UNIVERSITY OF ARIZONA
STUDENT SATELLITE PROJECT
Technical Note

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Reviewed by: ????

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Revision 1.0: Initial Draft 4/19/1998

1. Document Overview

The purpose of this Technical Note is to give a general overview of what the purpose of the Laser Uplink Experiment is, along with some of the overall system requirements and demands on the rest of the spacecraft.

The primary objective of the Laser Uplink Experiment is to design and construct a reliable and efficient laser communication system for UASat. This goal is to be accomplished by first developing a laser uplink between a ground station and the low earth orbiting satellite, with the overall aim of providing data transfer at a higher rate than standard radio and microwave communications. Once a design is established and proven to be useable in an update situation, a downlink can be explored in greater detail. Phase 1 of the experiment is to develop an uplink from the ground to the satellite. Phase 2 of the experiment is to develop a downlink, that can either fly on the first satellite, or on a future mission.

Implementation of this system involves utilizing solid state / semiconductor lasers coupled with optics at both the ground station and satellite terminals. The communication links will use lasers operating with wavelengths in clear atmospheric transmission windows.

Central to this task is the establishment of an optical groundstation. The groundstation will require the use of a telescope with a tracking rate capable of following UASat through its orbit over Tucson. If possible, a local observatory will be utilized with a minimal amount of modification. If necessary, a separate dedicated telescope will be procured and adapted. It will be necessary to provide a fast link between the optical groundstation and the main satellite ground control station.

2. Requirements

Since this is a “science” experiment or maybe more of a technical experiment) in the loosest terms, the following requirements are best described as being imposed on other systems. Many of the requirements are only ballpark estimates. After a series of test links and further design reviews, other requirements may arise, which will be covered in this and additional Technical Notes.

2.1 Need access to main satellite telescope optical train

The laser communication experiment needs to be able to interface to the Science Team's optical equipment. Since the main telescope will be used to collect laser light from the Optical Groundstation, it is important that we get as much signal as possible, which will mean we need access to the otpical train, before filtering.

2.2 Need a DMA (Direct Memory Access) or equivalent access to spacecraft CPU

Since we are planning a high speed link, (possibly in the area of 10 Mbps), it will be important to get the data to a storage buffer. Inside of the laser communication experiment will be some storage, but the majority of it will be handled by the main spacecraft CPU. This interface will depend on the bus interface being used on the satellite.

2.3 Purpose of this experiment is to demonstrate the feasibility of high speed, laser communication

The goal of our design, is to provide a reliable, 10Mbps connection between the satellite (in Low Earth Orbit) and the optical groundstation.

2.4 Majority of the power consumption will occur when we are receiving a transmission, and have to point and slew the satellite accurately.

2.5 Heating / Thermal Rad. / Radiation Requirements

These requirements will be developed, as components are selected to be used in our systems on the spacecraft. For the time being, certain environmental restrictions (guidelines) have been given by the MSA team.

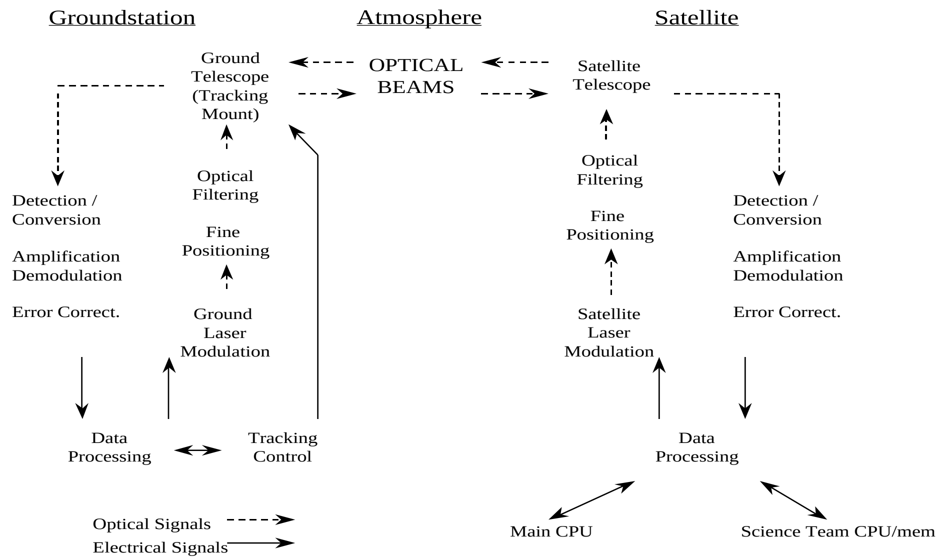
2.6 Space Requirements should be kept as compact as possible

2.7 Provide a power down and wakeup mode to conserve power

3. Descriptions/Designs/Discussion

3.1 Overall Instrument Block / Data Flow Diagram

Figure 3-1: System block digram



This diagram shows not only an uplink sequence to the satellite, but a downlink sequence, as a possible extension of the laser communication experiment.

3.2 Data transmission process

3.2.1 Uplink

Data starts out being generated at the groundstation, in the Data processing block of the diagram of Figure 3-1. Once the data is prepared and ready to be sent up to the satellite, the necessary housekeeping and data preparation is done at the groundstation. The data then goes into the Manchester encoding circuitry, into the amplification and into the laser modulation circuitry. As all this happens, the tracking control is making sure that the satellite is in view, and all the proper coarse point is established. Involved with this is a beacon system, that helps the satellite to align with the groundstation. Once the data transmission starts, fine pointing can be established (based on acknowledgements from the satellite). In phase one, acknowledgements can be sent from the TTC team. In Phase 2, the laser downlink can be used to provide feedback on the system.

On the satellite, a similar pointing process is initiated, to point the satellite as accurately at the groundstation as possible. Once the satellite is locked into pointing at Tucson (or wherever the groundstation may be), the beacon from the groundstation can help provide an accurate target, and provide information, that will allow the fine positioning equipment to make the proper adjustments.

Once the data transfer starts, it initially goes at a very slow, and stable speed. As the pointing is refined, the speed can be increased as appropriate. Throughout the entire process, optical filtering will help in improving the S/N (signal to noise) ratio.

At the satellite, the laser light will be directed to a communication photodetector, where it will be converted to a digital signal (after amplification and filtering). At that point, data will be sent to a buffer or whatever part of the spacecraft CPU requires the information.

3.3 Component Description

3.3.1 Ground laser

A laser is needed at the ground station to send data up to the satellite. The two types that we are considering are: 1) A InGaAsP semiconductor laser with a wavelength of 1500 nm. This laser will have a peak power of 100 mW or less. 2) A Nd:YAG/YLF/YAP solid state laser with a wavelength of 1064 nm. This laser will have a peak power of 1 - 5W. Due to relatively high transmission windows through the atmosphere at these wavelengths, and technological improvements in fiber optics and lasers, lasers operating in this area of the spectrum are ideal, and are becoming more readily available.

3.3.2 Photo-Detector

Tentatively both the ground station and the satellite will be using one of the photo conductive detectors, listed in Section 4. The final selection will be based on performance characteristics, and testing with test links.

3.3.3 Amplifier / Signal Processing

A high gain, low noise, low power amplifier is needed. Two configurations are under consideration. 1) An amplifier increasing the strength of the optical beam prior to incidence on the photodetector. 2) An amplifier to strengthen the electrical signal produced by the photodetector prior to signal processing._For example, a low noise JFET input OP amp could be used depending on the amount of power received by the detector

3.3.4 Manchester Encoding / Decoding / Buffering

This functionality will be provided in commercially available protocol chips, commonly used in LAN based Ethernet cards. Some simple buffering will be provided at this level, with further detail to be provided in a Technical Note.

3.3.5 Error Correction / Detection

A unique feature of the system will be a forward error correction module, which will help to minimize the amount of retransmission, and delays in the system. In addition to this, a standard retransmission protocol will be provided, which will worry about resending completely destroyed packets.

3.3.6 Optical Interfaces with main telescope

To be explained in further detail, once test links have been performed, and further design can begin.

3.3.7 Data processing through a Microcontroller (on satellite)

3.4 Groundstation Issues

3.4.1 Location (on or off campus)

3.4.2 Requirements for an optical telescope / mount / pointing control circuitry

3.4.3 Connection to the main groundstation

3.5 Test Links

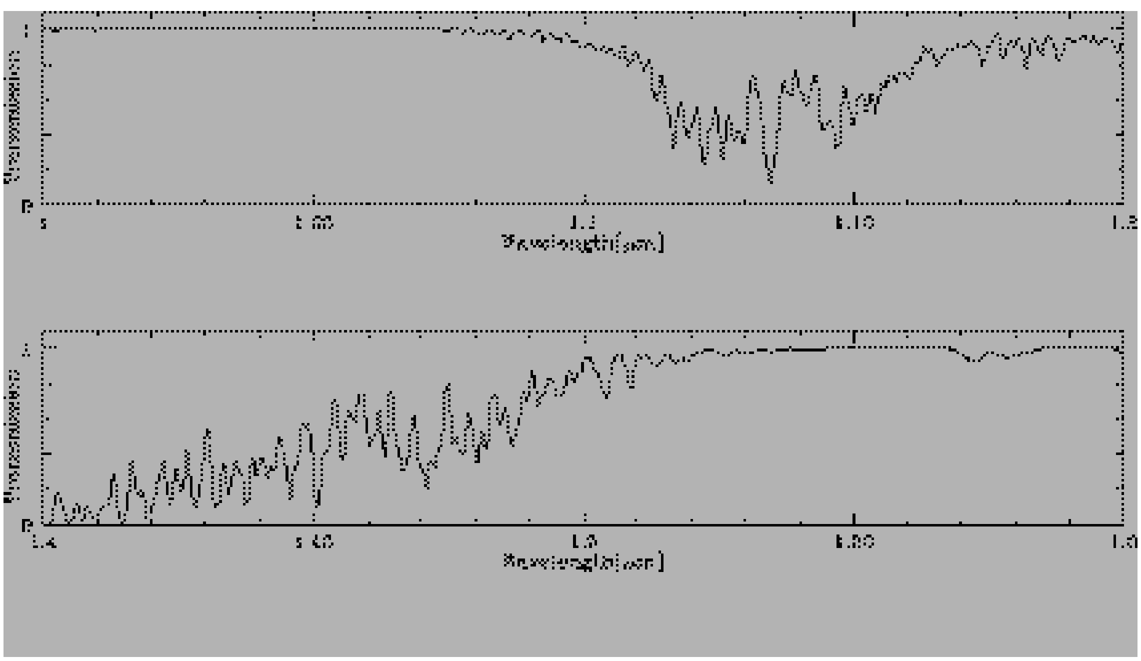
As the design of the experiment progresses, test links will be performed, to demonstrate the feasibility of a certain idea or design. At this point, there are preliminary test links, that will be described in further detail, as they evolve.

4. Lists

4.1 Atmospheric Transmission bands

There are two possible transmission bands possible (based on data from the Australian ????). In addition to this resource, JPL (Jet Propulsion Lab) has been conducting atmospheric visibility research at Mt. Lemmon. All these resources will be helpful in refining the type of laser wavelength to be selected

Figure 4-1: Atmospheric Transmission Windows



4.2 Laser Types Under consideration

Table 4-1: types of lasers being considered for the groundstation (4/24/98)

Laser Type	Wavelength [nm]	Output Power	Efficiency
ND-YAG	1064	2mW – 3W	>10%
InGaAsP	1550	<100mW	10 – 20%

4.3 Photodetector Types under consideration

Table 4-2: types of photodetectors being considered for satellite (4/24/98)

Type	Spectral Responsivity
PbS Lead Sulfide	
PbSe Lead Selenide	
PbTe Lead Telluride	
InSb Indium Antimonide	
Si doped Silicon	
Si PIN Silicon Avalanche	

4.4 System Estimates

The following table lists a “first-order” series of calculations for certain system parameters.

Table 4-3: System estimates (11/27/97)

Groundstation	Numerical Value
Power of laser	2W
Beam Divergence Min: Max:	 10 μrad 20 μrad
Link Distance Min: Max:	 400 km 2500 km
Beam Area at Satellite Min: diameter / area Max: dimeter / area	 4m / 12.5 m^2 50m / 1960 m^2
Received Power at satellite Min: Max:	 1.5×10^{-5} W 1.7×10^{-3} W
photons / bit Min: geometrically, detected Max: geometrically, detected (assuming 10 Mbps, Manchester (1/2 bit time)) Earth Background (no filter), daytime Earth Background (1 nm filter), daytime	 3.8×10^6 / 1.4×10^6 4.2×10^8 / 1.5×10^8 5.0×10^5 5.0×10^2

5. Interface Requirements and Specifications

Many of the interface issues will be dealt with, once a more detailed design is established. In the coming weeks, system level design work will be conducted, alongside the test links, to determine what interfaces will be necessary. At the time being, the following are going to be important interfaces: optical interfacing with the main satellite telescope, connections to spacecraft power and data busses, placement of equipment near the Science Team instruments, and the establishment of a command set to interact with the Laser Communication Experiment. Basically, we plan on complying to whatever data bus design is produced by the DCH team.

6. Current Status

Currently, we are still at the preliminary stage of defining what the system design will be like, on the satellite. Until test links can be constructed, designs up to this point will based on other experiments that are already being conducted (GOLD, Spot 4, AstroTerra, etc.)

7. Test Plan

At this time, there is no established test plan. The simple test to perform: does the communication system. After that, how well it performs will have to be evaluated.

8. Concerns and Open Issues

This is a very raw design. The biggest open issue is a thorough examination of other projects that have been (or are being) conducted. This will help the team focus on doing a more thorough design and development of the actual requirements of the system (from a numerical standpoint). Without an idea of the power and mass and space requirements, it will be very difficult to provide accurate information for other teams.

9. References

To be added in a future revision of the document (once the author has some additional time)