PERFORMANCE ASSESSMENT

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CONTEXT

The learners are fourth-year architecture students at Drury University. The students are enrolled in third and final capstone course of the structures sequence. The course description reads, "Application of engineering principles and analytical methods, as presented in the earlier structures coursework, to a multi-story architectural solution. Students will develop a holistic structural design response that withstands both gravity and lateral forces. The structural design will be refined by applying the principles of rigid-body statics and deformable body mechanics to the individual structural elements" [Catalog].

The students spend the entire semester performing the structural engineering for a two-story 16,000 ft^2 Archeology Center (see Exhibit A – Architect's Schematic Design). The engineering activities involve design, graphically representing (drawing) and sizing (calculating) all the structural elements. The final product is a comprehensive structures book. This specific performance assessment will examine one of the ten assignments. The assignment selected has a graphic sensibility and focuses the structural framing. The assignment accounts for 15 percent of the course grade. The learning objective is for the students to demonstrate the *ability to configure the beams, columns, and decking into a multi-story, post-and-beam structural framing solution that resists gravity loads*.

Architecture programs are accredited by National Architectural Accrediting Boards, Inc. (NAAB). NAAB publishes and updates the Conditions for Accreditation about every six years. For our last NAAB visit, my courses were responsible for satisfying one of the required performance criteria (see item B.5 below). NAAB also mandates (see level of accomplishment below). The faculty must supply evidence (student outcomes) demonstrating that the students meet the criteria.

Standards Set Forth by the Accrediting Board [2014 NAAB Conditions for Accreditation]

- Item B.5 – Structural Systems [2, p. 17]

  Ability to demonstrate the basic principles of structural systems and their ability to withstand gravitational, seismic, and lateral forces, as well as the selection and application of the appropriate structural system.

- Level of accomplishment [2, p. 15]

  Ability is the proficiency in using specific information to accomplish a task, correctly selecting the appropriate information, and accurately applying it to the solution of a specific problem, while also distinguishing the effects of its implementation.

Essential Question

How does a structural engineer develop a post-and-beam gravity load framing solution to an architect's schematic design?

GRASPS Task Design Prompts

Goal and Role

You are the structural engineer under contract to the architect through the AIA Document C401 Standard Form of Agreement Between Architect and Consultant. The duty of the engineer is to locate and size all the structural members according to the appropriate model building code. The architect has completed her architectural design of a two-story, 16,000 ft^2, Archeology Center located in Dinosaur National Monument, Utah. The drawings are now in your possession and you must develop a post-and-beam structural framing solution that resists gravity loads.

Audience

Your primary audience is the architect of record (I play this role as instructor) and your design colleagues in the firm (classmates assigned to this group). The other professional players are the general contractor and steel fabricator. The architect reviews the structural framing solution to validate that it meets her design idea. For example, the structure must not have any conflicts such as a column located in the T-Rex exhibit space. You meet with your peers to discuss your solutions. The general contractor must determine the appropriate means and methods to construct the building in addition to estimating its cost. The fabricators must draw and detail every single beam and column to fabricate. Outside professionals are sometime brought into the classroom to discuss your work.

Situation

Your challenge is to: (1) Review the framing protocols from the first structures course; (2) Review the architect's schematic design (floor plans, elevations, and sections); (3) develop a post-and-beam structural framing solution that resists gravity loads; and (4) meet with your colleagues and discuss your solutions before presenting the work to the architect.

Product, Performance, and Purpose

You will create your final framing plans with AutoCAD or Revit, convert them into a single 8.5 x 11 *inch* PDF file, and submit in the Moodle learning management system (LMS). The drawings must clearly illustrate the locations and dimensions of all beams, columns, and decking. The drawings must be overlayed on the architectural floor plans and shown independently. You may use SketchUp or freehand drawing for the process documents. This is a collaborative effort where you present and discuss with your colleagues. The purpose is to fulfill your obligations as stated in the C401 contract.

Standards and Criteria for Success

A successful framing solution shall: (1) Apply the post-and-beam method; (2) Follow the traditional framing protocols; (3) Include all necessary beams, girders, columns, and decking; (4) Provide column indicator lines and dimensions; and (5) Not impede on the design intent of the architect.

Performance Task Vignette

You are a structural engineer that has just signed a contract with a world-renowned architect. The architect's project is a 16,000 ft^2 Archeology Center at the site of an ongoing dig in Dinosaur National Monument, Utah. The National Park Service facility will serve as a public museum and a research center for the existing dig taking place along a stream bed. A sheer cliff on one side of the stream has yielded fossils dating from the Cretaceous Period. A feature of the museum exhibit room will be the display of the reconstructed skeleton of a small Tyrannosaurus Rex discovered in the cliff. Curators will provide brief tours of the museum and the dig site. A unique requirement of the building design is to integrate the public interior areas with the design of the observation area that overlooks the skeleton, the cliff face, and the ongoing excavation. The architect has just given your firm her schematic design. Your mission is to develop a post-and-beam structural framing solution that follows her design ideas.

Performance Assessment Plan

Class	Tasks (Technology in parentheses)
Class Period 1 ***Refreshers*** *(75 minutes)*	1. Watch the Video Summary (Moodle) 2. Read the Assignment requirements (Moodle) 3. Study the architect's schematic design (Moodle) 4. Review the past Lecture Notes on structural framing (Moodle) 5. Watch the Video Refreshers if you do not recall the lecture notes (Moodle) 6. Review the Sample Solution (Moodle)
Class Period 2 ***Upper Level*** *(75 minutes)*	7. Develop a Structural Framing Plan for the Upper Level on top of the Lower Level Floor Plan (freehand or SketchUp on a JPEG) 8. Meet with your design team and describe your solution and progress (in-person)
Class Period 3 ***Roof Level*** *(75 minutes)*	9. Develop a Structural Framing Plan for the Roof Level (SketchUp) on top of the Upper Level Floor Plan (freehand or SketchUp on a JPEG) 10. Meet with your design team and describe your solution and progress (in-person)
Class Period 4 ***Coordination*** *(75 minutes)*	11. Coordinate the two Structural Framing Plans (freehand or SketchUp) 12. Revise Upper Level Structural Framing Plan as needed (freehand or SketchUp) 13. Revise Roof Level Structural Framing Plan as needed (freehand or SketchUp) 14. Meet with the instructor and describe your solution and progress (in-person)
Class Period 5 ***Final Documents*** *(75 minutes)*	15. Create the final structural overlays on top of the architectural plans for each level using digital technology (SketchUp, [AutoCAD, or Revit)

	16. Create the final structural framing plans without the architectural plans underneath (SketchUp, AutoCAD, or Revit) 17. Meet with a local professional and describe your solution and progress (in-person)
Class Period 6 ***Submittal*** *(75 minutes)*	18. Reflect on your solutions and compare them with the requirements in the Grading Rubric (Moodle) 19. Revise your solution to meet the Rubric objectives (SketchUp, AutoCAD, or Revit) 20. Convert the drawings into a single 8.5” x 11” PDF file (Adobe Acrobat) 21. Submit the PDF file into the Assignment portal in the Moodle learning management system (Moodle)

Scoring Guide

Secondary Learning Objectives	0 Points	1 Point	2 Points
Post and beam framing	*The solution uses bearing wall construction*	*The solution includes bearing walls and post and beam construction*	*The solution uses post and beam construction exclusively*
Framing bay proportions	*The solution less than 40% of the framing bays applying the 1:1 to 2:1 proportion*	*The solution has framing bays that could be altered to fit within the 1:1 to 2:1 proportion*	*The solution has more than 80% of the framing bays applying the 1:1 to 2:1 proportion*
Perimeter columns	*The solution has more than 2 corner columns missing*	*The solution is missing two or less corner columns*	*The solution has columns at all building corners except where the reentrant corners are less than 6 ft*
Column orientation	*The solution does not illustrate wide flange columns*	*The solution illustrates wide flange columns, but less than 80% do not follow the recommended orientation*	*The solution illustrates has more than 80% of the exterior column flanges oriented perpendicular to the wind load and the interior column flanges parallel to the longitudinal building direction*
Column stabilization	*The solution does not adequately stabilize the columns with the beams and girders*	*The solution follows stabilization protocols 80% of the time*	*The solution shows perimeter columns with 3 and the interior columns with 4 points of contact whenever possible*

Vertical load path	*The solution 2 or more one-story columns that do not align with the columns above or below*	*The solution has one one-story column that does not align with the columns above or below*	*The solution illustrates that all columns extend vertically from footing to roof without any offsets avoiding transfer beams*
Column frequency	*The solution has way too many or too few columns*	*The solution could add or subtract a couple of columns*	*The solution has a reasonable number of columns*
Column-free spaces	*The solution does not coordinate with the architectural design*	*The solution has columns placed outside of the walls without the architect's approval*	*The solution has all the columns placed within walls except those approved by the architect*
Beam and girder lengths	*The solution does not address the maximum length restrictions*	*The solution no more than two of the beams or girders exceeding 36 ft*	*The solution has all the beams and girders under 36 ft*
Trusses	*The solution does not use trusses in the T-Rex exhibit*	*The solution uses trusses for both the girders and the beams in the T-Rex exhibit*	*The solution substitutes 40 ft trusses for the girders in the T-Rex exhibit*
Beam spacing	*The solution does not address the 5-12 ft span limitations for the decking*	*The solution uses unequal beam spacing between 5-12 ft*	*The solution uses equal beam spacing between 5-12 ft*
Beam direction	*The solution places beams in the longer direction of the framing bays more than 50% of the time*	*The solution places half of the beams in the shorter and half in the longer direction of the framing bays*	*The solution places beams in the shorter direction of the framing bays more than 90% of the time*
Horizontal load path	*The solution does not address horizontal load continuity*	*The solution attempts to, but insufficiently aligns the beams and girders in the longitudinal and transverse directions*	*The solution has at least two continuous load paths where the beams and girders align in the longitudinal and transverse directions*
Decking	*The solution does not indicate any decking*	*The solution does not have the decking aligned with all the building edges*	*The solution properly indicates the decking with lines having double arrows at the correct locations*
Decking directions	*The solution does not coordinate the direction of the decking amongst the adjacent framing bays*	*The solution has two or more staggered decking directions of adjacent framing bays*	*The solution attempts to limit the number of decking directions*

Framed deck openings	*The solution does not indicate framed openings with an 'X'*	*The solution is missing or incorrectly framing two or less of the deck openings*	*The solution properly frames all the deck openings*
Decking-beam-girder alignment	*The solution does not coordinate the decking – beams – and girders*	*The solution two or less regions where the decking, beams, or girders are going the wrong direction*	*The solution illustrates the decking as perpendicular to the beams, which are perpendicular to the girders*
Structural overlays	*No structural overlays are provided to demonstrate the integration of architecture and engineering*	*Only one structural overlay is submitted to demonstrate the integration of architecture and engineering*	*The solution includes two overlays: (1) Upper level framing plan on the Lower level architectural plan, (2) Roof level framing plan on the Upper level architectural plan*
Structural framing plans	*No structural plans are provided*	*Only one structural framing plan is provided*	*The solution includes two framing plans: (1) Upper level framing, (2) Roof level framing plan*
Graphic communications content	*The solution is missing most of the communications content*	*The solution is missing a couple of the communications content*	*The solution includes column lines, dimensions, bar scale, north arrow, drawing title, your name, etc.*
Graphic communications quality	*The solution does not utilize the architectural skills of the student*	*The solution illustrates hints of architectural expression, but does not fully integrate your architectural skills*	*The solution is of studio quality illustrated by different applications of line weights, grey-scale, use of mechanical drawing, exceptional lettering, etc.*
Formatting	*The drawings are not converted*	*Some of the drawings are converted into a PDF*	*All the drawings are converted into a PDF*
Timing	*Not submitted*	*Submitted late*	*Submitted on time*
Total Points			*/ 46*

NARRATIVE

Description of Technology

The students will use technology in their information seeking behaviors, preparing the process and final documents, and to disseminate their work for assessment. In Class Period 1, the students will access the Moodle LMS to locate the necessary documents to review. The documents are in various file extension formats such as PDF and MP4. The students have the option to use the drawing software program SketchUp to develop schematic design of the structural layouts used in Class Periods 2 to 4. SketchUp. For the final digital drawings, the students may continue with SketchUp or transition to more sophisticated programs such as AutoCAD or Revit. The final class period is dedicated to any last-minute revisions and the conversion to the required PDF format. The SKP, DWG, and RVT files can be printed into PDF formats or simply saved as a PDF. Sometimes the students have used Photoshop to add more creative contexts for the font types and styles, etc. and to better facilitate the transition to the 8.5 x 11 *inch* dimensions. The students are required to submit the final PDF into the Moodle LMS. Moodle has rubric capability. The rubric in this PA can be copied and pasted into the Moodle rubric, but only one box at a time. When using the rubric for assessment, the instructor simply clicks on the appropriate level of completion and may add comments to each objective. The teacher can also add overall commentary. The teacher can also draw directly onto the PDF.

General Considerations

I have been wanting to develop this type of assessment for quite a while. A numerical rubric for a visualization-based project is commonly avoided and even frowned upon in architecture. I think that is because we simply do not know how to construct a quality rubric. I attempted a deep dive into the framing protocols to establish scoring items targeting meaningful learning. I already have the basics for the architectural solution, but the challenging part was creating the rubric.

Explanation Architects must possess a holistic knowledge that transcends across other disciplines and trades such as mechanic, electrical, plumbing, acoustics, structures, etc. This performance assessment targets the discipline of structural engineering and the important learning objective of structural framing. The learners complete the structural framing assignment because it is important for the health, safety, and welfare of the public. Even the National Architectural Registration Boards (NCARB) license examination tests a candidate's knowledge about structures years later.

Interpretation The learners must interpret data provided by the architects. In this performance assessment, the data is the architectural schematic design supplied by the architect and the framing protocols or guidelines. The architectural design satisfies an owner's program by arranging the occupiable and service spaces in a building, positioning walls, doors, windows, circulation paths, etc. that has a particular form and aesthetic. For example, the Beaux Arts method places an emphasis on the fenestration patterns and the resulting elevation of a building. The structural engineers interpret the three-dimensional puzzle and must assemble a series of linear (beams and columns) and planar (floor decks) structural elements that marries the architectural design while following the protocols.

Application The capstone class is designated as a master's level course. Therefore, the course must require a level of knowledge to institutionally satisfy that of 'application'. The students learned the framing protocols in the introductory course. In this performance assessment, the students apply their introductory course prerequisite knowledge to develop a structural framing solution that responds to the architect's schematic design.

Perspective Placing the students in the role of a structural engineer is crucial to their learning and offers a different perspective. Furthermore, each student is meeting with their design team to describe and present their solution. The peer feedback will offer different perspectives as there are several outstanding solutions that may evolve from this project. The students have a meeting with an outside professional where they must also describe and present their solution.

Empathy Architects work closely with engineers. The learners should exhibit empathy for the engineers because they are being asked to perform the tasks of the engineer. The architects ask a lot of the engineers without even realizing the magnitude of their design choices. For example, the architects might have what appears to be a simple request of a column-free space. This design has a winding walking exhibit that makes the solution particularly challenging. When they are in the role of others experiencing their obstacles, one cannot avoid having empathy for what others are undertaking.

Self-Knowledge The last class period is devoted to finalizing the solution and comparing it to the grading rubric. This provides an opportunity for the students to reflect upon their solutions and revise accordingly. Being a structural engineer will help them become better architects. They will have an improved understanding of how architectural choices influence aspects of engineering.

Self-Assessment (According to Wiggins)

Wiggins should be able to dissect the understanding by design sequence. (1) The desired result is to satisfy the primary learning objective where the learner must be able to demonstrate the ability to configure beams, columns and decking into a multi-story, post-and-beam, structural framing solution that resists gravity loads. The objective is important due to its life safety implications and its integration with architectural design. The objective is also recognized by our accrediting board and further tested during the license exam. (2) The evidence has a graphical sensibility as the students must visualize the framing solution. The final evidence is the structural framing overlayed on top of the architectural design and the framing without the architectural plans. (3) The learning experiences are to interpret the architect's provided data and apply the framing protocols of accepted engineering practices. The students will use most of the class periods developing the solutions, meeting with their peers, a professional, and with the instructor, and then self-reflecting back to the essential question prior to submitting the design.

Peer Reviews

Victoria Miller and Sydnee Owens reviewed the PA. Victoria focused on style and grammar to offer better clarity in some instances. She also provided some crucial guidance in the scoring guide, "under several categories, you used vague quantifiers...like 'some, several, majority, etc.'. If possible, try to make it measurable." This was great advice, and I revised the rubric accordingly. She further commented, "Overall, this is great...you mentioned struggling with the scoring guide...but I think (except for the quantifier thing) it would be so useful for your students...it's very clear what the expectation is." I am hoping that my students will respond positively by having a detailed rubric rather than a messy and marked up drawing. Sydney offered suggestions to enhance the performance plan. I responded by adding more information into the table. My biggest concern was the rubric and Sydnee offered, "I think your rubric does an excellent job of outlining the requirements to reach the desired results."

Exhibit A – Architect's Schematic Design – Lower Level Floor Plan

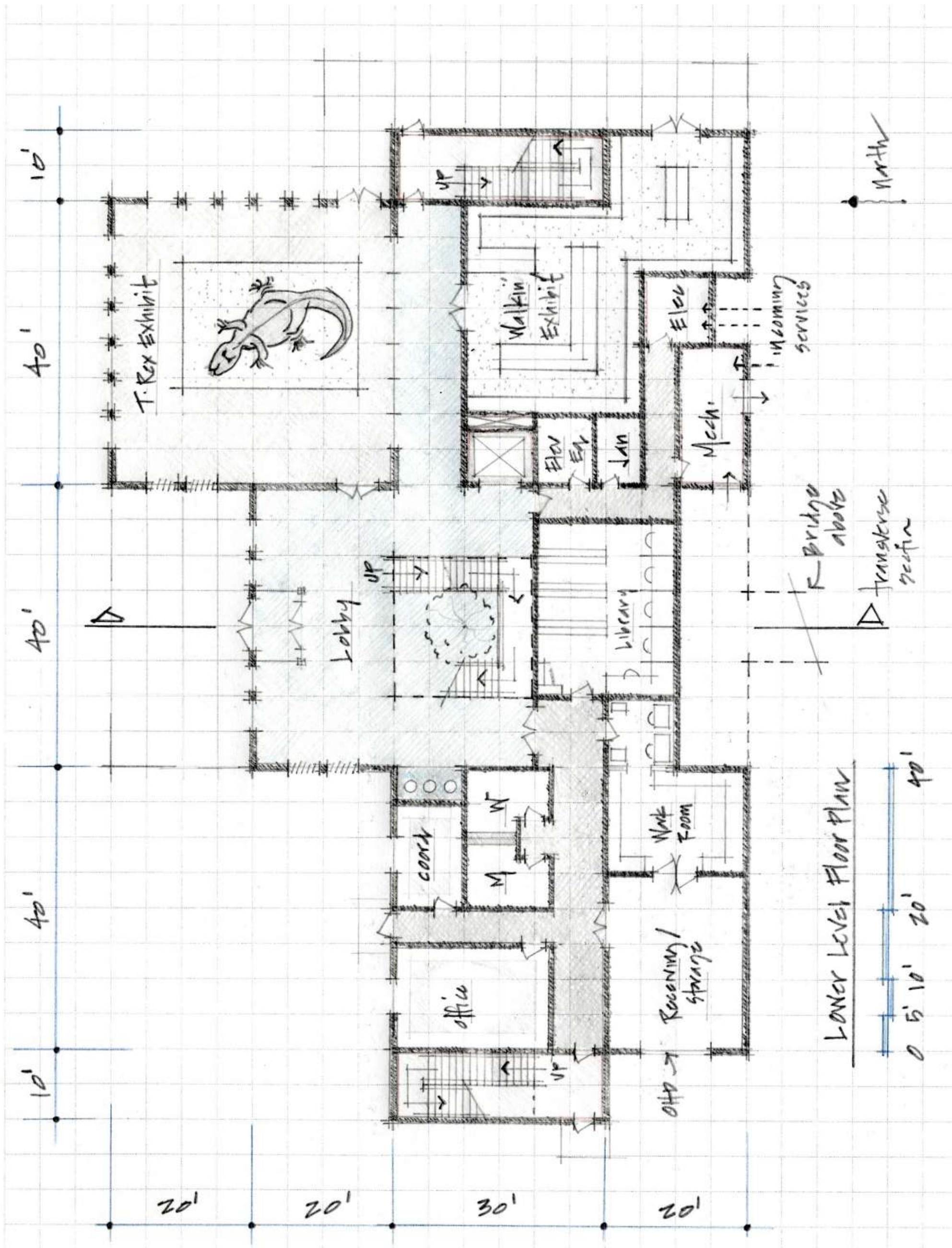

EXHIBIT A – ARCHITECT'S SCHEMATIC DESIGN – UPPER LEVEL FLOOR PLAN

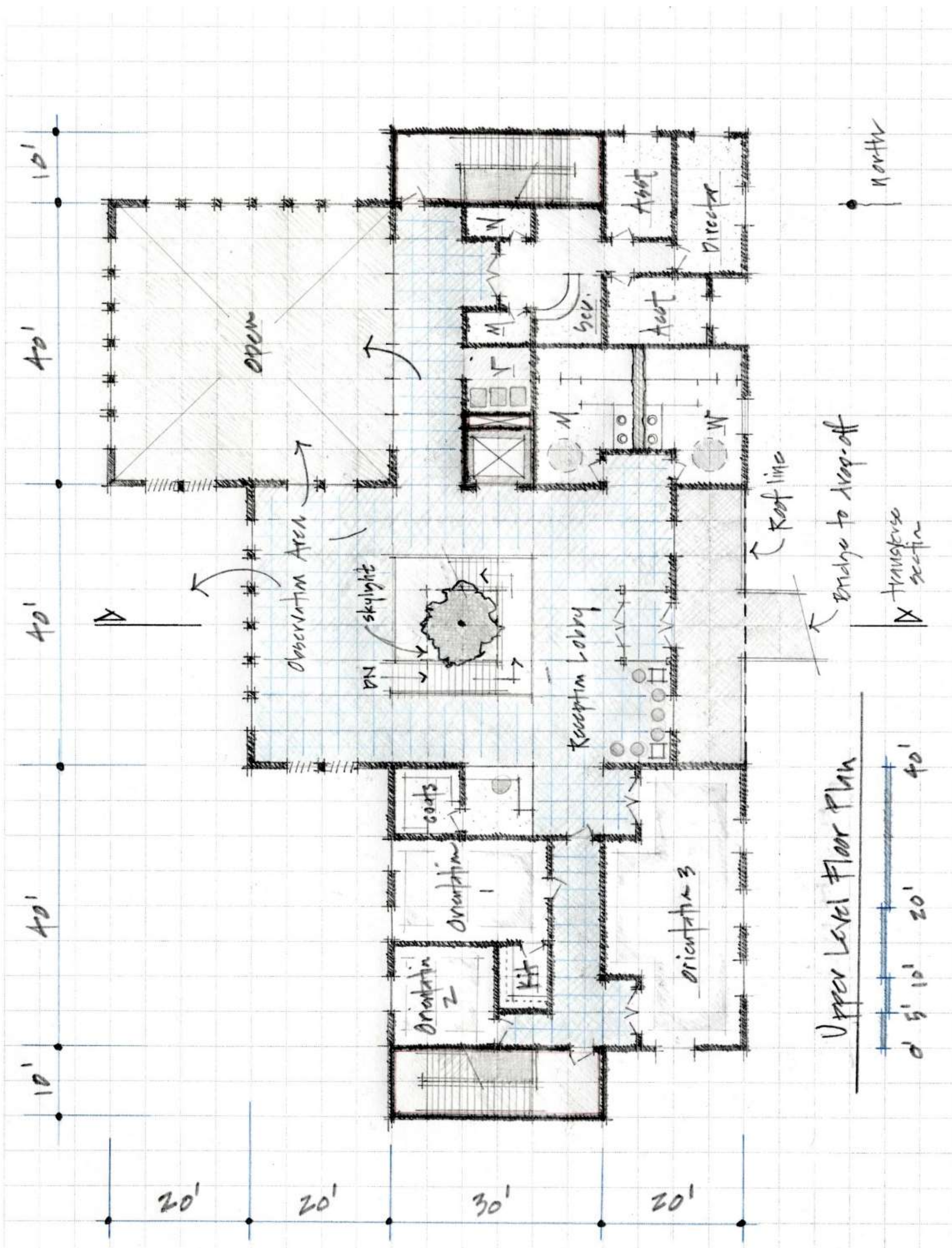

EXHIBIT A – ARCHITECT'S SCHEMATIC DESIGN – ELEVATION AND SECTION