EyePod-3: An all-in-one Global Data & Tracking Module

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Developing a reliable and research grade tracking and communication link for high-altitude balloons and Low Earth Orbit (LEO) satellites can be a daunting experience. Based on a decade of experience launching over 300 balloons a small but powerful all-in-one data and tracking product (EyePod and EyeStar) has been developed by NearSpace Launch Inc (NSL) to greatly simplify many balloon and satellite development programs. The goal of the EyePod-3 product is to streamline balloon platform launching and reduce costs while providing higher reliability for entry education and research group experiments and for developing more advance flight systems. The EyeStar for LEO satellites has recently been flight proven with the successful operation of the TSAT satellite (Spring 2014). The EyePod-3 implements the commercial Globalstar network of LEO satellites to communicate with balloons and also includes GPS, SD-card storage, experiment digital and analog inputs, wireless pod-to-pod communication, internal sensors, battery, tether line attachments, and a wireless cut-down mechanism. No ground station with tracking antenna is required. Another advantage of the EyePod-3 is the standardized Structured Query Language (SQL) database with GPS and sensors data   (temperatures, pressure, turbulence accelerometers, light intensity, winds, ascent rates, and other derived quantities). The EyePod size is 7cm long band 10cm in diameter cylinder ("hockey puck") and is now available from NSL with commercial FCC license, Value Added Reseller (VAR) protection, and data plans. As many institutions begin to use the EyePod a unique global data set will be available for study, for STEM learning, and for research data mining.

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I.   Introduction

Developing a reliable and research grade tracking and communication link for high-altitude balloons can be a intimidating experience due to limited ground station coverage, expensive ground station tracking, difficulty of links during turbulence and freefall tumbling, 2m antenna breakage and moving antenna patterns, intricate operation requirements, power constraints, data rates, data storage, and many other factors. To help solve these problems NearSpace Launch Inc. (NSL) has secured Globalstar and FCC approval for satellites and balloons to use the Globalstar LEO network for a balloon-to-satellite and/or satellite-to-satellite link.

Fig. 1 Globalstar operational satellite network concept. (www.globalstar.com)

II.   EyePod-3 to Bridge the Gap for Launching into NearSpace

The process for developing a full and robust balloon launch capability usually involves significant cost, time commitments, know how, experience, and suitable locations for flight and recovery.   Risk management also is an important consideration with the unknowns of system electronic failures, losing GPS tracking and at times complete payloads, turbulence wrecking communication antennas, software glitches, landing in tall trees, lakes, or private facilities, liability issues, and safety.

For teachers or researchers who want to focus on the teaching part and develop their own experiment boxes and not worry about all of the logistics of the tracking, communication link, launch, software, chase, and recovery the idea of an all-in-one data and tracking package (EyePod) or a "launch for hire" service may be a good alternative. A One Time (expendable) balloon platform (EyePod-lite) may allow new launch opportunities for wooded regions and oceans. At a fraction of the cost and time of developing your own system and using the economy of numbers, an off the shelf option may be a more effective way to get immediate results. By gracefully coming up to speed in nearspace flight, a bridge is established to fly your own experiments reliably with little risk.

Collaboration is another advantage of a Launch-for-Hire or Express Launch option because the launch provider makes baseline measurements of certified temperature, pressure, humidity, and accelerations in addition to providing routine upward and downward video camera support. There is also the likelihood of collaboration with outer experiment PODs from other institutions for comparison of data on the same flight.

III.   EyePod-3B Product Description

The EyePod-3 is based on our previous Hawkeye command radios for High Altitude Research Platform (HARP) balloon flight and the new Globalstar STX-3 Modem. The name EyePod comes from our previous Hawkeye design and the desire to fly many EyePod units in constellations and in greater numbers to generate 3-D atmospheric images and remote sensing images (multi-pixels in the Eye).   The Pod part of EyePod represents that it is a stand-alone balloon module, box, or now more commonly called Pod for balloons.

The Balloon EyePod-3 product also includes an 10 cm in diameter by 7 cm thick "hockey puck" structure for mounting to the balloon tether or an experiment, a Li-Poly battery, power distribution system, and standardized sensors (external temperature, 3Axis accelerometer, pressure sensor, and light sensor). An option for the EyePod-3 is a cut-down mechanism and sound transducer used with a handheld controller with Zigbee interface for chase teams to use to help find and drop the EyePod-3 from trees.

The new all-in-one product for satellites is called EyeStar-3 to represent deeper space and connection to the Globalstar network. Both products include commercial grade certification for research and commerce, GPS, Flight

Processor interface, 2 GByte storage memory stick, Globalstar simplex link (0.25 W ERP), patch antenna, general purpose data logger (10 user analogs, 4 digital inputs, 2 user count rates, SPI/Serial interface, and temperature sensor) and data plan options.

The EyePod-3 also serves as a low-cost backup beacon and enables accurate tracking and data transfer for over the horizon long deration flights, constellations of balloons, ocean flights, and other global and international flights. A picture of the small EyePod unit is shown in Figure 2 enclosed in thermal insulation. Also shown are the patch antennas and the servo system for the tree drop option.
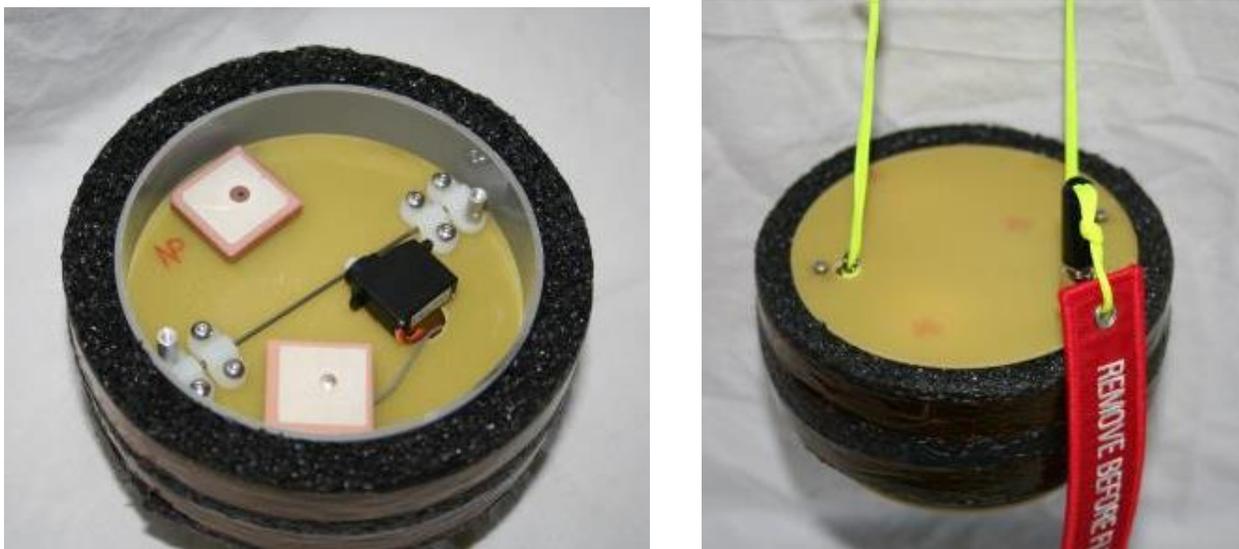

Fig. 2   EyePod picture top view of GPS antenna, Globalstar antenna, and optional cut down mechanism. Right photo shows tether mounts and pull before flight switch. Bottom of EyePod has a 15 pin connector for direct connection to your experiment Pod or Zigbee wireless connection to other remote pods.

A concept Block Diagram is shown in Figure 2 for the primary features of the EyePod-3 unit.
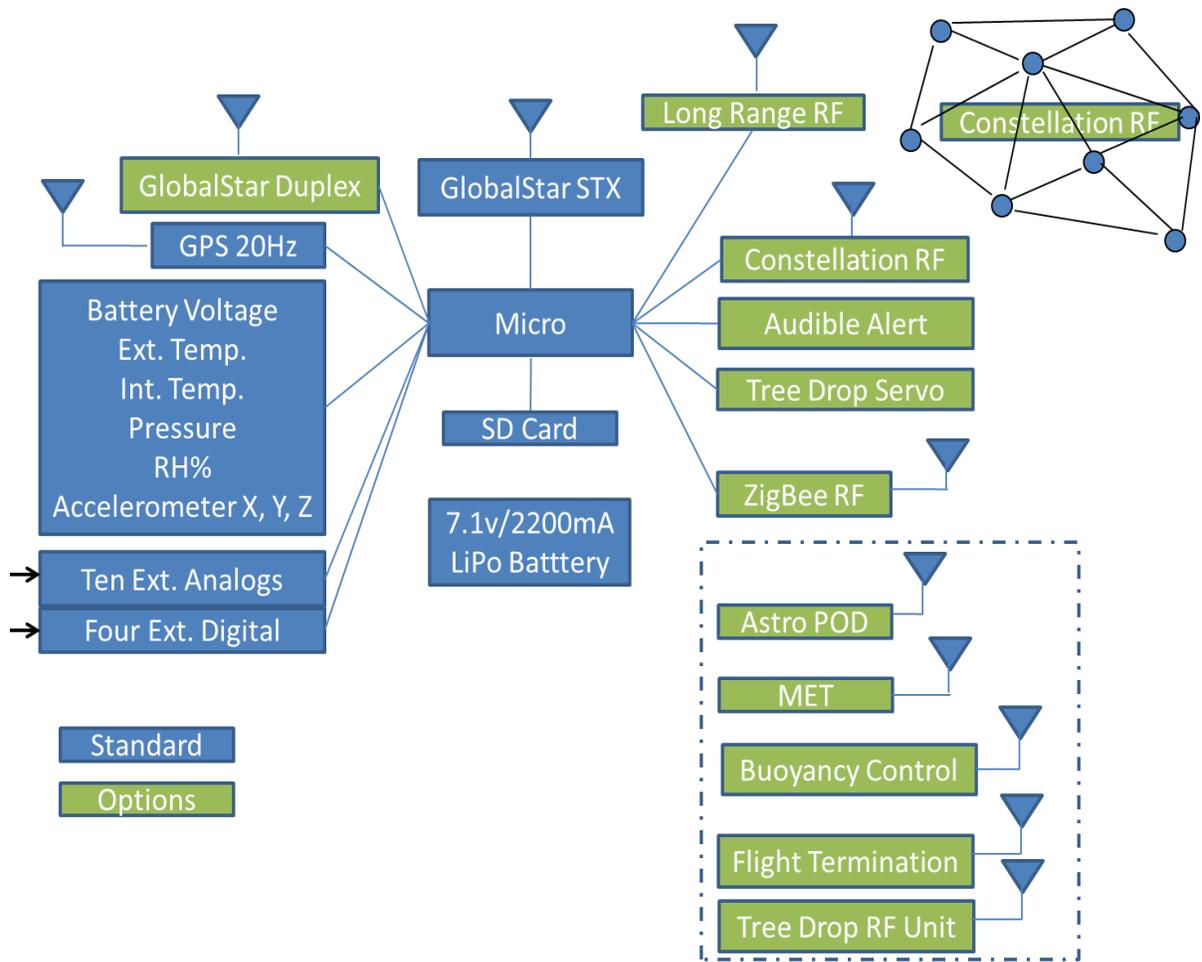
Fig. 3 All-In-One EyePod-3 data & tracking module. No ground station is required with the Globalstar link.

The specifications of the EyePod-3 unit are shown in Table 1 below.

Table 1   EyePod-3 Specifications

Description	Conditions	Min	Typical	Max	Unit
Power					
Battery with protection			7.1V / 2200mA		
RF characteristics					
Frequency range			1616.25		Mhz
Output power		+16	+18	+20	dBm
Frquency stability					
Bandwidth				2.5	Mhz
Modulation			BPSK		
User Communication port					
Protocol			Serial N81		TTL
Bus voltage		4.8	5	5.2	V
Data rate			38.4		Kbits
Beacon Mode					
Beacon Data Packet		0.5		60	Minute
GPS Data Packet		0.5		60	Minute
User Data Packet		0.5		60	Minute
Analog inputs					
Ten	10bit	0		5	VDC
Source impedance			2.5K		ohm
Digital inputs					
Four	TTL	0		5	VDC
Instruments					
Internal Temp.		-60		+50	C
Extenal Temp.		-60		+50	C
Pressure		2		1070	hPa
RH%		0		100	%
Battery Voltage		0		10	V
Accelerometer	X Y Z	-2		+2	G
Antenna characteristics					
Polarization	LHCP				
Efficiency			80		%
Realized gain			5		dBic
Bandwidth (3dB)	Both axes		100		Degree
VSWR			1.3:1		
Physical					
Diemeter			10		cm
Heigth			6		cm
Weight		275	300	350	g
Four Tether Mounting Rings			1		cm
Options					
Tree Drop RF Remote					
Cut Down (Servo)					
Audible Alert					
MET					
Astro POD					
Buoyancy Control					
FIght Termination					
Command					
SWARM					
Payload Can					
Globalstar Duplex					

IV.   Application Options for the EyePod-3

Five of the available options of the EyePod-3 unit are shown in Table 2 below.

Option 1 represents the full-up data and tracking system and is Research Grade certified.

Option 2 represents a Launch-for-Hire or Express Launch service (Voss and Dailey, AHAC 2013). In this case the full-up research grade Eyestar unit is included and all of the launch and chase is conducted at NSL. Additionally, data and video are streamed to the internet for live viewing. This option is ideal for experimenters who just want to fly atmospheric instruments without worrying about flight logistics or who live in a launch area with difficult terrain (water, forest, mountains) or have other liability, insurance, and risk concerns.

Option 3 below uses a low power high data rate modem to send student and research data down from a tethered balloon payload. In this option the risk is low and the tether balloon can be retrieved without a chase and ca be reused, students can test their experiments and collect real atmospheric data. Good photos and videos can also be obtained of the local surroundings.

In Option 4 below a low cost EyePod-lite can be used to fly instruments over great distances and over rugged terrain without worrying about recovery. Data and GPS tracking is transmitted in near real time over the Globalstar network for data analysis. The cost of the chase is eliminated and can be used to cover balloon system and data costs instead.

Finally, Option 5 includes a stripped down EyePod-lite version for simple data acquisition with an SD card.   For balloon flight other Ham radio or SPOT tracking systems can be used. Also the included EyePod sensors provide redundant and certified measurements.

Table 2   Some NSL EyePod-3 Options

Approach and Radio	Purchase	Performance	Initial Cost	Risk	Data Rate	Ground Station	Need for Training
1) **All-in-one System** Globalstar VAR, ISM, and Zigbee	NearSpace Launch Inc . **Full EyePod**	Real-time data & SD Card, GPS, sensors, tree cut-down, options Constellations, Research Grade	Medium	Low	High <1 s sampling	No	Medium
2) **Launch for Hire**, Full flight system, sensors, Data Base	NSL & others **Full EyePod**	Globalstar and ISM, Real-time data, common data base, SD card Research Class	Very Low	Very Low	High <1 s sampling	No	Very Low
3) **Tether system** Low power ISM	NSL & others **EyePod-Lite**	Realtime data, SD Card, GPS, <1000ft height, no Chase	Very Low	Very Low	High <1 s sampling	Yes	Low
4) **One-use** (dispose) Globalstar VAR	NearSpace Launch Inc. **EyePod Lite**	No chase cost, GPS, fly over poor recovery terrain (water, trees, etc.) Common data base	Very Low	Very Low	Medium 1- 100s sampling	No	Low
5) **Data Loggers**	**HOBO EyePod-Lite**	Earth and flight support systems, Must add GPS and Radio	Very low	low	High	No	Very Low

V.   TSAT EyePod and EyeStar Demonstration

A two unit Cubesat called TSAT was successfully launched in spring 2014 on a Space-X rocket from Cape Canaveral to the International Space Station (ISS) for global testing at high orbital speeds. Real time data from the Globalstar network was collected worldwide and was immediately placed on the Web on a secured server for general use.   The EyeStar All-In-One Data Collection and tracking module is similar to the EyePod but ruggedized for satellite space flight and does not include some of the atmospheric sensors and Wireless Zigbee options.   A similar Simplex unit used on Balloons was used on TSAT. Details of the flight and first results will be presented in the proceedings of the AIAA meeting August in 2014 at the Small Sat conference in Utah and are on the NSL web site. The simplex patch antenna was located on the ram side of the spacecraft. GaAs Solar Cells were used for power.
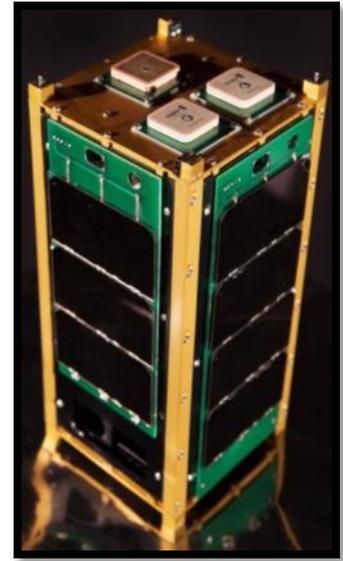
VI.   TSAT-Globalstar Coverage Maps

TSAT made the first global satellite coverage maps of the Globalstar data network (see Figure 5). Polar flights should also connect well to Globalstar through EyeStar -3 but this has not been demonstrated yet.
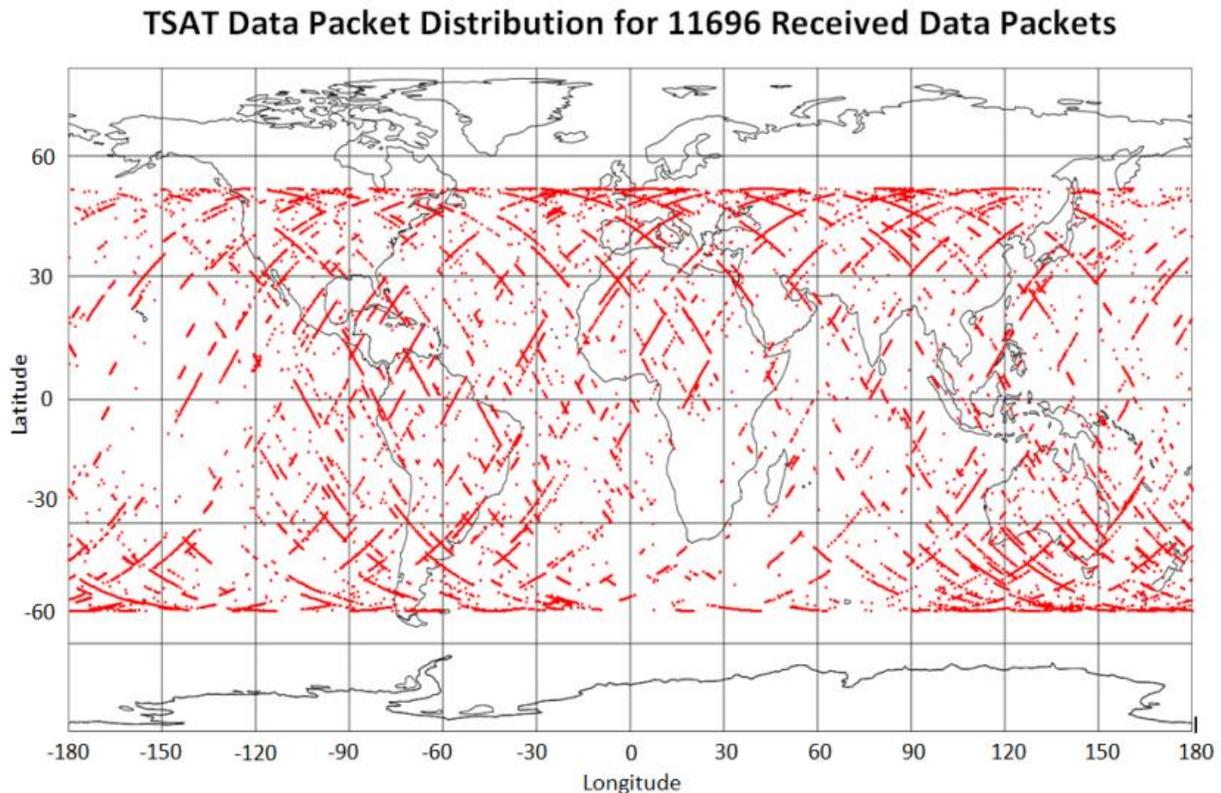

Fig. 4 TSAT dual Cubesat

Figure 5   TSAT global coverage map of data packets for anytime and anywhere coverage of balloon and satellite payloads. International and long duration balloon flights are ideal for EyePod.

VII.   Common Data Base Server and Data Plans

In Figure 6 a block diagram is shown to help illustrate how the data flows from balloons or a LEO satellite through the Globalstar network of more than 33 plus satellites and gateways to the NSL server. The data from multiple space platforms are then parsed into separate files with time, GPS, and spacecraft data for a specific customer to be downloaded or pushed to the customer server. A number of encryption and security measures are available.

One of the powerful capabilities of the EyePod data system that uses only one redundant Globalstar data stream is the opportunity to have a Common Time Ordered Data Base (see right side box in Figure. 6) with common GPS data and EyeStar sensor data. This data base can be open source so students and researches can compare their data to other common sensors flown at different time and locations. For example, your flight data temperature profiles could be inter-compared with temperatures at other solar zenith angles, other seasons, and other locations.
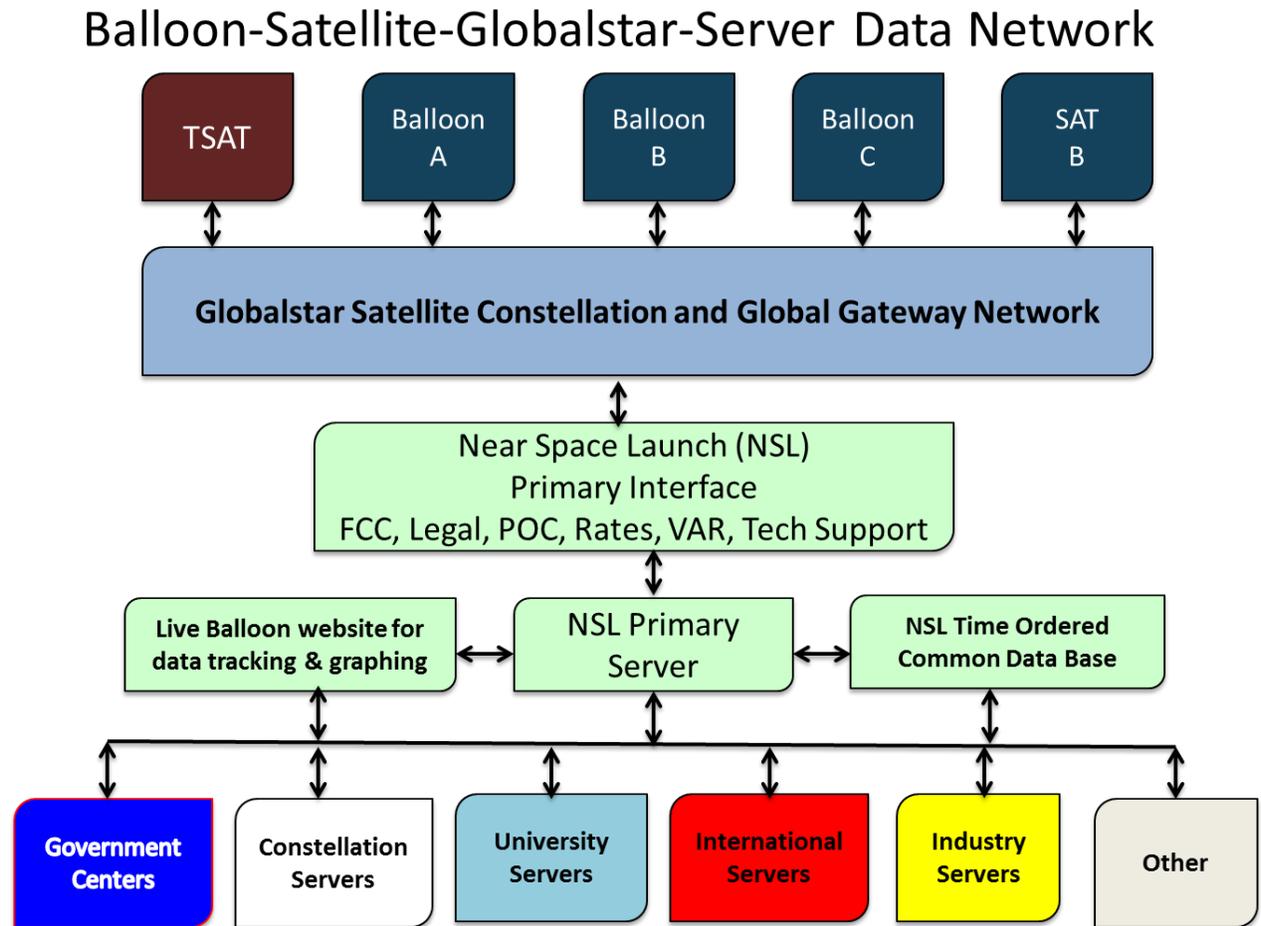
Fig. 6   Block diagram of how data flows from various Balloon and Satellite systems through the NSL primary server and then to servers or log-on file data transfers to other institutions

Launch-for-Hire customers can also watch their data streaming live on the internet while the flight is in progress and can also watch the balloon footprint on a map (see Figure 7). This so called Dashboard capability is useful for live data but it can also be used for post flight data plotting. Students particularly like watching the real-time display of their instrument performance and comparing it with the other sensors. Student data analysis and reports can begin immediately after the flight and before the payload is recovered.
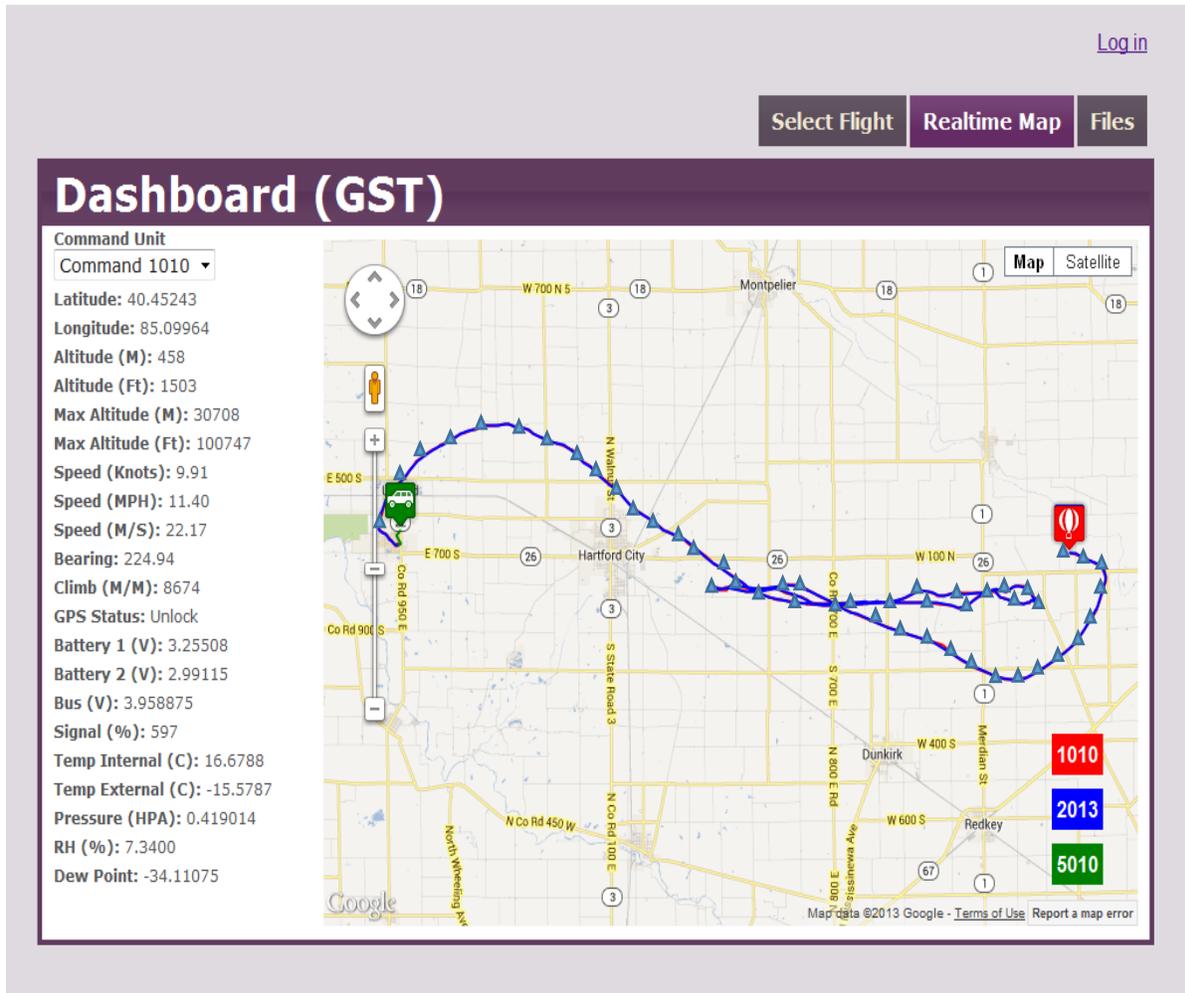
Fig 7 Shows one example of one Dashboard window available for real time tracking of a balloon flight. GPS, health and safety data is updated on the left-hand side of the Dashboard. Other windows can be used for graphing data as it becomes available.

NSL pricing from the Globalstar network is similar to the terrestrial data rates used for other Globalstar devices such as the SPOT tracker. For planning purposes, the basic data cost is approximately about 1 cent per byte for low data rate applications and about   0.35 cents for higher rate applications. There will also be some start-up fees like used in SPOT devices to cover NRE cost and FCC License costs. The fee structure is reserved to change as EyePods volume changes and more is understood of the service.   As an example, using 18 byte packets with four packets sent every minute and flight duration of 2 hours the data cost would be $86 at the low data rate cost. The EyePod-3 would also likely be programed to send a landing location packet every half hour for 24 hours to help

track any ground movement. For higher data rates in a One-Shot (expendable-no chase) launch, 100,000 total bytes of data sent down would cost $350. Costumers only pay for the data that they use.

VIII.   Conclusion

High Altitude Research Platforms (HARP) and Extremely Low Earth Orbit (ELEO) satellites are very important for our fundamental understanding of the near space environment below 300 km and for improving STEM education. The EyePod and EyeStar all-in-one flight modules are designed to advance access to near space for students, researchers, and commercial applications. Balloon and satellite launch missions meet and exceed the program ABET student objectives by inspiring students to create missions within scope that can unlock secrets of the uncharted regions of near space. With the EyePod-3B and Express Launch service of NSL and other Launch for hire opportunities becoming available the efficiency of teaching and discovery is accelerated especially as experienced students move from localized HARP programs into global nano-satellite opportunities.

Acknowledgments

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