I am an imposter. They told me so... finally... it's out...
What am I to do now with the life of agreeable fakery that binds me, in claimed feebleness, to things and to people, to suspect humanity. We could wonder about this... and wander... together... as if it were some new territory to discover... a blank map, some terra incognita... a Moby Dick\(^1\) on the move with Gregory Peck clutching at the ropes of his Harpoon, dead yet still alive at the same time... Step right up, Boys, Girls, and Androgynes, you'll get your money's worth... Log is so cheap... let yourself be what you're not, too, slip into a schizophrenic zone, a thick soup of contradictory desires emerging from the clay like the hydrocephalic Golem-Golum... that way you, too, can naively elude our unpredictable and irreducible conflicts, which are part and parcel of domination and slavery, destruction and the new, fusions of ugliness and beauty, obstacles and possibilities, garbage and fresh blooms, threats and various forms of protection, technicist prowess and forces of nature...
Here everything comes together and interlocks. It's all here, in the making, in a movement in the making... Step right up, Boys, Girls, and Androgynes... Let yourself get carried away, to see and tell what connects us, the people behind this Log, but also all the rest, the ones who stir up trouble and take shelter in these friendly, territorial, womblike refuges where you can circle around in the ill winds that blow through congregations and metropolises, in all those places, those little hotspots. And anyone can follow suit, as long as it goes toward making a "place" that we can mine for whatever remains habitable, desirable, or musical in the gloomy universe of planetary noise. It's good, it's really good. It comes in the form of a human group, a repeopling of the social structure in the form of a dream. A dream of social climates, empty lots, existing forms of nature and people and enhanced intimacy. It alters what exists, it marks out vanishing lines, subjectivities, it throbs in the form of

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1. In Herman Melville's novel, the animal's whiteness should be viewed as one of the last known lands to still resist the mapping of the world and its reduction. A last vestige of a time when nature did not allow itself to be tamed or ruled... before its sudden, violent, blinding awakening (Hurricane Katrina, El Nino, cyclones Jeanne, Tomas, and Nargis, Hurricane Xynthia, Typhoon Ewiniar, earthquakes in Indonesia, Japan, the coastal tsunami of Fukushima... a chain of devastating uncertainties that we couldn't predict, despite our seismographic sciences). Faced with the autistic, blind, deaf and dumb violence of our mechanisms of technological, industrial, mercantile, and human domination, nature reacts... in a stuttering version of the original chaos... in a mutiny against human organization... Gaia seems to take its revenge. Nature is not an ideological "greenwashing" in some cozy living-room politics, neither is it a millenarist eschatological Eden park, which we've been very lucky to escape from, liberating ourselves from the hedonist harvester so we can negotiate with the dark, hostile forces that were hiding in the depths of the forest...
Flying is a human dream. Propelled by the development of engine power, the aspiration to achieve manned flight and the subsequent desire to gain control over airspace were realized in a single century. Flying became a commodity, which made it possible to transport both people and goods around the planet many times faster than by naval or ground transportation. By reinforcing the exchange between countries and continents, flying has become a ubiquitous driver of globalization and, as currently witnessed, our subsequent planetary urbanization.

Today, rapid advancements in digital technology are changing the future of flight in a way that is profoundly relevant to architecture. Flying robots are about to conquer the sky. Consequently, airspace will be physically “addressable” by machines and therefore, counterintuitive to its intangible nature, a constructible “terrain.” Here, robots not only exhibit their inherent potential for dynamic motion, they also open up airspace to architecture by enabling aerially performed material interventions.

The implication of robotic flying machines is that any airspace can be deliberately accessed and affected as easily as it can be sensed. As exemplified by drones (generally used for military purposes), flying machines today can operate and locate themselves without the help of an on-board pilot. So-called Unmanned Aerial Vehicles (UAV) fly by the control of sensors and algorithms. They adjust their movements to forecasted trajectories and correct for external influences like wind gusts or payload. To locate themselves in airspace, they compare map data with reality or relate to spatial reference systems. Beyond simple motions, today flying robots autonomously perform such highly dynamic maneuvers that observers are inclined to attribute to them the skills of living organisms. Their sophisticated control algorithms could be regarded as a late triumph of applied artificial “intelligence,” as digital control dynamically negotiates and tames the instabilities of flight and the volatility of air. For the first time in history, airspace is accessible in such high resolution – literally measurable in centimeters – that it becomes “tangible” to architecture.

1. In the last decades, the Internet has complemented the powerful physical means of transportation by adding a generic transmission network for all kinds of immaterial information around the globe in almost real time.


3. Access to aerial locations has also led to significant changes in cartography. One example is the use of autonomous UAVs in landscape visualization and modeling of Alpine landscapes. Research has been done on the Gotthard Pass using a combination of remote sensing with drones and terrestrial laser scanners at the ETH Zurich. See Christophe Girard, “Scales of Topology,” in New Geographies 4: Scales of the Earth, ed. E. Hadi Jazary (Cambridge: Harvard University Press, 2011).

The most radical similarity between digital space and its most immaterial physical equivalent - airspace - is free spatial motion. Just as an “object” can be animated to take any path through a void and infinite digital space, flying robots are, while still adhering to laws of physics, free to move through the air in any direction without being constrained by machine-inherent boundaries. Since the advent of digitally controlled fabrication machines in architecture, robots and CNC machines have typically had fixed positions and defined working areas, which delimit the range of action and thus constrain the size of work they can act upon. As machines are usually smaller than buildings, their use in architecture is limited to the scale of a fragment or component. Flying robots, on the other hand, are neither bound to the ground nor restrained to a fixed working range, acting in a space substantially larger than themselves. This virtually infinite and truly spatial range of action privileges them to work at an architectural scale.

Gramazio & Kohler’s recent project, Flight Assembled Architecture, designed in collaboration with dynamic systems pioneer Raffaello D’Andrea and exhibited at the FRAC Centre Orléans in 2011, was conceived in the architectural tradition of real-utopian speculations about the future of the human habitat. A vertical village for 30,000 inhabitants arranged as a porous cylindrical structure 600 meters tall, the project is a speculation on the aggregation of an autonomous hyperbuilding comprising supersized modules that locally accommodate most of the functions a village requires. The FRAC exhibition featured a live robotic buildup performed by four flying quadrotor helicopters. The vehicles collaborated to erect a six-meter-high model of the vertical village at a scale of 1:100 by aggregating 1,500 lightweight modules to create the self-stabilizing structure. A network of intercommunicating computer programs guided the vehicles to the exact locations in three-dimensional airspace for pickup and subsequent nonstandard placement of each module. From its earliest stages, the design integrates computation, material, structure, and fabrication with aerial robotics in an intensive, collaborative enterprise.

In previous architecture exhibitions featuring live robots, visitors experienced the computer-controlled behavior of the robotic flying vehicles as natural and organic. Despite their obedience to flight paths - tracked in real-time by a motion capture system - the dynamic motions of the quadrocopters appeared fluid and without artificial bias. The vehicles attracted the attention of spectators in an almost meditative way, and the depositing of the transported modules was often applauded, as if the robots themselves were capable of appreciating human encouragement.

Airborne Aggregations

Flying robots introduce not only a novel perspective on airspace and robotics, but also on construction, where advancements in material systems and processes will presumably lead to profound changes in the design method, performance, and expressive language of architecture. The conditions for robotic construction are entirely liberated from the bottom-up accessibility of material, men, or machine. Structures can be erected without scaffolding or cranes. Robots loaded with material move independently of the structure they are building until they momentarily engage in the act of depositing material (or other forms of physical interactions). This new mode of materializing architecture has the potential to influence future design that is becoming inherent in their spatial (and temporal) morphology while still adhering to laws of gravity. Here - and this is relevant for future architectural practice - a new economy of nonstandard aggregation comes into play, in which elevated, remote, eccentric, and overhand locations are all accessible on equal terms.

Of course, building with flying vehicles puts forward manifold challenges. These entail a profound rethinkining of materials and their aggregation or assembly processes. A key issue for materials is weight. As the load capacity of flying machines is limited and the machines’ agility directly depends on their load, the development of high-performance lightweight materials will be necessary. The amount of material deposited with each building action might be substantially smaller than in conventional construction, but such-a development hints at an increase toward a higher resolution characteristic of robotically fabricated architecture. Another key challenge for aerial construction is precision. Stabilizing a flying vehicle at a seemingly fixed position in order to affect its environment from that particular “point in space” is highly difficult and requires us to replace the need for absolute precision in construction with more tolerant aggregation systems. If the quest for precision is changed, designs emerge that proactively give room to and express ambiguities and singularities resulting from constructive imprecision and dynamic material processes, turning these into deliberate architectural qualities.
Assembly under such conditions goes well beyond lifting a part into a position that is geometrically predetermined by other parts. Building "in the air" should leverage the full robotic degrees of freedom by arranging parts in ways so that their truly spatial, nonstandard joining adds relevant complexity and unprecedented, possibly rhizomatic qualities to the design. Aggregations through the secretion of nonsolid materials and other forms of material processes are also possible, as long as they match the lifting capacities of the machines and maintain energy and material resources efficiently. Even material delivery can change, with local materials or parts from a nearby setup factory flown directly to the building site. As a result of such profoundly altered constructive paradigms, radically new, nonstandard "aerial construction kits" need to be developed, which in turn can trigger surprising and intricate architectural inventions. This reconfiguration of material systems leads to an architecture that reinvents its agenda and fosters a new language and articulation of space through differentiated aggregations.

**Computational Piloting**

Flying robots manipulate material according to a detailed digital blueprint and operate under the explicit guidance of an architectural design. In projects such as Flight Assembled Architecture, the robotic system has a detailed overview of all relevant design and construction information at building time. The system is guided by design data while at the same time sensing itself in its environment. Thereby, the possible amount and differentiation of design information, as well as the complexity of behavioral rules that guide such robotic systems, is virtually unlimited.

Digital control enables robots to communicate and synchronize among themselves and respond to their environment in real time. Consequently, robots can manipulate or transport materials not only individually, but also in joint cooperation. Current "brute force" aerial construction methods — for example, with cargo helicopters — which rely on manual control and machines with overdimensioned capacities thus give way to more adaptive "soft" aerial alternatives, which use multiple, weaker robotic agents that collectively perform a desired action in an intelligent dynamic cooperation. Such robotic systems can even have complementary abilities, very much like workmen with different skills collaborating on today's building sites. Because they share a three-dimensional space in real time, their work capacity is to a large extent scalable. Myriad flying vehicles can cooperate in a swarmlike manner by distributing the workload among themselves and adaptively optimizing their collective performance by constantly reenforcing spatial demands amongst themselves. Far beyond mere optimization, this robotic multiplicity shifts the logic of making architecture from a coarse, serial, and industrial logic to a fine-grained, nonstandard, and truly digital resolution.

The better a virtual model links to its physical reality, the more likely computational design impacts that reality directly, since there is no need for translation or reinterpretation. A three-dimensional spline curve drawn in a CAD program, for example, can already be directly interpreted by a flying vehicle as a trajectory of movement through real space. An advanced computational design of such trajectories can become a deliberate set of differentiated movements of multiple flying agents in space. All six degrees of freedom for translation (xyz coordinates) and rotation (roll, yaw, and pitch) — classical definitions in mechanics — plus dynamic attributes such as velocity and acceleration link digital design directly to aerial robotics. Their free use as design parameters depends on the flying vehicle type and the desired motions. A multirotor vehicle, for example, can access any position and yaw orientation in space, while roll and pitch are usually coupled to its motion, and therefore cannot be designed independently. A dynamic, computational design using such parameters not only controls the spatial flight path along coordinates, but also prescribes its behavior — the timing and sequencing of material operations. Design decisions therefore orchestrate the correlation of spatial movements and material actions at building time, reminiscent of early digital architecture's use of the timeline in animation software to create form. Two decades later, the information produced no longer needs to be "frozen" in a static state of formal expression. Instead, it literally arranges the spatiotemporal motion and material action. Space, time, and architecture coincide again in the new, real-time perspective of the second digital age. Here, a new design methodology evolves, one open to envisioning architecture not only as a geometric final form, but also as a complex and refined generative process of robotic materialization.

In the future, by proactively designing robotic behaviors, the architect will have the option to literally intervene in the construction process. Aerial robots will become the architect's remote agents on the building site, materializing.
Aerating Verticality

Like the Internet, a prospective aerial architecture could not have existed in a predigital age. Produced digitally in all its stages, it “liquefies” the membrane between design and materialization while adhering to principles of reality. In an ideal scenario, aerial architecture explores new design methods that create an explicit synthesis between the capabilities of aerial robotic aggregations and prospective digital design techniques. Aerial architecture is thus not to be misunderstood as a closed definition, but rather as an open-ended, speculative mode of inherently architectural research and experimentation that values proactive risk-taking.

The scale at which aerial robotic construction will become operational remains unknown. On a small scale, for example, following the legacy of Frei Otto, Konrad Wachsmann, and Buckminster Fuller, lightweight tensile or space-frame structures can be taken further into nonstandard, aerial modes of production. But taking into account aerial architecture’s inherent bias toward construction at great height—its liberty to materialize itself “anywhere” in space—its most natural sphere of influence might be on a larger scale that addresses the verticality of the densely populated contemporary city. Today, with the spread of global urbanization, the distancing of human habitat from the natural ground has become a distinct reality in many densely populated cities. This rising “into the air” is expressed not so much as a poetic detachment of architecture from the ground like the vision of certain utopian projects of the 1950s and ‘60s, but as a pragmatically motivated, ever-expanding, and rather profane verticality, characterizing the morphology of today’s urban fabric and its skyscrapers. While doubts remain about the motivations and architectural qualities of many vertical urban developments, the ongoing evolution and expansion of the human habitat into its vertical dimension can hardly be denied. A half-century after Yona Friedman’s Spatial City, Constant Nieuwenhuys’s New Babylon, Archigram’s Instant City, and the Metabolist’s daring proposals for postwar Japan, the socioeconomic reality of mass urbanization has prepared and conditioned people to live in dense urban landscapes that expand activities to all accessible dimensions.

Interpreted as a truly spatial habitat, aerial architecture attempts to challenge the prevailing monotony, hermetic character, and plain verticality of high-rise typologies, which result not only from functional issues such as structural or economic constraints, but also from antiquated and repetitive design strategies. Three-dimensionally modeled building skins for dynamic shapes only superficially alter the high-rise in appearance. The aim is therefore to overcome the sheer vertical extrusion of building mass and its “shaping” by venturing into open, spatial, and constructive research on the manifold intricacies and omnidirectional possibilities of computationally designed aerial aggregations that transform the densely populated environments from the inside out. By taking advantage of the temporary suspension of material gravity provided by flying agents, the scope and typologies of physically buildable urban formations can be expanded.

This particular breed of architecture is not only conceivable as mountable, but also demountable, adaptable, or reconfigurable without the need for wasteful destruction. Structures can be designed to remain open-ended in order to be partially rearranged and dynamically adjusted over time. Conceived for temporary structural equilibrium, they are deliberately open to reinterpretation and reappropiication in contrast to the conventional high-rise, in which the lifespan tends to be rather short, and recycling largely unsolved. It is even possible that large buildings become replaceable “mobile homes,” fully or partially reusable in different locations and contexts, having second or third lives. The challenges, scales, and possibilities of aerial architecture remain to be fully explored.

Architecture in Suspense

Aerial architecture involves and affects humans, materials, goods, and information—the earthbound society, city, and landscape. The proposed shortcut between the aerial and the digital realm crystallizes a future space for intensive architectural exploration, drawing from contemporary design techniques as much as it draws from innovative aerial processes of making. From this synergetic perspective, it is well imaginable that flying robots will become productive airborne tools that trigger a new kind of architecture. But one needs to remain cautious so as not to fall into idealist romantic positions.
or succumb to positivist technological propaganda. The aim is a subtle reality-based research that promotes the embodiment of contemporary design techniques in a constructive culture. The desire is to create resilient architectural positions that can undermine current power structures through similar productive technologies without adopting reductive, opportunistic, or cynical attitudes. This savoir-faire is a powerful one to hold in architecture’s hands.

Yes, aerial architecture is as much about seduction as it is about power. Tenuous moments of flight, fluid dynamic motions, and deliberate behaviors lay bare and challenge the fundamental capacities of computational formations that are in the hands of today’s designers. Materialized through flying robots and material interactions, its intricate characteristics are key to leveraging contemporary computational design and fabrication strategies. If aimed at “running,” and thus performing, in human space and time, computational design in architecture is not disconnected from, but naturally integrates physical aspects of materialization, construction, fabrication, and robotics in its culture. Computational designs are thus no longer confined to or conceptually rooted in the virtual, but intervene in explicit, perhaps even autonomous, manners into our habitat. In fact, computational design becomes inseparable from the material, spatial, and social reality of architecture.

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