Form and numbers: Mathematical patterns and ordering elements in design

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Form and Numbers:
Mathematical Patterns and Ordering Elements in Design

by

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A thesis submitted in partial fulfillment of the requirements for the degree of
Master of Architecture
School of Architecture and Community Design
University of South Florida

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Date of Approval:
April 10, 2009

Keywords: mathematics, proportion, grid, architecture, art

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This thesis is dedicated to my Dad, without whom this idea would never have been born, and this ambition never fostered. Because of you, I never knew limitations, only possibility. This project is proof of your unwavering support and encouragement. And to my Nanny and Poppy, my absolute biggest fans, I wish you were here to see it finally materialized.
I would like to acknowledge all of my friends and family, and anyone who offered me a kind word of encouragement in the last four years. To my professors, I cannot thank you enough for taking the time to talk with me and critique my work. Seeing your passion for architecture and dedication to teaching has enriched me not only as an architect, but as a person. I would especially like to thank Rick Rados and Stanley Russell for bearing with me this past year and making sure I never lost sight of the essence of my project. To Jin Baek and Enrique Larranaga, though our interactions may have been brief I will never forget the insight and human quality you brought to my designs and conceptual thought process. To my friends, Daniel, Katrina, Miguel, Podes, Ricky, Ryan and Torend: there are no words for how grateful I am to you all. There were many times when it was your faith alone that kept me on track and in the studio. To my family, Mom, Philip, James, Grandma Mimi, Meghan and all the Thom/Burge clan: you were my rock. I made it to this point because of your eternal love and support. And to my chair, Dan Powers, I could not have realized this without you there, everyday constantly pushing me to achieve more. It is your support and expectations that got me through this final step.
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FORM + NUMBERS: MATHEMATICAL PATTERNS + ORDERING ELEMENTS IN DESIGN

Alison Marie Thom

ABSTRACT

...shapes and proportions in geometry transcend limitations of time and space...geometry describes spatial relationships at all scales...It can free us from superficial applications of “style” by offering profound sources for making space. The essential and most fundamental ordering principles of geometric form eliminate redundancy and at the same time offer infinite tangible variations for natural evolution and human creativity.

-Anne Tyng

In America, buildings are often constructed with the intent of being utile only 30-40 years. All over the world though, there are buildings that are hundreds of years old that are still very functional. Historically, architecture was a part of mathematics, and in many periods of the past, the two were indistinguishable. Architects were often required to be also mathematicians in ancient times. The idea of this thesis is to identify the relationship between mathematics and architecture and to reintroduce them in order to create a module for successful design.

Presence of mathematical boundaries help to attain visual consistency by relating a small scale to a larger scale. Spaces which meet these criteria are subconsciously realized as sharing critical qualities with natural and biological forms. Accordingly, they are perceived as more comfortable psychologically. Scaling coherence is a common element of traditional and vernacular architectures, but is often extensively deficient from contemporary architecture.

Architecture has used proportional systems to create, or limit, the forms in building since its inception.
In almost every building tradition, there exists a system of mathematical relations which governs the relationships between elements of design. These are often quite simple: whole number ratios or easily constructed geometric shapes. Many types of revival architecture have been employed in recent years, therefore it would be critical to identify why they have achieved a resurgence in popularity. However, historical allusions are generally superficial. No authentic scale or systems are used and the formerly unique qualities are not explored spatially.

The attraction to, and association with, forms possessing harmonic proportions is a mitigating factor in design that needs to be addressed. The natural beauty stemming from proportion, mathematics, and the proper relationship of elements to the whole is what renders a building aesthetically and experientially pleasing to a human. Post-Modern architecture is all but going in the opposite direction of achieving this goal. The idea that a building should scale down to dimensions humans can relate to and reveal its stature in the experiential qualities must be extracted from traditional architecture and employed in contemporary techniques.
Art and design is a realm of study where mathematics is often overlooked, but has a strong presence. Mathematics and art have a long historical relationship. Painting, drawing and photography are a few examples where mathematical properties are present in the form of perspective, the rule of thirds, and grids. The ancient Egyptians and Greeks knew about the 'golden ratio', regarded as an aesthetically pleasing ratio, and incorporated it into the design of their monumental buildings including the Great Pyramid, the Parthenon, the Colosseum. The golden ratio is used in the design and layout of paintings such as The Roses of Heliogabalus. Recent studies show that the golden ratio also plays a role in the human perception of beauty in body shapes and faces. The Platonic solids and other polyhedra are a recurring theme in Western art.

In Leonardo Da Vinci’s early writings he echoes the treatises of Italian Mathematician Leone Battista Alberti and artist Piero della Francesca:

... Perspective is a rational demonstration by which experience confirms that the images of all things are transmitted to the eye by pyramidal lines. Those bodies of equal size will make greater or lesser angles in their pyramids according to the different distances between the one and the other. by a pyramid of lines I mean those which depart from the superficial edges of bodies and converge over a distance to be drawn together in a single point.

Da Vinci developed mathematical formulas to compute the relationship between the distance from the eye to the object and its size on the intersecting plane; that is the canvas on which the picture will be painted:

*If you place the intersection one meter from the eye, the first object, being four meters from the eye, will diminish by three-quarters of its height on the*
intersection; and if it is eight meters from the eye it will diminish by seven-eighths and if it is sixteen meters away it will diminish by fifteen-sixteenths, and so on. As the distance doubles so the diminution will double.  

For these reasons, a building layout with these properties for Art + Design students would be complimentary as they could understand the subtle but critical presence of math in both Art and Architecture. As there is an existing layer of richness from mathematics incorporated into art, adding this concept to the design of the learning environment would enhance the creative process of the students.
PROBLEM STATEMENT

The challenge is to design a Graduate School of Art + Design for the University of South Florida. The grids and modules that will be used, are based off of mathematical ordering properties. Significant numbers to be incorporated are the golden section and the fibonacci sequence. The intersection of spaces and points on the grid will be emphasized. Corners and points of transition have visual presence and hierarchy.

Additionally, connection with an Arts District and the local university would be essential for exposure and joint endeavors. Graphicstudio is a university-based atelier engaged in a unique experiment in art and education, committed to research and the application of traditional and new techniques for the production of limited edition prints and sculpture multiples. Graphicstudio with the Contemporary Art Museum and the Public Art Program form the Institute for Research in Art in the College of Visual and Performing Arts at the University of South Florida. (USF 2008). This provides many opportunities for networking and linking with the arts and cultural scene of the greater Tampa Bay area.

Finally, being the School of Art + Design, the building should facilitate teaching the students about the composition and placement of form, or even the absence of form. This will inform the students about the importance of order and layout in design and the benefit of using mathematical ordering properties for spatial organization.
GOALS + OBJECTIVES

• Taking the element of the bend of the Hillsborough River and the shift of Tampa’s city grid, embracing the character of a point of intersection or transition; engaging the dynamicity of this nexus point.

• Use building to inform, with the use of mathematical ordering properties and systems of proportion to organize and plan the project, in a way that the students can understand the benefit of these design tools in their respective realms of study.

• Create a Riverwalk terminus, specifically relating to the Arts District.

• Form a connection with the Arts District, through vistas or structural gestures.

• Use the building to frame the view corridors of the river and downtown, for the creative benefit of the students and so as not to isolate the residential neighborhood to the north.

• Integrate into the urban and suburban fabrics by relating to the grid the site is on and the proximal shifted grid of downtown

• Create an urban presence, while not alienating the current residential context.

• Encourage pedestrian engagement on the riverwalk by providing public amenities to be shared with the students and by revealing the works of students throughout the site.
RESEARCH METHODS

Research for this document will be conducted using various architectural research methods and a diverse base of sources and media. Architectural research methods employed are Interpretive-Historical, Qualitative, Correlational, and both Precedent and Case Studies. Interpretive Historical research will occur in the form of Causal Explanations of History, studying facts and formulas of mathematics, and Structuralism, identifying the meaning not in the entity itself but in the relationship between entities, mathematics and architecture. Qualitative research encompasses the site and programming analysis, the collection and then interpretation of the data from a contemporary setting. Correlational research is used to explore the mathematical patterns occurring in nature, the measurement of existing structures and the subsequent ratios and proportions identified. Precedent studies will be used to inform on the building type and to identify advantages and disadvantages of already proposed design solutions. The Case Studies will be the investigation of existing buildings and exploring if they possess these mathematical properties, and if so how they are enriched by them.

The research will be conducted in the library, on the internet, at the site, at the Nexus 2008 Relationships in Mathematics and Architecture Conference, and through personal contact with scholars and professionals. The media will be books, periodicals, electronic journals, websites, on-site observations and photos, diagrams, e-mail correspondence, phone interviews, and lectures. This wide-ranging collection of methods and materials will insure an unbiased and thorough research base for the project.
The link between mathematics and architecture is often understated but always powerful. There are the obvious uses of mathematics in construction and dimensioning, however, the subtle presence of mathematics in conceptual and spatial design is the most significant. Though many see mathematics and art at opposite ends of the spectrum, in ancient times architecture was considered a mathematical topic and the disciplines have, up to the present time, retained close connections. Conceivably, once one realizes that mathematics is essentially the study of patterns, its connection with architecture becomes clearer. Mathematics is not only about formulas and logic, but about patterns, symmetry, structure, shape, and beauty. Such sequences and patterns are found everywhere in nature. Many buildings of traditional architecture employed these, and they are still being inhabited and used today. Thus, historically the connection between mathematics and the arts has been understood by humans, if only subconsciously. The challenge, then, is to identify systems of proportions and mathematical relationships that render spaces aesthetically pleasing and balanced to a person; then to create a contemporary building type incorporating them to achieve a more permanent and flexible-use method of building.

Architecture has used proportional systems to create, or limit, the forms in building since its inception. In almost every building tradition, there exists a system of mathematical relations which governs the relationships between elements of design. (Licklider 1965, 30) These are often quite simple: whole number ratios or easily constructed
geometric shapes. Many types of revival architecture have been employed in recent years, i.e. Gothic, Mediterranean, therefore it would be critical to identify why they achieved resurgence in popularity.

The apparent incoherence of modern architecture leads one to believe that in nature there must be some correlating principle, establishing limits for the designer. Jay Hambidge, an American artist who conceived the idea that the study of arithmetic with the aid of geometrical designs was the foundation of the proportion and symmetry in Greek architecture, sculpture and ceramics, also formulated the theory of “dynamic symmetry” as demonstrated in his works *Dynamic Symmetry: The Greek Vase* (1920) and the *Elements of Dynamic Symmetry* (1926). In his studies of the aforementioned, Hambidge determined two types of proportion or symmetry, one of which possessed qualities of activity, the other of passivity. The static is found in nature in crystal form, flowers and seed pods. The dynamic is identified in shell growth and leaf distribution. (Hambidge 1920, 7) A study of the basis of design in art shows that this active symmetry was known to primarily two peoples, the Egyptians and the Greeks; the latter only having developed its full possibilities for purposes of art. (Sagdic 2000, 125) Through study of natural form and shapes in Greek and Egyptian art, this principle for the proportioning of areas has been reclaimed in architectural language.

2. Measurement

The basis for proportion is size, so to develop a greater understanding of dimensional relationships we must recognize the systems which we use to represent this data. However objective it may seem, measurement is a system wrought with human experience and culture. Structures of measurements are highly symbolic. Historically, canonization of the bodies of leaders and gods were often the foundation for the standards. Although classification varies from one historical society to another, the articulated parts of the body are typically used to define small measures and are
identified in relation to the total of the entire body. (Tavernor 2002, 63) When the notion of the perfect body was not the basis of a nation’s linear measures, easily tradable and taxable items in the region, often cereal grain, were used as standards. Invariably, however, these related back to the proportions of a perfect body.

In Western society, a natural quality cannot be comprehended until it can be judged against the measurable. It is certain that Western culture would have difficulty realizing the irrationality of the ancient Indian scale of measures in which the yôjana (a day’s march for an army) variously equals 16 or 30 or 40 li, and is also equal to eight krôsas (keu-lu-she):

- a krôsa is divided into 500 bows (dhanus): a bow is divided into four cubits (hastas): a cubit is divided into 24 fingers (angulis): a finger is divided into 7 barleycorns (javas): and so on to a louse (yûka), a nit (likshâ), a dust grain, a cow’s hair, a sheep’s hair, a hare’s down … and so on for seven divisions, till we come to an excessively small grain of dust (anu): this cannot be divided further without arriving at nothingness … (Beal 1885)

For cases such as this, measures are generally rationalized in relation to a single coherent form and nothing is more readily accessible in daily experience than the human body and its constituent parts. (Tavernor 2002, 68)

Since Greek antiquity, it has been generally accepted in Western societies that a quality in nature cannot be appreciated until it has been measured, or can be compared with something that is measurable. The Greeks also realized that qualities could be described through a medium other than words, that is, through numbers. Their numbers were more than quantities, for they represented qualities too. Pythagoras defined the extraordinary properties of certain numbers, such as 6 and 10. He considered these integers to be perfect numbers, because they can be regarded as the sum of their parts: 6 is the sum of 1+2+3; and 10 the sum of 1+2+3+4. Consequently, Plato took these
numbers and used them to describe the natural harmony that existed in the world and universe. (Tavernor 2002, 68) Using the Pythagoreo-Platonic System a Greek sculptor, Polykleitos, created a sculpture of a man that was the visual manifestation of these perfect dimensions, in that its parts had a harmonious relationship to the whole. (Padovan 2002, 47) Here lies the inception of the ‘the canon’ for perfect proportions.

The system of weights and measures used in the ancient Greek world was motivated in its creation by an amalgamation of philosophy, mathematics and art. Marcus Pollio Vitruvius, the Roman architect working and writing in the first century BC, was familiar with this tradition and stated what was most certainly agreed upon widely, that the finest buildings of ancient times reflected in their form the human proportions of the Greek canon. (Vitruvius 1914, III.1) As the numbers of these proportions were derived from Pythagoras and Plato’s numerical summation of the universe, Vitruvius was aware that the measuring units he used to design buildings – the finger, palm, foot and cubit – and the perfect number relations between them are a combination derived from the measures of the universe and of the idealized body of man. As a result, body, architecture and the natural world were in perfect harmony, and the body of man was regarded as a symbolic manifestation encompassing the harmonious universe.

In recent centuries, measurement systems have lost any connection to the human experience, everyday life, art or symbolism. IThere is no evident reference to human form or these universal harmonies. The seemingly “rational” system of calibrated measurements to a disconnected object, such as the meter rod, is almost as irrational as the superfluous archaic Indian measurement systems. The meter has evolved into the standard of measure without relation to the corporeal form or the human condition. (Tavernor 2002, 71) It is purely an abstract scientific unit without tangible significance and stands in sharp contrast to the conception of numbers, measurement and mathematics
of ancient cultures.

3. Mathematics in Architecture

The first definite mathematical influence on architecture is that of Pythagoras. For the Pythagoreans, numbers took on a religious significance. The Pythagorean belief that “all things are numbers” clearly had great significance for architecture. At first, that might seem quite an impractical idea, but, in fact, it was based on some fundamental truths.

Pythagoras saw the connection between music and numbers and clearly understood how the note produced by a string related to its length. He established the ratios of the sequence of notes in a scale still used in Western music. By conducting experiments with a stretched string, he discovered the significance of dividing it into ratios determined by small integers. The discovery that beautiful harmonious sounds depended on ratios of small integers. This resulted in a module, a basic unit of length for the building, where the dimensions were now small integer multiples of the basic length.

Numbers for Pythagoras also had geometrical properties. Geometry was the study of shapes and shapes were determined by numbers. More importantly, the Pythagoreans developed a notion of aesthetics based on proportion. In addition, geometrical regularity expressed beauty and harmony and was applied to architecture with the use of symmetry.

However, to a mathematician today, symmetry suggests an underlying action of a group on a basic configuration, but it is important to realize that the word comes from the ancient Greek architectural term ‘symmetria’ which indicated the repetition of shapes and ratios from the smallest parts of a building to the whole structure. This clarifies what the principle that “all things are numbers” meant to the Pythagoreans and how this was to influence ancient Greek architecture.
Static symmetry, as mentioned previously, exists as patterns and shapes found in nature. Dynamic symmetry is more subtle and more vital than static symmetry and is predominantly the form to be employed by the artist, architect and craftsman. The principles of this method for proportioning spaces are obviously more appropriate when taking into consideration movement and experiential qualities.

The first application of dynamic symmetry, found in the Egyptian’s pyramid and temple buildings, originated around three or four thousand B.C. There method of surveying and marking off an orthogonal plot of land involved two men and a rope which was marked off into twelve units to which allowed for the creation of a right triangle of side lengths 3, 4 and 5: the Pythagorean triad. (Hambidge 1920, 152) However, not until centuries later, did the Greeks discover this from studying the Egyptian constructs. This method was used for the plan, then rotated up for the elevations, and used for generally all design and ornament. It allowed artists and architects control over proportions, spatial dimensions, and pictorial composition that was unprecedented. Unfortunately, the Euclidean development of this practical geometry, which was one of pure mathematics, lost all artistic and human application.

3. Limits of Nature

The patterns and proportional systems found in nature lay a framework of order that allows for exponential variety of shapes and designs. In The Power of Limits, Doczi uses the term ‘dinergy’ when speaking of the patterns evident in nature. Dinergy refers to the working of opposites united in a harmonious proportion. Dinergy is made up of two Greek words: dia (across, through, opposite) and energy. (Doczi 1981, 27) An example is the working of the minor and major parts of the golden proportion. In mathematics and the arts, two quantities are in the ‘golden ratio’ if the ratio between the sum of those quantities and the larger one is the same as the ratio between the larger one and the
smaller. The golden ratio is approximately 1.6180339887. This word was invented to refer to the universal pattern-creating process, the method for generating patterns and modules found in nature.

4. Human Proportion

When discussing proportion, especially human proportion, in architecture the name that most often comes to mind is Vitruvius. The aesthetics of proportion are most clearly addressed in Book III, where he gives the famous section on the proportions of the human figure. Vitruvius says that the proportions of a temple ought to be like that of a well-formed human figure, which he proceeds to describe in some detail. Often it is assumed that the emphasis here should be on the human figure itself, and on its natural proportions. Advocates of different systems of proportion have argued that Vitruvius was quite right about this, but that nature happens to have designed the human figure according to their own favored system. However, when the body is viewed as a vivid diagram, familiar to all, the importance again falls not on the human figure itself, but on the actual proportions of it. These proportions help to understand the relationship as they express the size of the parts in terms of a whole.

5. Aesthetics of Proportion

Proportion is found in bringing together the various constituent parts with the whole, when symmetry is also present. The aesthetic aspect of proportion is one approached from two viewpoints. The first being the intuitive approach, where the proportions of an object are modified to please the eye through a slow process of trial and error. In architecture this process may extend over many generations in the gradual refinement of traditional forms or the selection of the most admired proportions from nature. Both cases involve the eye’s desire for, what Sir Christopher Wren refers to as, ‘customary beauty’, the traditional or life-like, and its simultaneous desire for
‘natural beauty’, the harmony of proportion ‘achieved in such a manner that nothing could be added or taken away or altered except for the worse’. (Scholfield 18)

Proportion at various scales is most easily achieved by use of a module. Though the module itself may have no necessary aesthetic significance, it is helpful for describing the comparative sizes of an object and its parts, without fixing the absolute measurements. Vitruvius showed that by giving us the proportions of an order in terms of a module, we may construct it to any size necessary. (Scholfield 17)

Though aesthetics is most often perceived as a subjective quality, there are, in fact, methods for evaluating the level of aesthetical pleasure an object invokes. The secret of this universal aesthetic pleasure in beautiful forms lies in mathematics, reveals Harvard math professor, Dr. George D. Birkhoff. He has worked out a mathematical formula from which he can obtain the “aesthetic value” of a shape or form, and this mathematical expression of the beauty of an object conforms to the emotional judgment of those who look upon it. Therefore this qualitative element can be quantified; it may be compared and contrasted with other data and empirical research.

6. Examples in Architecture

One of the most important ideals of classical architecture is that the part relates to the whole, at all scales, and in very specific ways. The most common relationship is between component parts and the module of one-half the diameter at the lower third of the column shaft. The proportions used to generate the orders are derived from relationships found commonly in the human body and elsewhere in nature, such as the spiral of a Nautilus shell and in the distribution and proportions by which leaves diminish in size on a fern bush stem. These relationships are latent, but are easily visible upon closer study. (Doczi 47)

One of the elemental characteristics of classical design is the tri-partition of the language at all scales. There
is a bottom, middle, top; beginning, middle, end. Each order of columns, the basis for classical post and lintel design, consists of a pedestal, a column, and an entablature. In turn, pedestals consist of a plinth at the bottom, a dado in the middle, and a cornice at the top. A column has a base, a shaft, and a capital. The entablature has an architrave, a frieze, and a cornice. These can, in most cases, be reduced even further into three parts. The relationships delineated by the Orders are merely guidelines for the designer, offering base information from which individual design can begin.

The beginning of the twentieth century saw the heightened use of Euclidean or Cartesian rectilinear geometry in Modern Architecture. In the De Stijl movement specifically, the horizontal and the vertical were seen as constituting the universal. The architectural form therefore is constituted from the juxtaposition of these two directional tendencies, employing elements such as roof planes, wall planes and balconies, either sliding past or intersecting each other. The Rietveld Schröder House by Gerrit Rietveld is an example of this approach. Many of the latest attempts at incorporating natural proportions have been misconstrued or unsuccessful and led to the abandonment of these principles. The presence of these geometries and proportions from ancient to contemporary buildings is dwindling, though the benefit of its reintroduction to design theory is essential.

7. Existing Problems

In recent decades, historical ‘revival’ styles have gained enormous popularity in residential and civic building design. Mediterranean, Greek and Gothic are just a few of those found in abundance from the cities to the suburbs. However, historical allusions are generally superficial, i.e. a columnar façade and an arcade. No historic construction or design methodology is used and the qualities are not explored spatially. The facades are usually out of scale, so no actual proportions are identifiable.
It is not that these proportions are unknown, it’s that there full potential is not employed. Fibonacci sequences and patterns are used in elevation and to create ornament, but again not on a broader level that can be experienced by the inhabitant. Le Corbusier attempted to incorporate “harmonious measurements” and human proportion into architecture; however it was criticized as not having a direct correlation to anthropometric observations and not being comprehensive in its application. (Scholfield 1958, 5)

Architecture has always tried to achieve ends that not only relate to function, but also to aesthetics, philosophy, and meaning. And in many a case, the means to this end has been the beauty and structure of mathematics.

8. Research Methods and Goals

At this juncture, the goal for this project is to design a public building that is based on mathematical patterns, algorithms and proportions found in nature. The symmetries and patterns will be used to generate all facets of the building: plan, section, elevation. This means that any window and door openings; fixed seating location, size and height; corridor widths and ceiling heights; lighting position and aperture size; and stairs or walkways will all be based on the identified patterns modules of proportions appropriate for the certain scale. Additionally, the circulation both within and around the structure will be subject to these guidelines to achieve an inherently pleasing experiential condition for a person, regardless of program. The challenge will be to create a comprehensively designed space, verging on a gesamkunstwerk, or total work of art, that can also easily accommodate a variety of uses. The intent is to create a space and a module for construction that is site specific yet with the potential for being easily converted to accommodate future uses. Possible future programs will be suggested and how the building’s initial design facilitates the easy transition as well.

The architectural research methods most suitable for the development of this thesis project will be correlational
research and case studies. Exploring traditional architecture still in use and identifying the presence of these patterns and ratios will establish the framework for aesthetically pleasing form. These elements will be used to generate forms which will constitute the basis of the final building design. Conducting surveys of both those with and without architectural background of their responses to certain sizes, shapes and scales will assist in the final proposal. Additionally, attending a conference on mathematics in architecture will provide information on both historical and modern applications to be employed. The intent is to focus on the aesthetics and functionality of the space which will be most successfully achieved with a balance of precedent and primary research.
Ratio and proportion may seem like common terms which we use everyday, however, their mathematical definitions must be clarified for the purpose of this thesis as they are commonly interchanged mistakenly and misused.

Ratio (logos) is the relationship of one number to another, for instance 4:8 ("4 is to 8"). However, proportion (analogia) is a repeating ratio that typically involves four terms, so 4:8 :: 5:10 ("4 is to 8 is as 5 is to 10"). The Pythagoreans called this a four-termed discontinuous proportion. The invariant ratio is 1:2, repeated in both 4:8 and 5:10.

Plato holds continuous geometric proportion to be the most profound cosmic bond. In his *Timaeus* the world soul binds together, into one harmonic resonance, the intelligible world of forms (including pure mathematics) above, and the visible world of material objects below, through the 1, 2, 4, 8 and 1, 3, 9, 27 series. This results in the extended continuous geometric proportions, 1:2 :: 2:4 :: 4:8, and 1:3 :: 3:9 :: 9:27 (see Fig.X Lambda Diagram).

**RATIO**: between two numbers a and b

- Ratio between a and b
  - a : b or a/b
- Inverse ratio
  - b : a or b/a

**MEAN**: b, between a and c

- Arithmetic Mean b of a and c
  - $b = \frac{a+c}{2}$
- Harmonic Mean b of a and c
  - $b = \frac{2ac}{a+c}$
- Geometric Mean b of a and c
  - $b = \sqrt{ac}$

**PROPORTION**: between two ratios

- Discontinuous (4 termed)
  - a:b :: c:d
  - e.g., 4:8 :: 5:10
  - invariant ratio 1:2
- Continuous
  - a:b :: b:c => a : b : c
  - note: b is the geom. mean of a and c
Plato’s World Soul:

Extended Continuous Geometric Proportion

1:2 :: 2:4 :: 4:8
invariant ratio 1:2 or 1/2

1:3 :: 3:9 :: 9:27
invariant ratio 1:3 or 1/3

Figure 1: Lambda Diagram

So why does Plato ask us to make an uneven cut? An even cut would result in a whole:segment ratio of 2:1, and the ratio of the two equal segments would be 1:1. These ratios are not equal, therefore no proportion is present.

There is only one way to form a proportion from a simple ratio, and that is through the golden section. Plato wants one to discover a special ratio such that the whole to the longer equals the longer to the shorter. He knows this would result in his favorite bond of nature, a continuous geometric proportion. The inverse also applies, the shorter to the longer equals the longer to the whole.

The reason he uses a line instead of just numbers, is that Plato realized that the answer is an irrational number that can be geometrically derived in a line but cannot be expressed as a simple fraction.

Solving this problem mathematically, and assuming the mean (longer segment) is 1, we find the greater golden value of 1.6180339...(for the whole), and the lesser golden value of 0.6180339...(for the shorter). These are referred to as $\Phi$ “fye” the Greater and $\phi$ “fee” the lesser respectively. Notice the both their product and their difference is Unity. Furthermore, the square of the Greater is 2.6180339, $\Phi + 1$. Notice also that each is the other’s reciprocal, so that $\phi$ is $1/\Phi$. To avoid confusion, they will generally be referred to as The Greater, meaning $\Phi$, the mean as Unity (1), and the Lesser being $1/\Phi$.
PHI ON THE PLANE

Moving from the one-dimensional line onto the two-dimensional plane, the golden section is not difficult to discover. Starting with a square, and arc centered on the midpoint of its base swung down from an upper corner easily produces a large golden rectangle (lower first). Importantly, the small rectangle which we have added to the square is also a golden rectangle. Continuing this technique creates a pair of these smaller golden rectangles. Conversely, removing a square from a golden rectangle leaves a smaller golden rectangle, and this process can be continued indefinitely to produce a golden spiral (see Figure X: Golden triangle).
The origin of the golden section is often difficult to follow through history. Despite its use in ancient Egypt and the Pythagorean tradition, the first definition we have comes from Euclid, who defines it as the division of a line in extreme and mean ratio. The earliest known published essay works on the subject is *Divina Proportione* by Luca Pacioli [1445-1517 described by Leonardo Da Vinci, as the monk drunk on beauty. Da Vinci according to tradition having created the term *sectio aurea*, or “golden section.”

*Figure 4: Golden Circle*  
*Figure 5: Golden Spiral*
So why has the golden section retained its lure throughout the centuries? One of the eternal questions asked by philosophers concerns how the One becomes Many. What is the nature of separation, or division? Is there a way in which parts can retain a meaningful relationship to the whole?

Posing this question in allegorical terms, Plato in The Republic asks the reader to “take a line and divide it unevenly.” Under a Pythagorean oath of silence not to reveal the secrets of the mysteries, Plato posed questions in hopes of provoking an insightful response. This line begins to lead us to the golden section.

rabatment :: to take the short side of the rectangle and make a square out of it

The side of the square is a strong component to include in a composition. The viewer’s eye senses the structure and feels a sense of harmony. This is called the rabatment of the rectangle.

occult center :: literally “hidden from the eye”, not necessarily having any paranormal references. The occult center is not a finite point really, as it is the center of the infinite golden spiral.
Le Corbusier explicitly used the golden ratio in his Modulor system for the scale of architectural proportion. He saw this system as a continuation of the long tradition of Vitruvius, Leonardo da Vinci’s “Vitruvian Man”, the work of Leon Battista Alberti, and others who used the proportions of the human body to improve the appearance and function of architecture. In addition to the golden ratio, Le Corbusier based the system on human measurements, Fibonacci numbers, and the double unit.

He took da Vinci’s suggestion of the golden ratio in human proportions to an extreme: he sectioned his model human body’s height at the navel with the two sections in golden ratio, then subdivided those sections in golden ratio at the knees and throat; he used these golden ratio proportions in the Modulor system.

Le Corbusier’s 1927 Villa Stein in Garches, France exemplified the Modulor system’s application. The villa’s rectangular ground plan, elevation, and inner structure all closely approximate golden rectangles.

Le Corbusier placed systems of harmony and proportion at the centre of his design philosophy, and his faith in the mathematical order of the universe was closely bound to golden section and Fibonacci the series, which he described as:

... rhythms apparent to the eye and clear in their relations with one another. And these rhythms are at the very root of human activities. They resound in Man by an organic inevitability, the same fine inevitability which causes the tracing out of the
Golden Section by children, old men, savages, and the learned.

Figure 8 + 9: Diagram of Golden Section Properties, Villa Stein.
Nature widely expresses the golden section through a very simple series of whole numbers. The astounding Fibonacci series: 0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, 233, 377. ..is both additive, as each number is the sum of the previous two, and multiplicative, as each number approximates the previous number multiplied by the golden section. The ratio becomes more accurate as the numbers increase. Inversely, any number divided by its smaller neighbor approximates Phi, alternating as more or less than \( \Phi \), forever closing in on the divine limit. Each Fibonacci number is the approximate geometric mean of its two adjacent numbers,

Although officially recognized later, the series appears to have been known to the ancient Egyptians and Greeks. Ultimately Edouard Lucas in the 19th century named the series after Leonardo da Pisa, who made the series...
famous from his solution of a problem regarding breeding of rabbits over a year’s time, see diagram in Figure X. The solution being directly related to the Fibonacci sequence.

Fibonacci numbers occur in the family trees of bees, stock market patterns, hurricane clouds, self-organizing DNA nucleotides, and in chemistry. A turtle has 13 horn plates on its shell, 5 centered, 8 on the edges, 5 paw pins, and 34 backbone segments. There are 144 vertebrae in a Gabon Snake, a hyena has 34 teeth and a dolphin 233. Many spiders have 5 pairs of extremities, 5 parts to each extremity, and a belly divided into 8 segments carried by its 8 legs.

Emerging as a science in the 19th century,
Phyllotaxis has been extended to the spiral patterns of seeds in a sunflower head, petals in the daisy, scales of pine cones, cacti aereoles, and other patterns exhibited in plants, as seen in Figures X, X, + X. In the 15th century, Da Vinci observed that the spacing of leaves was often spiral in arrangement. Kepler [1571-1630] later noted the majority of wild flowers are pentagonal, and that Fibonacci numbers occur in leaf arrangement.

*Figure 15: Golden Angle*
CASE STUDY 1 :: MATHEMATICAL ORDERING SYSTEMS

ABSTRACT

The grid and module are mathematical ordering properties which are used in many facets of the design process. This case study will look at the projects of different programs and their use of the grid and/or module and how it is used to strengthen the relationship to the site and to generate form in their respective designs.

HYPOTHESIS

The works of architect Richard Meier, though varied on the surface, possess inherent similarities in the underlying design order by the way they are sited and integrated into the context by use of mathematical ordering properties. The influence from Le Corbusier lends the idea that form will follow the process of site analysis and laying down this framework. This use of grid and modules for site planning creates a sensitive relationship to the context on both macro and micro levels.

METHODOLOGY

Plan analysis and research of design influences and strategies will be used to gain an understanding of how the grid and module were employed in site integration and if, indeed, they were the basis for form generation.

Figure 16: Meier - The Hague
To best understand the employment of these mathematical ordering properties of grid and module it is necessary to first to understand the definitions, and the context which they are used. As defined by Random House in the 2006 Unabridged Dictionary:

grid \( (X,Y) \) :: a rectangular system of coordinates used in locating the principal elements of a plan :: a basic system of reference lines for a region, generally consisting of straight lines intersecting at right angles.

module \( (X,Y,Z) \) :: a standard or unit for measuring :: the dimensions of a structural component used as a unit of measurement or standard for determining the proportions of the rest of the construction :: a standardized, often interchangeable component of a system or construction that is designed for easy assembly or flexible use.

Figure 17: Grid and Module
I see man’s intervention as an aesthetic organization of the environment. I seek to impose a coherent system of mutually dependent values, a harmonious relationship of parts. (Meier 1)

Richard Meier, 1990

Heavily influenced by the modernists, especially LeCorbusier’s ideologies, Richard Meier employs a primarily rationalist style, using mostly white to emphasize the geometrical forms (Futagawa 23). His method of using Le Corbusier’s grid is varied. Though also influenced by Richard Meier, his grids are not always orthogonal.

As in the case of the Atheneum, a visitor center found in New Harmony, Indiana, Meier said the organizing grids could have been even diagonal. The grids begin to shift and overlap to inform the user of the building’s organization. The use of this ordering system allowed for the grid of the town nearby and the river to be addressed in the orientation and layout of the building and in the way one moves through the spaces when looking at the exhibits (Futagawa 24). While the building is very sculptural it remains very systematized and navigable.

The relationships of each façade to the condition at that elevation are addressed and then reflected in the materiality and the way you move through that wall. The building expresses itself through the differences amongst its exterior walls, as one can begin to see in Meier’s preliminary sketch of the site in Figure 2. The river side being more curvilinear and giving to the fluidity of the Wabash River banks nearby. The town side, which also has the entry, is more open and inviting. This allows one to understand that this is the point of transition to enter. On

Figure 18: Atheneum: Sketch of the site geometries
the forest side the building closes up more at the edge. Each particular place is dealt with sensitively. Meier asserts that the Atheneum is a good example of user perception of how the shifting of grids creates a buildings organization and generates form (Futugawa 26).

The Getty Center in Los Angeles, California, is an example of Meier’s use of the grid and geometries to bring a large project together cohesively and relate it to a site. The strongest visual example of the grid and module is evident throughout the site and expressed in every material used. There is a 3’x3’ module for the materials, which is employed for the façades and is used in multiples for all of the materials and modular pavers. The grids of both plan and elevation are aligned so that all control joints meet at the same points.

In Figure 4, one could count from the picture that the square window has a 3’x3’ dimension as the travertine cladding has an 18”x18” dimension here, therefore the linear window must also have a height of 18” and we can
know that it’s length will be some whole number multiple of 18”. In Figure 5, the ribbon windows are 18” squares and meet the 18” travertine cladding, while the skylights are 3’x3’. Here you can see that even Meier’s intangible building material, light, conforms to the grid in the shadow it makes on the wall and beam in a 3’ x 3’ fashion.

The complex is aligned on two natural ridges on the site which intersect at a 22.5 degree angle. One lines up with the street grid off Los Angeles and the second, with the swing of the San Diego Freeway as it turns north. The master plan for the project responds to this natural topography and the site’s orientation within the urban fabric of Los Angeles. The whole complex is organized on an orthogonal grid aligned with one of these two ridgelines. The public functions such as the museum and galleries happen on one axis, while the private sectors align with the other datum on the more private, western side of the site. The Research Institute faces towards the ocean and mimics the coastal edge in the facade of the museum.

Figure 21: Site axis in line with the freeway and mountain ridge
Figure 22: CONTEXT: Downtown Los Angeles grid in relation to the site

Figure 23: GEOMETRY: Grids and 22.5 degree angle intersections
Meier’s intent with these geometries is made more evident through a series of sketches he did for the project illustrating the various applications of the grid and regulating lines as can be seen in Figures 22-24.

CONCLUSION

The analysis, diagrams, and photographs constitute enough evidence of the grid and module, the presence of mathematical ordering properties and a strong visual and contextual link to the site. This case study has proven that these are design tools which can assist in large comprehensive projects to relate to the site and generate aesthetically pleasing forms.

This theory will again need to be tested when applied to the scale and type of this thesis project in the context of downtown tampa.
CASE STUDY 2 :: THE FIBONACCI SEQUENCE IN DESIGN

ABSTRACT

The Fibonacci sequence is an approximation of the golden section used to bring organization and visual harmony to a pattern or design. This study will investigate the use of these geometries and determine if and how it is used to add layers of meaning and complexity to the Rivergate Tower in Tampa, Florida.

HYPOTHESIS

Complexity and richness can be accomplished without ornamentation, through the incorporation of geometries and dimensions based on the Fibonacci sequence.

METHODOLOGY

Analysis of plans and diagrams and primary research of samples of design theory, via e-mail correspondence and by phone with the architect, will be used to discern how the Fibonacci sequence was used to add a level of richness to the building.

Figure 25: Rivergate Tower as viewed from Kiley Park amphitheatre
ANALYSIS

In an age where each city looks more like every other city and man’s alienation from nature mounts daily, this project represents a resistance. Designed to draw in the curious, its structure invokes complex mathematics. The Rivergate Tower represents a lighthouse, guarding the entrance to the city. Two beams of light shoot from the roof into the night sky, amplifying the lighthouse effect. A notch at the building’s top represents a locking into the city grid, and the adjacent cubes mimic city blocks. Every aspect of its design is linked to the ancient mathematical series, the Fibonacci Sequence.

Just as ancient man’s works manifested his connection with the earth, with time, place and culture; with nature and the cosmos, so then this project attempts to recapture, in a neo-modern way this mediating role of architecture in the urban setting. We have searched carefully for the special qualities of Tampa, sought to understand, respect, and where possible, evoke recollections appropriately singular to this city, to this place and to this time.

Architect Harry Wolf, hired in the 1980s to create a home for NCNB Bank, wanted the tower to be viewed as a grand entryway into the city on the river. With the understanding that there would always be a taller building added to the skyline in the future, he wanted the building to be distinct. Something special, connected to its space. The two cubes were designed to mimic an urban grid and its harsh edges. The building’s limestone exterior is a material natural to Florida.

The cylinder is linked to the urban grid by the cubic volumes of the banking hall which approximate the height of the base of the building opposite it, provide a breathing space between the two and mediate the scale from pedestrian to tower. Located at a pivotal point in the fabric of the city, the cylinder, archetype of tower, evokes metaphor of lighthouse or citadel guarding to the entrance to
the city. It’s positioning holds the urban corner and places it at the head of this new public River Garden. Through the use of geometric, number, proportion and material there is an aspiration to connect this building to time, place and culture.

Needing a way to organize his design, Wolf chose the Fibonacci sequence. As a result, the building’s exterior has five ridges; some of the squares on the cubes are 13 feet tall; the cubes are five stories high. The facades of the cubes are a geometric pattern based on the sequence.
He chose the Fibonacci number series to bring a sense of elegant organization to its design. Wolf also paid attention to the calendar, placing 365 paving stones around the floor of the tower, a design mirrored on the ceiling. Other markings represent days and months. “The idea is to make the building both simple and rich at the same time,” Wolf said. “It’s intended to be a book you read on many levels.”

It is the coincidental geometry of the river, as shown in Figure X, as it intersects the grid of the city that is the anchoring element to link together land and built-form. The precedence of the Islamic geometry in the Moorish traditions of Florida give insight into the division of the geometry, as well as the geometric veil that is stretched over the entire site. Grass, pavement, water and trees are interlaced to create a textile which, in its final form, speaks quietly to the onion-domed, University of Tampa across the river.

There is an intention here to allow these layers of narrative content, along with a precise geometric order, to inform and suffuse the building-
Figure 30: Fibonacci ratio's present in the river used to generate grid applied in plan and section

to make a building that while pure and austere can avoid corporate sterility with a subtle complexity of meaning. At each state of proximity, through modulation of scale, proportion and detail, the design seeks to re-establish the importance of the relationship between man and nature and, thereby, a heightened appreciation of today’s and tomorrow’s issues on the environment.

Wolf won at least three major design awards for the building. He said he hopes his design evokes the curiosity of those who pass by. “It looks like no other building there or anywhere else,” Wolf said. “And if they’re curious, maybe they’ll go inside and see the wonderful thing.”

**CONCLUSION**

This building clearly is a successful design, bother formally and functionally and that is achieved in large part due to the layer of mathematics employed in it’s planning and design.
SITE SELECTION

The most important needs in the site of the Graduate School of Art + Design are location and views. Primary goals would be proximity to the Tampa Arts District for opportunity to engage in joint exhibitions and allow for off-campus research and experience. An urban location would facilitate ease of transportation, using non-vehicular and mass transit options. Also the ability to walk to off-campus and art and culture destinations. Additionally, an urban location would support the goal of involving the public in exhibitions and events at the school and allow for the multi-story zoning. A location close to the park would make the public involvement easier as well as provide the students additional outdoor space to research and gain inspiration.
The intent of this thesis is to design a building and plan a site that has a strong connection to the context by means of regulating lines and connection to context and grids; and achieves form through the geometries of analysis and mathematical ordering properties such as the grid and module. The proposed building type is an Urban School of Art + Design, at the graduate level.

**SITE DOCUMENTATION**

**Macro location**

Latitude: +27.94722 (27°56'49.992"N)
Longitude: -82.45861 (82°27'30.996"W)
Time zone: UTC -5 hours
Country: Florida, United States
Continent: Americas
Sub-region: Northern America
Altitude: ~10 ft

**Micro location**

Tampa Armature Works
1910 N. Ola Ave, Tampa 33602
Neighborhood: Tampa Heights

*Figure 32: View from southeast*
SITE ANALYSIS :: GENERAL

Climate
Temperature: moderate, 59°-79°; ideal for outdoor studio and display spaces
Precipitation: moderate
Solar Orientation: southern

Surrounding Influences
Zoning and Uses: The south side of Tampa Heights is centrally located within the city and very accessible to downtown. Sound, diversified businesses that serve a larger market than the immediate neighborhood, in

Figure 33: South/Riverfront view
combination with the accessible Hillsborough River afford the community some very good opportunities. Florida Avenue is a bustling business area, in part, because the city has made it an impact fee free zone from Columbus to Martin Luther King, Jr. Blvd.

The mixed use development projects proposed in 2001 for South Tampa Heights have now been built and there is now a pleasant waterfront character to the community that everyone can enjoy for living, working, parks, waterfront access and marinas. Tampa Heights is now part of the City’s trolley system and there is easy access for us to all of the business and entertainment facilities in downtown Tampa and portions of Tampa and Florida Avenues have been transformed into two-way pedestrian friendly streets.
Space: Have a significant open vista on at least one side for studio views to downtown and of riverfront.

Sound Sources
Positive: Sounds of nature, water, and people are pleasing.
Negative: Noise of cars, traffic, and any industrial construction is not desirable and would need to be screened or avoided.

Access
Public Transportation: The accessible bus routes and proximity of the Marion Transit Center would provide adequate access.
Bicycle access: This is quite important for students, bike lanes are present on both major veins accessing the site.
Pedestrian Access: This is the most important method of access, new sidewalks would need to be laid from Tampa St. to the site.
Vehicular: This would be the faculty’s main transit method, it is very important and there is adequate access present.

Views
Positive In: The first-level gallery spaces, fabrication warehouses, library reading areas and entry spaces, bookstore, café, and sculpture garden would all provide engaging views to pedestrians and students alike.
Positive Out: Surrounding natural conditions, the skyline, proximal historic Tampa neighborhood are desirable views for students and faculty.
Negative In: These would be the service functions and possibly classrooms.

Negative Out: The interstate, power substations, and parking structures/lots would be views that would not be desirable and would be screened.

**Landscape**

Tree Cover: necessary for shade so as to be able to work outside for larger portions of the school year.

Landscaping: also necessary to provide privacy for students and screen negative views and sound sources.

C. With renovated housing, transit and interstate access, this site and its surrounding area are well positioned to become a community cornerstone and a major gateway to Downtown Tampa.

This site with its proximity to the downtown grid, Tampa Museum of Art, Tampa University and Blake Arts High School is optimal. Additionally, the proposed riverwalk gives the opportunity for increased community interest in facility and joint exhibition and events. It is positioned on the river at the bend with view corridors down the river in two directions and of the downtown skyline. The climate of Tampa is moderate year round, with a 72 degree average temperature and southern sun. The activity and noise immediately around the site is mostly positive: Blake
Arts High School, the river, Tampa Water Works Park. The interstate noise is the closest negative and is relatively far enough away. By positioning the project at the corner of the site and opening out to river will maximize possibility for dynamic intersecting and radial regulating lines, a street corner presence, and opening view corridors out to the river, city and eventually the riverwalk.
Figure 37: Site dimensions
SITE ANALYSIS :: GENERAL

TAMPA HEIGHTS
NEIGHBORHOOD MAP + BOUNDARIES

:: E Martin Luther King Blvd to the North
:: I-275 to the East
:: I-275/Hilsborough River to the South
:: N Boulevard to the West

Figure 38: Satellite view of Tampa Heights

Figure 39: Map of Tampa Heights
SITE ANALYSIS :: GENERAL

Figure 40: Macro Location
Points of Interest within walking distance to the USF Graduate School of Art + Design are:

1 :: Blake Magnet High School for the Visual, Communicative + Performing Arts
2 :: Riverfront Park
3 :: University of Tampa
4 :: Marion Street Transit Center
5 :: Tampa Bay Performing Arts Center
6 :: Tampa Museum of Art
7 :: Historic Tampa Theatre
8 :: Retail + Commerce
9 :: St. Petersburg Times Forum
10 :: Florida Aquarium

Figure 41: Micro Location
Figure 42: Macro analysis of the existing context buildings.

Figure 43: Micro analysis of the existing context buildings.
Natural light is ideal for outdoor painting and photography and for lighting any studio spaces. Tampa has a high number of sunny days throughout the year. This diagram shows the sun path, solar elevation angle and solar azimuth throughout the day and annually for Tampa.

Figure 44: Solar Azimuth Diagram

- **July 1 2008**
- **June 21**
- **December 21**
- **Annual variation**
- **Equinox (March and September)**

- **Sunrise**
- **Sunset**

00:02
03:05
06:08
09:11
12:14
15:17
18:20
21:23
SITE ANALYSIS :: CLIMATE

Average Hours of Daylight

<table>
<thead>
<tr>
<th></th>
<th>SUNRISE</th>
<th>SUNSET</th>
<th>LENGTH</th>
<th>CHANGE</th>
<th>DAWN</th>
<th>DUSK</th>
<th>LENGTH</th>
<th>CHANGE</th>
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<tr>
<td>+1 DAY</td>
<td>6:51</td>
<td>20:22</td>
<td>13:31</td>
<td>-00:01</td>
<td>6:25</td>
<td>20:47</td>
<td>14:22</td>
<td>-00:02</td>
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<tr>
<td>+1 WEEK</td>
<td>6:54</td>
<td>20:18</td>
<td>13:24</td>
<td>-00:08</td>
<td>6:29</td>
<td>20:43</td>
<td>14:14</td>
<td>-00:10</td>
</tr>
<tr>
<td>+2 WEEKS</td>
<td>6:58</td>
<td>20:12</td>
<td>13:14</td>
<td>-00:18</td>
<td>6:33</td>
<td>20:37</td>
<td>14:04</td>
<td>-00:20</td>
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<tr>
<td>+1 MONTHS</td>
<td>7:06</td>
<td>19:57</td>
<td>12:51</td>
<td>-00:41</td>
<td>6:42</td>
<td>20:21</td>
<td>13:39</td>
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<tr>
<td>3 MONTHS</td>
<td>7:37</td>
<td>18:51</td>
<td>11:14</td>
<td>-02:18</td>
<td>7:13</td>
<td>19:15</td>
<td>12:02</td>
<td>-02:22</td>
</tr>
<tr>
<td>6 MONTHS</td>
<td>7:20</td>
<td>18:05</td>
<td>10:45</td>
<td>-02:47</td>
<td>6:55</td>
<td>18:30</td>
<td>11:35</td>
<td>-02:49</td>
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</tbody>
</table>

Insolation :: Average Solar Radiation Intensity

Average Clearness Index

Figure 45: Insolation Chart

Figure 46: Clearness Chart
SITE ANALYSIS :: CLIMATE

Figure 47: Average Precipitation Chart

Figure 48: Average # of Wet Days Chart

Figure 49: Average Temperature Chart
The majority of the months the prevailing winds come from the NNE direction. During May-August winds are primarily east-west. The average windspeeds and waterfront location allow for substantial cooling breezes during most of the year.
The site’s location in a historic district is a positive influence as this area is in the middle of a regentrification and revitilization of residential amenities. Several historic properties located nearby give additional close cultural destinations.
The immediate context is primarily medium-density residential and the waterfront. The frontage along Tampa Street, between Palm Avenue and 7th Avenue is designated Heavy Commercial (HC24).

Figure 53: Land Use Diagram
SITE ANALYSIS :: SURROUNDING INFLUENCES

Figure 54: Proposed development of Riverwalk and Stetson University
Transportation in the area is ample. The site has easy access by foot and public transportation means. Achieved by means of proximity to: Hartline Transit Hub, the majority of bus lines terminate in downtown and Florida Ave. and Tampa St. are major veins of transit.
There is also vehicular and water access to the site. Water access would be an integral method for the riverwalk and tourist transportation.
PROGRAMMING + PREDESIGN ANALYSIS

*Programming: the definitional stage of design — the time to discover the nature of the design problem, rather than the nature of the design solution.*

(Hershberger 1)

Site Area: 306,984 SF (~7 acres)
Building Type: Graduate School
Total # of Students: 1200
Total # of Faculty: 60
Total # of Staff: 40

**PRIMARY VALUES**

**Institution:** Most important, is to provide security and a learning environment for students, secondarily to provide certain amenities and spaces to the general public.

**Meaning:** To achieve form with purpose, through geometry, patterns and proportional relationships, not form solely for form’s sake.

**Functionality:** The building must function well as a learning establishment and riverwalk terminus.

**Social:** The layout must allow for interaction between students in various studios and interdisciplinary interaction. The faculty needs to have privacy but not be isolated from the studio culture.

**Cultural:** Create a symbolic presence at the corner of the river and at the “gateway” to the Tampa Arts District. Utilize the existing Tampa Armature Works building, either as a façade or as materials.

**Temporal:** As a type of learning center that is heading towards increased involvement in the technologic world, the building should provide for and plan for future advancements in technology. It should establish permanence of building envelope and location, yet provide flexibility to allow for
internal change and evolution of the curriculum demands.

**FIELDS OF STUDY**

**Communication Design**

- Illustration is the art of picture-making for the purpose of communicating ideas and information
- Graphic Design is total information design, where pictures as well as words are created and designed to convey messages
- Advertising Art is a more focused combination of visual and verbal information design to create a message that moves consumers to action

**Fine Art**

This degree includes: painting + drawing; 3D + ceramics

The goal is exploring the complex relationships between form, process, material and content.

**Photography + Digital Imaging**

The creative utilization of technology, digital imaging, animation, artist’s books, interactive installations, performance and experimental video art.

**Entertainment Design**

Computer generated imagery (CGI) and video game design

**SPECIFIC FACILITY AND EQUIPMENT REQUIREMENTS**

**Printmaking**

Uses traditional processes (lithography, etching, etc...), photo-digital printmaking and poster making.

**Communication Design**

Facilities must include proximity to computer labs and studios.

**Digital Imaging/Media:**

This would include a *media cage*, which houses departmental photographic and electronic media equipment available for checkout to registered students. In addition to a variety of medium-format and large-format cameras, camcorders, audio recorders and microphones, tripods and lighting equipment, students can also reserve time in private darkrooms, the digital printing service bureau, a private lighting studio and an advanced electronic media lab.
utilizing computers equipped with final cut studio video production software as well as an array of digital audio production hardware.

**Fine Art:**
- Studios, gallery space, ceramic, metal and wood shops

**Entertainment Design:**
- Computer labs and studios.

**Photography + Film:**
- A 15-station open Macintosh lab; Adobe, Macromedia and other software for digital imaging, sound, animation, web and video production and post-production.
- Needs a shooting studio with lights and sweeps.
- Digital cameras, lighting equipment, tripods, and microphones available for checkout
- *Smart Gallery* - wired and wireless project room to develop and present electronic and interactive sculpture, installation and performance

**Printmaking**
- Provide print studios that include: etching presses and lithography presses and numerous stones; automated and manual screen presses of various sizes and two graphics darkrooms.

**General Facilities**
- Library
- Gallery
- Media Presentation Space
- Classrooms
- Smart Lecture – wired and wireless room for mixed media education and presentations
- Public Program – large lecture spaces for community projects and classes
- Studios
- General
- Semi-Private
- Faculty Offices
SPACE

LIBRARY

OCCUPANCY

500

AREA

45000SF

FUNCTION

- housing of book stacks
- periodical, microfiche, media storage
- viewing of electronic media
- research classes
- place for research and study

ACTIVITY LEVEL

VERY HIGH

EQUIPMENT

- shelves and racks for book/media/periodical storage
- tables/counters and chairs for study and reading
- computers and microfiches

SPATIAL RELATIONSHIPS

RIVERWALK

CAFE

RECEPTION

GALLERY

Figure 57: Library spatial relationships

DESIGN CONSIDERATIONS

- Needs sufficient daylighting for study and reading areas.
- Stacks and media must be lit artificially, away from sunlight.
- Ample archive storage space accessible.
- Flexible furniture arrangements provided.
- Smart wired
**SPACE**

**LIBRARY-CIRCULATION DESK**

**OCCUPANCY**

300

**AREA**

425 SF

**FUNCTION**

• service desk where materials are checked out from the library
• essentially the library ‘hub’

**ACTIVITY LEVEL**

VERY HIGH

**EQUIPMENT**

• circulation desk with shelving
• 3 chairs, 4 book trucks
• 2 circulation terminals, 1 self-check station, 1 printer, security device, telephones

---

**DESIGN CONSIDERATIONS**

• Visibility to entry is very important.
• Ample circulation, to accommodate possible public use as well.
SPACE

LIBRARY-STACKS

OCCUPANCY

300

AREA

Art History + Fine Arts 10000
Photography 5000
Communicative Design 5000
Arts, Humanities, Soc. Sciences 10000

Approx. 400,000 volumes total

FUNCTION

• bookstack area for each field of study and history
• essentially the library ‘hub’

ACTIVITY LEVEL

VERY HIGH

EQUIPMENT

• shelves enough for 80% of volumes

DESIGN CONSIDERATIONS

• visibility to entry
• ample circulation

Figure 59: Library-Stacks spatial relationships
### SPACE

**STUDIOS**

### OCCUPANCY

560

### AREA

70800SF

### FUNCTION

- the studios are the essence of the school
- both class time and after-hours work space

### ACTIVITY LEVEL

VERY HIGH

### EQUIPMENT

- sinks
- drafting size desk or tables

### SPATIAL RELATIONSHIPS

![Figure 60: Studio spatial relationships](image)

### DESIGN CONSIDERATIONS

- ample daylighting
- MIN. 12’ ceiling height
**SPACE**

**GALLERIES**

**FUNCTION**
- temporary and semi-permanent displays
- static work and interactive installations
- smaller gallery with temporary display would also serve as lobby
- gallery spaces that can become part of installation displays

**ACTIVITY LEVEL**
VERY HIGH

**SPATIAL RELATIONSHIPS**

**Figure 61: Galleries spatial relationships**

**OCCUPANCY**

SMALL: 65  
MAIN: 265

**AREA**

SMALL: 2000SF  
MAIN: 8000SF

**EQUIPMENT**
- shelves, racks and cases (all movable)  
- benches

**DESIGN CONSIDERATIONS**
- direct daylighting desirable in temporary gallery  
- flexible fixed lighting  
- indirect daylighting in main exhibition space  
- good circulation  
- cabling for new media
SPACE

DIGITAL MEDIA PRESENTATION SPACE

FUNCTION
• formal and informal presentations for large groups
• large lecture and seminar classes
• guest speakers

ACTIVITY LEVEL
MEDIUM

SPATIAL RELATIONSHIPS

PRESENTATION

RECEPTION

RIVERWALK

OCCUPANCY
500

AREA
5000SF

EQUIPMENT
• 500 movable, upholstered seats
• movable tables
• large screen computer/video
• whiteboard
• light and AV controls

DESIGN CONSIDERATIONS
• no daylighting
• minimum ceiling height of 25’
• sloped floor
• raised stage

Figure 62: Presentation spatial relationships
## School of Art + Design

<table>
<thead>
<tr>
<th>Site area</th>
<th>Building Program</th>
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<tbody>
<tr>
<td></td>
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<td>Faculty</td>
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<td>Adjunct Professors</td>
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<td>Staff</td>
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<td><strong>Total</strong></td>
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### SPACE

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<tr>
<th>Min. Clg. Ht.</th>
<th>NET S.F.</th>
<th>QUAN.</th>
<th>GROSS S.F.</th>
<th>Occup. Load</th>
</tr>
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<tr>
<td></td>
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<td>20'</td>
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<tr>
<td></td>
<td>15'</td>
<td>500</td>
<td>1</td>
<td>500</td>
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<tr>
<td>Seating</td>
<td></td>
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<td></td>
<td></td>
</tr>
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<td>1000</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storage</td>
<td></td>
<td>600</td>
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<td><strong>Total</strong></td>
<td></td>
<td><strong>4</strong></td>
<td><strong>7100</strong></td>
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### Media Presentation Space

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<th>QUAN.</th>
<th>GROSS S.F.</th>
<th>Occup. Load</th>
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</thead>
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<td></td>
<td>15'</td>
<td>4000</td>
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<td>Perm. Exhibition Gallery</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>15'</td>
<td>1000</td>
<td>2</td>
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<tr>
<td>Temp. Exhibition Gallery</td>
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<tr>
<td></td>
<td>10000</td>
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<td>10000</td>
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<tr>
<td>Sculpture Garden</td>
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*Figure 63: Square footage of Building Program*
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<td>Works of Art</td>
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<td>Paper and Photography</td>
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<tr>
<td>Stacks-Art History</td>
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<td>10000</td>
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<tr>
<td>Stacks-Fine Arts + Photography</td>
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<td>10000</td>
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<tr>
<td>Stacks-Communicative</td>
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<td>5000</td>
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<tr>
<td>Stacks-Arts, Humanities, Soc. Sciences</td>
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<tr>
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<td>20</td>
<td>5</td>
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<tr>
<td>Study Areas</td>
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<td>Reserved Materials</td>
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<tr>
<td>Workroom + Office</td>
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<td>250</td>
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<tr>
<td>Lobby</td>
<td>N/A*</td>
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<td>N/A*</td>
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<tr>
<td>Terrace</td>
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<td><strong>Total</strong></td>
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<td><strong>54450</strong></td>
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*Figure 64: Square footage of Building Program*
### Administration + Offices

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<tr>
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<td>Reception</td>
<td>400</td>
<td>1</td>
<td>400</td>
<td>6</td>
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<tr>
<td>Dean's Office</td>
<td>160</td>
<td>1</td>
<td>160</td>
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<tr>
<td>Asst. Dean's Office</td>
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<td>Bookkeeping Office</td>
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<td>Student Services</td>
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<td>Faculty Offices</td>
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<td>Adjunct Work Room</td>
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<td><strong>Total</strong></td>
<td><strong>20</strong></td>
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### Classrooms

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<td>Public program room</td>
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<td>Work Review Room</td>
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### Computer Lab

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<td>Primary</td>
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<td>Secondary</td>
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*Figure 65: Square footage of Building Program*
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<th></th>
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<tr>
<td>Fine Art</td>
<td>12'</td>
<td>1800</td>
<td>8</td>
<td>14400</td>
</tr>
<tr>
<td>Photography + Digital Imaging</td>
<td>12'</td>
<td>1500</td>
<td>4</td>
<td>6000</td>
</tr>
<tr>
<td>Printmaking</td>
<td>12'</td>
<td>1800</td>
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</tr>
<tr>
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<td>15'</td>
<td>1800</td>
<td>2</td>
<td>3600</td>
</tr>
<tr>
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<td>1800</td>
<td>2</td>
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<td>Total</td>
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<table>
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<th>Fabrication/Shops</th>
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<tbody>
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<td>Wood/Metal Shop</td>
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<td>10000</td>
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<td>Ceramics</td>
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<td>2500</td>
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<td>Plaster/Fabrics/Plastic</td>
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<tr>
<td>Lithography/Printing</td>
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<td>2500</td>
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<td>5000</td>
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<td>Enlarger Stations</td>
<td></td>
<td>100</td>
<td>1000</td>
<td>50</td>
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<tr>
<td>Private Darkrooms</td>
<td></td>
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<td>20</td>
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<td>Nonsilver darkroom</td>
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<tr>
<td>Digital Scanning + Printing Facility</td>
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<td>B/W + Color Photo Lab</td>
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<td>Film Editing + Eqmt.</td>
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Figure 66: Square footage of Building Program

72
### Digital Imaging

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<th>Occup. Load</th>
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<tr>
<td>Studio One</td>
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<td>Control Room</td>
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<td>Isolation Room</td>
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<td>Studio Two</td>
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<tr>
<td>Control Room</td>
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<td>Isolation Room</td>
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<td>Central Machine Room</td>
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</tr>
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<td>Midi Studio</td>
<td>750</td>
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<tr>
<td>Director's Studio</td>
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<td><strong>Total</strong></td>
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<td>4210</td>
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| **Bookstore**                               |          |             |
| Retail Area                                 | 1500     | 1           |
| Retail Stockroom                            | 400      | 1           |
| **Total**                                   | 2        | 1900        |

| **Café**                                    |          |             |
| Café Area (addl. Seating outdoors)          | 1500     | 1           |
| Kitchen                                     | 400      | 1           |
| **Total**                                   | 2        | 1900        |

*Figure 67: Square footage of Building Program*
**Service and Maintenance**

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<th>N/A*</th>
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<tr>
<td>Receiving</td>
<td>N/A*</td>
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<td>N/A*</td>
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<tr>
<td>Loading Dock</td>
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<td>400</td>
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<tr>
<td>Trash and Recycling</td>
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<td>Custodial</td>
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<td>Communications, Data, Electrical Equip.</td>
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<tr>
<td>Total</td>
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<td>4200</td>
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</table>

**Total**

| Total Net | 207550 | 3454 |
| Wall thickness and structural @ 10% | 20755 |
| Building Service Equipment @ 10% | 20755 |
| Circulation @ 20% | 41510 |
| **Total** | **290570 SF** |

**Parking**

| Student (.5 spaces per) | 320 | 500 | 160000 |
| Faculty + Staff (1 space per) | 320 | 100 | 32000 |
| **Total** | **192000 SF** |

*N/A*: non-assignable space to come from gross % allotment of unassigned program space

*Figure 68: Square footage of Building Program*
Urban School of Art + Design
Net Square Footages by Usage

Figure 69:
ADJACENCY DIAGRAMS

Figure 70: Administration adjacency diagram

Figure 71: Faculty and Adjunct adjacency diagram
ADJACENCY DIAGRAMS

Figure 72: Media-presentation space
Figure 73: Library adjacency diagram

ADJACENCY DIAGRAMS
Figure 74: Studio adjacency diagram
Figure 75: School adjacency diagram
Figure 76: Schematic Volume + Section Studies
Figure 77: Concept Diagram: plan, section + elevation overlay
Figure 78: Site Plan :: 1”=20’ Scale
Figure 79: Level 2 Plan :: 1"=20′ Scale
Figure 80: Level 3 Plan :: 1”=20’ Scale
PLAN :: level 4

Figure 81: Level 4 Plan :: 1”=20’ Scale
Figure 82: Level 5 Plan :: 1"=20’ Scale
Figure 83: Level 6 Plan :: 1"=20’ Scale
Figure 84: Level 7 Plan :: 1"=20’ Scale
Figure 85: Roof Plan :: 1"=20' Scale
ELEVATIONS

Figure 86: View of the facade when looking east

Figure 87: View of the facade when looking south
ELEVATIONS

Figure 88: View of the facade when looking west

Figure 89: View of the facade when looking north
Figure 90, 91 + 92: Gallery: Elevation, Plan, and Perspective
Figure 93, 94 + 95: Studio Geometries: Elevation, Plan, and Perspective
Figure 96: Perspective rendering: SW corner, gallery geometries
Figure 97: SW gallery framed views
Figure 98: Student Gallery geometries: plan, elevation, perspective
Figure 100: Main approach entry at SE corner
Figure 101: View of approach from riverwalk
Figure 103: Gallery, Cafe, Bookstore and Classrooms

Figure 104: Studios and circulation core
Figure 105: SW Gallery and water feature

Figure 106: Fabrication warehouses
The investigation for this thesis began with the research of mathematical patterns and properties in design, and the proposal of a unit to be employed in the project. The selected module proposed that there was a proportion identifiable by people, even if subconsciously, as aesthetically pleasing: the golden ratio. Equally important, it suggested that this proportion could enhance one’s innate design process by presenting the surroundings in frames and forced perspectives that reinforced the geometries of layout and design. Some of these include: the rule of thirds, composition of a canvas, and the use of a grid.

In beginning of the task of site planning for such a large project, the site was first divided horizontally and vertically to form eight main golden rectangles. Using Fibonacci numbers as the dimension of intervals for the regulating lines, the site was easily turned into a framework of significantly proportioned plots. The significant 3:5 angle of the river was drawn into the site to connect to Downtown’s Arts District and embrace the shift in the city’s street grid.

The module of 34’ x 55’ was selected as the standard for student buildings, i.e. classrooms, lecture halls, studio spaces, galleries and the library. Smaller variations of this module were used as appropriate, though not a directly scaled down version off that rectangle but a golden rectangle of the next proportion, 21’ x 34’, 13’ x 21’, etc...

Doorways and mullions were used to frame openings in the same fashion, so that views were constrained by these...
proportions as well.

The goal of the classrooms and lecture rooms was to provide enough of a view to stimulate interest but not too much as to distract from the teaching and learning process. Studio spaces however, were designed to allow for broad vistas, though framed and directed by golden ratios. The galleries and the libraries were designed for the inclusion of varying levels of natural light, with outward views treated as a secondary feature.

Though some may argue that this imposition of views and perspectives would hinder the creative process, it was the goal of this project to present the views as inspiration and leave the rest of the building as a fairly simple canvas for the play of light and shadow, and transparency and opacity.

Another benefit of using these proportioned modules is that the dimensions of at least one side of each of the adjacent modules would be equal, on the x, y or z axis, while the overall volume may differ in size. This makes the modules easy to juxtapose and interchange. In turn, this creates a versatile building arrangement for the accommodation of various functions.

Should the focus of the school shift to a more research based curriculum, the library and lecture spaces could easily be expanded or additional modules could be added to the building’s framework, without compromising the original design concept. The same could be done if there was a need for more studio spaces or fabrication areas. Future uses could be accommodated by shifting the spaces and orientation.
This thesis aimed to explore the relationship between mathematics and architecture. Although the applications and uses of the proportioned, 3-dimensional geometries may not be consciously significant when initially experienced, the resultant spatial qualities will impart meaning and understanding at the subconscious level. Consequently, this subconscious meaning of architecture through mathematics, employed by Egyptian, Classical and Renaissance masters, can be replicated in a contemporary context.
ENDNOTES


BIBLIOGRAPHY


