ONCE UPON A TIME THERE WERE FIREWORKS

THE NEW NOCTURNAL DRONES LIGHT SHOWS

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DRONE LIGHT SHOWS
FIREWORKS
SKY DRAWING

This paper investigates the recent innovative application of drone information technology to create complex visual narratives in the night skies, which refer to the more traditional images made by fireworks.
The object of study involves two main topics. The first consists in a critical analysis of bibliographic literature in the field of pyrotechnic art through the consultation of texts from the sixteenth century to the twentieth century. The second is represented by the analysis of the recent digital technique of setting up colored images, created in the night sky by the movement of luminous drones. Compared to fireworks, the attention towards this type of luminous aerial views is decidedly increasing. In this sense, the luminous drones present themselves as alternative fireworks, reusable with countless different visual narratives and three-dimensional choreographies synchronized with musical performances. An increasingly widespread development of this digital display technology is therefore conceivable in the future. Therefore, it is of interest here to analyze the methods of implementation for the construction of the image and the transition from drawing 'on paper' to drawing 'in the sky'.

INTRODUCTION

Nowadays, the innovative technology of the luminous drone is attracting the public attention thanks to the realization in the night skies of complex visual narratives, consisting in colored images created in the sky by the movement of luminous drones and that refer to the more traditional images made with fireworks.

This paper refers to the disciplinary area of drawing and investigates the configuration of visual images in the night skies through the comparison between the analogical techniques of fireworks and the digital ones of light drones[1].

The object of study involves two main topics, to which investigation methodologies correspond. The first consists of a critical analysis of the bibliographic literature in the field of pyrotechnic art through the consultation of texts from the sixteenth century, including: *Pirotechnia del signor Vannuccio Biringuccio* (Biringuccio, 1540); *La Pirotechnia osia Trattato dei Fuochi d'Artificio di Giuseppe Antonio Alberti* (Alberti, 1749); *Illustrated Catalogue of Day/Night Light Bomb Shells of Hirayama Fireworks* (1883); *A Pirotecnia moderna. Tratado general de Fuegos de Artificiales y manera práctica de prepararlos … por Juan B.ta Ferré Vallvé* (Di Maio, 1916). From these readings we can deduce considerations regarding the pyrotechnic schools for the aerial shot, the analysis of the holidays' lighting scenarios, the description of the configuration methods in the sky of the different visual effects of the fireworks ('firecrackers', 'spears', 'snakes', etc.), the variety of luminous designs depending on the geometric arrangement of the so-called 'stars' (balls of black powder and other chemical compounds) and their coloring to emphasize the plastic effect.

The other topic is represented by the analysis of the recent digital technique (2012) capable of creating colored images in the night sky thanks to the movement of luminous drones. The ability to visualize concrete (and not projected) visual forms in the sky depends on conceiving the drone as a 'pixel space' or as a single light point, part of a choreographic group

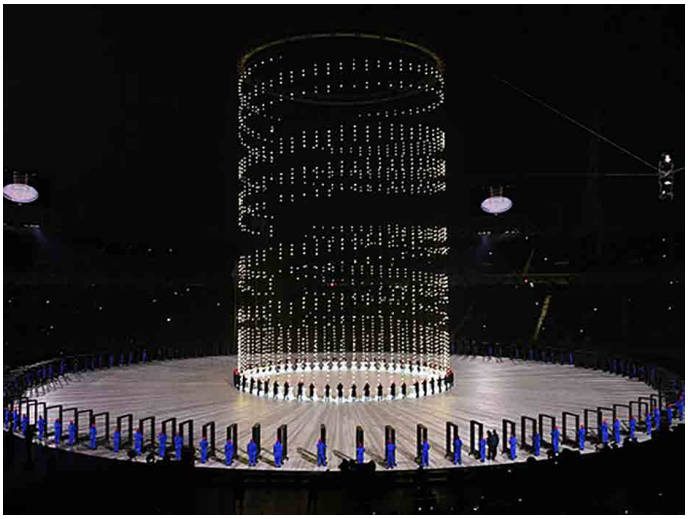

Fig. 1 Alexey Filippov, Sputnik, AFP (photo by), *Light drones used in the opening ceremony of the 23rd Winter Olympic Games in Pyeongchang*, 2018. Retrieved March 3, 2021 from <https://www.agi.it/sport/olimpiadi-invernali-2018/giochi_invernali_corea-3471364/news/2018-02-09/>

Fig. 2 Joseph Mayo (photo by), *Intel Drones x Super Bowl Halftime Show with Lady Gaga*, 2017. Retrieved March 3, 2021 from <https://clios.com/music/winner/partnerships-collaborations/intel/intel-drones-x-super-bowl-halftime-show-with-lady--23870>

called a 'swarm of drones', whose simultaneous coordination by units ground control with proprietary software allows you to create flat or three-dimensional, fixed or dynamic, monochrome or colored images in the sky.

At the moment, there are few companies on a global scale able to carry out luminous drone shows in the night skies (outdoor) as well as indoors at very high costs, both for the number of drones to be available and for the specialized skills to guarantee (computer engineers, flight experts, videogame and/or cinematographic animators). However, even if still limited to exceptional events such as the corpo-

rate ones of *Intel* or *Damoda* or, in 2017, the Lady Gaga concert and the closing ceremony of the *Fortune Global Forum* in China or the opening ceremony of the Winter Olympics in South Korea in 2018 (Figures 1, 2), light drone shows are also affecting New Year's Eve parties such as 2020 in Shanghai and 2021 in Seoul and Scotland.

PYROTECHNIC TREATISES FROM THE FIFTEENTH TO THE TWENTIETH CENTURY BETWEEN DEVICES SHAPE AND FIREWORKS DESIGN

The pyrotechnic exhibition design bases its theoretical and applicative knowledge in multidisciplinary fields of a chemical, engineering, mathematical and geometric type. Also on the scientific value of drawing as a field of cognitive investigation for the design specificities of firing machines, which require geometric rigor to correctly set and define 'jet' and 'shape' of the fire.

In this context, this study offers a critical analysis of bibliographic production in the field of pyrotechnics through the study of texts (Italian, European, Oriental) starting from the sixteenth century, bearing in mind that, although originating in ancient China, the stages historical technological development of this practice are based mainly on the studies of fire artillery.

Specifically, this study does not aspire to examine the staging of the fireworks exhibited by Italian, European and Eastern treatise writers in their multiple thematic aspects, but to investigate mainly the result from the point of view of the formal representation that they once assumed after being 'threw' up in the air. Associated with a broader investigation of the extraction techniques, melting and preparation of the combustible material, it will be highlighted how the technique of setting up the 'structural shape' of the firing or deflagration device will prove to be the main functional component for determining shape and design of the fire.

For this reason, the analysis of the geometric configuration of the device is essential to that of the jet of fire, so much so that the introduction in subsequent eras of more advanced technological and construction systems have allowed us to imagine ever more creative pyrotechnic shows.

The *Pirotecnia* (pyrotechnics) in 1500 was the art of melting metals to extract them from their minerals and pour them in cannons and statues. Fireworks originate in the pyric compositions, worked to engage combustion effects and similar to those of black powder, from which they are derived. In this sense, black powder is one of the most used raw materials in pyrotechnics, alone as a launching charge or mixed with other materials in different compositions.

One of the first Italian treatises, who illustrated its principles, was Vannuccio Biringuccio (1480-1539) in his treatise entitled *Pirotechnia del signor Vannuccio Biringuccio* (Biringuccio, 1540). Structured in *Ten books*, the treatise describes with clarity and precision the techniques of mining and smelting as well as the art of goldsmithing and glassmaking. *Book VIII* illustrates the *Arte piccola del Gitto* (small art of fire jet) (p. 438) while in *Book X* appear the indications *De gli ordini di far fuochi artificiati* (orders to make fireworks) (p. 549). Here, the 'saltpetre' (potassium nitrate) is described as one of the indispensable materials (together with sulfur, coal, turpentine oil and powerful wine spirit) to obtain a compound which, after cooking (to remove the humidity), is used for the construction of underground mines –invented by Francesco di Giorgio Martini (1439-1502) and applied for the first time by Captain Pietro Navarra (1460-1528)–, trumpets and tongues of fire, *pignatelli* (fire thrown by hand) and fires, which burn in the water. For the staging of urban shows and religious and/or civil festivals, the treatise writer proposes the creation of 'pinwheel' shaped fires which, although "harmful to all living things [...] invite people to long to see them" (Biringuccio, 1540, p. 606). In fact, in 1886, after centuries of uninterrupted tradition, the danger of this firework led to the prohibition of

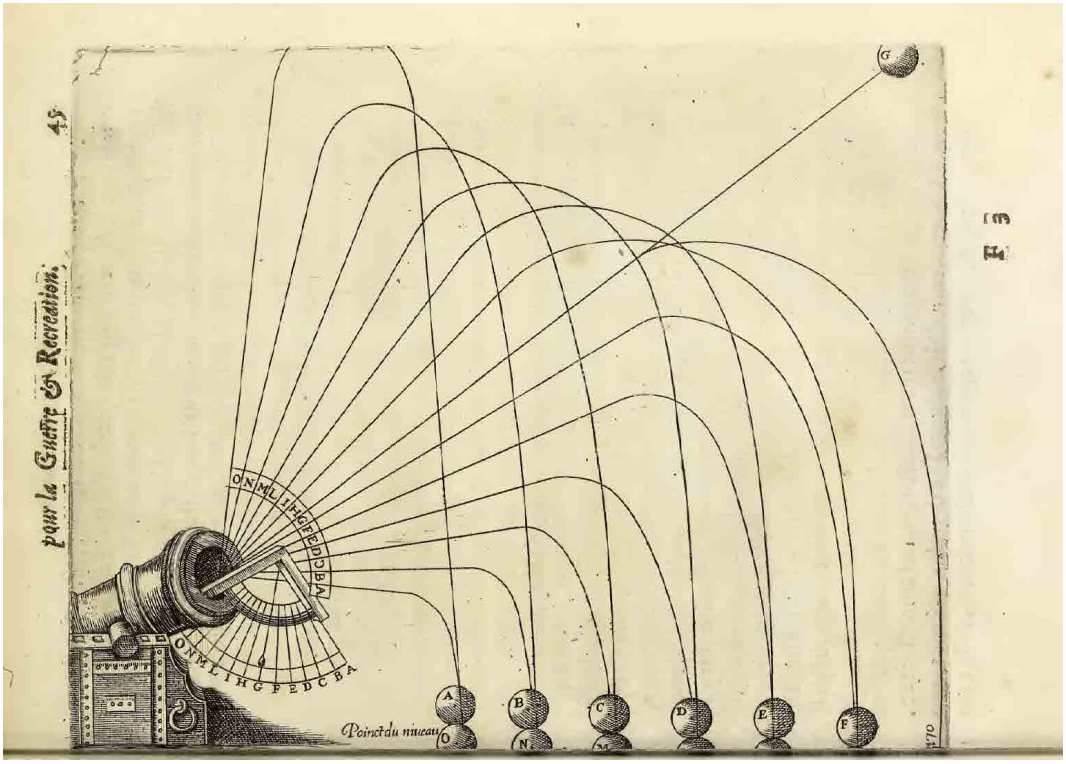

Fig. 3 Hanzalet Lorrain, *Comment il favt caifster le canonpour donner au butproposé*, 1630 (how to launch the cannon to give the proposed goal. Hanzalet Lorrain, 1630, *La pyrotechnie de Hanzalet Lorrain …*, p. 45, fig. 3).

the fireworks show in Rome of the famous Pinwheel of Castel Sant'Angelo, conceived by Michelangelo Buonarroti.

Scholar of artillery technique and trained on the work *La pyrotechnie …* by the French Hanzalet Lorrain (1630) (Figure 3), the Bolognese essayist Giuseppe Antonio Alberti (1712-1768) describes in his treatise *La pirotechnia, o sia, Trattato dei fuochi d'artificio* (1749) the shaping of 'simple' fires such as rockets, serpentines, cassettes (precursors of modern air fires), fountains and jets. As already Biringuccio, Alberti focuses on the description of pinwheels and their different shapes. Starting from the 1500s, the pinwheel had been one of the main fire devices most used and, together with the rocket, the most used pyrotechnic technique for night shows in religious and/or civil celebrations.

The pinwheels were paper canes, attached to light wooden wheels hinged in the center to irons and loaded

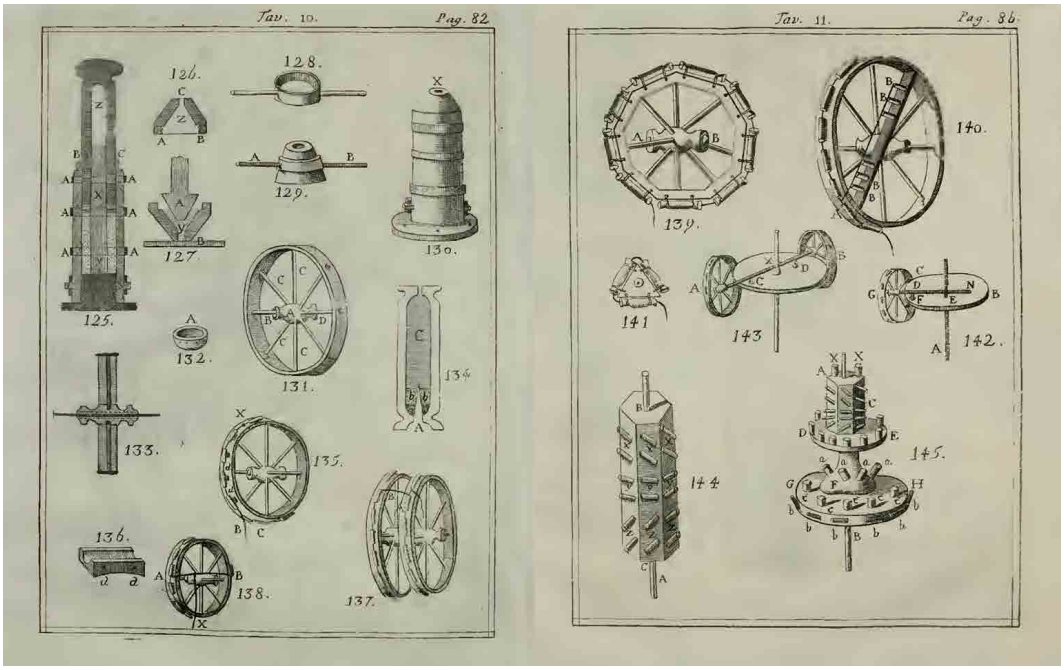

Fig. 4 Giuseppe Antonio Alberti, *Delle Girandole e Di varie cose le quali fanno il loro effetto girate dalle girandole*, 1749 (about the pinwheels and various things to make their effect. Giuseppe Antonio Alberti, 1749, *La pirotechnia, o sia Trattato dei fuochi d'artificio …*, pp. 82, 86, tables 10, 11).

with explosive mixture which, as they burned, turned the wheel so rapidly that the fire appeared to be constantly moving. However, the lightness of the device did not guarantee long duration for the show, so much so that Alberti proposed a solution consisting of several wheels stacked around the central iron.

From the analysis of the iconographic apparatus of the treatise, it is possible to state that the wheels of the pinwheels had both vertical and horizontal position (Figure 4), depending on the choice from the observer's point of view. The vertical solution generated pinwheels perfectly visible at eye level, while the horizontal ones required more complex devices, placed on top of pyrotechnic machines designed by architects, and set designers for religious and/or civil celebrations. The different inclination of the pinwheel rods (glued at various heights) threw the fire in different directions. The effect, called 'cascade', is represented in the 1775 painting by Jakob Philipp Hackert, where the fireworks display is set up on top of Castel Sant'Angelo in Rome (Figure 5). The versatility linked to the

Fig. 5 Philipp Hackert, *Feuerwerk auf der Engelsburg in Rom*, 1775, Weimar. Retrieved March 14, 2021 from <https://it.m.wikipedia.org/wiki/File:Hackert,_Feuerwerk_auf_der_Engelsburg_in_Rom,_1775.jpg>

different arrangement and inclination of the rods on different wooden supports allowed the treatise to codify the staging of pinwheels in the shape of sun, moon and stars (as Star of David) and, by inserting these pieces on an iron, the individual effects could produce even more 'complex games'.

In addition, in his treatise Alberti also expounded the technique of water fires such as bombs, globes, sprays and pinwheels, warning the reader that the combustible mixture required more rigorous preparation so that the fire could do its job correctly in water. However, after the consultation of numerous volumes of bomb technicians of the past and practiced the art of the pinwheel, in his work Alberti stated that he had never made a pinwheel in the shape of an "ellipse or ovate" because "a good thing never came out" (Alberti, 1749, p. 88). A cross-shaped rail device remains documented in *Plate 12*, where the rod placed on its end had to generate an ovate-shaped pyrotechnic effect (Figure 6).

The eighteenth century represents a creative season for art and the study of the fireworks for entertainment and shows. The countless engravings of festivals in the main European capitals bear witness to this, including that of 1749 entitled *A View of the Fire-Workes and Illuminations at his Grace*

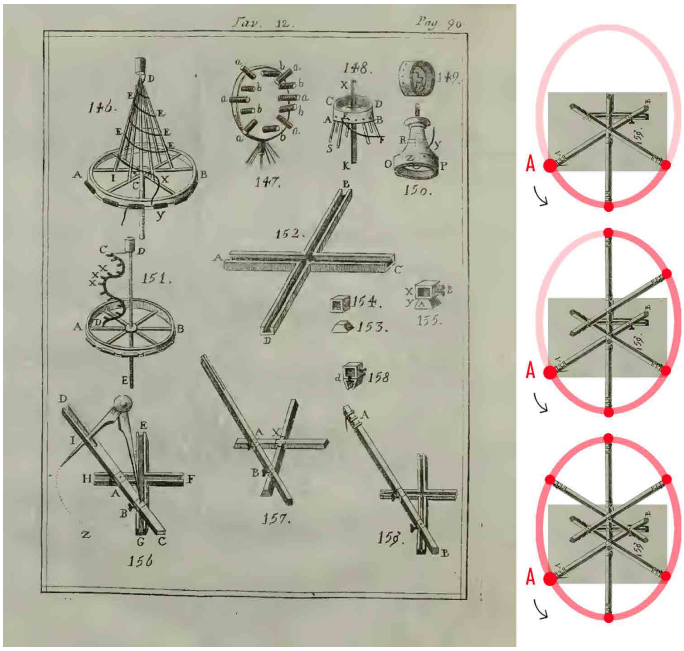

Fig. 6 Giuseppe Antonio Alberti, *Velie Girandole in forma Ovale*, 1749 (pinwheels in oval shape. Giuseppe Antonio Alberti, 1749, *La pirotechnia, o sia Trattato dei fuochi d'artificio …*, p. 90, *Tab.* 12. On the right, reconstruction of the oval by Vincenzo Cirillo).

the Duke of Richmond's at White-Hall and on the River Thames, on Monday 15 May. The work, preserved in the *British Museum*, illustrates the fireworks display for the benefit of King George II of Great Britain who celebrates the signing of the treaty at *Aix la Chapelle* in 1748 for the end of the war of the Austrian succession. Particularly interesting are the plastic effects used for the occasion and described in the side panels of the image including the wheel, the sun, the spirals, the water rockets (Figure 7). The event, however, retains a fatal memory because during the fireworks show, one of the fireworks landed on the main pavilion, lighting several thousand fireworks and killing many spectators.

In the 19th century, the modern meaning of pyrotechnics was born, defined as that art of delight in which fire is a sign of exultation, a splendid synthesis of 'light' and 'color'. From this moment, in fact, the fireworks are colored because mineral substances are added to the combustible compound which, at the time of the explosion, produce colored trails (mainly red, yellow, green, blue, orange, purple) at the sight of the

Fig. 7 Unknown, *A View of the Fire-Workes and Illuminations at his Grace the Duke of Richmond's at White-Hall and on the River Thames, on Monday 15 May*, 1749. Retrieved March 14, 2021 from British Museum Digital Collection.

spectator. Some nineteenth-century treatises are exclusively dedicated to colored pyrotechnic art, guiding the reader to the choice of materials for the visualization of specific colors, as in the case of the oriental work *Illustrated Catalog of Night Light Bomb Shells of Hirayama Fireworks* (1883) (Figure 8) and exclusively dedicated to the chromatic display of fire at night, or of the *ratado general de Fuegos de Artificiales y manera práctica de prepararlos …* (1902) edited by Gregorio Hermosa.

At the same time, the so-called 'day firebombs' were born in Japan, colored objects made of very light silk paper in which the heat of the small fire placed inside allowed them to fly. The bombs, thanks to a mortar, threw these objects (currently called 'lantern') into the air which, once they reached a certain height, fell apart. Manufactured in Iokoama by *The Kirayama Fireworks Co.*, these 'bombs' were

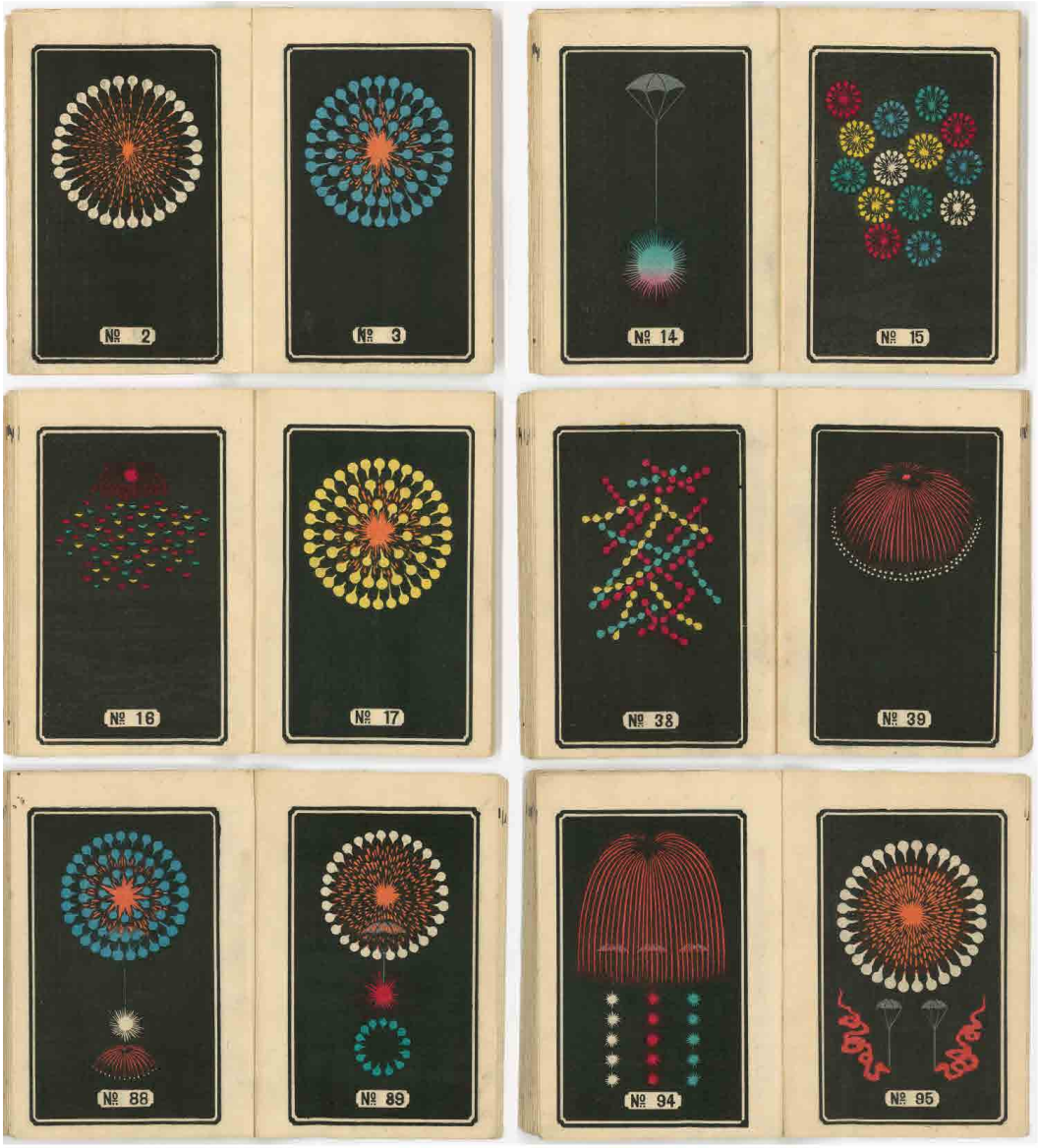

Fig. 8 Hirayama Fireworks, 1883. *Illustrated Catalogue of Night Bomb Shells*... Retrieved March 14, 2021 from <http://archive.org/details/IllustratedCatalogueOfNightBombShells>

illustrated in the catalog of 1883 (already mentioned for the nocturnal one) entitled *Illustrated Catalog of Day Light Bomb Shells of Hirayama Fireworks* (1883) (Figure 9) and, not containing explosive materials, were exported to other countries without restrictions.

Fig. 9 Hirayama Fireworks, 1883. *Illustrated Catalogue of Light Bomb Shells* ... Retrieved March 14, 2021 from <https://www.lib.city.yokohama.lg.jp/Archive/DTRP0320?SHIRYO_ID=4855>

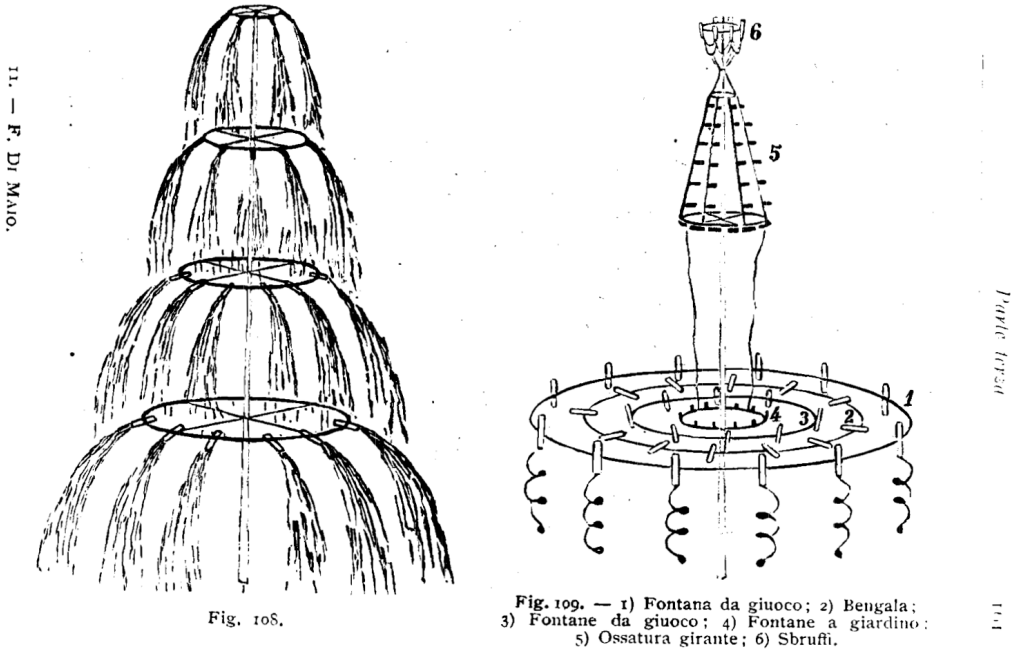

Fig. 10 Francesco Di Maio, *Mortaletti*, 1916 (Francesco Di Maio, 1916, *Pirotecnia moderna*, p. 159, figg. 105-106).

In the early 1900s, pyrotechnic treatises became more and more technical, codifying and grouping fires, elementary components, and more complex devices into multiple types (Di Maio 1916). In particular, the types of fires were collected in: fixed (fountains, *tracchi*, spears, flames, candles, *sbruffi*, *mortaletti*); aerial (rockets, dragons, artichokes); bombs, grenades and gaskets (small fires within larger compositions, stars, snakes, doves, rain). The elementary components (simple devices) are divided into bunches of flying rockets (rods), wheels, sunflowers, pinwheels, columns, spirals while the complex ones, also called 'big fires', are based on the combination of the simple ones (Figure 10). At the same time, it is precisely from this century that an ever-increasing awareness of the violent impact and the lack of sustainability that this art, louder than bright, has on the environment and on the well-being of people and animals is born.

DRONE LIGHT SHOW: THE SHOW OF FLYING PIXELS. METHOD AND TECHNOLOGIES

Nowadays the technological progress is more and more pushed and quick. Consequently, hardware and software, that are generated to carry out a task in a definite sector, are quickly adapted and brought to perfection in order to accomplish objectives that are different from the native ones.

In this direction an example is given by UAS (Unmanned Aircraft System) which was created for military purposes and used afterwards for civil aims also thanks to the growing interest showed by the scientific community (Remondino, 2011, pp. 25-32; Nex, 2013, pp. 1-15) which has offered its substantial contribution. In fact, these systems are used and studied in a way more and more frequent and in different disciplinary fields, such as : agricultural and forestal management (Grenzdörffer, 2008; Aicardi, 2016, pp. e1- e7); generation of Digital Terrain Model (Wani Sofia, 2012, pp. 272-275; Mustafa, 2016, pp. 1439-1445); monitoring of landslides and of mountainous and rocky walls (Mancini, 2013, pp. 6880-6898; Dall'Asta, 2015, pp. 391-397); interventions due to natural disasters (Baiocchi, 2013, pp. 21-25; Chiabrando, 2017, pp. 69-76); 3D reconstruction (Oniga, 2017, pp. 551-558); documentation and 3D mapping of cultural and archaeological heritage (Bolognesi, 2014, pp. 113-119; Gutierrez, 2016, pp. 10-13; Pérez-Alvárez, 2019).

The UAS owe their great success to the typical characteristics of versatility, manageability and stability of cameras. To these characteristics it is added the strong development UAS are undergoing as regards their control which leads them to be equipped with increasingly sophisticated and performing on-board computers. The on-board computer of a UAS uses numerous sensors to maintain the stability of the aircraft in order to facilitate its control.

Among these systems, the responsible for managing the position of the aircraft is the satellite positioning system which also allows the UAS to follow paths defined by several points in space (waypoints) and consequently to carry

out planned trajectories. Therefore, the miniaturization of the positioning system, supported by the possibility of the combined use of one or more satellite constellations, offers the possibility of realizing imaginable scenarios, such as coordinating single examples of UAS in trajectories in order to form a single unit, to avoid collisions and to receive signals concerning the context in real time to modify the relative parameters in a short time. Furthermore, in the fields of robotics and computer science, systems and algorithms of vision and artificial intelligence are developing to solve complex problems in a way that robots (including UAS) organized in swarms achieve their goal programmed in a completely autonomous way and without hindering each other (Araki, 2017). The persevering search for procedures to fly simultaneously hundreds (Graf, 2018), if not thousands of aircraft in formation, together with new forms of spectacularization, is giving the possibility to experiment a new approach of representation (Figure 11).

A few years have already passed since September 2012, year in which the Research and Development unit of Ars Electronica, *Futurelab*, proposed a new form of unprecedented representation at one of the main European open events, the Linzer Klangwolke in Linz, in which often previously light shows of fireworks and lasers were proposed and were remarkably successful (Dorfman, 2018). On that occasion, a fleet of quadcopters made up of 49 aircraft equipped with LED lights enchanted the audience by flying in swarms and executing predetermined and planned trajectories, by giving life to 3D wireframe images of abstract and real shapes. It is possible to carry out a parallelism between the digital representation of a shape and its repetition through this method of drawing three-dimensional figures in the air. So, every single aircraft is a pixel which, when placed in relation with the others (one-group relationship), is able to represent a vastness of shapes and dynamic sequences on the gigantic display of sky.

The single-whole relationship opens up a very current research in the field of artificial intelligence, in order to artificially

Fig. 11 *The flight of 2198 miniature UAV over Saint Petersburg*. Retrieved March 3, 2021 from <https://www.everythingrf.com/News/details/11280-high-precision-gnss-modules-from-u-blox-used-in-the-record-breaking-drone-air-show>

re-propose the natural phenomenon known as 'swarm intelligence' (Rivière, 2020, pp. 4249-4256). In this way the single autonomous UAS is able to fly in the group by interacting both with the others and with the surrounding environment.

This is made possible by the use of a software with artificial intelligence logic to which each UAS sends signals of various kind, on the base of which decisions will be made quickly in order to act and also avoid each form of disasters. The speed with which technological and digital innovations make progress suggests that the time interval of separation from that first experience has been characterized by profound transformations and improvement in this field.

If it is considered that in just three years the number of aircraft involved has doubled, *Intel* and *Ars Electronica Futurelab* entered the *Guinness World Record* with the "Drone 100" show at Ahrenlohe airport in Germany, and from that same date, in which twenty-five operators controlled individually 4 aircraft, just two years later in December 2017 a swarm of 1,180 light UAS were guided by a single operator during the closing show of the *Fortune Global Forum* in China.

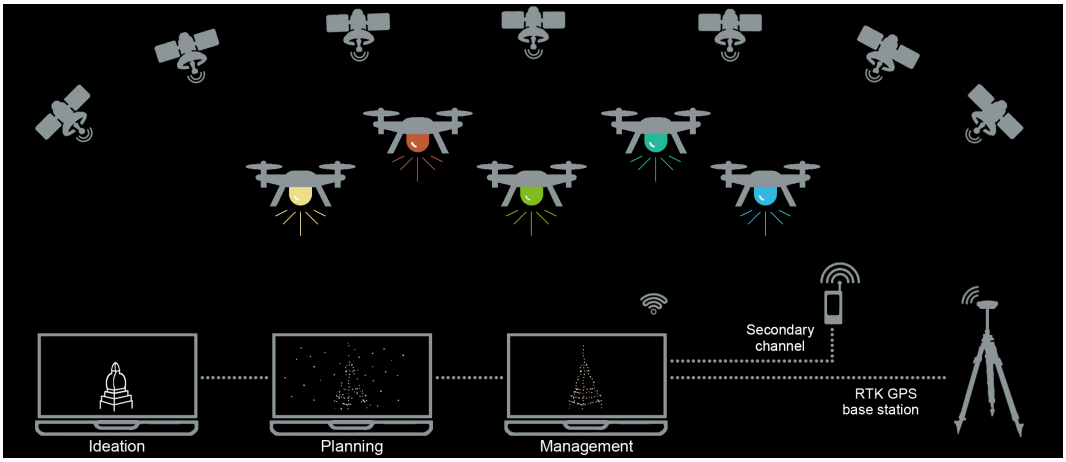

Fig. 12 Rosina Iaderosa, *Methodological process and technologies used for drone light show*, 2021.

The record was broken a few months later, in July 2018, on the occasion of the 50th anniversary of the *Intel* company, which realized the flight of a swarm composed of 2,018 UAS (Combodrone, 2020) over its headquarter in Folsom, California. In order to obtain both increasingly performing results and a system with deep compatibility between the parts, some manufacturers have developed specific hardware and software, such as the small Shooting Star quadcopter from the *Intel* manufacturer (Intel, nd).

Since it is necessary to respect characteristics of lightness and safety, unlike the commercial ones, these models are only equipped with a satellite system and a high-power LED light. Furthermore, the aircraft do not consist of single elements assembled by means of screws, but of a single frame in plastic and polyurethane foam to which the four propellers are attached, in turn inserted in protective cages. Also for these models the satellite receiver is a fundamental component in the success of the operations. In fact, it allows to plan the route in advance and establish the beginning, the end, any hovering points and those for changing the shades of the lights. Properly designed hardware is not sufficient for carrying out operations (Figure 12). Therefore, the system is made up of a series of other elements, including a ground station on the ground that, once the relative calculations have been

Fig. 13 The *3,051 UAS drone light show over the sky of Zhuhai. The small UAS were coordinated in order to represent satellite stations and symbolic elements of the aerospace*. Retrieved March 5, 2021 from <https://www.guinnessworldrecords.com/news/commercial/2020/10/3051-drones-create-spectacular-record-breaking-light-show-in-china; https://skymagic.imgix.net>

made, pilots and synchronizes via radio each multirotor both in terms of movement in the sky and the variation of shade. In addition, it needs a group of systems: a laptop for control, a Wi-Fi router, an RTK base station, a telemetry radio to establish communication between the laptop and the RTK base station, and a radio to transmit satellite corrections and emergency commands to aircraft on the secondary channel (Drone Show Software. Retrieved March 03, 2021 from https://droneshowsoftware.com/software).

Regardless of the actors in the field and the type of representation that it is wanted to implement, the process is carried out through the steps of conception, planning, animation, simulation, control and execution.

In the initial phase, the figurative mental idea is realized, through preliminary sketches and drawings or by choosing and modeling digital figures belonging to existing libraries. The subsequent planning phase is essential for securing operations. The safe flight areas, the command posts and the positions of the public, in fact, must be calibrated by taking into account the optimal viewing angles and the emergency points, through an in situ survey and a virtual reproduction. It is mandatory that there is a safe and non-violable fence around the launch area. In addition, the airspace to be reserved for the operation must include a double geographical fence and safety exclusion zones. Once these two phases have been defined, it is possible to proceed with the anima-

tion phase, for which it is necessary to use a 3D modeling and animation software through which it can be to calculate and program the movement path and trajectories of each aircraft. Once this step is completed, it is necessary to virtually simulate the flight to test the UAS and validate the trajectories. With the control phase it is possible to enter in the operational section of the process, being a basic step to check all programming on site both in terms of safety and procedure.

The airfield is set up near the area identified as the launch area and the safety protocols are finalized. After a further check-in, through the support of the management software, the flight is carried out.

Most of companies operating in this sector have developed special algorithms that allow in a single proprietary software to manage all the operations in order to simplify the phases both programming and management; so they significantly can reduce the possibility of error due to continuous transport of the project in different programs.

In conclusion, the development of information technology and the continuous progress of communication technologies will lead to the possibility of obtaining swarms with an increasing number of aircraft since the tracking of the position will be more and more accurate and therefore the aircraft will be able to fly closer and closer. Nowadays the Guinness world record is held by Damoda which hovered 3,051 UAS in Zhuhai, China. On that occasion, symbolic elements of aerospace science and technology were represented. It is also desirable that the increase in hardware involved in a single show opens the possibility of more detailed schemes, of increasingly complex and articulated representations and of using this technology for the dissemination of the architectural and historical-artistic heritage. Some examples, in this sense, are the show, held at the beginning of 2021 in the Chinese sky of Tianjin, in which 600 UAS, by flying in swarm mode for 26 minutes and 19 seconds, represented the life and works of Van Gogh and the shows proposed to celebrate the patron saint of Turin every year from 2018.

Fig. 14 From left to right: representations of Van Gogh's life and his most famous works; dynamic representation of a man interacting with city architecture; some shows in Turin representing both the architectures and involvements. Retrieved March 5, 2021 from <https://www.guinnessworldrecords.com/news/commercial/2021/2/600-drones-create-dazzling-van-gogh-animation-across-night-sky-645910> and <https://mole24.it>

They represent the symbolic monuments of the city, such as Mole Antonelliana, or the same city architecture becomes the stage and scenic backdrop of the event (Figures 13, 14).

CONCLUSIONS

Differently to fireworks, which have always been the protagonists of undoubted charm and visual attraction, the attention towards aerial views with luminous drones is decidedly increasing. In fact, in the eastern world where the primitive concept of gunfire was born, an eco-sustainable and less dangerous version of the traditional firework is in a continuous development by ten years about thanks to staging of light shows which simulate splendid visual syntheses of 'light' and 'color' without the aid of explosive materials through the use of drone. Nowadays fireworks are submitted to widespread and considerable criticism both for the effects of air and soil pollution and, above all, for the heavy acoustic consequences caused by the fireworks to the detriment of animals and people. On the other hand, the luminous drones

represent alternative fireworks, which can be used again with countless different visual narratives and three-dimensional choreographies synchronized with musical performances. It is possible to think that in the future there will be an increasingly widespread development of this digital display technology, whose methods allow the implementation of visual images for the transition from drawing 'on paper' to drawing 'in the sky'.

NOTES

1 The paper is the result of the collaboration between all authors: Ornella Zerlenga is directly responsible for the chapters *Introduction* and *Conclusions*, while Vincenzo Cirillo for *Pyrotechnic treatises from the fifteenth to the twentieth century between devices shape and fireworks design* and Rosina Iaderosa for *Drone light show: the show of flying pixels. Method and technologies*.

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