QB2 PocketQube System

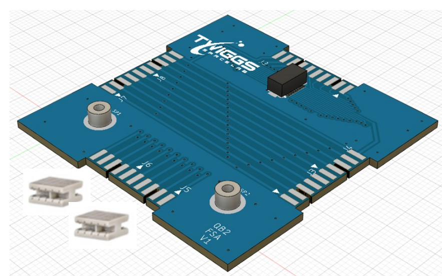
Learn to Build, Test and Operate a Picosatellite

Company Overview: **Twiggs Space Lab, LLC** ("**TSL**") is focused on creating STEAM based products and curricula to stimulate, engage, and encourage students to pursue interests in science, technology, engineering, arts, and math. Our company's mission is to inspire future generations of engineers and scientists to make the world a better place through innovative research in space. The QB2 PocketQube System includes the hardware, software, and curricula necessary to provide students with a comprehensive hands-on experiential learning opportunity associated with building, testing and operating a picosatellite.

QB2 PocketQube System: Cubito ("**QB2**") is Spanish for "little cube." The QB2 PocketQube System is based on a concept and standard first proposed by Professor Bob Twiggs of Morehead State University. Professor Twiggs coined the term "PocketQube" because the intention was to develop a satellite (5 cm x 5 cm x 5 cm) which could fit in a pocket. The QB2 PocketQube System is a picosatellite platform that includes the most common nanosatellite subsystems with the flexibility to incorporate additional components such as solar panels, GPS, secure digital card, additional communications hardware (WiFi, LoRa radio, and others), and a TSL or a custom developed payload. The QB2 PocketQube System has the functionality and versatility to arrange the subsystem modules in a FlatSat (horizontal) or stacked (vertical) configuration. The QB2 PocketQube System can be purchased by individual system modules or as a complete QB2 Engineering Model ("**QB2EM**"). Each module includes detailed User's Manuals and software codes.

QB2EM: The complete QB2EM includes a Pelican case, QB2EM, TSL USB flash drive with software libraries and User's Manuals, Bottom Plate Adapter, Chassis Structure, Top and Side Panels, screws and nuts, FlatSat Adapter, Board to Board Connectors, USB Cable, and Arduino Uno Adapter. The QB2EM is comprised of the following subsystems: (1) CDH – (Command and Data Handling); (2) BAT - (Battery Module); (3) EPS – (Electrical Power Subsystem); (4) ADS – (Attitude Determination Subsystem); (5) BT+BLE– (Communication Subsystem Bluetooth + Bluetooth Low Energy); and (6) PRT – (Proto Board).

FSA: The FlatSat Adapter Board ("**FSA**") is shown in the ***Figure 1***. The FlatSat configuration is accomplished by using connectors to join the boards at the electrical contact points. Multiple FSA can be joined together and is a function of the number of subsystem modules used in the test configuration. An example of FSA assembly is shown in ***Figure 2***. Once the FSA are connected, individual QB2 Modules can be attached by using the BUS connector.



Board to Board Connectors

Figure 1 Flat Sat Adapter Module

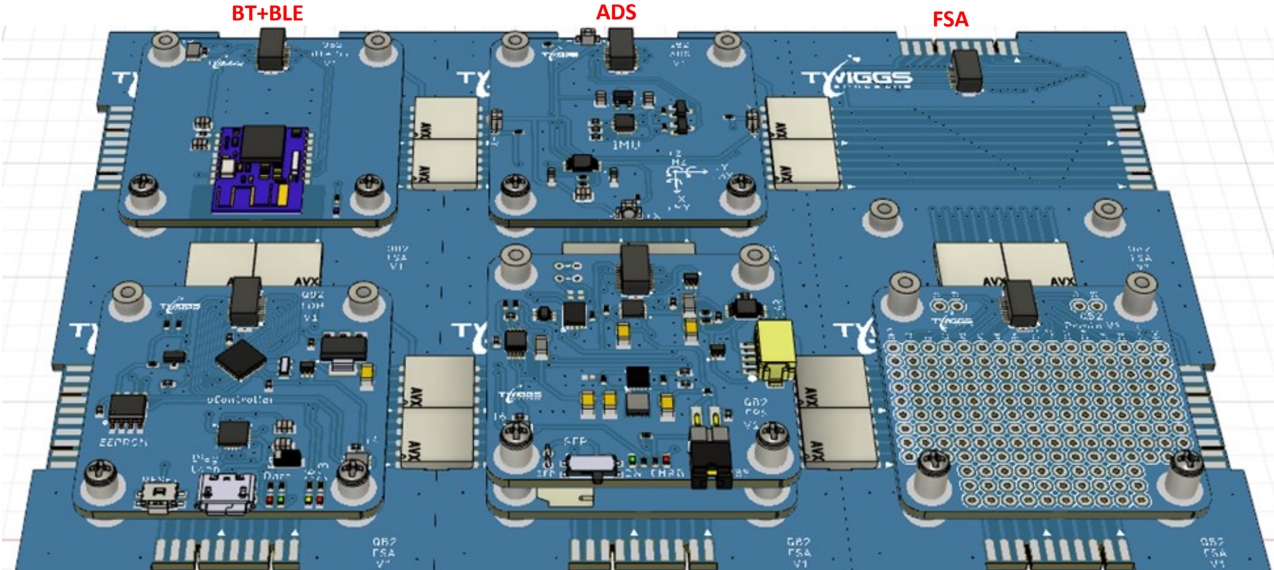


Figure 2 QB2EM FlatSat Configuration

AUA: The Arduino Uno Adapter is a board that can be used with your existing Arduino Uno board to act as the Command and Data Handling Subsystem ("**CDH**"), that processes the information relating to health, safety and status of the spacecraft as well as the rest of the subsystems. Arduino Uno Adapter ("**AUA**") includes the same sensors, reset button functionality, and LED indicators included in the CDH. The AUA also includes a connector to stack QB2 modules on top of the AUA, "Pin Headers" to get access to the signals required by the QB2 PocketQube System, and an I2C connector (4 pin JST SH 1.0mm connector) to easily attach I2C breakout boards (like STEMMA QT). The QB2 AUA is shown in the ***Figure 3***. The purpose of the AUA is to allow students to start programing and system development without initially purchasing the CDH Module. Students will be able to connect additional QB2 modules or stack them as needed. This provides an economical way for students to begin their experiential learning on the QB2 without having to purchase the complete QB2 PocketQube System.

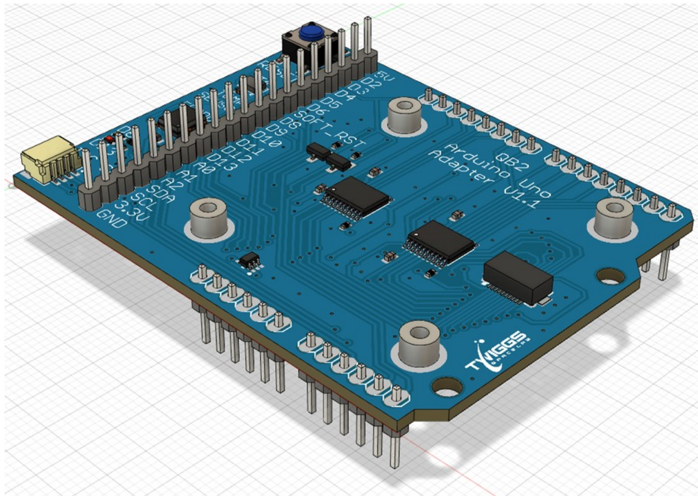


Figure 3 Arduino Uno Adapter (AUA)

CDH: The Command and Data Handling Subsystem ("**CDH**"), also knowing as the On-Board Computer ("**OBC**"), processes the information relating to health, safety and status of the spacecraft as well as the rest of the subsystems. It receives, processes, and transmits data among the several spacecraft subsystems. In addition, the CDH Module can store data on-board. The QB2 CDH Module has an ATmega328P microcontroller (100% compatible with the Arduino Pro Mini 3.3V). The CDH Module is shown in the ***Figure 4***. The CDH includes 3 analog input ports, 12 GPIOs, I^2C interface, LED indicators, reset button, independent 256 kbit EEPROM and a temperature sensor .

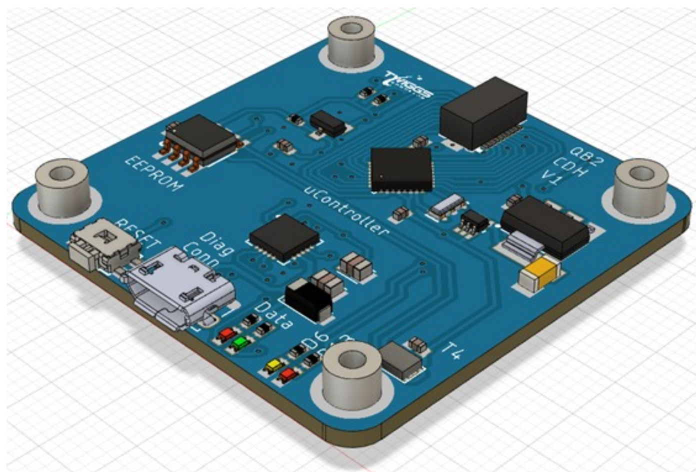


Figure 4 CDH Module

BT+BLE: The Communication Subsystem Module ("**COM**") (commonly referred to as the Telemetry, Tracking & Command Subsystem "**TT&C**" for the spacecraft), provides the conditioning, transmission, reception, spacecraft health telemetry and some mission data signals. The QB2 COM Module has different types of COM Modules available (Bluetooth, BLE, WiFi, LoRa, Xbee), and other modules under development. The QB2 COM Module provided with the standard QB2EM is the dual option that provides both Bluetooth and Bluetooth Low Energy capability ("**BT+BLE"**) in the same module, and includes a temperature sensor. The QB2 BT+BLE Module is shown in ***Figure 5.***

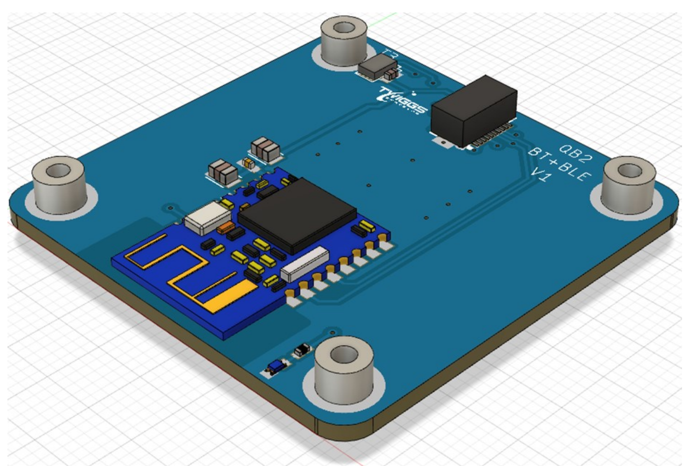


Figure 5 BT+BLE Module

BAT: The Battery Module ("**BAT**") is part of the Electrical Power Subsystem ("**EPS**") and its main function is to store the electrical energy. When a satellite is in orbit, there are Sun and Eclipse periods. During Sun periods, the solar panels will generate electricity that is stored in batteries. During Eclipse periods the solar panels cannot generate electricity and the satellite will use the electrical energy stored in the batteries for the proper operation of the satellite. The QB2 BAT Module is shown in ***Figure 6***. The QB2 Battery Module must be attached directly under the QB2 EPS Module due to the location of the battery connector. The Lithium-Ion Rechargeable Battery will be charged using the USB connection when the BAT Module is connected to the EPS and the CDH. In addition, the BAT Module can be charged when a 5V source is connected to the "**SOLAR**" connector located in the EPS. The BAT Module also includes a temperature sensor.

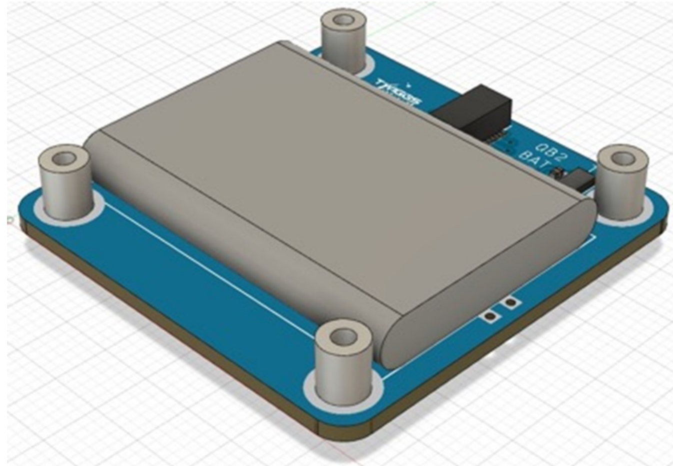


Figure 6 BAT Module (BAT)

EPS: The Electrical Power Subsystem ("**EPS**") on a satellite generates, stores, conditions and distributes electrical power as necessary to enable the satellite to fulfill the mission requirements during all phases and expected modes of operation. The QB2 EPS Module is shown in ***Figure 7***. QB2 EPS Module must be attached directly over the QB2 BAT Module due to the location of the battery connector. The QB2 EPS Module includes two LED indicators, to indicate "Power ON", and "Battery charging", a temperature sensor, battery charger, battery monitor, power meters, and power inhibits.

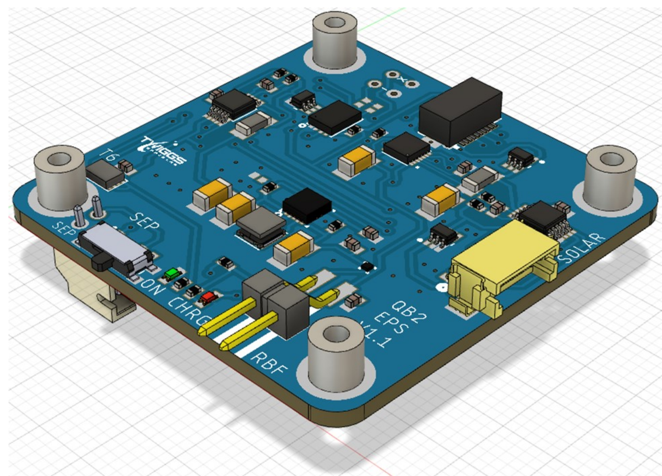


Figure 7 EPS Module

ADS: Attitude Determination Subsystem ("**ADS**") defines a satellite's orientation in space. Nadir direction is when the satellite is pointing "down toward Earth" and Zenith direction is the opposite direction. The primary function of the ADS is to provide information to the Attitude Control Subsystem ("**ACS**") to keep the satellite pointed in the right direction. Accelerometers and Gyroscopes are used to determinate the satellite orientation, in addition, by comparing the strength of the local magnetic field with a high-fidelity model of Earth's magnetic field, the magnetic sensor (Magnetometer) can determinate the orientation of the satellite with respect to the Earth. Magnetometers are more useful for satellites operating in Low Earth Orbit ("**LEO**"). Sun sensors are used to determinate the position of the satellite with respect to the Sun in order to obtain a better determination of the satellite orientation once it is in space. The QB2 ADS Module is shown in ***Figure 8***.

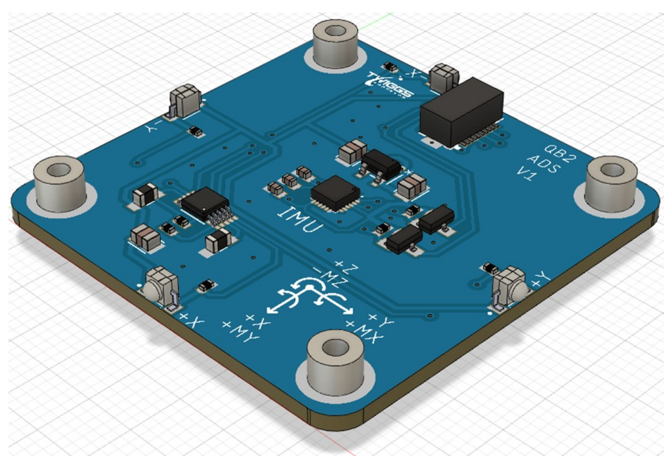


Figure 8 ADS Module

PRT: The Proto Board Module for Payload Development ("**PRT**") is a board designed to implement customized payloads. The payload is the subsystem required to meet the objectives of the satellite mission. The size and specification of the satellite are driven by the payload requirements. The PRT Module is designed with standard 100 mil hole separation for installing electronic components, as well as pads that easily connect the signals from the top and bottom BUS connectors. The QB2 PRT Module is shown in ***Figure 9***.

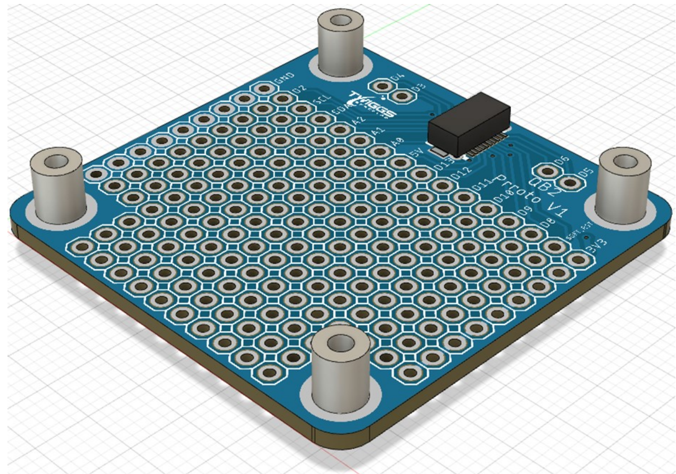


Figure 9 BAT Module (BAT)

BPA: QB2 Modules can be stacked and installed on the Bottom Plate Adapter ("**BPA**"). After stacking the QB2 Modules utilizing the bus connectors, slide the assembled QB Modules through the four 50mm screws until the bottom QB2 Module contacts the Chassis Structure. The four Coupling Nuts (or Hex Nuts) can be used to hold the QB2 Modules to the BPA as shown in ***Figure 11***.

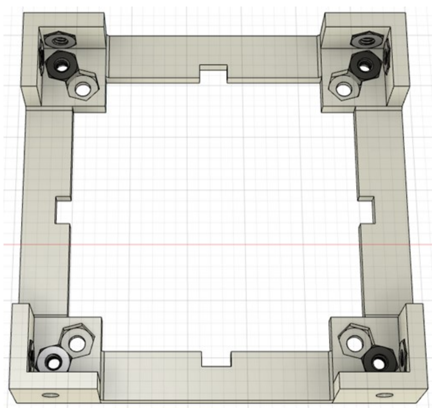


Figure 10 Hex nuts installed in the Chassis Structure for the Top side

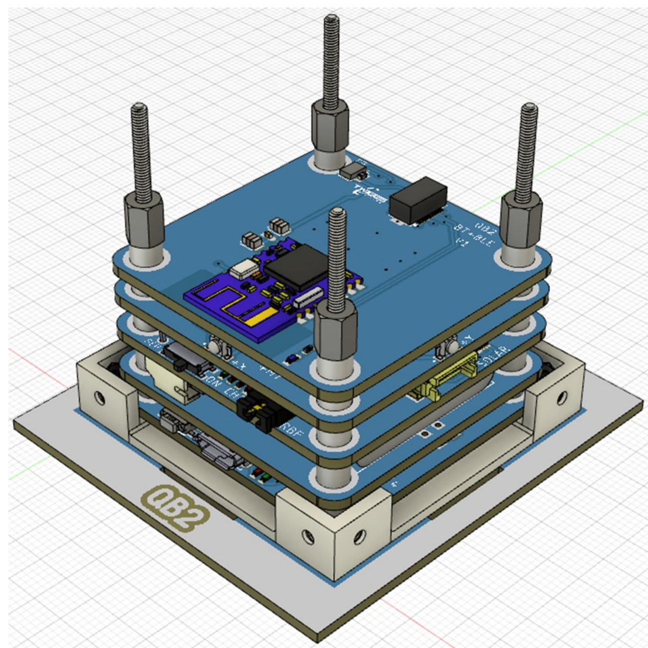


Figure 11 QB2EM Using the BPA

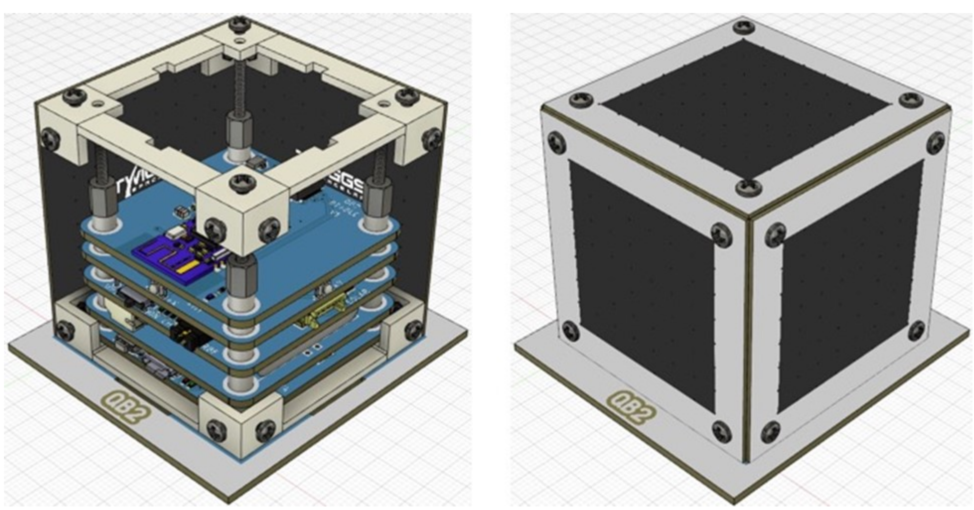


Figure 12 QB2EM with Panels

Ground Station: The Ground Station ("**GS**") primary function is to receive satellite telemetry and transmit commands to the satellite, or in this case the QB2EM. If your computer is Bluetooth enabled, it can be equipped to function as a GS with a few simple steps. QB2 Telemetry is displayed as numerical values and as a Plot graph in real time. On the left of the screen (View window), Data groups or Data plots can be enabled or disabled. On the Data window a Group for each subsystem (CDH, EPS, Battery, ADS, Communications) telemetry data in shown in numerical format and Data plots for each value. To display information not shown, click on the right scroll-down bar in the window and drag it down, see ***Figure 13***.

Figure 13 QB2EM Telemetry using Plot mode

Telemetry Data: An additional feature provided by the Application is to download the received data in a CSV file (comma-separated values) that can be open as a spreadsheet to do a data analysis. ***Figure 14*** shows an example of how the data is displayed in a spreadsheet format. The first column displays the date and time the data frame was received, and the following columns display the telemetry data for that data frame. Data can be analyzed, and graphs generated from this file format.

13-47-05

RX Date/Time	(CDH) ID:	(CDH) Temp 2 (CDH) [C]	(EPS) Temp 1 (EPS) [C]	(EPS) +5V Voltage [V]	(EPS) +5V Current [mA]	(EPS) +5V Power [mW]	(EPS) +3.3V Voltage [V]	(EPS) +3.3V Current [mA]	(EPS) +3.3V Power [mW]	(Battery) Temp 5 (BAT) [C]	(Battery) V Batt [V]	(Battery) % Batt [%]	(ADS) Temp IMU [C]	(ADS) Acceleration X [g]	(ADS) Acceleration Y [g]	(ADS) Acceleration Z [g]	(ADS) Gyroscope X [dps]	(ADS) Gyroscope Y [dps]	(ADS) Gyroscope Z [dps]	(ADS) Magnetometer X [uT]	(ADS) Magnetometer Y [uT]	(ADS) Magnetometer Z [uT]	(ADS) Sun sensor +X	(ADS) Sun sensor -X	(ADS) Sun sensor +Y	(ADS) Sun sensor -Y	(Communications) Temp 3 (COM) [C]
2021/11/16/ 13:47:05::500	69	26.5	26	0	0	0	3.3	34.6	114.09	26	4.04	92.4	27.84	-0.15	0.11	9.84	0	0.01	-0.01	-6.3	-48.1	4	43	25	41	24	26.5
2021/11/16/ 13:47:08::665	69	26.5	26.5	0	0	0	3.3	35.8	118.05	26	4.11	92.4	27.84	-0.11	0.16	9.78	0	0.01	-0.01	-8.4	-47.5	4.2	42	25	41	24	26.5
2021/11/16/ 13:47:11::881	69	26.5	26	0	0	0	3.3	38.8	127.99	26	4.03	92.4	27.89	-0.04	0.21	9.77	0	-0.01	-0.01	-7.5	-47.8	4.8	42	24	39	23	26.5

About Us: ***Twiggs Space Lab, LLC*** was founded by Professor Bob Twiggs and Matt Craft to develop inspirational STEAM based products with an emphasis on systems engineering and space technologies. Professor Twiggs is the co-inventor of the CubeSat and inventor of the PocketQube and CanSat. In 2010 he was selected by the Space News publication as one of 10 space professionals "That Made a Difference in Space." TSL's products and programs help prepare students for exciting careers in Space 2.0 and other STEM careers.

Contact: For more information on the QB2 or other TSL products contact Matt Craft at matt.craft@twiggsspacelab.com or Jose L. Garcia at jose.garcia@twiggsspacelab.com.

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