

**Petition for Exemption from  
Federal Aviation Regulations  
— and —  
Request for Approval to Operate  
Unmanned Aircraft Systems  
Under Section 333**

**Submitted by: Ars Electronica Linz GmbH  
In Cooperation with Intel Corporation**

Dated: December 19, 2014

Filed By:

By Electronic Submission to:  
[www.regulations.gov](http://www.regulations.gov)

Brendan Murphy  
Perkins Coie LLP  
1201 Third Ave., Suite 4900  
Seattle, WA 98101  
206.359.6179  
[bmurphy@perkinscoie.com](mailto:bmurphy@perkinscoie.com)

By Paper Submission to:  
U.S. Department of Transportation  
Docket Operations  
West Building Ground Floor, Room W12-140  
1200 New Jersey Avenue, SE  
Washington, DC 20590

Counsel for Intel Corporation

## TABLE OF CONTENTS

|   | <b>Page</b> |
|---|-------------|
| A. INTRODUCTION .....   | 1           |
| B. LEGAL AUTHORITY FOR THE REQUESTED EXEMPTIONS.....  | 2           |
| C. IDENTITY OF THE PETITIONER.....  | 3           |
| D. THE PROPOSED FLIGHTS.....  | 3           |
| E. ARS AND ITS EXPERIENCE SAFELY OPERATING LIGHT SHOWS.....   | 4           |
| F. THE HUMMINGBIRD UNMANNED AIRCRAFT SYSTEM .....   | 6           |
| 1. Hummingbird technical specifications .....   | 6           |
| 2. The flight control system .....  | 7           |
| 3. Communications link .....  | 8           |
| 4. Lost link protection.....  | 8           |
| 5. Payload.....   | 9           |
| 6. Manuals.....   | 9           |
| 7. Maintenance.....   | 9           |
| 8. Battery power and flight duration.....   | 9           |
| 9. Noise .....  | 10          |
| G. UNMANNED AIRCRAFT OPERATORS AND OBSERVERS .....  | 10          |
| H. THE AIRSPACE AND MEASURES TO ENSURE SEPARATION FROM<br>MANNED TRAFFIC AND PERSONS ON THE GROUND..... | 11          |
| 1. The airspace and geo-fence.....  | 11          |
| 2. Safety of persons on the ground.....   | 13          |
| I. CONDITIONS OF FLIGHT.....  | 14          |
| 1. Daylight hours.....  | 14          |
| 2. VMC conditions.....  | 14          |
| 3. Visual line of sight.....  | 14          |
| 4. Advance coordination with the FAA .....  | 14          |
| J. PRIVACY .....  | 14          |
| K. REGULATIONS FROM WHICH EXEMPTION IS SOUGHT AND<br>EQUIVALENT LEVEL OF SAFETY .....                   | 15          |
| 1. Part 21 (Airworthiness Certification).....   | 15          |
| 2. Parts 45 and 47 (Registration and Marking).....  | 16          |
| a. Registration.....  | 16          |

**TABLE OF CONTENTS**  
(continued)

|   | <b>Page</b> |
|---|-------------|
| b.    Marking.....  | 16          |
| 3.    Parts 61 and 67 (Pilot and Medical Certificates) .....    | 17          |
| 4.    Part 91 (General Operating and Flight Rules) .....        | 19          |
| L.    GRANTING THE EXEMPTION IS IN THE PUBLIC INTEREST .....    | 23          |
| M.    NATIONAL SECURITY CONSIDERATIONS.....                     | 24          |
| N.    PROPOSED CONDITIONS AND LIMITATIONS ON THE EXEMPTION..... | 24          |
| O.    SUMMARY FOR PUBLICATION IN THE FEDERAL REGISTER .....     | 25          |
| P.    CONCLUSION.....   | 26          |

## **A. Introduction**

Ars Electronica Linz GmbH (“Ars”), in cooperation with Intel Corporation, petitions for exemption from certain federal aviation regulations and requests approval to operate unmanned aircraft systems in the national airspace system under Section 333 of the FAA Modernization and Reform Act of 2012, 49 U.S.C. § 44701(f), and 14 CFR Part 11. To summarize briefly, Ars is an Austrian company that specializes in light shows with unmanned aircraft flying in various formations. It has successfully conducted several shows in Europe, the Middle East, and Australia. In cooperation with Intel Corporation, Ars wishes to bring the same audience experience to the United States and to demonstrate the capabilities and benefits of the automated flight control systems that make unmanned formation flight possible and safe. Unmanned aircraft light shows are potentially a cheaper, more environmentally friendly, and safer alternative to the traditional fireworks show for celebrating public events and holidays. American audiences cannot currently enjoy them because of the prohibition on unmanned flight for any commercial purpose absent specific authorization, which is available only under Section 333 of the FAA Reform and Modernization Act of 2012 (the “2012 Act”).

The current aviation rules, developed as they were in the context of manned flight, make operating a light show with unmanned aircraft either illegal or impractical. Uncritically applying these rules to unmanned use cases simply does not make sense, does not advance safety, and stifles innovation. And doing so conflicts with Congress’ mandate to integrate unmanned aircraft systems into the national airspace system. The use case addressed in this petition exemplifies the type of use case that Congress wanted to permit through Section 333, in that the aircraft characteristics and the particularities of the proposed flights result in an equivalent or higher level of safety than the regulations otherwise would provide.

Several features of the aircraft and flights assure the safety of other users of the national airspace system and persons and property on the ground.

1. Each unmanned aircraft weighs less than 2 pounds fully loaded and flies less than 6 knots groundspeed during a light show.
2. All aircraft fly within a small cylindrical airspace measuring less than 1,000 feet diameter.
3. All aircraft operate below 400 feet above ground level. The vertical and lateral airspace limits assure separation from all other traffic.
4. All flights are within visual line of sight of the operators and observers. Given the small size of the airspace, all aircraft will fly within about 1,100 feet of the operators and observers.
5. The aircraft are controlled by a flight control system that automatically controls each aircraft’s position and altitude. Aircraft fly between preprogrammed GPS position and altitude waypoints. Before each flight, Ars runs computer simulations to verify that the aircraft following these waypoints will maintain appropriate separation from each other, fly within airspeed limits, and stay within the predefined airspace.

6. A two-boundary GPS geo-fence ensures that all aircraft stay within the defined airspace.
7. An exclusion zone drawn well outside the geo-fence ensures that aircraft do not fly over or near any non-participants.

Congress did not include any required showing of public interest in Section 333, so a showing of public interest arguably is not required to obtain operating authority under that section. Even so, granting the requested exemptions advances the public interest in at least three respects. First, unmanned formation flight demonstrates the ability of numerous unmanned aircraft to fly in small spaces near populated areas using sophisticated flight control technology and helps promote public acceptance of unmanned aircraft systems, especially in novel use cases that were not possible with manned aircraft. Second, light shows are a safe and environmentally friendly alternative to fireworks displays. Third, light shows provide a free entertainment show to the public, paid for by the show sponsor. Section L below elaborates on these points.

This petition addresses the rules that require exemption. Ars will, per FAA requirements, file a separate application for a Certificate of Authorization or Waiver that details the precise location and airspace proposed for any given flight.

## **B. Legal Authority for the Requested Exemptions**

Congress, in the 2012 Act, mandated the FAA to integrate unmanned aircraft systems (UAS) into the national airspace system. It directed the FAA to “develop a comprehensive plan to safely accelerate the integration of civil unmanned aircraft systems into the national airspace system,” and to draft rules to accomplish this integration. 2012 Act, § 332(a), (b). In particular, Congress directed the FAA to develop regulations that “allow for civil operation” of UAS weighing less than 55 pounds. *Id.* at § 332(b)(1). Congress further mandated that the FAA permit certain small UAS to operate even before final UAS regulations are implemented. *Id.* § 333.

Under Section 333, the Secretary of Transportation “shall determine if certain unmanned aircraft systems may operate safely” before the regulations are complete—that is, if they “do not create a hazard to users of the national airspace system or the public or pose a threat to national security.” 2012 Act, §§ 333(a), (b)(1). Congress directed the Secretary to consider six factors bearing on safe operation: (1) size, (2) weight, (3) speed, (4) operational capability, (5) proximity to airports and populated areas, and (6) operation within visual line of sight. *Id.* If a small UAS can operate safely, the Secretary must establish the requirements to facilitate that operation. 2012 Act, § 333(c). Notably, Section 333 does not require any demonstration that a particular UAS flight advances the public interest. Congress declared that integrating UAS into the national airspace system *is* the public interest.

Section 333 provides the overarching legal basis to permit small UAS to operate under certain conditions in the national airspace system notwithstanding that the rules developed in the era of manned flight would otherwise bar those operations. Separately, the FAA has long-standing authority to grant exemptions from any regulation prescribed under sections 44701-44716 of Title 49 upon finding the exemption is “in the public interest.” 49 U.S.C. § 44701(f). Congress has long identified “encouraging and developing civil aeronautics” as a matter “in the

public interest” that the Administrator must consider in carrying out the agency’s safety responsibilities, including granting exemptions. 49 U.S.C. § 40101(d)(3). And more particularly, in the 2012 Act Congress made integrating UAS into the national airspace system not just a matter of public interest, but an imperative.

**C. Identity of the Petitioner**

The petitioner is Ars Electronica Linz GmbH, which is located at:

Ars-Electronica-Straße 1  
4040 Linz, Austria  
Tel. +43.732.7272.0  
Fax. +43.732.7272.2  
E-Mail: info@aec.at

This petition is submitted in cooperation with Intel Corporation, which is located at:

2200 Mission College Blvd.  
Santa Clara, CA 95054

The initial point of contact for questions regarding this petition is Brendan Murphy, who is outside counsel for Intel Corporation. His contact information is:

Brendan Murphy  
Perkins Coie LLP  
1201 Third Ave., Suite 4900  
Seattle, WA 98101  
206.359.6179  
bmurphy@perkinscoie.com

**D. The Proposed Flights**

The flights for which Ars seeks authorization are light shows with up to 200 unmanned aircraft. The shows last approximately 5-8 minutes each, and will be conducted near or after sunset but before the end of civil twilight. They will use “Hummingbird” quadcopters, which have light-emitting-diode (LED) modules and fly in various formations in a preprogrammed “animation.”

The animation can take many forms. At its simplest, the aircraft can simply arrange themselves in a pattern such as a logo. The best example of this is a light show Ars performed near the Tower Bridge in London in which 30 unmanned aircraft flew in the formation of the *Star Trek* logo. The automated flight control technology permits much more complicated animations as well. The aircraft can, in a single show, form multiple formations, rotating about multiple axes.

The show sponsor, which is Intel Corporation for the flights addressed in this petition, chooses the type of animation and desired audience experience. Ars determines the number of aircraft and volume of airspace required to perform the show. The required airspace is small,

typically less than a thousand feet across and a few hundred feet high, because the automated flight control technology enables a few hundred aircraft to fly in a tight formation. Once Ars and the sponsor identify feasible locations, Ars inputs the position and altitude waypoints for each aircraft to follow, programs the LED modules, and links the positions and light display in a single time sequence. The show unfolds by the aircraft flying their waypoints and displaying the lights and colors prescribed in the time sequence.

Each aircraft weighs less than two pounds, including its LED module, and flies slower than 6 knots groundspeed during the show. The aircraft operate inside a small airspace that is segregated from all other aircraft and persons on the ground. The flights addressed in this petition will occupy an airspace measuring no more than 1,000 feet in diameter, with a maximum altitude 400 feet above ground level. A two-boundary GPS geo-fence prevents aircraft from exiting the airspace. The 400-foot altitude cap, the small size of the airspace, and the geo-fence ensure separation from all other aircraft. The flight area and geo-fence are surrounded by a large exclusion zone to ensure that aircraft do not fly over or near nonparticipating persons.

Ars can safely operate a show with 200 aircraft. The practical limits are the show location and available airspace. The airspace must allow the aircraft to maintain at least 6 meters separation from each other during flight, and the site must accommodate a safety exclusion zone large enough to protect people on the ground. Because the flight control system is automated and the aircraft fly the time sequence with no control inputs from a pilot, a few operators can safely manage a show involving 200 aircraft.

**E. Ars and its Experience Safely Operating Light Shows**

Ars is an Austrian corporation that began operations in 1979 and focuses on digital art and media. One of its main operations involves fusing artistry with research and development and industrial applications in its FutureLab. The FutureLab is a media art laboratory that mixes artistic and technological innovation. The staff includes experts from a wide variety of fields, including physics, electrical engineering, computer science, and 3D/graphical design. The FutureLab’s activities include conception and realization of exhibition projects and artistic installations as well as joint ventures with partners in academia and the private sector. Unmanned aircraft light shows are one such project, which premiered in 2012.

Ars has conducted 10 nighttime light shows that are similar in concept to the flights proposed in this petition. Those shows involved the same type of aircraft and safety measures discussed in this petition, and took place with no incidents or hazards to other aircraft or persons on the ground. They are listed in the table below, with links to photographs and video footage of the show where available.

|   | <b>Name and Description of Light Show</b>   | <b>Location</b> | <b>Date and Video/Photo Link (if available)</b>  |
|---|---|-----------------|--|
| 1 | <i>Klangwolke</i><br>This show involved four flights of 49 UA flying in various formations. | Linz, Austria   | September 2012<br>Video available at <a href="http://www.aec.at/spaxels/shows/linz-klangwolke-2012/">http://www.aec.at/spaxels/shows/linz-klangwolke-2012/</a> |

|    | <b>Name and Description of Light Show</b>  | <b>Location</b>               | <b>Date and Video/Photo Link (if available)</b>   |
|----|--|-------------------------------|---|
| 2  | <i>Star Trek Into The Darkness Promotion</i><br>This show involved 30 UA flying in the formation of the <i>Star Trek</i> logo near the Tower Bridge in London. | London, United Kingdom        | March 2013<br>Video available at <a href="http://www.aec.at/spaxels/shows/star-trek-into-darkness/">http://www.aec.at/spaxels/shows/star-trek-into-darkness/</a>  |
| 3  | <i>International Bergen Festival</i><br>This show involved multiple flights with up to 30 UA flying in various formations.                                     | Bergen, Norway                | May 2013<br>Photos available at <a href="http://www.aec.at/spaxels/shows/bergen-festival-2013/">http://www.aec.at/spaxels/shows/bergen-festival-2013/</a>   |
| 4  | <i>Ljubljana Festival</i><br>This show involved multiple flights with up to 27 UA flying in various formations.  | Ljubljana, Slovenia           | June 27, 2013<br>Photos available at <a href="http://www.aec.at/spaxels/shows/ljubljana-festival-2013/">http://www.aec.at/spaxels/shows/ljubljana-festival-2013/</a>  |
| 5  | <i>QUT Robotronica</i><br>This show involved 30 UA flying in various formations.   | Brisbane, Australia           | August 18, 2013<br>Video available at <a href="http://www.aec.at/spaxels/shows/brisbane-robotronica-2013/">http://www.aec.at/spaxels/shows/brisbane-robotronica-2013/</a>   |
| 6  | <i>We are here/Ars Electronica Festival</i><br>This show involved 30 UA flying in various formations.  | Linz, Austria                 | September 5, 2013<br>Video available at <a href="http://www.aec.at/spaxels/shows/we-are-here/">http://www.aec.at/spaxels/shows/we-are-here/</a>   |
| 7  | <i>European Capital of Culture Opening</i><br>This show involved 30 UA that formed the City of Umea's logo and the stars of the European Union's flag.         | Umea, Sweden                  | March 1, 2014<br>Video available at <a href="http://www.aec.at/spaxels/shows/umea_burning_snow/">http://www.aec.at/spaxels/shows/umea_burning_snow/</a>   |
| 8  | <i>Islamic Capital of Culture Opening</i><br>This show involved 15 UA formation flights, each with 15-25 aircraft, during a two-week festival.                 | Sharjah, United Arab Emirates | March 2014<br>Video available at <a href="http://www.aec.at/spaxels/shows/sharjah-clusters-of-light/">http://www.aec.at/spaxels/shows/sharjah-clusters-of-light/</a>  |
| 9  | <i>German Day of Unity</i><br>This show involved 30 UA flying in various formations.   | Hannover, Germany             | October 3, 2014<br>Video available at <a href="http://www.ndr.de/nachrichten/niedersachsen/tag-der-deutschen-einheit/Echt-was-los-in-Hannover-Lichter-Laser-Emotione,lichtshow104.html">http://www.ndr.de/nachrichten/niedersachsen/tag-der-deutschen-einheit/Echt-was-los-in-Hannover-Lichter-Laser-Emotione,lichtshow104.html</a> |
| 10 | <i>43rd National Day Celebration</i><br>This show involved 30 UA flying in various formations.   | Dubai, United Arab Emirates   | December 1, 2014<br>Photos available at <a href="https://www.flickr.com/photos/arselectronica/sets/72157649516888522">https://www.flickr.com/photos/arselectronica/sets/72157649516888522</a>   |

For each show, the show sponsor obtained the necessary government approvals to operate unmanned aircraft. Not all of these shows took place in jurisdictions that required permission from the national aviation authorities. Of those that did—Germany, Sweden, Australia, and Dubai—the regulators authorized the shows.



The above table lists the public performance light shows, which represent only a fraction of Ars' experience operating unmanned aircraft in formation flight. Counting test flights before shows, promotional flights, and flights for video shoots, Ars has conducted more than 75 flights involving large numbers of unmanned aircraft flying in various formations. Not one flight has presented a hazard to other traffic or persons on the ground.

**F. The Hummingbird Unmanned Aircraft System**

The light shows will use up to 200 Hummingbird unmanned aircraft manufactured by Ascending Technologies GmbH ("AscTec"). AscTec is a German company that designs and manufactures micro unmanned aircraft systems for civil use and research. The company's contact information is: Ascending Technologies GmbH; Konrad-Zuse-Bogen 4 /// 82152 Krailling; Germany; T +49 89 89556079-0; F +49 89 89556079-19; team@asctec.de; [www.asctec.de](http://www.asctec.de).

The Hummingbird is a battery-powered quadcopter that weighs less than two pounds fully loaded. For light shows, each aircraft carries an LED module that weighs approximately 100 grams (.22 lbs). The maximum airspeed the aircraft can reach in any configuration is 15 m/s, or 29.16 knots. That speed is not relevant because the aircraft can only achieve it when operated individually by remote control, which is a different means of operation than proposed here. During a light show, aircraft operate in GPS mode, which limits groundspeed to 8 m/s, or 15.55 knots. Even this figure is not the relevant one because Ars further limits the maximum groundspeed of all aircraft during a light show to 3 m/s, or 5.83 knots. Given its low mass, low range, and low speed, the Hummingbird is primarily suitable to fly in formation inside a small airspace, within the operators' visual line of sight.

**1. Hummingbird technical specifications**

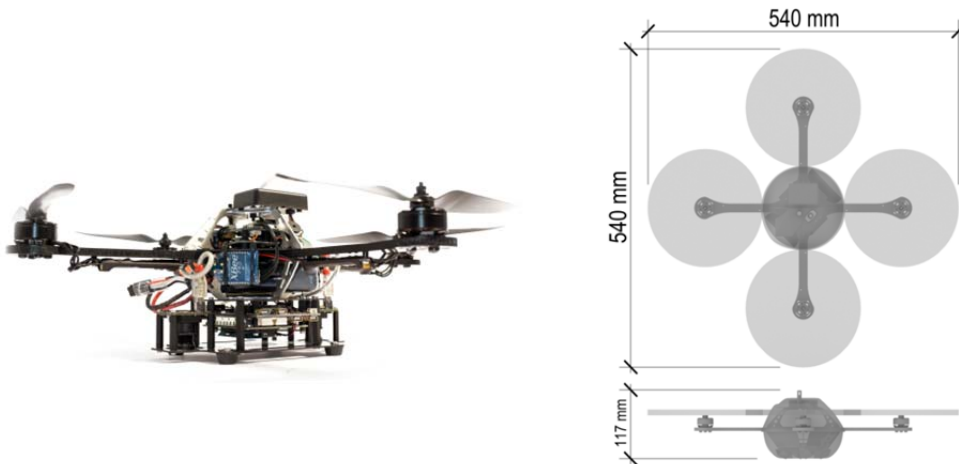
The below table lists the AscTec Hummingbird technical specifications:

|                        |  |
|------------------------|--|
| Aircraft type          | Quadcopter (4 rotors)  |
| Dimensions             | 540 mm x 540 mm x 117 mm<br>(21.26 in x. 21.26 in x. 4.61 in)                                  |
| Propulsion type        | 4 electrical, brushless DC motors with maximum power of 80 watts each<br>Maximum thrust of 20N |
| Rotor type             | Fixed pitch, variable RPM  |
| Rotor diameter         | 8 in   |
| Rotor weight           | ≈ 8 g (≈ .28 ounces)   |
| Maximum rotor RPM      | 8,000  |
| Battery type           | Lithium ion polymer<br>3 PP2100 cells  |
| Empty weight           | ≈ 350 g (≈ .77 lb)   |
| Minimum takeoff weight | ≈ 510 g (≈ 1.12 lb)  |
| Maximum takeoff weight | ≈ 710 g (≈ 1.57 lb)  |

|   |   |
|---|---|
| Maximum payload                                     | ≈ 200 g (≈ .44 lb)  |
| Flight time (no payload)<br>With LED module payload | 20 minutes<br>10 minutes (at moderate speeds)   |
| Range   | 1 km (.62 miles)  |
| Max wind speed for flight<br>(without payload)      | 10 m/s (19.44 knots)  |
| Maximum speed                                       | 15 m/s (29.16 knots) airspeed in manual mode<br><br>In GPS mode, speed is limited to 8 m/s (15.55 knots) groundspeed. Groundspeed during a light show is further limited to 3 m/s (5.83 knots). |
| Maximum rate of climb                               | 5 m/s (984 ft/min)  |

The manufacturer has published the Hummingbird's safety data sheet online at [http://www.asctec.de/downloads/public/AscTec-Hummingbird\\_Safetydatasheet.pdf](http://www.asctec.de/downloads/public/AscTec-Hummingbird_Safetydatasheet.pdf). A video demonstrating the aircraft is also available at the manufacturer's website: <http://www.asctec.de/en/uav-uas-drone-products/asctec-hummingbird/>.

Below is a photograph of the Hummingbird unmanned aircraft system and a schematic showing its dimensions.



## 2. The flight control system

The Hummingbird controls vertical and lateral movement by varying rotor RPM rather than using airflow over flight control surfaces. To move laterally, the aircraft varies RPM among the four rotors to induce a small pitch or roll attitude and moves along a horizontal plane. To move vertically, the rotors increase or decrease RPM collectively to increase or decrease power output.

The Hummingbird uses an automated flight control system that allows a few operators to control many aircraft at the same time, enabling the aircraft to fly safely in close formation for light shows and other applications. For a light show, Ars loads the flight control system software

onto laptops for each operator, and links the laptops to each other and to a communications link to form a ground control station. Each operator can oversee multiple aircraft from one laptop.

The flight control system uses GPS to determine each aircraft's position in real time. Each aircraft also has accelerometers, but they have minimal input in the aircraft's position determination. Each aircraft uses a barometric altimeter to measure altitude. They report altitude with reference to above ground level because the ground control station is considered "zero" altitude, regardless of height above sea level.

Ars is aware of the FAA policy that "UAS that are designed to be completely autonomous, with no capability of pilot intervention, are not authorized in the national airspace system." Interim Operational Approval Guidance 08-01 ¶ 8.2.9 (March 13, 2008). The flights described in this petition do not involve such autonomous flight. The operator can manually control any aircraft at any time.

The details of the flight control system are proprietary and are described in the proprietary supplement.

### **3. Communications link**

The ground control station communicates with each aircraft via a 2.4 GHz link, the details of which are described in the proprietary material supplement. It is an off-the-shelf FCC-compliant communications solution that does not require any additional FCC approvals for use on unmanned aircraft in the United States.

The ground control station uses this communications link to upload position commands to each aircraft. The aircraft use it to download their current state in real time, including GPS position, altitude, battery level, and engine status.

The communications link has a range of approximately 600 meters (1,968 ft.). The ground control station is generally positioned near the boundary of the flight area or geo-fence and is always within range of all aircraft during the show. Ars does not propose to use a mobile ground control station.

### **4. Lost link protection**

The aircraft have lost link protection to ensure safe and automatic recovery within the flight area if the communications link or GPS signal is disrupted.

If an aircraft loses communications with the ground station, it holds its current position and altitude for 10 seconds and attempts to regain the signal. If it cannot do so, the aircraft follows the "emergency home" procedure and automatically returns "home," which is the point from which it took off. The aircraft flies to a point directly above its home position at a predefined minimum altitude, or its altitude at the time of signal loss if that altitude is higher than the minimum, and then lands.

If an aircraft loses the GPS signal, it levels itself and descends at a controlled rate of 8 meters per second (1575 ft./min). When the GPS signal is restored the aircraft switches back to its regular GPS-position-controlled mode and reverts to its assigned position.

## **5. Payload**

Each vehicle is equipped with an LED module weighing approximately 100 grams (.22 lbs). The LED modules display red, green, blue, and white light of varying brightness and hue during the light show. The modules are secured to each aircraft to preclude accidental payload loss in flight.

## **6. Manuals**

The aircraft manufacturer publishes a manual online at <http://wiki.asctec.de/display/AR/User+Manual>. The manual addresses how the aircraft and its systems work, the various flight control modes, preflight procedures, emergency procedures, weather and operating limitations, troubleshooting, and safety.

The aircraft manufacturer also publishes a safety data sheet online at [http://www.asctec.de/downloads/public/AscTec-Hummingbird\\_Safetydatasheet.pdf](http://www.asctec.de/downloads/public/AscTec-Hummingbird_Safetydatasheet.pdf). The safety data sheet contains technical information as well as a description of emergency modes.

## **7. Maintenance**

The Hummingbird requires very little user maintenance. The principal user-level maintenance is the hardware inspection, which is done before and after every flight and after every repair. The details of the inspection are proprietary and are described in the proprietary material supplement.

The aircraft manufacturer has a checklist that Ars also reviews before each flight to verify the aircraft and control system are in a condition for safe operation. The checklist is proprietary and is included in the proprietary material supplement.

Ars tracks inspection and maintenance for each aircraft, by serial number, in a database.

## **8. Battery power and flight duration**

The batteries power the engines and LED module. Maximum flight duration without using the LED modules is 20 minutes, and 10 minutes when using them. Each aircraft continuously reports its battery state to the operators, who can command an aircraft to land if its battery depletes faster than expected.

To ensure adequate power margin, Ars limits the light shows to 8 minutes or less. This limitation allows the aircraft to land with at least 20% reserve battery power, which is within the margin the FAA has permitted in prior grants of exemption. *See, e.g.,* Clayco Grant at 15.<sup>1</sup>

---

<sup>1</sup> Prior Grants of Exemption are cited in shorthand by the operator's name. Full citations are listed in Appendix B.

To maximize the audience experience, Ars may run a few shows back to back. Between shows, Ars exchanges the batteries so that each aircraft begins a flight with fully charged batteries.

## **9. Noise**

The aircraft are electrically powered and emit very little noise. A detailed noise analysis is not necessary because “if a determination is made under Section 333 that an airworthiness certificate is not required, noise certification and testing will also not be required for the subject aircraft for the term of the exemption.” FAA, *Public Guidance for Petitions for Exemption Filed Under Section 333* (Sept. 25, 2014), at 4.

The light show may be set to music. Ars or Intel will coordinate with local authorities to ensure compliance with all applicable noise ordinances.

## **G. Unmanned Aircraft Operators and Observers**

The light show presents a novel use case in at least three respects: (1) the aircraft are controlled by an automated flight control system rather than human commands or conventional aircraft controls, (2) one operator oversees multiple aircraft, so individual aircraft do not have a single, dedicated “pilot in command,” and (3) operating light shows involves skills specific to light shows rather than traditional aeronautical knowledge. The safety in this use case comes from flying in a small airspace separated from other aircraft and people on the ground, and from flying a preprogrammed formation that is verified safe through computer simulations, not from a certificated pilot manipulating each aircraft’s controls. As a result, traditional notions of who should be permitted to operate these aircraft do not apply.

The position commands the aircraft follow result from an extensive development process between Ars and the show sponsor. The sponsor specifies the desired audience experience, for instance flying in a logo formation as in the London show or an animation set to music. Ars determines the required number of aircraft, defines the airspace boundaries (and those of the surrounding geo-fence and exclusion zone), and programs the positions and altitudes for the aircraft to follow. Ars then runs computer simulations to verify that the aircraft can execute the position instructions within the defined airspace boundaries while maintaining the required 6-meter separation from each other and staying below the maximum 3 m/s groundspeed.

The individual operator’s role in a light show is to monitor the aircraft and issue the computer commands that initiate the takeoff, light show, and landing. The operator ensures that all aircraft are online and communicating, monitors battery and GPS state, and stands ready to command landing or other action if a problem develops. The automated flight control system does everything else, executing the position instructions developed in the pre-show planning process described above.

The operators generally do not have pilot or medical certificates. They have, rather, extensive experience developing and safely flying light shows around the world. Pilot training and the type of aeronautical knowledge developed through manned flight simply do not carry over to light shows. These aircraft do not fly like conventional aircraft. They do not enter traffic patterns, navigate busy airways, or fly in IMC. Most importantly, they do not fly near other

aircraft or people on the ground. A computer controls their position in a small airspace where they cannot interfere with other users of the national airspace system. The skill set to safely execute a light show comes from experience operating these aircraft and these light shows, not from flying fixed-wing aircraft or helicopters.

All flights will take place below 400 feet above ground level, which is below the minimum allowed altitude for manned aircraft traffic (other than on takeoff and landing) and is entirely within the altitude zone permitted for unmanned model aircraft flight. 14 CFR § 91.119, Advisory Circular 91-57. This altitude limitation, in conjunction with the small lateral area of the airspace, ensures separation from manned traffic. As a further safety measure, Ars will use ground-based observers to provide additional see-and-avoid capability to detect any wayward traffic that may approach the flight area. Specifically, Ars will station two dedicated observers near the flight area whose sole function is to observe the surrounding airspace before takeoff and during the light show for any approaching aircraft, gliders, parachutists, or other traffic. The observers will be positioned so each has unobstructed views of at least 180° of the airspace surrounding the flight area, and together have a 360° view. The observers will remain in constant verbal communication, via two-way radio, with the operators. If the observers detect approaching traffic that may result in an airspace conflict, the operators will command all aircraft to immediately land.

Observers will comply with the guidelines stated in FAA Order 8900.1, vol. 16, ch. 5, section 3, in that (1) they will assist the operators to ensure aircraft stay within the VLOS limit and remain clear of other aircraft, (2) they will not use magnification devices or night vision goggles other than to augment normal vision within the VLOS limit, (3) they will be stationed in the locations that afford the best available view of the entire area where the flight is conducted, and (4) they will not “daisy-chain” to extend the VLOS limit. The fifth condition, dark adaptation, does not apply because Ars does not propose to fly during nighttime hours.

## **H. The Airspace and Measures to Ensure Separation from Manned Traffic and Persons on the Ground**

### **1. The airspace and geo-fence**

All flights, no matter where conducted, will take place within a small cylindrical airspace that is separated from all other aircraft and surrounded by an exclusion zone on the ground to ensure separation of aircraft from all nonparticipating personnel. The FAA has already granted exemptions for unmanned aircraft to fly on closed movie sets. *Astraeus Grant* at 23. The proposed flights are similar in concept because they occur within a defined airspace in which there is no potential conflict with nonparticipating aircraft or personnel.

All aircraft will fly lower than 400 feet above ground level. This is the altitude below which the FAA already permits unmanned flight for model aircraft. It is also below the “navigable airspace,” which is the “airspace above the minimum altitudes of flight prescribed by regulations ... including airspace needed to ensure safety in the takeoff and landing of aircraft.” 49 U.S.C. § 40102(a)(32); 14 CFR § 1.1. The FAA defines “minimum safe altitudes” as generally at least 500 feet. 14 CFR § 91.119.

The radius of the cylinder, whose circumference forms the outer boundary of the airspace, may vary slightly depending on the location chosen for the flight. The maximum lateral limit that Ars envisions is a 150 meter radius, which is 492 feet. Thus the airspace, regardless of location, would have a maximum diameter of 300 meters (984 ft). As such, all flights will take place entirely within a cylindrical airspace measuring less than 1,000 feet across and less than 400 feet above the ground.

The primary means to keep aircraft within the defined airspace is the flight control system. The system commands all aircraft to follow preprogrammed positions that computer simulations verify in advance are inside the airspace.

Ars uses geo-fencing as a secondary safety measure. A geo-fence is a GPS-based virtual fence that, if crossed, triggers a reaction in the aircraft's control system to take some action to either remain inside the fence or safely land. For maximum protection, Ars uses a two-boundary geo-fence that encircles the airspace. The inner boundary is a few meters outside the airspace boundary. If an aircraft reaches the inner boundary, the flight control system commands it to return home, which is the position from which it took off. An aircraft returns home in this situation by flying at a prescribed altitude to a point directly above its home position and then landing. The prescribed altitude is the higher of a preset minimum altitude (currently 35 meters agl, but this can be changed) or the altitude of the lowest waypoint during the flight. In other words, if the aircraft's lowest waypoint was 50 meters agl, it will fly that altitude, not the 35 meter minimum.

The outer geo-fence boundary is a few meters outside the inner boundary, and provides an extra level of safety in the unlikely event a vehicle breaches the inner boundary. If a vehicle reaches the outer boundary, all four engines switch off and the vehicle descends in a non-controlled manner to the ground. The exclusion zone, described in the next section, ensures that an aircraft descending in such manner cannot reach people on the ground.

All aircraft take off and land within the designated airspace; they do not need any transit airspace. The launch site can be on the ground or an elevated platform such as a rooftop, depending on the features of a given site. To ensure adequate margin from the platform boundary, Ars will have a 5 meter buffer between launch/recovery positions and the edge of the platform.

Ars will not use any moving platform for a launch site. If it uses a vessel such as a barge, the vessel will be anchored.

Ars will address the precise location and classification of the airspace in the application for Certificate of Authorization or Waiver. At this time, Ars does not contemplate flying within class B airspace.

Some potential sites lie within 5 nautical miles of an airport, and therefore would not fit within limitations the FAA has imposed on some Section 333 authorizations. See Clayco Grant at 19. The FAA should not impose such a limitation here because the small lateral and vertical limits of the airspace ensure ample separation from traffic using nearby airports. To further

ensure safe and smooth operation, Ars or Intel will coordinate with ATC and the operator of any airport within 5 miles of the flight area well in advance of any flight.

## **2. Safety of persons on the ground**

An exclusion zone on the ground ensures that aircraft do not fly over or near any nonparticipants. The exclusion zone encircles the airspace and its boundary lies well outside the outer geo-fence boundary. People not involved in operating the light show are barred from entry.

Ars determines the size of the exclusion zone based on the maximum distance an aircraft could travel if it exited the outer geo-fence at 10 m/s (19.44 knots) groundspeed and descended with no power. The 10 m/s assumption is conservative, by a factor of three, because aircraft are limited to 3 m/s groundspeed in a light show. Ars may reduce the speed assumption in developing the exclusion zone boundary for a particular site, provided the speed used exceeds the maximum speed of any aircraft during a flight.

The exclusion zone provides an over-sized safety buffer based on a worst-case scenario. As an example, for an airspace of 125 meters radius, and using the 10 m/s second conservative assumption, the exclusion zone would have a radius of approximately 190 meters, thus providing a safety buffer of 65 meters. Although the buffer is less than the 500-foot safety margin reflected in section 91.119(c), it results in higher safety because the exclusion zone is designed to ensure that an aircraft leaving the geo-fence with maximum energy lands well inside the safety area.

Ars will use a combination of physical barriers (fences, tape) and security personnel to enforce the exclusion zone. The means chosen will be appropriate to the site and the proximity of persons, streets, and buildings to the exclusion zone boundary. For each location used for a flight, Ars and Intel will develop a site-specific safety plan that outlines the precise boundary of the exclusion zone and the means to enforce it.

Some potential sites under consideration have public streets within the area of a likely exclusion zone. Ars or Intel will work with local authorities to obtain permission to close these streets.

Some potential sites also have commercial or industrial buildings (not residential buildings) that would lie within the exclusion zone. Ars does not propose to evacuate persons from commercial or industrial buildings within the exclusion zone, but will ensure that any non-participants stay within the buildings during each flight. Given the low mass and speed of the aircraft, the structure provides a physical barrier protecting nonparticipants. The FAA has recognized that physical barriers provide equivalent safety to the separation requirements in part 91.119. *Clayco Grant at 15* (“If barriers or structures are present that can sufficiently protect nonparticipating persons from debris in the event of an accident then the UA may operate closer than 500 feet to persons afforded such protection.”).

Ars or Intel will provide all required notifications to, and obtain all required permits from, state and local authorities. Ars or Intel will also obtain permission from the owners of all property encompassed by the flight area and exclusion zone.



## **I. Conditions of Flight**

### **1. Daylight hours**

All flights will be conducted before the end of civil twilight. Ars does not, at this time, request authorization to fly at night.

### **2. VMC conditions**

All flights will be conducted in visual meteorological conditions. The aircraft can operate in minor precipitation such as drizzle, provided conditions remain VMC.

Due to their low mass and the requirement to stay on position during formation flight, the flights will only be conducted with maximum sustained and gusting winds lower than 6 meters per second, or 11.66 knots.

### **3. Visual line of sight**

All flights will be conducted within visual line of sight (VLOS) of the operators and observers. For clarity, Ars regards VLOS for these purposes as being within sight of the human eye with no magnification aids. Prescription corrective lenses may be worn.

As a practical matter, all aircraft necessarily will remain within visual line of sight because of the small airspace. Operators and observers are typically situated within or immediately adjacent to the flight area. With a flight area less than 1,000 lateral feet and 400 vertical feet, the farthest an aircraft can get from an operator or observer is less than 1,100 feet—well within visual line of sight.

### **4. Advance coordination with the FAA**

Ars will coordinate with the FAA on every planned flight by submitting a written Plan of Activities to the Flight Standards District Office having jurisdiction over the flight area at least 3 business days before any flight. The Plan of Activities will contain (1) the dates and times of flights; (2) the name and phone number of the operator and the person(s) responsible for on-scene operation of the UAS; (3) a statement that the operator or show sponsor has obtained permission from property owners and/or local officials to conduct the show; (4) a description of the flight, including maps and diagrams of the airspace, geo-fence boundaries, and exclusion zone; and (5) a site-specific safety plan to ensure separation of the aircraft from all non-participating personnel. Ars will also request, 48-72 hours before any flight, that the local air traffic organization issue a NOTAM advising other airspace users of the flight.

## **J. Privacy**

The aircraft carry no cameras or recording equipment. The aircraft and flights pose no privacy concerns.

## **K. Regulations from which Exemption is Sought and Equivalent Level of Safety**

This section addresses the specific rules for which Ars seeks an exemption and explains why the proposed flights will operate with an equivalent or greater level of safety.

### **1. Part 21 (Airworthiness Certification)**

Absent an exemption, a person cannot “operate a civil aircraft in air commerce without an airworthiness certificate in effect ....” 49 U.S.C § 44711(a)(1). Part 21, subpart H, prescribes the procedural requirements for issuing an airworthiness certificate.

Section 333 directs the FAA to consider whether airworthiness certification is required for certain unmanned aircraft systems that, due to their “size, weight, speed, operational capability, proximity to airports and populated areas, and operation within visual line of sight do not create a hazard to users of the national airspace system or the public or pose a threat to national security.” 2012 Act, § 333(b)(1).

The Hummingbird aircraft and flights addressed in this petition qualify for relief from certification requirements under the factors Congress established. First, they are small, have low mass, and fly slow. They are less than 2 feet long and 2 feet wide, weigh less than 2 pounds with full payload, and fly slower than 6 knots in a light show. They are smaller, lighter, and slower than the aircraft for which the FAA has already granted exemptions. Astraeus Grant at 6 (<55 lbs, <50 knots); Trimble Navigation Grant at 6 (<6 lbs, <74.5 knots); Clayco Grant at 5 (<10 lbs, <43.4 knots); Woolpert Grant at 2-3 (<15 lbs, < 58 knots); VDOS Grant at 4, 12 (<6.5 lbs, <87 knots).

Second, the flight control system and geo-fence circumscribe the aircraft operational capability to a small airspace free of potential conflicts with manned aircraft and nonparticipating persons.

Third, all aircraft will be operated within visual line of sight of the operators and visual observers.

Finally, the proximity factor favors an exemption in light of the measures to ensure separation from air traffic and people on the ground. Light shows by nature are more effective near an audience, which as a practical matter will be a populated area such as the Highway 101 corridor in the San Francisco Bay Area or the San Francisco waterfront. The precise locations will be addressed in the applications for Certificates of Authorization or Waiver. The point of the proximity analysis is not whether people happen to be nearby, but whether the flight poses a hazard to them. Parsing out population densities near the flight area makes sense in analyzing the concept of “congested areas” under section 91.119, for example, because an equipment failure at low altitude poses a danger to people on the ground in the whole area where an aircraft may land. But this use case is different because of the exclusion zone that separates aircraft from people on the ground. That zone provides an over-sized safety buffer that ensures any aircraft leaving the geo-fence touches down well before it can reach nonparticipating persons. Nobody outside the exclusion zone, no matter how populated the surrounding area, faces the hazard of being hit by an aircraft. For that reason, nobody is in “proximity” to the aircraft, even if the flight takes place near population centers or an airport.

As a result of the aircraft physical characteristics, operation within visual line of sight in a small defined airspace, and the measures to separate the aircraft from other traffic and persons on the ground, the flights do not create a hazard to users of the national airspace system or the public, nor do they pose a threat to national security. The FAA therefore should exempt these aircraft, when used for the flights discussed herein, from airworthiness certification requirements.

## **2. Parts 45 and 47 (Registration and Marking)**

### **a. Registration**

The aircraft proposed for use in the light shows are owned by Ars, which is a foreign corporation. Foreign ownership makes the aircraft ineligible for United States registration. 49 U.S.C. § 44102(a)(a); 14 CFR § 47.3(a).

The aircraft are not registered with any government. Registration is not practical because the aircraft are used for shows in a variety of countries. They are shipped to the event venue before the event, flown, and then shipped back. The aircraft do not have the physical space to display a registration number large enough to be seen from more than a few feet away. They already have identification numbers in the form of serial numbers (ranging from 20000-29999), which allow tracking for maintenance and recordkeeping purposes. And most importantly, these aircraft do not fly in airspaces where registration is necessary for communications, traffic control, or enforcement purposes. They fly in formation in a small airspace with advance permission of the authorities. Registration does not make sense in this use case.

Aircraft operated in the United States generally must be registered. 49 U.S.C. § 44101(a). An exemption is permissible and appropriate. The FAA does not apply the registration requirements to all vehicles that technically meet the definition of “aircraft” in Title 49. Model aircraft operated under the authority of Advisory Circular 91-57 are considered “aircraft” but are generally not registered. *See* 49 U.S.C. § 40102(a)(6), 14 CFR § 1.1; *Huerta v. Pirker*, Docket No. CP-217 at 5 (NTSB, Nov. 18, 2014) (“the definitions on their face do not exclude even a ‘model aircraft’ from the meaning of ‘aircraft’”).

As with model aircraft, the Hummingbird aircraft used in light shows are a use case in which registration does not make sense. Other than the commercial nature of the operation, the flights discussed in this petition are similar to the model aircraft use case in that they operate below 400 feet and in airspace that precludes conflicts with manned aircraft and people on the ground. In fact, the operation here is even safer given the enforcement of an exclusion zone, something that model aircraft operations typically lack. The FAA should treat these aircraft similarly and exempt them from the registration requirement. Moreover, this use case is essentially an exhibition for which marks are not required. 14 CFR § 45.22.

### **b. Marking**

There are marking requirements applicable to U.S.-registered rotorcraft, but they do not apply to operating an unregistered rotorcraft such as the Hummingbird. These include 14 CFR §§ 45.21(a), 45.23(a), and 45.27(a). Section 45.23(b) does not apply because the aircraft are not certified in the limited, restricted, or light-sport category, nor are they experimental or

provisionally certificated aircraft. Because the marking requirements pertain to registered aircraft, exemption from the registration requirement logically means that no registration markings are required. Similarly, an exemption is not required from 14 CFR § 47.3(b) because these aircraft are not presently eligible for U.S. registration by virtue of foreign ownership.

### **3. Parts 61 and 67 (Pilot and Medical Certificates)**

The light show use case departs from the usual norm of one or more pilots operating a single aircraft. Ars is aware of the FAA's policy that each pilot in command "control[] only one unmanned aircraft (UA) at a time"—a policy that makes sense in a majority of use cases. FAA Order 8900.1, vol. 16, ch. 4, § 1. But it does not make sense for a use case involving computer-controlled flight in a small airspace with a technological means such as geo-fencing to prevent egress. The measures taken to separate the airspace from other aircraft and people on the ground provide a level of safety beyond that provided by having a pilot behind the controls of each aircraft. Given the safety provided by automated flight control and the small airspace, and the ability of an operator to command any or all aircraft to land if necessary, the FAA should depart from the one-PIC-per-aircraft model for this use case.

Similarly, the requirements that the operator of a civil aircraft of the United States have a pilot certificate, whether commercial or private, and a medical certificate do not make sense in this use case. 14 CFR § 61.3. Light show flights do not involve traditional elements of aeronautical knowledge. The flight control system, not the operator, controls the aircraft. To take manual control, the operator uses a mouse or computer command, not a control stick or wheel. The knowledge and expertise to safely fly a light show is specific to operating light shows, not flying conventional rotorcraft, navigating congested airspace, analyzing weather systems, communicating with ATC, and other skills relevant to manned flight or to flying unmanned aircraft in operations similar to manned flight. The operators' experience in these light shows coupled with the airspace limitations provide an equivalent level of safety as having a pilot certificate.

The FAA has recognized that certain operations "without a pilot certificate may be allowed." FAA Order 8900.1, vol. 16, ch. 4, § 1. This use case is one such operation, given the controls to assure separation from other aircraft and people on the ground. The FAA should exempt Ars from requirements that operators have any pilot or medical certificate, including 14 CFR §§ 61.3 and 61.23.

In two recent grants of exemption, the FAA denied petitioners' requests to exempt unmanned aircraft operators from requirements to have a pilot and medical certificate. Trimble Navigation Grant at 14-15; Clayco Grant at 11-12. The FAA cited a lack of authority to "exempt from the statutory requirement to hold an airman certificate." Trimble Navigation Grant at 14. It wrote that Section 333 "provides limited statutory flexibility relative to" section 44704 for airworthiness certification but "does not provide flexibility relative to other sections of Title 49," such as section 44711. *Id.* The FAA nevertheless exempted the petitioners from the requirement of a commercial certificate, and allowed operation with a private pilot certificate and third-class medical certificate notwithstanding the commercial nature of the operation. *Id.* at 15.

Ars urges the FAA to reevaluate its position on the scope of Section 333's authority. The statute provides broad authority to allow UAS operations to accomplish Congress' mandate to integrate UAS into the national airspace system; nothing limits this authority to airworthiness certification.

The structure and language of the statute indicate that Congress empowered the FAA to authorize UAS operations based on a set of safety factors, unbridled by rules such as airworthiness certification, registration, and airman's certificates that might otherwise bar such operations. Specifically, Section 333 requires the Secretary of Transportation to determine "which types of unmanned aircraft systems" do not create a hazard to other users of the airspace system or threaten national security by virtue of their "size, weight, speed, operational capability, proximity to airports and populated areas, and operation within visual line of sight." 2012 Act, § 333(b)(1). For UAS that meet these criteria, the Secretary must determine whether to require a certificate of waiver, certificate of authorization, or airworthiness certification. 2012 Act, § 333(b)(2).

The reference to airworthiness certification in Section 333(b)(2) presumably forms the basis of the FAA's interpretation. But Congress did not limit the Secretary's authority to airworthiness certification. Rather, Congress identified airworthiness certification as something the Secretary may require for UAS that otherwise meet the six criteria in subsection (b)(1). The Secretary has already found that airworthiness certification is not required for certain UAS to operate safely. That is all that is required to permit them to operate. The Secretary can impose other "requirements for the safe operation of such aircraft systems" under subsection 333(c), and for certain use cases a requirement of a pilot certificate makes sense. But nowhere did Congress say that Section 333 is intended to provide relief only from airworthiness certification requirements.

If the FAA is unable or unwilling to reconsider its interpretation of Section 333's scope, Ars proposes to satisfy a requirement of an airman certificate by conducting each light show flight under the operational control of a person holding at least a private pilot certificate and third-class medical certificate. The FAA has allowed other commercial UAS operations with this level of airman certification. *See* Trimble Navigation Grant at 15; Clayco Grant at 12-13; Astraeus Grant at 15-18. Because the Hummingbird aircraft operate under the direction of the flight control system and fly between preselected GPS waypoints for a show, there is no pilot skill involved in operating them. For that reason, the individual operators supervising groups of aircraft on the flight control system laptop interface will not have this certification. They will, rather, operate under the control of the pilot. If the pilot perceives an airspace conflict or other problem, the pilot can command the operators to land the aircraft immediately.

The FAA has stated that one reason it requires a pilot certificate is "pilots holding a private pilot certificate are subject to the security screening by the Department of Homeland Security that certificated airmen undergo." Trimble Navigation Grant at 15. Ars proposes to accommodate this security concern by allowing the Department of Homeland Security, the FAA, or any other concerned agency to perform a security review of the flight team. In addition, representatives of these agencies or any other federal law enforcement agencies are welcome to attend any light show.

#### 4. Part 91 (General Operating and Flight Rules)

The general operating rules include several requirements that are not practical for unmanned flight in general or that Ars would not be able to comply with in conducting the flights proposed in this petition.

Section 91.7 requires that an aircraft be in airworthy condition and states that the pilot in command is responsible for determining this status. 14 CFR § 91.7. Ars does not intend to operate any aircraft in an unsafe condition, but believes an exemption may be required to permit the operators, who do not have pilot certificates, to make the required determination. The operators should be permitted to make this determination because they are familiar with these relatively simple 1.5-pound aircraft and the manufacturer's preflight inspection and test protocols. The operators will ensure aircraft are in airworthy condition before flight by following the manufacturer's preflight inspection and test protocols.

Section 91.9(b) prohibits operating a U.S.-registered civil aircraft unless the flight manual or other "approved manual material, markings, and placards" are "available in the aircraft." 14 CFR § 91.9(b). Ars does not believe an exemption is required because the aircraft are not U.S. registered and because of the FAA's recent interpretation that "the intent of these regulations is met if the pilot of the unmanned aircraft has access to these documents at the control station from which he or she is operating the aircraft." FAA Interpretive Memorandum, *Interpretation regarding whether certain required documents may be kept at an unmanned aircraft's control station* (August 8, 2014), at 1. Regardless of the registration issue, Ars will ensure that each operator has all of the manuals described in section F.6 available at the ground control station during each flight.

Section 91.9(c) requires that U.S.-registered civil aircraft be marked in accordance with part 45. Ars believes this requirement does not apply because these aircraft are not eligible for U.S. registration. In any event, the FAA should exempt Ars from this requirement regardless of registration for the reasons stated in section K.2 above.

Section 91.103 requires that the pilot in command, before the flight, become familiar with all available information concerning that flight. Ars does not intend to operate the aircraft without the operators familiarizing themselves with all information concerning the flight, including weather, conditions imposed by the FAA on operation, manned aircraft flight in the vicinity, the condition of the aircraft, and the site-specific safety plan. But an exemption may be necessary because the operators do not have pilot certificates and therefore may not technically qualify as "pilot in command." The operators are experienced flying these unmanned aircraft in several light shows. An exemption is warranted for the same reason cited in relation to pilot certification.

Section 91.111 prohibits operating an aircraft "so close to another aircraft as to create a collision hazard," and requires that any formation flight be prearranged with the pilot in command of each aircraft in the formation. 14 CFR § 91.111(a), (b). During the light show, the aircraft will fly in formation as close as 6 meters apart. Formation flight in close quarters is necessary to display the light show features while using a relatively small airspace that can be easily segregated from both manned flight and persons on the ground. The flight control software

and the accuracy of modern GPS permit the aircraft to fly seamlessly in formation without interfering with each other. Moreover, the flight team runs computer simulations using the programmed aircraft positions to verify adequate separation between aircraft. As a result, the aircraft can and do safely fly in formation very close together.

Section 91.113 requires “each person operating an aircraft” to maintain “vigilance” to “see and avoid other aircraft.” 14 CFR § 91.113(b). As the FAA has noted, unmanned aircraft “inherently cannot comply” with this requirement because of “the absence of an onboard pilot.” FAA Order 8900.1, vol. 16, ch. 1, § 3. An exemption is warranted because the proposed flights will take place within the visual line of site of the operators and observers, and more importantly within a small airspace bounded by a geo-fence that separates the aircraft from other traffic and persons on the ground. Given the small size of the airspace and operation within visual line of sight, the operators will have the same visual see-and-avoid ability on the ground as they would in aircraft.

Section 91.119 prohibits flying below 500 or 1,000 feet except when necessary for takeoff or landing, depending on surface congestion below, and prohibits operating within 500 feet of a person, vessel, vehicle, or structure. 14 CFR § 91.119(b)-(c). An exemption is necessary because all flights will be conducted below 400 feet above ground level, with the lowest aircraft having a minimum altitude of approximately 45 feet agl during the light show. The FAA has recognized, in designating 400 feet as the ceiling for model aircraft operations, that unmanned aircraft can safely operate below this level. Advisory Circular 91-57. The low altitude contributes to safety by ensuring separation from manned flight, which generally must remain well above this threshold. Moreover, the exclusion zone provides greater safety to people on the ground than a minimum altitude. A minimum altitude simply puts time between the aircraft and people below; the exclusion zone provides distance that an aircraft cannot overcome even if it loses power.

Because of the small airspace and slow aircraft speed, the exclusion zone will likely result in less than 500 feet of separation between nonparticipating persons and the aircraft. An exemption from section 91.119(c) is therefore necessary. That regulation’s 500-foot requirement has no relationship to aircraft mass, speed, or operating conditions—the variables that determine how much separation is safe. The exclusion zone, by contrast, accounts for these variables, and is actually conservative in assuming a maximum groundspeed more than 3 times the limit of these aircraft. It a safety zone calculated to ensure safe separation under the specific conditions of light show flights.

The exclusion zone provides higher safety than a separation distance unmoored from the specific conditions of flight. As such, the aircraft should be permitted to operate less than 500 feet from nonparticipants, provided the aircraft stay within the flight area and nonparticipants stay outside the exclusion zone (except, as discussed above, people inside buildings). As for participants, the operators and observers will be inside the exclusion zone. The aircraft will fly within 500 feet of them but not so close as to present an undue hazard to them under § 91.119(a).

Some flight locations may have commercial or industrial structures within the flight area or exclusion zone. Aircraft will necessarily fly within 500 feet of them, and may fly within 500 feet of structures just outside the exclusion zone boundary. Due to low mass and slow speed, the

aircraft pose no threat to structures. Regardless, aircraft during a light show will stay at least 25 horizontal meters and 15 vertical meters from structures, except for any structure used as an elevated launch platform. Ars will respect the rights of property owners by obtaining the express permission of the owners of all real property within the flight and exclusion zones.

Ars will bar vehicles and vessels from entering the flight and exclusion zones during the flight. Vehicles and vessels outside the exclusion zone but within 500 feet of aircraft face no risk because the aircraft, due to the geo-fence and automatic engine shutdown feature, cannot travel that far from the flight area.

Sections 91.126, 91.127, 91.129, and 91.130 require certain communication and coordination with ATC, depending on the classification of airspace used. Locations under consideration for light show flights fall within class C, D, E, or G airspace. Ars does not propose to operate in class A or B airspace. An exemption from these regulations is warranted because the aircraft will operate in a small airspace, well below manned traffic, with advance coordination with the FAA and local air traffic control. Ars will provide advance notice to ATC at least 3 days in advance and will request a NOTAM to advise all traffic of the light show. The traffic coordination function ordinarily provided through ATC communication is not necessary given the limited airspace used for the flights and the advance coordination with the FAA.

Section 91.151(a) prescribes minimum fuel requirements for VFR operations to ensure an adequate fuel reserve on reaching the intended destination, between 20 and 45 minutes depending on whether the aircraft is fixed or rotary wing and the operation is day or night. Regardless which time period applies, the Hummingbird aircraft could not practically comply with this regulation because their maximum flight duration is 10 minutes with the LED modules. The aircraft take off and land at one location and stay within a few hundred feet of it for the entire show. The operators continuously monitor the battery state of each aircraft and can manually land any aircraft that has a battery problem. Ars limits light shows to 8 minutes to provide a 20% power reserve margin, which is more than enough to safely land. As with the aircraft for which Clayco received Section 333 approval, in “the event that the UAS should run out of power, it would simply land within the access controlled operating area. Given its weight and construction material, the risks are less than contemplated by the current regulation.” Clayco Grant at 15.

Section 91.203 requires a civil aircraft to carry within it “an appropriate and current airworthiness certificate,” which must list the registration number assigned to that aircraft. 14 CFR § 91.203(a)(1). It also requires the aircraft to carry an “effective U.S. registration certificate issued to its owner” or one issued by a foreign country. 14 CFR § 91.203(a)(2). Ars addressed exemption from the certification and registration requirements in sections K.1 and K.2 above, so this discussion will address exemption from the requirement to carry documentation on board the aircraft. The FAA has recently interpreted the “carry” requirements as satisfied by “maintaining these documents at the pilot’s control station.” FAA Interpretive Memorandum, *Interpretation regarding whether certain required documents may be kept at an unmanned aircraft’s control station* (August 8, 2014), at 2. Ars will maintain all required documentation at the ground control station where it can be readily accessed by any operator or FAA inspector. As a result, exemption from section 91.203 is not necessary. *See* Astraeus Grant at 19-20 (“Based on the FAA Memorandum subject ‘Interpretation regarding whether certain required documents may be



kept at an unmanned aircraft's control station, dated August 8, 2014, the requested relief from 14 CFR §§ 91.9(b)(2) and 91.203(a) and (b) is not necessary.”).

Section 91.215 requires aircraft operating in certain airspace to have ATC transponder and altitude reporting equipment. The requirement applies to all airspace from the surface to 10,000 feet within 30 miles of certain airports, including San Francisco International Airport. 14 CFR § 91.215(b)(2) & App. D, § 1. The sites Ars currently contemplates lie within SFO's 30-mile mode C veil. An exemption is necessary because these aircraft do not have a transponder or altitude reporting equipment—other than for reporting altitude to the ground control station. The Hummingbird aircraft are designed to fly in limited airspace within a few hundred feet of, and under the control of, a ground control station. They will not share airspace with manned flights or other traffic. Moreover, Ars will keep local ATC advised of the time and location of any flight, as well as request a NOTAM. These measures provide the safety assurance otherwise provided by section 91.215.

Subpart E of Part 91 contains regulations on maintenance responsibilities and documentation that apply to the “maintenance, preventive maintenance, and alterations of U.S.-registered civil aircraft.” 14 CFR § 91.401(a). These regulations arguably do not apply because the aircraft proposed for these flights are not registered in the United States or elsewhere. To the extent the FAA interprets the regulations in this subpart to apply, an exemption is necessary.

Specifically, the regulations in this subpart require:

- Maintenance may only be performed as prescribed in Part 91, subpart E, and Part 43. 14 CFR § 91.403(b). Part 43 requires that persons who maintain, rebuild, alter, or perform preventive maintenance on any U.S.-registered aircraft have the specified certificate, and that they make certain maintenance record entries. 14 CFR §§ 43.1(a), 43.7, 43.9, 43.11. It also specifies who may return an aircraft to service and what paperwork is required. 14 CFR §§ 43.5, 43.7.
- The owner or operator must have the aircraft inspected and ensure that maintenance personnel make appropriate entries in the maintenance records indicating the aircraft has been approved for return to service. 14 CFR § 91.405(a), (b).
- An aircraft that has undergone maintenance or preventive maintenance cannot be operated until it has been approved for return to service by a person authorized under section 43.7 and required entries have been made in the maintenance records. 14 CFR § 91.407(a).
- Aircraft that do not carry passengers for hire must undergo annual inspections. 14 CFR § 91.409(a).
- The owner or operator must keep certain maintenance records. 14 CFR § 91.417.

The FAA should grant an exemption from these maintenance requirements because Ars employs a maintenance and quality assurance program that meets or exceeds applicable

regulatory standards for U.S.-registered aircraft and ensures that aircraft are in a condition for safe flight before takeoff. Specifically, Ars complies with the manufacturer's pre-flight inspection and test checklist before each flight. Ars documents maintenance in a master database that tracks each aircraft by serial number. Further, the type of maintenance that can be performed in the field is very simple, such as replacing a rotor, and lies well within the skill set of an average model-aircraft enthusiast. The type of maintenance skill afforded by a mechanic or airman certificate simply does not apply to a 1.5-pound aircraft, particularly where maintaining an item generally means replacing rather than repairing it.

#### **L. Granting the Exemption is in the Public Interest**

Unmanned aircraft are a revolution in aviation, with the same type of transformative potential as the introduction of the jet engine. Unmanned aircraft open up uses that were never possible with manned aircraft. Flying a few hundred aircraft in a small airspace is just one of them. The possibilities are spurring innovation in many areas, including new types of flight control technology. This one use case showcases the advances in this area. A few people, using technology, can fly many aircraft in complicated aerial formations. Synching the aircraft movement to a light display turns the sky into a public stage.

Although Section 333 does not require a showing of public interest, granting the exemptions requested in this petition is in the public interest for a number of reasons. First, the proposed flights demonstrate the transformative potential of technology in a sector with rapidly increasing importance for the national economy. They show, for example, how technology and automation enable numerous aircraft to fly in small spaces near populated areas. Such demonstrations help promote public acceptance of unmanned aircraft, especially in novel use cases that were not possible with manned aircraft. Public acceptance is a social good because it will lead to quicker implementation of socially beneficial unmanned aircraft flights. Examples include formations of unmanned aircraft covering a large area for search and rescue or post-disaster surveys; providing precision crop pollination and monitoring; or serving as a distributed communications network in an emergency.

Second, light shows are a safe and environmentally-friendly alternative to fireworks displays. They provide in-sky animations that can be custom-designed, and typically use less airspace than large public fireworks shows. Fireworks shows involve risk of serious injury to the sponsors and audience members. For example, an explosion at a Simi Valley July Fourth fireworks show in 2013 injured almost 30 people. Shows using unmanned aircraft involve no combustible materials and employ an over-sized safety buffer zone to separate aircraft from people on the ground. Fireworks also involve a large environmental footprint, whereas the Hummingbird aircraft use only electrical power. The FAA has cited improved safety and reduced environmental burden as public interests in recent grants of exemption. Trimble Navigation Grant at 20; Clayco Grant at 16.

Finally, unmanned aircraft light shows provide a free entertainment show to the public, paid for by the show sponsor, which audiences can enjoy for miles away. The fact that local governments and corporate sponsors often spend millions of dollars on public light shows for events such as July Fourth attest to this public benefit.

## **M. National Security Considerations**

The Hummingbird unmanned aircraft do not implicate any national security considerations due to their low mass, payload, and speed.

Ars or Intel will notify state and local law enforcement authorities about each planned flight at least 24 hours before conducting it, and will notify the local FSDO and air traffic organization at least 3 days before flight.

## **N. Proposed Conditions and Limitations on the Exemption**

Ars proposes the following conditions and limitations on flights:

1. Operations are limited to Hummingbird aircraft manufactured by AscTec.
2. Each aircraft will weigh less than 2 pounds, including energy sources and payload.
3. No aircraft can exceed a groundspeed of 6 knots during flight.
4. Flights must be operated at an altitude below 400 feet AGL. All altitudes reported to ATC must be in feet AGL.
5. All aircraft will operate within visual line of sight of the operators and at least two observers at all times. The operators and observers must use human vision unaided by any device other than corrective lenses prescribed by a medical or eye-care professional.
6. The observers and operators must be able to communicate verbally at all times, either orally or with a communications device.
7. Prior to each flight the operators must inspect and test each aircraft per the manufacturer's documentation to ensure that it is in a condition for safe flight. If any aircraft is not in a condition for safe flight, it cannot be flown until the necessary maintenance has been performed and it is in a condition for safe flight. The preflight inspection must include verification that the ground control station is set up and operating properly, and that the communications link is functioning correctly.
8. The aircraft may not be operated directly over any person, except authorized and consenting personnel associated with the operator or the show sponsor.
9. The UAS may only be operated within a cylindrical airspace measuring no more than 1,000 feet diameter and 400 feet above ground level. The operator must use GPS geo-fencing to ensure that aircraft do not leave the flight area.
10. The operator must implement and enforce an exclusion zone on the ground to ensure that non-participating personnel cannot approach the flight area. The

exclusion zone must be large enough to ensure that any aircraft that exits the geo-fence will reach the ground before reaching the boundary of the exclusion zone.

11. If the UAS loses the GPS signal or communication with the ground station, it must automatically return to a predetermined location or land within the airspace approved for flight.
12. The operator must obtain an Air Traffic Organization-issued Certificate of Authorization or Waiver before conducting any operations under this grant of exemption. This COA will also require the operator to request a NOTAM at least 48 hours before the operation.
13. At least three days before any flight under the grant of exemption, the operator will submit a written Plan of Activities to the local FSDO with jurisdiction over the area of the proposed flight. The Plan of Activities must include the following:
  - a. Dates and times of flights;
  - b. Name and phone number of the operator and the person(s) responsible for on-scene operation of the UAS;
  - c. A statement that the operator or show sponsor has obtained permission from property owners and/or local officials to conduct the show, and if requested a list of the property owners and local officials from whom permission was obtained;
  - d. A description of the flight, including maps and diagrams of the airspace, geo-fence boundaries, and exclusion zone; and
  - e. A site-specific safety plan to ensure separation of the aircraft from all non-participating personnel.
14. The UAS must remain clear of, and yield right of way to, all other aircraft.
15. All flights must be conducted in VMC. Regardless of classification of airspace used, the aircraft may not be operated less than 500 feet below or less than 2,000 feet horizontally from a cloud or when visibility is less than 3 statute miles.
16. The operators must maintain all manuals relating to the aircraft at the ground station during each flight.

**O. Summary for Publication in the Federal Register**

Ars Electronica Linz GmbH, in cooperation with Intel Corporation, filed a petition for exemption and request for approval to operate unmanned aircraft under Section 333 of the FAA Modernization and Reform Act of 2012. Ars requests permission to operate multiple unmanned aircraft in a cylindrical airspace measuring less than 1,000 feet diameter and less than 400 feet above ground level for light shows. Ars seeks exemption from the requirements of airworthiness

certification under Part 21, registration and marking requirements under parts 45 and 47, pilot and medical certificates under parts 61 and 67, and operating and maintenance requirements under part 91.

**P. Conclusion**

The current rules governing airworthiness certification, airspace use, airmans' certificates, registration, and the like make sense with manned aircraft. They also make sense with unmanned aircraft that function like manned aircraft, or that travel the same airspace as manned aircraft. But innovations in unmanned aircraft technology have opened up use cases that these regulations simply did not contemplate. Some of these use cases employ controls that provide a higher level of safety than any regulations could. The flights proposed here are a good example. They consist of short flights, with tiny aircraft, in a small airspace separated from other aircraft and persons on the ground. They satisfy every safety factor that Congress identified in section 333. As such, the FAA should grant the requested exemptions and authorize Ars to conduct the flights described in this petition.

Dated: December 19, 2014

Submitted By:

Ars Electronica Linz GmbH



\_\_\_\_\_  
Horst Hoerther  
Senior Director

## Appendix A: Proprietary Supporting Documentation

| Document | Description  |
|----------|--|
| 1        | <i>Ars Ground Control Quick Start Guide</i>                                  |
| 2        | AscTec preflight checklist, entitled <i>Indoor and outdoor test protocol</i> |

## Appendix B: Full Citations

| Citation in Text         | Full Citation   |
|--------------------------|---|
| Astraeus Grant           | <i>In re Astraeus Aerial</i> , Exemption No. 11062, Regulatory Docket No. FAA-2014-0352 (September 25, 2014)        |
| Trimble Navigation Grant | <i>In re Trimble Navigation Ltd.</i> , Exemption No. 11110, Regulatory Docket No. FAA-2014-0367 (December 10, 2014) |
| Clayco Grant             | <i>In re Clayco, Inc.</i> , Exemption No. 11109, Regulatory Docket No. FAA-2014-0507 (December 10, 2014)            |
| Woolpert Grant           | <i>In re Woolpert, Inc.</i> , Exemption No. 11114, Regulatory Docket No. FAA-2014-0398 (December 10, 2014)          |
| VDOS Grant               | <i>In re VDOS Global, LLC</i> , Exemption No. 11112, Regulatory Docket No. FAA-2014-0382 (December 10, 2014)        |