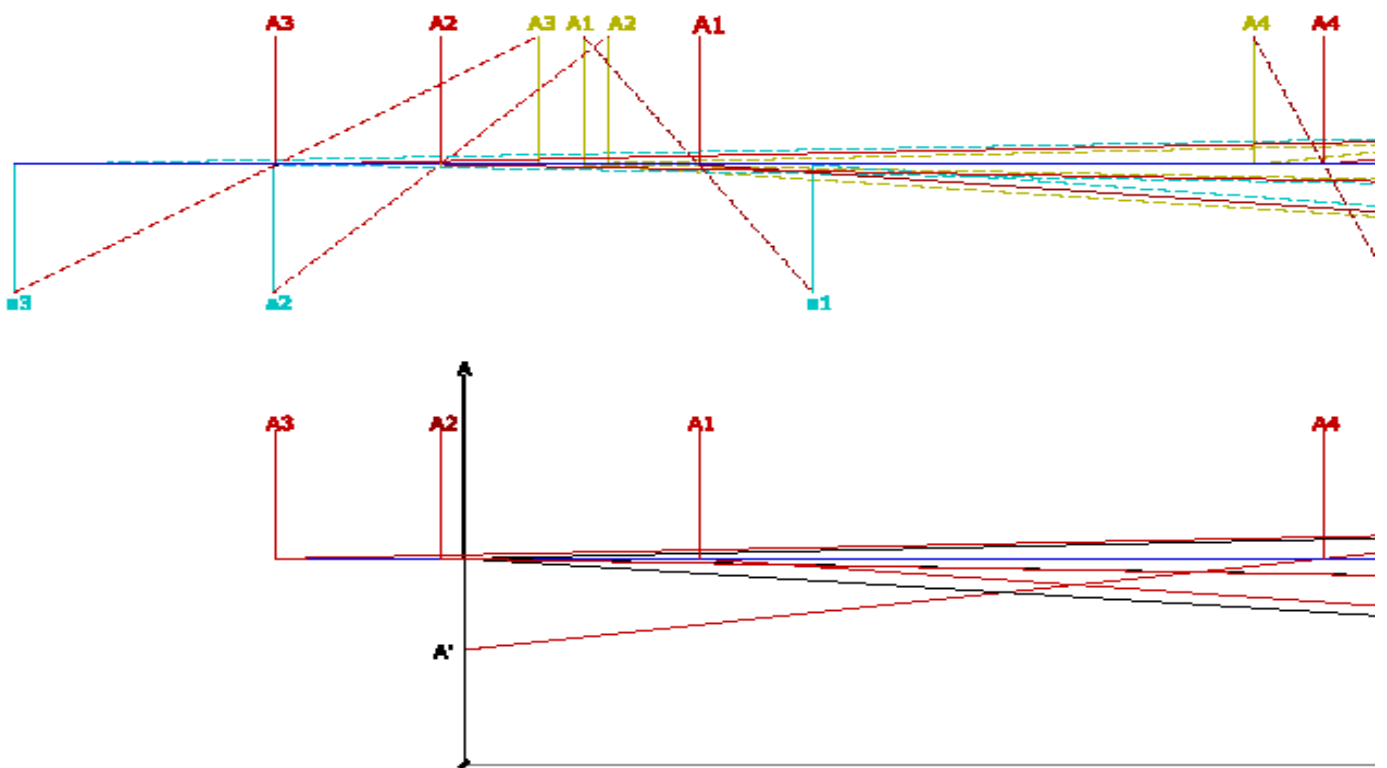


Fig. 14 and 15 Leaks from the frame of the concealed frame (fragments)

Fig. 14 (top) Fugue of the horizontal crosspieces of the hidden frame. We dimension the angles between the mean vanishing lines of the horizontal crosspieces in the two perspectives (b1a1 and B1A1 etc.) and the mean line between the two. ⁽⁶⁾ Fig. 15 (bottom) Fugue of the horizontal crosspieces of the hidden frame. We dimension the angles between the middle lines that we have just defined in Fig. 14 and the vanishing lines to a single vanishing point A. ⁽⁶⁾

As we have already explained, the large painting is a copy of the small painting, enlarged using a camera obscura. And the small one, how could it have been constructed? Obviously, inside the same camera obscura, with its objective - its lens - placed at the point of view of the perspective of the two. The dimensions of the small painting confirm this thesis: they are similar to those of Vermeer's paintings, which Steadman (2001) claims were painted with a camera obscura ⁽¹¹⁾. And also those of Velázquez's Villa Medici landscapes ⁽¹²⁾, "early exercises in the use of the camera obscura" (Alpers 1995). There he traced the image projected on the back wall onto the canvas hanging upside down. To prevent his own shadow from getting in the way of his drawing, he marked points at the ends of the straight lines and joined them with a ruler.



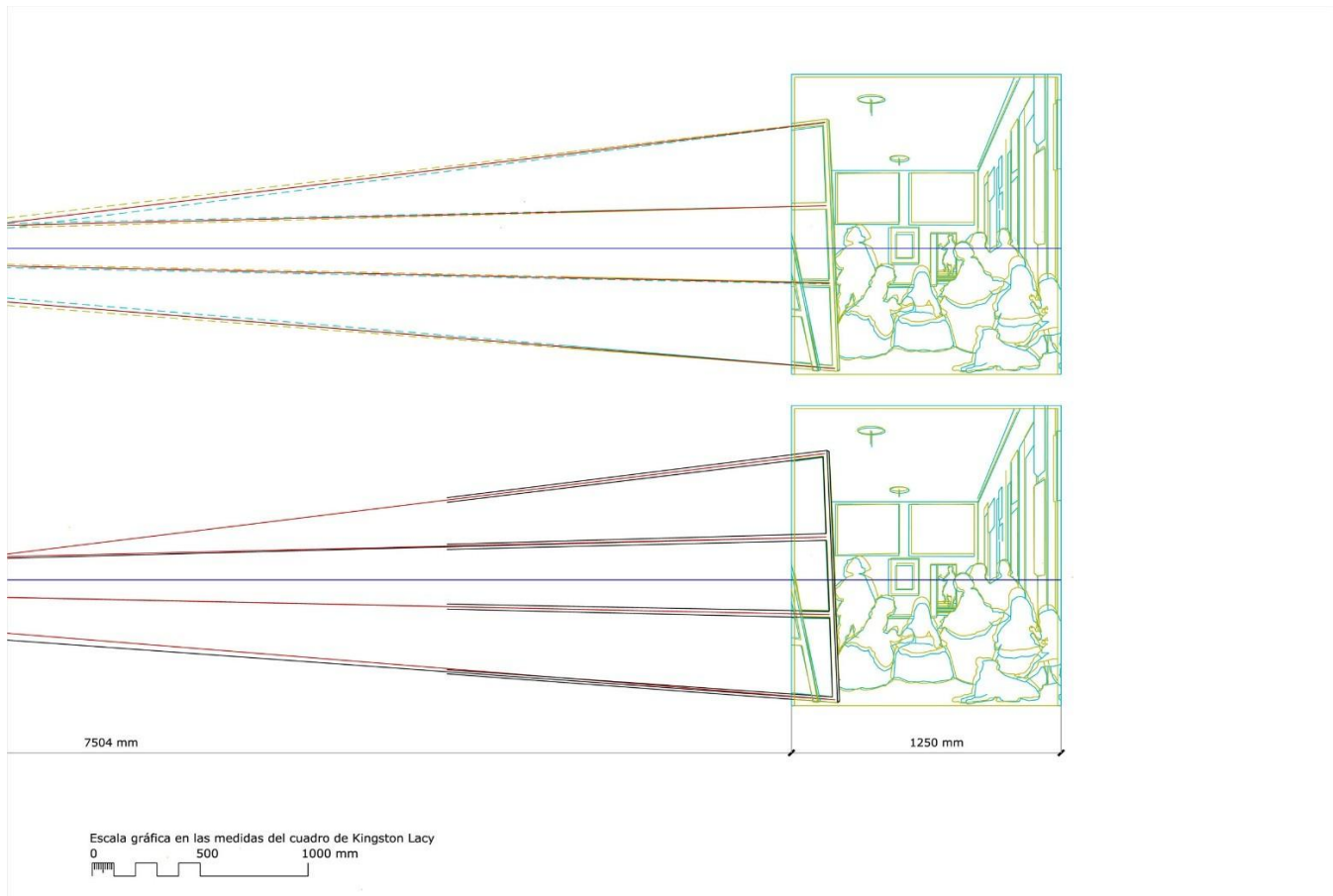


Fig. 14 and 15 (Full image)

The distance from the left edge of the small frame to the vanishing point of the horizontals of the concealed frame frame is 7504 mm.

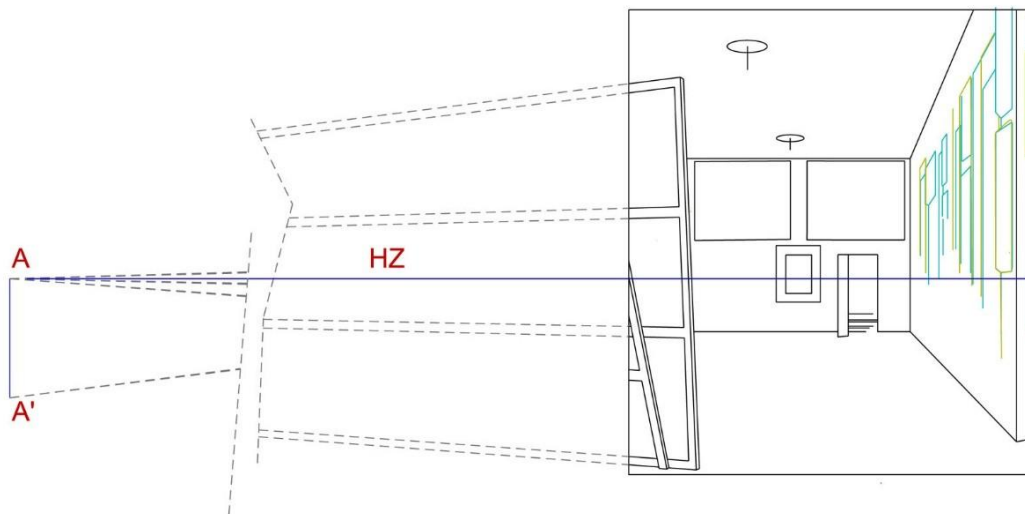


Fig. 16 Our perspective

This is no longer exactly the perspective of either of the two paintings, but a new one, intermediate and with the horizontal lines of the horizontal lines of the stretcher converging on A. Except for those of the highest crossbar, which run away to'. The perspective on the right wall remains to be specified.

2. Two compositional decisions

By taking the small painting out of the camera obscura and turning it halfway around to complete the painting of the perspective and background, Velázquez was able to see it properly for the first time. Immediately, he made two fundamental compositional decisions: to add the door in the background and the door in the background.

a.) Trim the height of the hidden box

We have already mentioned our doubts about the possibility that the picture Velázquez is painting in *Las Meninas* is a portrait of the kings. Let us consider another of the hypotheses that have been put forward, namely that the painting is "for the more sophisticated, the painting itself".
of *Las Meninas*" (Marías, 1995).

The strongest reason for denying that possibility is that *Las Meninas* is considerably taller than the mysterious painting it contains, and of which we see the back. If that frame and canvas had the dimensions of those of *Las Meninas*, they would be lost above its upper frame, giving the painting a strange, unfinished appearance. Boxed vertically to the left and right, why not cut it down in height? We can easily imagine Velázquez making the compositional decision to let the ceiling - the only ceiling in his entire oeuvre (Tusquets, 2019) - pass over the painting whose back we see. Such a decision would have justified the unusual height of the painting and would have completed the harmony, balance and calm of his composition (**Fig. 20**).

Following this reasoning, Velázquez cut a quarter of the height of the canvas of the hidden painting so that it would not be lost above the frame, but so that the ceiling would pass over it, reaching the left frame.

Unlike the lower cross pieces, the upper crosspiece (A4B4 and a4b4) is painted as if it were not horizontal. Its fugue in the two paintings is very different from that of the others (**figs. 14** and **15**). There are only two possible explanations for this: that the hidden painting was not rectangular or that Velázquez had made a mistake in the fugue.

The first of these explanations must be ruled out: there are no 17th-century paintings on canvas that are trapezoid-shaped, almost rectangular. Let us consider the other possibility: it would be a single error in a very precise perspective. Why would this have happened? We will answer this question a little later.

b.) Add the door at the back

Velazquez decided to paint a door on the back wall. That would give more depth to the painting and place a point of light in that open door. From the point of view he was using (V) there was no door in the background on the right, because there wasn't one, as we have already explained when discussing Moffit's perspective deconstruction.

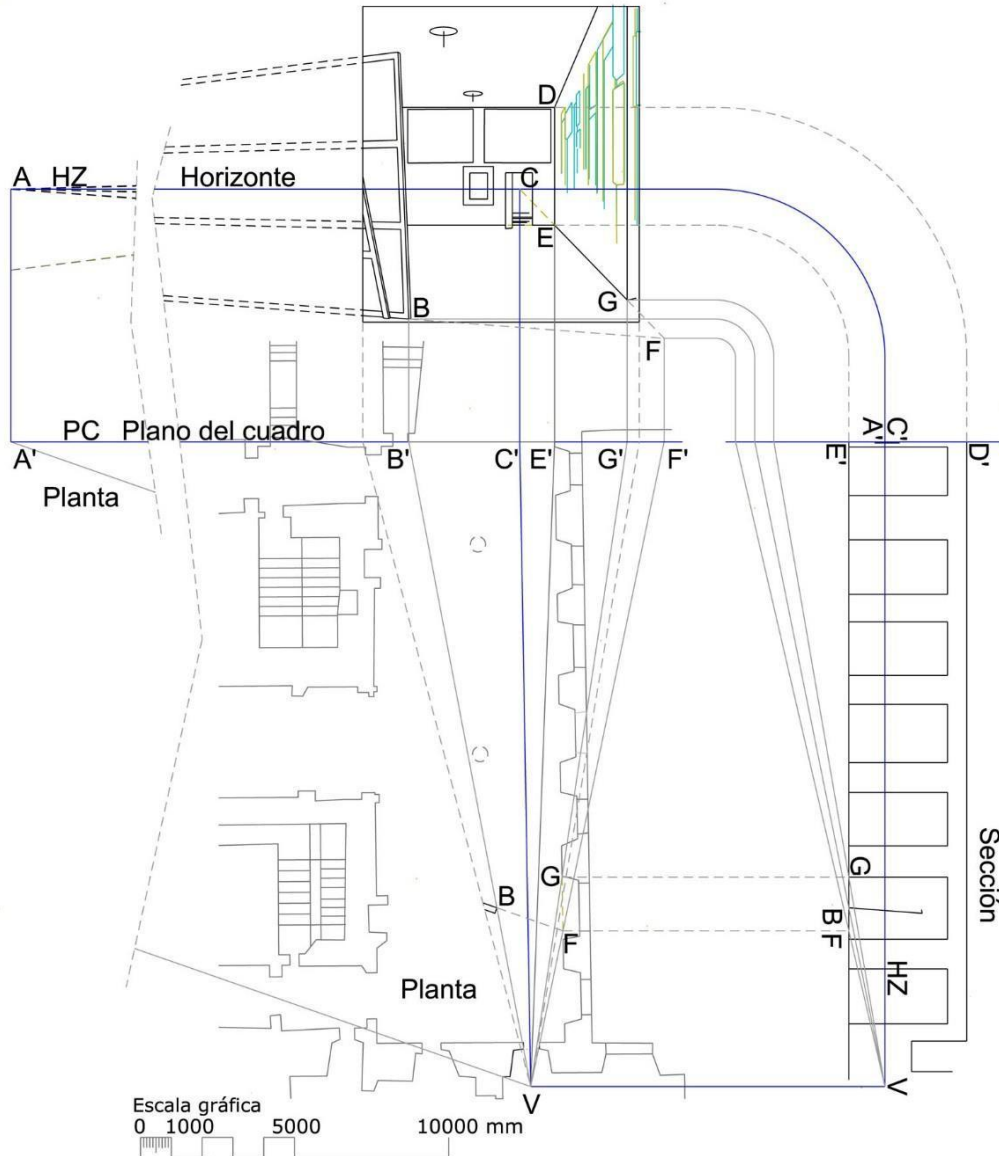


Fig. 17 Location of viewpoint V.

For the geometric procedure for locating the point of view of the perspective, see note 7. The result of this operation coincides with Moffit's thesis: the point of view is in the *Golden Tower*, on the axis of the door that connects it with the *Gallery*.

Where there was a door was on the left. Behind it started the *Rubinejo Staircase*, which led to the first floor, to the more private rooms of the king and queen, and also to the *Ochavada Piece* and the *Hall of Mirrors*, which had been fitted out under Velázquez's direction in the works that were completed in 1648 (Brown, 1978).



Fig. 18 Detail of the plan of Madrid by Pedro de Teixeira (1656).

In line with our assumption, the windows that open towards the *Emperors' Garden* (in the picture: above number 2) start from the ground. This arrangement, which must have been Velázquez's decision - and which reproduces a layout very common in popular Mediterranean architecture - drastically improved the sunlight in the *Gallery*, with the midday sun reaching the north wall in winter and not entering the room in summer, due to the different inclination of the sun's rays in summer and winter. Consequently, it also improved the natural thermal control in that room and, ultimately, its comfort and environmental quality. Note also that this arrangement of windows is different - and more plausible - than that which appears in other representations of the building, including the model in the Madrid History Museum.

The architect Oscar Tusquets told us some time ago that in the preparation of his latest book (2019) he had observed the same anomalies in that door, and that he thought it was very important that the door had not been where Velázquez painted it: it would prove that *Las Meninas* is not a painting of "photographic" realism, but the result of a meditated study of composition, in which the painter's inventiveness plays a fundamental role.

To paint the door in the background, Velázquez moved the camera obscura forward so that he could see it. With the camera, he also moved the point of view from V to V' ⁽¹³⁾. (**Fig. 20**) For this reason, the door is painted at a larger size than the rest of the wall in the background. (The same thing happens when framing a photograph: if we move closer to the figure we want to photograph, the size of that figure grows). The line of the dihedral floor - back wall, which we see between María Agustina Sarmiento and the Infanta, is painted in a hesitant manner, in what looks like a *pentimento* ⁽¹⁴⁾, with two lines at different heights in the two paintings, like a plinth or a shadow which makes it credible that the door opens towards the back, and not towards onwards ⁽¹⁵⁾.

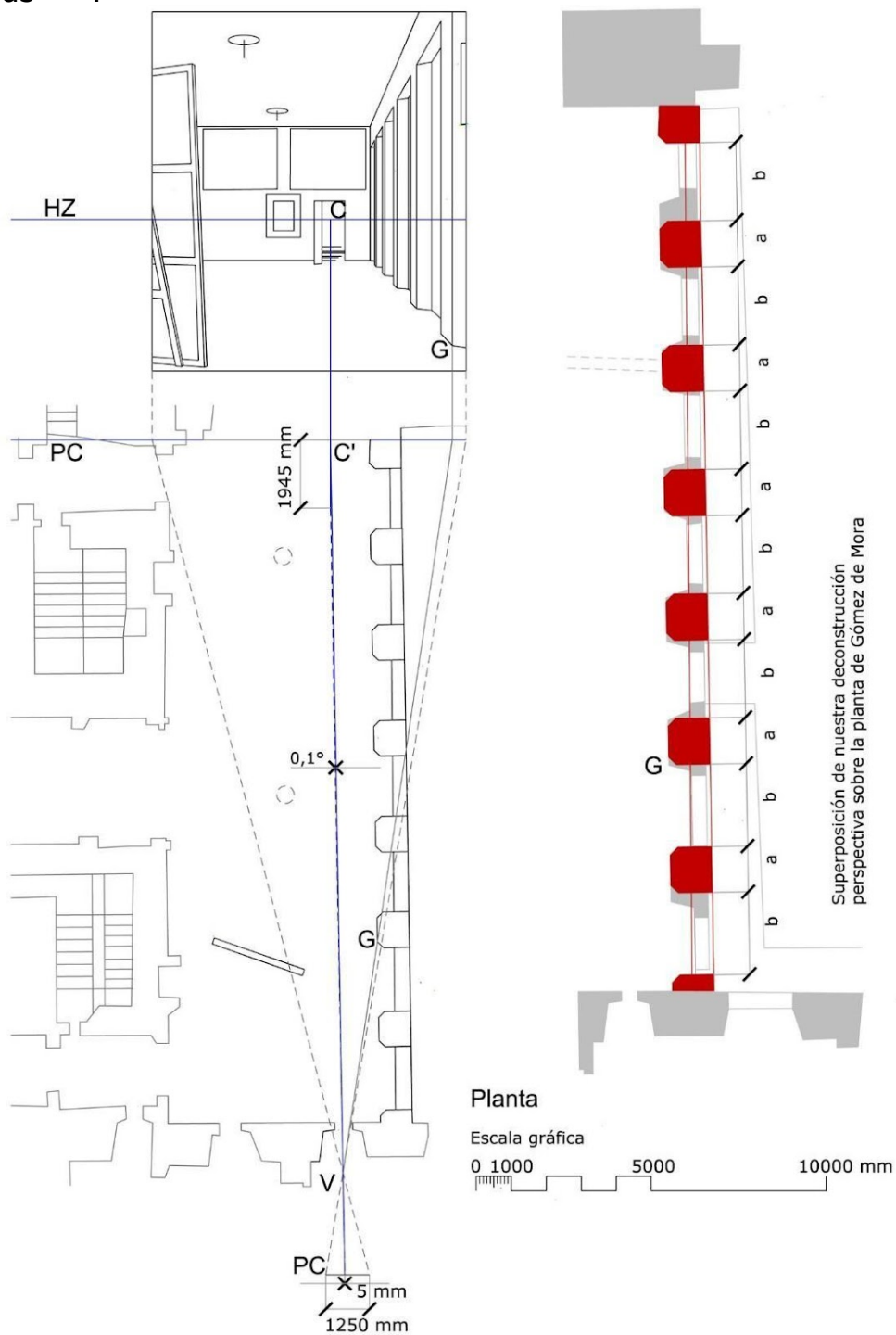


Fig. 19 Deconstruction of the perspective of the south façade.

Left: An angle of 0.10° with vertex at viewpoint V (between the continuous line VC' and the dashed line to its left) produces a distance of 5mm. in the small square, but displaces 1945 mm. the point C'. This makes the deconstruction of the perspective of the windows and the south façade practically impossible.

Right: Superimposition of our deconstruction (assuming a regular distribution of the widths of the hollow and solid) on Gómez de Mora's plan. It can be seen that the differences between one and the other are small.

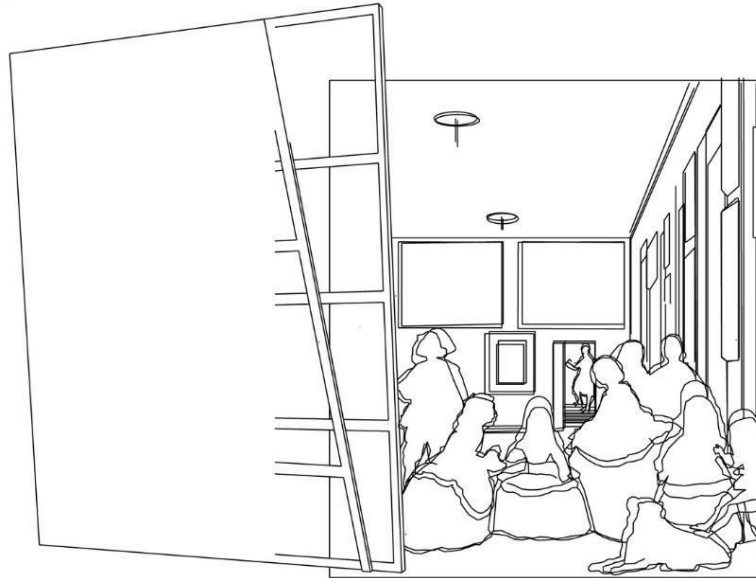


Fig. 20 The height of the hidden box.

Las Meninas is the hidden painting, which is lost beyond its limits. Why not cut it down? Velázquez must have had a good reason for giving himself so much work, with such a large painting, with so much empty space.

The perspective of the painted door panels is well constructed. All the constructive elements are also well described and represented. The main problem with this door is that it is clearly larger than the gap it is supposed to close in the back wall ⁽¹⁶⁾. (Fig. 21 and 22) Velázquez solved this disparity in size between the door and the back wall without any consideration. He must have thought that no one would notice. He was right... until now.

We have left unresolved the error in the escape of the highest crossbar of the frame of the hidden painting. One possible explanation would be that Velázquez had also drawn that line in the camera with the V' viewpoint. This would have shifted the vanishing point of the line to the right and would have tilted it more. The two errors would be explained by the way in which Velázquez would have made these two changes, using the camera obscura.

A well-founded objection to this explanation, raised by two experts in drawing and perspective - Lluís Clotet and Angel Orbañanos - is that Velázquez did not have to go to so much trouble to paint these two details and do it badly... It is true: Velázquez could have just painted them. Perhaps he made a mistake in tracing the escape of the highest crossbar by eye. But, we argue, this hypothesis does not explain the accumulation of mistakes in the door at the back.

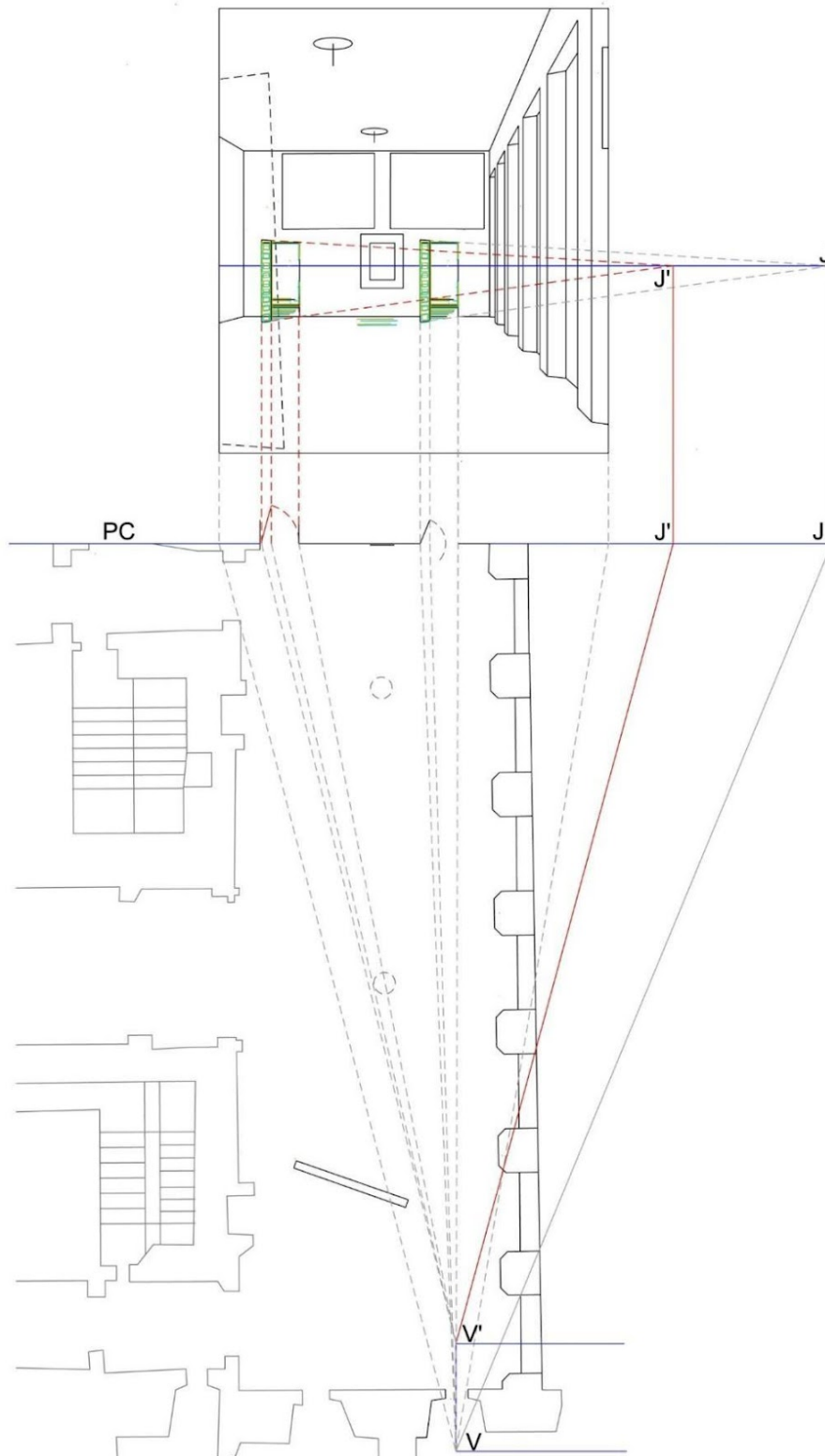


Fig. 21 Painting of the door at the back.

Velázquez painted the door in the background from the V' point of view, while the rest of the perspective was drawn with the point of view - the lens of the camera obscura - in V.

If Velázquez had painted it with the naked eye and constructed the perspective with the data he had, he would have painted it perfectly. He would not have made any of these absurd mistakes. We still prefer - though perhaps because of the affection we have for things we have worked hard for - our explanation.

In any case, it does not alter anything substantial: Velázquez painted a door where there was none, and he made a mistake in the escape by cutting the height of the hidden painting, which was *Las Meninas*.

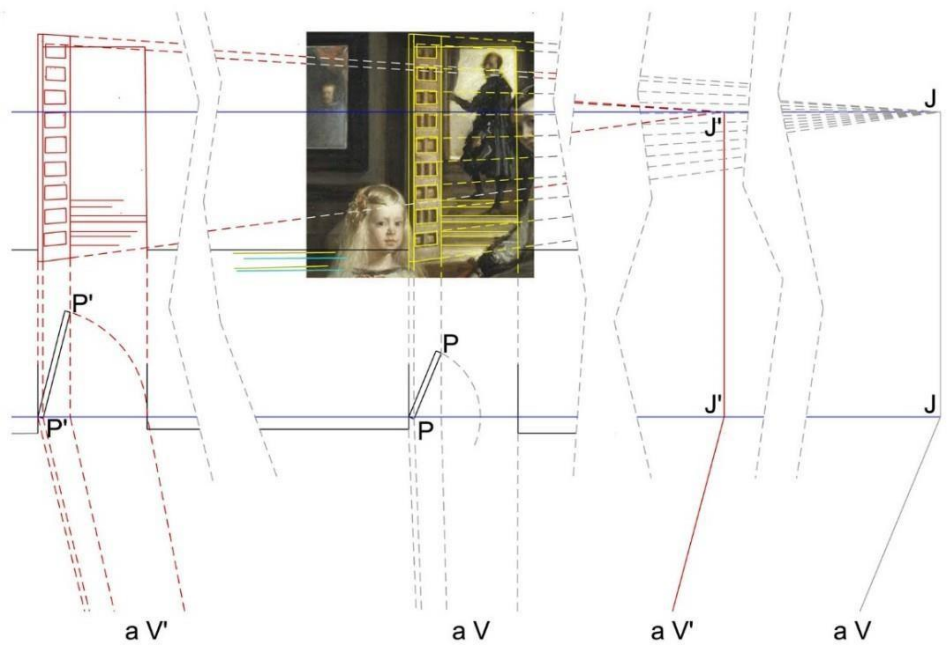


Fig. 22 Painting of the door at the back.

Enlarged detail of the previous figure. If the door had been where Velázquez paints it, its leaf PP would not have closed the gap. On the other hand, with the door on the left and the viewpoint in V', the door leaf P'P' closes the gap.

3. The camera obscura as an opaque projector

Velázquez returned the camera obscura to its initial position in the *Golden Tower* and from there, illuminating its interior and darkening the *Prince's Lower Room* - using it as an opaque projector - he projected onto the large canvas at the correct distance so that the projected image would cover it completely. He traced that projection onto the large canvas using again the same procedure: marking the extreme points of the straight lines, and joining those points with a ruler ⁽¹⁷⁾. (Fig. 23)

In fact, a camera obscura ⁽¹⁸⁾ always works by projecting illuminated images into a darkened enclosure. The magnificent **Richard Learoyd's** photographs allow us to understand that to function by projecting an image onto photographic paper - or onto a blank canvas - a camera obscura does not even need particularly intense lighting.

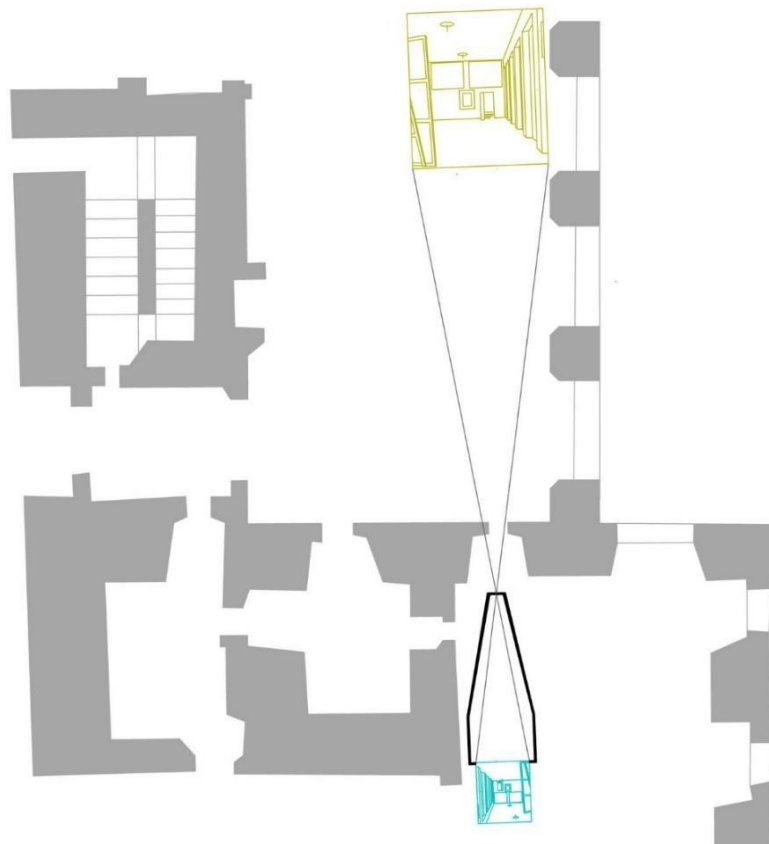


Fig. 23 The camera obscura as an opaque projector.

This, and no other, had to be the location of the camera obscura for the perspectives of both the large and the small painting to have the point of view that they do.

The location of the camera obscura in the king's chambers should come as no surprise; in those days they must have been well-guarded machines, discreetly displayed. On the other hand, the film projectors are still housed today in a small, closed room with only a small opening to project into the hall...

4. Completion of the big picture

He set aside the camera obscura and completed the large painting, darkening it and adding the figures and other elements of the painting. We do not know what specific process he used to paint the figures. We must start from the obvious: human figures are not geometrical and therefore geometry cannot help us in this case. What we can say in this respect are mere hypotheses of our own, based on common sense and Ockham's razor, a suitable instrument for understanding Velázquez, who - as the architect Adolf Loos - did not appreciate unnecessary and superfluous work.

Velázquez's problem was that *Las Meninas* is too wide a painting (and the room in which he was painting was not so wide...), so he could not paint all the figures in one go, looking out of only one side of the painting. He had already encountered the same problem when painting *The Surrender of Breda*, which is a much wider painting than *Las Meninas* (367 centimetres), and he had solved it perfectly. The two procedures described below seem to us to be the most plausible: (Fig. 24).

a.)

Velázquez could perhaps have placed the painting in position 1 and painted the figures on the right, from Nicolasito Pertusato to José Nieto, looking from the right of the painting. At another time, he moved the canvas to position 2 and painted the figures on the left (María Agustina Sarmiento and the Infanta), looking from the left. While painting them, the models were more or less where they are depicted. Had he not done so, their shadows would have denounced the situation.

Finally, in order to portray himself, he had to use a mirror (as is usual in these cases, from [Johannes Gump](#), Velázquez's contemporary, to [Norman Rockwell](#)). In order not to appear left-handed, he switched palette and brushes.

Let us explain this change of hand: the geometrical proof of the use of mirrors in painting lies in the well-known but always surprising phenomenon that the mirrors seem to change sides left and right, as if the characters reflected were not right-handed but "sinister" (19).

b.)

Alternatively, Velázquez could also have moved the mirror he used for his self-portrait and painted the other figures reflected in the mirror instead of the painting. This second procedure would have resulted in the figures appearing with their right and left sides reversed. But it would not have been serious because it seems that left-handed women did not pose a problem, unlike men. Perhaps because they did not carry swords.

Let's see an example: in the two portraits of the Infanta Margarita kept in the Kunsthistorisches Museum in Vienna, which Carl Justi (1888) attributed to Velázquez, the Infanta wears a very similar dress, a sash over her shoulder, a bouquet of flowers and a hairstyle, but changing from the left to the right. One looks like a mirror image of the other. The Infanta's dress does not flap, but closes in the center.

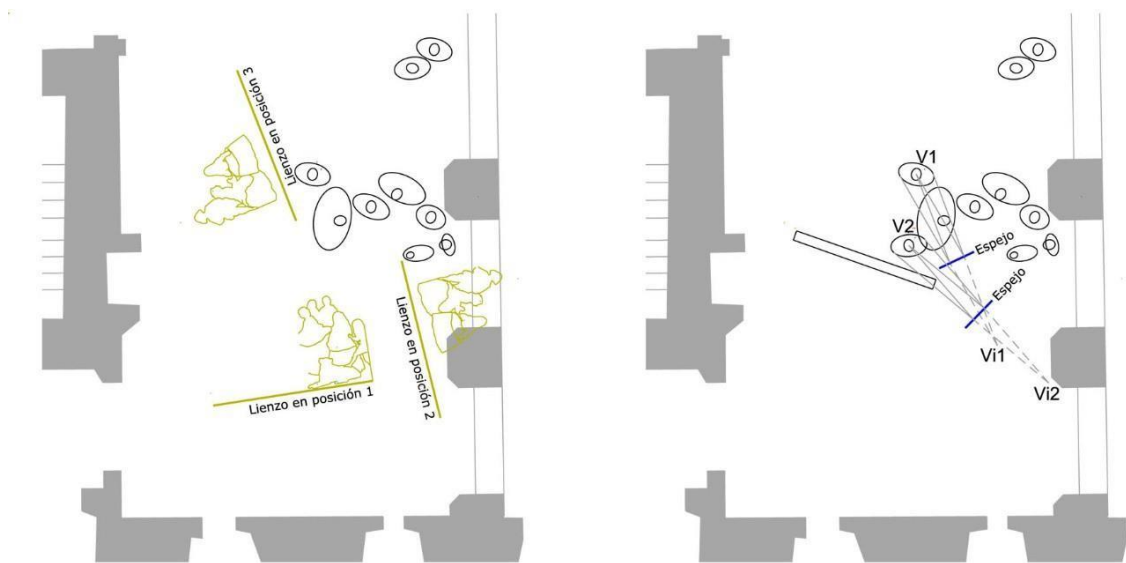


Fig. 24 Canvas positions for painting the figures.

Two different procedures: Left (a), move the canvas. Right (b), moving a mirror. Velázquez portrayed himself with his eye at V1. The virtual point of view of the mirror in that position is Vi1⁽⁴⁹⁾. But in V1 Velázquez was too far from the canvas to be able to paint himself. He approached it to position V2 and moved the mirror to see himself reflected in the same way as from V1 (with the virtual point of view at Vi2), and he painted himself without any problem. He was also able to paint the other figures with the same system.

The same thing happens between *Las Meninas* and the portrait - from the same year 1656, also by Velázquez - of **the Infanta in white and silver** (Vienna, *Kunsthistorisches Museum*). The hairstyle changes from left to right. Again, one of the two portraits must have been painted reflected in a mirror).

If Velázquez - as we posit in this second supposition - painted all the figures using the same mirror with which he painted his self-portrait, this would resolve a doubt that has been raised by anyone who has seen the painting:

Who are Velázquez, the Infanta, Isabel de Velasco and Mari Bárbola looking at in *Las Meninas*? The kings who would have entered? And would the dog have remained asleep while they were doing it? Impossible. They looked at Velázquez and saw themselves reflected in the mirror. The mastiff had fallen asleep, because dogs are not interested in mirrors. When Velázquez was going to paint it, he ordered Nicolasito Pertusato to wake it up so as not to paint the melancholy figure of a sleeping dog, and made the *tour de force* of capturing and painting the dog's face in the very short time it was waking up.

5. Completion of the small picture

Having finished painting the large painting, Velázquez - undoubtedly a practical man - wanted to make the most of the small one. Antonio López often says that "Velázquez is one of the few painters who has no expendable works" (Moneo, 2007). Of course, Velázquez did not want it to be known that he had used a machine to paint *Las Meninas*. An architect - the liberal art in which Velázquez wanted to be recognised - knows how to construct perspectives geometrically.

Instead of destroying the proof of his perhaps ignoble - but effective - practice, Velázquez wanted to make the most of the small painting. He was sure that no one would ever understand exactly what that little square was. He asked his son-in-law to copy the figures from the large painting to the small one, which he did without using any machine, by eye. When painting Mari Bárbola and Nicolasito Pertusato, del Mazo moved their figures a little, leaving the lower edge of the edge of the window closest to us visible.

That start of the edge, point G, is the main proof that the painting process of *Las Meninas* was the one we are describing, and that Kingston Lacy's painting is the "pictorial negative" of the perspective of the interior it represents, and that it was painted by Velázquez, with the addition of the figures painted by his son-in-law. It was sold as it was, reasonably, "for a price not as high as that of a Velázquez, nor as low as that of a del Mazo" (Díaz Padrón, 2013).

Later, after having sold the small painting, Velázquez added the figures of the king and queen in the so-called "mirror" in the background to *Las Meninas* in the Prado. It is plausible to think that he did so at the request of the kings themselves, who did not want to be left out of this magnificent painting.

Those figures are not in Kingston Lacy's *Las Meninas*. Velázquez painted them with absolute nonchalance, blissfully unaware of the rivers of ink they would cause to flow... (We are looking at him, saying something like "Of course, Your Majesty, I understand you perfectly well and I'm going to solve that mistake, to correct that oversight of mine right now"... and mumbling shortly afterwards "What a bore that woman is"). With the painting of that false mirror, or window into an imaginary space, Velázquez concluded the long, complex and deceptive process of painting that impressive trompe l'oeil we call *Las Meninas*.

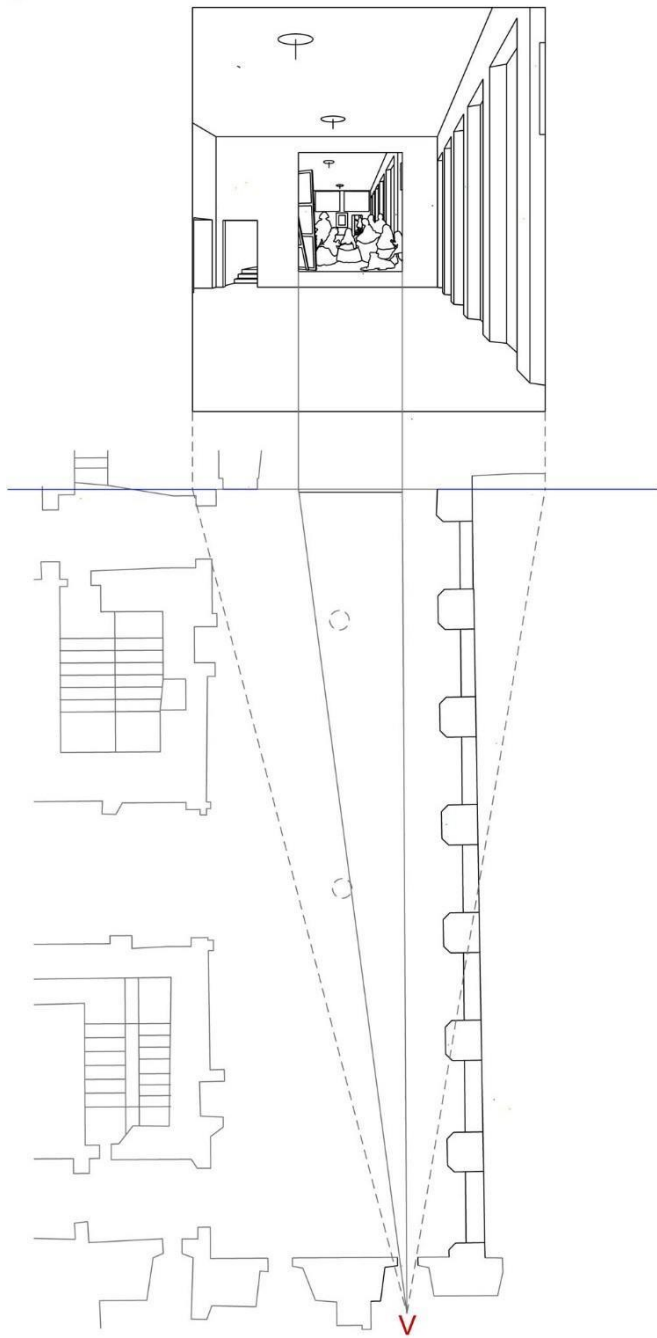


Fig. 25 *Las Meninas* hanging on the east wall of the *Lower Room of the Prince*.

This would be the vision the king would have as he exited the *Golden Tower* and entered the *Gallery*.

Epilogue

"This painting was highly esteemed by Her Majesty, and while it was being done she frequently attended to see it painted; and likewise the Queen our Lady Doña María Ana of Austria came down many times, and the Infantas and ladies, esteeming it as a pleasant delight and entertainment".

The complexity, spectacularity and novelty of the process of painting *Las Meninas* explain this comment by Antonio Palomino, quoted by Moffit (1983), which was only given when Velázquez painted *Las Meninas*. It is well known that kings are bored by posing and watching a painter paint, even if the painter is Velázquez; but the painting of *Las Meninas* was unimaginably dazzling. Viewers could - in 1656! - (We don't know what the Inquisition would have thought of this "pleasant delight" ... magic. In any case, another reason for the matter of the painting of *Las Meninas* to be kept discreet).

From here on, what we are writing is only our speculation about the relationship between *Las Meninas* and the space it represents. The question we ask ourselves is: Where was *Las Meninas* exhibited in the Alcázar of Madrid until the fire in the building in 1734?

Antonio Palomino wrote, and Moffit (1983) also quotes: "It was placed in His Majesty's lower room in the room of the office". More specifically, in our opinion, *Las Meninas* was exhibited on the east wall of the *Gallery of the Prince's Lower Room* (**Fig. 25** and **26**) We cannot provide any evidence for this hypothesis, but we are convinced that it is plausible, and it is based on some certain facts, such as, for example, that the painting was painted in that room and, given its dimensions, it seems difficult to move it from there to other rooms in the Alcázar. And also that it was saved, despite its gigantic size, in the fire at the Alcázar in 1734, in which hundreds of paintings were burnt. It could easily have been removed to the *Emperors' Garden* through one of the windows on the south façade of the *Prince's Lower Room*.

Why precisely on the east wall? ⁽²⁰⁾ Because there, and only there, would the painting appear as a mirror or as an opening into another space that would duplicate the depth of the *Prince's Lower Room*. By placing it there, Velázquez was showing his skill in the construction of perspectives, that characteristic knowledge of architecture (**Fig. 25**).

This also explains the enormous height and the empty space at the top of *Las Meninas* (Tusquets, 2019): like a mirror, the painting should reflect (or, like a window, open onto) the totality of the space. Let us remember, moreover, that Velázquez, in general, distrusts precision (Moneo, 2019), undoubtedly prefers what Heinrich Wölfflin (1915) called *Unklarheit* ⁽²¹⁾ and takes very little interest in geometric perspective in almost all his work, why should he do so here?

Why did Velázquez insist so much on the accuracy of the perspective in *Las Meninas*? Quite simply, because he designed the painting from the outset to hang on that wall, showing the value of the alterations he himself had designed and carried out as architect, as well as the king's aposentador and in charge of maintenance and works at the Alcázar.

As an architect, Velázquez is strikingly different from those of his time: he opens large windows, arranges gardens and interior spaces, renovates staircases or is sent to find "a fresco artist, as well as paintings, sculptures and furniture for the salons" (Brown, 1978). He was less concerned with forms than with enlivening interior spaces "by the subtle control of light and shade" (Brown, 1978). His interest, it would seem, was in environments, in their creation and representation.

Velázquez was a painter, but also an architect and set designer. In *Las Meninas* he presents his works and establishes a theatrical journey through them, towards the first floor, the *Ochavada Piece* and the *Hall of Mirrors*. A path that links reality to fiction and leads us through a canvas that is a mirror or a window open to the same space as the painting... this is the path that José Nieto, the queen's aposentador, invites us to follow from the door of the forum. In a door on the other side, as if it too were a specular reflection (**Fig. 26**).

In this setting, *Las Meninas* appears as a particularly sophisticated example of *mise en abyme*: the work is inside the reality it represents, which in turn we see in the painting, and the painting, once again, inside itself and with its back to us?

That Velázquez used a camera obscura to construct the perspective of *Las Meninas*? No doubt he did. But that does not detract from its merit: he used it for what it was necessary: to trace the perspective, not to paint. It would have been stupid not to do so; without that machine Velázquez would not have been able to achieve with such perfection the duplication of real space in the painting, the effect - so baroque! - of confusion between reality and its representation.

In any case, Velázquez is still the best, "*le peintre des peintres*", as Edouard Manet called him, and in addition, *Las Meninas* shows us two lesser-known facets of Velázquez's genius: the architect and the set designer. In *Las Meninas*, in its original location, the reality of the real and the figurative space of the painting were totally intermingled. This explains Palomino's comment: "*Las Meninas*: Between the figures there is atmosphere: the historical is superior; the whimsy is new; and finally, there is no price that equals the taste and diligence of this work; because it is truth, not painting". (cit. in Moffit, 1983)

Eugenio Trías (1985) wrote with extreme precision about the painting as representation, as window and as mirror that perspective:

"...turns the painting into an open window that "lets us see" whatever is there or happens behind the glass (...) In this way, the painting is established as the creation of a painting, that is, as a flat surface that shows or reveals an interior (...) The painting is the place in which a representation can take place, that is, a staging in which a certain presence is collected and reflected. The painting is, in this sense, a mirror of the world, a mirror that reflects some episode, event or set of events in the world".

In writing about *Las Meninas*, many of the historians and thinkers were right (and no one was entirely right, as is often the case and should be remembered more often...) even if it seems impossible to us: Moffit, Díaz Padrón and all the others; even Michel Foucault (and his followers, such as Oscar Tusquets) was right when he began *Las palabras y las cosas* (1966) with a fascinating but geometrically impossible description of *Las Meninas*, which ends with: "Perhaps there is, in this painting by Velázquez a representation of classical representation and the definition of space that it opens up...".

If it had not been for this text by Foucault, we would surely not have begun to endeavour to discover the mystery of this marvellous painting. Wrong or not, Foucault's text on *Las Meninas* is a useful, productive discourse. Like Tusquets' observations and reflections. Like Moffit's finding, which placed the point of view of *Las Meninas* in the *Golden Tower*, and which seemed to us at first to be completely absurd. Or like the solitary and quixotic effort of Díaz Padrón to explain against all odds that the small painting is earlier than the large one and was painted by Velázquez...

In 1974 Rafael Sánchez Ferlosio advised against writing about *Las Meninas*: "God forbid that I should now start writing literature about this painting, which lends itself so well to it". But if anyone, despite the warning, insists on doing so, let them not be confused into believing that anything goes, even the most absurd errors: to err as well as Foucault, Tusquets, Moffit or Díaz Padrón is an art reserved for a few privileged minds.

The rest of us, what we have to do is not to definitively discard any idea, no matter how crazy it may seem to us, to make good use of the instruments at our disposal - in this case, the computer - and to dedicate the time, attention and concrete, artisanal work (Sennet, 2008) required to the important things: like that edge that can be seen in the small painting of *Las Meninas*, and not in the large one.

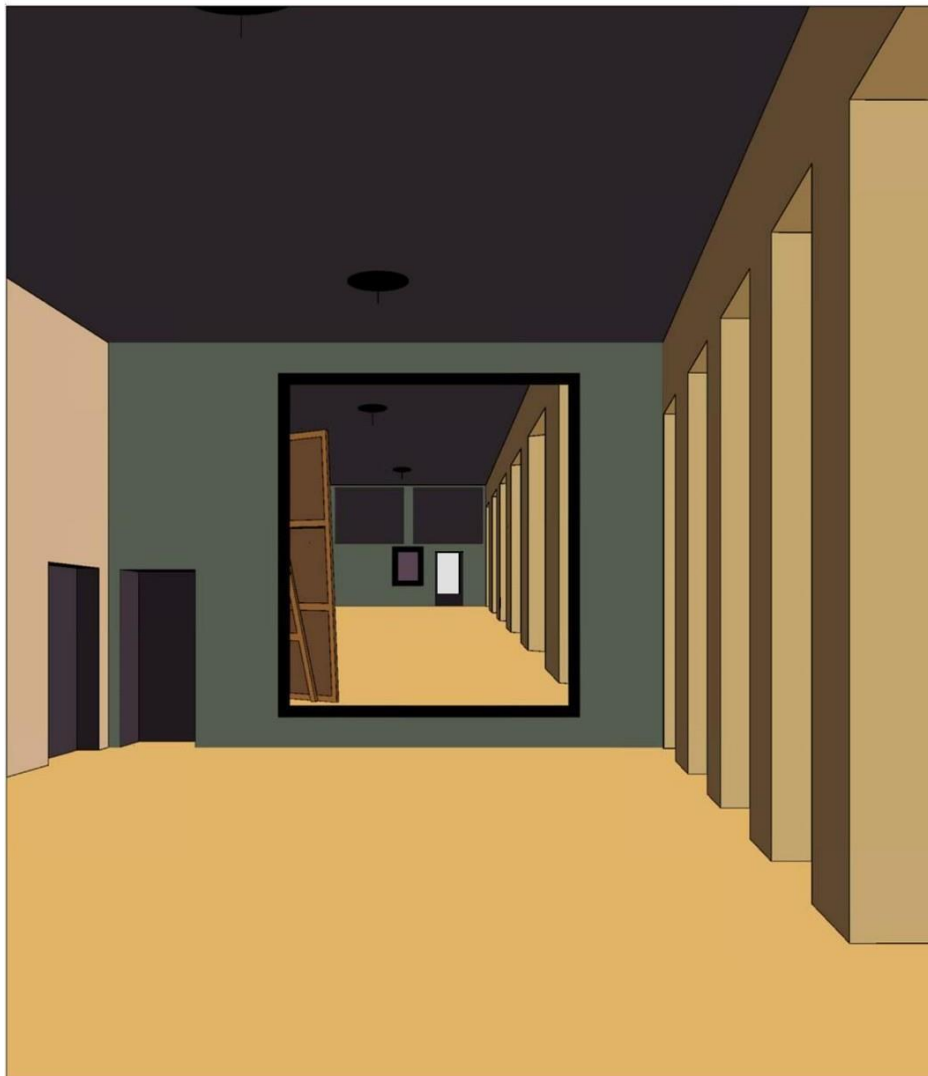


Fig. 26 *Las Meninas in situ*.

Drawing by the author in collaboration with Borja Gutiérrez Febles, architect.

Notes

(1) We have used reproductions from *Wikimedia Commons* for this study. Prado: File: *Las Meninas* (1656), by Diego Velazquez. Available online [here](#). Accessed: 14 March 2020. Kingston Lacy: File:Meninasking.jpg Available online [here](#) Accessed: 27 April 2020. This image should match the image of the same painting: '*Las meninas*' (The Handmaidens of the Infanta Margarita in the Household of Philip IV) (after Velázquez) by Juan Bautista Martínez del Mazo, shown on the National Trust website, but it does not. The Wikimedia Commons image is cropped on the right, so that neither the body of Nicolasito Pertusato nor his right leg can be seen. This should be corrected.

(2) The coincidence of the perspectives of the large and small paintings is striking. Let us make it clear: as the two paintings have very different dimensions, we are comparing the inclinations and not the dimensions of the lines. The edge closest to us on the right-hand upright of the above- mentioned frame is a straight line in the small painting and a line broken into three straight lines in the large one. But if we consider the straight line that joins the upper and lower ends of the upright in the large frame, we can measure with the computer the angle it forms with the same edge in the small frame: 0.04° (see **Fig. 6**).

(3) The other common procedure for copying drawings by scaling them up uses a grid. We can rule it out in this case for at least three reasons: this precision would require a very small grid. In addition, a grid 2.24 times the original size is impracticable and, finally, the outer limits of the smaller and larger grid should coincide, and here they cannot do so because the perimeter of the two squares do not coincide. Moreover: the reasons for discarding the grid are typical conditions in any enlargement obtained by projection.

(4) Moffit and Fox start, as is usual in perspective deconstructions made without using CAD, from the idea that the perspective of *Las Meninas* is frontal (Usandizaga, 2019). This does not affect the results they obtain in this case.

(5) To avoid confusion, we use the nomenclature of Moffit (1986) throughout the text for the premises and dependencies of the Alcázar in Madrid, and we write all these names in italics).

(6) To find the vanishing points we drew the mean lines of the crossbars (to reduce the number of variables) and saw that the differences in angle between their vanishing lines are very small between the large ("A1B1", "A2B2", "A3B3" and "A4B4") and small ("a1b1", "a2b2", "a3b3" and "a4b4") squares (Fig. 14). The proximity of the vanishing points of the three lower crosspieces allows us to locate a point intermediate to all of them, point A. The differences in angle between the transom shaft leakage and the leakage at A are also minimal (Fig. 15). The margin of difference is greatest at the lowest cross member, AB1. This may be partly a consequence of the deformation produced by the camera obscura lens, and is also due to the difficulty of working so close to the ground. We do not know how to explain the vertical shift that only occurs between B2 and b2. Perhaps a movement of the lens when refocusing at that point in the large frame?

(7) It must be remembered that all the lines that are parallel in reality, projected orthogonally in plan and section (following the dihedral system of descriptive geometry), in perspective they run away to a single point. If they are also horizontal, the vanishing point will be on the horizon. To find the point of view V in the plan, we follow these steps (Fig. 17):

1. Draw the line PC, the dihedral line between the ground plan and the plane of the box. We extend the line DE to its intersection with PC, E'. At this point we are going to locate the angle of the angle in plan between the back wall and the south façade.
2. Starting from this angle, we draw our tracing of Gómez de Mora's plan, giving the wall in the background the same dimensions as it has in the perspective.
3. We descend vertically the points A, B, C, E, G and F from the perspective to the line PC, obtaining the points A', B', C', E', G' and F'. We draw a line parallel to E'G and containing the point C'. As these two lines are parallel in plan, in perspective they run away at the same point: C. The point of view has to be on the line that we have just drawn in plan, parallel to E'G and passing through C.
4. We draw a line joining point G' with point G in plan, which is situated on the edge closest to us of the fifth masonry block between the windows. The point of view V is at the intersection of the line G'G with the parallel to E'G which contains C'. The line A'V (parallel to the BF) allows us to check that the procedure we have followed is correct.
5. We lower the section on the ground plan and find the viewpoint V in the section, at the intersection of the prolongation of the horizon HZ with the parallel to PC containing V (in plan).

(8) The vanishing direction VC' of the depth lines is parallel to the façade and 1130 millimetres away from it. A turn of only one tenth of a degree of the line VC would produce a displacement of 5 millimetres in the position of point C' in the small square, but one of 1945 millimetres in the distance in plan from the back wall to the point of view V (Fig. 19) The transverse displacement in the perspective is proportional to the sine of the angle, which tends to zero at such small angles; but in the depth of the plan it is proportional to the cosine of those angles, which tends to one.

(9) It should be noted that Gómez de Mora's plan is not very precise. It is not a site plan, nor is it dimensioned, but rather a survey probably intended for administrative and inventory purposes.

(10) Velázquez could not have used a box camera obscura, as Moffit (1986) suggests, because the dimensions and operation of this type of camera obscura only allow drawing on paper and in a very small format. It is impossible to trace the perspective of the small painting with one of these cameras. Philip Steadman, many years after the publication of his book (2001), acknowledged some of its weaknesses. He did so in an interview (Steadman, 2014), stating that a camera obscura does not provide the conditions for painting, but it does provide the conditions for drawing. We fully agree with him. The camera obscura is - and has been - used to draw perspectives, not to paint.

(11) According to Steadman (2001), the largest of Vermeer's interior paintings is *Allegory of Painting*, which measures 120x100 cm, *The Music Lesson* and *The Concert* are just over 70 cm high, and most of the others are less than 50 cm high.

(12) *View of the garden of the Villa Medici* and *View of the garden of the Villa Medici in Rome with the statue of Ariadne* measure 48.5x43 cm and 44.5x38.5 cm respectively.

(13) This second point of view V' means that we cannot consider *Las Meninas* a perspective as a "symbolic form" according to Erwin Panofski's definition (1927).

(14) Tusquets (2019) states that the large painting seems to be painted *alla prima*. We believe it would be more accurate to say that its perspective seems to have been drawn with little hesitation, and not, on the other hand, the figures. This would confirm our version of the process of creation of *Las Meninas*. We hope that the X-ray analysis of the two paintings - which we feel it is essential to update - will confirm our hypotheses.

(15) In our perspective, the horizontal line passing through E, which represents the dihedral floor - back wall, is higher. If we wanted to lower it, we would have to move ED to the right and point D would no longer be the trihedron angle back wall - right wall - ceiling (Fig. 17).

(16) There is also another problem with the perspective of this door: if it were where it appears in the painting, the plan of its leaf would have to be parallel to the line JV and, if it were, when it closed it would not cover the entire opening (Figs. 20 and 21). On the other hand, if the door were actually further to the left than where Velázquez paints it (for example, where Gómez de Mora draws it in his plan), the vanishing point J would be displaced to the left (J'), so that the inclination of the line J'V' would be considerably greater, and the door would cover the entire width of the frame when closed.

(17) We can get an idea of the length of the ruler Velázquez used: it allowed him to draw the right edge of the frame in a single stroke on the small painting, but he had to make the same line in three strokes when copying it on the large one (Fig. 6).

(18) The non-rectangular plan we assume for the camera obscura would make it possible to shift the point of view in order to paint the door in the background. In all this work we have disregarded the width of the doors drawn by Gómez de Mora. Almost all of them are evidently narrower than necessary. In order not to hide this problem, we have drawn them in the same way as Gómez de Mora.

(19) Since the angles of incidence and reflection in a mirror are equal, the reflected image is the image seen from an imaginary viewpoint V_i on the other side of the mirror, on the line perpendicular to the mirror that contains the viewpoint V. The distance to the mirror of the point of view V is equal to the distance from the mirror to the point V_i . This reasoning, which explains the mystery of the change from right to left, can be applied to both plan and section and allows us to see how a mirror does not change up and down, but the image projected on the back wall of a camera obscura does. This [video](#) gives a good explanation for the question of the apparent change between left and right in mirrors. And Luis Bru Villaseca, in "La flecha del tiempo y la simetría en la naturaleza" (1981), explains that the differentiation between right and left depends on an arbitrary decision which, once taken for one body, is determined for any other.

(20) We are aware that we are denying some of Moffit's (1983) assertions taken from the 1686 inventory about the position of *Las Meninas* in the Alcázar, but we are convinced that we are right to do so.

(21) The terms *Klarheit* and *Unklarheit* used by Wölfflin (1915) are usually translated as "absolute clarity" and "relative clarity", but *Unklarheit* is a stronger word: lack of clarity, darkness, confusion... Indeed, a precise name for a typical condition of baroque art.

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