CHAPTER 11

Geometry and Scenography in the Late Gothic Choir of Metz Cathedral

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The Cathedral of Metz, although little known even among historians of medieval art, deserves recognition as one of the largest and grandest of medieval churches. With vaults some 42 meters high, Metz Cathedral ranks with Amiens as the tallest French cathedral completed in the Middle Ages. The clerestory at Metz is the tallest of any Gothic church and the cathedral's late Gothic transept frontals enframe the largest stained glass windows in the history of architecture. With impressive specifications such as these, the cathedral's relative obscurity demands explanation. One important factor in this neglect has surely been the cathedral's location in Lorraine, a territory located on the border of the French and German cultural spheres that belongs fully to neither. Metz was occupied by the Germans in the decades following the Franco-Prussian war, in precisely the years when the French were coming to a new appreciation of their great cathedrals such as Chartres, Reims and Amiens.

To the extent that Metz Cathedral has been studied at all, attention has tended to focus on the thirteenth-century portions of the building, in which connections to the Reims Cathedral workshop are clearly discernible.[1] In the one scholarly monograph on Metz Cathedral, published by Marcel Aubert and Jean Vallery-Radot in 1931, the late Gothic transept and choir of the building are treated only briefly, and they are not treated at all in the more recent studies of the nave undertaken independently by Christoph Brachmann and Sergio Sanabria.[2] All of

[1] At Metz, as at Reims, the arcade features cantonnated piers with beltlike foliate capitals of uniform height, surmounted on the nave walls by thick muscular shaft bundles. Both buildings also feature champenois passages and similar treatments of bases, moldings and profiles.

[2] The major scholarly monograph on the building is still Marcel Aubert, *La cathédrale de Metz* (Paris, 1931). More recently, Christoph Brachmann has analyzed the nave architecture of Metz cathedral in the context of thirteenth-century episcopal power, in *Gotische Architektur in Metz unter Bishof Jacques de Lorraine: Der Neubau der Kathedrale und seine Folgen* (Berlin, 1998). The preliminary results of Sergio Sanabria's rigorous archaeological study of the nave have only begun to appear in print, as in, e.g., Sergio Sanabria

these authors, noting the striking extent to which the cathedral's late Gothic east end harmonizes with the earlier nave, have chosen to concentrate their attention on the period when the overall flavor of the project seems to have been established. Thus, one of the most ambitious and successful cathedral-building projects of later northern Gothic architecture has been left essentially unstudied.

Consideration of the later campaigns at Metz, however, can reveal a great deal about the methods and attitudes of Late Gothic designers confronted by the achievements of the High Gothic and Rayonnant periods. In particular, careful analysis of the cathedral's plan geometry reveals surprising connections to and transformations of thirteenth-century design practice. Together, these suggest that a new dialog between scenographic and purely geometrical design strategies was taking place at the very end of the Gothic period.

The plan of Metz Cathedral departs in a number of significant respects from the pattern established by great thirteenth-century cathedrals such as Amiens (Figure 11.1). Some of the peculiarities seen at Metz, such as the absence of a conventional west-façade block, reflect the vagaries of the cathedral's institutional history and early building sequence, and need not intrude further into the present discussion.[3] It is worth noting, however, that the thirteenth-century builders of the nave had already decided to construct an aisle-less transept. Thirteenth-century dado walls were built up against the lower western faces of the cathedral's Ottonian transept, which was retained along with the Ottonian choir until the construction of their Late Gothic successors. It seems, therefore, that the thirteenth-century builders already envisioned the Gothic transept as a simple glass box of colossal

and Kristina Luce, "The Rayonnant Gothic Buttresses at Metz Cathedral," in Michael Wolfe and Elizabeth Smith, eds., *Technology and Resource Use in Medieval Europe: Cathedrals, Mills and Mines* (Aldershot, 1997). Two other recent works on the cathedral that deserve mention are Marie-Antoinette Kuhn-Mutter, *La cathédrale de Metz: des pierres et des hommes* (Metz, 1994), which is noteworthy for its handsome photographs by Raymond Kuhn, and P.E. Wagner and J.L. Jolin's *15 Siècles d'architecture et urbanisme autour de la cathédrale de Metz* (Metz, 1987) which offers a valuable urbanistic perspective on the cathedral's history, though it breaks no new ground in the archaeological investigation of the monument itself.

[3] Because of the orientation of its hilltop site, Metz Cathedral is not even aligned on a conventional east-west axis. Instead, the choir of the church – its "east end" – is actually to the geographical north, while its "north" and "south" transepts face west and east, respectively. The two apsidal protrusions on the cathedral's "south" are conventionally oriented. The "western" one served as the choir for the formerly autonomous collegiate church of Notre-Dame-la-Ronde, which was progressively incorporated into the fabric of the cathedral. Because of the original distinction between the two churches, the cathedral's towers were planted to the "east" of Notre-Dame-la-Ronde rather than at the "western" end of the nave as a conventional facade block. Henceforth the quote marks around these directional terms will be eliminated to avoid distraction, but it should be remembered that these terms label the parts of the cathedral according to ecclesiastical rather than geographical convention.

dimensions. The present transept, begun in 1487, realizes this basic vision faithfully, with Late Gothic mannerisms evident only in the detailing (Figure 11.2).

The case of the choir plan is far more subtle. With its three shallow chapels disposed in a basically octagonal array, the east end of Metz Cathedral at first appears more geometrically rigid than the analogous portions of a thirteenth-century cathedral like Amiens, in which many chapels seem to squeeze next to each other with almost arbitrary tightness, as if they were drawn onto the surfaces of a closing Japanese fan (Figure 11.1). Upon closer inspection, however, the Metz plan begins to display curious features that complicate this picture of geometrical rigidity. To begin with, the stellar vaults of the chapels appear compressed and flattened in plan, as though the chapels were not sufficiently deep to contain their notionally octagonal geometries. The choir "straight bays," moreover, pinch slightly inwards at their eastern end; the exterior walls of the aisles bend towards the building's centerline and the freestanding piers of the choir proper are similarly biased inwards. Impressionistically, the latter aspect of the design may be understood as part of the transition from the huge open spaces of the nave and transept to the somewhat quicker visual rhythm of the strongly faceted hemicycle. Geometrically, however, this biasing of the walls appears to mark a real departure from the design methods of the thirteenth century, in which the principal walls were typically straight until they reached the hemicycle proper. A quick look at the plan of Metz Cathedral, therefore, suggests that the late Gothic designers conceived the geometrically rigid plans of the boxy transept and octagonal hemicycle zone independently, joining these two zones with walls set at whatever angle was necessary to achieve a smooth linkage. Such a preliminary analysis contains important grains of truth, but the surprising logic of the Metz plan cannot be appreciated without a much more detailed analysis of the choir geometry and its relationship to the rest of the cathedral, especially as it was experienced by visitors to the church.

From the perspective of the church-goer, Metz Cathedral appears both aesthetically and geometrically unified, at least in a broad sense. The overall articulation of the cathedral's late Gothic east end harmonizes with that of the thirteenth-century nave. As noted earlier, scholars have generally seen this as deliberate historicism on the part of the Late Gothic builders. An even more striking coordination between the east end and the thirteenth-century work emerges when one stands in the nave aisles looking east (Figure 11.3). A chapel window stands enframed at the end of each aisle, in an arrangement that appears to be purposefully scenographic. It would seem, in other words, that the designers of the Late Gothic choir anticipated the ways in which visitors to the cathedral would experience it optically and perspectivally, deliberately ordering the forms of the cathedral's east end to produce visually satisfying vistas like the one down the nave-aisles to the chapel windows.[4] This observation immediately

[4] Marvin Trachtenberg has demonstrated the importance of scenographic as well as geometrical thinking in the architectural and urbanistic culture of Trecento Florence. As

raises questions about the conception of the choir plan and its geometry. How was this optical alignment conceived? How did the designers combine scenographic considerations of this kind with their traditional geometrical methods, which were conceptually independent of the viewer's experience?[5] What were the sources of the geometrical thinking that allowed the Metz designers to achieve these effects, and what does this suggest about the relationship between High and Late Gothic design?

These questions could be tackled directly if the intentions of the Metz designers were recorded in contemporary plan drawings. Such drawings would give access to the cathedral's "ideal plan," unaffected by the irregularities that can creep into the building during construction through both mistakes and design refinements.[6] Unfortunately, however, no such plans for Metz Cathedral survive, and the physical fabric of the church displays numerous asymmetries and irregularities that greatly complicate analysis of its intended plan geometry. These irregularities, moreover, have not been accurately recorded in the modern plans thus far published in the nineteenth and twentieth centuries. Figure 11.4 presents the results of a new survey in which these anomalies have been carefully recorded to permit the present geometrical analysis.[7]

Trachtenberg explains, Florentine builders were willing to mix strict geometrical reasoning with improvisational and contextual thinking. A generally analogous mixture of impulses seems to have been at work in the Metz workshop a century later, although the theoretical premises of the northern builders may have been very different than those documented by Trachtenberg in the Florentine case. See Marvin Trachtenberg, *Dominion of the Eye: Urbanism, Art and Power in Early Modern Florence* (Cambridge, 1997).

5 Here once again Trachtenberg's analysis of Italian urbanism offers an interesting gloss on the situation at Metz. In a talk entitled "Perspectivism and Other Planning Strategies in Renaissance Urbanism," delivered at the University of Iowa on April 10, 2000, Trachtenberg contrasted the "perspectivist" design strategies of Florentine Trecento planning with the "auratic" approach seen two centuries earlier in the Campo Santo at Pisa. He argued that the layout of the Pisa Cathedral complex enhances the viewer's sense of the buildings as autonomous and geometrically coherent objects precisely because their arrangement does not scenographically frame a series of ideal views for the visitor's benefit. The traditional geometrical methods of Gothic design, similarly, make no direct appeal to the subjective experience of the viewer. The arrangement of the Metz chapel windows appears particularly interesting in this context because it suggests a shift from this purely "auratic" mode.

6 Important collections of medieval architectural drawings of this kind have been preserved in several major centers in the Germanic world, most notably Strasbourg and Vienna. The geometrical logic behind these designs can often be gleaned directly from such drawings, especially in cases where construction lines or compass pricks record the working process of the draftsmen. See, e.g., Roland Recht et al., *Les Bâtisseurs des cathédrales gothiques* (Strasbourg, 1989), Hans Koepf, *Die gotischen Planrisse der Wiener Sammlung* (Vienna, 1969) and Francois Bucher, *Architector: The Lodge Books and Sketchbooks of Medieval Architects* (New York, 1979).

7 The most accurate overall plan of the cathedral is still the one drawn up by Paul Tournow, the architect in charge of the cathedral in the later nineteenth century during the

Significantly, Figure 11.4 reveals that while the north-nave-aisle axis lines up exactly with the eastern chapel window as shown in Figure 11.3, the same relationship does not quite pertain to the south, where the chapel window axis sits some 70cm inboard of the aisle axis.[8] This disparity can be understood as a symptom of a general distortion of the hemicycle structure towards the north. A line drawn through the northernmost of the four major hemicycle buttresses and the associated freestanding hemicycle pier intersects the main longitudinal axis of the building at an angle of only 19 degrees off perpendicular, instead of the 22.5 degree angle that octagonal symmetry would lead one to suspect. All the other radial lines converge to a center displaced slightly to the west of this intersection point. The two of these lines embracing the axial chapel make angles of 24 and 21 degrees with respect to the building's principal axis, attesting once again to the northward displacement of the choir geometry, the origins of which will be discussed in detail below. Broadly speaking, however, these distortions can be seen as the unfortunate but almost inevitable result of working on a crowded hilltop site in which the retention of the earlier cathedral's Ottonian choir prevented direct surveying to the hemicycle's geometrical center. The irregularities in the choir structure are almost imperceptible

German occupation of Metz. A streamlined and simplified version of this plan was published in Aubert's monograph (see Figure 11.1) and is found in most publications and guidebooks dealing with the cathedral. Tournow's plan, however, misrepresents certain aspects of the choir geometry, most notably the proportions of the salient buttress flanges, by exaggerating the distinction between the thicknesses of the two major buttresses flanking the axial chapel. Moreover, Tournow's elevation drawings frequently omit the slight changes of detail that provide valuable evidence for changes in the direction of the Metz workshop. Aubert's monograph, meanwhile, includes a few valuable drawings that scrupulously record the precise shape and size of piers, shaft bundles and other small elements, but the information from such drawings is strictly local. To complement these extant studies, I surveyed the choir of the cathedral during visits to Metz in the summers of 1998 and 1999. I am pleased to acknowledge the assistance of John Hiser and Sergio Sanabria, without whose collaboration I could not have taken the necessary measurements. This survey was based on taking massively redundant sets of triangulated distance measurements with a steel tape. The new choir plan drawn up from these distance measurements was then compared to the sets of laser-sighting data taken from a series of strategically chosen fixed sighting points, which give highly precise checks on the angular relationships between the parts of the building. The accuracy of the new choir plan was confirmed by its excellent agreement with this laser-sighting data. Sanabria's far more detailed survey of the nave, meanwhile, provides a newly rigorous basis for analysis of the earlier campaigns at the cathedral.

8 In this paper, "inboard" means "towards the cathedral's principal longitudinal axis." This term should serve to remind the reader that when elements are moved "inboard," the overall scale of the plan shrinks. The shifting of elements "outboard," conversely, result in an overall scaling up of the composition. Such considerations are important because analysis of the highly distorted Metz choir plan depends on careful consideration of its overall scale, as explained more fully below.

to the visitor, but they muddy the waters of geometrical analysis to a dismaying extent. It becomes difficult to determine, for instance, whether the Cathedral's Late Gothic designers intended for the windows of the chapels to line up precisely with the aisle axes, or whether they were content to work with a geometrical schema that only approximated this scenographically satisfying arrangement.

Lacking direct access to the Cathedral's "ideal plan" of the kind that medieval drawings could provide, one must attack such problems by testing hypothetical "ideal plans" against a carefully measured plan of the actual cathedral.[9] In effect, the researcher must attempt to recreate the thinking of the medieval designer, drawing ideas from the forms of the building and the nature of the geometrical problems involved. Because of its dependence on personal imagination, the process of trial-plan generation is necessarily somewhat subjective. In practice, however, there are only a finite number of natural solutions to most design problems and a sufficiently rigorous process of plan testing can effectively isolate the likely "ideal plan" by weeding out irrelevant candidates. This process of plan analysis, like the traditional Gothic planning process itself, takes geometry as its point of departure. The contribution of scenographic thinking to the Metz choir design, therefore, can only be properly assessed after a certain amount of purely geometrical discussion.

In the case of the Metz choir, care must be taken to distinguish between the geometry of the main floor level and that of the crypt. As noted above, the geometry of the stellar vaults in the chapels appears curiously compressed. At the crypt level, however, the chapel vaults are not stellated and their simple rib pattern clearly proclaims that each is conceptually organized around a perfect half-octagon (Figure 11.5). Stellated vaults were first introduced at Metz Cathedral in the so-called Bishops' chapel constructed in 1440, a half century before work began on the choir chapels. In the Bishops' chapel, the stellate vault fits naturally into the five-eighths of an octagon that define the chapel apse. This may be clearly seen Figure 11.1, where the Bishops' chapel appears midway up the Cathedral's southern flank. In the choir chapels, however, the same stellation pattern has been awkwardly wedged into the spaces defined by the smaller form of a half octagon in the crypt – in each crypt chapel, the fanlike form of the three primary octagon facets is flanked by two half-facets, rather than by two more full facets as in the Bishops' chapel. Since the crypt level was necessarily constructed before the choir superstructure, the crypt plan probably reflects the thinking of the original designer's "ideal plan" more faithfully than the upper stories.

This interpretation receives support from a series of modifications in the articulation of the upper stories. Together, these suggest that the original master, who used curvilinear tracery and relatively simple forms, was replaced by a second master with a taste for historicizing geometrical tracery and more complex decorative forms such as stellated vaults. This second master's workshop constructed the north choir aisle, the upper portions of the north transept, and enough of the north upper chapel to fully determine its design. The remainder of the cathedral appears to have been constructed in accord with the designs of a third master, since the molding profiles, buttress sections and other details of stylistic "handwriting" differ from those of the north side. In its essentials, however, the geometry of the cathedral plan appears to have been laid down by the first master in his design for the crypt.

9 As discussed below, the fabric of the Metz choir attests to several changes in the leadership of the Metz workshop, but the overall cohesion of the design together with the pervasive use of drawing as a design tool in the later Middle Ages strongly suggest that an "ideal plan" did in fact exist when ground was broken for the choir.

As Figure 11.5 shows, the geometry of the crypt incorporates two elegant relationships that together determine many parameters of the overall choir design. First, it can be seen that a line drawn through the centers of the southern and axial chapels will intersect the adjacent major buttresses on the exact middle of their exterior faces. When the same scheme is used to produce the line segment through the center of the north chapel, the corner of a large rotated square begins to emerge, locking the chapel centers onto the line segments joining the midpoints of the buttress faces. Because of the octagonal symmetry of the chapel array, these line segments are inclined 22.5 degrees with respect to the cathedral's principal axes. The second major relationship evident in Figure 11.5 involves an even larger square oriented parallel to these principal axes; its eastern face is defined by a line segment passing north-south through the center of the axial chapel, terminating on the midpoints of the diagonally-planted exterior faces of the north and south chapels. By symmetry, analogous squares could be drawn at 45 degree increments to produce two systems of interpenetrating eight-pointed stars, one rotated 22.5 degrees with respect to the other.

These two systems interlock with each other beautifully and automatically, as Figure 11.6 demonstrates. The faces of the major buttresses necessarily lie on the dotted lines connecting the corners of the cardinally-oriented star. This basic geometrical armature can be readily elaborated to produce the overall outlines of the Metz choir, as shown in Figure 11.7. The exterior walls of the chapels and even the wedge-shaped forms of the principal buttresses all emerge naturally from the simple assumption that the chapels were intended as perfect half-octagons. This geometrical schema may be thought of as geometrically rigid; the internal logic of the figure determines everything except its overall scale. It is significant, therefore, that this geometry already specifies the locations of the sightlines to the centers of the north and south chapel faces, indicated in Figure 11.7 by the two dotted lines running east-west.

This observation holds the key to the relationship between geometrical and scenographic thinking in the Metz choir plan. The view down the north-aisle axis shown in Figure 11.3 certainly seems to suggest that the builders of the Metz choir meant for the chapel window to line up with the aisle axis, but careful measurement of the choir as a whole suggests that this relationship was only approximated in the "ideal plan" that guided the construction.[10] It must be remembered, after all, that the southern chapel window sits some 70 cm inboard of the associated aisle axis (Figure 11.4). The geometrical logic behind the choir plan, therefore, cannot simply be determined by sighting down one aisle or the other. Instead, consideration must be given to the overall layout of the choir as a whole. As noted briefly above, the fundamental distortion in the choir geometry is a slight rotation of the whole hemicycle towards the north. Because rotations leave scale unaffected, the overall size of the hemicycle structure should in principle be the same as that specified in the "ideal plan." As it turns out, the east end of the cathedral would have to be some 6% larger than it actually is to achieve perfect window alignment with both the north and south-nave-aisles. The key point here is that all the parts of the building are slightly smaller than they would have been if perfect alignment between the chapel windows and the aisle axes had been intended. Since this discrepancy of scale cannot be explained away by the northward rotation of the choir geometry, it suggests that the "ideal plan" of the cathedral did not incorporate this perfect alignment. It might at first seem surprising that the "ideal plan" for the Metz choir would have only approximated a scenographically satisfying relationship of this kind, but it must be remembered that Gothic design methods were fundamentally geometrical rather than optical. Paradoxically, this 6% mismatch between the chapel windows and nave-aisle axes appears to have resulted from a design process in which the geometrical harmony between the new and old portions of the building was of paramount importance.

The Late Gothic masters of the Metz workshop had inherited several basic geometrical givens from their thirteenth-century predecessors. Of these, the most fundamental was the span of the nave, 15.60 meters from pier centerline to pier centerline. The span of the nave side-aisles was half that of the main vessel, or 7.80 meters. Similarly, the construction of the low dado walls along the western face of the transept established the location of the inner transept walls exactly 15.60 meters out from the centerline axes of the nave piers. The transept thus has an overall interior width equal to three times the span of the main nave vessel, or six times the span of an aisle. Although the nave span is in some ways the more fundamental quantifier, it is convenient to call the span of the aisle as "one unit," so that the nave span is two units and the transept span six units. In this nomenclature, the centerlines of the nave aisles each appear 1.5 units out from the building's principal

[10] It may sound strange to say that an "ideal plan" could embody a relationship only approximately, but there is no real contradiction at work here. Perfect geometry does not automatically translate into perfect scenography. Indeed, the elegant and inherently "perfect" geometry of the Metz choir's "ideal plan" was subtly incompatible with the idea of perfect optical alignment between the chapel windows and the aisle axes, as explained more fully below.

axis. All of these basic parameters were literally built into the portions of the western transept wall constructed during the thirteenth century. Symmetry, structural prudence and decorum obliged the Late Gothic builders to adopt the same simple and harmonious proportions in their completion of the transept.

Since the Late Gothic builders of the Metz transept were employing the characteristic 7.80 m unit inherited from the thirteenth-century nave side aisle, one might well suspect that it was used in laying out the radially symmetric portions of the east end as well. It is surprisingly easy, in fact, to generate a trial geometry based on this module that accords well with the actual geometry of the Metz Cathedral hemicycle. In developing a trial choir plan for a Gothic cathedral, it is important to remember that the compass was a major tool of design and that circular construction lines often served as the conceptual armatures upon which faceted and polygonal forms were developed. In this instance, therefore, it makes sense to begin by using the compass to add substance to the geometrical skeleton described by Figure 11.7. As Figure 11.8 shows, a plausible wall thickness for the chapels emerges naturally by inscribing half-octagons within the half-circles that can themselves be inscribed within the slightly larger half-octagons defining the cathedral's exterior wall surfaces. When the inner-wall surfaces of adjacent chapels are projected slightly inwards towards the center of the hemicycle, they converge at points that lie on the same great circle that defines the location of the chapel centers. In view of the simple modular relationship governing the layout of the cathedral's nave and even its Late Gothic transept, it is tempting to imagine that this great circle might have a radius based on the same 7.80 meter module. In particular, it makes sense to explore the idea that the great circle has a radius of 15.60 meters, or two units, so that it could be interpreted as the rotated analog of the exterior walls of the choir aisle, which intersect the transept two units out from the building centerline.

In principle, this hypothesis ought to be easy to test. In practice, however, the cathedral's complex articulation, the decision to add stellar vaults in the upper chapels and the subtleties of the distortion to the north all conspire to complicate the analysis. The design of the stellar vaults deliberately obscures the true geometrical center of each chapel. For that reason the geometrical center of each chapel can best be located by looking at the arch moldings that enframe the chapel entrance, but these shaft bundles present puzzles of their own. In a typical High Gothic building, such shaft bundles would be relatively simple, with a single obvious geometrical centerline through the central shaft. In the Late Gothic choir of Metz, however, the shaft bundles are enormous and dauntingly complex masonry masses with no similarly obvious centerline. As Figure 11.9 shows, these shaft bundles are geometrically conceived around two related focal points: the first, within the mass of the shaft bundle proper, is defined by the intersection of the lines flanking the wedge-shaped wall between the chapels; the second, within the mass of this wall, is defined by the lines that describe the flat back faces of the shaft bundles. These two focal points correspond to the inner and outer foci of the inter-chapel walls seen in the schematic geometry of Figure 11.8.

In testing this construction against the building as a whole, some consideration must be taken of the two slightly different center points apparently used in the layout of the hemicycle piers. Since archaeological and stylistic analysis suggest that the northern side of the building was the first to have been completed, one might suspect that the center point associated with the north buttress was the more fundamental of the two. Indeed, circles drawn through this center point locate the components of the outer buttress envelope with no asymmetries, suggesting that it was used in the layout of the exterior wall and the crypt. The second center point appears to have been used only for the layout of the southern free-standing hemicycle piers, as part of the third master's attempt to recover from the northwards rotational distortion that he had inherited from his predecessors. When testing circular constructions against the overall plan of the Metz choir, therefore, the more eastern center point should be used.

The clarity of the results amply rewards the pain of the preamble: as shown in Figure 11.10, a circle with 15.60 meter radius struck from this more eastern center point passes exactly through the salient points defined by the interchapel walls, inscribing itself perfectly within the great octagon defining the chapel entrances. This circle also appears to have been used to define the inner faces of the main buttress culées on the deck above, as Figure 11.11 reveals. The crucial point is that this circle of radius 15.60 meters locates the geometrical center points of the chapels, which in turn define the location of the chapel windows. Since the lines from the hemicycle center point to the northern and southern chapel centers should each fall 45 degrees from the cathedral's principal axis, the distance from this principal axis to the optical axis of each chapel center and window should in theory be equal to the radius of the great generating circle divided by the square root of two (1.414).[11] And, as the circle itself has a radius of 15.60 meters or two units, the distance between the cathedral's principal axis and the chapel axes should be 11.03 meters or root two (1.414) units. The actual distance from the principal axis to the nave-aisle axes, meanwhile, is 11.70 meters or 1.5 units – roughly 6% longer. Thus, the previously noted fact that the overall scale of the choir is 6% too small to achieve perfect optical alignment with the nave-aisle axes may be understood as a direct consequence of the decision to base the choir plan on a circle with the geometrically natural two-unit radius.

This fundamental result begins to suggest that geometrical elegance took precedence over scenographic effect in the design of the Metz Cathedral choir, despite the clear sensitivity to scenographic effect evident in the placement of the chapel windows at least approximately along the aisle axes. The determination of the overall scale of the Metz choir, moreover, permits the elaboration and

[11] This follows simply from the fact that the sine of 45 degrees is 1/(root two), which is to say 1/(1.414).

enrichment of the preliminary geometrical analysis sketched in Figures 11.5 through 11.8. As Figure 11.12 shows, a circle of radius one unit drawn at the center of the hemicycle can be exactly inscribed within the stellated form defining the outboard faces of the four principal hemicycle buttresses. The outer corners of adjacent buttress culées, therefore, are separated from each other by exactly the span of the nave. Since the large circle of radius 2 units plays such a natural and fundamental role in the layout of the building's exterior structural envelope, it makes sense to explore the possibility that the center points of the freestanding hemicycle piers are similarly located on the inner circle of radius 1 unit, as the four small dots on this circle suggest. Such a geometry automatically begins to explain the curious inward pinching of both the choir and the aisle walls; the freestanding piers and shaft bundles of the ambulatory would stand out from the building centerline slightly less than the analogous elements in the nave.[12]

Figure 11.13 lends credence to this reconstruction by demonstrating that lines projected inwards from the wedge-shaped walls between the chapels define kite-shaped zones precisely centered on the four putative pier center points. The actual hemicycle piers, although far more complex in their details, are laid out on plans of this same asymmetrical kite shape, as shown in Figure 11.14. This relationship can hardly be seen as approximate or fortuitous, since measurement of the carefully drawn pier section reveals precisely the same angular relationships predicted by the global geometry of Figure 11.13: the angle between major shafts is 110 degrees on the side facing into the choir and 70 degrees on the side facing the ambulatory. There thus seems to be ample reason to have confidence in this recreation of the ideal plan of the Metz Cathedral hemicycle.

Figure 11.15 presents a fairly complete version of the geometrical armature underlying this plan and Figure 11.16 isolates several of the major geometrical relationships that define its logic. The eight-pointed stars of Figure 11.16A link the nave span to the chapel axes and exterior faces in root two steps; Figure 11.16B recapitulates the fundamental relationship between the chapel centers, the major buttress faces and the hemicycle; Figure 11.16C shows how this pattern can be interpreted in terms of rotated squares and Figure 11.16D demonstrates the relationship between the minor chapel buttresses and the circumscribing octagon around the whole composition. Figure 11.17 extends this geometrical system into the design of the chapels and their details. Figure 11.17A shows how the geometrical skeleton of an ideal chapel is organized around the forms of nested eight-pointed stars – or half-stars – and Figure 11.17B shows how this scheme was meant to be embodied in the fabric of the Cathedral.

Unfortunately, perhaps, the geometrical rigor of these elegant schemes was not

[12] More precisely, they would stand out .924 as far as those in the nave, since .924 is the cosine of the 22.5 degree angle at which the hemicycle geometry meets the "straight" bays of the choir.

fully realized in the actual cathedral. As noted previously, the construction process was complicated both by the steep slope of the hilltop site and by the decision to retain the Ottonian crypt, which effectively prevented the late Gothic builders from sighting directly to the geometrical center of the new crypt when they were laying out its foundations. Only after the walls rose above the roof of the crypt would the builders have been able to survey the site with total rigor, and by that point the location of the basic structure would already have been fixed. The original error in layout seems to have involved the buttress and hemicycle pier at the junction between the north aisle and the north bay of the ambulatory. Since the line between these elements intersected the main longitudinal axis of the building at only 19 instead of 22.5 degrees off perpendicular, the whole geometrical scheme of the hemicycle was effectively dragged to the north. The faulty zone appears to have been constructed at least in part by the second Late Gothic master of the Metz workshop, who may not have fully understood the intentions of the original designer.

The task of cleaning up this geometrical mess appears to have fallen to the third master of the Metz workshop, whose crews constructed most of the cathedral's southeastern zone. These zones were constructed with far more geometrical precision and standardization of detail than those to the north.[13] Figure 11.17C shows how this master handled the construction of the superstructure in the cathedral's axial chapel, the exterior footprint of which had already been defined during the earlier campaigns that produced the crypt: the chapel as a whole was shifted far to the north by the choir's overall rotation; the long vertical slash denotes the building's true centerline, while the short hash mark to its left locates the point halfway between the corners of the chapel's minor buttresses. The northward displacement of the chapel was particularly vexing because it would be clearly visible to anyone in the nave who happened to look through the hemicycle to the chapel's central window. The third master and his workshop addressed this problem by pushing all the interior elements of the chapel subtly to the south within the exterior envelope defined by his predecessors. The flange of wall to the north of the central window, for instance, is fully 140 cm long, while that to the south is only 96 cm long and the champenois passage along the northeast face is slightly wider than the southeastern one.[14] Thanks

13 The structural system in this zone was also somewhat heavier than in the north, suggesting that the third master did not completely trust what had been set by his immediate predecessors. The culées of the southern hemicycle, for instance, have extra flanges that contribute to their stability and the inner and outer skins of southern triforium are linked by stone diaphragm walls instead of rising free as they do to the north.

14 These adjustments are carefully disguised on the chapel interior, but the shifting of the central window to the south is clearly visible on the upper face of the chapel exterior. No such shifting is evident on the crypt opening immediately below. Clearly, the third master was able to sight across the entire site during his construction of the upper chapels in ways that the builders of the crypt could not. He was therefore able to recognize and correct for geometrical problems that had not been evident during the construction of the crypt.

to these adjustments, the three intervals between the chapel's four principal shaft bundles are all within 2 centimeters of the value predicted by the "ideal plan." If it were not for the third master's brilliance in restoring geometrical order by concocting fixes of this kind, many of the clues pointing to the elegance of the original plan would have been lost in a haze of error and imprecision.

The geometry of the Metz choir, as it emerges from the preceding analysis, attests to an intriguing mixture of old and new design methodologies in the Late Gothic era. As noted at the beginning of this paper, the Metz choir plan differs in many respects from the thirteenth-century choir plans of cathedrals such as Amiens (Figure 11.1). With its strict interlocking of square and octagonal geometries, the Metz plan in many respects seems more closely related to the fifteenth-century plan of Saint-Maclou in Rouen, which has been carefully analysed by Linda Neagley (Figure 11.16 and 18).[15] Close analogies can also be drawn between the plan of the Metz choir and that of the octagonally-symmetric array of unfinished chapels at Batalha Abbey in Portugal, another ambitious undertaking of the fifteenth century (Figure 11.19).[16] All of these Late Gothic projects share an emphatically rigid polygonality that seems to contrast with the more fluid geometrical approach seen in choir designs like that of Amiens.

Despite its characteristic Late Gothic flavor, however, the Metz choir design clearly deserves to be understood as an advanced speculation on themes introduced in the High Gothic era. In particular, the geometrical logic behind the Metz plan can be discerned already in the thirteenth-century plan of Reims Cathedral (Figure 11.20). At first glance the two plans appear very different, because Reims has five deep chapels instead of three shallow ones and because the Metz chapel array subtends only 135 degrees instead of 180 degrees. Both plans, however, display strict polygonality; Nancy Wu has recently explained the geometry of the Reims choir in terms of a series of rotated pentagons and decagons analogous to the rotated squares and octagons of the Metz plan.[17] Even more tellingly, both plans incorporate a geometrically intimate dialogic relationship between the chapel centers and the external buttress faces (compare Figures 11.5 and 11.20). In the Reims plan, the relevant construction lines need to be drawn through the centers of every other chapel instead of through adjacent chapels, but the logic of the relationship in the two schemes is essentially identical.[18] Finally, both plans present

15 Linda Neagley, *Disciplined Exuberance: The Parish Church of Saint-Maclou and Late Gothic Architecture*, (University Park, 1998).

16 Some of the Batalha chapels even display the exact same stellar vault geometry as the Metz choir chapels and Bishops' chapel. The relationships between Portuguese, English and continental Late Gothic were complex and they deserve further scholarly attention.

17 Nancy Wu, *Uncovering the Hidden Codes: The Geometry of the East End of Reims Cathedral* (Columbia University Dissertation, 1996).

18 At Reims, the main buttresses even present flanged faces parallel to these internal construction lines. The same mannerism is evident at Metz on the major northern buttress

chapel windows nearly but not quite aligned with the nave aisle axes, although the motif was treated somewhat differently in the two buildings.

The differing treatments of the window-aisle relationship at Reims and Metz attest to a slow transformation of Gothic design methodology between 1200 and 1500. At Reims this relationship seems to have come about basically by accident, as an unimportant corollary of the overall plan geometry. The visitor to Reims barely notices the approximate alignment of the window because a large and prominent shaft bundle intrudes into the vista from the outboard side of the aisle. At Reims, therefore, one has no sense that a vista has been self-consciously framed by the designers, who appear to have been concerned with pure geometry rather than with scenographic effects. At Metz, on the other hand, a new scenographic sensibility is clearly evident in the treatment of such vistas. No shaft bundles or other major elements intrude on the carefully framed view of the chapel windows from the nave-aisles and the squared-off, boxy layout of the chapel zone as a whole allows the visitor to perceive the interlocking of rectilinear and diagonal optical axes.

If the Metz plan attests to a new interest in scenography on the part of later Gothic designers, it also attests to the limitations of that new interest, which was never fully integrated into the fundamentally geometrical methods of northern Gothic design. Despite their clear interest in the scenographic alignment between the chapel windows and the nave-aisle axes, the builders of Metz Cathedral appear to have worked from a geometrically elegant "ideal plan" in which this alignment was realized only approximately.[19] Even in the years around 1500, therefore, these northern Gothic designers continued to rely heavily on a set of geometrical design methods inherited from the thirteenth century. Indeed, the close affinities between the designs of the Reims and Metz choirs demonstrate a startling continuity of Gothic design practice over a period of nearly 300 years.

Metz Cathedral, of course, should not be interpreted as a reliable microcosm of Late Gothic design as a whole. The later portions of Metz Cathedral, after all, have

of the hemicycle, but it was suppressed in the other major buttresses, which seem to have been built slightly later.

[19] It might be argued on this basis that the approximately "correct" optical alignment of visual axes at Metz corresponds to the approximately "correct" perspective of fifteenth-century northern painters such as Jan van Eyck. Craig Harbison uses a similar comparison between architecture and painting to explain the irregular plan of the house of Jacques Coeur in Bourges. See Harbison, *The Mirror of the Artist: Northern Renaissance Art in its Historical Context* (New York, 1995), pp. 34–8. Gothic architecture, like Flemish painting, was based on premises essentially different from those that came to dominate the neo-classical art of the Italian Renaissance, in which geometry played a very different role. This divergence between northern and Italian practice was most acute in the period from roughly 1400 to 1500. As noted previously, however, the mixture of geometric and scenographic thinking seen in the choir planning for Metz Cathedral around 1500 in some respects recalls the urban planning methods of Trecento Florence as explicated by Trachtenberg.

escaped serious scholarly attention in large part because of the Metz workshop's perceived stylistic conservatism. There can be no doubt that the late Gothic masters of the Metz workshop meant for their contributions to harmonize with the cathedral's magnificent Rayonnant nave. From this perspective, their decision to model the geometry of the Metz choir on that of Reims can be seen as a highly appropriate gesture of deliberate geometrical historicism, since the Metz nave itself appears to have been begun by builders from the Reims workshop. Given the high ambition evident in the later campaigns at Metz Cathedral, however, the plan of the choir must have been seen as excellent and praiseworthy even in the years around 1500. This plan, therefore, stands as a fascinating example of northern architectural thinking in the closing years of the Gothic era, when the impersonally geometrical strategies of earlier Gothic design were being inflected by more subjective considerations of the viewer's scenographic experience.

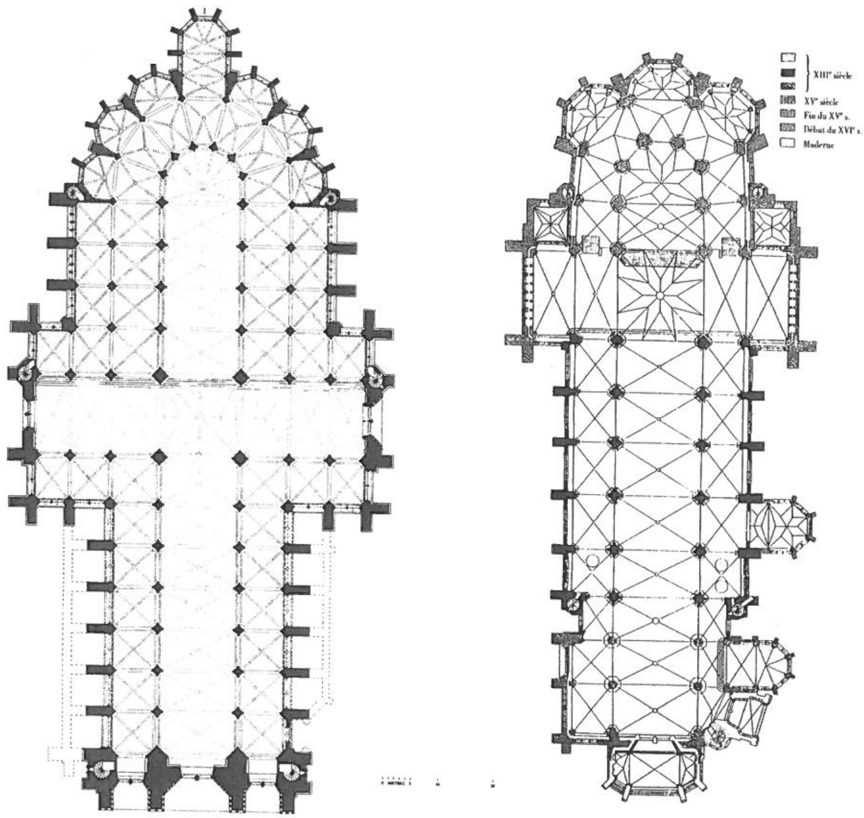


Figure 11.1. Amiens and Metz Cathedrals: comparative plans to the same scale (Amiens after Murray and Addiss 1990, Metz after Aubert 1931).

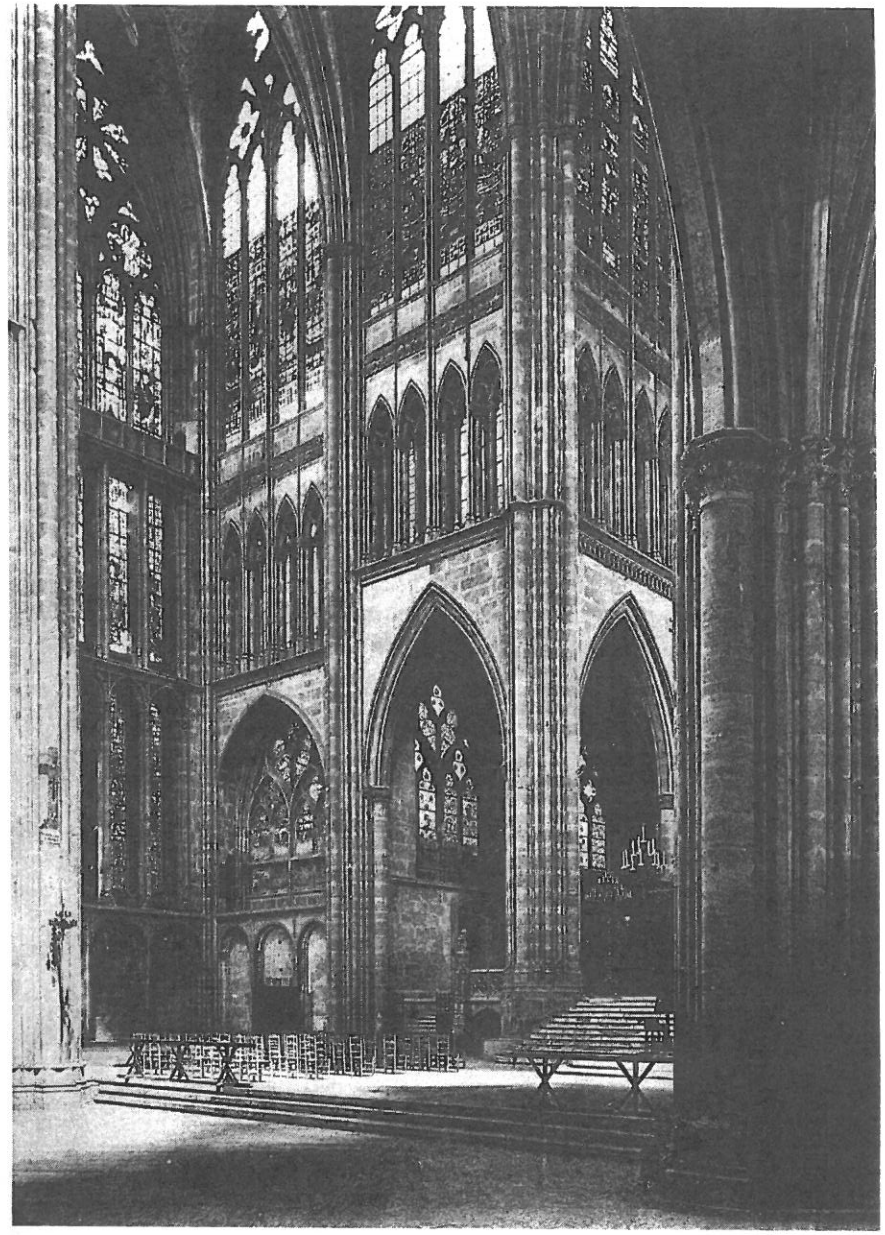


Figure 11.2. Metz Cathedral: view into north transept (photo: Aubert 1931).

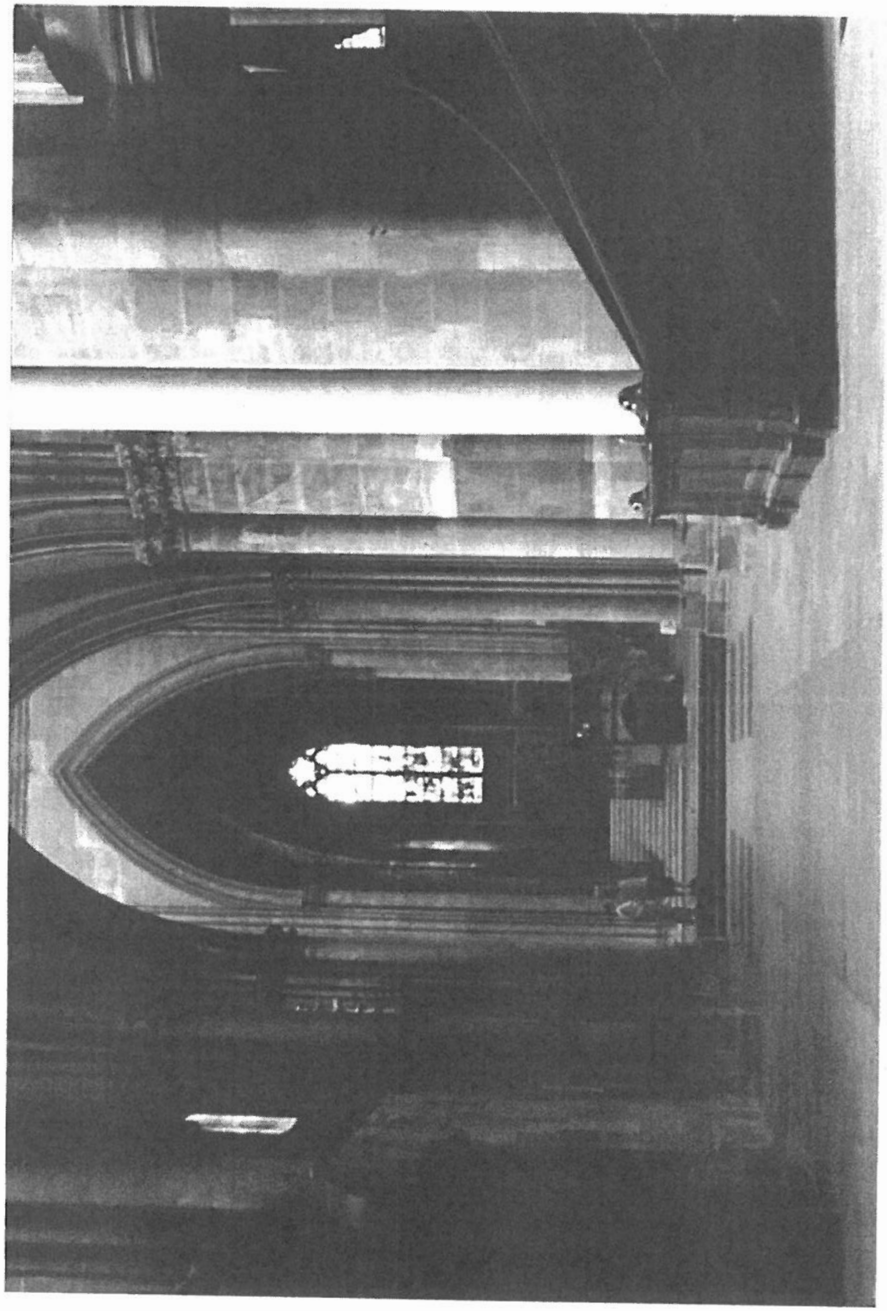


Figure 11.3. Metz Cathedral: view down north aisle, looking east.

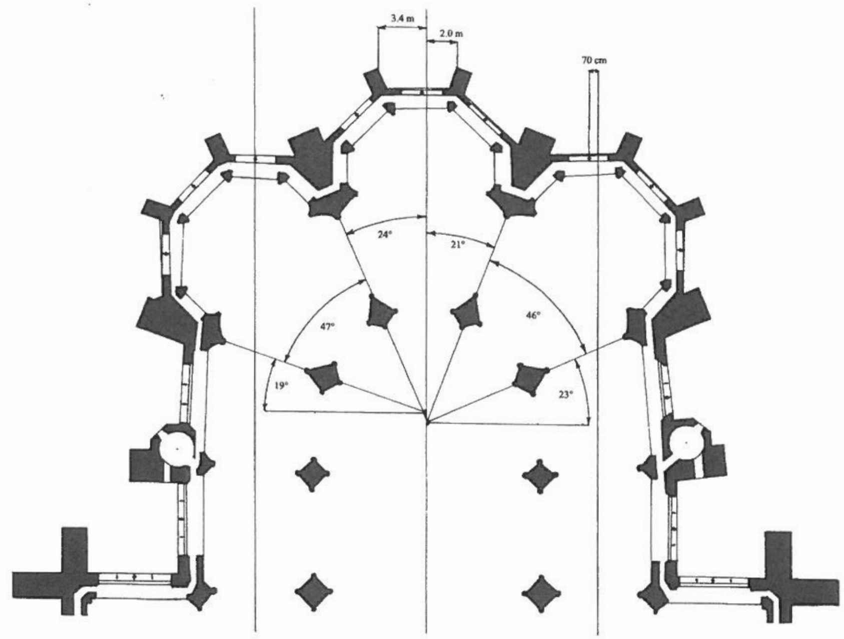


Figure 11.4. Metz Cathedral: choir plan with distortions noted.

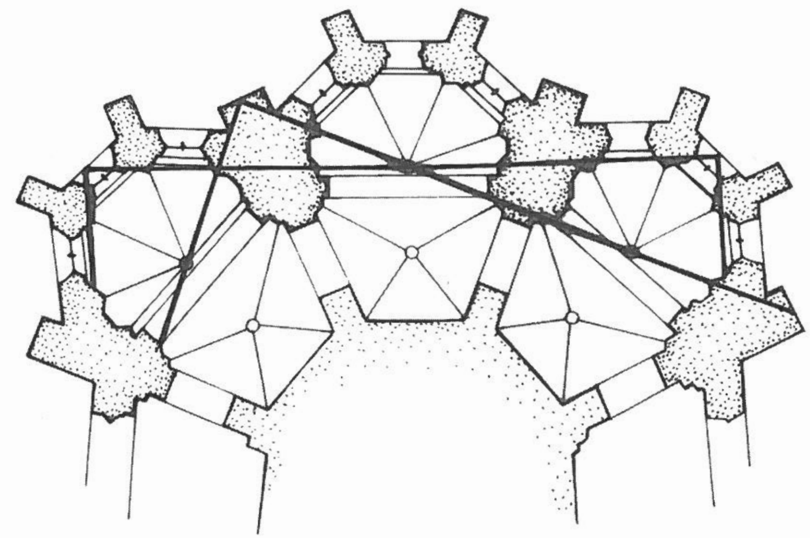
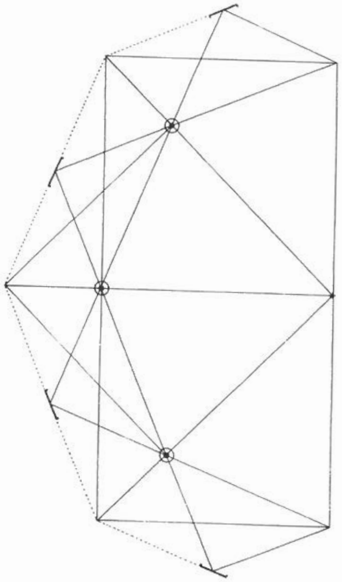
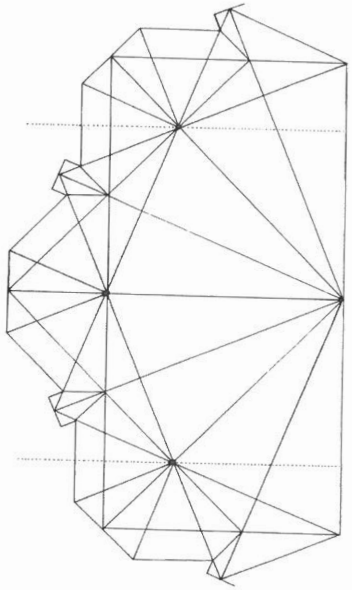
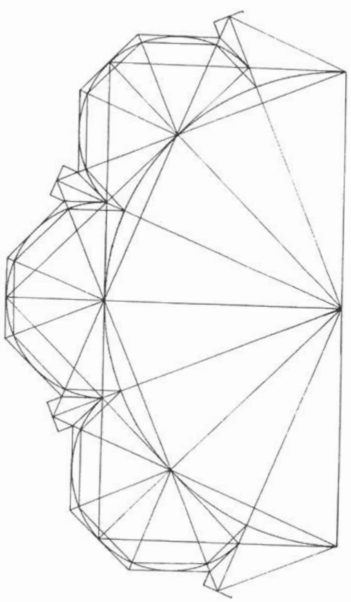


Figure 11.5. Metz Cathedral: crypt plan with geometric relationships (drawing: Bork, modified after Aubert 1931).







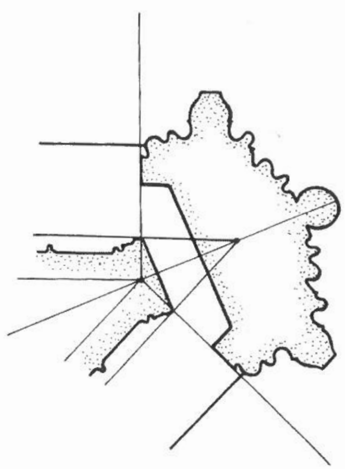


Figure 11.6. (upper left): basic crypt geometry.
Figure 11.7 (upper right): basic geometry of buttress placement.
Figure 11.8 (lower left): basic geometry of wall thickness.
Figure 11.9 (lower right): plan of choir shaft bundle (drawing: Bork, after Aubert 1931).

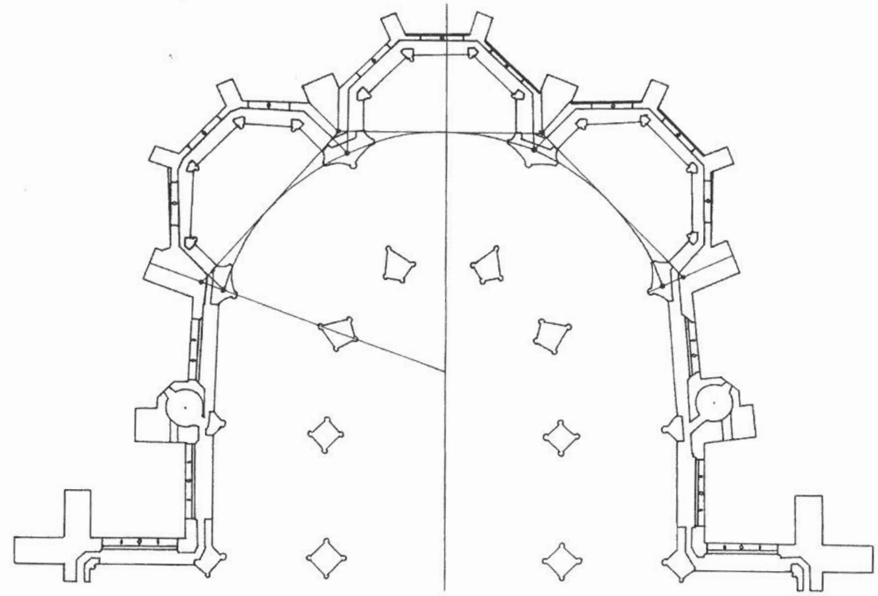


Figure 11.10. Application of 15.60 m circle to the choir plan.

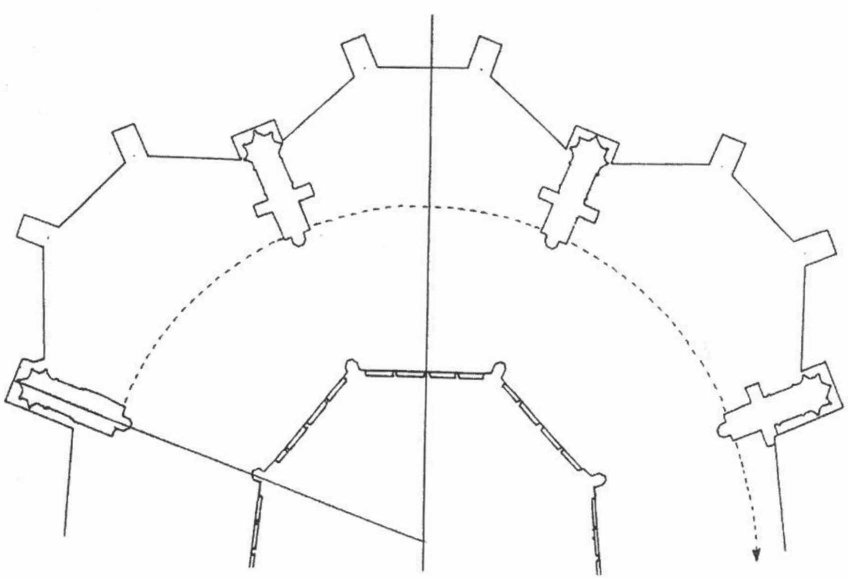
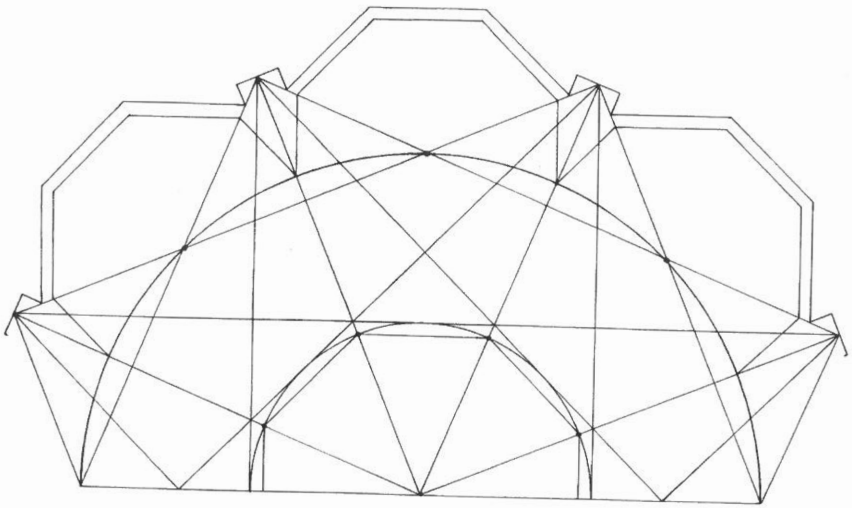
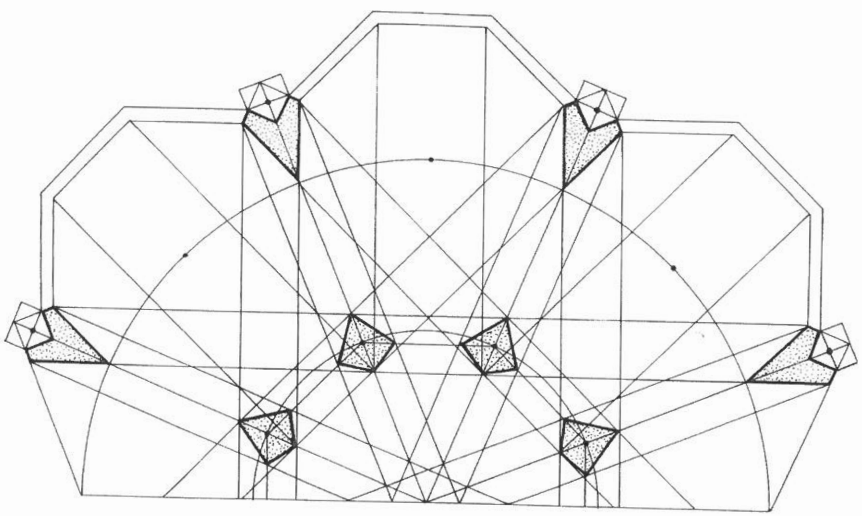


Figure 11.11. Plan of chapel roof with 15.60 m circle and buttresses shown.





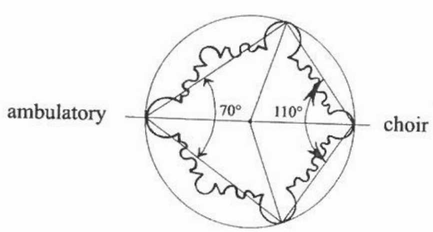
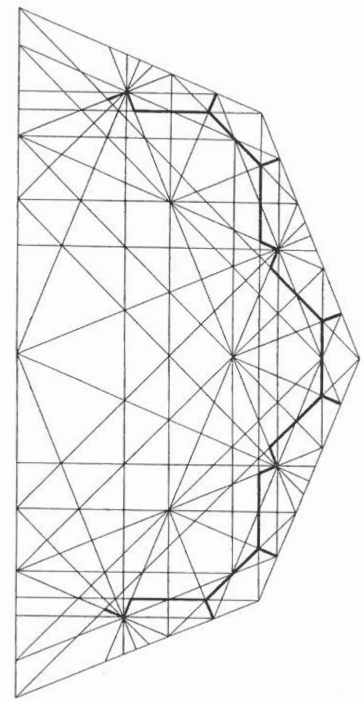


Figure 11.12. Metz Cathedral: projection of geometry inwards.
Figure 11.13. Metz Cathedral, locating and shaping freestanding piers.
Figure 11.14. Metz Cathedral: plan of freestanding choir piers (drawing: Bork, modified after Aubert 1931).



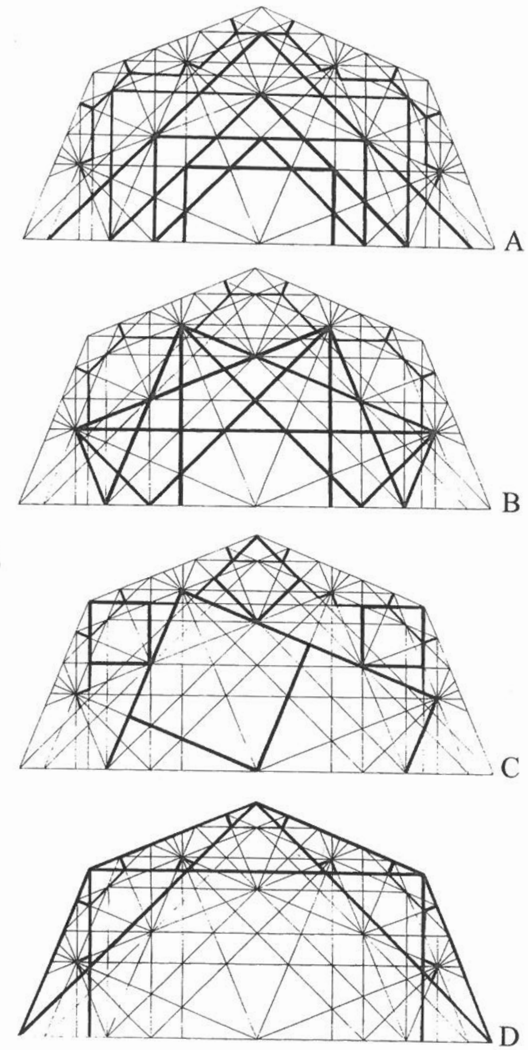
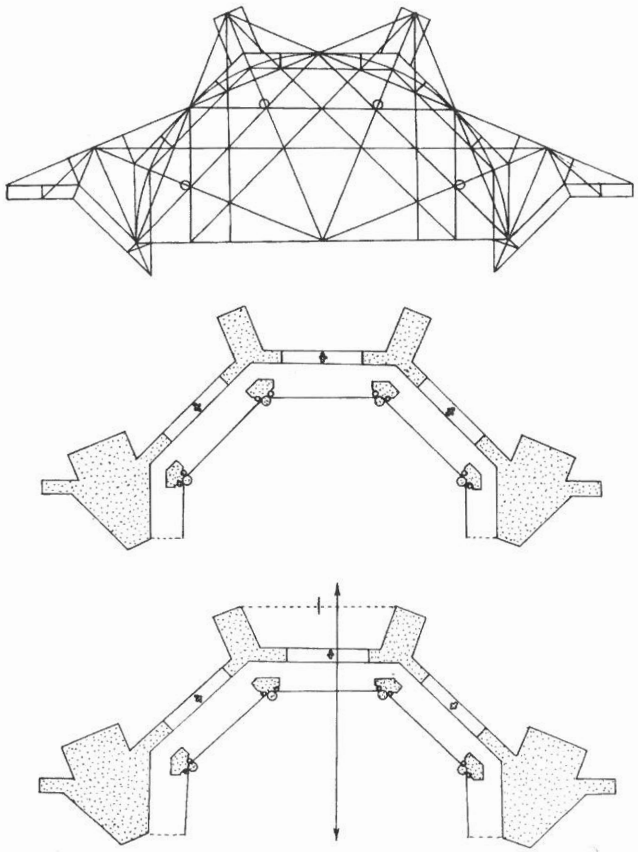


Figure 11.15 (left): Overall choir geometric armature.
Figure 11.16 (right column): Geometry of choir with various schemae highlighted.



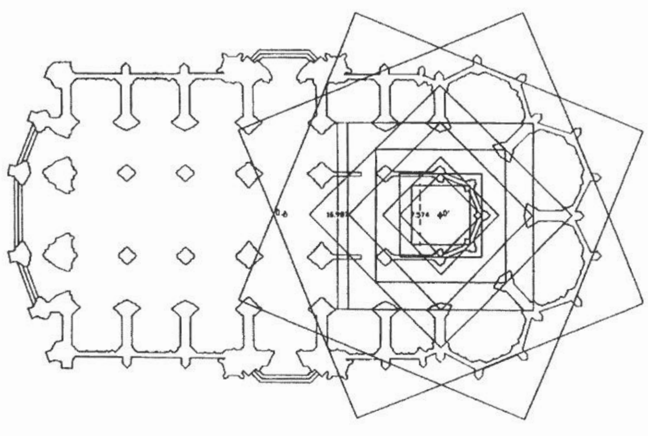


Figure 11.17. (top 3 drawings) Metz Cathedral: geometry and plan of chapel, with distortions in axial chapel shown.

Figure 11.18. Rouen, Saint-Maclou: plan of choir geometry (after Neagley, 1998).

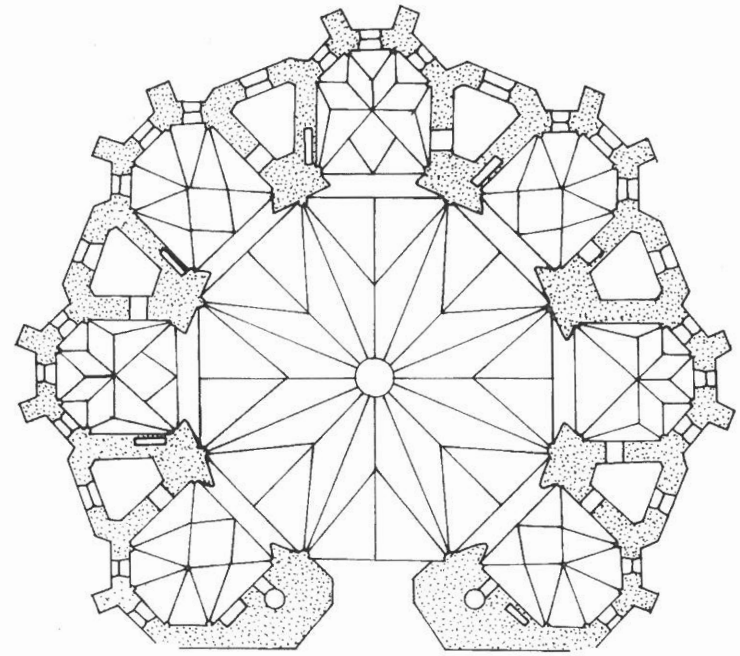


Figure 11.19. Batalha Abbey: plan of unfinished chapel complex (drawing: Bork after Swaan 1977).

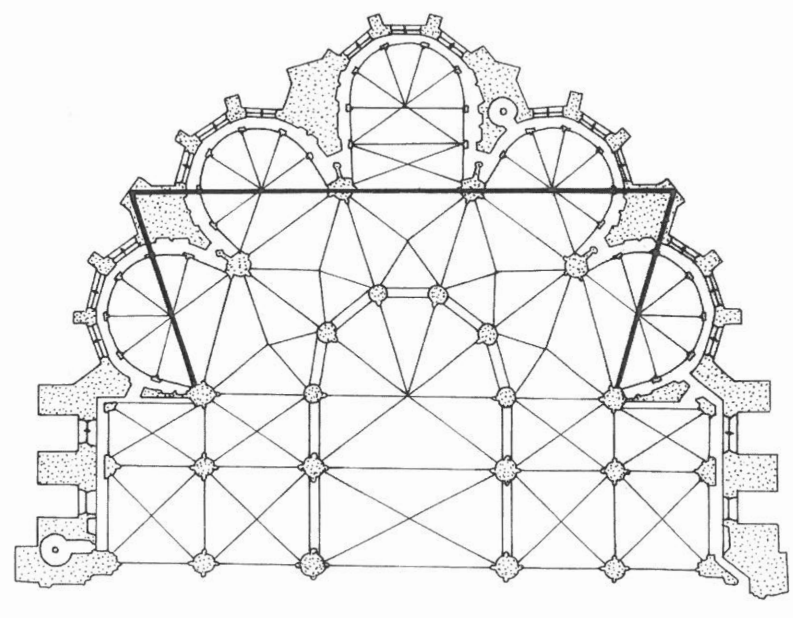


Figure 11.20. Reims Cathedral: choir plan with geometry (drawing: Bork,