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Geometer's Angle

Thomas Jefferson's Poplar Forest

Abstract. A unique geometric construction known to Thomas Jefferson reveals a rich interplay of root-two geometric elements when applied to Jefferson's octagonal plan of Poplar Forest, his eighteenth-century villa retreat.

Thomas Jefferson and classicism

In Colonial America, when buildings were typically "designed" by craftsmen and tradesmen, rather than architects, Thomas Jefferson was largely responsible for introducing the classical aesthetic to architecture. His designs reflect the neo-classical movement that emerged as Humanism in Renaissance Europe, then flourished in the Enlightenment from the 1730s to the end of the eighteenth century. Jefferson scholar Fiske Kimball considers that "directly or indirectly American classicism traces its ancestry to Jefferson, who may truly be called the father of our national architecture" [Kimball 1968, 89].

An "amateur" architect with no formal training, Jefferson first became aware of classical architecture through books, then later gained first-hand experiences of ancient Roman and eighteenth-century French buildings while serving as American Minister to Paris (1784-1789). He studied the written treatises of Marcus Pollio Vitruvius, Leon Battista Alberti, Inigo Jones, Sebastiano Serlio and others who relied on classical rules of architecture and mathematical techniques for achieving proportion [O'Neal 1978, 2]. On architectural matters, Jefferson is reported to have said that Andrea Palladio "was the bible," even though he knew his buildings only through books.[1]

Jefferson practiced the Roman classical architecture of Palladio and late eighteenth century France, and borrowed extensively from classical sources. He based the Rotunda of the University of Virginia in Charlottesville on measured drawings of the Pantheon published in Giacomo Leoni's *The Architecture of A. Palladio.* Models for the Virginia State Capitol in Richmond, which he designed with the assistance of French architect and antiquarian Charles-Louis Clerisseau, included the Temple of Balbec, the Erechtheum in Athens, and the ancient Roman temple Maison Carrée at Nîmes in France.[2] This was the first government building designed for a modern republic, the first American work in the Classical Revival style, and the first modern public building in the world to adapt the classical temple form for its exterior [Nichols 1976, 169-170; Kimball 1968, 42].

Geometric proportion

That Jefferson followed classical rules for applying simple proportions involving whole numbers to the orders and other components of building design is well documented.[3] But he also was familiar with techniques for achieving harmony through incommensurable ratios associated with elementary geometric figures. His designs often feature fundamental geometric shapes and volumes. The University Rotunda, whose dome he describes as a "sphere within a cylinder," presents an array of circles, squares and triangles.[4] For the Virginia Capitol, he selected as sources "the most perfect examples of cubic architecture, as the Pantheon of Rome is of the spherical…."[5] The plans for his Monticello residence present regular octagons, semi-octagons and elongated octagons.

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There is some evidence that Jefferson applied incommensurable proportions through geometric techniques. For the Washington Capitol he specified that neighboring properties "be sold out in breadths of fifty feet; their depths to extend to the diagonal of the square." In other words, the lots conform to the incommensurable ratio 1: √2 ("Opinion on Capitol," 29 November 1790 [Ford 1904-1905, VI: 49]). His plan for the University Rotunda expresses root-two, root-three, and perhaps even Golden Mean symmetries [Fletcher 2003].

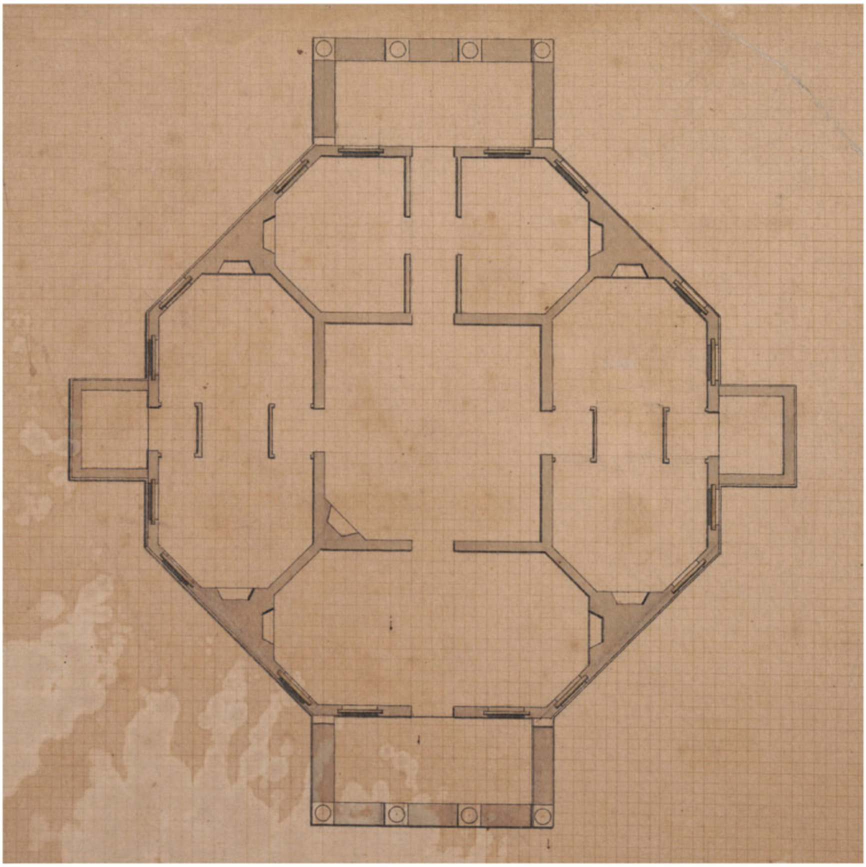

Fig. 1. Thomas Jefferson, Poplar Forest, First Floor Plan. Image (ca. 1820), inked, shaded and tinted by John Neilson (atrributed). Scale: about 10′ = 1″. On heavy paper, not watermarked, with co-coordinate lines drawn by hand, 9″ x 11.5″. (N-350, K-Pl.14). Courtesy of The Jefferson Papers of the University of Virginia, Special Collections, University of Virginia Library, Charlottesville, Virginia

Poplar Forest

A clear example of incommensurable proportion is Jefferson's octagonal villa retreat at Poplar Forest, located on the eastern slope of the Blue Ridge Mountains in Bedford County, Virginia, ninety miles southwest of Monticello, his principle residence. Building construction began in 1806, while Jefferson resided as president in Washington, supervising the project remotely through written instructions, working drawings and sketches. The villa was made habitable by the time of his retirement in 1809, but would require another sixteen years to complete [McDonald 2000, 178-81]. Jefferson first proposed the octagonal house for his Pantops farm, north of Monticello, as a future residence for his grandson Francis Eppes. But instead he realized the plan at Poplar Forest, one of his working plantations where Eppes eventually settled.[6]

Poplar Forest is of brick construction and octagonal in plan, containing a central square space, flanked on three sides by elongated octagonal rooms. On the fourth side, a short entry hall divides a pair of smaller rooms. The central dining room is skylit and measures 20′ x 20′ x 20′, a perfect cube. On the east and west, alcove beds divide the two main bedrooms into sections [Chambers 1993, 33-35]. During construction, Jefferson added pedimented porticoes on low arcades attached on the northern and southern facades, and stairwells east and west.[7] Fig. 1, attributed to Jefferson's workman John Neilson, shows the first floor plan complete with additions to the original design.[8]

Following a fire in 1945, the interior was rebuilt leaving only the walls, chimneys and columns original. Since 1983, under the leadership of Director of Architectural Restoration Travis McDonald, Poplar Forest has been the subject of extensive research and restoration. The goal is to enable the public to experience Jefferson's retreat according to our best understanding of his original design.

Jefferson's regard for octagonal plans by Robert Morris, Inigo Jones, Palladio and others has been reviewed extensively. C. Allan Brown observes octagonal symmetry in the landscape design at Poplar Forest. And in the building plan, E. Kurt Albaugh cites the "two-fifths" rule of proportion that closely approximates the octagon's inherent root-two ratio [Albaugh 1987, 74-77; Brown 1990, 119-121; Chambers 1993, 33; Lancaster 1951, 9-10]. In fact, a specific technique for constructing the octagon, drawn more than once by Jefferson, offers compelling evidence of a consistent geometric approach to Poplar Forest's design.

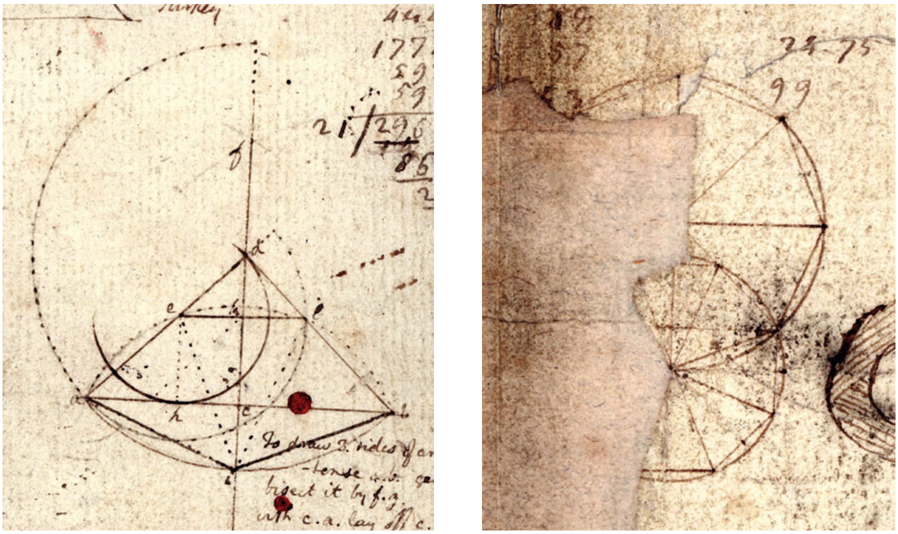

Fig. 2. Jefferson's sketches of octagons. a, left) dividing two sides of a square in root-two ratios; b, right) two completed octagons and the algebraic proof. Images: Objects; assorted sketches and calculations, 1 page, undated, MHi29. Original manuscript from the Coolidge Collection of Thomas Jefferson Manuscripts. Massachusetts Historical Society [Jefferson 2003: MHi29]

A page of Jefferson's notes and scribbles, possibly executed during a visit to Poplar Forest, includes a technique for drawing three sides of a regular octagon together with two sides of a larger octagon. Both are accomplished by dividing two sides of a square, or the sides of a 45° right triangle, in root-two ratio (fig. 2a). A drawing of two completed octagons (fig. 2b) and an algebraic proof accompany the construction.[9]

How to draw three sides of an octagon on a given base

- Draw a horizontal line AB.
- Place the compass point at A. Draw a semi-circle of radius AB that intersects the extension of line BA at point D.
- From point A, draw a line perpendicular to line BD that intersects the semi-circle at point C (fig. 3).

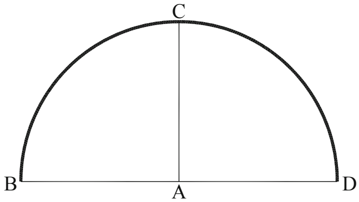

Fig. 3

- Connect points B, C and D.
- From point C, draw a circle of radius CB that intersects point D and the extension of line CA at point E (fig. 4).

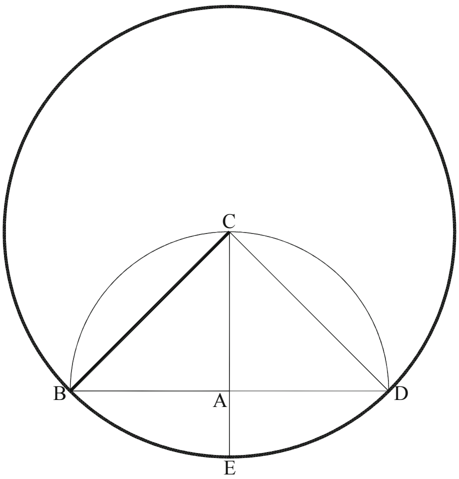

Fig. 4

- Connect points B, E and D.

The result is two sides of a regular octagon inscribed within the circle of radius CB.

- Complete the octagon (fig. 5).

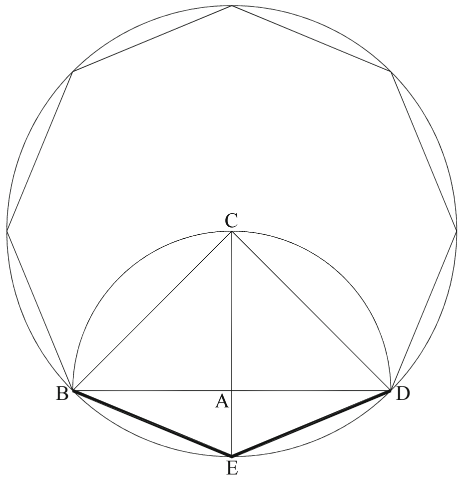

Fig. 5

- From point E, draw a circle of radius EB that intersects line BC at point F and line CD at point G.
- Connects points B, F, G and D.

The result is three sides of a regular octagon inscribed within the circle of radius EB.

- Complete the octagon.

If radius CB of the large circle is 1, side BE of its inscribed octagon equals $\sqrt{(2-\sqrt{2})}$ (0.7653…). Radius EB of the small circle therefore equals $\sqrt{(2-\sqrt{2})}$ and side BF of its inscribed octagon equals $(2-\sqrt{2})$ (0.5857…) (fig. 6).

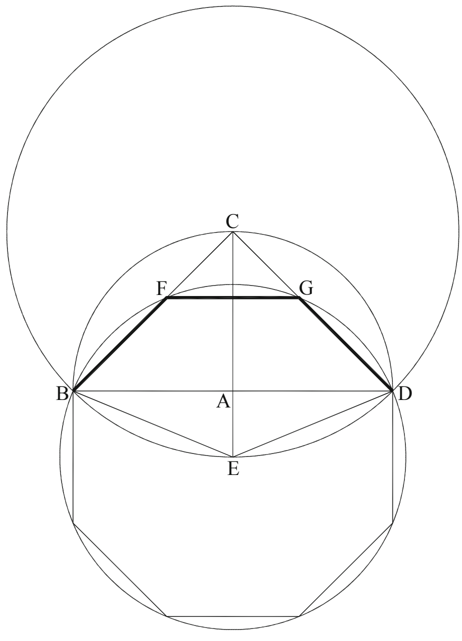

Fig. 6

We see from fig. 2a that Jefferson knew how to proceed further with this geometric construction.

- From point F, draw an arc of radius FC that intersects and is tangent to line BA at point H.
- Connect points F and H.
- Extend line FH until it intersects line BE at point I
- Alternatively from point F, draw an arc of radius FG to point I.
- Connect points G, F and I.

The result is two sides of a square.

- Complete the square (fig. 7).

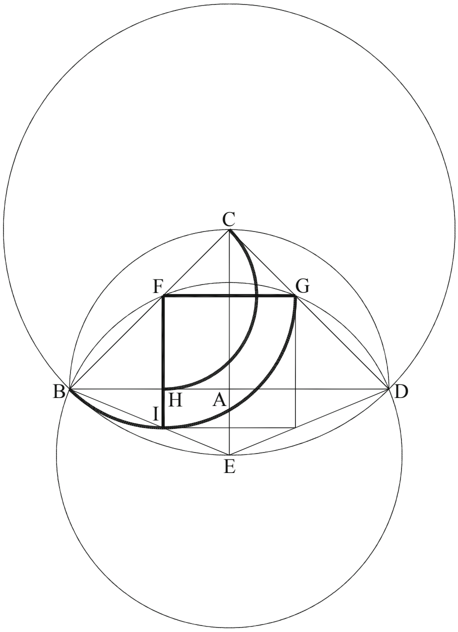

Fig. 7

Root-two symmetry

In fig. 8, the construction is scaled to Jefferson's plan for Poplar Forest. The small circle of radius EB circumscribes the octagonal footprint. Each side of its inscribed octagon, such as BF, locates an exterior wall. Center point C of the large circle locates the midpoint of the portico front.

- Repeat the semi-circle of radius CE at each quadrant, as shown.

The semi-circles intersect at points J, K, L and M.

- Complete the regular octagon.

The octagon divides into a center square, four root-two rectangles and four 45° right triangles. The square locates the center room of the Poplar Forest plan (fig. 9).

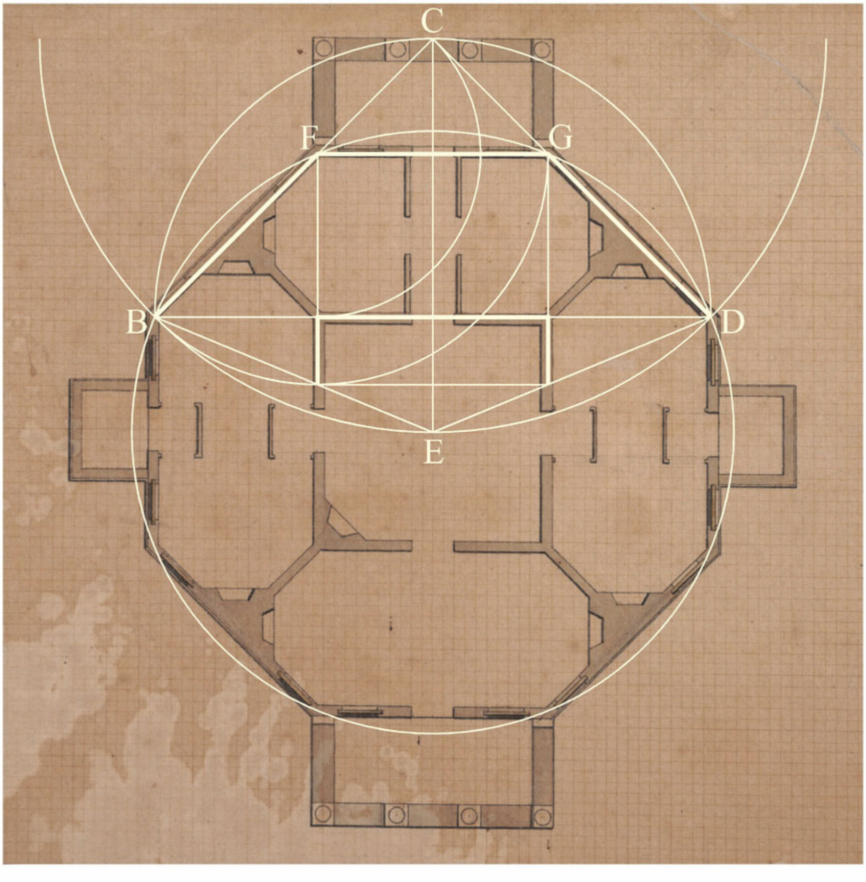

Fig. 8. Thomas Jefferson. Poplar Forest, First Floor Plan, with geometric overlay by the author

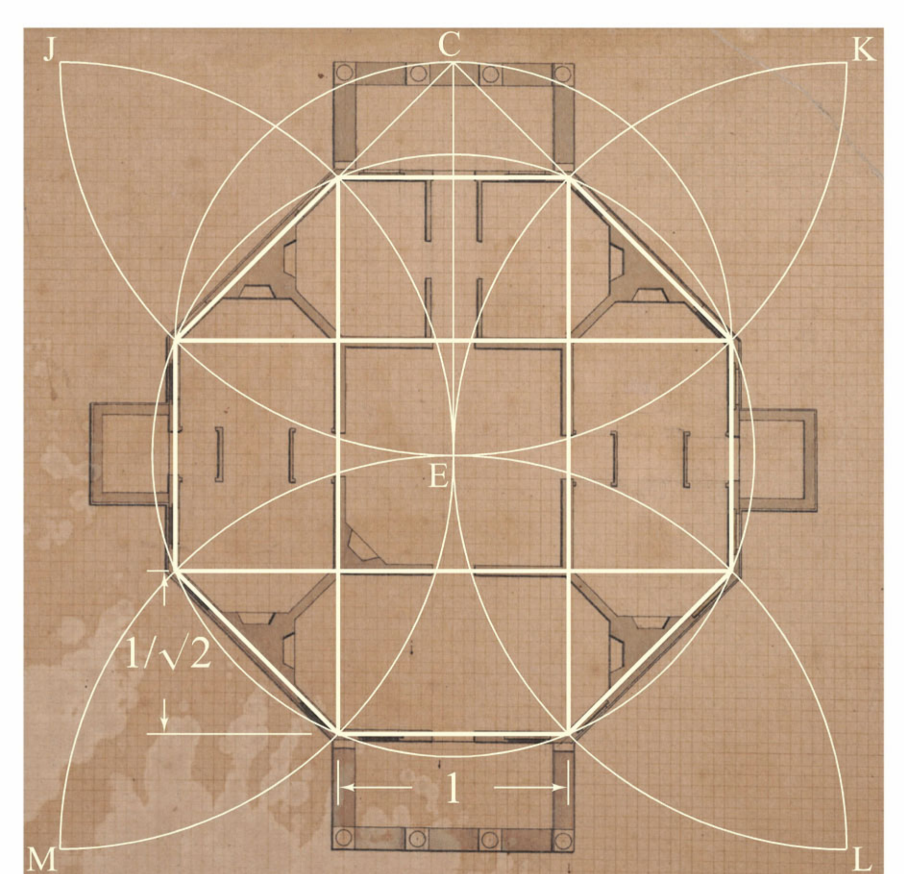

Fig. 9. Thomas Jefferson. Poplar Forest, First Floor Plan, with geometric overlay by the author

To construct the elongated octagonal rooms at each quadrant:

- Divide each 45° right triangle in half, into smaller 45° right triangles.
- Join a small 45° right triangle to each end of a root-two rectangle.

The result is an elongated hexagon (fig. 10, right).

- Locate the two sides of each small 45° right triangle. Connect their midpoints, as shown (fig. 10, upper left).
- Join the new shape to each end of a root-two rectangle.

The result is an elongated octagon that locates the room at each quadrant. Chimneys occupy the remaining spaces (fig. 10, left).[10]

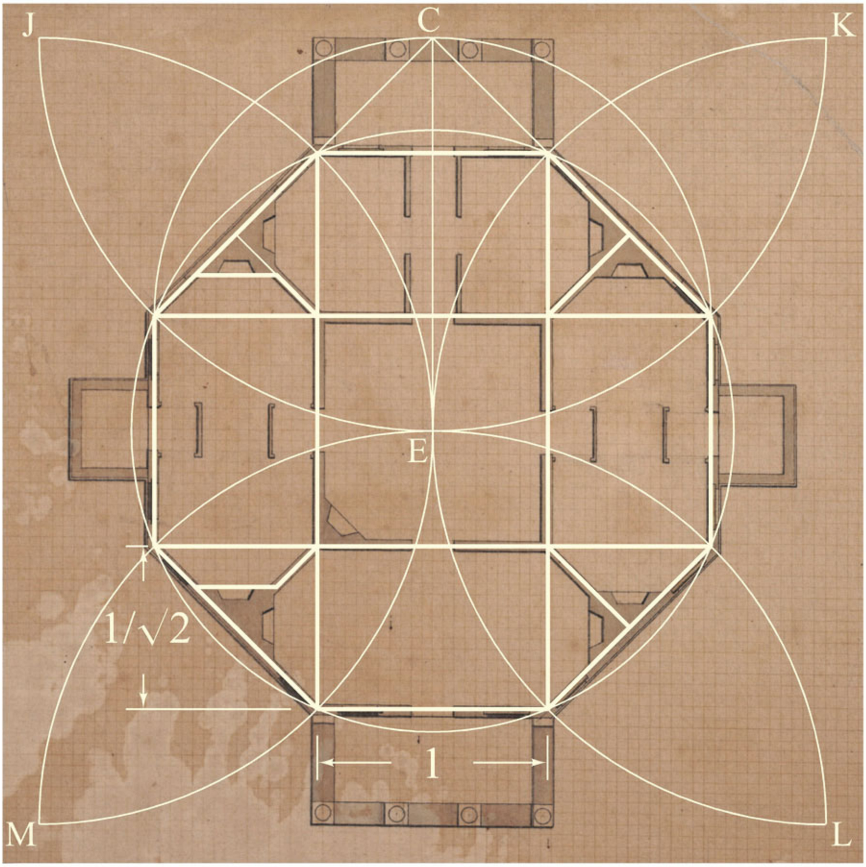

Fig. 10. Thomas Jefferson. Poplar Forest, First Floor Plan, with geometric overlay by the author

- Connect points J, K, L and M.

The result is a square that encloses the northern and southern porticoes.

- Inscribe a circle within the square.
- Inscribe a regular octagon within the circle.
- Two edges of the octagon locate the stairwells east and west (fig. 11).

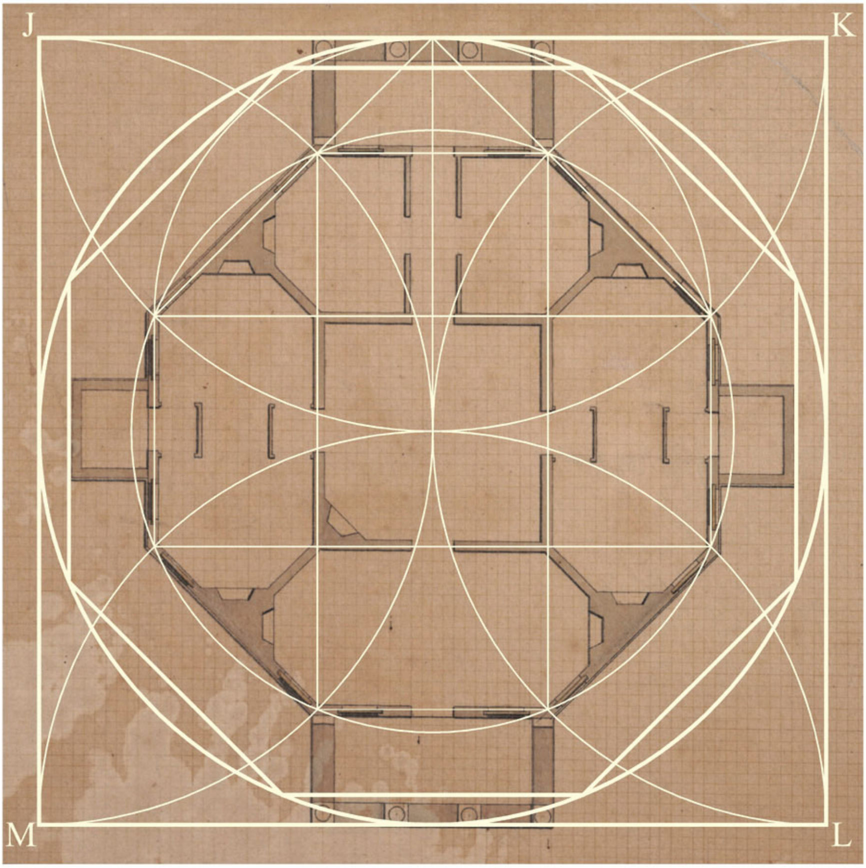

Fig. 11. Thomas Jefferson. Poplar Forest, First Floor Plan, with geometric overlay by the author

Jefferson was proficient in a variety of mathematical disciplines that included arithmetic, algebra, geometry, trigonometry and Newtonian calculus, as well as mechanical and natural applications such as navigation, surveying, astronomy and geography. Geometry, which he explored in both planar and spherical configurations, held special interest. But rather than study mathematics for its own sake, Jefferson endeavored to apply his knowledge in tangible ways, as at Poplar Forest, where a simple geometric construction yields a rich, harmonic composition.

Notes

1. Colonel Isaac A. Coles to General John Cocke, 23 February 1816 [Adams 1976, 283]. Jefferson toured the agriculture of southern France and northern Italy in 1787, intending to visit Palladio's hometown of Vicenza at a later date [Nichols 1976, 163, 167].
2. Jefferson, "An Account of the Capitol in Virginia," no date, Miscellaneous Papers [Lipscomb and Bergh 1905-06, XVII: 353].
3. See [Kimball 1968]. Joseph Lasala has analyzed the Pavilions of Jefferson's University of Virginia according to the Palladian system of dividing a module, based on the lower diameter of a column, into minutes and seconds. From this are derived an order's six major components: the base, shaft and capital of the column; and the architrave, frieze and cornice of the

entablature. The order, once determined, fixes the size and distribution of other building components [Lasala 1992].

4. Jefferson to William Short, 24 November 1821 [Jefferson 2007].
5. Jefferson, "An Account of the Capitol in Virginia," no date, Miscellaneous Papers [Lipscomb and Bergh 1905-06, XVII: 353].
6. Jefferson to John Wayles Eppes, 30 June 1820 [Jefferson 2007]. Compare Jefferson's plan for the house at Pantops, before 1804, and the first floor plan of Poplar Forest drawn by John Neilson [Chambers 1993, 33-34, Kimball 1968, 182-183, figs. 193,194].
7. Jefferson proposed the additions in a letter to bricklayer Hugh Chisolm following a visit to Poplar Forest in 1806. Jefferson to Hugh Chisolm, 7 September 1806, Massachusetts Historical Society [Chambers 1993, 36-37, Kimball 1968, 182-183].
8. Although presently attributed to Neilson, Kimball in 1968 credited the drawing to Jefferson's granddaughter Cornelia J. Randolph [Kimball 1968, 183].
9. See [Chambers 1993, 21] on connecting the notes to a trip to Poplar Forest in 1800. The construction appears elsewhere in Jefferson's notebooks during various phases of building and remodeling at Monticello. One example is a theorem for drawing "three sides of an octagon" on a given base, dated 1771(?), apparently in preparation for octagonal projections in the plan. See [Jefferson 2003: N123; K94]. A similar construction, dated 1794-1795(?), accompanies studies for Monticello's remodeling. See [Jefferson 2003: N138; K140].
10. Jefferson's preliminary sketches for Pantops/Poplar Forest, before 1804, produce octagonal rooms in this fashion. See [Jefferson 2003: N260; K193].

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About the geometer

Rachel Fletcher is a geometer and teacher of geometry and proportion to design practitioners. With degrees from Hofstra University, SUNY Albany and Humboldt State University, she was the creator/curator of the museum exhibits "Infinite Measure," "Design by Nature" and "Harmony by Design: The Golden Mean" and author of the exhibit catalogs. She is an adjunct professor at the New York School of Interior Design. She is founding director of the Housatonic River Walk in Great Barrington, Massachusetts, co-director of the Upper Housatonic Valley African American Heritage Trail, and a director of Friends of the W. E. B. Du Bois Boyhood Homesite. She has been a contributing editor to the *Nexus Network Journal* since 2005.