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LANDSCAPE RESEARCH RECORD is published annually and consist of papers focused on landscape architecture subject areas. Each issue is a collection of papers presented at the Council of Educators in Landscape Architecture annual conference of that year. Conference theme is expressed as the subtitle of *Landscape Research Record.* The views expressed in papers published in *Landscape Research Record* are those of the authors and do not necessarily reflect the views of the conference planning committee, or the Council of Educators in Landscape Architecture.

PEER REVIEW OF PAPERS: All papers published in *Landscape Research Record* have been reviewed and accepted for publication through the Council of Educators in Landscape Architecture's peer review process established according to procedures approved by the Board of the Council of Educators in Landscape Architecture. Reviewers are recruited by track chairs from among conference attendees and other outside experts. The track chairs also serve as co-editors in the peer review process. The Council of Educators in Landscape Architecture requires a minimum of two reviews; a decision is based on reviewer comments and resultant author revision. For details about the peer review process and reviewers' names, see REVIEWERS in Table of Contents.

IN THIS ISSUE: In 2019, the conference committee accepted 440 abstracts for presentation and rejected 43 abstracts. Authors of accepted abstracts were invited to submit a full paper. A total of 73 papers were received, 60 papers were selected for peer review. Finally, 36 papers were accepted for publication in this issue. The organization of this issue follows the standard conference tracks listed in the table of contents.

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FOREWARD

Welcome to the eights issue of Landscape Research Record, published by the Council of Educators in Landscape Architecture (CELA). In 2013, the CELA Board approved and adopted a procedure to become fully responsible for publishing peer-reviewed conference papers annually and named the publication Landscape Research Record (LRR). LRR is a post-conference publication and published online only.

This eighth issue of LRR is a collection of peer-reviewed papers presented at CELA 2019 hosted by The University of California, Davis (UC Davis). The 2019 annual conference focused on research, scholarship and creative activity that highlighted the theme of "Engaged Scholarship" which created an opportunity to examine our collective past and future contributions to community-based education and real-world problem solving.

This issue contains 36 quality peer-reviewed papers resulting from the conference. We hope you find them to be a collection of provocative and insightful research that enriches CELA's dialog of research and creative inquiry on the processes of debate and discussion.

Galen Newman, PhD, ASLA, APA
Texas A&M University
Editor-in-Chief, Landscape Research Record No. 8
CELA Vice President for Research & Creative Scholarship 2018-2020

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DESIGN RESEARCH BASED DEVELOPMENT OF CAMOUFLAGE LANDSCAPE FEATURES TO PREVENT CRIMINAL UAV ACTIVITY

HEWITT, ROBERT

Clemson University email Hewitt@clemson.edu

NASSAR, HALA

Clemson University email Hassar@clemson.edu

1 ABSTRACT

The popularity of small consumer drones (UAVs) has prompted increased use of these vehicles in and around public outdoor spaces, with expected commercial drone numbers to reach nearly 7 million by 2030 (FAA). Research in landscape architecture related to UAV (drone) use in public space to date, has just begun to address conceptual approaches to landscape assessment, representation, and park user behavior (Kullmann, Park). While research related to the development of countermeasures for security purposes is more extensive, no research to date addresses the development of landscape countermeasures for the use of UAVs in criminal activities. The paper presents design-based research (DBR) methodology and findings funded by a multiyear, multidisciplinary NSF grant to develop landscape architectural interventions that discourage the use of UAVs for criminal purposes at correctional facilities.

Consistent with design based research (DBR) models (Brown), this project is complex, incorporating the development of a) landscape assessments for potential UAV launch and landing sites around prisons; b) the creation of UAV tracking and monitoring systems, and c) the development of model countermeasures. The paper describes design and placement of embedded landscape features utilizing landscape camouflage principles for UAV detection systems in forested upstate North Carolina. Modelled camouflage mimicked landscape features and were fabricated in two stages: 1) landscape superstructure, and 2) landscape camouflage. The embedded landscape features incorporated a launch warning system capable of alerting prison officials of drone launch locations, identifying future drone operators, and predicting drone flight paths.

Keywords: Design Based Research, Drones, Prisons, Security Countermeasures

2 INTRODUCTION

The development of small consumer drones (UAVs) has prompted increasing use of these vehicles in and around public outdoor spaces, such as parks, stadiums, outdoor amphitheaters, and festival grounds, with expected commercial drone numbers to reach nearly 7 million by 2030 (FAA, Beasley). Anticipated novel uses of commercial UAVs is projected to follow this trend, extending UAV use to the delivery of small commercial payloads across long distances over short periods of time, akin to proposals by Amazon's PrimeAir service (BBC News). UAV ability to deliver such payloads quickly and over long distances, however, appears likely to extend to a broad spectrum of quasi-legal and clearly illegal activities, as well, including the smuggling of contraband.

Given the high demand for contraband items like cell phones, drugs, weapons, and alcohol in prison settings, the potential for UAV-related smuggling is raising awareness and concern about potential gaps in prison security planning worldwide (Guardian, Welch). For example, correctional facility authorities show increasing concern that smugglers can easily take advantage of existing surveillance blind spots using drone counter surveillance to guide contraband drops with little fear of being detected. This concern is reflected in recent sharp increases in overall reported prison smuggling incidents (Titheridge), in resent reports that UAVs are airdropping contraband into prisons (Rosenwald), and in reports that prison insiders are using cell phones to notify smugglers when and where to airdrop contraband from nearby hidden locations(Kalinich). Because available drone technology is constantly improving, authorities are especially concerned that drones will become more difficult to detect over time.

2.1 Background

The paper addresses findings from the first year of a multiyear, multidisciplinary NSF grant to develop countermeasures that discourage unauthorized use of UAVs in public space (including uses for criminal purposes). As part of that grant, design and research faculty from Clemson and Duke Universities examined threats posed to prison security by drone contraband smuggling around a forested upstate North Carolina prison site. Because UAV detection for prisons in this context encompasses complex analysis, collaborative tasking, and innovative design processes, the paper elaborates the project research process consistent with design based research (DBR) models (Brown). In broad strokes, this DBR project incorporates: a) landscape assessment for potential UAV launch and landing sites around prisons; b) UAV tracking and monitoring systems component development, and c) counter-measure development employing landscape camouflage.

Figure 1 NC Prison Surrounding Forest UAV Launch and Landing Site Analysis

More specifically, landscape assessment for potential UAV launch and landing sites around the prison evaluated: a) landscape cover characteristics within 1 mile of the prison; b) line of sight potential for drone pilots and prison security staff; and c) potential access/egress routes for contraband smugglers. Figure 1 illustrates the broader landscape context surrounding the Scotland Correctional Facility in North Carolina. The maximum-security prison is located in a forest clearing at the center of the illustration. A one-mile radius circle circumscribes the prison as an indicator of relative scale and distance. An airport lies partly within the one-mile radius, as does a small town, several water bodies, a stream, and several farms. There is relatively little topographic change across the illustrated landscape (approximately 200 across in gently rolling small hills). Relatively long sightlines extend from the prison's surrounding forest edge to the fenced/walled prison yard, especially north and west of the prison yard. The entire landscape is crisscrossed with small roads surrounding the prison. There are numerous paths leading through the surrounding forest, which intersect with the surrounding network of small roads. In general, these environmental conditions provide numerous potential opportunities for drone contraband smuggling.

Landscape assessment also incorporated key prison personnel interviews to understand staff situational awareness (SA). For purposes of this DBR, SA describes human comprehension of temporal and spatial events within the prison and surrounding environments at three levels: 1) accurate perception of the relevant environment and its activities; 2) comprehensive understanding of those activities in the context of prison security; and 3) predictability of future situational changes (Pew). For purposes of the study, prison security personnel described their situational awareness of the surrounding landscape as a dynamic environment routinely probed in multiple locations by smugglers, who were suspected of communicating with people inside the prison.

Prison officials' initial response to the perceived inadequacy of their security included a) the development of active measures around the prison property, with regular formal and informal patrols at varying times and locations to collect information and prevent potential smuggling; and b) the installation of battery operated motion-detection cameras with internal data storage mounted at hidden locations near suspected smuggling routes. After initial camera system installation, NC prison personnel recounted that they had discovered six drone-assisted contraband drops. They subsequently reexamined their security blind spots and identified several areas in the surrounding landscape that they believed might provide cover for future smuggling, offering good lines of sight for drone pilots or navigation spotters and potentially successful access/egress smuggling routes.

3 METHODS

3.1 Site Specific Landscape Architecture/UAV Issues and Conceptual Design

In further discussions with prison staff, design and research faculty proposed DBR in situ experiments to test an embedded Launch Warning Camera System (LWCS) that was capable of alerting prison officials of drone launch locations, to identify future drone operators, and predict drone flight paths. The proposed LWCS was intended to identify smugglers in real time and warn prison staff when contraband smugglers are present. It serves as the embedded landscape component of a more comprehensive detection system, named a Prison Reconnaissance Information System (PRIS), developed at the Duke University Humans and Autonomy Lab (HAL Website: http://hal.pratt.duke.edu/).

The embedded LWCS would incorporate solar energy collection elements, battery storage, thermal camera and microphone for image and acoustic data analysis, and motion detectors. It would operate within PRIS hardware infrastructure that includes: 1) a remote server that stores and transmits data, and 2) a mobile alerting interface (MAI) installed on secure prison personnel smartphones. The PRIS system is designed so that when HAL developed algorithms recognize intruders through LWCS real-time imagery analysis, a warning alert is transmitted to a mobile alerting interface (MAI). The PRIS then uploads data from the system server, displaying intruder location and drone directional movement sent to prison staff smartphones, enabling prison security response. For purposes of this project, PRIS hardware needed to be replicable and inexpensive, and in the case of the LWCS, needed to withstand operating conditions in the surrounding forest with little maintenance. Identification of the proposed

LWCS site was critical to the DBR, not only as a site for experimentation, but as a locus for security design theory to include UAV) drone countermeasures in existing landscape security design thinking.

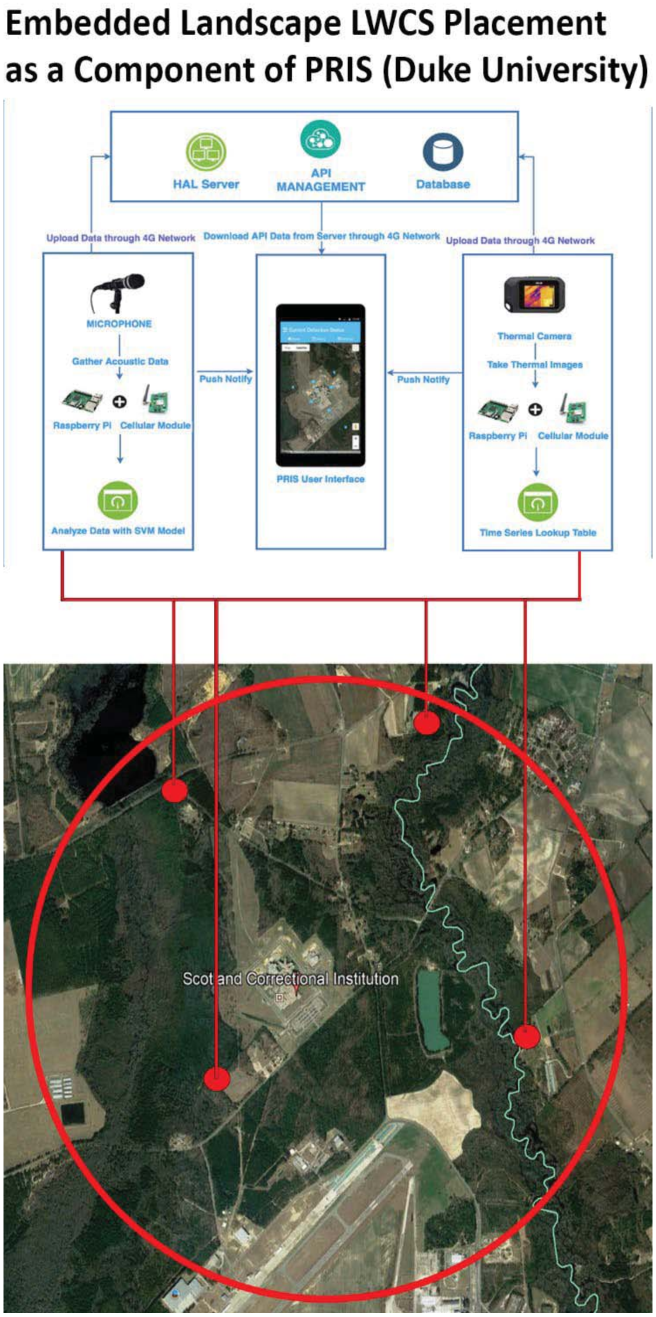

Figure 2 LWCS Embedded Landscape Components

The diagram in Figure 2 illustrates Prison Reconnaissance Information System (PRIS) architecture with a schematic of potential LWCS embedded landscape components in the project landscape. Anticipating drone launch sites within 1 mile of the prison, research faculty analyzed potential experimental sites based on landscape cover, navigation lines-of sight, and access/egress potential. A promising 16-acre area was identified approximately .4 miles from the prison. The site was surrounded by mixed mature and immature hardwoods and pines, contained a walkable path leading to nearby roads (.2 miles from a potential launch site). The site incorporated landscape elements capable of supplying cover for drone flight spotters. <u>The experimental site is not identified here for security reasons.</u>

Two small sites within the selected 16-acre area were field tested as candidates for LWCS experimental locations. One site exhibited more understory landscape cover, denser detritus with significant amounts of brush, trees tall enough for full solar exposure at their tops, and trees with foliage dense enough to discourage visibility from the ground. A path ran through the site with locations suitable for potential embedded LWCS testing. Initial in situ tests of the thermal camera, motion detector, and mobile alerting interface (MAI), verified motion detection reliability, thermal image legibility, and MAI operation.

Given this broader DBR context, the relevant DBR landscape architecture problem described in the remainder of the paper is: *how can an in situ power supply system providing solar collection and battery storage for PRIS-related hardware be camouflaged in forested upstate North Carolina prison surroundings to evade detection by contraband smugglers attempting to launch and navigate drones?*

Conceptually, this DPR landscape architecture problem is: *nested in environmental contexts with differing situational awareness between two groups of people, using the same environment for conflicting security purposes (in this case one group using (UAVs) drones to counteract the security design of the other group)*. Heuristically, a designed landscape in this context advantages one group over the other. Pragmatically: a) the security group receives accurate perceptions and understanding from the shared designed environment, enabling an accurate prediction of future contextual change; b) the drone smuggling group receives less than full access to those perceptions and understanding - to the extent they are unable to fully predict future contextual change; c) the resulting difference in situational awareness is proportional to the effective use of embedded landscape camouflage and technology; which d) advantages the security group's use of the shared environment. In terms of DBR processes, the design of embedded landscape features in these contexts follow long-established camouflage principles utilizing concealment, deception, misdirection, screening, mimicry and pattern, intended to maximize the perceived integration of embedded landscape elements within surrounding landscapes (Hartcup, Root).

The design and camouflage principles elaborated in the DBR process complement existing basic security design principles now largely focused to site hardening against blast damage delivered through road systems with large vehicles. Existing security design principles relevant to the DBR process employ in varying degrees: 1) unity (the repetition of a limited number of elements); 2) harmony (the elements that are used to create unity must go together); 3) emphasis (giving added importance to certain elements); 4) balance (the overall balance of weight and mass of site elements in a symmetrical, asymmetrical, regular, or irregular arrangement); 5) scale (the relationship of the size of the site elements and the pedestrian or user); and 6) rhythm (the sequencing of site elements).

3.2 Embedded Landscape DBR Utilizing Landscape Camouflage Principles

Employing camouflage principles to conceal and screen the solar collection and battery storage components of the embedded landscape DBR considered: size and location of the solar panel and battery with access open to sun all year, power generation, storage capacity, distance from thermal camera, cable voltage capacity, gross size and weight of the embedded component. Solar panel dimensions and battery size suggested a component with a minimum 20"x 14"x 16" interior camouflaged space. Case study assessment of tree component deceptive camouflage for solar panels and microwave towers, and case studies for potential mimicry of a variety of animal nest configurations common to local forest trees recommended bird's nests as initial embedded camouflage prototypes. Red tail hawk nests were used as prototypes for the following reasons: a) they are typically found in large trees 13 to 69 ft off the ground with good solar access like those in situ; b) their great variation in construction and vegetative materials enabled ready prototyping with material found in situ; c) in situ tree species were common red tail hawk nesting sites; and d) typical red tail hawk nest dimensions offered ample opportunity to conceal and screen the embedded LWCS components (generally 28" to 38" in diameter and up to 38" tall).

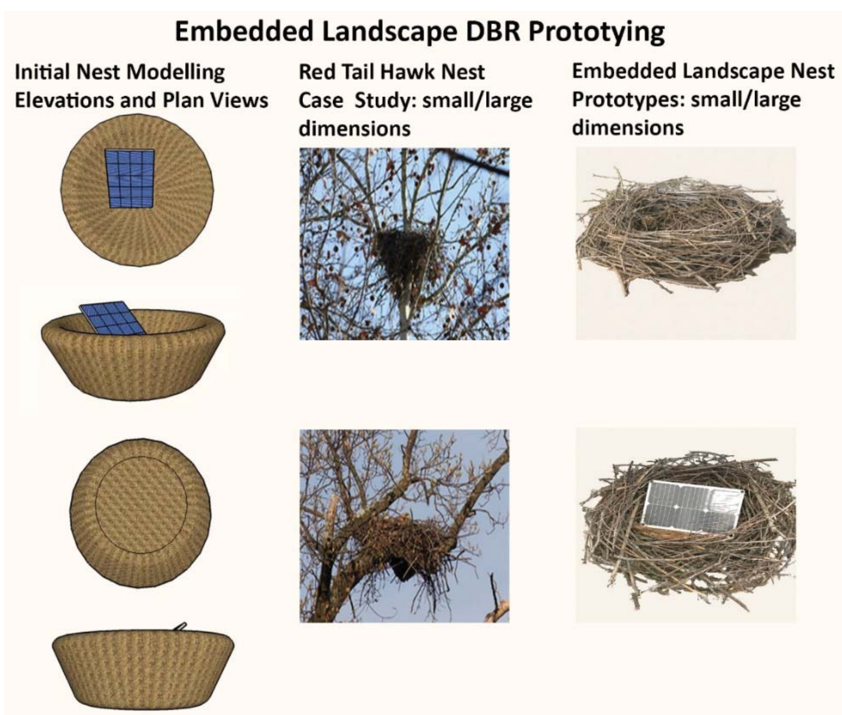

Figure 3 Red Tail Hawk Nest Prototypes

Construction and vegetative materials derived from shed twigs and branches, pine needles, and leaf detritus were gathered at the experimental site and transported to DBR assembly areas at Clemson University. The nest construction material was configured as two prototypes: one - 40"+ outside diameter, and one - 34"+ outside diameter. The larger nest was configured with thicker branches. Individual and small assemblies of branches and twigs were 3-D scanned to access the feasibility of 3-D printing for the nests or its various parts. Scanned branches were, in general, digitally incomplete or required too much digital reworking after initial scanning to efficiently and inexpensively utilize 3-D printing technology to completely or partially fabricate the nests. Instead, the two nests were modelled using construction adhesives and traditional "wood weaving" techniques.

Figure 3 above illustrates DBR iterative prototyping employed in the embedded landscape feature conceptual development. The DBR prototyping identified: 1) potential nest types by size, scale and configuration, 2) a model nest configuration capable of a range of suitable proportional dimensions, and 3) two nest configurations fabricated with woven wood branches and construction adhesives capable of enclosing the solar panel and battery storage components required by the LWCS and PRIS.

Figure 4. 3-D modelling of the embedded nest in a tree seen from tree top and ground levels.

Figure 4 above illustrates digital 3-D modelling of the nests mounted in rendered trees similar to those on site. DBR evaluation of the 3-D models suggested the nests would be very difficult to see from ground level for several reasons: 1) the height of the tree and branch leaf cover; and 2) the restricted sight angles surrounding on site trees. The smaller of the two nests was evaluated as comparatively less visible and weighed less, potentially reducing the risk of the nest dislodging from its mountings in inclement weather. Evaluation of increased potential risk for personal injury/property damage resulting from the dislodgement of the heavier nest recommended a smaller and lighter prototype.

Because the woven wood and glued nest configurations occasionally lost structural integrity under routine transportation and handling, the nests proposed for field-testing were further prototyped as camouflaged superstructures. Two superstructure prototypes with examples of solar mounting plate and weaving pins, gridded elliptical trusses, and a solar orientation devise were modeled. One superstructure prototype was modelled with ¼" water-cut stainless sheet steel Type 304. Another superstructure prototype was modelled with ¼" CNC router-cut sheet Lexan polycarbonate resin thermoplastic. The steel prototype was estimated to weigh approximately 12 pounds, and require considerable effort to machine and weld. The Lexan prototype weighed approximately 4 pounds and was more easily machined and welded.

A smaller Lexan prototype for field testing was fabricated using split trusses assembled with Lexan adhesive and configured in a 3.5" on center interlocking grid. The gridded trusses interlocked through paired notches at intersection points. The initial prototype was fastened with additional ¼" plastic snap ties to secure the woven wood camouflage. The Lexan superstructure was coated with a matt finish acrylic to reduce potential Lexan reflectivity, which might appear “unnatural” in a forest setting. The solar orientation devise was mounted for solar panel installation, and adjusted for appropriate solar exposure for the preliminary field testing site. The nest is currently mounted in a tree consistent with trees in the prison test site at a Clemson University field testing location. Initial tests will last 3 months through winter weather to assess construction weathering, fastening systems, solar panel function, and potential animal interference and damage. In response to anticipated field testing data, a final camouflaged nest will be field tested at the North Carolina prison test location. Following tests will assess the effectiveness of the camouflage and security design principles of the embedded landscape feature, and recommend final LWCS and PRIS adaptations for final site design and system installation.

4 DISCUSSION

The paper has presented descriptions of design-based research (DBR) addressing landscape contexts supporting the use of “drones” (UAVs) for criminal purposes at correctional facilities. Consistent with DBR models, this project is complex and iterative. The project specifically addresses a model for landscape architecture DBR that incorporates: a) the development of landscape assessment for potential ”drone” launch and landing sites around prisons; b) the creation of “drone” tracking and monitoring systems; and c) the development of model countermeasures. Its methodology focuses on the placement and prototyping of embedded landscape components employing landscape camouflage principles to surreptitiously house “drone” detection systems located in forested upstate North Carolina. As a process, the methodology incorporates: 1) conceptual development of the design problems; 2) establishment of theoretical rationale for design problem resolution; 3) development of relevant design principles grounded in existing landscape security guidelines/camouflage design criteria; and 4) iteration intended to resolve complexity in human/machine/environmental design problems. In this case, the embedded landscape features are conceptualized and designed to: a) incorporate launch warning system technology to alert prison officials of drone launch locations: b) identify drone operators and pilots; c) predict “drone” flight paths; and d) accomplish these goals without detection by potential criminals at minimal expense. To illustrate DBR fabrication processes, the paper described model prototyping of camouflage and mimicked landscape features in two stages: 1) landscape superstructure, and 2) landscape camouflage. Fabricated models are now in preliminary field-testing prior to final testing at the prison site.

In broader context, the model landscape architecture DBR methodology presented here is consistent with general DBR methodologies structured in four iterative phases: 1) collaborative analysis of the practical problem; 2) development of solutions based on existing design principles and technological innovation; 3) iterative cycles of testing and refinement of solutions, and 4) researcher reflection to create design principles and enhance solution implementation (Reeves, T.C. 2006). From the standpoint of broader landscape architecture DBR applications, the paper suggests increasing potential for security design contexts across a broad spectrum of quasi-legal and clearly illegal conditions (Gregor). Extension of landscape architecture DBR akin to that presented here is immediately relevant to research currently underway through NSF sponsored grants related to the design of public space, given the rapidly increasing use of recreational and commercial “drones” (Cummings, M., Hala Nassar, Robert Hewitt). Similar NSF grants incorporate landscape architecture-based DBR to assess and redesign a wide range of urban transportation components, including street reconfigurations, street furniture design and placement, and detection warning systems to protect pedestrians, bicyclists, and UAV occupants. In anticipation of projected increasing automation and surveillance in the public realm across a wide range of contexts, DBR collaborations addressing the human/machine/environmental interface, akin to those presented here, suggest much more attention to landscape architecture DBR and its practical applications in this sector.

From a theoretical standpoint, extension of landscape architecture DBR akin to that presented here further supports foundations of landscape architecture design theory that contemplates increasingly insecure human/machine/environmental contexts. For example, while landscape architecture continues to contribute significantly to contemporary security design, contributions to date have focused more on design “hardening,” associated with a landscape’s ability to withstand physical attacks, especially the use of explosives delivered in large payloads. Increasing availability and advancing technology associated with “drones and like UAVs, however is widening the scope, range, size and intention of the security environment, To that point the above paper introduces model design considerations and concepts in line with “situational awareness theories” commonly associated with military and pilot navigation theory, as an important component of DBR. Further application of these theories in landscape architecture DBR, as well as other theories commonly in use among expanding collaborating disciplines offer important new ground for expanding definitions of contemporary landscape architecture theory in research and practice.

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Figure 1. NC Prison Surrounding Forest UAV Launch and Landing Site Analysis 2018, Image by the authors.

Figure 2, LWCS Embedded Landscape Components 2018, Image by authors and Prof. Mary L. Cummings

Figure 3, Red Tail Hawk Nest Prototypes 2018, Image by authors

Figure 4. 3-D modelling of the embedded nest in a tree seen from tree top and ground levels. 2018, Image by authors