Fig. 5, Harrenstein House, kitchen burnt adobe fireplace. Photo by Bill Sears, 1966.

The radial shaped plan of the house is 45 ft in diameter; 8 ft tall in the at the center point. The interior highpoint (at the inside of a wall) of each hyperboloid is 11 ft 2 in, the exterior highpoint is 160” (13 ft. 4 in).

Interior

The residence retains sufficient integrity to convey its significance. The footprint and envelope of the house is unchanged. The details, fixtures and finishes are associated with Modern Movement; the detailing captures and showcases a distinctive style and retains a unique “sense of place.” The geometric, one story plan creates intimate and expressive interior spaces while promoting a vision of “tomorrow.” The details in combination with the design and the response to views create an outstanding and unique example of expressive Modern design.

The geometric zonal configuration creates a series of wedge shaped rooms with a total of 1,986 sq ft. of interior space (Pima County Assessor). The public living spaces: entryway, kitchen and dining room, are open and on the eastern side of the disk. Each are connected to exterior patios and outdoor space. The bedrooms are clustered in the western wedges off a crescent hallway that is created by a 3/4 tall Philippine mahogany paneled wall. The central space is a sunken circular living room. The dining room has polished terrazzo floor, the entranceway sandstone, and the bedrooms and living room carpeted.

Fig. 6, Harrenstein House, South Elevation Entrance, photo by Bill Sears 1966.

The entryway is located on the south elevation with a glass sliding door, and built-in interior and exterior planters. A rubber tree planted in 1963 is extant. Entering the house, the kitchen service room is to the right with a built-in burnt adobe fireplace; glass doors lead to the backyard, swimming pool and guest house/garage beyond. To the north of the kitchen is the dining room.

The details of the interior showcase employ a limited material palette, masterfully used to capture an elegant modernist sensibility, while at the same time functional spaces are cleverly fit into the constraints of the structural form. The carefully-framed views of surrounding desert celebrate the natural environment and create a juxtaposition between the ultra modern interior and Sonoran desert.

Guest House & Garage
The guest house is embedded into the sloping grade of the site, reducing the visual intrusion of on the views of the main house. The rectangular building faces south and its roof serves as a sundeck. The guest house is 624 sq. ft.

Pool
The kidney shaped pool is the focal point of the back yard.

Alternations
The only alteration to the property was the removal of the asbestos ceiling in the early 2010s and exposure of the cast concrete.

Integrity
The Harrenstein House retains sufficient integrity of both site and residence to convey significance. The minimal alterations thave not diminished the integrity. The property conveys its original stylistic expression. The property retains its original use of materials and workmanship. The property retains its original design details, including: the thin-shell concrete roof, fireplaces, original bathrooms, casework and the exterior elevations. The massing of the house is retained and is unchanged from period of significance. The limited alterations have have almost impact on the original design. The house retains its original spatial qualities.

Geographic Information
The Harrenstein House reflects the land planning ideals set forth during post WWII Tucson and Pima County. The house is located in an area featuring large lot sizes, and native landscaping, and vegetation. The original lot is intact.

Boundaries
The boundaries are consistent with the original 1960 subdivision lot. The original viewshed, both of and from the property is preserved.

8. Statement of Significance

Applicable National Register Criteria
(Mark "x" in one or more boxes for the criteria qualifying the property for National Register listing.)

☐ A. Property is associated with events that have made a significant contribution to the broad patterns of our history.
☐ B. Property is associated with the lives of persons significant in our past.
☑ C. Property embodies the distinctive characteristics of a type, period, or method of construction or represents the work of a master, or possesses high artistic values, or represents a significant and distinguishable entity whose components lack individual distinction.
☐ D. Property has yielded, or is likely to yield, information important in prehistory or history.

Criteria Considerations
(Mark "x" in all the boxes that apply.)

☐ A. Owned by a religious institution or used for religious purposes
☐ B. Removed from its original location
☐ C. A birthplace or grave
☐ D. A cemetery
☐ E. A reconstructed building, object, or structure
☐ F. A commemorative property
☐ G. Less than 50 years old or achieving significance within the past 50 years

Areas of Significance
(Enter categories from instructions.)
architecture and engineering

Period of Significance
1962-63

Significant Dates
1962-63 date of completed construction.

Significant Person
(Complete only if Criterion B is marked above.)

Cultural Affiliation

Architect/Builder
Dr. Howard Paul Harrenstein

Period of Significance (justification)
The Period of Significance is 1962-63 - the period of design and construction.

Statement of Significance Summary Paragraph (Provide a summary paragraph that includes level of significance, applicable criteria, justification for the period of significance, and any applicable criteria considerations.)

Fig. 7, Harrenstien House west elevation, photo by Howard Harrenstien 1963. THPF digital collection.

The Harrenstein House, built in 1962-63, is eligible for listing on the National Register of Historic Places under Criterion C, at the local level of significance, as a rare surviving example of a thin-shell concrete single-family residential building utilizing hyperboloid construction in Tucson, Arizona. The experimental construction of the house utilized three intersecting hyperbolic surfaces to create a highly distinctive form. During and after construction, it was recognized locally for its innovative design. The Tucson Daily Citizen Homes, a weekly newspaper magazine, featured the house on its cover on Saturday June 11, 1966. Mary Brown the Citizen Homes Editor wrote the feature detailing the development and design of the distinctive property. Because of the site location, in a densely vegetated desert lot, the house was obscured from view and the unique architectural expression forgotten until it was featured as part of Tucson Modernism Week in 2016. Although there are other examples of hyperbolic paraboloid structures in Tucson this is the most expensive known residential design. The house is an outstanding example of the Expressionist subtype of Architecture of the Modern Movement in Tucson.

Narrative Statement of Significance (Provide at least one paragraph for each area of significance.)

In 1962-63 University of Arizona Civil engineering professor Dr. Howard Paul Harrenstein constructed an experimental home for his family in the foothills of the Santa Catalina Mountains. Harrenstein, blending his expertise in structural design and background in civil defence to create a highly distinctive thin-cast concrete residence. The home, located in Santa Catalina Estates, (Fig. 10) was inspired by "Los Manantiales" (1958) designed by Mexico City architect, Felix Candela. (Fig. 8)

Fig. 8, "Los Manantiales" (1958) designed by architect Felix Candela, Mexico City, photo by Howard Harrenstien. THPF digital collection.

The Harrenstein House was composed of three intersecting hyperbolic paraboloids, and is a masterful combination of artistry and structural engineering. Harrenstein was an authority on shell construction, he earned bachelor's degrees in both architecture and architectural engineering from Kansas State University and received a master's degree in structural engineering and doctorate degree in engineering mechanics from Iowa State University. He published numerous papers on thin-shell concrete construction including his 1960 "Hyperbolic Paraboloidal Umbrella Shells under Vertical Loads" in the Journal of the American Concrete Institute and 1961 "Configuration of Shell Structures for Optimum Stress" in the Proceedings of the Symposium on Shell Research, Delft, Aug. 20–Sept. 2, 1961" printed by Amsterdam North-Holland Publishing Company.

Fig. 9 Concept Model (Harrenstein House) 1961, THPF Digital Collection.

Howard Harrenstein worked with his father, Jacob Harrenstein, a general contractor, to build the house. Harrenstein created a model which provides a reference for the design development of the project. (Fig. 9) From the model, the design was refined from eight to six sections, and the central courtyard eliminated. In 2016, Harrenstein was interviewed by the Arizona Daily Star. He noted that the forms for each section were erected and the concrete poured mostly with buckets before moving on to the next section. "Each section was one-sixth of the total circle [...] So we would put it in place and then we'd do the concrete. Then we'd move it 60 degrees and we'd do it again. We worked around the circle and the next thing we knew, the circle was complete."

Harrenstein's professional engineering work was focused on of civic defence during the American Cold War with Russia. Tucson was a locus of the Titan Missile Defense System with 18 active missile silos sited around the city, making the area a known nuclear target. The Titan II launch complex 571-7 south of Tucson was listed as a National Historic Landmark in 1994.

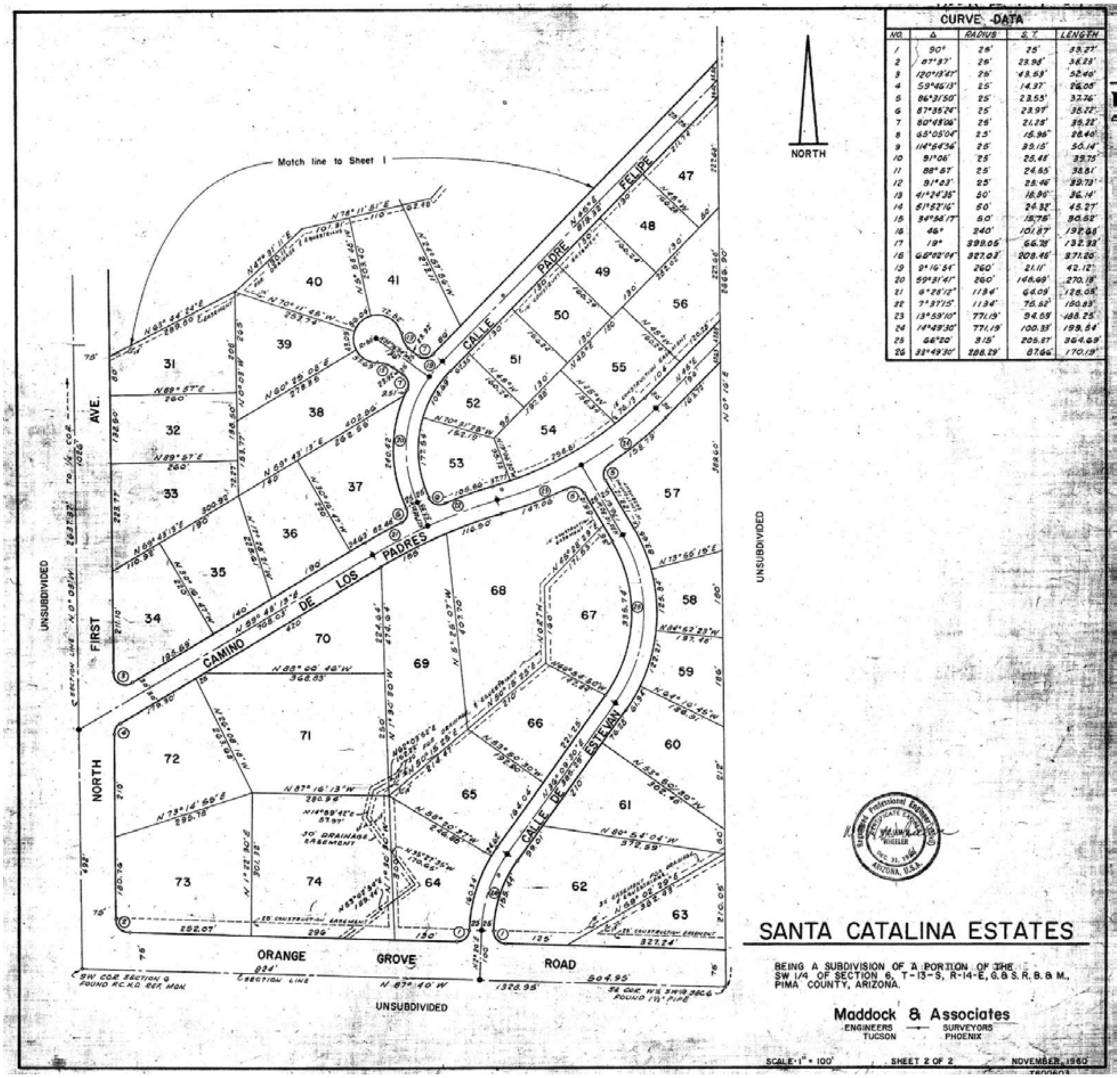

Fig. 10. Santa Catalina Estates, subdivision plat map, 1960.

Harrenstein, an expert and consultant in bomb shelter design, embedded his expertise in civic-defense into the architecture of the house. Not only was the house conceived to survive an attack, Harrenstein nested a bomb shelter underneath the center of the home. The house is not only an outstanding example of expressive modern architecture but a physical articulation of the Atomic Age.

In 1966, three years after the completion of the house, Harrenstein accepted a position at the University of Hawaii, sold the property, and permanently left Tucson.

Fig. 11, Harrenstien House under construction, photo by Howard Harrenstien 1962-63. THPF digital collection.

Architect of the Modern Movement in Tucson 1945 - 1975

Sarah Allaback's 2003 Essays on Modern Architecture produced for the National Park Service provides a context for evaluating architectural significance. Allaback introductory essay is excerpted:

> American architects began to experiment with styles beyond the traditional neoclassical in the early nineteenth century. Styles were chosen for their historical associations and the buildings were considered architecturally pure versions of the past. By the end of the century, architects felt free to combine styles in an "eclectic" manner, without such concern for stylistic origins. New technologies and building materials encouraged this emerging experimentation. If this was all modern, however, it was certainly not "modernism." When European modernism arrived in the United States in the 1920s no one could mistake it for anything that went before. Historians quickly labeled this early phase of modern architecture the International Style. It was short-lived. The white, geometric forms were too bleak for Americans, especially since they came without the social meaning of their European counterparts.

> The International Style was imported to the United States, but its early development was not without American influence. As European architects began experimenting in wild new forms of architecture, materials and forms, they studied the designs of Frank Lloyd Wright, whose work had been published in portfolios by 1910. Nothing Wright designed remotely resembled the sleek European buildings, but none could deny that his work was both modern and impossible to ignore. [...] different forms of modern architecture with very different sensibilities were able to develop side by side in America. Frank Lloyd Wright and his Prairie School influenced all American architects, even immigrants like Richard Neutra and Walter Gropius.
>
> By the 1950s, modern architecture had been popularized to the point where it lost its shocking newness. The developers of Levitttowns and other postwar subdivisions introduced popular versions of "the modern home." While middle-class Americans enjoyed the luxury of picture windows, carports and split-levels, the architectural profession moved beyond what most people would consider domestic space. Philip Johnson's famous Glass House was the architectural equivalent of the artist framing a blank canvas. Once everything had been removed but glass, leaving the essence of a building, there was no place left to go. Postmodernism developed in the late 1950s and early 1960s as a rejection of the blankness of modernism. It was all about adding layers of meaning, however artificial. Although refreshing at the time, this self-conscious style could not sustain itself. Architects of the twenty-first century are designing modern architecture that is colored by its own modernistic past. And, according to architectural histories, that past has already stood the test of time. [...] roughly from the late 1920s to the early 1960s. Whether or not we appreciate these buildings, they represent a key moment in our history, a time when all historical reference was thrown aside in favor of something new and unexplored. From our perspective, the explosion of modern architecture is dulled by familiarity. But in the 1920s a line was crossed that we can barely comprehend. Buildings went from being cultural books--their stories revealed in symbols and inscriptions rich in historical meaning--to being mute wonders of technology suggesting infinite possibility. The architectural historian and critic John Jacobus, Jr., reminds us that "nearly every present day architect, whatever his station or real sentiment, at least professes allegiance to the outward materialistic manifestations of the creative revolution that took place with the International Style." Modern buildings exemplify the search for the limits of building and design, the exploration of new interpretations of what is comfortable, and the effort to maximize human potential through building.

In the Pre-WWII era, Tucson and Southern Arizona's built environment was defined by a host of revival architectural styles that promoted the region's romantic southwestern roots. In the late nineteenth and early twenty century, Architect Henry Trost moved to Tucson from Chicago having worked in the office of Louis Sullivan. His architectural expression blended the Chicago school with regionalism, and shaped the growing cities of Arizona including Tucson, Bisbee, and

Douglas, before moving to El Paso Texas. His architecture was early manifestation of American modernism pioneered by Sullivan. Not until the interwar years would Tucson-based architects Richard Morse and Arthur T. Brown began experimenting with European ideas of Modern architecture. Morse's Forest Lodge (1935), designed for Margaret Howard, Countess of Suffolk and Berkshire, was directly inspired by his time in Europe looking at Modern architectural design pioneered by the Bauhaus.

Like many cities after the WWII, Tucson was growing rapidly. In 1940, the population was 35,000 - by 1960, it had exploded to 212,000. This population boom translated to significant housing development and the outward expansion from the urban core. A new cohort of young architects and architectural designers began to shape the city.

Numerous Subtypes of architectural expression emerged within Tucson's Modern Movement. The subject of this nomination falls into the category of Expressionism. Adrain Sheppard, FRAIC, in the paper The Return of Expressionism and the Architecture of Luigi Moretti provides a broad national context of the American emergence architectural Expressionism:

> The European Expressionist movement of the 1920's and 1930's had little or no impact on North American thinking before World War II. In the mid-fifties however, well after the demise of the movement in Europe, some architects in America began to question current architectural trends at home. These doubters of Modernism found their inspiration in various models of nonconventional architecture, including the Pueblo style, the more unusual work of Wright, the Amsterdam School housing, and the architecture of Rudolf Steiner in Germany. Much like their European counterparts, American Expressionist architects took a radical position with respect to their work. They shared an anti-academic and anti-historical attitude towards design and believed that architectural unity could be best served by formal continuity rather than by the application of compositional or geometric rules. They adopted a language of sweeping curves, jagged surfaces, uneven or distorted structural systems, sculptural effects, asymmetry, and dynamic forms. Although the number of Neo-Expressionist architects in America was relatively small, their work was a confirmation that the movement constituted a potent force on the continent.
>
> The most extravagant of the American architects was Bruce Goff who taught and practiced mainly in Oklahoma and its neighbouring states. Goff was both fearless and formally exploratory, and was labelled by Peter Cook as the primary exponent of Experimental Architecture in the United States. Goff's lifelong plea was for a highly creative form of architecture, and he produced a totally original vocabulary. For Goff, every building had to be a prototype and a unique experience. He spoke often of a 'continuous present' and of notions of composition that had no beginning and no end. Goff had no specific architectural style. He switched easily from free-form, to the use of bric-a-brac, to highly geometric configurations, to pseudo-Wrightian modes. His architecture was one of wilderness romanticism and objets trouves, of had hoc solutions,

and of the use of discarded industrial materials. He believed that architecture was an impure art because it had to solve a multitude of problems. Not only did he accept the notion of compromise, but he embraced it. Like Venturi, he was totally opposed to an exclusive, idealized architecture.

No building of Goff's epitomizes his approach to architecture more eloquently than the Eugene Bavinger House (1950), near Norman, Oklahoma. The house is a complex, indefinable composition of circles, masts, and spiral walls. The roof as well as secondary volumes is supported by an idiosyncratic cable structure attached to a central mast. The outer walls of the Bavinger House are made of rubble masonry and other materials. In other houses, Goff used coal, rope, paper, and material retrieved from rubbish heaps. He became a hero of the architectural counter-culture of the 1950's and 1960's. His place in the culture of America is similar to that of Lucien Kroll in Belgium. The latter also maintained that Modernism is essentially a totalitarian barbarism that is exclusive, but taught to be inclusive. Goff designed the Green House (1960), also in Norman, and similar in nature to the Bavinger House. The house is a collage of eccentric shapes, unusual materials, and rich textures. Critics see his houses as a true expression of Mid-western regionalism.

[It is worth noting that in 1974 Bruce Goff's Tucson project Barby, Celestine, House, number 2 was constructed at 711 N. Camino de Fosforo, Tucson, Arizona. The house retains its integrity and significance as an important example within Goff's design portfolio.]

A parallel can be drawn between the radicalism of Goff and Venturi. Both architects were "bored" by the blandness of Modernism, both took a populist stand, and both sought to create an architecture of richness, joy, and ambiguity. They wanted to enrich the language of Modernism and invent a new way of approaching architecture, yet despite their common concerns, the two architects are profoundly different. Venturi's view of design is highly cerebral and based on the interpretation of precedent and history, while Goff is all gut, feeling, and subjectivity.

Frank Lloyd Wright was by far America's most versatile architect. Although he cannot be considered an Expressionist in the true sense of the term, some of his post-war buildings clearly embody the values and formal ideas associated with Neo-Expressionism. The Guggenheim Museum in New York is, par excellence, a Neo-Expressionist icon. In the 1940's, Wright produced some highly unconventional houses which were radical departures from his earlier Prairie domestic architecture. Neil Levine speaks of the figurative nature of Wright's Prairie houses which can be read and understood much like the figurative paintings of Cezanne and Bruce Goff borrowed this phrase from Gertrude Stein, a writer he greatly admired. Both he and Stein liked the concept that things had no beginning and no end, that one could add, subtract, or alter anything. Picasso. In the Herbert Jacobs House (1944) in Middleton, Wisconsin, known as the Solar Hemicycle, the domestic figuration is gone and the forms bear little resemblance to the conventional elements that make up Wright's Prairie houses. In the Jacobs House, form is not dictated by precedent and local design traditions, but by the sensibilities of the architect, the nature of the land, and the premise of the program

The Italian-born Paolo Soleri, more than any other American architect deserves the label of NeoExpressionism. Soleri produced an enigmatic body of work which belongs to the world of sculpture rather than that of architecture. His buildings, while interesting and provocative, are places and spaces one can inhabit but in which one cannot live. Their beauty is derived from their poetic logic and their philosophical underpinnings. Soleri is not as concerned with the here and now as with the development of a Utopian world of reveries, shapes and sustainable ecology. From 1956, when he settled in Scottsdale, Arizona, Soleri devoted his life to creating an environment of on-going experimentation in desert ecology and urban planning. His work is strongly influenced by the Jesuit Paleontologist movement and by the writings of Pierre Teilhard de Chardin. His most famous project, Arcosanti, [North of Phoenix, Arizona] begun in 1970 is a dream-like 'city on the mesa' and more a poetic manifesto than a work of architecture. Similarly, Soleri's design studio in Scottsdale (1961) is an outlandish building which looks like an assembly of skeletal elements, strange shapes, tilted knobby columns, ribbed vaults, and a myriad of odd architectonic elements. The studio has a Gaudi-like appearance (Fig. 27) which is no coincidence but the result of similar interests in using structure as a primal design instrument.

[Tucson is home to Paolo Soleri's 1986 University of Arizona Cancer Center Chapel. The building has been repurposed as offices, but the chapel remains intact and retains its integrity and significance.]

During the 1960's, Eero Saarinen was one of America's principal masters of the NeoExpressionism movement. It is ironic that he was also one of America's most successful establishment architects. He was able to produce a body of significant Expressionist works for corporate and institutional clients who usually seek the route of safe, conservative architecture. Saarinen was one of the few architects who convinced his clients that daring, unconventional buildings made corporate sense. He began his career as a committed follower of Mies van de Rohe and produced a series of highly disciplined buildings, most notably the General Motors Technical Centre in Warren, Michigan (1948-56), which he designed with his father, Eliel. The Centre was as pure and rational as any Mies building, no less an essay in rationalism and visual order than Mies' campus for the Illinois Institute of Technology.

Soon after the completion of the General Motors Centre, Saarinen changed his vision dramatically. His first and most significant Neo-Expressionist building was the TWA Terminal (1959-1962) at Kennedy Airport (formerly Idlewild). In this project, he attempted to express the idea of flight. Allan Tremko described the Terminal as "an abstraction of spatial liberty, expressed in continuous movement beneath the soaring roof". Saarinen believed that modern architecture lacked drama. He wanted to create memorable buildings with daring structural techniques. His goal was “to express the drama and the specialness and excitement of travel” Arcosanti was begun in 1970, and by 2005 only 3% of the entire project was completed. It is a view shared by the great cathedral builders of the past who took well over a century to complete a project. . His solution was to create a vast 315-foot-long concrete shell made of four intersecting barrel vaults supported by four enormous Y-shaped columns. It was a totally new solution for an airport terminal building. The terminal was an optimistic statement and a prototype for a new monumentality, setting a conceptual precedent: the transformation of the classical notion of monumentality. Only Hans Scharoun’s Philharmonie in Berlin and Jorn Utzon’s Opera House in Sidney have attained the same level of free-form monumentality and Expressionism.

Concurrently, Saarinen designed two other significant Neo-Expressionist buildings, the Ingalls Hockey Rink at Yale University (1956-1958) and Dulles International Airport (1958-1962) in Chantilly, Virginia (near Washington, DC). Both buildings used a suspended flying roof system to span the great space below. In the Yale Ice Hockey Stadium, Saarinen suspended a steel-cable roof on both sides of a central concrete arch spanning the entire building longitudinally. From a formal point of view, the building is a dynamic interplay of convex and concave forms, of sloped and straight walls, of high and low spaces. Together with the TWA Terminal, it is the building which best conveys Saarinen’s interest in architectural dynamism. Dulles International Airport has a simple rectangular plan, but the form of the building is complex. The terminal is a compact building and an exercise in architectural and technical formalism. The structural concept is manifest and consists of colonnades of tilted and tapered columns on the two long facades of the terminal from which is suspended a steel-cable roof. The roof is high in the front, lower in the rear, and its lowest point, as in all catenaries structures, is in the middle of the span. The colonnades, together with the curved shape of the roof, emphasise the dynamic qualities of the building.

In Tucson, during the late 1950s and early 1960s, a number of local architects including Nicholas Sakeller, Arthur Brown, William Wilde, and Charles Cox began experimenting in the Expressionist idiom, responding and tailoring designs to the environmental conditions of the Arizona Sonoran desert. These architectural and engineering compositions employed new technologies and mathematical principles. Hyperbolic paraboloid structures and thin-shell concrete systems emerged as design methods to push the boundaries of traditional construction.

Architecture & Engineering Significance

The development of thin-shell concrete as a building material was detailed in the June 2002 essay by Bradshaw, Richard et. al. titled “Brief History of Thin Shells” from the paper “Special Structures: Past, Present, and Future” published in the Journal of Structural Engineering from the American Society of Civil Engineers. The essay examined the history, form and utilization of of thin shell construction and hyperbolic paraboloids. This paper provides an excellent context of the development of this modern construction idiom:

> Architectural thin shells discussed in this work are a modern development. The domes and cylindrical shaped structures of antiquity and the Middle Ages were thick and could only resist compressive loads. The first modern architectural shell is generally credited to that built by the Zeiss optical company in Austria in the 1920s. In the United States, shells were extensively studied by the aircraft industry in the 1930s. In 1933, Donnell, an aeronautical engineer, formulated the general equations for cylindrical shells, including both bending and membrane actions.
>
> While Eduardo Torroja of Spain is credited for the systematic engineering study of *architectural* shells in the 1930s, it was the work of Felix Candela in Mexico that ignited the sudden surge of popularity of shells in the 1950s. His shells were spectacular both for appearance and for bold engineering. At a time when a 75-mm 3 in. thick shell was considered daring, Candela built a hyperbolic paraboloid shell with less than 16 mm 5/8 in thickness for the Cosmic Ray Pavilion at Ciudad Univ. in Mexico City show examples of how Candela skillfully created different shells from the same hyperbolic paraboloid geometry.
>
> It was an article in *Progressive Architecture* 1955 on the shells of Candela that launched the modern shell era by attracting the attention of architects. [Examples] of the remarkable early shells [are] the air terminal in St. Louis, MIT auditorium in Boston, TWA terminal in New York, Sports Palace in Italy, and Exhibition Hall in Paris. The latter, designed by Esquillan, is one of the engineering marvels of the 20th century, whose statistics define its uniqueness. [...] Remarkably, this was all in 1957, before the use of computers.
>
> The history of civil engineering has repeatedly shown that new types of structures have been built before their behavior was fully understood. This is as true of modern shells as it was of the cathedrals of the Middle Ages; that rational explanation for their success was found only after the persistence of their existence forced their recognition. The early practitioners had to rely on intuition and courage rather than on written knowledge. It can be certain that a great deal of anxiety took place before Candela built his 16 mm 5/8 in. thick Cosmic Ray Pavilion. One could only imagine the fortitude it took to remove the forms from under the 218 m 715 ft span of Esquillan's Exhibition Hall.
>
> The structures of the skilled practitioners of the art, such as Candela, Esquillan, Torroja, and Nervi are distinguished by their elegance in minimizing the thickness, eliminating the ribs, and avoiding the hinges at the abutments. It suffices to note that the span-to-thickness ratio of a well-designed shell is considerably larger than that of an eggshell. Ribs are used to carry the shear forces from the shell to the abutments and to prevent buckling of the edges. However, it is possible to eliminate many ribs by making

the shell itself act as the rib. This requires skilled analysis, which test the knowledge and nerve of the designer. Hinges between the shell and the abutments reduce the capacity of the structure and serve only to simplify the design.

<u>Shells and Geometry</u>

There is no type of structure that has so intimate a relationship with space geometry as a shell. There are two important yet simple geometrical observations in shells: all constructed shells are only fragments of a more complete geometrical shape; and all geometric surfaces would either continue to infinity or intersect with themselves.

[...]

Shells can be singly curved e.g., cylinders and cones or doubly curved e.g., sphere or hyperbolic paraboloid. Paraboloid is a shell of revolution made by revolving a parabola about its axis. A hyperbola produces a hyperboloid of two sheets when rotated about its axis of symmetry, and a hyperboloid of one sheet when rotated about the common axis between its two parts. The latter is often used for cooling towers, because it can be formed of straight lines. Another doubly curved shape formed of straight lines is the conoid, for which a straight line travels along another straight line at one end and a curve at the other end. Shells of translation are generated by translating one curve along another. A circle-translated tangent to a straight line generates a cylinder, and if translated along another circle produces a torus.

[...]

All shells have either positive bowl-shape or negative saddle-shape curvature. The behavior of these two types of shells is very different. Positive curvature shells are subject to buckling, as the entire shell is subject to compression forces. In contrast, material failure is more common in negative curvature shells with brittle materials such as concrete.

Hyperbolic paraboloids HP are doubly curved surfaces with negative curvature. An HP can be generated by lifting one corner of a square shape. [...] Lines parallel to the x- and y-axes remain straight lines. This is very important because the surfaces can be formed with straight forms, which are much more economical than curved forms. An HP can also be generated by translating a convex parabola along a concave one shows an HP in its more usual orientation and a structure built from it. If the convex parabola had been translated along another convex parabola instead of the concave parabola, it would have produced an elliptic parabola with a positive curvature. [...] [A] simple change in the geometric parameters can result in a very different shape with greatly different structural behavior.

In Arizona the development and utilization of thin-shell construction was experimented within an array of new construction materials and structural techniques pioneered after WWII. In Tucson, the first popular mention of hyperbolic paraboloid construction in newsprint appeared in the Arizona Daily Star on December 23, 1956 in a national column titled "Residence Given Unusual 'Twist'" The article discussed the Donald Dean houses in Kansas and highlighted the use of a hyperbolic paraboloid roof. (That property is now listed in the National Register of Historic places). (Wylie, Hugh J., Arizona Daily State, Residence Given Unusual 'Twist', December 23, 1956)

In 1957, John Wise, structural engineer with the Portland Cement Association based in Los Angeles, California, spoke at a meeting of the Tucson Chapter of the National Society of Professional Engineers discussing the "Design of Thin-Shelled Concrete and Hyperbolic Paraboloids. (Arizona Daily Star, Wise to Address Engineer Society, April 11, 1957). In December of that same year Walter Kunzy, a structural engineer from the Chicago office of the Portland Cement Association lectured at the University of Arizona on "Thin Shell Concrete". (Arizona Daily Star, Cement Engineer To Speak at the UA, December 5, 1957).

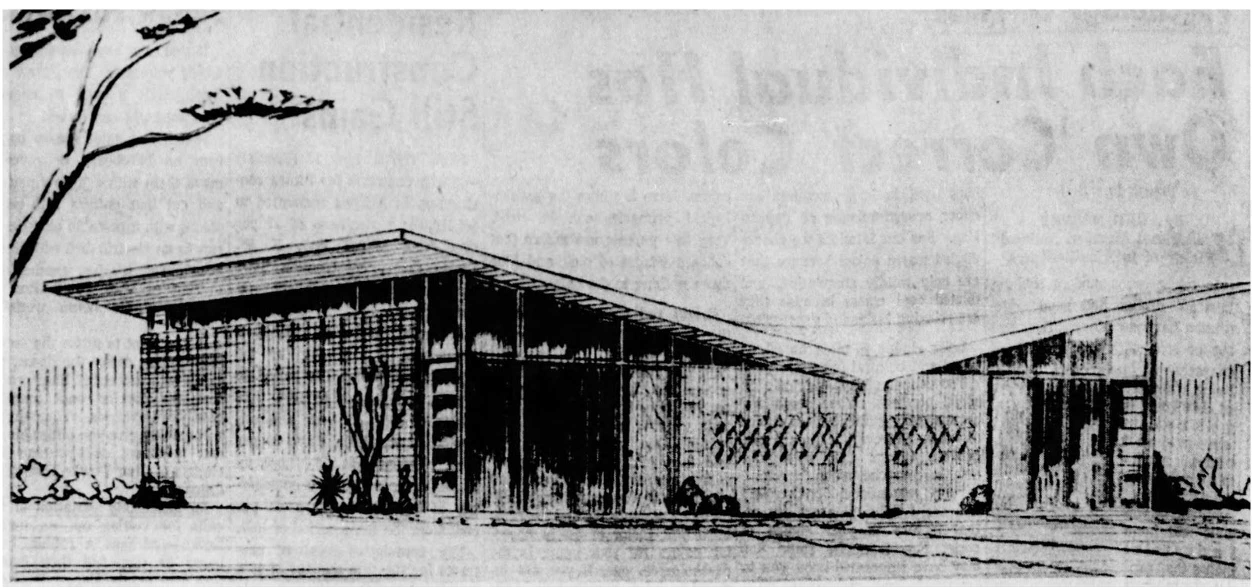

Fig. 12, Sentinel Land and Development Corp. Model House, Architect J.H. Beck drawing, 1958.

Within six months the first Arizona building to use a hyperbolic paraboloid concrete structure began construction in Tucson. Richard R. Hughes president of Sentinel Land and Development Corp. built a demonstration duplex with plans to build 100 more. Although the plan to develop a hundred homes was never realized, the extant model was constructed at 4616-18 East Fairmount Avenue with a 40 x 50 foot thin shell concrete roof supported by two columns, creating a 2,000 square-foot livable space. (Fig. 12) The project was designed by architect John H. Beck and AE Consultants Inc, architect and engineers. T.W. Kramer civil engineer and W.M. Waggoner mechanical engineer worked on the project and W.L. Johnson Construction Co, was the contractor. (Arizona Daily Star, Hyperbolic Paraboloid Structure Being Built, May 18, 1958.)

In June 1958 the Harlow Nursery hired Tucson architect William Wilde designed an addition. The building utilized thin-shell concrete technology in the construction of a barrel design roof. The building at 5620 East Pima was developed in consultation with Johannessen Girand and Taylor consulting and construction completed by Jaco Construction Company. The Tucson Daily Citizen noted it was the "first thin-shell concrete structure to be poured in Tucson." (Tucson Daily Citizen, Another Tucson First, June 21, 1958.)

Fig. 13, Harlow Nurusy, Thin Shell concrete barrel roof design, Architect William Wilde, 1958.
Photo Tucson Daily Citizen, 1958

The same year, Architect Charles Cox was commissioned to design a new sanctuary for the Catalina American Baptist Church (1900 N Country Club Rd, Tucson, AZ 85716) using a large hyperbolic paraboloid design. (Fig. 14) (Tucson Daily Citizen, Church Style the First of its Kind, June 7, 1958.) The sanctuary was constructed between 1960-61 and listed on the National Register of Historic Places in 2011. During 1958, architect Nicholas Sakellar & Associates designed a concrete ceiling utilizing a hyperbolic paraboloid, built by Johnson Construction Company for the Saddle & Sirloin Steakhouse at 2130 North Miracle Mile Strip for owner James Sfarnas. The building, part of the Miracle Mile Historic District (listed 2017), is designated as a non-contributor because of modifications that obscure the design, however the hyperbolic paraboloid form can be seen from north elevation. (Tucson Daily Citizen, Teagarden To Open At Saddle, July 27, 1962)

Fig. 14, Catalina Baptist Church, Construction Photograph 1960-61,Catalina Baptist Church Collection

In 1959, architect John Beck again utilized the hyperbolic paraboloid form, for the new Dodge automobile sales agency Bill Breck Dodge, Inc. located at the southeast corner of East Speedway Boulevard and Bentley Avenue (demolished). The Arizona Daily Star at the time noted the main structure "will employ the modernistic hyperbolic paraboloid roof style, will house a 15,000 square foot showroom and administration office." (Arizona Daily Star, Bill Breck to Open New Dodge Agency in City, August 18, 1959.) The same year, a 2 million dollar medical office building at 601 North Wilmot Road was designed by architectural Emerson Scholar of the firm of Scholer and Fuller on the northwest corner of 5th Street and Wilmot Road. The building, believed at the time to be the largest structure in the southwest employing this structural principle, utilized a massive system of hyperbolic paraboloids. (demolished) (Tucson Daily Citizen, Medical Building Planned, Feb 9, 1960.) (Tucson Daily Citizen, $1 MIllion Medical Building Planned Beneath Gigantic Concrete Umbrella, October 22, 1959.) In Phoenix that year, the geometric structural system was used as a roof form at the Lou Regester warehouse at 4701 West Colter. (Arizona Republic, Umbrella Roof, November 8, 1959.)

New technologies continued with experiments by local Tucson architects, and in February 1960, Architect Arthur T. Brown used plastic and aluminum to construct a house replete with a hyperbolic paraboloid roof. (Riddick, John, Plastic Home in Tucson May be First of Its Kind, Feb 25, 1960.) In October of 1960 The American Concrete Institute held a conference in Tucson hosting 300 attendees from across the American west, Canada and Mexico. Dr. Gene Nordby, head of the University of Arizona Civil Engineering department, served as the general chairman of the conference. The conference presented papers on defense, and breakthroughs in technology and design. The attendees looked at advances in engineering. The Tucson Daily Citizen reported: "For example they have found that they could make extremely thin sections and by forming them into special geometrical shapes like hyperbolic paraboloids and domes…One of the beauties of the thin shell construction is that it has a high factor of survey." (Reddick Josh, Advances, Tucson Daily Citizen, Uses of Concrete Pondered by 300 Experts, Oct 31, 1960.)

In 1961 Sunset magazine constructed a demonstration garden at the Arizona Sonoran Desert Museum. (Fig. 15) The garden included a wall made of native rock and utilized a hyperbolic paraboloid concrete shell to form a dramatic division of the garden area. Landscape architect Guy Greene designed the project. (Ernenwein, Leslie, Tucson Daily Citizen, Garden at Desert Museum to be Completed in 62', March 1, 1961.)

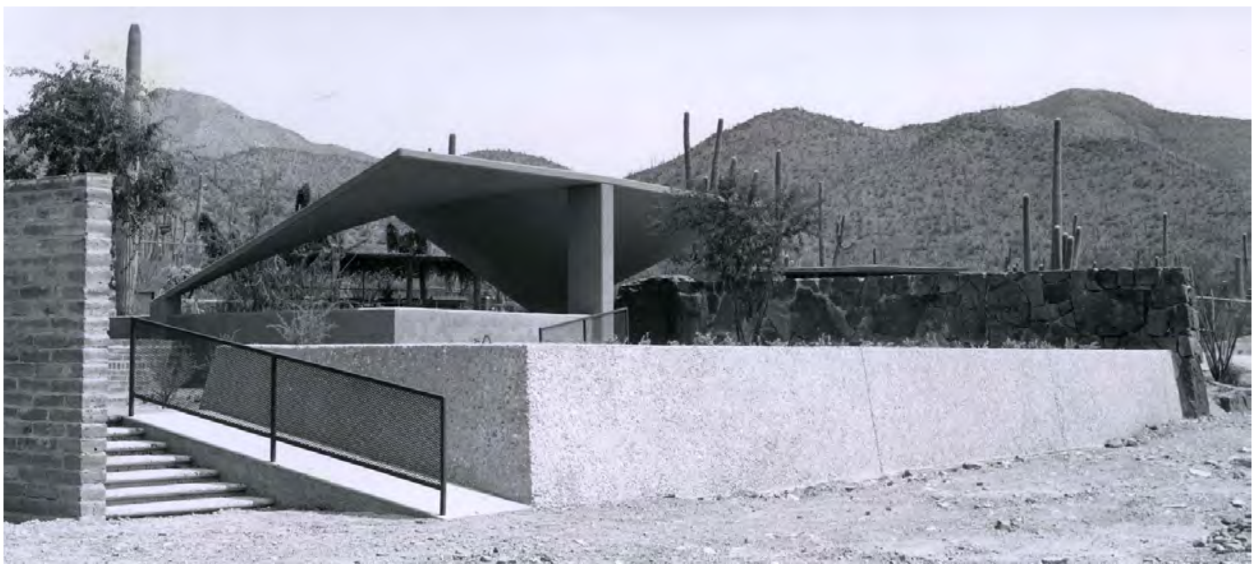

Fig. 15, Sunset Magazine Demonstration Garden, Desert Museum, Landscape Architect Guy Greene, Photo by Bill Sears, 1962

In 1961, Reid and Hazard, Tucson-based architects, designed the Flowing Wells Elementary School with a "rolling barrel-style roof". The drawings were developed in partnership with the architectural firm of Shaver & Co. of Salina, Kansas. The school was a series of four classroom buildings built in a semi-circle around multi-purpose buildings. The roofs were created with a 12-shell barrel design of thin-shell concrete. (Tucson Daily CItizen, Flowing Wells Board Ok's Design of Elementary School, January 27, 1961.)

Regionally, the La Concha Motel Lobby (1961) in Las Vegas (Fig. 16) was designed by Paul Williams. The form and shape, derivative of Felix Candela's "Los Manantiales" (1958) in Mexico City, is geometrically related to the Howard Harrenstein House design. It is in this window of time and within this design context that Harrenstein conceives and builds his home. His design is the most aggressive use of thin-shell concrete and hyperbolic paraboloid construction in residential architecture in Tucson.

Fig. 16, La Concha Motel in Las Vegas (Paul Williams, 1961). photo 2011.

From this period, the other notable regional example utilizing the hyperbolic paraboloid and thin-shell construction was major redevelopment of Nogales, Sonora. In 1962, both the U.S. and Mexico invested millions in a new border stations. The American Port was conceived and designed by the Tucson architectural firm of Scholer & Fuller as a geometric International-style building. The Border Crossing and Aduama in Nogales, Sonora was designed by Mexico City architect Mario Pani as part of a complete re-envisioning of the Sonoran border town. Pani's style was organic and exuberant. The port was conceived as two cascading cast concrete arches. The entry was only one aspect of a new building complex which included buildings with cast concrete barrel vaults, expressive forms more sculptural then architectural, a large hyperbolic parabola, (Fig. 17) and a railway station designed by Raul Mendez featuring a series of angular hyperer projections and idiosyncratic sail shapes that point over the railroad tracks punctuating the sky.

Fig. 17, Nogales Border redevelopment 1962, Architect Mario Pani. Photo by THPF

In Arizona, the hyperbolic paraboloid reached an apex with the construction of the Memorial Coliseum at the Arizona State Fairgrounds. (Fig. 18) Designed by Phoenix architects Lescher & Mahoney with participation from the Tucson firm of Place & Place, the monumental structure marked the end of the general use of this structural system in construction in Arizona as tastes began to shift.

Fig. 18, Memorial Coliseum at the Arizona State Fairgrounds, Photo courtesy of: CMag

Dr. Howard Paul Harrenstein

Howard Paul Harrenstein was born in Kansas City, Missouri in 1931. Harrenstein received a bachelor of science in architectural engineering and a bachelor of architecture degree from Kansas State University, and Masters of Science degree in civil engineering and Ph.D. in theoretical and applied mechanics from Iowa State University. His thesis titled Configuration of Shell Structures for Optimum Stresses was published in 1959.

Fig. 19, Dr. Howard P. Harrenstein, 1975

In 1959 he served as an assistant professor of civil engineering at Iowa State University.
His was the primary author on numerous papers including “Structural Behavior of a Plate Resembling a Constant Thickness Bridge Abutment Wingwall” (1959) published by Iowa State College of Agriculture and Mechanic Arts and “Stress Distribution in Hyperbolic Paraboloidal Shells Under Concentrated Loads” (1961) published by Iowa State University of Science and Technology. (Arizona Daily Star, Regents Okay 132 Faculty, Staff Appointments, June 25, 1960)

In June of 1960 Harrenstein was appointed Associate Professor of Civil Engineering at the University of Arizona and relocated his young family to Tucson. Harrenstein was a regular presenter at professional conferences including the American Society for Engineering Education and Arizona Section of Civil Engineers. With three academic colleagues, Harrenstein received an national award from the American Institute of Architecture, and the U.S. Office of Civil Defense in 1962 for a bomb shelter design. (Arizona Republic, Four UofA Professors Share Prize, Nov, 28, 1962.)

In February 1962, the Tucson Mayor and Council appointed Harrenstein to the first Civil Defence Commission. (Tucson Daily Citizen, Mayor, Council Appoint Civil Defence Council, Feb 19, 1962.) Harrenstein worked with the University of Arizona and the newly formed Tucson-Pima County Civil Defense Agency to present workshops to "acquaint architects, engineer, builders, contractors and others with methods of identifying, improving, constructing or improving community and family bomb shelters." (Arizona Daily Star, Bomb Protection Workshop Slated at UA Nov. 20, November, 13, 1962.) In early 1963 Harrenstein led a fifteen week course in "nuclear fallout." (Tucson Daily Citizen, Fallout Course Under Way, February 9, 1963.)

Harrenstein was a charter member of the Structural Engineer Association of Southern Arizona formed in May of 1963 (Arizona Daily Star, Engineers' New Group to Meet, May 9, 1963.) In February of 1964 Harrenstein was appointment as director of the Tucson-Pima County Civil Defence Agency. (Arizona Daily Star, Harrenstein Considered for CD Post, January 29, 1964). With 18 Titan II missile silos headquated in the Sonoran desert, Tucson was a known nuclear target, and in his role, Harrenstein developed a theoretical total shelter system for the city.

In 1966 Harrenstein accepted a position at the University of Hawaii and left Tucson with his family. In April of that year he was formally appointed Associate Dean of College of Engineering & Director of the Engineering Research Center at the UofH. In 1972 Harrenstein joined the University of Miami in Florida as the dean of the School of Engineering and Environmental Design and professor of civil engineering.

Harrenstein served as the chairman of the architectural engineering division of the American Society for Engineering Education and for six years was the chairman of the ASEE- Associated Collegiate School of Architecture- Office of Civil Defense Advisory Committee to Civil Defense.

In 1975 Harrenstein became the director of the Solar Energy Research Center at Florida Technological University. Harrenstein continued to practice engineering and by 1983 had opened the consulting firm of Howard P. Harrenstein and Associates in Miami, Florida

The Harrenstein house is the only example of his architectural and engineering design in Arizona.

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Previous documentation on file (NPS):

____ preliminary determination of individual listing (36 CFR 67) has been requested
____ previously listed in the National Register
____ previously determined eligible by the National Register
____ designated a National Historic Landmark
____ recorded by Historic American Buildings Survey #____________
____ recorded by Historic American Engineering Record # ___________
____ recorded by Historic American Landscape Survey # ____________

Primary location of additional data:
____ State Historic Preservation Office
____ Other State agency
____ Federal agency
____ Local government
____ University
____ Other
Name of repository: _____________________________________

Historic Resources Survey Number (if assigned): ________________

10. Geographical Data

Acreage of Property 0.97 Pima Co GIS

Use either the UTM system or latitude/longitude coordinates

UTM References
Datum (indicated on USGS map):

Zone: Easting: Northing:

Use either the UTM system or **latitude/longitude coordinates**

Latitude/Longitude Coordinates (decimal degrees)
Datum if other than WGS84:________

(enter coordinates to 6 decimal places)

1. Latitude: 32.324070° N Longitude: 110.957145° W

Verbal Boundary Description (Describe the boundaries of the property.)
Major cross streets are Orange Grove and Oracle Roads with the property to the north of Orange Grove and west of Oracle Road.

The legal description for 6450 N Calle de Estevan in Pima County GIS is:

SANTA CATALINA ESTATES LOT 60

The boundary is the lot shown on the attached site map.

Boundary Justification (Explain why the boundaries were selected.)
The Boundary matches those if the subject lot as described.

11. Form Prepared By

name/title: Demion Clinco
organization: Tucson Historic Preservation Foundation
street & number: PO Box 40008
city or town: Tucson state: Arizona zip code: 85717
e-mail info@preservetucson.org
telephone: (520) 247-8969

date: May 20, 2019

Additional Documentation

Submit the following items with the completed form:

- **Maps:** A **USGS map** or equivalent (7.5 or 15 minute series) indicating the property's location.
- **Sketch map** for historic districts and properties having large acreage or numerous resources. Key all photographs to this map.
- **Additional items:** (Check with the SHPO, TPO, or FPO for any additional items.)

Figure 11. Boundary map of Harrenstein House . Pima Maps GIS, 2018.

Photographs
Submit clear and descriptive photographs. The size of each image must be 1600x1200 pixels (minimum), 3000x2000 preferred, at 300 ppi (pixels per inch) or larger. Key all photographs to the sketch map. Each photograph must be numbered and that number must correspond to the photograph number on the photo log. For simplicity, the name of the photographer, photo date, etc. may be listed once on the photograph log and doesn't need to be labeled on every photograph.

Photo Log

Name of Property: Harrenstein House
City or Vicinity: Tucson
County: Pima State: Arizona
Photographer: Jude Ignacio and Garadene Vargas
Date Photographed: 2016

Description of Photograph(s) and number, include description of view indicating direction of camera:

AZ_PimaCounty_HarrensteinHouse _0001
Looking northeast, south front elevation, main entrance

AZ_PimaCounty_HarrensteinHouse_0002
Looking north, south front elevation

AZ_PimaCounty_HarrensteinHouse_0003
Looking northwest, south front elevation thin-shell detail

AZ_PimaCounty_HarrensteinHouse_0004
Looking north west, south and east elevation, front elevation and kitchen elevation detail

AZ_PimaCounty_HarrensteinHouse_0005
Looking east, west facade, site wall and landscape

AZ_PimaCounty_HarrensteinHouse_0006
Looking northeast, interior dining room and window wall

AZ_PimaCounty_HarrensteinHouse_0007
Looking southwest, interior living room and entryway

AZ_PimaCounty_HarrensteinHouse_0008
Looking southwest, dining room interior view

AZ_PimaCounty_HarrensteinHouse_0009
Looking west from kitchen, philippine mahogany cabinet casework detail

AZ_PimaCounty_HarrensteinHouse_0010
Looking southeast, interior, kitchen fireplace

AZ_PimaCounty_HarrensteinHouse_0011
Interior, bathroom detail

AZ_PimaCounty_HarrensteinHouse_0012
Interior Bedroom Detail