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Preface

This case study was compiled by Declan Robillard and is meant to be a regurgitation of public information provided by Rocket Lab and its customers. The results are intended to provide a historical baseline for the community satellite team, known as BATSat, as they begin brainstorming and base lining BATSats capability and size. The author was not, and never intended to be, reimbursed for these efforts and the research and writing was done on personal time. Most of this information was compiled from the Rocket Lab Press Kits for each launch.

The Rocket Lab Experience

Rocket Lab has quickly become a leader in the small sat marketplace. They promote three aspects that set them apart from their competition; Responsive Launch Vehicles, Responsive Launch Sites, and Responsive Satellites.

Responsive Launch Vehicle

Their launch vehicle, Electron, is designed for standardized, rapid production. An entirely new Electron is currently built from scratch every 30 days, making Rocket Lab the company building the highest number of complete rockets anywhere in the world right now. This high production rate ensures there are always launch vehicles on standby, ready to be assigned a payload for launch on demand

Responsive Launch Sites

Rocket Lab delivers the highest number of launch opportunities globally - more than 130 each year. Rocket Lab's Launch Complex 1 in New Zealand can support up to 120 launches per year, offering unmatched launch schedule flexibility. Launch Complex 2 on Wallops Island, Virginia, is tailored specifically for government missions and can support up to 12 launches per year.

Responsive Satellites

Rocket Lab's Electron launch vehicle is a standardized design, created to suit a range of satellites and missions, from a CubeSat rideshare to a single microsat. By not building to tail numbers, Rocket Lab provides unrivalled flexibility for on-demand launch. Satellites are integrated onto the stand-alone payload plate which can then be mounted to any Electron vehicle, enabling rapid and responsive launch opportunities. Rocket Lab goes one step further with the creation of the common Photon satellite bus. Small satellite operators simply provide their sensor and Rocket Lab looks after satellite build, launch and ground segments. Photon removes the need for operators to build their own spacecraft and is an end-to-end solution for increasing flexibility for quick-reaction launches, without sacrificing reliability.

Rocket Lab's Resume

Date	Mission	Customer	Launch Site
25 MAY 2017	It's a Test	Test Launch	LC-1, NZ
21 JAN 2018	Still Testing	Rideshare	LC-1, NZ
11 NOV 2018	It's Business Time	Rideshare	LC-1, NZ
16 DEC 2018	This One's for Pickering	NASA	LC-1, NZ
28 MAR 2019	Two Thumbs Up	DARPA	LC-1, NZ
5 MAY 2019	That's a Funny Looking Cactus	USAF	LC-1, NZ
29 JUNE 2019	Make It Rain	Spaceflight	LC-1, NZ
19 AUG 2019	Look Ma, No Hands	Rideshare	LC-1, NZ
17 OCT 2019	As The Crow Flies	Astro Digital	LC-1, NZ

Electron's Past Missions (https://www.rocketlabusa.com/missions/completed-missions/)

Summary of Non-Rideshare Payloads

It's a Test

It's a Test was the first launch of Rocket Lab's Electron launch vehicle. When Electron lifted-off at 16:20 NZT from Rocket Lab Launch Complex 1 on the Mahia Peninsula in New Zealand, it became the first orbital-class rocket launched from a private launch site. The mission saw Electron complete a perfect first stage burn, stage separation, second stage ignition and fairing separation. Electron successfully reached space and put Rocket Lab in an incredibly strong position to accelerate into commercial operations.

Still Testing, Spire

The Still Testing mission was Rocket Lab's first orbital launch of the Electron vehicle. Electron lifted-off at 14:43 NZDT from Rocket Lab Launch Complex 1 on the Māhia Peninsula in New Zealand on 21 January 2018. The launch marked the beginning of a new era in commercial access to space.

Still Testing carried a Dove Pioneer Earth-imaging satellite for Planet, as well as two Lemur-2 satellites for weather and ship tracking company Spire. Dove was intended for a 300 km x 500 km orbit at 83 degrees inclination. https://www.planet.com/pulse/meet-dove-pioneer/

Two Thumbs Up, R3D2, DARPA

R3D2 (Radio Frequency Risk Reduction Deployment Demonstration) is a prototype membrane array antenna designed to improve radio communications in a small spacecraft. The payload was packed tightly inside a small satellite during launch and deployed to a full size of 2.25 m in diameter in low Earth orbit. R3D2 weighed 150 kg and was designed to enter a 425 km x 425 km orbit at 39.5 degrees by Electrons kick stage.

As the Crow Flies, Astro Digital

The orbital parameters for this mission will see Electron's Kick Stage deploy the payload to an altitude of more than 1,000km - more than twice the altitude reached by any Rocket Lab mission to date. The mission is named 'As The Crow Flies' in a nod to Astro Digital's Corvus Platform, which provides flexible and cost-effective solutions across a wide range of applications and mission profiles on bus variants ranging from 6U and 16U CubeSats to ESPA Class. Corvus is also a widely-distributed genus of birds which includes crows.

Summary of Rideshare Payloads

Its Business Time

It's Business Time was Rocket Lab's third Electron launch. It's Business Time was manifested with commercial satellites from Spire Global, Tyvak Nano-Satellite Systems, Fleet Space Technologies, as well as an educational payload from the Irvine CubeSat STEM Program (ICSP) and a drag sail technology demonstrator designed and built by High Performance Space Structure Systems GmBH (HPS GmbH).

The payloads were launched to a 210km x 500km circular orbit at 85 degrees, before being circularized to 500 x 500 km using Rocket Lab's Curie engine powered Kick Stage.

LEMUR-2-ZUPANSKI and LEAMUR-2-CHANUSIAK - Spire

Electron will loft two Lemur-2 satellites, LEMUR-2-ZUPANSKI and LEMUR-2-CHANUSIAK, for data and analytics company Spire. These satellites will join Spire's constellation of more than sixty nanosatellites currently in Low Earth Orbit. The Lemur-2 satellites are used for Automatic Identification System (AIS) vessel tracking data to monitor ship movements over the most remote parts of the globe. They also employ GPS Radio Occultation to monitor weather. Spire collects data for Earth from space, to help business and governments address previously insurmountable problems affecting everyone on the planet. Its constantly improving constellation of LEO satellites uses listening sensors to listen to the planet in real-time, gaining access to rich and untapped data sources totally off-limits to camera-based technology and inaccessible from the ground.

TYVAK – GeoOptics Inc

It's Business Time will also carry a satellite for GeoOptics Inc., built by Tyvak Nano-Satellite Systems. Headquartered in Irvine, CA, Tyvak Nano-Satellite Systems provides end-to-end nanosatellite solutions to governments, universities, and commercial organizations.

IRVINE01 – Irvine CubeSat STEM Program (ICSP)

IRVINE01 is a CubeSat built by high school students participating in the Irvine CubeSat STEM Program (ICSP), a group of six high schools from Irvine, California. The ambitious program will mark the first time American high school students have put an operational satellite into orbit. The IRVINE01 CubeSat program is an educational mission that gives high school students the experience of building, testing,

and controlling a solar-powered nano-satellite. IRVINE01 is designed to carry a camera and a solar panel propulsion system and collect data such as temperatures and the satellite's speed, direction, location and altitude. Originally manifested on a different launch vehicle, ICSP selected an Electron rocket due to the launch vehicle's gentle payload environment which offers a smooth ride to orbit.

NABEO – HPS GmBH

NABEO is a new drag-augmentation subsystem that will be tested for the first time as part of the It's Business Time mission. Designed to passively de-orbit inactive satellites at the end of their functioning life, NABEO is a small sail is made of an ultra-thin membrane that can be coiled up tightly within a spacecraft and then deployed once the satellite reaches the end of its orbital lifespan. The large reflective panels unfold to increase the spacecraft's surface area, causing it to experience greater atmospheric drag. Because the sail is reflective, it also makes use of solar radiation pressure to maneuver; a technique called solar sailing. This enables the satellite to be lowered to an orbit where the aerodynamic drag takes over and pulls the satellite back into the Earth's atmosphere enabling much faster de-orbiting.

PROXIMA – Fleet Space Technologies

It's Business Time will loft two Proxima satellites for Australian company Fleet space Technologies. The satellites will form the foundation of Fleet's global Internet of Things (IoT) communications constellation that will provide internet connectivity for millions of sensor devices based in remote locations on Earth.

This Ones for Pickering, ELaNa-19, NASA

ELaNa-19 lifted 13 CubeSats to low Earth orbit for NASA's ELaNa (Educational Launch of Nanosatellites) program. This was the first time that NASA CubeSats had enjoyed a dedicated ride to orbit on a commercial launch vehicle. The total payload weight was approximately 78 kg and was designed to enter a 500 km x 500 km orbit at an 85 degree inclination by Rocket Lab's kick stage.

CubeSail - University of Illinois at Urbana-Champaign

Jointly developed with Colorado University Aerospace to demonstrate solar sail technology. It is intended to be a risk reduction mission for the UltraSail concept proposed for interplanetary and interstellar missions. www.cubesail.us

NMTSat - New Mexico Institute of Mining

NMTSat is an educational mission for graduate and undergraduate students. It hosts three space weather instruments, plasma probe, magnetometers, and GPS occultation experiment. In addition is contains an electrical health monitoring system and an optical status beacon experiment.

CeREs - Goddard Space Flight Center

Developed to be a scientific investigation mission to advance the understanding of the radiation belt electrons energization and loss processes in support of the Geospace program), as well as characterize solar electrons and protons by making measurements of the energy spectra.

CHOMPTT - University of Florida/NASA Ames Research Center

CHIMPTT is a technology demonstration of a precision ground-to-space time-transfer using a laser link to an orbiting CubeSat. The mission uses a satellite laser ranging facility located at the Kennedy Space Center to transmit short infrared laser pulses to CHOMPTT. This will allow time measurements with an accuracy of 200 ps (6 cm light-travel time).

ALBus - Nasa Glenn Research Center

ALBus is a technology demonstration mission of a digitally controlled electrical power system capability and novel use of Shape Memory Allot technology for reliable deployable solar array mechanisms. It will demonstrate power management and distribution of 100 watts to a target load.

ISX - SRI International/California Polytechnic State University

The Ionospheric Scintillation Explorer (ISX) CubeSat is a Space weather investigation to better understand the multifrequency radio wave interference produced by the atmosphere at sunset near the equator. www.polysat.org/in-development

STF-1 - West Virginia University/NASA's Independent Verification and Validation Facility

The STF-1 mission is to demonstrate the utility of the NASA Operation Simulator for Small Satellites (NOS3) across the CubeSat development cycle, from concept planning to mission operations. It is also equipped with a set of diverse science experiments including a cluster of Micro Electro0Mechanical System (MESM) Inertial Measurements Units to produce attitude knowledge, a space weather experiment with a Geiger counter and a Langmuir probe, a II-V Nitride based materials optoelectronics experiment, and a Novatel OEM615 GPS coupled with advanced algorithms for precise orbit determination. www.stf1.com

RSAT - United States Naval Academy

RSAT is a technology demonstration for an in-orbit mobile platform to survey and possibly repair a much larger, conventional spacecraft. The satellite has two 60 cm, 7 degree of freedom robotic arms fitted with claws. This iteration of Rsat mission will test out performance of robotic arms in space as a free-flyer.

Sheilds-1 - Langley Research Center

Sheilds-1 is a technology demonstration of environmentally durable space hardware. It incorporates three experiments; vault electronics, charge dissipation film resistance, and vault shielding development.

DaVinci - North Idaho STEM Charter Academy

DaVinci is an educational mission that will provide education for students worldwide about radio waves, aeronautical engineering, space propulsion and geography. DaVinci will send communication signals to schools across the globe, utilizing amplified radio frequencies to deliver inspirational Morse Code

messages to Space Ambassadors with the theme of "Lighting Up Minds Around the World". www.projectdavincicubesat.org

That's a Funny Looking Cactus, STP-27RD, USAF

The STP-27RD payload consisted of three satellites, SPARC-1, Falcon ODE, and Harbinger. This payload weighted in at 180 kg and utilized the kick stage to deploy the three satellites in precise accuracy.

SPARC-1 – AFRL/RV

The Space Plug and Play Architecture Research CubeSat (SPARC-1) mission is a joint Swedish-United States experiment to explore technology developments in avionics miniaturization, software defined radio systems, and space situational awareness (SSA).

Falcon ODE - USAFA

The Falcon Orbital Debris Experiment (Falcon ODE), sponsored by the United States Air Force Academy, will evaluate ground-based tracking of space objects.

Harbinger - York Space Systems

Harbinger, a commercial small satellite built by York Space Systems and sponsored by the U.S Army, will demonstrate the ability of an experimental commercial system to meet DoD space capability requirements.

Make It Rain, Spaceflight

Make it Rain was a rideshare mission aimed for 450 km x 450 km. There were seven satellites including BlackSky's Global-3 microsat, two U.S. Special Operations Command (SOCOM) Prometheus satellites and Melbourne Space Program's ACRUX-1 CubeSat. The total mission payload mass is 80 kg.

Global-3 – BlackSky

The BlackSky constellation of 1 m resolution earth observation microsatellites will be deployed by BlackSky Global. The satellites feature the SpaceView-24 imaging system built by Harris Corp.'s Exelis with an aperture of 24 cm It has a ground resolution of 0.9 - 1.1 m from an orbital height of 500 km. They have a onboard propulsion for a 3 year orbital life. The satellites are built by Spaceflight Services based on their SCOUT bus.

Prometheus 2.7 – SOCOM/LANL

Prometheus is series of 1.5U CubeSats for technology development and demonstration. It was developed by the Los Alamos National Laboratory (LANL) with the dual objective of evaluating new low-cost development and operations methodologies while also assessing the operational utility that can be provided with CubeSat technology. It was DoD funded.

The Prometheus system consists of CubeSats along with supporting ground and field segment equipment, all designed as an integrated system. LANL is serving as the primary builder and system integrator and will perform on-orbit system checkout, test, and evaluation. The satellites were based on the earlier Prometheus and Perseus satellites. The Prometheus satellites cost less than $100,000 each, are expected to have a service life of three to five years and are demonstrating the capability to transfer audio, video, and data files from man-portable, low-profile, remotely located field units to deployable ground stations terminals using over-the-horizon satellite communications. Each satellite features four deployable solar arrays and a deployable helix antenna. The second generation Block 2 satellites feature several improvements. The solar arrays have been enlarged and the attitude control system has been improved. An star field sensor and a GPS receiver were added. Also they provide the opportunity for hosted payloads, as a 1.5U payload module can be added to each satellite.

ACRUX-1 - Melbourne Space Program

The ACRUX-1 is a student-built 1U CubeSats developed by the non-profit organization Melbourne Space Program.

The purpose of the ACRUX 1 project is to develop, built and launch a student-built CubeSat from scratch, to test the functionality of the subsystems, to develop the basics for future satellite missions. The satellite uses the validated 1U CubeSat form-factor with low-gain antenna capabilities and minor flight control abilities. The satellite is primarily an in orbit engineering demonstrator model.

Look Ma, No Hands, Rideshare

Rocket Lab's eighth mission lifted-off on 19 August UTC from Launch Complex 1 in New Zealand, carrying a total of four satellites aboard an Electron launch vehicle.

On board were satellites destined to begin a new constellation for UNSEENLABS, as well as more rideshare payloads for Spaceflight, consisting of a spacecraft for BlackSky and the United States Air Force Space Command.

The mission launched a CubeSat that formed the cornerstone of a new maritime surveillance constellation for French company UNSEENLABS. The constellation aims to deliver precise, reliable, and secure maritime data, enabling organizations to monitor their own vessels and observe those that present risks, such as pirates and illegal vessels.

Mission management and rideshare aggregator, Spaceflight, also manifested three satellites on its second rideshare mission with Rocket Lab. Among the rideshare payloads was BlackSky’s Global-4 Earth-imaging satellite. The satellite joined BlackSky Global-3, which was launched to low Earth orbit on an Electron vehicle in June 2019. BlackSky’s constellation delivers rapid-revisit satellite imagery to assist with monitoring economic activity such as crop development and herd migration, or surveying damage following natural disasters.

The final spacecraft manifested on the mission were two experimental satellites for the United States Air Force Space Command, designed to test new technologies including propulsion, power, communications, and drag capabilities for potential applications on future spacecraft.

UNSEENLABS – UNSEENLABS

The first payload onboard Electron is a CubeSat that will form the cornerstone of a new maritime surveillance constellation for French company UNSEENLABS. The constellation aims to deliver precise, reliable, and secure maritime data, enabling organizations to monitor their own vessels and observe those that present risks, such as pirates and illegal vessels.

Spaceflight Ride Share

Electron will also launch three satellites for mission management and rideshare aggregator Spaceflight, as part of the company's second rideshare mission with Rocket Lab. Among the rideshare payloads is BlackSky's Global-4 Earth-imaging satellite. The satellite will join BlackSky Global-3, which was launched to low Earth orbit on an Electron vehicle in June 2019. BlackSky's constellation delivers rapid revisit satellite imagery to assist with monitoring economic activity such as crop development and herd migration, or surveying damage following natural disasters. The final spacecraft manifested on the mission are two experimental satellites for the United States Air Force Space Command, designed to test new technologies including propulsion, power, communications, and drag capabilities for potential applications on future spacecraft.

Rocket Lab's Photon

As the global leader in small satellite launch, Rocket Lab has now introduced the next evolution of its mission services, the in-house designed and built Photon satellite platform.

Rocket Lab now delivers an all-inclusive spacecraft build and launch service that enables small satellite customers to focus on delivering their service from orbit and generating revenue, rather than building their own satellite hardware. Our customers simply bring their payload or idea and we do the rest, taking care of the complete satellite design, build and launch as a bundled and streamlined experience.

Photon is an advanced and planned evolution of the Rocket Lab Kick Stage. Operating a high-powered iteration of the flight-proven 3D printed Curie propulsion system, Photon can support missions with up to a five year on-orbit life span. Equipped with an S-band communication system, a high-fidelity attitude control system, and a robust avionics suite, Photon is the complete spacecraft solution for a range of LEO missions, from constellation development, through to technology demonstrations and hosted payloads.

Rocket Lab's Maxwell

Rocket Lab has internally developed a series of rail-based CubeSat dispensers named Maxwell. The Maxwell series is available in a variety of CubeSat form factors, including 1U, 3U, 6U, 12U and 16U. The 3U Maxwell is shown in Figure 13. Non-standard sizes such as 2U or 8U are also available. Custom sizes can be accommodated according to customer specifications. The Maxwell dispensers are extremely lightweight, with the 3U dispenser weighing less than 1 kg. The dispensers have been designed to be compatible with spacecraft designed to the CubeSat Design Specification, in addition to offering extra volume compared to comparable systems. The Maxwell dispensers have been designed to environments

in excess of Electron's own benign launch environments, and as such are compatible with not only Electron, but other launch applications as well. Maxwell dispensers can be manufactured quickly and have relatively short lead times, in support of Rocket Lab's effort toward significantly improving launch integration schedules. For customers looking for a way to perform vibration testing on their CubeSats, Rocket Lab also offers test-only versions of the Maxwell for repetitive use. Please contact Rocket Lab for additional details on the Maxwell dispensers.