Title

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The Drone’s Eye

Applications and implications for landscape architecture

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Introduction: the satellite’s gaze

As the most ‘grounded’ of the arts, landscape architecture has a more restrained legacy of engagement with technological innovation than other design disciplines. This reticence is partially a consequence of landscape architecture’s customary role as ameliorator of the negative impacts of industrialization. It also results from working with the medium of the real landscape, whose unruly nature tends to resist both straightforward representation and technological fashion (Kullmann 2014; St-Denis 2007). Nevertheless, innovation in mapping and imaging technology has clearly influenced the evolution of landscape architectural theory and practice. In the twentieth century, both the modern theodolite and aeroplane photography transformed the way in which landscape architects imaged, and hence designed, the landscape. Whereas the surveyor’s precise triangulation abstracted a site into discrete features, the aeroplane’s orthophotos provided intriguing glimpses into the material landscape of continuity and interconnectedness (Anker 2001).

Figure 1. Satellite image of urbanization of San Francisco Bay, California (© 2015 Landsat 8, USGS/ESA).

By the turn of the millennium, ubiquitous satellite imagery confirmed that the entire urbanised planet is comprised of landscape (Dettmar and Weilacher 2003) (figure 1). This recognition enabled the interpretation of cities as ecological systems, which ultimately led to the establishment and elevation of landscape urbanism within the design fields (Waldheim 2002). Around the same time, more user-friendly GIS interfaces and increased spatial datasets revived the instrumentality of mapping after three-decades of marginalization in the field. Advancing well beyond Ian McHarg's transparent film overlays, digital mapping augmented the physical landscape to include hitherto invisible webs of information, energy, and matter (Amoroso 2010).

Satellite imagery and satellite-derived GIS mapping—which little more than a decade ago required expensive manned aeroplane or helicopter imaging flights, visits to mapping agencies, or was simply impossible to source or create—is now widely accessible. Indeed, its convenient utility is such that landscape architects, like the wider public, are habituated to using satellite imaging and mapping as an extension of themselves in both professional practice and everyday life (Kurgan 2013). This seamless use of technology fits within a broader digitally driven pattern of dissolving divisions in society between work/leisure, professional/amateur and specialist/generalist (Prior 2010). Set within this context, online satellite mapping has undoubtedly invigorated wider cultural engagement with the landscape.

Nevertheless, although it may have facilitated the democratization of mapping and landscape, the satellite's remote gaze also has significant limitations. Across a century and a half, the eye in the sky rotated from the oblique to the vertical as it passed from hilltops and cathedrals to camera equipped balloons, kites, pigeons, and aeroplanes. Ultimately settling into low earth orbits, the satellite represents the apex of this skyward journey (Cosgrove 1999). While this lofty position reveals cultural and natural patterns and associations on the ground, the nuances and details that enrich the landscape are often camouflaged from view in shadowed, interstitial and underneath spaces (Rekittke et al 2013).

Although landscape architects are well practiced at endeavouring to decipher these ambiguities, even trained specialists with access to continually improving satellite image resolutions routinely struggle to accurately interpret events on the ground (see Monmonier 2002). This is partly attributable to the limited assimilation of Cartesian constructions of space into human spatial perception, whereby abstract planimetric forms habitually fail to resonate with an individual's perception of the world (Mitchell 1992; Pickles 2004). The recurring popularity of more immersive pre-Cartesian representations such as the bird's-eye-view is testament to this lingering apprehension (Söderström 1996).

These critiques also extend to GIS, which trades off site specificity for the prodigious expansion of mapping coverage. In real-world conditions, the interpolation of site mapping from large data sets diminishes the quality of spatial information at the site-scale at which the majority of landscape architectural project work occurs (see Couclelis 2009). Indeed, the confidence invested in satellite imagery is now so high that the traditional cartographic practice of ground truthing maps is attributed lower priority (see Chrisman 2005; Cosgrove 1999; Pickles 2004). The downgrading of ground truthing is symptomatic of a wider uncoupling between the map as a virtual construct and the terrain to which it ostensibly pertains. Given that landscape architecture is deeply invested in the agency of maps to interpret, abstract, conceptualize and reconfigure the ground, this untethering is significant for the discipline. Set against this background of detached satellite mapping, the capacity for next-generation drone technology to reposition overhead imaging nearer to the ground is potentially noteworthy for landscape architecture.

Research scope

Situated within the context of technological advancements in landscape imaging, this reflective article evaluates the applications and interprets potential direct and indirect implications of next-generation drone technology on the theory and practice of landscape architecture. Following Swaffield and Deming's (2011) classification of landscape architectural research methods, evaluation measures an outcome against a pre-existing standard, while interpretation makes sense of a phenomenon by placing it in context. Through direct experimentation with the technology on a real site, the products of drone imaging are compared against established site mapping and imaging standards.

Because of its novelty, extant literature that directly addresses the topic of drone-based imaging and mapping in landscape architecture is primarily limited to professional and non-critical contexts (see Girot and Melsom 2014). As is typical throughout the history of imaging innovation, this early discourse focuses on the technical capabilities of drone hardware and software. To address the broader disciplinary relevance of the topic, the article balances reportage of technical applications with discussion of key implications for the discipline. In doing so, the research contributes to the recovery of site specificity in the field, which innovation in mapping and imaging technologies have long promised in theory but delivered less so in practice.

Viewed within the wider context of pervasive community reticence towards surveillance, the probable proliferation of civil drones raises a range of pressing practical, legal and societal questions. These include: the need for a universal traffic control system; the further clarification of regulatory grey zones between professional and amateur use; and, as occurred with mobile phones a decade ago, general cultural consensus on socially acceptable use (Clarke and Moses 2014; Coley and Lockwood 2015). Although well beyond the scope of this article, the eventual resolution of these issues is an essential prerequisite for the seamless integration of drone imaging technology into landscape architectural practice and theory.

Next-generation UAVs

Gyroscopically stabilized multi-rotor Unmanned Aerial Vehicles (UAVs or drones) have been available for consumers to fly below 150m in the EU and 122m in the US since 2009, and reliably carried high-definition camera sensors since 2012. In landscape architectural practice and research, early adopters apply drones to site documentation, design communication and observation of cultural patterns and natural processes (Rekittke et al 2013). Whereas this first generation of drone technology requires active piloting from the operator, next-generation drones incorporate automated navigation. Through the integration of GPS with on board avionic sensors, automated navigation enables the pre-definition of virtual flight paths and the capacity to autonomously track the ground dwelling 'pilot' from the air. Automated navigation also facilitates the optical recording of topographic features, which are composited and orthorectified (geometrically corrected) into extremely high-resolution georeferenced aerial images (orthomosaics) and converted through photogrammetry into three-dimensional digital surface models.[1]

In practice, the various features of next-generation drone technology are intended for divergent user groups. Methodical topographic imaging, mapping, and modelling is principally calibrated to applications in agriculture, forestry, mining, construction and related sectors. In these contexts, areas of up to 40 hectares (based on current battery technology) can be captured as optical, near infrared or thermal data for a range of analytics including vegetation cover, soil saturation, water quality, and earth movement. Conversely, the self-tracking and virtual flight path features are primarily aimed at the mass-consumer market. Relinquishing direct control over avionics transforms drones into personal mirrors in the sky, enabling operators to witness themselves positioned within the surrounding landscape in the third person.

Drones in practice: functionality for landscape architecture

As a field that recurrently seeks new methods for capturing and representing the complex and indeterminate nature of the real landscape, the physical aspects of topographic drone imaging are most directly applicable to landscape architecture. However, as a social art, landscape architecture also has a vested interest in the cultural implications of the more consumer-oriented drone features. From this unique disciplinary position that spans professional and amateur domains of drone functionality, the following section examines primary functions of the technology as pertaining to landscape architectural practice.

Case study methodology

Drone imaging and mapping functionality is evaluated through direct field experimentation with drone hardware at a former landfill site. Situated on the eastern shore of San Francisco Bay in California, this particular location was selected as an ideal case study site for testing drone functionality on account of its highly complex topographic structure. Now designated as the Albany Bulb park reserve, the site comprises a deformed topography of concrete-and-rebar outcroppings, thickets of dense brush, networks of unplanned paths, and cultural artefacts left by former occupants (Kullmann 2017; Moffat 2015). While this complex landscape structure underpins the immersive experience of the site, it has also proven difficult to represent—and consequently, effectively plan and manage—using established mapping and imaging techniques. The site offered the additional advantage of being free of no-fly ordinances such those applied around airports and within national, state, and regional parks.

Three examples of drone hardware were selected to cover a spectrum of technologies, including entry level camera equipped consumer drones (DJI Mavic Pro equipped with integrated 12-megapixel CMOS sensor), pro-sumer drones combining more advanced features with consumer-quality sensors (3DRobotics Solo drone equipped with GoPro Hero4 sensor), and pro-sumer drones equipped with more advanced and sensors (3DRobotics Solo UAV equipped with Sony UMC-R10C sensor). Test surveys were carried out around noon in overcast conditions to reduce the impacts of sun shadow distortion on the photogrammetry process. The results of this case study are discussed below and summarized in Table 1.

	Drone imaging	Aeroplane imaging	Airborne LiDAR	Satellite imaging
1. Operating restrictions	**Variable** Restrictions operating near people and no-fly zones are increasingly common	**Medium** Air traffic control restrictions may limit when and where aircraft can fly	**Medium** Air traffic control restrictions may limit when and where aircraft can fly	**Low** Imaging satellite orbit well above territorial jurisdictions
2. Image resolution	**Extremely high** 1-2cm typical pixel size	**Very high** 7.5cm typical pixel size (5cm soon available in some markets)	**Very high** 1-2 metre point spacing typical for online data sources	**Moderately high** 40cm typical pixel size
3. Image capture restrictions	**Low** Image capture generally not impacted by cloud cover or winds under approximately 25 knots	**Moderate** Cloud cover and low atmospheric visibly limit image capture	**Low to moderate** The low altitudes typically flown for LiDAR capture are often below the cloud ceiling	**High** Cloud cover and with very fast and narrow orbit tracks limits image capture
4. Data refresh rates	**Potentially very high** As often as required but this is contingent on the user's availability to perform on site surveys	**Variable** With online subscription vendors, refresh rates vary significantly between	**Variable** Readily accessible LiDAR coverage is patchy but improving	**High but inconsistent** Very fast and narrow orbit tracks, and cloud cover limit refresh rate consistency
5. Historical data availability	**Currently low** With the potential to accrue over time as survey data is shared online	**Moderate** Online subscription vendors typically only store their own survey data	**Low** Due to the relatively new application of LiDAR, access to historical data is low	**High but inconsistent** High variation of historical image quality and high variation of data between locations
6. Digital surface model detail	**Extremely high** Photogrammetry detail is improved with the inclusion of oblique and eye level imagery	**Moderate** Aeroplane imagery is used to create Google Earth's photogrammetry 3D Buildings feature	**Very high** Offers additional benefit of higher precision and choice of including or excluding vegetation	**Low** Satellite photogrammetry is used to create Google Earth Terrain

Table 1. Comparison of multiple factors between drone imaging, aeroplane imaging, airborne LiDAR, and satellite imaging.

Function 1: high fidelity on-demand orthogonal imagery

In locations where drones are permitted, the capacity to self-generate highly detailed orthomosaics is the most directly transferable application of next-generation drone technology to landscape architectural practice (table 1.1). This function was tested at the Albany bulb study site using a high-definition camera equipped UAV flown at an altitude of 61m. This altitude was selected as a practical compromise between image fidelity, public safety, total flight time and image processing time. Using freely available software (Pix4Dcapture), the hundreds of raw images captured during the flight were assembled into a single, ultra-high resolution orthomosaic (figure 2).

Comparison against readily available aerial and satellite imagery for the site reveals significant clarity differentials (table 1.2). At 2cm pixel resolution, the resolution of drone aerial imagery (figure 2.a) is 14 times higher than fixed wing aerial imagery captured and hosted by a subscription-based online vendor (figure 2.b) and 625 times higher than satellite imagery hosted by Google Earth (figure 2.c).[2] In comparison to satellite and aerial imagery, the drone imagery provides an unparalleled overhead window onto the details of the Albany Bulb that closely correlate with the clarity of the landscape as perceived from the ground.

In addition to high fidelity, drone imaging could be undertaken whenever required and was not impacted by cloud cover (table 1.3). This contrasts with off-the-rack satellite and aerial imagery, for which cloud cover, orbits and other scheduling factors beyond the control of the individual dictate timing and refresh rates. Moreover, satellite imagery is normally filtered to prioritize general aesthetic criteria such as greenness, contrast, low cloud cover and short shadowing, even though less visually agreeable imagery may reveal important aspects of a site undergoing change over multiple timeframes (Sheppard and Cizek 2009). For the Albany Bulb site, Google Earth satellite imagery is typically updated anywhere between one and twelve times per year, while the subscription-based aerial imaging service is updated twice per year (table 1.4).[3] In comparison, user operated drone imagery can be updated through recapture flights at customized intervals as required (contingent on suitable flying conditions). When captured at relatively consistent intervals, repeat drone surveys can be composited into time-lapse sequences that animate landscape change across a day, season, or year. A comparative deficiency of user-generated content is the absence of a systematic imagery archive that predates the landscape architect's engagement with a site (table 1.5). This gap is likely to be filled over time, as drone mapping sharing platforms become increasingly populated with predominantly amateur content.

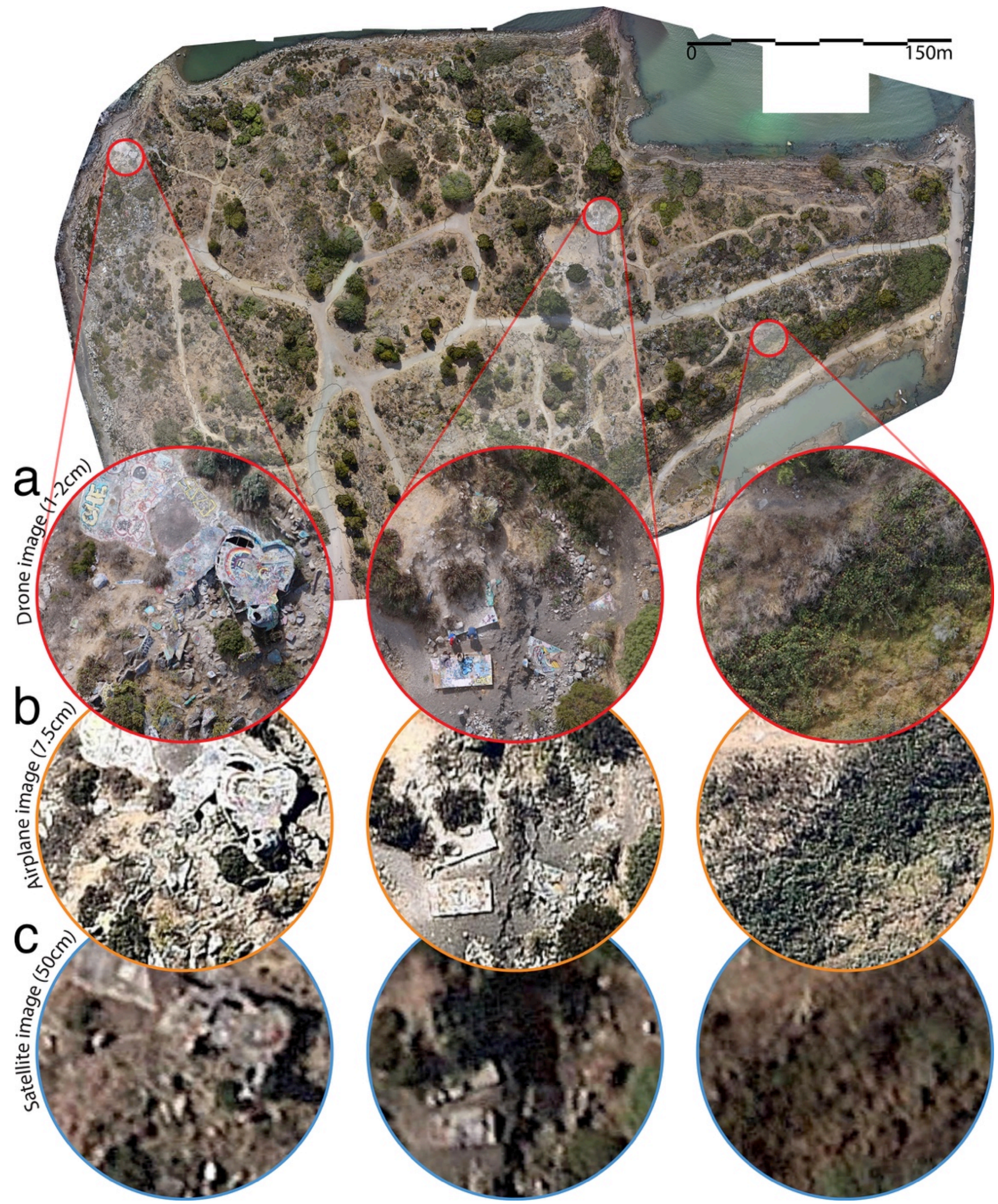


Figure 2. Drone orthomosaic of the Albany Bulb, San Francisco Bay, California, incorporating resolution comparison with aerial and satellite imagery (drone imagery captured using 3DRobotics Solo UAV equipped with Sony UMC-R10C sensor flown at 61m altitude and processed using Pix4Dcapture).

Function 2: digital elevation and surface modelling

The second category of drone functionality relevant to landscape architecture incorporates the third dimension in the mapping process. The same imagery captured for the orthomosaic of the Albany Bulb study site was digitally triangulated through the process of photogrammetry, which applies the three-dimensional parallax effect to overlapping images.[4] The digital elevation model that resulted from this process was converted into relief data with a contour interval of 1m (figure 3). Comparison against freely available aerial and satellite contour information for the site reveals significant clarity differentials. The drone map (figure 3.a) captures topographic detail that is only loosely represented in contours derived from airborne LiDAR (figure 3.b), and completely absent from contours interpolated from regional satellite-derived GIS relief data (figure 3.c). A clear point of differentiation between the various data sources is the treatment of vegetation, which is recorded as a surface in the drone digital surface model and eliminated in the LiDAR based digital terrain model (table 1.6). Depending on the site and needs of the landscape architect, the inclusion of vegetation is either a negative feature, in the sense that it obscures the ground plane, or a positive feature, in the sense that it registers vegetal form.[5]

The inclusion of overlapping oblique drone imagery (and potentially ground level photography) into the image set creates a more complete digital surface model. Using the same digital photogrammetric process used to generate digital elevation models, vertical and overhanging surfaces that appear distorted or remain obscured from vertical imagery are rendered in texture and form. This function was tested at a location in the Albany Bulb case study site that features a decaying concrete structure, paved areas, rocky ground and low shrubland. The area was captured in circular patterns at altitudes of 30m and 60m using a UAV equipped with a consumer 'action' camera (figure 4). Where available, comparable readily available techniques are presently limited to angled views in Google Earth with Photorealistic 3D Buildings and Terrain settings

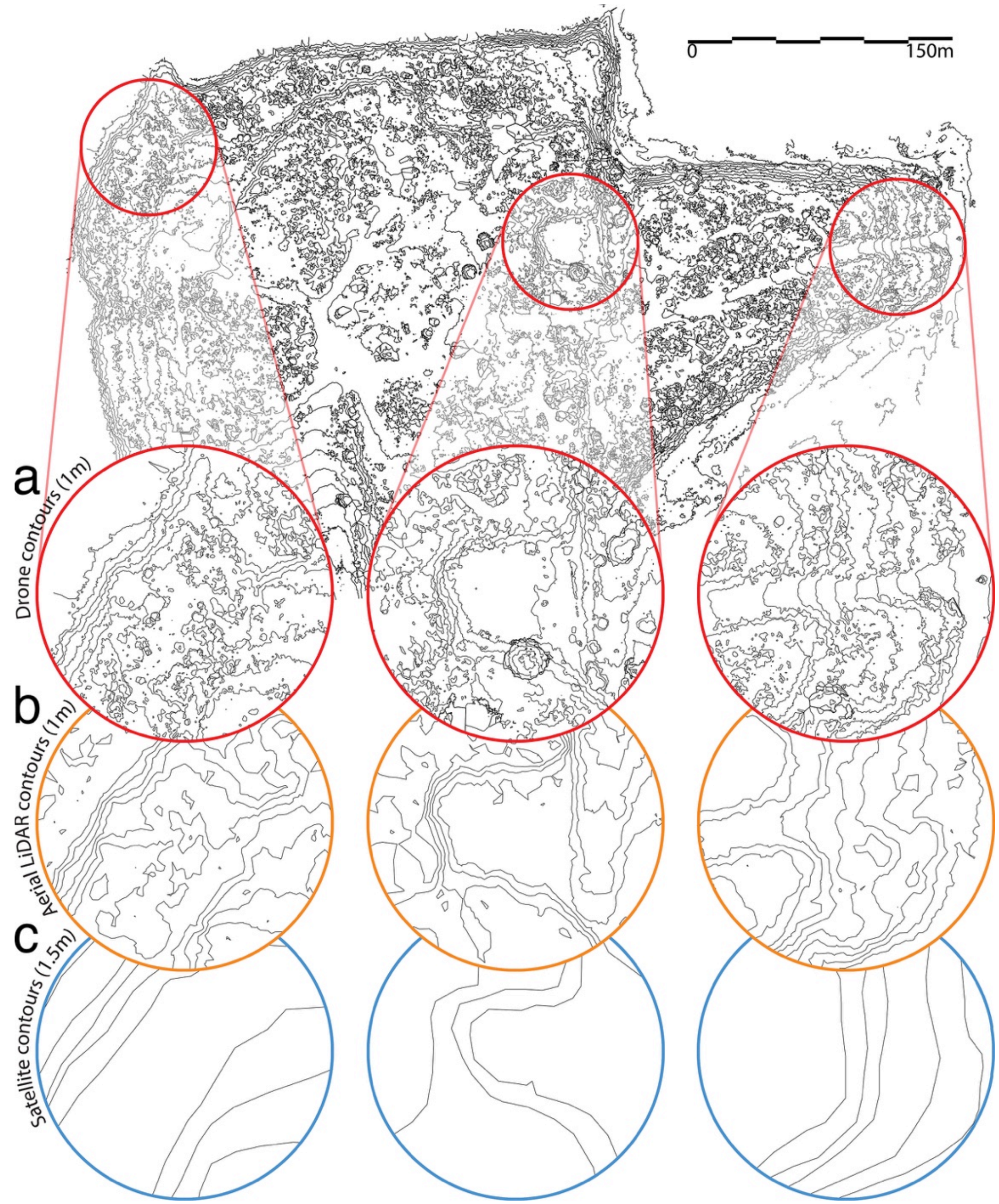
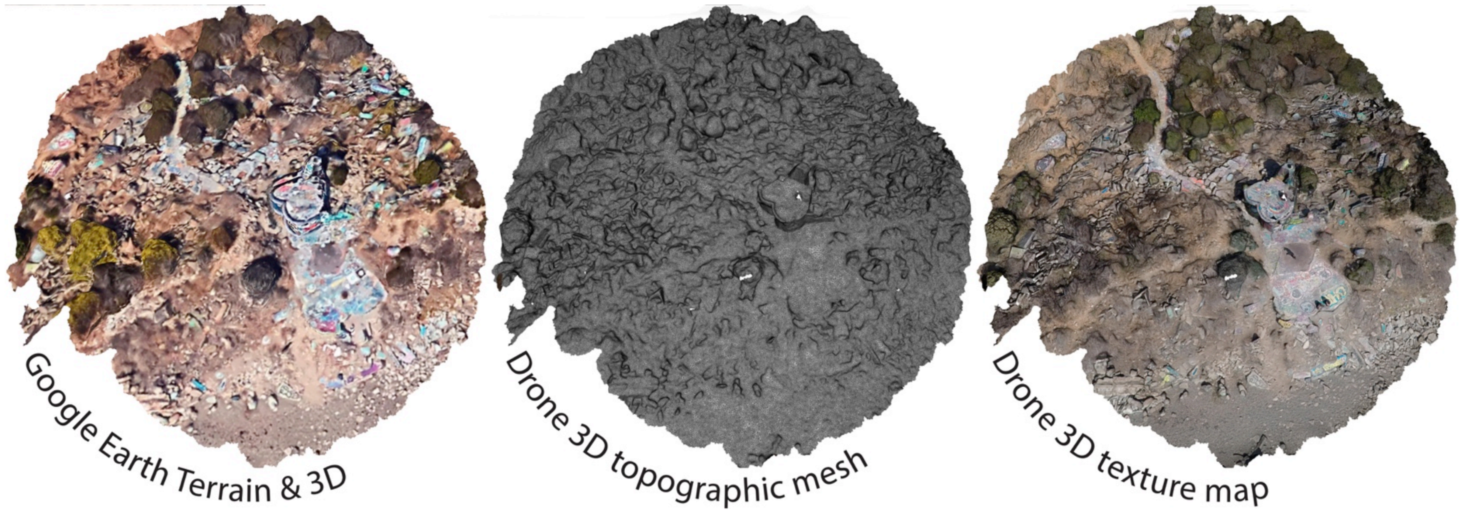


Figure 3. Drone photogrammetry of the Albany Bulb, incorporating resolution comparison with LiDAR and GIS contour data (drone photogrammetry captured using 3DRobotics Solo UAV equipped with Sony UMC-R10C sensor flown at 61m altitude and processed using Pix4Dcapture).

Figure 4. 3D model of topographic features at the Albany Bulb, incorporating detail comparison with Google Earth (3D mesh captured using 3DRobotics Solo drone equipped with GoPro Hero4 sensor flown at 30m altitude and processed using Pix4Dcapture).



activated. In comparison with this aeroplane-derived photogrammetry, the drone-based 3D model provides significantly more detail in both the topographic mesh and the texture map (table 1.6).

Function 3: fly-by-wire, self-tracking

The third category of drone functionality relevant to landscape architecture utilizes automated navigation in a cinematic, as opposed to cartographic, capacity. Camera tracking between virtual waypoints enables real landscapes to be recorded in motion using complex choreographies that are comparable to the gravity-defying experiences within virtual environments. While aspiring amateur filmmakers are most likely to adopt this feature, it is also pertinent to landscape architectural visualization. For two decades, the promise of fly-through animation has remained marginal in practice. This is attributable to the entrenched position of the static image in design communication and the technical challenge of convincingly simulating both the real and proposed landscape (Eggington 2012). Recent advancements in the sophistication and accessibility of virtual reality technologies provide a platform for greater integration of temporality and kinetics into landscape architectural design process and visualization. On compatible drones, immersive first-person viewing goggles that enable the pilot to embody the drone's viewpoint in real time further enhance the usability and control of fly-by-wire features.

The application of the self-tracking function to landscape architecture is less clear. This feature, whereby the drone camera autonomously tracks or circles the operator from a predefined distance, is primarily aimed at amateurs self-recording their outdoor activities. If literally applied to landscape architecture, the self-emphasis that this feature indulges conflicts with the entrenched disciplinary ethos of downplaying the profile of the designer in the context of the wider landscape (Kullmann 2016; Beardsley 2000). In this context, a more productive translation of the self-tracking feature positions the landscape architect as the steward or curator of a landscape experience. Testing this role at the Albany Bulb case study site, the landscape architect leads the viewer through the nuanced experiential qualities of the landscape (figure 5). Calibrated to track the landscape architect from 7m above the ground surface, the drone provides a third-person prospect of the excursion that simultaneously captures both the immersive qualities of the landscape and a sense of overall context and structure.

Figure 5. Still sequence of drone filming in self-tracking mode while exploring the Albany Bulb (captured using DJI Mavic Pro portable consumer drone equipped with integrated 4K HD sensor flown at 10m above and 15m behind the pilot's position).

Drones in theory: suppositions for landscape architecture

For landscape architecture, drone imaging and mapping technology offers on-demand high-definition oblique and planimetric aerial imagery, three-dimensional topographic modelling, and malleable cinematic-tracking. Image detail and user-control distinguish these features from established satellite mapping and ground survey techniques. The implications of these functions are manifested directly through application in landscape practice and research, and indirectly through wider cultural absorption of landscape themes. Through six suppositions that draw on key traditions and/or challenges in the field, the following discussion explores the potential implications of drone mapping in the professional discipline of landscape architecture.

Supposition 1: reviving the bird's-eye-view

For the purpose of design visualization, drones capture the contextual landscape with greater convenience, control and cost effectiveness than traditional manned aircraft. Drone imagery is also more precise and realistic than alternative virtual techniques that include sampling Google Earth (with Terrain and Photorealistic 3D buildings activated), or manually 3D modelling and rendering large tracts of the contextual landscape. With the aid of established digital perspective-matching techniques (Kullmann 2014; Lange and Bishop 2005), design propositions can be montaged into the drone-derived contextual imagery. Given that early adopters in landscape architecture already deploy drones for this purpose, more usable drone technology is likely to further empower the recent revival of the historically prominent bird's-eye viewpoint in design culture (figure 6).

Figure 6. Bird's-eye-view of the New Presidio Parklands Project, San Francisco (© 2014 The Presidio Trust).

Combining a structural view from above with close-range immersion in the landscape, the bird's-eye-view is particularly effective at 'naturalizing' a projected design concept into an existing setting. As its recurrent use to conjure the atmosphere of planned cities illustrates, the bird's-eye-view has proven particularly effective at projecting aspirational outlooks (Appleyard 1977; Cosgrove 2008). More recently, ubiquitous commercial air travel and the return of geometrically reconstructed overviews through Google Earth have demonstrated the universal capacity of the bird's-eye-view to engage the imagination (Busch 1996). James J. Gibson's ecological approach to perception provides a framework for explaining this capacity for engaging the imagination, whereby the imagined bird's-eye-view is a critical step in an individual's formation of a cognitive map of their environment. Once attained in the mind's-eye, the imagined bird's-eye-view is transcended so that the hidden and unhidden to fuse into a single mental image (Gibson 1986).

The key role of the imagined bird's-eye-view in the process of individual environmental cognition is also consequential for the drone-enabled proliferation of the representational bird's-eye-view. This connection is expounded through the lens of postmodern mapping, which seeks to substitute the traditional position of placeless Cartesian suspension above the field of survey with a multiplicity of maps constructed from within (Casey 2007). Although positioned in opposition to the distanced Cartesian overview, constructing individual maps from within is not limited to ground-level perspectives on everyday life. By extending an individual's horizons out over the surrounding landscape, the near-ground angle of the bird's-eye-view actually enhances the process of individual mapping and place making. The multiple oblique aerial angles that both landscape architects and amateur drone operators capture, share, and adapt delineate overlapping representations of local landscapes, and though association, many individual senses of place.

Supposition 2: digitally re-envisioning chorography

Despite its accessibility, the bird's-eye-view is unlikely to disrupt the rational order and instrumentality of the Cartesian plan, which since the nineteenth century has relegated the bird's-eye-view to a supporting role (Hinchcliffe and Deriu 2010). In this context, cultivating a link between the three-dimensional mapping features of next-generation drones and the deeper genealogy of the bird's-eye-view is potentially fertile territory for landscape architecture.

Although perceived today as a primarily pictorial enterprise, the bird's-eye-view is historically derivative of chorographic mapping practices. As the most grounded of Claudius Ptolemy's classical hierarchy of the natural order, the remit of chorography is the local region, where it registers features at the near scale in which everyday life takes place (Cosgrove 2008). Whereas the bird's-eye-view is painterly, chorographic representations contain both pictorial and quantitative information about the landscape (Cosgrove 1999) (figure 7). However, whereas quantitative geographical methods seek to eliminate the vagaries of interpretation, chorography admits the creative contribution of the individual mapper. This is embodied in the common Renaissance practice of depicting the mapper in the third person within the representation. In this sense, chorography fulfils the original conception of surveyable space, where the surveyor is situated within the same landscape that is being mapped (Casey 2002).

Figure 7. Renaissance chorographic survey of a region by Leonhard Zubler, 1607. (Creative Commons License 2016, Max Planck Institute for the History of Science, Library).

Notwithstanding these qualities, chorography's dependency on fixed oblique viewing angles fundamentally unbalanced the whole representation in comparison with the stable spatial consistency of the plan view (Söderström 1996). Moreover, problems of distortion and continuity further curtailed chorography. With each chorographic map constructed to a unique internal logic and ending at a forest, ridge, or horizon, assembling numerous overlapping and distinctive chorographies into a coherent whole proved problematic.

Digital techniques potentially release chorography from these historical deficiencies. Key characteristics that historically problematized analogue chorography may be reinterpreted as opportunities for landscape architecture through drone-based digital chorography. First, the static viewing angles that destabilized analogue chorography are substituted with a multitude of viewpoints captured during the drone imaging process. When digitally assembled, this kaleidoscopic array of angles is conveyed through user-centred mapping, which dynamically reconfigures a map representation to follow the map-user's point of view (Hackenberry et al 2006). Granting the map-user active input enhances the historical essence of chorography as analogous to a highly malleable lens that continuously changes viewpoints (Nuti 1999). This function is particularly suggestive of application in design communication and community participation processes.

Supposition 3: returning to the field

Current regulations and technologies dictate that drone operators accompany their equipment to (or close to) the mapping site. The act of launching the drone upwards from the ground reverses the downward zoom of satellite imagery and places the landscape architect physically on the site and virtually within the frame of the map. Although future developments in offsite drone dispatching may dilute this practice, at present drone mapping technology complements the landscape architectural tradition of direct onsite experience, observation, and mapping. Landscape architecture is potentially enriched by this digitally escorted return to the field from which the discipline became progressively insulated in the digital age (see Girot 2013).

Even in the advent of remote drone dispatching, the drone's close relationship with the ground reintroduces a form of fieldwork to the site mapping process (see Ninsalam and Rekittke 2016). Although not physically grounded in the traditional sense of the surveyor's eye-level inspection, the drone's eye extends the scope of fieldwork into the topographic zone between the ground and the low atmosphere. This 'thickened' version of fieldwork fulfils the original terms of site surveying, whereby working from the inside out, an overview of landscape is attained (Casey 2002; Cosgrove 2008). In rediscovering the role of surveyor—as opposed to mapper—the landscape architect becomes spatially and temporally embedded in the process of site delineation.

The capacity to represent nuanced landscape characteristics directly impacts the landscape architect's ability to engage, retain or amplify these qualities through design. Therefore, just as abundant satellite imagery fuelled disciplinary interest in large-scale landscape systems, a drone-enabled revival of fieldwork suggests increased disciplinary focus on retaining and incorporating the pre-existing qualities of sites. This focal shift is particularly applicable to the exploration and mapping of complex and ambiguous post-industrial wastelands and other marginal sites. Although these marginal sites are often suggestive of fertile alternatives to traditionally designed public space, the coarse fidelity of satellite mapping typically omits their more elusive characteristics. Consequently, these sites have proven challenging for landscape architects to represent, engage, and advocate for (see Kullmann 2015a; de Solà-Morales Rubió 1995). The drone's capacity to capture detailed site qualities suggests considerable capacity in supporting these activities.

Supposition 4: re-integrating scales

Viewed within the context of two decades of emphasis on large-scale associations, systems and infrastructures, renewed interest in the near-scaled landscape constitutes a significant shift in disciplinary focus. This shift in scales is most constructively positioned as an enhancement, rather than displacement, to the agency of satellite imagery and mapping in landscape architectural practice and discourse. Overlapping scales are particularly relevant to addressing the persistent schisms between site design and regional planning, the city, and the region, and between gardens and landscape (see Baird and Szczygiel 2007; Howett 1985). Normalizing the garden, the city, and the region into a unified theory of landscape architecture remains an important on-going aspiration for the discipline (Girot 1999; Waldheim 2016).

Overlapping scales of landscape mapping and imaging are also relevant to the continued evolution of landscape urbanism. In particular, the drone's eye is potentially instrumental in grounding landscape urbanism, whose 'satellite ecologies' have been criticized for overlooking the place-making aspects of urbanism (see Heins 2015; Thompson 2012). Although some of the more accessible lessons—such as respecting riparian zones and programming outdoor space—proved applicable, landscape urbanism remained more convincing as a lens on the urban condition than a grounded instrument of urban design (see Kullmann 2015b). Reconciling the obstructive division of the larger systemic scales of landscape urbanism with the local place-making scale of traditional urbanism is directly relevant to the ecological and social challenges that contemporary planetary urbanism presents (see Brenner 2014).

Hypothetically, the reintegration of scales creates a platform for other innovations within landscape architecture. The reinvigoration of socially based approaches to landscape design is one such possible by-product. As occurred with ecologically based approaches, the influence of socially based approaches to landscape design began to wane in the 1980s. In both instances, declining influence was due to the limitations of the analogue tools available at the time and the perception that the associated methodologies led to prescriptive design outcomes (see Gifford 2007; Hamilton and Watkins 2009). However, unlike social approaches, ecologically based approaches underwent a significant revival in the late 1990s, as GIS and satellite imagery catalysed the creative potential of ecology and mapping. By illuminating the scale at which people interact with the landscape, drone imagery has the potential to contribute to social factors undergoing a similar digitally propelled creative renewal (see Birtchnell and Gibson 2015).

Supposition 5: revisiting determinism

Although revolutionary for the field, McHarg's original analogue mapping process was heavily critiqued for its data-driven determinism that arguably left no space for creativity (Eckbo and Porterfield 1970). While the second wave of GIS-based creative mapping sought to reconcile this 'analysis paralysis' of too much data with the 'fantasy fatigue' of design whimsy and metaphysics, in practice a division lingers in the form of an inflection point between gathering information and projecting ideas (Corner 1999). In a traditional interpretation of the design process, the designer places the data aside and simplifies the site in order to clarify key features and tectonics. In this context, the high level of detail that the drone's eye offers landscape architects is potentially as deterministic as the satellite-derived data of McHarg's suitability analysis.

Here, the application of ground-based laser scanners is instructive. A decade and a half after designers first experimented with its creative potential (see Lange 2002; Weir 2001), the technology remains underutilized in mainstream landscape design practice. While the persistently prohibitive cost of the apparatus is undoubtedly a factor, low uptake is possibly also attributable to the hyper-precision of the technology itself. When applied to the landscape, the exactitude of the laser-scanned point cloud freeze-frames features and phenomena that are complex, ephemeral, and variable. With the mapping fidelity of this technology surpassing the fidelity at which the designer can conceptualize form, it is possible that some landscape architects may be hesitant to creatively engage with such intensely comprehensive site data.

To some extent, any design determinism attributed to either highly detailed laser scanning, or drone mapping may eventually be neutralized through further familiarity with the technology. The history of technical innovation in creative media supports this premise, whereby new imaging technology is celebrated first for its technical accomplishment before eventually being assimilated into creative practice (North 2005). Moreover, the optical basis of drone-based photogrammetric mapping is unlikely to match the precision of lasers (ground or airborne) or, indeed, the surveyor's theodolite. However, although drone-based photogrammetry may be unsuitable for a site survey for a complex construction project, it provides a level of accuracy that is appropriate to many other of the wide variety of project types and phases that landscape architects undertake. For example, for preliminary design, community advocacy, or speculative work, the technology differentiates useful spatial, material, and atmospheric site information, while also maintaining a degree of openness for interpretation.

Supposition 6: reimagining everyone as a landscape architect

While the practical professional application of drone imaging and mapping is most evidently applicable to landscape architectural practice, the cultural impact of the drone's near-ground perspective is also significant to the field. Mirroring the evolution of smart phone usage, the use of drones as appliances of personal vanity is likely to outstrip the use of drones as deliberate instruments of surveillance and cartography. When first recording imagery, the amateur drone operator's attention will invariably fixate on the surveyor (themselves) situated within the image/map. However, once this third-person vanity is satisfied, attention turns to the near landscape, which fills out most of the image/map. Consumers seeking to record their activities inadvertently capture more of the landscapes in which they are immersed than they do their own bodies in action.

The professional discipline of landscape architecture has a vested interest in how this circumstantially imaged landscape is utilized. This imagery is unlikely to remain inert in the same manner that eye-level self-photography reconstitutes landscape as a cropped scenic backdrop. By its very nature, the bird's-eye-view implies a certain degree of imagination and envisioning of alternative futures, and through its historical connection to chorography, implies a degree of instrumentality for enacting those visions. Given that imagining and actuating landscapes is traditionally the task of landscape architects, expanding this role into wider culture through mass-consumer drone imaging hypothetically broadens cultural awareness of landscape architecture.[6]

The propagation of the landscape architect's point-of-view within wider culture suggests both opportunities and challenges for the field. On the one hand, two decades of absorption of landscape themes into other spatial design fields proved to be a dispersing influence for the profession of landscape architecture (Kullmann 2016; Miller 1997). On the other hand, it also empowered the field, as widespread access to satellite imagery altered how society views itself and its environment, and increased engagement with natural and cultural landscapes at the structural scale. Correspondingly, the low-aerial view point that drone imaging proffers is likely to exert substantial agency over how individuals view, image and cognitively map their immediate landscapes. This near-scale view potentially catalyses broader public literacy and engagement with place making, which would constitute a positive development for landscape architecture.

Conclusion: the drone's agency

The enhanced imaging and mapping capabilities of next-generation drone technologies are highly applicable to the near-scale at which landscape is both experienced and designed. Given that existing satellite derived mapping technologies and techniques poorly serve this scale, the drone's eye exhibits significant transformative potential in landscape architectural practice and theory.

In practice, landscape architects gain the capacity to aerially image and map landscape sites to a level of clarity comparable to the world as perceived from the ground. Several characteristics distinguish this capability from incumbent techniques. First, camera-equipped drones can access the interstitial underneath and in-between spaces that contribute to landscape character but remain obscured from 700km low earth satellite orbits. Second, in contrast to the short, pre-set image capture windows of low earth orbits, drones enable direct temporal control over imaging. And third, whereas designers engaged in mapping currently mine satellite, aerial and spatial data that agencies and corporations provide, drones facilitate direct unfiltered on-site user engagement in the creation of content.

In theory, instrumentalizing the bird's-eye-view through chorography provides a platform for re-assimilating the strategic advantages of top-down aerial sensing with the grounded inside-out fieldwork of site observation. Just as ubiquitous satellite cartography brought ecological and infrastructural scales into view for the discipline, the situational nature of this re-envisioned chorography suggests the recovery of ground truthing and a reengagement with site specificity.

This potentially facilitates the reintegration of large and small scales in discourse, which is relevant to the on-going quest for a more unified theory of landscape architecture.

In addition to these direct implications, the wider cultural impact of the drone's low-aerial perspective is also significant for landscape architecture. Everyday user participation in self-actuated near-ground imaging may contribute to the assimilation of key landscape themes into the existing culture of image sharing. This also feeds back into landscape architecture through the recent trend of wider digital technological innovation becoming increasingly accessible and relevant to the landscape architecture. Along with a host of newly accessible visualization techniques derived from the fields of cinema and gaming, drone-imaging technology participates in the overdue integration—as opposed to appropriation—of the digital into landscape architectural theory and practice.

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Notes

[1] In addition to the multirotor UAV technology that is the focus of this article, fixed wing UAVs offer several advantages, including longer flight times, higher sensor payload capacities and more stable flight characteristics. However, with less portability, larger takeoff/landing zones and the inability to hover, fixed wing drones are unlikely to become as ubiquitous as multirotor consumer drones.

[2] This comparison is based on Satellite image resolutions of 50cm. Since regulatory changes in 2014, Google Earth satellite image resolution has been incrementally increased in some locations to 40cm and less frequently to 30cm. The online aeroplane image vendor Nearmaps™ claims an image resolution of 7.5cm.

[3] Typical update rates derived from the author's examination of Google Earth™ history function between 2012–2016 (inclusive), and examination of Nearmaps™ history function between 2015–2016 (inclusive).

[4] Stereophotogrammetry is possible with as little as 50% overlap between images, although higher overlaps of over 80% provide the most accurate results (see Devriendt and Bonne 2014).

[5] Drones equipped with LiDAR sensors combine the advantages of the drone's proximity with the precision and vegetation penetration of LiDAR. While this technology has been too expensive and heavy for general use on consumer drones, this is rapidly changing as lighter and less expensive sensors become available.

[6] This notion draws on Hans Hollein's positioning of 'everyone as an architect' within the all-encompassing scope of modernism's total-design, which dissolved boundaries between design scales and specialization (Hollein 1968).