Narrative Statement – LEMUR-1 Application

A. Introduction and Background

NanoSatisfi Inc. (NanoSatisfi), a Delaware corporation based in San Francisco, California, requests a conventional experimental radio license to conduct a market trial pursuant to 47 C.F.R. §§ 5.3(k), 5.54(a)(1), and 5.602. With this experimental license, NanoSatisfi seeks to research and evaluate the demand in the maritime, meteorological and education markets for nanosatellite technology as part of its ongoing market trial.[1]

NanoSatisfi creates tools that make it simple for anyone to interact with space by offering convenient, affordable, and on-demand access to satellites.[2] The enterprise grew out of a volunteer effort by four graduate students at the International Space University who began building a prototype nanosatellite as a platform for making space accessible and affordable to students. Early funding for the concept came from the crowd-funding website Kickstarter, where the original ArduSat (short for Arduino-based satellite) concept raised more than $100,000 from nearly 700 private space enthusiasts.[3]

Kickstarter Launch – ArduSat-1 and ArduSat-X. Based on the success of this Kickstarter campaign, and pursuant to a grant of special temporary authority awarded earlier this year,[4] two

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[1] *See* NanoSatisfi Inc., File No. 0532-EX-PL-2013, Call Sign: WG2XXW (Dec. 7, 2013) (awarding NanoSatisfi an experimental license to conduct a market trial using its ArduSat-2 satellite).

[2] NanoSatisfi, *Homepage* (last accessed July 10, 2013), http://www.nanosatisfi.com/.

[3] *ArduSat – Your Arduino Experiment in Space*, Kickstarter (last accessed July 9, 2013), http://www.kickstarter.com/projects/575960623/ardusat-your-arduino-experiment-in-space.

[4] The Commission granted Special Temporary Authority to ArduSat Inc. for operating these satellites on April 26, 2013 (Call Sign: WG9XFC; File No. 0917-EX-ST-2012). ArduSat Inc. has since applied for a full experimental authorization through the end of 2014. *See* File No: 0787-EX-PL-2013 (filed Dec. 24, 2013). Note that ArduSat Inc. is a non-profit corporation founded solely to launch these two satellites. While the applicant here, NanoSatisfi, was founded by many of the same members of the ArduSat Inc. team, NanoSatisfi is a separate, for-profit entity.

ArduSats (the ArduSat-1 and the ArduSat-X) were launched on August 3, 2013[5] and, after a brief stay in the International Space Station, released into orbit on November 19, 2013.[6] Since these satellites have been launched, Kickstarter funders and others are using these satellites to test experiments, play games, take pictures, and run applications. For this pioneering work related to the ArduSat-1 and ArduSat-X, the Obama Administration has recognized NanoSatisfi Co-founder and CEO Peter Platzer as a Champion of Change.[7] While these first two satellites are not a part of the ongoing market trial that is the subject of this application, they provide useful background of the company and suggest the power of ArduSat technology.

ArduSat-2, LEMUR-1, and Extension of the Ongoing Market Trial. Based on the experience with ArduSat technology and the great deal of interest surrounding it, NanoSatisfi sought and received authority to conduct a market trial to determine if a somewhat more advanced ArduSat – the ArduSat-2 – had consumer and commercial applications in the maritime, meteorological, and educational markets.[8] The ArduSat-2 was launched into space on January 9, 2014 as part of the Cygnus Orb-1 resupply mission to the International Space Station (ISS),[9] and it was released from the ISS on February 28, commencing transmissions shortly thereafter.[10]

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[5] Japan Aerospace Exploration Agency, *Launch Result of H-II Transfer Vehicle "KOUNOTORI4" (HTV4) by H-IIB Launch Vehicle No. 4* (Aug. 4, 2013), *available at* http://bit.ly/1ewSHIE.

[6] NASA, *Crew Deploys Tiny Satellites and Tests Spacesuit Repairs* (Nov. 19, 2013), *available at* http://1.usa.gov/1hJEJSm.

[7] *Creating Next Generation Innovators Through Space Education*, The White House (June 6, 2013), http://www.whitehouse.gov/blog/2013/06/06/creating-next-generation-innovators-through-space-education.

[8] *See* Call Sign: WG2XXW, File No.: 0532-EX-PL-2013 (granted Dec. 7, 2014).

[9] Orbital Sciences, *ISS Commercial Resupply Services Mission (ORB-1)* (last accessed Mar. 4, 2014), https://www.orbital.com/NewsInfo/MissionUpdates/Orb-1/MissionUpdate/.

[10] *See, e.g.*, NASA, *It's a March of the CubeSats as Space Station Deployment Continues* (Mar. 3, 2014), http://1.usa.gov/1jOJJal.

NanoSatisfi seeks approval to operate an additional nanosatellite – the LEMUR-1, as part of its ongoing market trial with the ArduSat-2 in order to continue testing the educational, meteorological, and maritime markets. The LEMUR-1 houses additional technology to that of the ArduSat-2, and additional satellites, including the LEMUR-1, are a critical component of the market trial because they enable NanoSatisfi to test the type of frequent revisit times necessary to explore, in particular, the meteorological and maritime markets.

B. Description of Equipment and Theory of Operation

NanoSatisfi seeks to continue its market trial of the educational, meteorological, and maritime markets from the initial ArduSat-2 with the addition of the more advanced LEMUR-1.

1. The ArduSat Concept.

An ArduSat is a nanosatellite built in the CubeSat form factor,[11] a standard that helps reduce the cost of launching small satellites into space by allowing for a common deployment system. The basic unit for the CubeSat form factor is a single 10-centimeter cube, weighing no more than 1.33 kilograms. The CubeSat standard, however, is scalable along one axis, allowing up to three of these 10-centimeter cubes to be joined together (so-called "1U," "2U," and "3U" CubeSats). The original ArduSats are constructed according to the 1U form factor, while the AruSat-2 and LEMUR-1 models are designed to the 2U and 3U specifications, respectively.

ArduSats carry a suite of sensors and a payload computer that can be reprogrammed while in space. The user-programmable payload computer is comprised of an array of Arduino processors (AVR processors) and can run code developed on the ubiquitous, open-source Arduino software development platform. ArduSats were invented with the purpose of creating an

[11] *See* California Polytechnic State University, *CubeSat Design Specification* (last visited July 10, 2013), http://www.cubesat.org/images/developers/cds_rev12.pdf.

inexpensive, accessible development platform in space on which students, teachers, hobbyists, and researchers could affordably create and run their own custom-built experiments and applications.

Under this original educational focus – the primary purpose of the ArduSat-1 and the ArduSat-X – users can design their own space-based applications, experiments, and even space games using the Arduino open-source prototyping platform. Once a user-designed application has passed testing on an ArduSat clone located on Earth, users can upload their applications to the payload computer of an ArduSat that is orbiting in space, where it is monitored and maintained by the satellite's main computer. From there, the applications are free to sample data from the payload sensors and bus, take pictures, and return data to the user's web browser whenever the satellite is in range of a participating ground station. At the end of the user's experiment period, which can be up to a week in length, any remaining data is downlinked and returned to the user.

An ArduSat's payload consists of a suite of sensors, including an optical spectrometer, a Geiger counter, an atmospheric sensor, an infrared sensor, an accelerometer, a gyroscope, a magnetometer, a sun sensor, an electromagnetic wave sensor, a dual-frequency GPS receiver (for ionospheric studies), a megapixel camera, and more. The sensors (and other telemetry values) are sampled by the user-generated programs running on the payload computer. The first two ArduSats began transmissions on November 19, 2013 under Call Sign WG9XFC.[12]

2. ArduSat-2.

[12] *See* File No. 0917-EX-ST-2012; *see also* NASA, *Crew Deploys Tiny Satellites and Tests Spacesuit Repairs* (Nov. 19, 2013), *available at* http://1.usa.gov/1hJEJSm.

The ArduSat-2 fits the 2U CubeSat form factor, with a total mass of 2.66 kg and an outer envelope of 10x10x20 centimeters (excluding the deployable dipole antenna). With this additional capacity, the ArduSat-2 follows the same basic ArduSat concept but has increased room onboard for hosting experiments, improved data downlink capability, and new payload sensors. The ArduSat-2 commenced transmissions on February 28 under Call Sign WG2XX and is being used to test the maritime, meteorological, and educational markets.[13]

3. LEMUR-1.

The LEMUR-1 is a 3U CubeSat, adding an additional 10-centimeter cube to the ArduSat-2, for a total mass of approximately 4 kilograms and an outer envelope of 10x10x34.5 centimeters (excluding the deployable antenna). This additional capacity primarily houses another receiver allowing for supplemental gyroscopic equipment for steering the satellite more precisely. The LEMUR-1 is schedule for launch in May 2014.

[13] *See* File No. 0532-EX-PL-2013.

C. Construction, Launch, and Orbit Details

Summary of LEMUR-1 Construction, Launch, and Orbit							
Schedule of Construction	**Proposed Integration Date**	**Launch Service Provider**	**Launch Vehicle Operator**	**Mission**	**Method of Deployment**	**Proposed Launch Date**	**Orbit**
Currently undergoing subsystem integration and testing. Scheduled to be delivered to CalPoly on April 7, 2014.	Mid-April 2014	CalPoly Launch Services	International Space Company (ISC) Kosmotras	Secondary payload on the University Satellite ("UniSat")-6 Mission (Dnepr Rocket).	PicoSatellite Orbital Deployer (P-POD) attached to the DNEPR vehicle	Currently scheduled no earlier than May 1, 2014	Altitude: 600 km; Inclination: 97.984 degrees (Sun Synchronous Orbit)

D. Purpose, Scope, and Objective of Market Trial

NanoSatisfi Inc. seeks authority to continue its market trial, which was initially approved as a basis for its authority to operate ArduSat-2. The LEMUR-1 will be the second of NanoSatisfi's satellites for this trial testing the demand for ArduSat technology in the meteorological, maritime, and educational markets. To adequately test the demand for these markets, NanoSatisfi must provide a service with high revisit times. For purposes of the experimental period, NanoSatisfi is targeting a still lengthy six hours, which will require a small constellation of up to fifteen satellites. As to this application for the LEMUR-1, NanoSatisfi requests a two-year experimental authorization to continue this market trial.

1. *Maritime Monitoring*.

NanoSatisfi requests authority to test the market for using its nanosatellite technology to monitor maritime activity. Current maritime monitoring systems are generally land-based and do not offer the ability to track ships when they are outside of a 50-mile zone. NanoSatisfi plans

to test a satellite-based system relying on a small constellation of up to fifteen satellites, including the LEMUR-1, so that satellites will provide reasonable re-visit times of less than six hours. The satellites will passively monitor Automatic Identification System ("AIS") signals at 161.975 MHz and 162.025 MHz for purposes of tracking nautical activity (note that they will not emit any signals at these frequencies). For purposes of this trial, no equipment will be required onboard subject vessels as vessels with gross tonnage of 300 tons or greater are already required by international law to carry a functional Automatic Identification System (AIS) beacon transmitter on-board.[14]

NanoSatisfi believes that such data is of interest to shipping companies, harbor operators, governments, Vessel Traffic Service (VTS) data providers, and financial services companies. Additionally, NanoSatisfi hopes to fuse optical data with communication data to help detect pirate ship activity. However, these uses have to be verified, which is the purpose of this experimental period.

During this experimental period, NanoSatisfi expects to have a small number of pilot customers (less than 100) to help refine the service and quantify the market need for this data, which it predicts could be tens of thousands of customers across the globe.

2. Meteorological Monitoring.

NanoSatisfi requests authority to test the market for using its nanosatellite technology to conduct atmospheric studies. Current satellite-based systems rely on large, expensive satellites and suffer from extensive delays and long revisit times. NanoSatisfi plans to test a satellite-

[14] *See* The International Convention for the Safety of Life at Sea, Dec. 2002 Amendments (Dec. 2002), *available at* http://bit.ly/15vyqx5.

based system relying on a small constellation of up to fifteen satellites, including the LEMUR-1. These satellites will provide reasonable re-visit times of less than six hours.

To conduct this meteorological monitoring, LEMUR-1 and the other satellites in the constellation will passively monitor GPS signals at L1 (1575.42 MHz) and L2 (1227.60 MHz) frequencies (no transmissions are required). Based on these GPS signals, the satellites will employ a relatively new technique – GPS-Radio Occultation.[15] Because GPS signals refract differently as they pass through the atmosphere depending on temperature and the concentration of water vapor, it is possible to measure weather patterns using this technology, and there is a great deal of interest both commercially and in government to explore this technology further. For example, the Weather Forecasting Improvement Act of 2013 (H.R. 2413) specifically includes provisions for the National Oceanic and Atmospheric Administration to examine this technology.[16] Weather monitoring technologies such as GPS-Radio Occultation and others are currently receiving particularly extensive attention because of a looming gap in the US government's ability to monitor the weather with one of its satellites scheduled to reach the end of its useful life in the near future and without a replacement scheduled for some time.[17]

NanoSatisfi believes that such data is of interest to governments, consumers and the financial services community. Additionally, NanoSatisfi hopes to fuse optical data with atmospheric properties to provide an enhanced value-added product. However, these uses have to be verified, which is the purpose of this experimental period.

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[15] *See, e.g.*, NASA, *Generating Climate Benchmark Atmospheric Surroundings Using GPS Radio Occultations* (July 2007), 1.usa.gov/1bOUxEI.

[16] *See, e.g.*, Dan Leone, *Commercial Weather Provisions in NOAA Bill Survive First Vote in House*, SpaceNews (Jul. 9, 2013), http://bit.ly/16bpmwo.

[17] *See* U.S. Government Accountability Office, *Polar-Orbiting Environmental Satellites* 25 (June 2012), *available at* http://www.gao.gov/assets/600/591643.pdf.

During this experimental period, NanoSatisfi expects to have a small number of pilot customers (less than 100) to help refine the service and quantify the market need for this data, which it predicts could be tens of thousands of customers across the globe.

3. *STEM Education*

Especially in the United States, but also in Europe and elsewhere throughout the world, economies are suffering from a lack of graduates in the crucial fields of science, technology, engineering, and math (STEM). While these fields are generally accepted to be at the very core of our ability to innovate, generate jobs and stimulate economic growth, budget cuts in our education system have increasingly endangered these fields and created a problematic dearth of graduates.

NanoSatisfi is testing a novel approach to inspire students to pursue careers in these fields by giving them access to control the sensors and cameras of a nanosatellite. Students will engage in an online curriculum similar in format to those offered by Udacity or Coursera. At the end of this online curriculum, students will have access to the satellite's microprocessor to upload their own experiment and control the sensors and cameras. Using a simple online satellite control interface, users can program and control the satellite, provide instructions on sensor activation, track the satellite's orbit, implement experiments and download data and pictures from space. Users already have access to the ArduSat-2 and will have access to the LEMUR-1 for purposes of testing their experiments and running their applications. Hiding the complexities of space, this simple, integrated environment democratizes space for schoolchildren everywhere so that it is no longer only the province of rocket-scientists.

During this experimental period, NanoSatisfi plans to work with a select number of pilot organizations (less than 200) to help refine the service and curriculum and qualify the market for

this kind of educational tool. Nanosatisfi estimates that the total market for this tool could be in the hundreds of thousands of customers across the globe.

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Including authority to operate the LEMUR-1 under this proposed market trial will help NanoSatisfi better evaluate the demand for its technology in each of these various sectors. Consistent with 47 C.F.R. § 5.602, NanoSatisfi will own all transmitting and receiving equipment in the study, and it will ensure that all trial devices are rendered inoperable at the conclusion of the trial.

E. Contribution of the Proposed Market Trial to the Radio Art

Testing the LEMUR-1 as part of this proposed market trial promises to significantly contribute to the development, extension, expansion and utilization of the radio art. As described above, NanoSatisfi's proposed market trial will explore three areas to determine the market demand for innovative nanosatellite technologies. The LEMUR-1 will be among the first nanosatellites employed for monitoring meteorological and maritime activities and for allowing the general public to access space in a meaningful way. If these market trials are successful, NanoSatisfi plans to widely deploy its technology, promising to offer extensive consumer and educational benefits.

F. Orbital Debris Mitigation Statement

Consistent with 47 C.F.R. § 5.64, NanoSatisfi has included an Orbital Debris Assessment Report (ODAR) for the LEMUR-1 as an exhibit to this application. As discussed therein, LEMUR-1's expected orbital life is approximately nine years based on a conservative initial orbital altitude of 620 kilometers. In a very unlikely worst-case scenario, if both the solar panels and the antennas fail to deploy, and assuming a worst-case drag configuration, the outer limit of

LEMUR-1's orbital life is approximately twenty-nine years. At the end of LEMUR-1's orbital life, the nanosatellite will re-enter the atmosphere and completely burn up before reaching the ground. LEMUR-1 does not contain any hard metals or other hazardous materials that could survive reentry.

G. Onboard Cameras

NanoSatisfi has submitted an application to the National Oceanic and Atmospheric Administration ("NOAA") to operate LEMUR-1's two onboard cameras (one is for visible light and one is for infrared light), and the application is undergoing formal review. NanoSatisfi already has obtained licenses for the cameras onboard the ArduSat-1, ArduSat-X, and ArduSat-2.[18]

H. Conclusion

By granting this application, the Commission can help NanoSatisfi make space accessible to anyone and to unleash the valuable commercial applications made possible with innovative nanosatellite technology.

The "stop buzzer" point of contact for the market trial is Joel Spark, Lead Engineer Satellite Bus (415-947-9865; joel@nanosatisfi.com).

[18] *See* NOAA, *About the Licensing of Private Remote Sensing Space Systems* (last accessed Feb. 28, 2014), http://www.nesdis.noaa.gov/CRSRA/licenseHome.html (click on "NOAA Licensees").