UNIVERSITY OF ARIZONA
STUDENT SATELLITE PROJECT

# Technical Note

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Revision 1.0: Initial Draft

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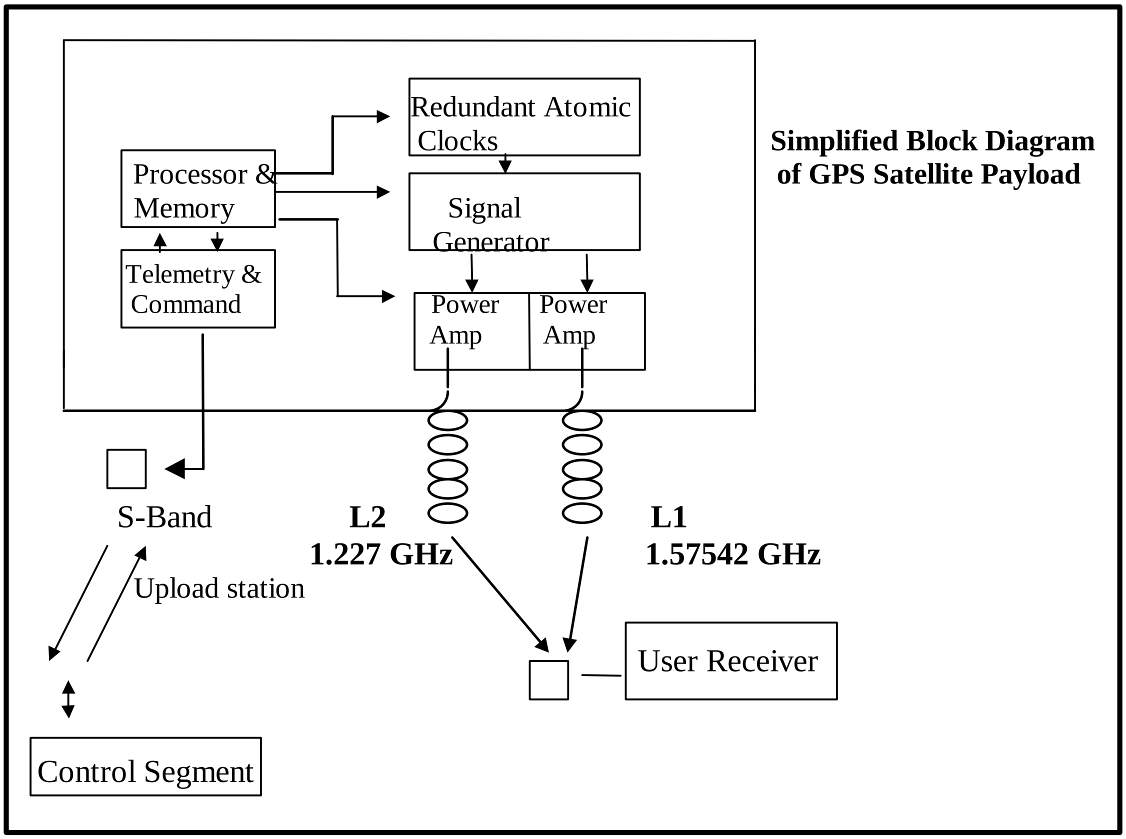
## 1. Document Overview

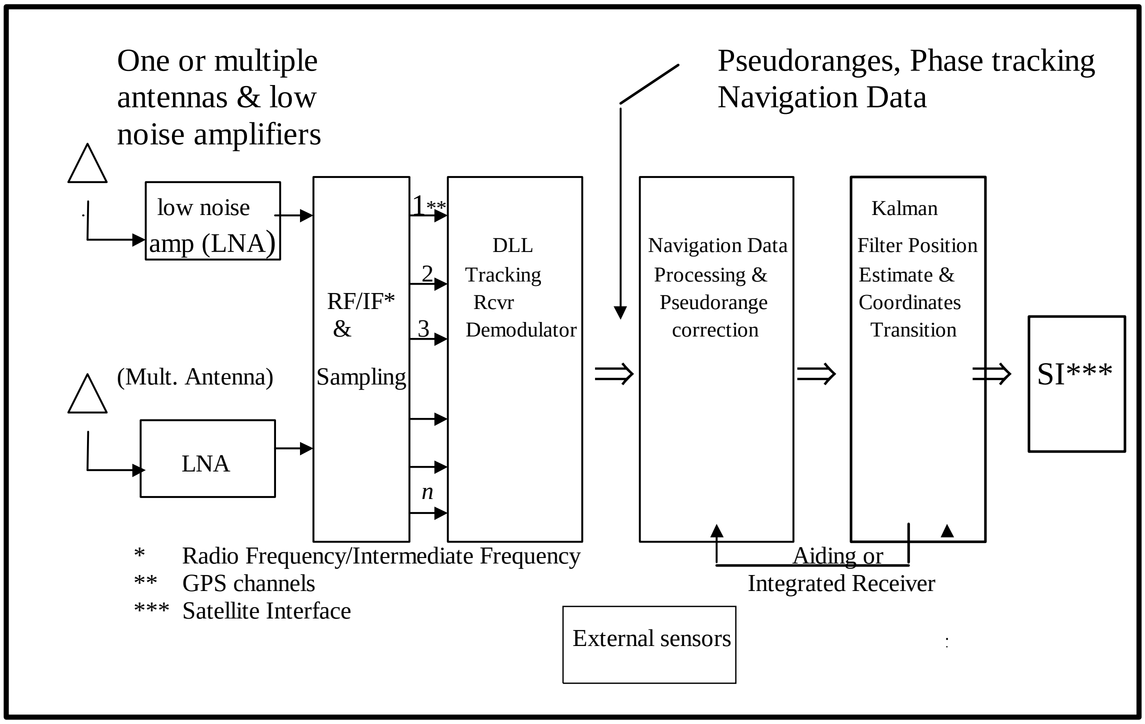
The primary purpose of a GPS receiver will be to obtain an accurate 3-dimensional position of the UASatellite and be utilized as a time reference. The following is background information concerning the theory behind GPS navigation so to better conceptualize how it will operate aboard the UASat. GPS is divided into three segments: space, control and user. The GPS *space* segment pertains to providing adequate simultaneous access to a minimum of four satellites per user. Four satellites are required so to provide real-time 3-dimensional navigation. The following illust-



**Simplified Block Diagram of GPS Satellite Payload**

rates what is known as the *control* segment of GPS. The control segment has many tasks including the maintenance of each satellite being in its proper orbit, making necessary corrections to satellite clocks, generate and upload navigational data to each GPS satellite and command major relocations in case of a satellite failure [Spilker and Parkinson, 40-41].

The chart below narrows the scope to conceptualize GPS architecture also known as the GPS *user* segment. The antenna output passes to the radio frequency filter (also known as low-noise amplifier) which filters out high level interfering signals in adjacent frequency bands. The signal then passes through serial stages of radio frequency amplification, down conversion, and intermediate frequency (IF) amplification and sampling/quantizing. These samples are then fed to a parallel set of DLL's which track different satellite signals and recover the carrier, which is bi-phase modulated with both the GPS codes and the GPS navigation data. The parallel measurements of pseudo-ranges and carrier phase along with the navigation data from each satellite are then sent to the navigation data processor where position of each satellite is calculated. It is here where the pseudo-range and phase data are corrected (possible errors include: clock errors, earth rotation, ionosphere delay troposphere delay, and equipment delays). This information is then processed by the Kalman filter which estimates the user position and velocity state vector [Spilker and Parkinson, 43-45].



*    Radio Frequency/Intermediate Frequency
**   GPS channels
***  Satellite Interface

## 2. Requirements

*Receiver Requirements*: In order to confidently rely on the onboard receiver it must be able to operate under extreme conditions.

(1) Thermal fluctuations (Receiver must operate at temperatures between -40º C to +70ºC) *reconfirm*
(2) Altitude extremes (up to 450km)
(3) Vibration & shock

*UASat Requirements*

(1) Accuracy (Generally receivers are accurate within 50meters)
(2) Power Consumption
(3) Cost
(4) Size and weight
(5) GPS receiver must interface with inertial measurement system. (i.e. Magnetometer or other navigational aids) By having such integration, a temporary shadowing or other interruption of the GPS satellite signals by a momentary obstruction can be accommodated by an inertial system that can allow the navigation systems to continue to operate without interruption.

## 3. Descriptions/Designs/Discussion

Since the GPS receiver will be commercially purchased, it will already include performance ratings. In the event the chosen receiver is *not* space rated,(which will likely be the case because space rated products are often far too expensive), one of the two alternatives must be chosen:

(1) Physically test the receiver in a thermal chamber, Electro Magnetic Interference (EMI) radiation chamber, shock and vibration shake table. Upon completion of these tests, it will drastically decrease the uncertainty of the onboard receiver.

(2) Choose a receiver which has already been successfully used in a similar satellite program (the second alternative may be more desirable for two main reasons.)
    (a) The necessary time and resources may not be readily available to conduct necessary tests.
    (b) If the tests were performed and the receiver did not meet the minimum requirements, we would have gained valuable knowledge yet be left with possibly a broken receiver that would no longer be returnable.

### Error Considerations

*GPS Week Number Rollover*—Although this problem is expected to be resolved by August of 1999, well before UASat is expected to be launched, the GPS receiver itself may be purchased before Aug. ‘99. In the event this purchase does take place before that date, the manufacturer should be asked if the rollover issue has been resolved for that particular receiver being purchased.

*Selective Availability* is a term used to describe the reduced accuracy purposely initiated by the US Government so to reduce the potential for GPS to be used by enemy personnel. Most receivers are equipped to handle DGPS (Differential GPS) and accuracy is usually increased to approximately a 2m margin of error. DGPS will incur an added expense to the program so it is necessary to know if a 50m (approx.) margin of error is within the guidelines for the scope of this program. Otherwise DGPS will need to be investigated further.

*Ionospheric Effects*—Although the UASat will be orbiting 400km above the earth, the GPS may still be subject to errors related to the ionosphere. The lower ionosphere (75-100km) should not effect the UASat but the ionosphere peak electron content (200-400km) may become a source of error for the GPS. The ionosphere is a region of ionized gases that varies widely from day to day and with solar conditions and also has a large diurnal fluctuation. The ionosphere can cause two primary effects on the GPS signal. The first is a combination of group delay and carrier phase advance, which varies with the exact paths and the electron density through which the satellite to user signal traverses the ionosphere. The second ionospheric effect is known as scintillation. This will sometimes cause the received signal amplitude and phase to fluctuate rapidly with time. [Spilker and Parkinson, 49-50]

*Multipath Effects*—Multipath effect errors account for approximately 90% carrier phase errors. A multipath error occurs when an antenna receives a signal that reflected off a surface, then was received by the antenna. By having antennas placed in different locations, the errors will conceivably vary from antenna to antenna. When determining the antenna placement, it is imperative to allow the antennas an unobstructed field of view and if possible, position the antennas away from reflective surfaces. In turn, this will help reduce the multipath effects. As it stands, carrier phase errors caused by multipath is approximately 5mm rms. (This was calculated using a complex reflective surface, such as a spacecraft). [Lightsey, 467]

## 4. Lists

## 5. Interface Requirements and Specifications

Once a GPS receiver is decided upon, the interface requirements and specifications will be more easily addressed. (All specification sheets found in the GNC lab do list interface requirements).

## 6. Current Status

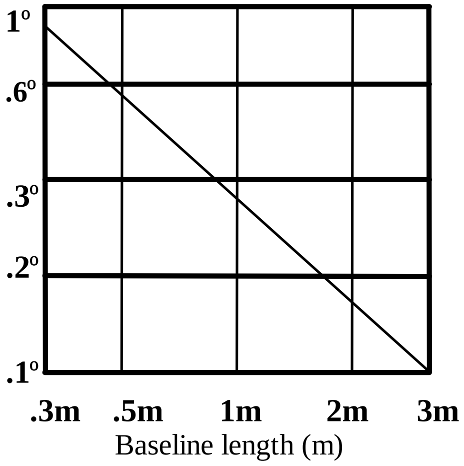
The SSP must first decide if the GPS receiver will also have attitude determination capability. Then at that point, decide which commercially produced receiver will best fit the needs of the UASat. Several receivers have been researched and their performance specifications can be found in the GNC lab (Room S420). In addition to a variety of performance specs available, a Trimble contact has been established and a Tans Vector Installation Manual is available.

## 7. Test Plan

It would be in the best interest of the program to build a mock-up UofA satellite so to test the GPS receiver, especially if the receiver were to have attitude determination capability because antenna positioning is so critical. Regardless of the receiver chosen, the mock-up satellite would be small enough to easily transport and therefore capable of testing accuracy before liftoff. In addition to physically testing the unit, it would also be worthwhile to investigate past satellite programs using the chosen receiver. In fact, since many universities participate in similar NASA programs, it is even possible to acquire software and literature regarding that mission because all such information is considered ‘public domain.’

## 8. Concerns and Open Issues

Since attitude determination is of importance, particularly for the photometry experiment, the UASat must seriously address this issue. One such issue that needs to be resolved is the effect of the earth’s magnetic field on a magnetometer. If the magnetometer is greatly effected, it will not be capable of producing the needed accuracy for attitude determination and an alternate method must be developed. One such alternate method includes the use of a GPS receiver with attitude determination capability. This too, comes with drawbacks. One such drawback is the power consumption: 7 Watts. Next, is the placement of the four antennas: Can they be adequately separated so to take advantage of the attitude determination capabilities? Below is a graph estimating the accuracy based on antenna separation. (See Lightsey, 469 for more details pertaining to the following graph).



One potential scenario involves using GPS attitude determination coupled with the use of gyros. This combination is said to improve the absolute pointing error by a factor of three when GPS is used alone (Barbour, 1). To further increase accuracy, a Kalman filter can be utilized to combine GPS and gyro measurements. It is imperative that such issues are resolved so to ensure the necessary accuracy for the UASat.

## 9. References

1. Barbour, N., P. Madden and M. Socha. (XXXX) *A Micromechanical Gyro Package with GPS under development for small pointing satellites*.
2. Spilker, Jr., James J. and Bradford W. Parkinson. (1996) ‘Overview of GPS Operation and Design.’ In Spilker and Parkinson, eds., *Global Positioning System: Theory and Applications* (vol. 1) Reston, Virginia: American Institute of Aeronautics and Astronautics, Inc.
3. Lightsey, E. Glenn. (1996) ‘Spacecraft Attitude Control Using GPS Carrier Phase.’ In Spilker and Parkinson, eds., *Global Positioning System: Theory and Applications* (vol. 2) Reston, Virginia: American Institute of Aeronautics and Astronautics, Inc.
4. Trimble Navigation Limited, Mobile Communications and Positioning Division. (1998) <http://www.trimble.com/products/catalog/pd_ml1005.htm> Date accessed: June 12.