Welcome to the age of the hand-held satellite!

Small satellites such as picosats are revolutionising the spacelaunch industry, opening the door to orbital access for students and citizen scientist experimenters. These satellites have unlimited potential and their application is only bounded by the imagination, says **Randa Relich Milliron**, CEO/Co-Founder, Interorbital Systems

The promise of small affordable satellites is changing the face of the space launch industry as these diminutive devices open orbital access to students and citizen scientist experimenters around the world. The pioneering group of small companies and creative individuals who are now carving out myriad niche markets spanning everything from evolving on-orbit applications to offering boutique satellite construction are forming a 21st century enterprise system capitalising on a paradigm shift not unlike the transition from mainframe room-size computers to the personal computer. Now the billion-dollar bus-size satellite has been cloned and downsized to fit in the palm on one's hand: picosats known as TubeSats and CubeSats – true personal satellites are here! And in the same way PCs have become readily available, the tiny sats will soon beam greeting from space, collect and transmit experimental data, make and distribute space music, or perform as yet-to-be-determined functions for many new citizen-scientist builders/owners around the world. Kits for these small satellite are now available (with a launch to orbit on an IOS N5 rocket included) for the academic price of as little as $8,000, from Interorbital Systems, of Mojave, California.

Orbital round-up

These small satellites have unlimited potential. Just a few of their applications include de-orbiting space debris (for space traffic safety and potentially for profit) and servicing or re-fueling "big iron" satellites. Like an army of sci-fi bots, a swarm of tiny sats can capture and bring new life to dead or dying mega-satellites by replacing worn or outdated modular components, or by refueling the birds to allow many more years of service. After a communication satellite's propellants are depleted by active station-keeping, a hugely expensive space asset becomes nothing more than space junk. An array of CubeSats and TubeSats can be trained to service and repair their bigger cousins. By prying open stuck solar-cell panels to bring damaged spacecraft to full re-powering potential, or by ferrying stranded satellites to their proper orbits, these miniature work-horses can – for a fraction of the cost of replacing lost or functionally dead satellites – bring these billion-dollar machines new life. When the large satellites do reach their end of service, a microsat armada can carry them to a cemetery orbit, or direct them to a location where they can safely re-enter Earth's atmosphere to burn-up upon re-entry. Additional examples of experimental uses for small sats include instant communication nodes; Earth observation platforms; advertising/social media experimentation; space-qualification of hardware and software in formation-flying, tethering, propulsion-system testing; space burial; art and music projects; animal migration and asset-tracking; private messaging system. The list is endless and bounded only by the imagination.

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Launch manifest for N5 missions I and II, 2013

Payloads on the current launch manifest for the first two Neptune 5 missions range from academic, to arts, military, pure space science, music, and even to projects that are destined for the Moon! A detailed list of the payloads and launch missions is given below:

TubeSats to be launched onboard Neptune 5 mission:

- Morehead State University

CubeSats to be launched onboard Neptune 5 mission:	
Launch team	**Satellite**
University of California, Irvine	UCISAT1
FPT University, Vietnam	**F-1** CubeSat
Nanyang Technological University, Singapore	**VELOX-P** CubeSat
Adobri Solutions Ltd	"PLAN B" for the Google Lunar X PRIZE(GLXP) competition
EuroLuna team for GLXP	**Romit 1** (2-Unit CubeSat from Denmark)
NASA Independent Verification and Validation (IV&V) facility	1 CubeSat & 2TubeSats
King Abdullah University, Saudi Arabia	KAUST; 2 IOS CubeSats;1TubeSat; 1 suborbital payload
Earth to Sky, spaceweather.com, school students from Bishop, California	**The Golden iPod** (revised version of the Voyager)
Islamabad Institute of Science and Technology	**I CUBE-1**

Small sat applications include de-orbiting space debris (for space traffic safety and potentially for profit) and servicing or re-fueling "big iron" satellites

(Kentucky Space) (TubeSat and 2 suborbital payloads)

- Small sat by InterAmerican University of Puerto Rico
- University of Sydney, Australia - (2) i-INSPIRE (initial-INtegrated SPectrograph, Imager & Radiation Explorer)
- Aslan Academy (Private LA High School) - STEM Program
- Project Calliope (Space Music Project)
- Universidad de Puerto Rico / Marcelino Canino Canino Middle School, STEM micro-meteoroid impact study
- GLXP Team SYNERGY MOON Space-Qualifying Rover Team Astronomska Udruga Vidulini's (AUV) Comms

- GLXP Team Part-Time Scientists / Fluid & Reason Software (2) (US/Germany) FRETS1
- Naval Postgraduate School (3) (TubeSats as ad-hoc orbital communication nodes) and 2 suborbital payloads
- Defense Science and Technology Lab (DSTL) United Kingdom
- Austrian Arts Group mur.at with MURSAT 1: Earth-as-Art Project
- United States Military Academy at West Point (2)
- Brazilian Space Institute/108 5th-7th Grade Students, Ubatuba, Sao Paulo, Brazil STEM Program UBATUBINO
- Mexican Satellite Project ULISES Sat from PLAY Festival's Arts/Soccer Opera from Space
- TriVector Services (Huntsville) TRACsat – TriVector Radiation and Attitude Control Sat
- La Despensa (The Pantry) Advertising Agency/ Iniciativas en Idiomas (Madrid, Spain)
- NASA Independent Verification and Validation (IV&V) Facility (2)
- Galaxy Global, 1 TubeSat, donated to NASA Educational Program
- Institute of Advanced Media Arts and Sciences/The Science Project, Inc., Japan (7)
- AKQA Advertising, San Francisco
- Universidad de Chile, Santiago
- University of Sao Paulo, Brazil (2)
- David Lawrence K-8 School, North Miami, Florida

Introducing the builders and their projects!

FPT University, Hanoi, Vietnam will fly its F-1 CubeSat, which is an educational picosatellite being developed by the University's FSpace Laboratory, to provide students training in aerospace engineering applications. The satellite measures 10x10x10 cm and weights 1 kg, and carries a low-resolution camera (640x480 pixel) to take photos of the Earth, as well as a magnetometer and several temperature sensors to study the space environment. The project is headed by Thu Vu Trong, head of FSpace Laboratory.

When the large satellites do reach their end of service, a microsat armada can carry them to a cemetery orbit, or direct them to a location where they can safely re-enter Earth's atmosphere to burn-up upon re-entry

Students (ages 10-13) training at LIT-INPE, Brazilian Space Institute. Elementary school and university students work with post-graduates and space professionals on the same satellite project

The Golden iPod is a modern version of Voyager's Golden Record, with a 16GB storage capacity. It is a project of Earth to Sky, spaceweather.com, and a group of middle school and high school students from Bishop, California.

Mexico's Space Opera: PLAY

Juan Diaz Infante's PLAY Festival brings the world ULISES I Satellite, the platform for an original Space/Soccer Opera Project. Eleven composers are working on the project—like the eleven members of a soccer team!

The NASA Independent Verification and Validation (IV&V) Facility: Marcus Fisher, Associate Director of West Virginia based IV&V is interested in getting multiple spacecraft into orbit so his team members can explore SWARM concepts and robotic applications, including creating software that runs as an intelligent fault manager/in-flight decision maker, and in another set of experiments, remotely controls manipulators and attitude control systems.

TRACsat – TriVector Radiation and Attitude Control Satellite: Fundamental to many satellite missions is positioning the satellite in a desired orientation in orbit. Developed by Huntsville,

Interorbital Systems' N5 Five-Module Small-Sat Launcher

Alabama based TriVector Services, Inc., the TRACsat aims to use simple electronics to determine the attitude of a nanosatellite in orbit.

i-INSPIRE: University of Sydney will fly the i-INSPIRE (initial - INtegrated SPectrograph, Imager and Radiation Explorer) satellite, which is also Australia's first university satellite to be launched and operated in space. It will carry a novel photonics-based spectrograph, an imaging camera, and a radiation detector. The satellite project is headed by Dr Xiaofeng Wu and Iver Cairns, members of the academic staff at the university. Scientific goals include (1) analysing the first spectra from a spaceborne, photonics-based spectrograph, and identifying features related to the Earth, Sun and radiation events, (2) obtaining first images of Australia from an Australian satellite, and (3) obtaining radiation maps of the Earth to compare with space weather events and spectrograph data.

The ultimate STEM programs: Brazil's Ubatuba-Sat and University of Puerto Rico/ Marcelino Canino Canino Middle School's Micrometeoroid Impact Study. Both programs give hands-on training to children in the design and manufacturing of satellites. The Puerto Rican group is already known in NASA circles for the launches they've already conducted in partnership with the agency. Their aggressive spaceflight program, which will use a TubeSat to measure micro-meteoroid strikes in the 310-km orbit, is led by Gladys Munoz and Oscar Resto and is part of the Puerto Rican Space Grant Consortium. In Ubatuba, Brazil, the 108 students of an average age of 11 years are competing to build the best TubeSat mock-up. The team with the best mock-up gets to build the actual spacecraft under the mentorship of the Brazilian Space Institute. The program is the brainchild of Emerson Yaegashi and Candido Osvaldo, both school teachers in Ubatuba.

Military payloads from the US Military Academy at West Point, the Naval Postgraduate School in California and the UK's Defense Science and Technology Lab will conduct on-orbit tests and experiments that encompass many communications functions using small sats in creative ways such as ad hoc orbital nodes for ground-to-space comm links, Earth imaging/surveillance, and software/hardware viability testing.

The NEPTUNE 5 (N5) will lift 30-40 kg or about 30 small sats per launch to Low Earth Orbit; the N36 will carry 1,000 kg to LEO, or a lander and rover to the surface of the Moon

Arts-Meet-Science payloads: MURSAT - Earth-as-Art Project developed by Austrian Arts Group mur.at and Dr Sandy Antunes' 'Project Calliope' add satellites with art, music, and photography as their core missions. Sandy wants to sonify the ionosphere and send back sounds for composers to freely use them in musical works. MURSAT will serve as an Earth imaging system for the Austrian teams' art project.

Interorbital Systems: Enabling space access

The low-cost space launch programs described above would not be possible without a dedicated small-satellite launcher: Enter the IOS NEPTUNE! The NEPTUNE rocket series, developed by Interorbital, is a modular (bundled) family of rockets that can be configured with between 5 to 36 CPMs (Common Propulsion Modules – identical rocket modules designed for mass production and common to every NEPTUNE vehicle) to meet any spacelaunch mission requirement. The NEPTUNE 5 (N5) will lift 30-40 kg or about 30 small sats per launch to Low Earth Orbit; the N36 will carry 1,000 kg to LEO, or a lander and rover to the surface of the Moon —the planned scenario for Interorbital's Google Lunar X Prize Team SYNERGY MOON mission. GST

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