

## Standard Testing Methods for Satellite Communication Systems

Jerry Stoner  
 Spacecraft Systems and Operations Lab  
 2348 Howe Hall, Ames, IA 50010; (515) 294-2972  
 Jerry507@iastate.edu

**ABSTRACT:** University space programs continue to push the envelope of small satellite technology. Because budgets are often limited, and equipment costs can often be prohibitive to even well-established space programs, it becomes necessary to maximize the benefit/cost ratio of testing methods. Expensive testing is often not an option, nor is it realistic. Traditional methods such as anechoic chambers or antenna test ranges are not options, and testing the craft on the ground is not practical. Because of the complexities encountered with testing, the Spacecraft Systems and Operations Lab (SSOL) developed a standardized test environment for communications system testing.

Using the High Altitude Balloon Experiments in Technology (HABET) program, a spacecraft can be tested at altitudes exceeding 100,000 feet using flight hardware. With remote launch capabilities, a balloon can be launched downrange and a satellite overhead pass can be simulated. HABET equipment is well understood, allowing parameters to be examined in great detail. The ability to transmit commands to the HABET bus means that the spacecraft can be triggered, much as it would be when separated from the launch vehicle. With these characteristics, the SSOL can use HABET to inexpensively test small satellites in a standardized environment very similar to space.

### INTRODUCTION

A major limitation to testing satellite communications systems is that the system must be tested in environment that cannot exist on Earth. However, thorough testing is necessary to avoid missing a vital parameter and rendering the system worthless in the hostile environment of space. Given that launch and design costs are not trivial this outcome is very undesirable. Therefore, good testing is an absolute necessity.

The problems associated with testing satellite communications systems mainly stem from the magnitude of the distances against which the designer is asked to compete. A satellite orbiting at 750Km requires the signal strength to be carefully monitored so the signal levels don't drop too low. Adequate testing at comparable distances is very difficult due to the curvature of the Earth. Balloons bypass this problem by lifting the test system off the surface of the Earth and achieving very large altitudes.

Testing the antenna pattern is another difficulty using conventional testing methods. The antenna pattern determines how much land mass the satellite can communicate with and is therefore very important. Testing the antenna pattern for systems that use low frequencies is exceptionally difficult because distances between the two antennas must be large. Balloons alleviate this problem because their ascent and descent

curves are predictable and fairly steep, making it easy to test the antenna at all its anticipated look angles.

The HABET ground station provides a suite of equipment and capabilities that allow us to use balloons to test small satellites such as those built by participants of the Cubesat program. HABET balloons provide a cheap and easily accessible option to participants who would have considered traditional testing methods far too costly. By knowing a great deal about the equipment used to measure the parameters of the communications system, and being able to place the balloon in the right place in the sky, HABET balloons provide a cheap and easily accessible way to add a testing option to participants who would have considered such testing far too costly.

### GROUND STATION CAPABILITIES

The SSOL can provide customers with a suite of ground station capabilities that allow for broad characterization of a communications system. Through the use of automated or non-automated methods, spectrum analyzer plots, oscilloscope curves and recordings of S Meter and raw audio output from our receiver are gathered. From this data, it is possible to eliminate possible sources of interference and make excellent estimates on actual signal strengths on orbit.

Many satellites use the amateur radio bands and communications methods. The SSOL is equipped with a FT-736R HAM radio receiver (Figure 1) that can

operate on the 144MHz and 440MHz bands. We have the capabilities to decode standard 1200 baud AFSK and 9600 baud FSK packets as well as produce raw audio recordings of the received data. Because both methods have a switching frequency well inside the frequency limits of standard soundcards it is possible to record the data waveforms directly into audio files that can later be examined in any number of free or commercial utilities. Information about the received eye can be extracted from these waveforms, and can provide significant help in troubleshooting problems.

**Figure 1: Yaesu FT-736R HAM Radio Receiver**



Modern HAM receivers have a very low noise figure. The SSOL ground station is equipped with low loss feed lines and a preamp for the 70Cm band that allow for excellent tracking of HABET payloads. HABET has three transmitters available in the payload box to accommodate a variety of satellite range tracking requirements. The SSOL can receive the GPS locations of the payload box out to 1500Km line of sight distance. Additionally, these low noise figures contribute to an excellent ability to measure the communications system parameters. The system noise temperature for the 2m system is 407.3K and 369.3K for the 70Cm system.

**Table 1. Link Budgets for Various Transmitter Configurations**

Frequency	1 Watt	2 Watt	5 Watt
144MHz (2m)	12.1dB	15.1dB	19.1dB
446MHz (70Cm)	6dB	9dB	13dB

An S meter with a recordable output is available and waveforms can be provided for any portion of the flight. Unknown spacecraft parameters like transmitting antenna gain can be calculated using a combination of ground station parameters such as antenna gains and cable losses, and easily known parameters like transmitted power. Unknown spacecraft parameters like transmitting antenna gain can be calculated using a combination of ground station parameters such as antenna gains and cable losses, and easily known parameters such as transmitted power. Because the spacecraft will pass over the ground station at many

different angles, the pattern can be measured with a high degree of accuracy.

In order to analyze the frequency content of the transmitter, a spectrum analyzer is available for measurements in both HAM bands. This is a HP70000 analyzer (Figure 2) which can measure down to divisions of 50Hz. The HP70000 can be used to monitor the transmitter and make sure it is not producing any splatter into other channels, and helps pinpoint possible signs of interference from nearby transmitters that could corrupt the transmitting signal.

**Figure 2: HP70000 Spectrum Analyzer**



In most situations, the recording is automated, easily providing real time data to the customer. For non-automated recordings, information such as screen shots and numerical data are available in a variety of formats. Iowa State University provides a high-speed internet option if the customer wishes to download the data directly. CD-ROMs, ZIP disks or DVDs are also available, and live, streaming, data can be provided, if requested, at an additional cost.

## HABET CAPABILITIES

The HABET Payload System is well established, and provides reliable delivery and retrieval of payloads. The SSOL has performed 57 launches in its 7-year history. Basic payload boxes provide accurate positioning and environmental data, inside and around the box. Full onboard facility customization is provided to meet specific customer requirements. An uplink capability allows commands to trigger special events during the flight.

HABET provides an inexpensive method for accessing high altitudes, but does not provide that capability year round and in all weather conditions, because it is a balloon. Winds at the launch site must be less than 10mph and visibility must be better than 5 miles. This can cause delays in launch times. Depending on the time of year, several days may pass before a decent spot in the weather opens up.

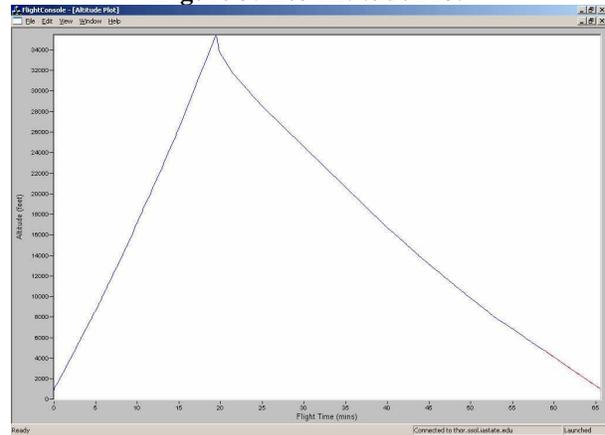
If the customer does not have a complete satellite system for test, just the communications system may be

tested. The HABET boxes are able to meet custom antenna mounting demands and are square, allowing similar mount arrangements for a typical cubic satellite. The payload can weigh up to 50 Lbs and up to 4 cubic feet is available. Special payload sizing and weight requirements are available upon request. Power is available inside the box for any required voltage. Batteries can be provided that supply 13.5 Watt/Hour per cell at 1.5V.

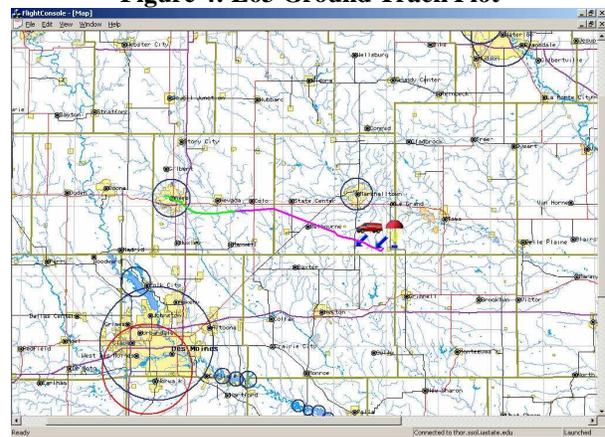
Flight paths are one of the major advantages with balloons. When balloons are released, they maintain a steady ascent rate up to their maximum altitude. If a balloon is launched far enough up wind, the flight path leaves the ground station at the desired angles, allowing the most realistic look angles to be simulated. The software used to predict the flight path of HABET payloads as they ascend and descend is very accurate in predicting the flight path in all three dimensions. This allows the flight to be positioned so the desired look angles are achieved.

To achieve the desired look angles, it is necessary for the balloon to pass close to the ground station. For example, if the balloon is at a vertical distance of 60,000ft, and a look angle of 40 degrees is needed, then the balloon must be at a horizontal distance of at least 13 miles from the ground station. The reliability of the tracking software in predicting the balloons trajectory becomes a major limiting factor in the ability of the system to move the balloon into position to track. A good measure of the software accuracy is the difference between the actual and predicted of the landing sites. The average error of the actual landing site to the predicted landing site is 29.5 miles. The effect of this error depends greatly on the ground track distance and the ascent and descent rates of the balloon, however, the error usually translates into less than one degree of difference in the look angle.

**Figure 3: L63 Altitude Plot**



**Figure 4: L63 Ground Track Plot**



One of the less desirable effects of using a balloon is its tendency to sway and revolve around the parachute cord. Balloon sway usually does not exceed an arc of 60 degrees, which may cause problems in antennas with highly directive patterns. The sway has a slow period however, so if transmission times are small enough, sway may not affect the communications system greatly. The rotation of the package is fairly quick, commonly 90 degrees per second, which may effect the functions of the communication system.

The major objective of the test flight is to gather data on the functioning of communications package, and accurate position data is vital to calculating several performance parameters. HABET reports back its position through either standard GPS, differential GPS, or on request, a WAAS enabled GPS. This can give positions accurate to 15, 3 to 5 or less than 3 meters respectively. When the HABET payload is far away, the relatively high inaccuracy of the standard GPS does not significantly impact the calculations.

The Altitude Hold system is currently under development. This system will allow the ground station

to control the altitude of the balloon payload by pumping helium into and out of pressure chambers, thus controlling the ascent and descent rates. This will allow a complete characterization of the satellite path. Once the general orbit is known, then the balloon can be programmed to follow that same arc through the sky, and accuracy in the estimate of performance parameters is improved.

## **PREVIOUS EXPERIENCE**

The HABET balloon system has been used twice before to test communications systems. On HABET missions L65 and L66, Stanford University flew a communications system developed for NASA. During these two flights, the communications system was tested and validated. This system was later used in support of other NASA flights. On mission H55, the antenna which would later be flown on a Mars mission was tested on HABET. The antenna was 40 meters in length and the University of Iowa, who had designed the antenna, lacked an anechoic chamber big enough to test it. This mission was a great success and the antenna was flown without any major changes.

## **Launch Types and Cost Estimates**

There are two options for launches available to a customer based on the type of testing that is required. To test the satellite at long ranges only, it is sufficient to do a launch from the regular launch site that is used at Iowa State University. For characterization of the antenna on the satellite, an upwind test is required so that a large array of angles is available to be measured. The upwind test will not yield the same ranges as the regular launch, but the ranges will still be sufficiently large. Perhaps the great advantage that HABET has is its cost. A typical launch through the SSOL will cost

about \$1000 depending on the level of integration required. Because the dominant features in the launch costs are the same for both launch types, the cost is essentially the same.

## **CONCLUSION**

Through the use of HABET balloons, any small satellite program can perform a rigorous real world test regimen at a price affordable to the average program. The equipment provided by the SSOL allows a great deal of data to be gathered to assist in the troubleshooting process as well as to predict with certainty how the communications system will perform in the reality of space.

## **ACKNOWLEDGMENTS**

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