Version 2.0

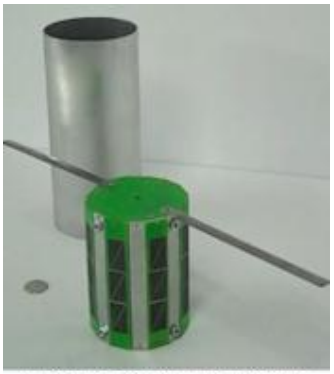
INTERORBITAL SYSTEMS
TubeSat Satellite Kit

TubeSat Kit Specifications and Pricing

General Description: The TubeSat Personal Satellite Kit can serve as an educational platform for use by advanced students of space science, or as a low-cost satellite option for electronics hobbyists or professional satellite builders who wish to carry out experiments, space-qualify hardware, or place applications in Low-Earth Orbit. The TubeSat can also serve as a Personal Satellite for artists, musicians, advertisers, or individuals who wish to send items into space, to transmit messages from space, or to use the TubeSat as a private mausoleum for space burial. Individual builders or teams have the option of basing their final designs on the standard components that come with the satellite kit, or of replacing all the TubeSat's standard components with their own hardware. As long as the size, weight, and safety restrictions are adhered to, builders can equip their TubeSats with anything they wish. If required, and for fees based on mission requirements, Interorbital Systems and its partners can offer design, development, and manufacturing services to individuals who do no possess the technical skills required to build the spacecraft.

A TubeSat kit includes the following components:

- ▼ Printed Circuit Board (PCB) Gerber Files
- ▼ PCB Mounting Hardware
- ▼ Transceiver (FCC or equivalent license required)
- ▼ A Battery Pack
- ▼ Solar Cells
- ▼ A Power Management System (PMS)
- ▼ Microcomputer and Development Kit
- ▼ **Development** Software
- ▼ Antennas
- ▼ TubeSat Assembly Manual (CD)



TubeSat with Sample Ejection Cylinder

The standard Interorbital TubeSat Kit can function as a basic satellite bus or as a stand-alone satellite. If the builder decides to use the kit as a stand-alone satellite, it has many applications including the following:

- ▼ Automatic simple, repeating "message from orbit" transmission
- ▼ Amateur radio relay
- ▼ Space advertising

These are just a few examples. For these applications, the builder must develop software to allow the satellite to carry out the desired function.

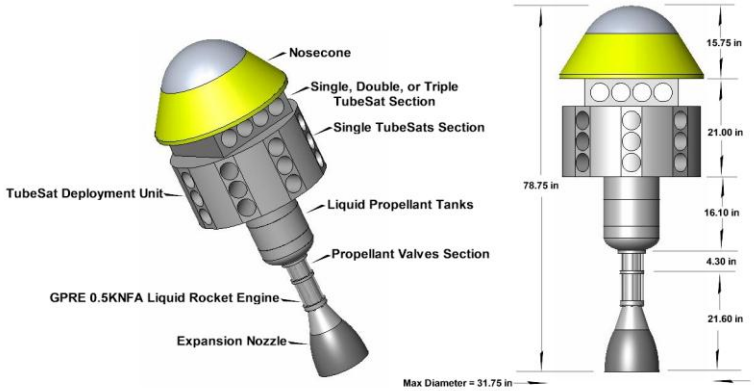
For those who wish to include an experiment or hardware application, some of the possibilities can include, but are not limited to, the following:

- ▼ Earth-from-space video imaging
- ▼ Earth magnetic field measurement
- ▼ Satellite orientation detection (horizon sensor, gyros, accelerometers, etc.)
- ▼ Satellite attitude-control system
- ▼ Orbital environment measurements (temperature, pressure, radiation, etc.)
- ▼ On-orbit hardware and software component testing (microprocessors, etc.)

▼ Tracking migratory animals from orbit
▼ Testing satellite stabilization methods
▼ Biological experimentation

Once again, these are just a few examples and they all require additional hardware not included in the basic kit. For these functions, the builders must assemble and test their own hardware and integrate it into their satellite.

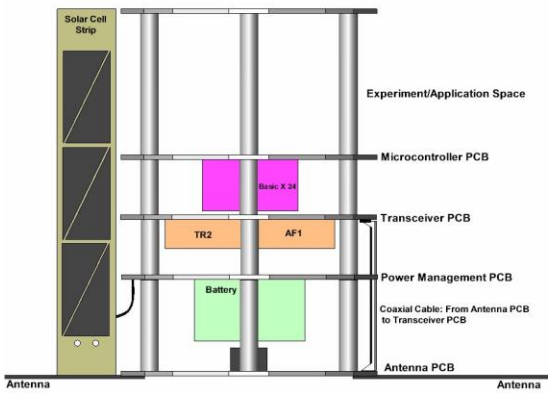
Builder Experience: We recommend that a TubeSat purchaser have experience in electronic device assembly and programming microcontrollers. The builder should also have experience programming with the BASIC or Arduino C programming language. Of course, if a builder does not have the recommended experience, he or she can use the TubeSat as a learning device. Developing and constructing a TubeSat is also an ideal team-building project.



TubeSat Design: TubeSats are hexadecagon-shaped structures with an internal component rack assembled from stand-offs and printed circuit boards (PCBs). The exterior of the TubeSat is assembled from eight (8) PCBs, each holding six (6) solar cells, and eight (8) thin aluminum strips. The sats are designed to be ejected from their own dedicated TubeSat ejection cylinders. For each launch, there are multiple TubeSat ejection cylinders which are arranged in a TubeSat Deployment Unit.

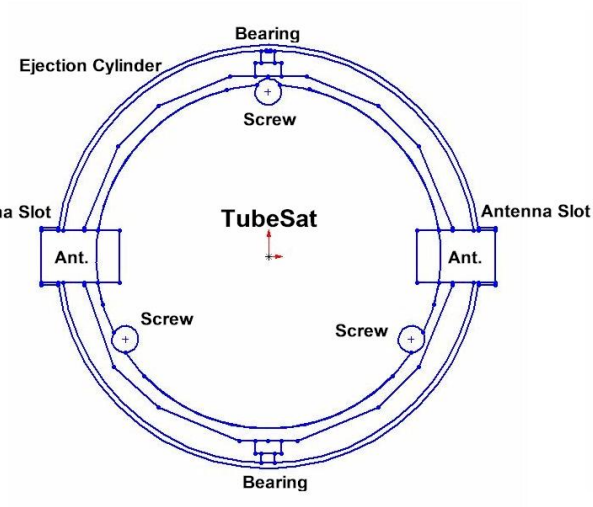
The TubeSat structure includes eight (8) external guide bearings that center the TubeSat in its ejection cylinder, and facilitate the satellite's ejection. This arrangement allows the TubeSat to be smoothly actuator-deployed from its ejection cylinder with minimal friction.

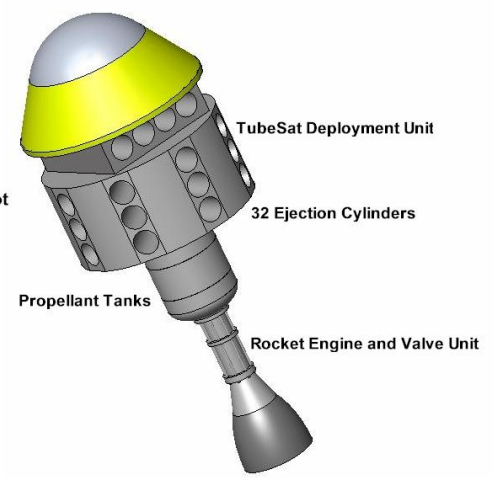
TubeSat Component Layout



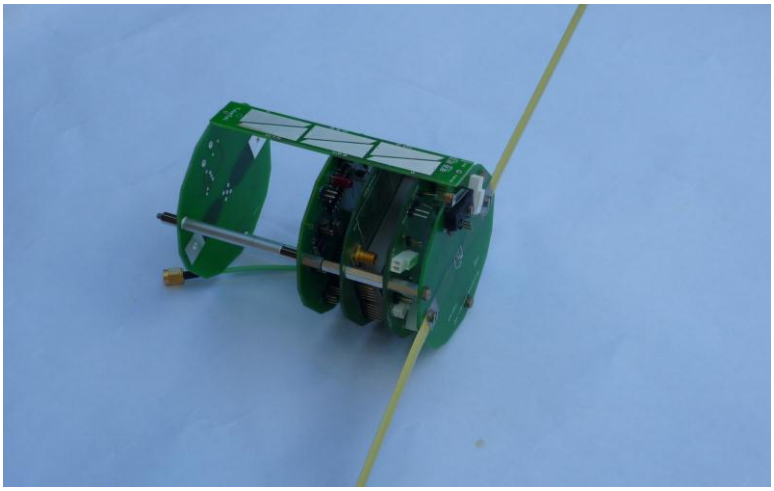
The TubeSat ejection cylinders have an inside diameter of 9.91 cm (3.9 in). A solenoid actuator positioned behind a push plate shoves the satellite out of its ejection. Detents in the push-plate prevent the satellite from rotating during deployment.

The minimum gap between each TubeSat and the inside diameter of its ejection cylinder is 4.826 mm (0.19 in); the maximum gap is 6.096 mm (0.24 in). This provides clearance for the solar cells, antennae, or other hardware. The solar cells are arranged in strips around the outside of the TubeSat. Solar cell deployment is not required. The standard TubeSat antennae are made of spring-steel and slip over the outside of the Ejection Cylinder, allowing automatic antennae deployment upon release.





The TubeSat components are attached to several printed circuit boards. The printed circuit boards are separated by groups of stand-offs. The Tubesat's exterior structure consists of the solar cell PCBs and aluminum strips.



Although the TubeSat kit includes all the basic components required to build a low-cost satellite bus or a fully functioning satellite, it is the task of the TubeSat builder to integrate the components into the satellite envelope. This includes PCB fabrication, soldering (including reflow), drilling holes, mounting the hardware on PCBs, wiring, programming, testing, and everything else required to assemble a working satellite. The builder must also develop his or her TubeSat's experiment or application software.

The basic components are Commercial-Off-The-Shelf (COTS).

COTS Component List

1) Transceiver Options

Before IOS can send you your transceiver, you must apply to the FCC or non-US equivalent for a transmit-and-receive frequency allocation for space-based operations. If you would like to communicate in the amateur radio band, you should apply for a frequency between 435 MHz and 438 MHz (for the Radiometrix) or for a frequency between 2.4000 GHz and 2.4835 GHz (Microhard n2420 with spread spectrum). You or a team member must also possess an amateur radio license.

If you wish to operate your TubeSat commercially, you can select the spread-spectrum Microhard n920 which operates in the Industrial, Science, and Medical band (ISM). You should apply for transmit and receive frequency between 902 MHz and 928 MHz. In the US you will be given an FCC Experimental Radio Service license.

Once you have your frequency allocation, you will send IOS a letter of verification from the granting agency. If you have chosen the Radiometrix, IOS will send you a Radiometrix transceiver tuned to operate in the range of your licensed frequency. If you have chosen a Microhard transceiver with spread spectrum, you can order your transceiver directly from Microhard Inc. The less-expensive Radiometrix transceiver price is included in the basic cost of the TubeSat kit. The cost of the more expensive Microhard units is not included. If you choose a Microhard transceiver or other transceiver, you will be sent a rebate equal to the price of the Radiometrix units. Contact IOS for the current prices.

Radiometrix Transceiver Option

Transceiver: Radiometrix TR2M
http://www.radiometrix.com/files/additional/tr2m.pdf

In addition to the Transceiver, you will receive the following amplifier. This will also plug into your transceiver PCB

Amplifier: Radiometrix AFS2
http://www.radiometrix.com/files/additional/afs2.pdf

Output: 100mW or 500mW (using AFS2 amplifier)
Frequency: 420-480 MHz in 5MHz increments

The Radiometrix transceiver is programmable over a short frequency range (See Radiometrix web site). Since this transceiver operates in the amateur radio band, an amateur radio license and frequency allocation is required (responsibility of TubeSat builder) to use the transceiver. The advantage of the amateur radio band is that anyone in the world with an amateur radio receiver (even a hand-held receiver with the proper antenna) can receive transmissions from the satellite. Builders will need to have a hand-held or other amateur radio to communicate with the satellite transceiver during development.

The amateur radio band cannot be used for commercial communications. Information about how to obtain the required amateur band frequency allocations for satellites can be found at:

http://www.iaru.org/satellite/IARUSATSPEC_REV15.6.pdf

Spread-Spectrum PC Board Options

Microhard Nano Series n920F Transceiver. This transceiver operates in the ISM band.
http://www.microhardcorp.com/brochures/n920.Brochure.Rev.1.02.pdf
Output: 100-1000 mW (selectable)
Frequency range: 902-928 MHz (programmable)

Microhard Nano Series n2420F Transceiver. This transceiver operates in the ISM and amateur satellite band. http://www.microhardcorp.com/brochures/n2420.Brochure.Rev.1.02.pdf
Identical to the n920F except for frequency range.
Output: 100-1000 mW (selectable)
Frequency range: 2.4000-2.4835 GHz (programmable)

Users of the n2420F from space normally require compliance with the amateur radio rules. For non-US use only.

The specifications for both Microhards are identical except for the frequency range. Microhard transceivers are programmable. Transmit and receive frequencies can be selected and set by the user. The n2420F requires an amateur radio license and frequency allocation for use. The n920 requires an FCC or equivalent license for use from space (Contact the FCC or equivalent agency in non-US countries) and is for commercial or non-commercial use.

The Microhard Development Kit includes two transceivers, two Nano Motherboards with Power Adaptors and Rubber Ducky Antennas, and 2 straight-through serial cables (9-pin M to 9-pin F). In order to program the transceivers, either 2 PCs with HyperTerminal (or equivalent) and 1 COM port each, or 1 PC with HyperTerminal and 2 COM ports are required.

General: TubeSat builders are responsible for satisfying the amateur radio licensing frequency allocations requirements as well as for obtaining any licenses for transmitting to and from space. Interorbital Systems does not have the power to grant such licenses or to allocate frequencies.

Builder Option

The builder also has the option of replacing the standard transceiver with a transceiver of his or her choice. Any transceiver must comply with international licensing and frequency band requirements.

Batteries
Li-Ion 3.7V 2600 mAh Rechargeable Battery Module (COTS)

Power Management Board
In-house design

The power management system uses the output of the solar cell complex to keep the on-board batteries charged.

Microcomputer options
Net Media BasicX-24p with Development Kit
http://www.basicx.com/

Arduino microcomputer
Open source software available online
http://www.arduino.cc

It is important that the satellite control software be designed to turn the transceiver on only when transmitting or receiving, and to cease transmission or reception when the battery power is dangerously low, to avoid battery damage

Solar Cells
Spectrolab Triangular Advanced Solar Cells (TASC)
Efficiency: 27%
http://www.spectrolab.com/DataSheets/PV/PV_NM_TASC_ITJ.pdf

The solar cells are arranged around the TubeSat tube in strips of three (3) rectangles with two (2) triangles per rectangle. The number of individual triangular cells amounts to forty-eight (48) per TubeSat. Each triangle can generate an output of thirty-one (31) mA. The total output generated by the cells at any one time on orbit will depend on the satellite's orientation. The builder has the option of integrating additional solar cells into his or her TubeSat. Extra solar cells are available from IOS. See price list below.

Assembling a TubeSat: TubeSat was designed to give the builder maximum design flexibility. The arrangement of its components can be modified according to the builder's plan. In addition, the builder has the option of replacing the standard components with his or her own component choices. A builder can also opt to remove all the components from the satellite and fill the space with mementos or even cremains (ashes for burial in space). TubeSats are fully customizable.

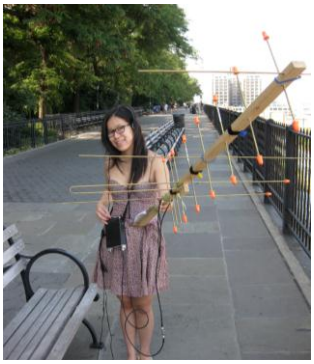
The basic components are enough to build a satellite that can carry out simple operations such as transmitting a message from space or relaying text and messages from a ground station to the satellite for re-transmission. These applications will require the builder to develop software to carry out these functions.

When using the standard PCB spacing, the volume available for the Experiment or Application Space (EA Space) has a diameter of 8.56 cm (3.37 in) and a length of approximately 5.0 cm (about 2.0 inches). The standard experiment and application weight is 250 grams (0.55 lbs).

Parts Replacements: If the builder should accidentally damage a TubeSat component, Interorbital will replace the part at cost. TubeSat builders also have the option of buying a backup TubeSat kit at a reasonable cost.

Payload Environment: TubeSats and the TubeSat Ejection Cylinders are not sealed and will always maintain internal pressure at ambient. The maximum payload G-force is 3.5 Gs during the Satellite Module engine burn. Since both the NEPTUNE 30 and 45 have a low thrust-to-weight ratio, the vibration, shock, and acoustic environments are relatively benign. Vibration, shock, and acoustic data will be made available shortly.

Orbital Environment: TubeSats are deployed in a circular 310-km altitude polar orbit. The polar orbit allows TubeSat communications from any point on the planet with daily minimum line-of-site distances. When a small satellite is deployed, there is almost always some degree of tumbling or spinning. It is possible to eliminate the tumbling by using a static stabilization system. The simplest method is to attach magnets to the outside of the TubeSat to allow it to orient itself with Earth's magnetic field. Launches to other orbits and altitudes are available at additional cost.



Communication with Orbiting Satellite: Once a TubeSat is on-orbit, the builder will be able to precisely calculate the position of the satellite. With the TubeSat transceiver output set to at least 500 mW and the satellite directly overhead, communication can be achieved with a simple hand-held Amateur Radio receiver (not included with kit) if the satellite is transmitting on an amateur radio band. In this case, a simple Yagi antenna is required (see picture above). Satellites with Microhard transceivers will require a more sophisticated ground station.

More powerful ground stations allow communications at steeper angles. Interorbital is currently helping to coordinate a global network of receivers that will eventually be capable of receiving satellite transmissions for posting on a central website. In future, Interorbital will make a portable ground station kit available.

Shipping to Interorbital Systems before Launch: TubeSats should be completed and delivered to IOS at least 2 weeks before the scheduled launch date and delivered along with all testing, inspection, integration, and regulatory paperwork to Interorbital Systems. If complete and proper documentation accompanies the satellite, the spacecraft will be integrated into the NEPTUNE Rocket for launch.

TubeSat Dimensions:

TubeSat Shell: Max OD = 8.94 cm (3.52 in) ID = 8.56 cm (3.37 in), Length = 12.7 cm (5.0 in)
Deployment Cylinder: OD = 10.20 cm (4.00 in) ID = 9.91 cm (3.90 in)
The minimum gap between each TubeSat and the inside diameter of its ejection cylinder is 4.9 mm (0.19 in) and the maximum gap is 6.096 mm (0.24 in). This gap can be utilized for solar cells, antennas, or other hardware.

Support: The TubeSat Builders' Forum. http://groups.yahoo.com/group/TubeSat/

All Specifications and Pricing Subject to Change

Price List

All TubeSat kit and CubeSat kit sales with full payment include the price of a launch to a targeted 310-km circular polar orbit. The following prices are the base prices for academic/nonprofit organizations. CA sales tax will be required from taxable buyers. Contact IOS for more information.

TubeSat kit with launch:	$8,000.00
TubeSat launch only:	$8,000.00
CubeSat kit with launch (1.00-kg):	$15,000.00
CubeSat kit with launch (1.33-kg):	$19,125.00
CubeSat launch only:	$12,500.00
TubeSat backup kit (Available only to builders who have already purchased a TubeSat or IOS CubeSat)	$1350.00
Spectrolab solar cells	
Strip of 6 triangles:	$30.00
Rectangle with 2 triangles:	$10.00
Payload space on low-altitude test launches (50,000 ft):	$750/kg
Individual components are also available:	(please inquire)
Shipping cost for non-US orders:	$150.00
Export and Import License Services:	$500.00 ($250.00 each)

California residents must include 8.25% sales tax
All Prices are Subject to Change

Contact Interorbital Systems at 661.965.0771 or ios@interorbital.com
Website: www.interorbital.com