Manufacturing Design Review



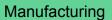
P4LO



Positioning For Lunar Operations

Team Advisor: Dr. Jade Morton









Agenda

- 1. Project Overview/Objectives
- 2. Schedule
- 3. Manufacturing
- 4. Budget

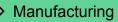




Project Overview



Schedule







Background



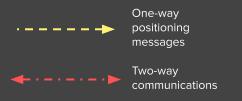


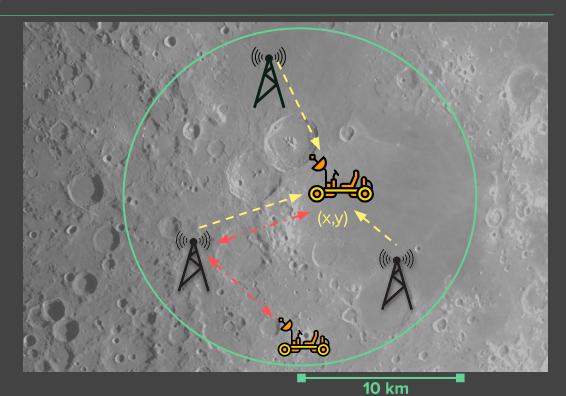


Lunar CONOPS

Overview

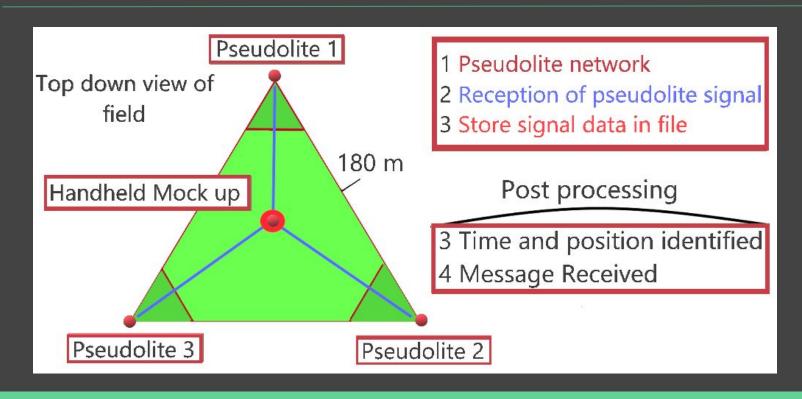
- Provide ground-based positioning and communication to the South Pole
- 10 km radius region





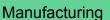


P4LO CONOPS













Mission Statement

P4LO (Positioning For Lunar Operations) is a prototype network of software defined radios that demonstrates an architecture for the lunar communication and positioning system LunaNet.



Schedule

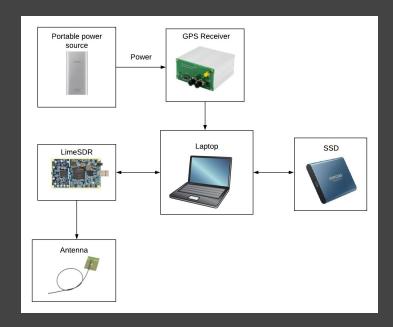
Manufacturing

Budget



What is a Pseudolite?

- A portable ground station
 - Transmitspositioningmessages
 - Receives user communication messages





Pseudolite Hardware Block Diagram



How will positioning work?

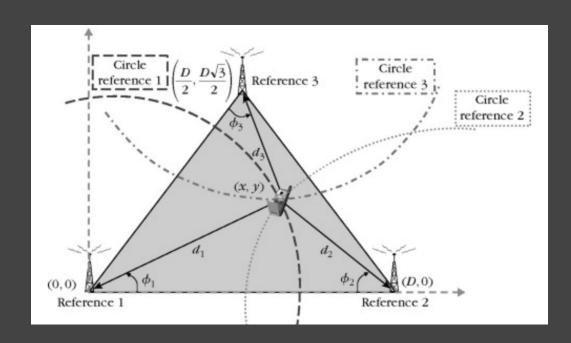
- Known pseudolite positions
- Time of arrival (TOA)
- System of equations with 3 unknowns (x, y, clock bias)
- Least-squares solution to account for noise and measurement error

$$d_1 = c(t_1 - t_0) = \sqrt{x^2 + y^2}$$

$$d_2 = c(t_2 - t_0) = \sqrt{(D - x)^2 + y^2}$$

$$d_3 = c(t_3 - t_0) = \frac{1}{2}\sqrt{(D - 2x)^2 + (D\sqrt{3} - 2y)^2}$$

t_i: TOA at reference i; c: speed of light







Manufacturing

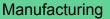




Mission Success

- Key Functional Requirements
 - Scalable Positioning System
 - Sub 10 (m) positioning within specified area
 - 30 ns 1-sigma transfer time
 - Communication Network
 - Communication operating between 2.4 2.48 GHz
 - 1 MHz Signal Bandwidth
 - Framework allowing for up to 170 users communicating within region
 - Data rate of at least 1 kilobit per second









Customer Value Proposition

Schedule

- Develop testing scenario
 - Testing out a scaled down version of the system
 - What it takes to test the system
 - What works, what doesn't
- Develop/Integrate hardware & software
 - LimeSDR (Radio)
 - Performance metrics
 - External clock integration
 - GNU Radio v3.8 (Software)
 - Performance
 - Interfacing with LimeSDR





Manufacturing





Critical Elements

Signal Generation and Transmission

- LimeSDR GNU Radio
- Antenna
- GPS ReferenceOscillator (SynchronizePseudolites)
- Laptop and SSD

Signal Reception

- LimeSDR GNU Radio
- Antenna
- GPS Reference
 Oscillator (Used as stable oscillator)
- Laptop and SSD

Signal Processing

- Acquisition and tracking
- Data extraction
- Positioning Solution











Changes since CDR

- Signal Reception: SSD + Laptops instead of Raspberry Pi
 - Due to computation restrictions, boot Linux off external SSDs connected to laptops for additional speed and memory
- Signal Transmission: Pseudolites equipped with a reference oscillator
 - GPS disciplined oscillator (GPSDO)
 - Parts have been selected and ordered.



Schedule



Work Breakdown Structure



		P4LO		
Deliverables	Management	Electronics / Hardware	Software	Testing
PDD	WBS	Interface LimeSDR	HDOP Algorithm	Testing Location
CDD	Cost Plan	Set up LimeSDR Environment	Near-Far Mitigation	Signal Transmission / Reception
PDR	Risk Assessment	Wired Signal Transmission / Reception	SDR Software	Antenna Test
CDR	Organizational Chart	Wireless Signal Transmission / Reception	Tracking / Acquisition	Signal Interference / Noise Test
FFR	Work Plan	Override SDR Clock with Receiver Clock	GNU Modulation / Multiplexing	Multiplexing Test
MSR	Test Plan	Manufacture Housing for Hardware	Encode Time onto Signal	Compute Clock Bias
TTR	AIAA Management	Interface Hardware with Tripods	Finalize Positioning Algorithm	Position Verification Test
AIAA			Software Integration	Full Systems Test
SFR				
PFR				

System

Complete

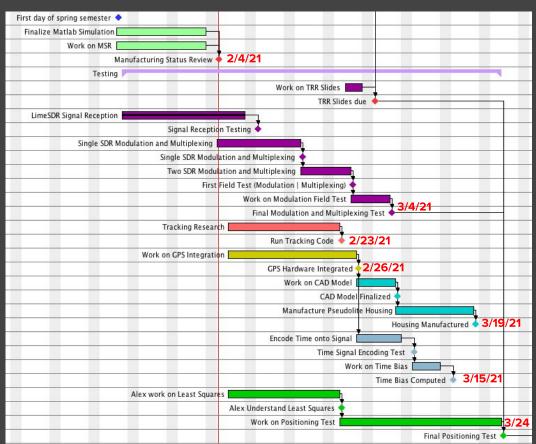
Incomplete

n Progress



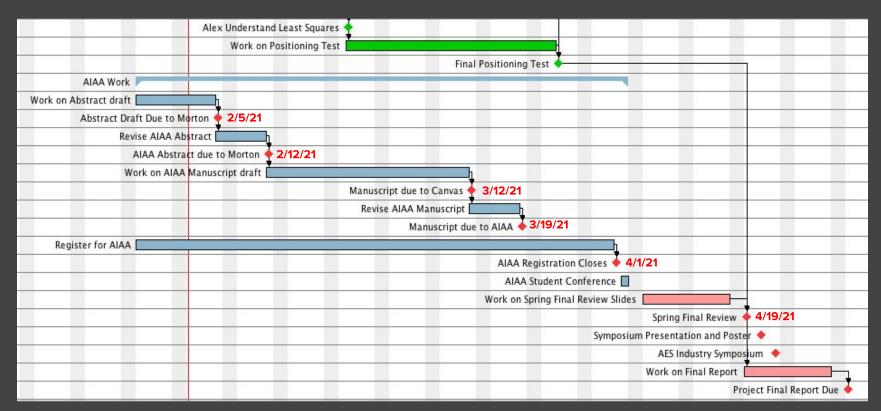
Spring Schedule







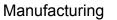






Manufacturing









Manufacturing Overview

Purchase

- LimeSDR
- Reference Oscillator
- Antenna
- SSD
- Tripod

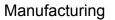
Integrate

- Pseudolite electronics
 - Antenna
 - GNU Radio
 - Laptop
- Pseudolite clock
 - Override internal clock
- Calibrate system

Develop / Manufacture

- GNU Radio script
- Communications Protocol
- Positioning Algorithm
- Pseudolite Housing









Manufacturing Overview

Purchase

- LimeSDR
- Reference Oscillator
- Antenna
- SSD
- Tripod

Integrate

- Pseudolite electronics
 - Antenna
 - GNU Radio
 - Laptop
- Pseudolite clock
 - Override internal clock
- Calibrate system

Develop / Manufacture

- GNU Radio script
- Communications
 Protocol
- Positioning Algorithm
- Pseudolite Housing





Manufacturing





Integrate: Pseudolite Electronics

Task: Send and receive test signals using pseudolite electronics

- GNU Radio 3.8 (Software)
- Ubuntu Linux booted on a Samsung T7
 500 GB External SSD
 - o Running GNURadio
 - o 1 GBps read/write
- Dual Band TE Connectivity Patch Antennas
- LimeSDR USB 3.0
- ASUS Zenbook (Core i5 @ 3.5 GHz)
- Write samples to file



Status: Done



Schedule

Manufacturing

Budget



Integrate: Pseudolite Clock

Task: Override internal LimeSDR clock in each pseudolite

- **Synchronize** all pseudolites in order to get accurate range measurements.
- Provide a more **stable** oscillator for higher quality transmitting and receiving.
- Using a GPS-disciplined oscillator (GPSDO)

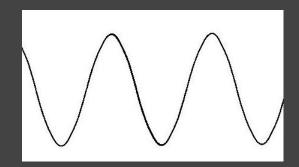
Status: Shipping (ETA: 2/5/21)







GPSDO













Integrate: Calibrate System

Task: Measure and calibrate for total system bias (Pseudolite + GPSDO) when transmitting

Status: Waiting for overall system integration









Manufacturing

Budget

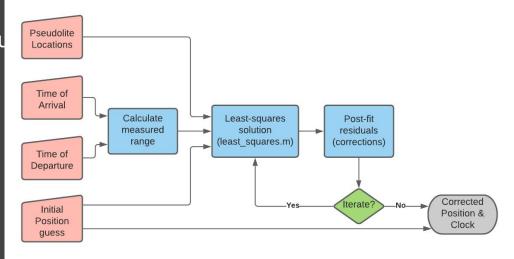


Develop: Positioning Algorithm

Task: Develop code to process received samples and then compuposition.

Status:

- Signal processing script in progress
- Positioning script done



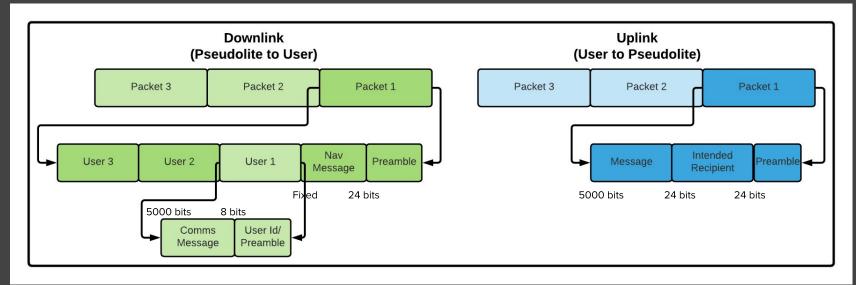
Positioning Script Block Diagram



Develop: Communications Protocol

Task: Format communication data into packets

Status: Done











CDR Status Update

- GNU Radio system setup
- Signal detection between two transmitters
- Measured signal interference at testing location
- Preliminary CAD Housing Model Done
- Selected Referenced Oscillator



Budget



Overview

Schedule

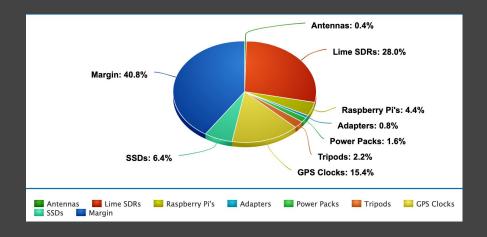
Manufacturing

Budget



Cost Plan & Margin

Group	Cost (USD)
Dual TE Connectivity Antennas (4)	\$19.80
Lime SDR's (4)	\$1,399.80
Raspberry Pi (4)	\$220.00
Adapters & Connectors (4 Sets)	\$39.80
Miadi Portable Charger (Power Pack) (4)	\$79.96
5 Feet Tripods (4)	\$111.96
GPS Disciplined Oscillator (4)	\$769.53
Samsung External SSD 500Gb(4)	\$319.96
Budget Status	
Order Total	\$2,960.81
Balance	\$2,039.19
Available Margin	40.78%







Manufacturing





Major Item List & Status

Item	Status	
Dual Band TE Connectivity Antenna (4)	3 Delivered 1 Not Shipped (ETA2/5)	
Lime SDR's (4)	1 Delivered 3 Shipped (ETA 2/1)	
Laptops (4)	4 (Team Members Provided)	
GPS Disciplined Oscillator (4)	1 Shipped 3 Not Shipped (ETA 2/10)	
Samsung External SSD 500Gb(4)	4 Shipped (ETA 2/1)	

Obstacles: P-card access, Shipping Logistics & Hardware Pickup



Questions?



Backup Slides





LimeSuiteGUI - GNU Radio - Gr-LimeSDR Plugin

Wiki.myriadrf.org. 2020. Gr-Limesdr Plugin For Gnuradio - Myriad-RF Wiki. [online] Available at: https://wiki.myriadrf.org/Gr-limesdr_Plugin_for_GNURadio [Accessed 30 November 2020].

"Raspberry Pi Icon #35510." Raspberry Pi Icon #35510 - Free Icons Library, icon-library.com/icon/raspberry-pi-icon-20.html.

Al Williams, et al. "Software Defined Radio App Store." Hackaday, 7 May 2016, hackaday.com/2016/05/07/software-defined-radio-app-store/.

Radioparts Two-Way Radios, Parts and Accessories, www.radioparts.com/telewave-ant140f2.

"Radio Waves Clip Png." Pngio, pngio.com/PNG/a104378-radio-waves-clip-png.html.

"Cell Tower." Cell Tower - ClipArt Best, www.clipartbest.com/cell-tower.

"Custom Laptop Stickers. Print or Download." Custom Mission Patches - Design and Print NASA-Style Mission Patch Stickers for Your Team., mission-patch.com/.

Jon. "Using the Interlocking CU Alone." University of Colorado, 30 Aug. 2019, www.cu.edu/brand-and-identity-guidelines/using-interlocking-cu-alone.

LunaNet: Establishing a Flexible and Extensible Lunar Exploration Communication and Navigation Infrastructure: NASA Goddard Space Flight Center.

D.J.Israeletal., "LunaNet: a Flexible and Extensible Lunar Exploration Communications and Navigation Infrastructure," 2020 IEEE Aerospace Conference, Big Sky, MT, USA, 2020, pp. 1-14. Doi: 10.1109/AERO47225.2020.9172509 URL: http://ieeexplore.ieee.org/stamp/stamp.isp?tp=arnumber=9172509isnumber=9172248

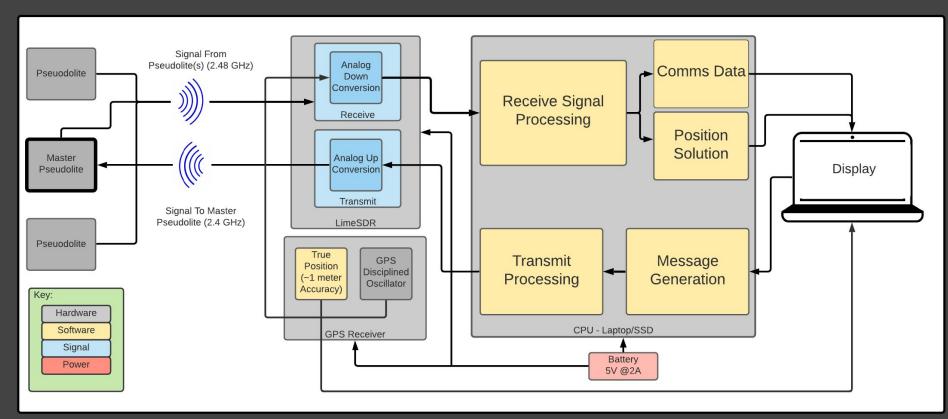
Muñoz David. Position Location Techniques and Applications. Academic Press, 2009.



Intro/Overview



Overall FBD





Solution > CPE

DR

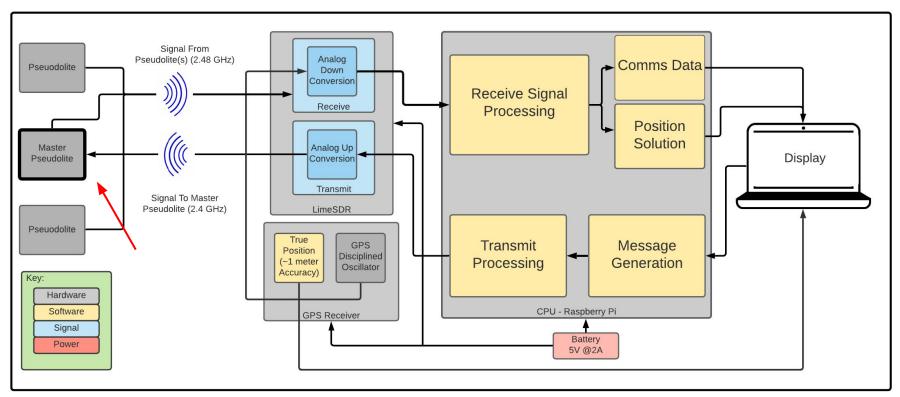
Risk & M

V&V

Planning



Overall FBD





Solution

CPE

DR

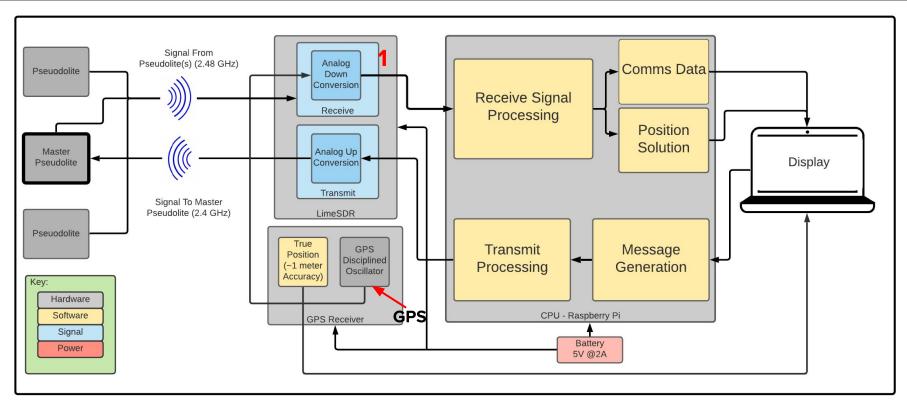
Risk & M

V&V

Planning



Overall FBD





Solution

CPE

DR

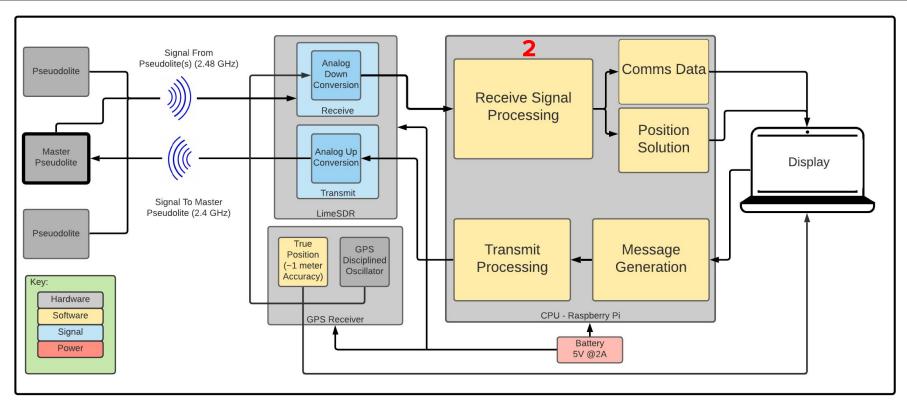
Risk & M

V&V

Planning



Overall FBD





Solution > CPE

DR

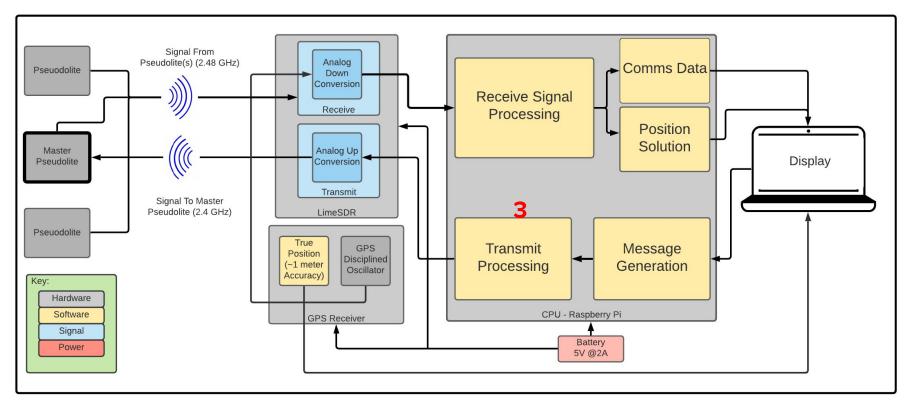
Risk & M

V&V

Planning



Overall FBD





Scaled Down Testing (Placeholder Title)

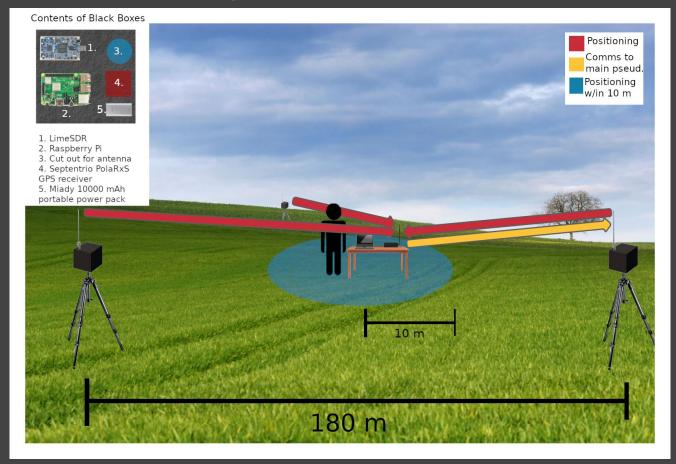
- Scale from 2.4 km to 0.18 km dist. between transmitters
- Assume 2D (only x and y, no height)
- Transmitting on Earth is at least as complicated as on the Moon
 - Atmospheric losses
 - RF Interference
 - Man-made structures/materials interfering
- Not testing environmental constraints

A scaled-down test in Boulder, CO is still able to validate the design for use on the lunar surface



Design Solution Set Up







Solution

CPE

DR

Risk & M

V&V

Planning



Critical Project Elements

Critical Project Element	Design Solution
Positioning System	One-Way Pseudolite Ranging
Antenna	Dual Band TE-Connectivity Antenna
Communication	BPSK Modulation CDMA Multiplexing
Software Defined Radio	LimeSDR
Clock	Septentrio PolaRxS - GPS Receiver
CPU	Raspberry Pi





Software Overview

GNU Radio

- Reference oscillator integration
- Signal reception and transmission
 - Modulation
 - Multiplexing
 - Up/Down Conversion
 - Acquisition
 - Tracking

Matlab

- Packet Creation
- Positioning algorithm
- For simulation
 - Modulation
 - Multiplexing
 - Up/Down Conversion
 - Acquisition
 - Tracking

LimeSDR

- Overwrite clock with reference oscillator
- Integrate antenna

Open Source Edited
Outside Leveraged

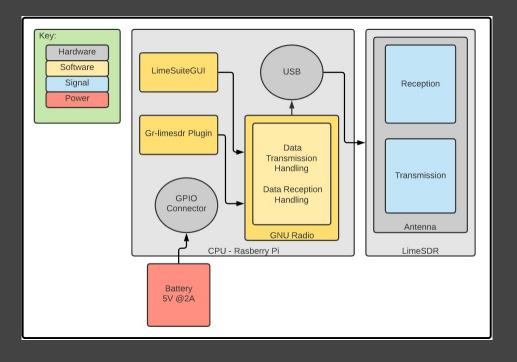


Hardware

Risk & M



Pseudolite Electronic Configuration



- Electronic/Hardware functional block diagram.
- DR 2.1.3: The system will operate using the LimeSDR electronics device
- The LimeSDR combined with the GNU Radio software package.
- FR1: The system must operate under a scalable LPS model
- How is this scalable?

DR 2.1.3: LimeSDR is in use





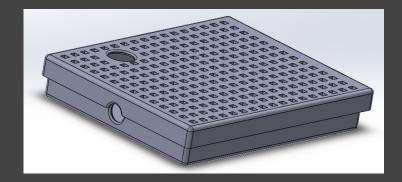


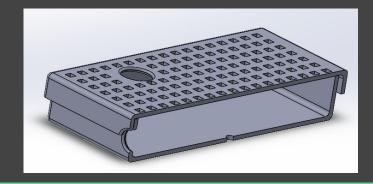




Mechanical Hardware Integration - CAD

- CAD model of case for holding the limeSDR, GPS, power supply, and Raspberry Pi
- Holes for cable, antenna, and ventilation.
- To do: get a tripod so that the model can be made to attach









CPE

Risk & M

V&V

Planning



SDR - Requirements

- FR1: The system must operate under a scalable LPS model
 - DR 2.1.3: The system will operate using the LimeSDR electronics device
- FR2: Demonstrate SMS-like communication
 - DR 2.2.1: Device must demonstrate wireless transmission and reception of data

DR

- FR 4: System will transmit and receive data between (2.4 2.48 GHz)
 - o DR 2.4.1: Demonstrate uplink transmission at 2.4-2.48 GHz
 - DR 2.5.1: Demonstrate downlink transmission at 2.4-2.48 GHz





CPE

DR

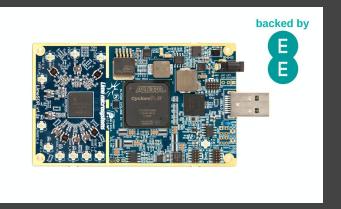
Risk & M

V&V

Planning



LimeSDR (SDR - "Software Defined Radio")





LimeSDR (Hardware)

- Customer requirement
- Reception and Transmission of signal
- Ability to work with modulator/demodulator software packages
- Functions at 2.4-2.48 GHz

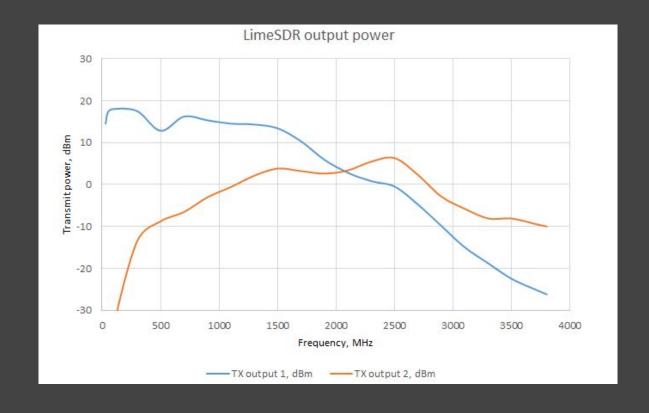
GNU Radio (Software)

- Suggested by customer
- Able to implement all communication schemes and all frequency ranges
- Able to do simulation and testing











Baseline Design

Feasibility

Summary



Antenna - Requirements

FR4: The system will transmit data on the S-Band frequency.

DR 2.4.1: Demonstrate uplink transmission at a frequency range between
 2.4-2.48 GHz

FR5: The system will receive data on the S-Band frequency.

DR 2.5.1: Demonstrate downlink reception at a frequency range between
 2.4-2.48 GHz



Solution

CPE

DR

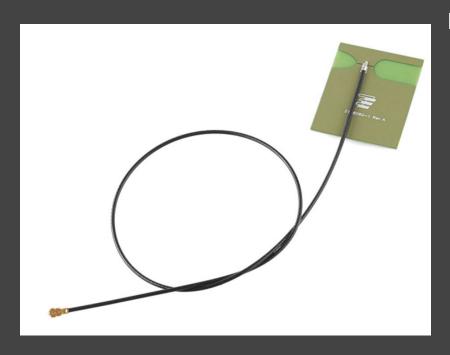
Risk & M

V&V

Planning



Dual Band-TE Connectivity Antenna



Dual Band-TE Connectivity

- Peak Gain 2dBi
- Embedded Antenna Style
- Freq Range: 2.4-3.8GHz
- Low Weight (<3.3gram)
- Low Cost (5 USD)
- Voltage Standing Wave Ratio (VSWR) -MAX 3:1



Antenna - Selection Analysis

Customer Requirement: S-Band (due to radio silent far side of the moon)

Frequency Range	PROS	CONS
S- Band: (2-4 GHz)	 Previous communication satellites (NASA) Unlicensed bandwidth (2.4-2.483 GHz) good for testing Low Cost system 	 Large amount of interference (Many devices at this bandwidth) Mainly used for large antennas (transmission)



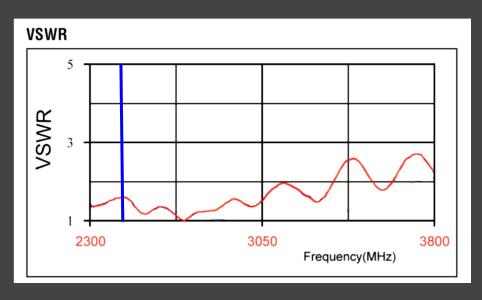
Baseline Design

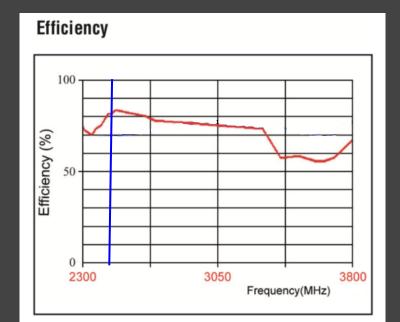
Feasibility





Antenna - Evidence of Feasibility





DR 2.4.1, 2.5.1

FEASIBLE



Baseline Design

Feasibility

Summary

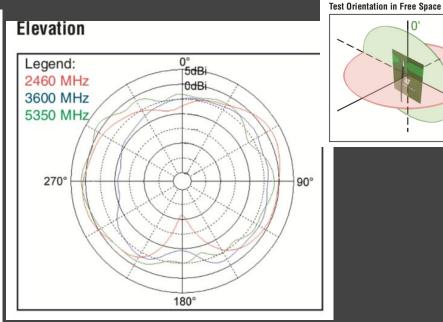


azimuth plane elevation plane

Antenna - Evidence of Feasibility

Legend: 2460 MHz 3600 MHz 5350 MHz

180°





Overview

CPE

DR

Risk & M

V&V

Planning



Antenna Design Requirements

Solution

FR4: The system will transmit data on the S-Band frequency.

• DR 2.4.1 : Demonstrate uplink transmission at a frequency range between 2.4-2.48 GHz

FR5: The system will receive data on the S-Band frequency.

• DR 2.5.1: Demonstrate downlink reception at a frequency range between 2.4-2.48 GHz



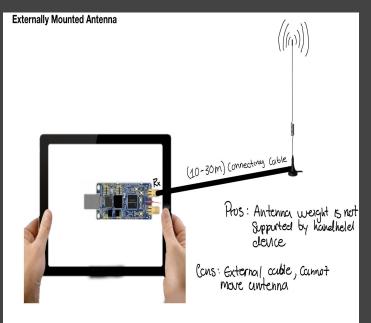
Baseline Design

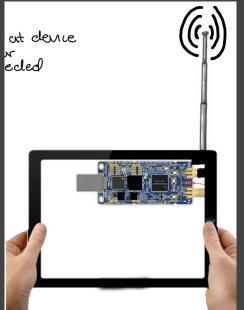
Feasibility

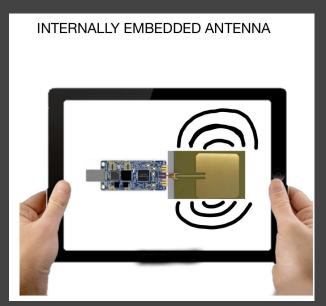




Antenna









VSWR Equations



$$VSWR = \frac{1 + |\Gamma|}{1 - |\Gamma|} = \frac{V_{\text{max}}}{V_{\text{min}}}$$



= Absolute Reflection Coefficient





Antenna Tradestudy BU-Slides (Table 1)

Table1.Antenna Options with performance characteristics				
Antenna Model	Antenna Type	Antenna Design Configuration	Gain (dBi)	Bandwidth(GHz)
TE Connectivity Antenna	Omnidirecti onal- DualBand	Embedded	2	2.4-3.8 GHz, 5.150-5.870 GHz
Laird-MAF94051	External Dual-Band Omnidirecti onal	Attached	2	2.4-2.5
Laird OC24006H	Omnidirecti onal/ horizontally polarized	External	6	2.4-2.5
Argain-N2420M	Single Band embedded	Embedded	2.81	2.4-2.49





Antenna Tradestudy BU-Slides (Table 2)

T		2502000000		•	
Table?	.Antenna	and	other	charac	teristics
Idulez	.Antenna	anu	OHIGH	Charac	เษาเอแบอ

Tablez. Afterna and other characteristics				
Antenna Model	Weight (grams)	Unit-Cost (USD Currency)	Connector Type	Effective Area (Ae) or Effective Antenna Aperture (m^2)
TE Connectivity	3.3	4.79	Cable-Side Entry	0.001828
Laird-MAF94051	113.4	7.64	RP SMA Connector with 90 degree elbow	0.001814
Laird OC24006H	260	50.20	N-Female	0.004556
Argain-N2420M	0.5	1.80	IPEX/MHF/U FL	0.002186



Antenna Tradestudy BU (Effective Area Equations)

$$A_e = \frac{\lambda^2}{4\pi}G = \frac{c^2}{f^2} \times \frac{G}{4\pi}$$

Eq#1 is assuming Linear Gain and Eq#2 Assuming dB Gain

$$A_e = \frac{c^2}{f^2} \times \frac{10^{\frac{G(dB)}{10}}}{4\pi}$$





Table3. Point Matrix Cr	iteria	1
-------------------------	--------	---

Metric	High Score (3)	Medium Score(2)	Low Score(1)
Cost Effectiveness	low cost for a high performance and capabilities (price<5)	The antenna has an average cost for its capabilities(5-30)	The antenna has a high cost for its capabilities (Over 30)
Weight	The antenna is very light (Under 50 grams)	The antenna has a medium weight (from 50-200grams)	The antennas has a high weight value (over 200 grams)
Compatibility	The antenna can easily connect to the SDR, The user has no issues when using the antenna	The antenna is compatible with the sdr without any extra hardware but needs intervention for it to start working	The antenna is not compatible with the sdr without any extra hardware and needs intervention for it to start functioning
Performance/Specs	Omnidirectional, Operates in designated frequency, high bandwidth, good materials, Large Effective Area,etc.	The antenna has all the required specs but does not have good materials or other hardware constraints	The antenna doesn't satisfy all the needed requirements





Antenna TradeStudy BU-Slides (Table 4)

Metric	Weighting	Antenna #1 TE	Antenna #2 Laird-1	Antenna #3 Laird-2	Antenna #4 Argain
Cost	0.15	3	2	1	3
Weight	0.30	3	2	1	3
Compatibility	0.15	3	3	2	3
Performance/Specs	0.40	3	3	3	2
Total Score	100%	100%	80%	65%	90%





Power Budget

Component	Max Operating Power (Transmit)	Max Operating Power (Receive)
LimeSDR	4.5W (More like 2mW)	NA
Antenna	NA	3.0W
Raspberry Pi	NA	3.5W
Total	4.5W	6.5W
	or approx 2mW	

Battery Pack: Miady

5V 2A spread evenly from two outputs



Power Pack (Selected Battery)



Miady 10000mAh Dual USB Portable Charger







Scaling and Power

Scaling

- In the real-life application of this project we will use 2.4km side-lengths for the pseudolite geometry
 - Calculated using the horizon of the Moon.
 - Would also need to take into account any terrain on the Moon.
- Scaled down geometry was created for practical reasons.

Power

- Current testing power is 2 mW which is more than enough (even for a pseudolite configuration with 2.4km side-lengths)
- As part of our testing we will vary transmit power and plot ranging accuracy vs.
 SNR in order to determine the optimal transmit power.





CPE

Risk & M

V&V

Planning



Pseudolite Clocks

FR3: All clocks must be within 30 ns of each other for the duration of a test (2 hr)

DR

- On-board Clock (TCXO): Drifts on average
 0.05ns every second
- Pseudolite Clocks: GPS Disciplined
 - Using clock bias to keep pseudolite clock synced
 - Reduces jitter
 - Septentrio PolaRxS
- Expected Accuracy: 0.5 ns





Navigation



Solution

CPE

Risk & M

V&V

Planning



Positioning System Requirements

FR3: The system will be able to provide an architecture for a navigation solution with a 10 meter position accuracy and a 30 nanosecond 1-σ transfer time

DR

• **DR 2.3.2**: Provide LPS coverage to the Moon's South Pole

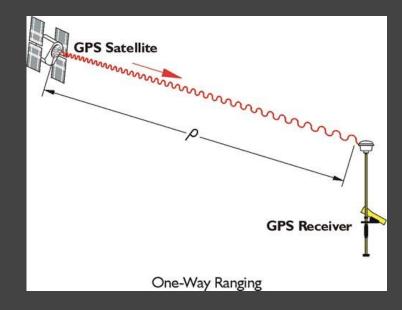
Solution: Pseudolite geometry composed of a 0.18km equilateral triangle + GPS-disciplined clocks





One way ranging

- Requires accurate clocks on both ends to determine the distance based on time differences.
- Lots of research/documentation available supporting the algorithms and systems.
- Only satellite transmits.
- The energy and time required is low due to only one transmission of data.

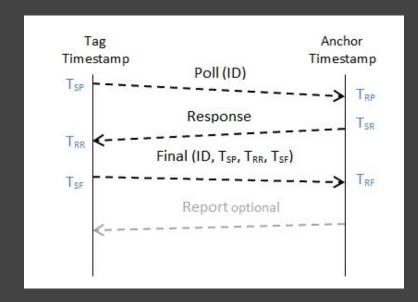






Two way ranging

- Requires clocks on both ends but does need them to be synced up with each other.
- Receiver must transmit data BACK to the transmitter multiple times.
- Both the satellite and the receiver know the location of the satellite.
- The energy and processing requirements are high due to the fast data transmission requirements.







One way vs Two way ranging

	One way	Two way
Power required	Low	High
Position information	Only receiver	Both receive info
Clock synchronization	Required	Not required





Positioning Algorithm: Least-Squares Solution

- Reason for using least-squares method
- Position Guess and corrections

$$G = A = \begin{bmatrix} -\frac{x^{(1)} - x_0}{R_0^{(1)}} & -\frac{y^{(1)} - y_0}{R_0^{(1)}} & -\frac{z^{(1)} - z_0}{R_0^{(1)}} & 1 \\ -\frac{x^{(2)} - x_0}{R_0^{(2)}} & -\frac{y^{(2)} - y_0}{R_0^{(2)}} & -\frac{z^{(2)} - z_0}{R_0^{(2)}} & 1 \\ -\frac{x^{(3)} - x_0}{R_0^{(3)}} & -\frac{y^{(3)} - y_0}{R_0^{(3)}} & -\frac{z^{(3)} - z_0}{R_0^{(3)}} & 1 \\ \vdots & \vdots & \vdots & \vdots \\ -\frac{x^{(m)} - x_0}{R_0^{(m)}} & -\frac{y^{(m)} - y_0}{R_0^{(m)}} & -\frac{z^{(m)} - z_0}{R_0^{(m)}} & 1 \end{bmatrix}$$

$$\delta \rho = G \begin{bmatrix} \delta \mathbf{x} \\ \delta b \end{bmatrix}$$

$$\begin{bmatrix} \delta \hat{\mathbf{x}} \\ \delta \hat{b} \end{bmatrix} = (\mathbf{G}^T \mathbf{G})^{-1} \mathbf{G}^T \delta \mathbf{\rho}$$



Solution

CPE

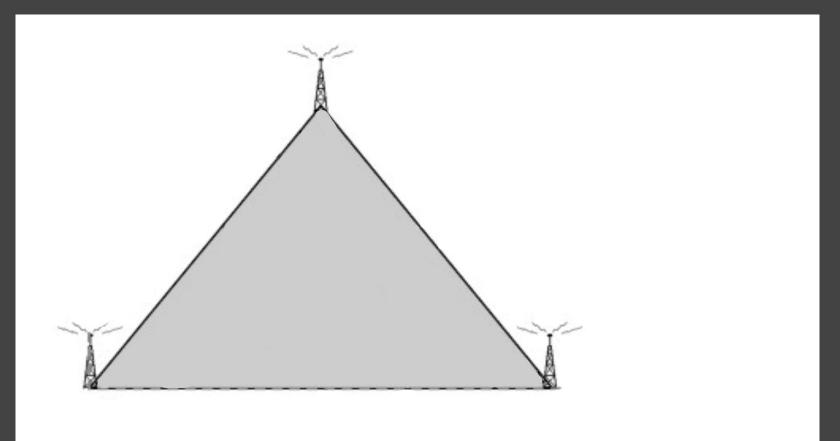
DR

Risk & M

V&V

Planning







Solution

CPE

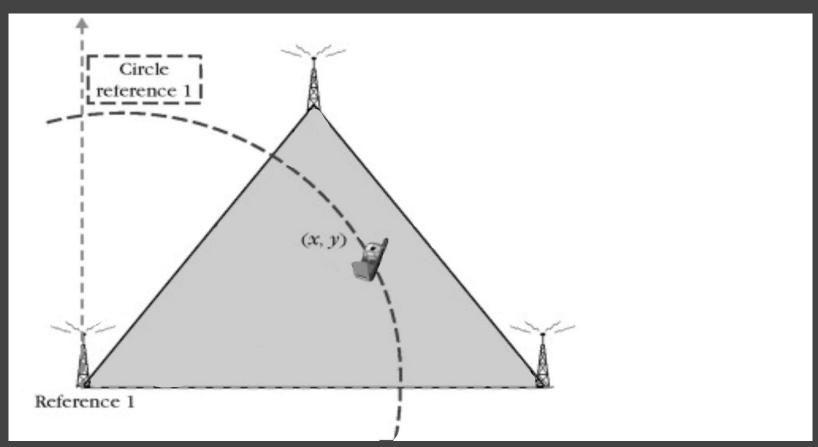
DR

Risk & M

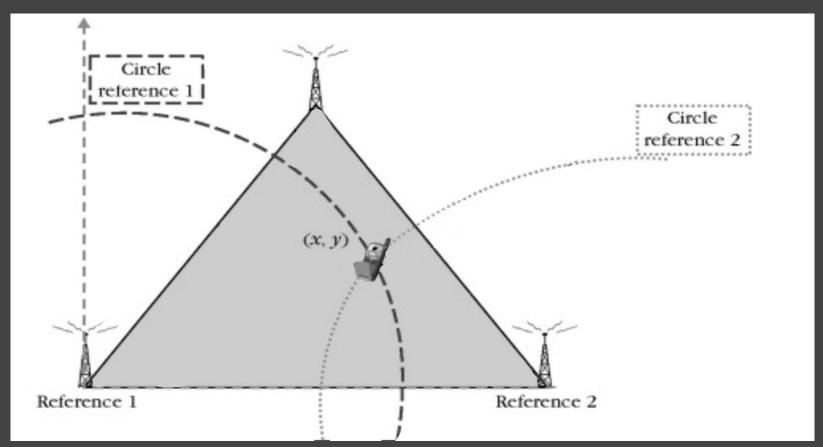
V&V

Planning











Solution

CPE

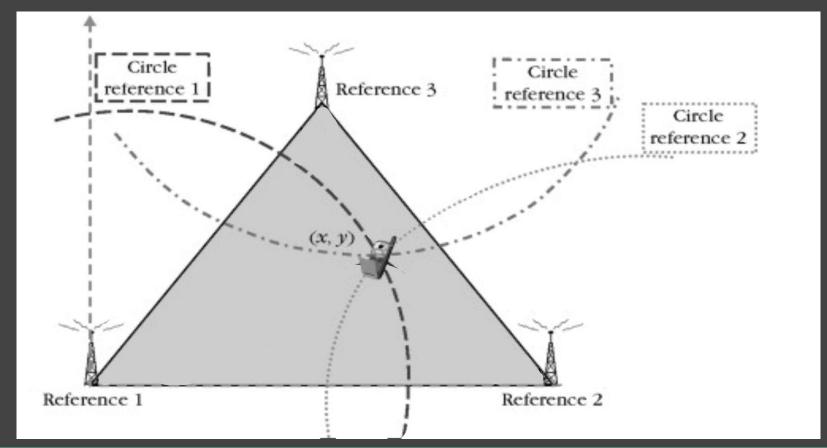
DR

Risk & M

V&V

Planning



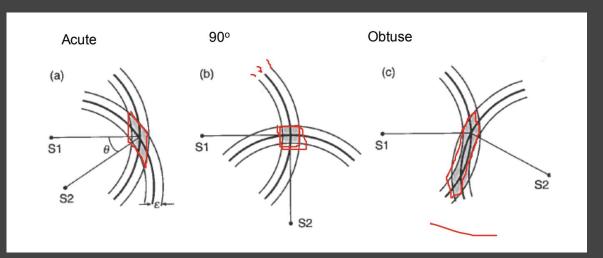




Positioning System - HDOP

Horizontal Dilution Of Precision

Definition: "Used to specify error propagation as a mathematical effect of navigation pseudolite geometry on positional measurement precision".



RMS horizontal error =
$$\sqrt{\sigma_E^2 + \sigma_N^2} = \sigma$$
 HDOP

RMS vertical error =
$$\sigma_U = \sigma$$
 VDOP

RMS 3-D error =
$$\sqrt{\sigma_E^2 + \sigma_N^2 + \sigma_U^2} = \sqrt{\sigma_x^2 + \sigma_y^2 + \sigma_z^2} = \sigma$$
 PDOP (6



Positioning System - HDOP

The DOPs provide a simple characterization of the user-satellite geometry. The more favorable the geometry, the lower the DOP. The lower the DOP and σ , the better the quality of the position estimate, in general. If a receiver is limited in the number of satellites it can track simultaneously, the user pays a price with larger rms position error due to higher DOP values.

RMS horizontal error =
$$\sqrt{\sigma_E^2 + \sigma_N^2} = \sigma$$
 HDOP (6.27a)

RMS vertical error =
$$\sigma_U = \sigma \cdot \text{VDOP}$$
 (6.27b)

RMS 3-D error =
$$\sqrt{\sigma_E^2 + \sigma_N^2 + \sigma_U^2} = \sqrt{\sigma_x^2 + \sigma_y^2 + \sigma_z^2} = \sigma$$
 PDOP (6.27c)





CPE

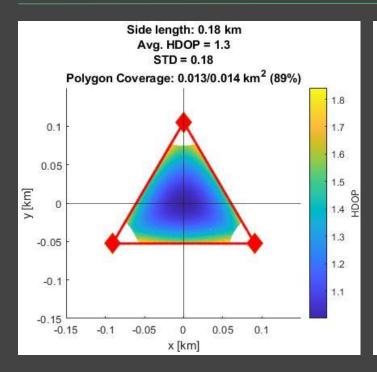
DR

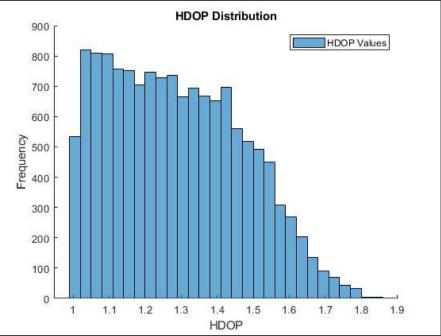
Risk & M

V&V



Pseudolite Geometry









CPE

DR

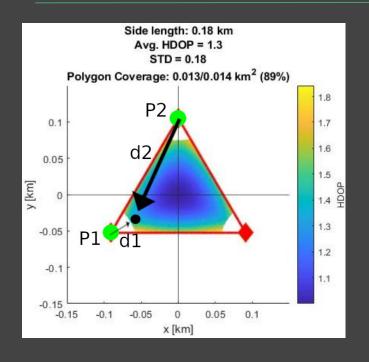
Risk & M

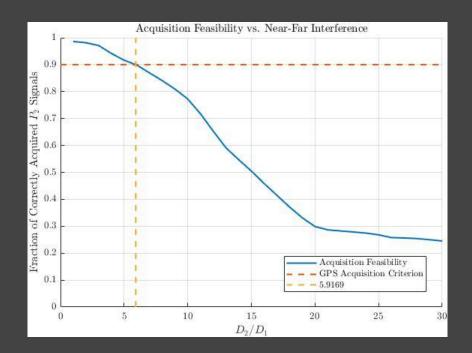
V&V

Planning



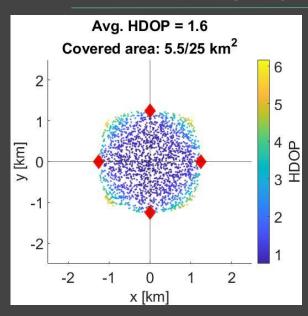
Near-Far Problem

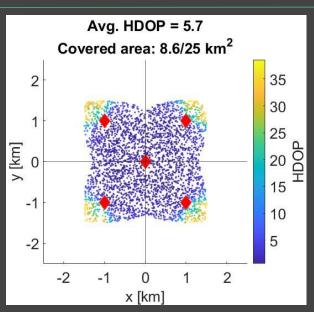


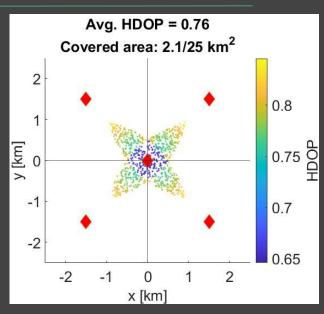




Positioning System - Evidence of Feasibility



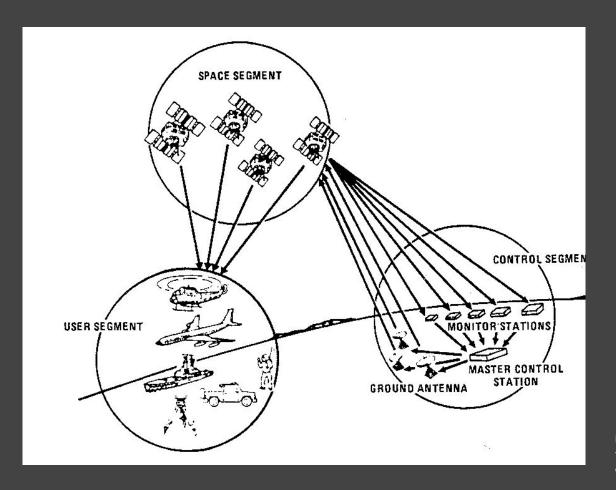




DR 2.3.3





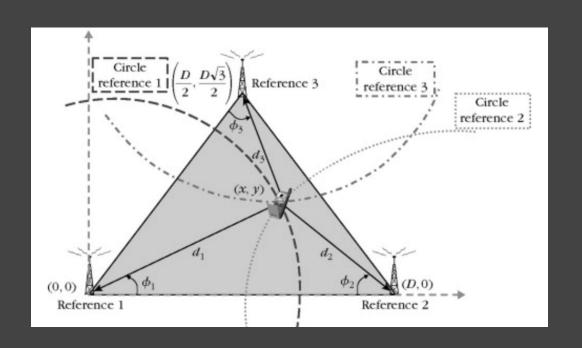


http://allaboutgps101.blogspo t.com/2010/12/what-are-3-se gments-of-gps-systems.html





Time of Arrival (TOA)



$$d_1 = c(t_1 - t_0) = \sqrt{x^2 + y^2}$$

$$d_2 = c(t_2 - t_0) = \sqrt{(D - x)^2 + y^2}$$

$$d_3 = c(t_3 - t_0) = \frac{1}{2}\sqrt{(D - 2x)^2 + (D\sqrt{3} - 2y)^2}$$

t_i: TOA at reference i; c: speed of light





Time of Arrival (TOA)

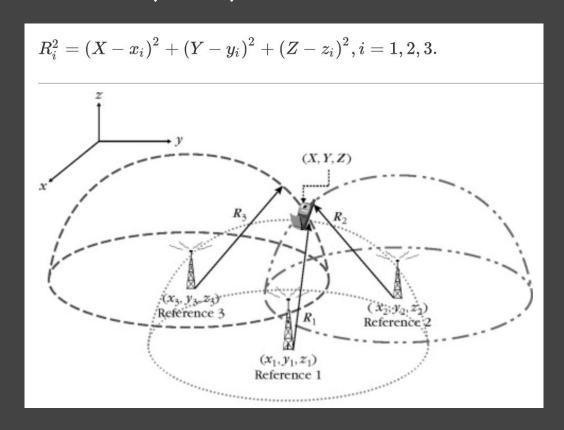
$$d_i = c(t_i - t_0),$$

$$egin{align} d_1^2 &= x^2 + y^2, \ d_2^2 &= (x_2 - x)^2 + (y_2 - y)^2 = (D - x)^2 + y^2, \ d_3^2 &= (x_3 - x)^2 + (y_3 - y)^2 = rac{1}{2}(D - 2x)^2 + (D\sqrt{3} - 2y)^2. \ \end{pmatrix}$$



F

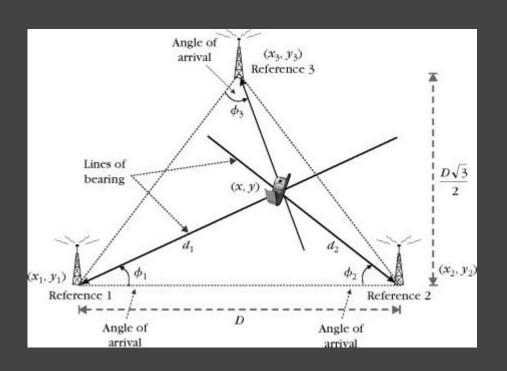
Time of Arrival (TOA)







Angle of Arrival (AOA)

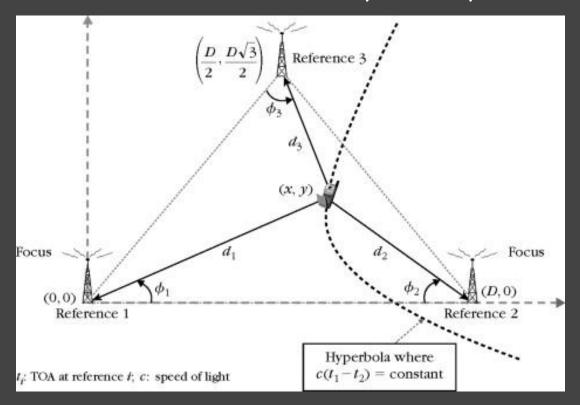


$$egin{aligned} x &= d_i \cos(\phi_i) + x_i, \ y &= d_i \sin(\phi_i) + y_i, i = 1, 2, 3. \end{aligned}$$





Time Difference of Arrival (TDOA)







Time Difference of Arrival (TDOA)

$$d_{ij} = d_i - d_j = c(t_i - t_o) - c(t_j - t_o) = c(t_i - t_j), i = 1, 2, 3, j = 1, 2, 3, i \neq j.$$

$$d_i = d_{ij} + d_j;$$

$$egin{aligned} d_2^2 &= (d_{21}+d_1)^2 \ &= (x_2-x)^2 + (y_2-y)^2 \ &= x_2^2 - 2x_2x + x^2 + y_2^2 - 2y_2y + y^2 \ &= x_2^2 - 2x_2x + y_2^2 - 2y_2y + d_1^2, \end{aligned}$$

$$d_1^2 = x^2 + y^2$$
.

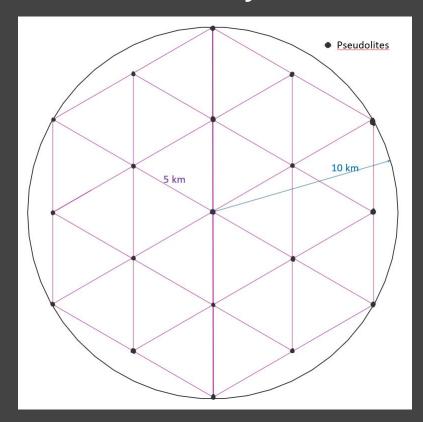
$$(d_{21}^2-x_2^2-y_2^2)+2d_{21}d_1=-2x_2x-2y_2y, \ \,$$

$$(d_{31}^2-x_3^2-y_3^2)+2d_{31}d_1=-2x_3x-2y_3y.$$





Lunar Pseudolite Geometry







Positioning Solution

Tentative Trade/Analysis Aspects

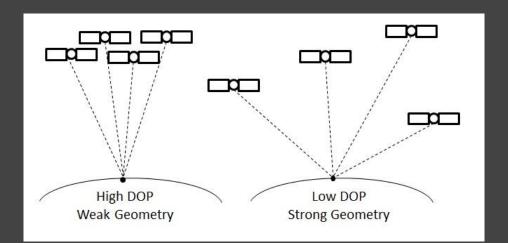
- Will we need accurate clocks
- How complicated the positioning algorithm will be / is it feasible for us to implement
- Antenna requirements
- Near Far problem





GNSS: Error sources

- Error sources can be divided into two categories:
 - Ranging error: signal quality, errors in transmitter location, environmental effects, receiver design, etc....
 - Geometry: Geometric Dilution of Precision (GDOP). Measures the quality of the geometric distribution of the satellites visible to the receiver.



https://www.polyu.edu.hk/proj/gef/inde x.php/glossary/dilution-of-precision/





GNSS: Architecture

- 3 segments:
 - Ground control segment
 - Provides satellites with ephemeris data and almanac
 - Provides clock-correction factors and data on atmospheric effects
 - Keeps satellites "in check"
 - Space segment
 - Satellites which send out coded ranging signals, ephemerides, correction parameters and almanac.
 - User segment
 - Receiver (which in the case of this project, can also transmit SMS messages)
 - Acquires and track satellite signals.
 - Computes position solution.
 - For this project, THIS is the segment we'll be working with. All other segments will be assumed as working.



Comms





Communications - Requirements

FR 2: The prototype will provide two-way SMS-like messaging

- **DR 2.1:** Device must have wireless transmission and reception of data
- **DR 2.2:** Communication data rate must be at least 200 bits/s

FR 3: The prototype will provide path to navigation solution with 10 meter positioning accuracy and 30 nanosecond 1-sigma transfer time

- **DR 3.1**: Receiver Signal to Noise Ratio must be at least 20 dB
- FR 4/5: The communication link must operate at 2.4-2.48 GHz
- FR 6: The architecture must be extendable to 170 simultaneous users
- FR 7: The communication link must have 3 dB channel bandwidth of 1 MHz



Solution

CPE

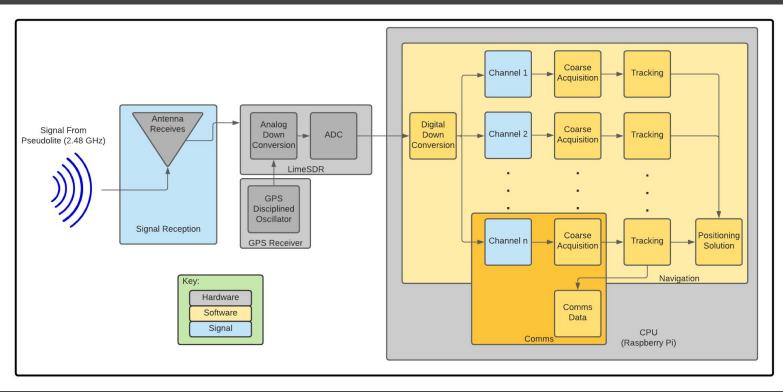
DR

Risk & M > V&V

Planning

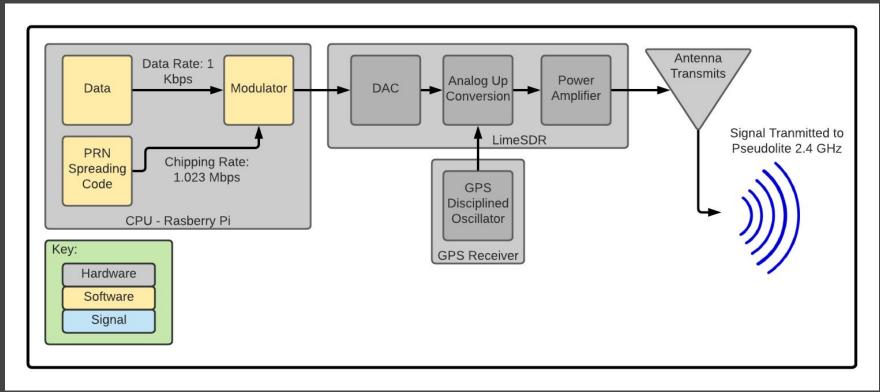


Receive FBD





Transmit FBD





Solution

CPE

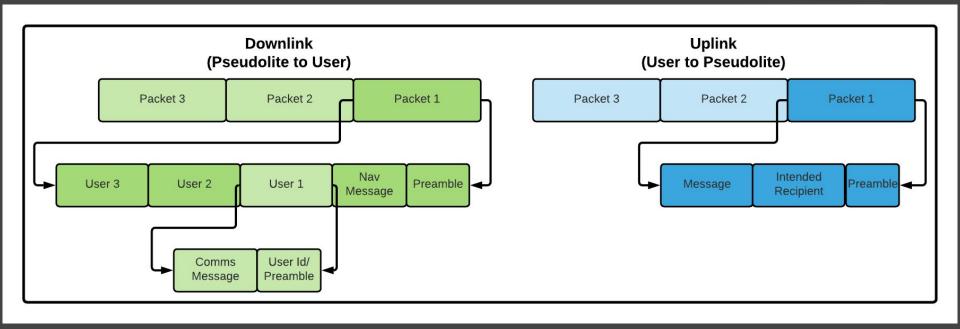
Risk & M

V&V

Planning



Signal FBD



DR





CPE

DR

Risk & M

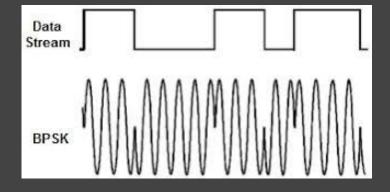
V&V

Planning



Link Design: Modulation

- Design Choice: Binary Phase Shift Keying (BPSK)
- Reasoning:
 - Low bit error rate (BER)
 - Low complexity
 - Able to use carrier phase to get even more precise signal time of arrival
 - Currently used in GPS implementations







CPE

DR

Risk & M

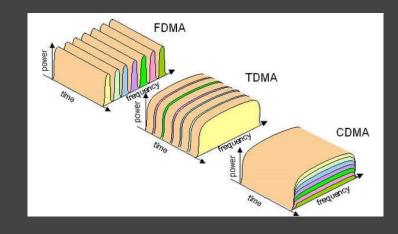
V&V

Planning



Link Design: Multiplexing

- Design: Code Division Multiple Access
- Reasoning:
 - Able to use phase of spreading code to calculate time of arrival (TOA)
 - Single Frequency
 - Asynchronous CDMA
 - Low cross-interference
- Specification (Design Solution):
 - 1023 bit Gold Code PRN chipping code
 - 1.023 MHz chipping rate
 - 1 ms code period (same as data rate)





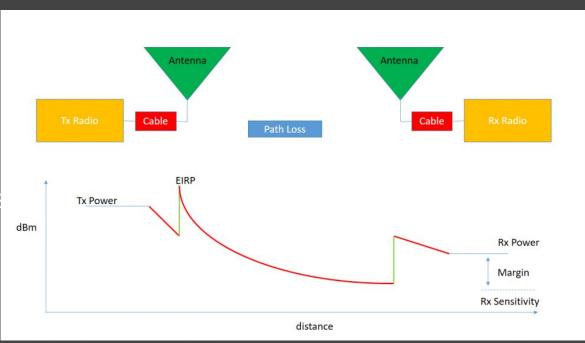


Communications - Link Budget

Link Budget (Single User):

- Data Rate: 1 kbps
- Frequency: 2.4 GHz
- Modulation: BPSK
- Distance: 10 km
- Transmit Power: 2 mW
- Minimum Receive SNR: -12 dE
 - o BER: 10⁻⁸, Eb/N0: 12 dB
- Link Margin: 9 dB

DR 2.1, 2.2, FR4, FR 5



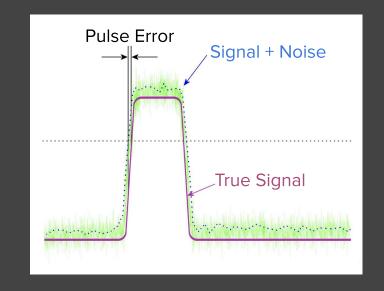


Minimum Ranging SNR

- FR 3: System will provide path to a position to 10 m accuracy (30 ns transfer time)
 - DR 3.1: Received SNR (Signal-to-Noise Ratio) must be at least 20
 dB from following formula

$$\delta R = \frac{c_0}{2B\sqrt{2SNR}}$$

- FR 7: Link must operate at 1 MHz bandwidth
- Link Budget operates on a 48 dB-Hz minimum C/N₀



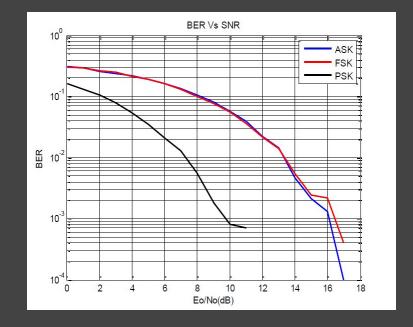
DR 3.1, FR7



Modulation: Phase Shift Keying

- Modulation Scheme must be compatible with SDR
 - Compatible with LimeSDR
 - Compatible with GNU Radio
- Low Bit Error Rate
- Single Frequency
- Use carrier phase for additional position accuracy
- GPS uses Phase Shift Keying

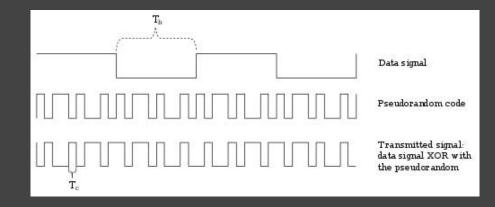
DR 2.1, 2.2, 3.1, FR4, 5, 7 SDR Compatibility





Multiplexing: CDMA

- CDMA used in GPS
- CDMA code rate relates to first level of position accuracy
- CDMA can operate on single frequency
- Receiver can receive multiple signals simultaneously
- CDMA with 1023 bit chip code:
 - One way ranging: more end users overall,
 more precise timing requirements
 - Two way ranging: each user contributes to multiple access interference



One Way Ranging: FR 6

MORE ANALYSIS

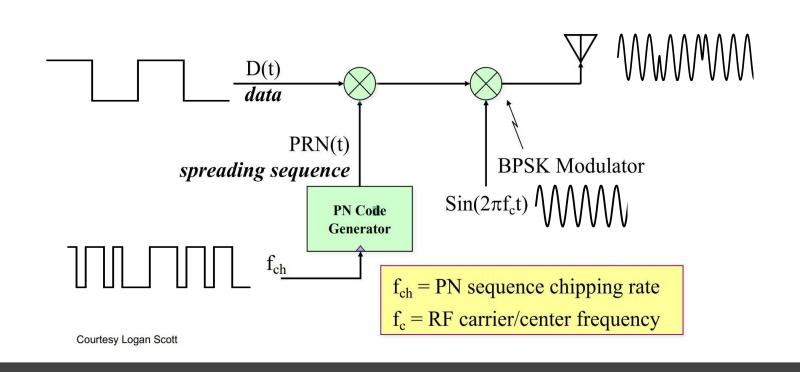
Two Way Ranging: FR 6

MORE ANALYSIS

DR 2.1, 3.1, FR 4, 5, 7

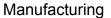


Signal Generation













Downlink Packet Breakdown

- Preamble
 - Unique 24 bit code sequence to allow for signal correlation
- Navigation Message
 - Element of set bit length providing timing for positioning algorithm
- User ID
 - 8 bit element containing a unique user identification sequence for each user to identify intended recipient
 - Designed to accommodate 30 user requirement
- Communications Message
 - 5000 bit text communication element broken into 8 bit characters
 - Message will be appended with ' (space) buffers to maintain constant size





Manufacturing

Budget



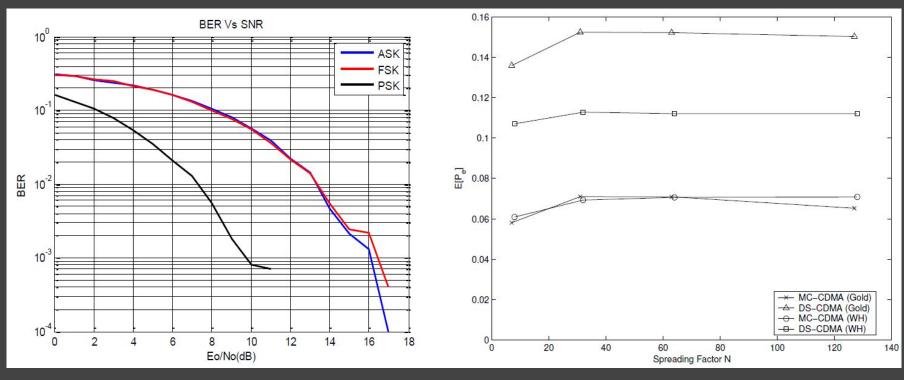
Uplink Breakdown

- Preamble
 - Unique 24 bit code sequence to allow for signal correlation
- User Identification
 - 8 bit element containing a unique user identification sequence for each user to identify transmitting user
 - Designed to accommodate 30 user requirement
- Communications Message
 - o 5000 bit text communication element broken into 8 bit characters
 - Message will be appended with ' '(space) buffers to maintain constant size





Bit Error Rates of Modulation Schemes







Pseudolite Link Budget 1

	UPLINK	DOWNLINK			
	(Receiver to	(Satellite to			
PARAMETER	Satellite)	Receiver)	UNITS	Symbol	Reference
Speed of Light	3.0E+08	3.0E+08	m/s	C= λ*f	constant
Frequency	2.4	2.4	GHz	f	Input: system choice, X-band mil.com.sat.
Wavelength	0.125	0.125	m	1	
Range	10	10	km	R	Input: Geostationary Satellite [km]
Boltzman's Constant	1.380E-23	1.380E-23		k	constant
Donzinano constant	7.0002 20	7.0002 20	117(112 119		CONTOLUNA
Data Parameters	Uplink	Downlink	Units	Symbol	Reference
Bit Error Rate / Probablility of Bit Error	10-8	10-8	[-]	BER	Input: design requirement
Data Coding Scheme	QPSK	QPSK	1.1	DEN	Input: chosen modulation (SMAD Tab.13-10)
Required Bit Energy to Noise Ratio	12	12.0	dB	Eb/No	Lecture Pt. 2. Slide 15
Data Rate	1000	1.000	bps (Hz)	R	Input: based on mission / objective
Carrier to Noise Ratio Density	42.00	42.00	dB-Hz	Pr/No	Lecture Pt. 2. Slide 15
Required Design Margin	6.00	6.00	dD-112	1 1/140	Input design rule (Hoffmann chap. 9.4.4)
Minimum Pr/No	48.00	48.00	dB-Hz		Input designifule (Florithanii Chap. 3.4.4)
William Fi/NO	40.00	40.00	UD-11Z		
Noise (applies to receiving elements)	Uplink	Downlink	Units	Symbol	Reference
Receiving Antenna Noise Temperature	400	400	K	Ta	Lecture Pt. 2, Slide 13
Receiver Cable Loss	0.9	0.9	dB	Lc	SMAD Table 13-10
Receiver Noise Figure (based on receiver)	3.0	3.0	dB	NF	SMAD Table 13-10
Receiver Noise Factor	2.0	2.0	[-]	F	Lecture Pt. 2. Slide 10
Receiver Noise Temperature	288.6	288.6	K	Tr	Lecture Pt. 2, Slide 10
Reference Temperature	290	290	K	To	SMAD Egn13-24
Receiver System Noise Temperature	580.32	580.32	K	Ts	Lecture Pt 2. Slide 13
Receiver System Noise Power	-200.96	-200.96	dBW-Hz	No	Lecture Pt 2, Slide 9
Receiver System Noise Fower	-200.30	-200.30	UDVV-112	INU	Lecture Ft Z, Sinde 9
Receiver Parameters:	Uplink	Downlink	Units	Symbol	Reference
Receive Antenna Diameter		NA	m	D	Input: given geometry from spacecraft
Receive Antenna Area		NA	m^2	A	Geometry
Receive Antenna Efficiency		NA	[-]	h	Input typical value
Receive Antenna Effective Area		NA	m^2	Ae	efficiency * area
Receive Antenna Gain	2 00		ower Ratio	Gr	Lecture Pt 1, Slide 14
Receive Antenna Gain	180.0	180.0	Degrees		Lecture Pt 1, Slide 14
	0.0	180.0		qr	
Receive Antenna Pointing Accuracy	0.00	0.00	degrees dB	er	Input: pointing error e for chosen system
Receive Antenna Pointing Loss	-0.5	-0.5	dB dB	Lpr	SMAD 13-21
Receiver Cable Loss (see noise)		500		Lc	Input: typical value
Receiver Figure of Merit	0.00	0.00	dB/K	FOM	
Propagation Parameters:	Unlink	Downlink	Units	Cum hai	Deference
Space Loss	Uplink -120.05	-120.05	dB	Symbol Ls	Reference Lecture Pt 2, Slide 3
Atmospheric Attenuation (clear air)	0	0	dB	La	Lecture Pt 2, Slide 7
Polarization Loss	0	0	dB	Lp	Input: typical value



Satellite Link Budget 1



	UPLINK	DOWNLINK			
	(Receiver to	(Satellite to			
PARAMETER	Satellite)	Receiver)	UNITS	Symbol	Reference
Speed of Light	3.0E+08	3.0E+08	m/s	C= 2*f	constant
Frequency	2.5	2.5	GHz	f	Input: system choice, X-band mil.com.sat.
Wavelength	0.120	0.120	m	ì	
Range	10000	10000	km	R	Input: Geostationary Satellite [km]
Boltzman's Constant	1.380E-23	1.380E-23	W/(Hz-K)	k	constant
Data Parameters	Uplink	Downlink	Units	Symbol	Reference
Bit Error Rate / Probablility of Bit Error	10-6	10-6	[-]	BER	Input: design requirement
Data Coding Scheme	QPSK	QPSK	3000		Input: chosen modulation (SMAD Tab.13-10)
Required Bit Energy to Noise Ratio	11	12.0	dB	Eb/No	Lecture Pt. 2, Slide 15
Data Rate	1000	1,000	bps (Hz)	R	Input: based on mission / objective
Carrier to Noise Ratio Density	41.00	42.00	dB-Hz	Pr/No	Lecture Pt. 2, Slide 15
Required Design Margin	3.00	6.00	dB		Input: design rule (Hoffmann chap. 9.4.4)
Minimum Pr/No	44.00	48.00	dB-Hz		
					N. 49244
Noise (applies to receiving elements)	Uplink	Downlink	Units	Symbol	Reference
Receiving Antenna Noise Temperature	400	25	K	Та	Lecture Pt. 2, Slide 13
Receiver Cable Loss	0.9	0.9	dB	Lc	SMAD Table 13-10
Receiver Noise Figure (based on receiver)	3.0	1.0	dB	NF	SMAD Table 13-10
Receiver Noise Factor	2.0	1.3	[-]	F	Lecture Pt. 2, Slide 10
Receiver Noise Temperature	288.6	75.1	K	Tr	Lecture Pt. 2, Slide 10
Reference Temperature	290	290	K	То	SMAD Eqn13-24
Receiver System Noise Temperature	580.32	31.75	K	Ts	Lecture Pt 2, Slide 13
Receiver System Noise Power	-200.96	-213.58	dBW-Hz	No	Lecture Pt 2, Slide 9
D 1 D 1					
Receiver Parameters: Receive Antenna Diameter	Uplink NA	Downlink NA	Units	Symbol D	Reference
		NA NA	<i>m</i> m^2	A	Input: given geometry from spacecraft Geometry
		NA	[-]	h	Input: typical value
	NA NA	0.002			
Receive Antenna Effective Area Receive Antenna Gain	NA 20.00		m^2 ower Ratio	Ae	efficiency * area
	200000			Gr	Lecture Pt 1, Slide 14
Receive Antenna Beamwidth Receive Antenna Pointing Accuracy	20.0 0.2	180.0 0	Degrees	qr	Lecture Pt 1, Slide 16
Receive Antenna Pointing Accuracy Receive Antenna Pointing Loss	0.2	0.00	degrees dB	er	Input: pointing error e for chosen system SMAD 13-21
Receiver Cable Loss (see noise)	-0.5	-0.5	dB dB	Lpr Lc	
Receiver Cable Loss (see noise) Receiver Figure of Merit	0.03	0.08	dB/K	FOM	Input: typical value
receiver rigure or werit	0.03	0.00	UD/K	1 OW	
Propagation Parameters:	Uplink	Downlink	Units	Symbol	Reference
Space Loss	-180.37	-180.37	dB	Ls	Lecture Pt 2, Slide 3
Atmospheric Attenuation (clear air)	0	0	dB	La	Lecture Pt 2, Slide 7
Polarization Loss	0	0	dB	Lp	Input: typical value
11075.53	×.				





Pseudolite Link Budget 2

Transmitter Parameters:	Uplink	Downlink	Units	Symbol	Reference
Transmit Antenna Diameter	NA	NA	m	D	Switch Receive
Transmit Antenna Area	NA	NA	m^2	Α	Switch Receive
Transmit Antenna Efficiency	NA	NA	[-]	h	Switch Receive
Transmit Antenna Effective Area	NA	NA	m2	Ae	Switch Receive
Transmit Antenna Gain	2.00	2.00	dBi	Gt	Switch Receive
Transmit Antenna Beamwidth	180.00	180.00	degrees	qt	Switch Receive
Transmit Antenna Pointing Accuracy	0.00	0.15	degrees	et	Switch Receive
Transmit Antenna Pointing Loss	0.00	0.00	dB	Lpt	Switch Receive
Transmit Line Loss	-0.5	-0.5	dB	Lt	Input: based on chosen cable/geometry
Transmit Power	-27.0	-27.0	dBW	Pt	10*LOG10(Transmit power)
Tramsmit Power, Linear	0.002	0.002	W		Input: chosen transmitter
Effective Isotropic Radiated Power	-25.49	-25.49	dBW	EIRP	Sum of Power, Gain, and Losses in dB
Link Budget:	Uplink	Downlink	Units	Symbol	Reference
Effective Isotropic Radiated Power	-25.49	-25.49	dBW	EIRP	From Above
Propagation Losses	-120.05	-120.05	dB	L	Sum of Losses
Receive System Gain	1.50	1.50	dB	Gr	Sum of antenna gain and system losses
Received Power	-144.04	-144.04	dBW	Pr	Sum of Power sent out minus losses
System Noise Power	-200.96	-200.96	dBW-Hz	No	
Carrier to Noise Ratio Density	56.93	56.93	dB-Hz	Pr/No	
Minimum Pr/No	48.00	48.00	dB-Hz		
Link Margin	8.93	8.93	dB		





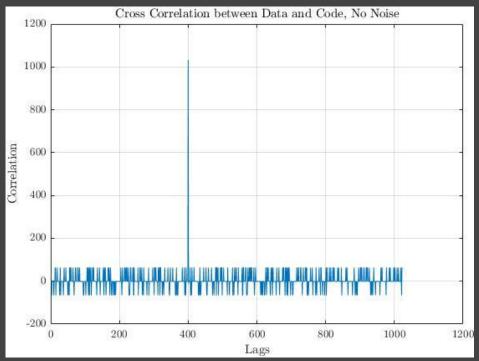
Satellite Link Budget 2

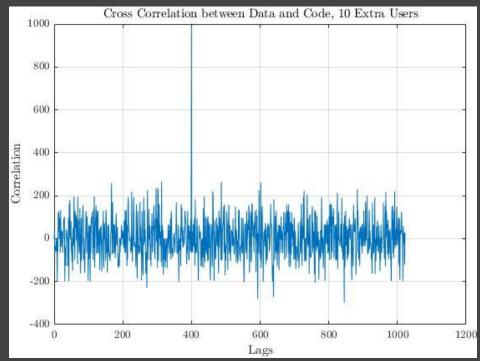
Transmitter Parameters:	Uplink	Downlink	Units	Symbol	Reference
Transmit Antenna Diameter	NA	NA	m	D	Switch Receive
Transmit Antenna Area	NA	NA	m^2	Α	Switch Receive
Transmit Antenna Efficiency	NA	NA	[-]	h	Switch Receive
Transmit Antenna Effective Area	0.002	NA	m2	Ae	Switch Receive
Transmit Antenna Gain	2.38	20.00	dBi	Gt	Switch Receive
Transmit Antenna Beamwidth	180.00	20.00	degrees	qt	Switch Receive
Transmit Antenna Pointing Accuracy	0.00	0.15	degrees	et	Switch Receive
Transmit Antenna Pointing Loss	0.00	0.00	dB	Lpt	Switch Receive
Transmit Line Loss	-0.5	-0.5	dB	Lt	Input: based on chosen cable/geometry
Transmit Power	3.0	14.1	dBW	Pt	10*LOG10(Transmit power)
Tramsmit Power, Linear	2	25.6	W		Input: chosen transmitter
Effective Isotropic Radiated Power	4.89	33.58	dBW	EIRP	Sum of Power, Gain, and Losses in dB
Link Budget:	Uplink	Downlink	Units	Symbol	Reference
Effective Isotropic Radiated Power	4.89	33.58	dBW	EIRP	From Above
Propagation Losses	-180.37	-180.37	dB	L	Sum of Losses
Receive System Gain	19.50	1.88	dB	Gr	Sum of antenna gain and system losses
Received Power	-155.97	-144.90	dBW	Pr	Sum of Power sent out minus losses
System Noise Power	-200.96	-213.58	dBW-Hz	No	
Carrier to Noise Ratio Density	44.99	68.68	dB-Hz	Pr/No	
Minimum Pr/No	44.00	48.00	dB-Hz		
Link Margin	0.99	20.68	dB		



CDMA Signal Acquisition



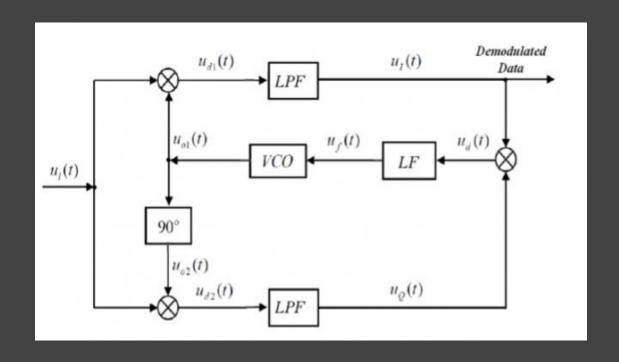








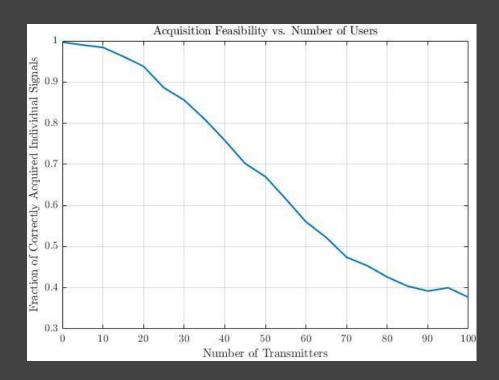
Simple Tracking Loop (Costas Loop)







Multiple Access Interference



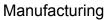


LimeSDR Hardware/Software Validation







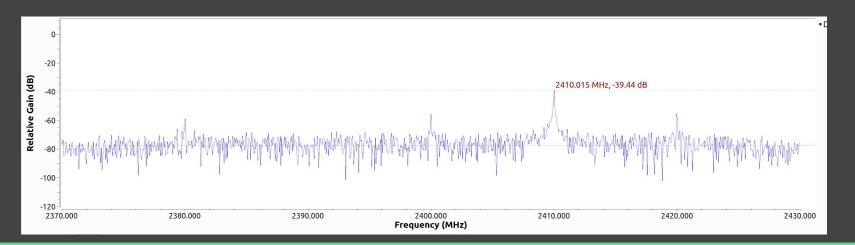






Signal Interference (Simple Tranceiver)

- Preliminary interference and verification test resulted in positive results.
- Single tone SNR:
 - At 1 foot separation 40dB
 - At 590 feet (180 Meters) -15dB (Extrapolation)













Downlink Packet Breakdown

- Preamble
 - Unique 24 bit code sequence to allow for signal correlation
- Navigation Message
 - Element of set bit length providing timing for positioning algorithm
- User ID
 - 8 bit element containing a unique user identification sequence for each user to identify intended recipient
 - Designed to accommodate 30 user requirement
- Communications Message
 - 5000 bit text communication element broken into 8 bit characters
 - Message will be appended with ' (space) buffers to maintain constant size





Manufacturing





Uplink Breakdown

- Preamble
 - Unique 24 bit code sequence to allow for signal correlation
- User Identification
 - 8 bit element containing a unique user identification sequence for each user to identify transmitting user
 - Designed to accommodate 30 user requirement
- Communications Message
 - o 5000 bit text communication element broken into 8 bit characters
 - Message will be appended with ' '(space) buffers to maintain constant size



Gr-LimeSDR Installation Process

The goal is to create a universal installation script, which a person could run on a Linux terminal and have access to a LimeSDR Development Environment.

LimeSuiteGUI







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Gr-LimeSDR Installation Process

Integrating gr-limesdr plugin package.

DR

Example script:

- [3] Gr-limeSDR Plugin Installation: (Source Code Installation)
- [3.1] Installing Dependencies:
- -> sudo apt-get install libboost-all-dev swig

Just in case:

- -> sudo apt-get install gnuradio-dev
- [3.2] Building gr-limesdr from source: (Only for GNU Radio 3.8!)
- -> git clone https://github.com/myriadrf/gr-limesdr
- -> cd gr-limesdr
- -> git checkout gr-3.8
- -> mkdir build
- -> cd build
- -> cmake ..
- -> make
- -> sudo make install
- -> sudo Idconfig



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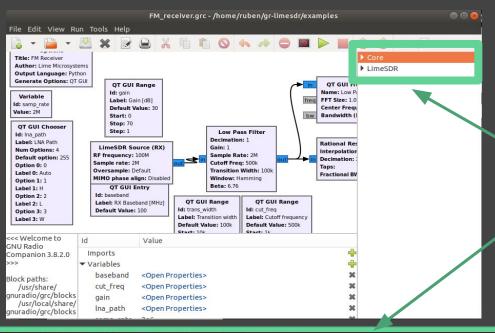
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Gr-LimeSDR Development Environment

DR



- We have a head start in the environment setup!
- We can also verify that the GNU Radio communicates with the Gr-LimeSDR plugin
- We can already verify the LimeSDR communicates with the given software via the LimeSuiteGUI



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Gr-LimeSDR Installation Process

The goal is to create a universal installation script, which a person could run on a Linux terminal and have access to a LimeSDR Development Environment.

Example script:

[1] - LimeSuiteGUI Installation: (PPA Installation)

- -> sudo add-apt-repository -y ppa:myriadrf/drivers
- -> sudo apt-get update
- -> sudo apt-get install limesuite liblimesuite-dev limesuite-udev limesuite-images
- -> sudo apt-get install soapysdr-tools soapysdr-module-lms7 To open the LimeSuiteGUI simply type the command:
- -> LimeSuiteGUI

To close, simply close the window.

If you have access to the LimeSDR, you can verify the GUI can talk to it by typing the command:

-> SoapySDRUtil --find="driver=lime"

[2] - GNU Radio Installation: (PPA Installation)

Note: The Release version must be 3.8.2.0

- -> sudo add-apt-repository ppa:gnuradio/gnuradio-releases
- -> sudo apt-get update
- -> sudo apt install gnuradio

To optimize GNU Radio kernel usage type:

-> volk_profile

To Open GNU Radio GUI:

-> gnuradio-companion

To close, simply close window.



Schedule

Manufacturing

Budget



Integration: LimeSDR + GNU Radio

- gr-limesdr plugin for GNURadio
 - Provides LimeSDR Transmit and Receive blocks
 - Can specify Rx/Tx channels for multiple antennas
- Automatically finds the LimeSDR
- Configurable via .ini file
- These blocks feed samples into the well documented GNURadio sample stream

LimeSDR Sink (TX)

RF frequency: 100M

Sample rate: 2M

Oversample: Default

LimeSDR Source (RX)

RF frequency: 100M

Sample rate: 2M

Oversample: Default

MIMO phase align: Disabled

out



Project Risks and Mitigation



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Risk Identification

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Risk ID	Description	Likelihood	Consequence
COM-3	Near-Far problem: Difficulty to hear weak-far signals from strong-close signal sources	4	5
ELE-1	Time synchronization between pseudolite and GPS receiver	3	5
SOF-1	Team inexperience handling new software. For example, GNU radio	3	4
COM-2	Signal Interference in testing environment	4	3
SOF-2	Lime-SDR, Raspberry Pi, and other hardware components not communicating correctly	2	5
COM-1	Multiple User Communicating	5	2
LOG-1	Hardware/Electronics don't arrive on time which sets back schedule of overall project	2	4



Overview

Solution

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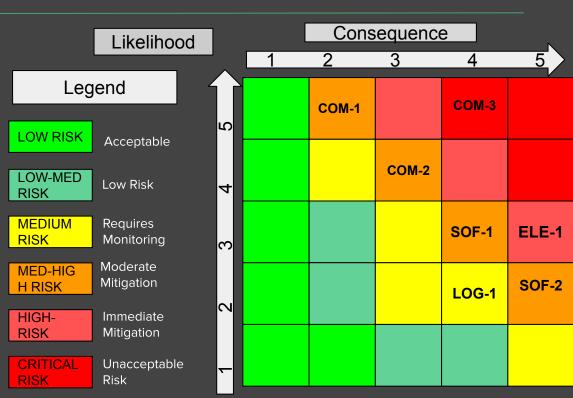
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Risk Matrix

Risk ID	Description
COM-3	Near-Far problem: Difficulty to hear weak-far signals from strong-close signal sources
ELE-1	Time synchronization between pseudolite and GPS receiver
SOF-1	Team inexperience handling new software. For example, GNU radio
COM-2	Signal Interference in testing environment
SOF-2	Lime-SDR, Raspberry Pi, and other hardware components not communicating correctly
COM-1	Multiple User Communicating
LOG-1	Hardware/Electronics don't arrive on time which sets back schedule of overall project





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Risk Mitigation Table

Risk ID	Description	Mitigation Approach	
COM-3	Near-Far problem: Difficulty to hear weak-far signals from strong-close signal sources	 Test within pseudolite geometry boundaries Automatic gain control 	
ELE-1	Time synchronization between pseudolite and GPS receiver	Conduct initial test to verify limeSDR clock override with Septentrio PolaRxS GPS reciever.	
SOF-1	Team inexperience handling new software. For example, GNU radio	 Fall semester early development Online tutorials, device users manual External Resources: Dr Akos, Dr Rainville, Steve Taylor, Sam Holt 	
COM-2	Signal Interference in testing environment	Change testing area to back up location (Platteville), change testing time to reduce interference (overnight)	
SOF-2	Lime-SDR, Raspberry Pi, and other hardware components not communicating correctly	 Fall semester early development. Refer to overall block diagram, Dive into specific functional block diagrams and debug issues (divide and conquer). 	
COM-1	Multiple User Communicating	Design an optimal CDMA code for each user	
LOG-1	Hardware/Electronics don't arrive on time which sets back schedule of overall project	Change provider of electronics to avoid schedule variance (Amazon, SparkFun, BestBuy,etc)	



Overview

Solution

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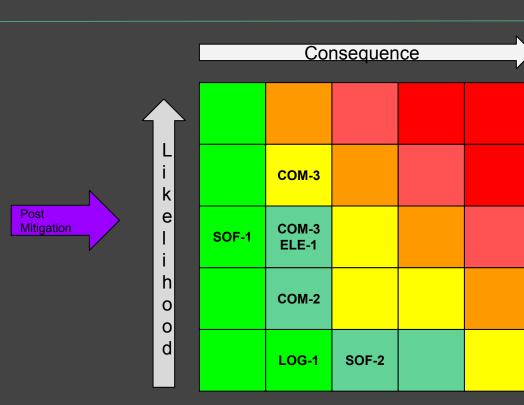
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Mitigation Effects

Risk ID	Description
COM-3	Near-Far problem: Difficulty to hear weak-far signals from strong-close signal sources
ELE-1	Time synchronization between pseudolite and GPS receiver
SOF-1	Team inexperience handling new software. For example, GNU radio
COM-2	Signal Interference in testing environment
SOF-2	Lime-SDR, Raspberry Pi, and other hardware components not communicating correctly
COM-1	Multiple User Communicating
LOG-1	Hardware/Electronics don't arrive on time which sets back schedule of overall project





Verification and Validation





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Signal Reception

LimeSDR demonstrates reception signal through wired connection

- Laptop running GNU radio creates signal and sends to LimeSDR
 - Create 100 bit .txt file to use as transmission signal
 - Send bits to LimeSDR using USB connection
- Verify receipt of signal to the LimeSDR
 - Create .txt file from bits and compare sent and received signal



Overview

Solution

CPE

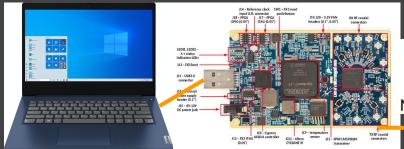
DR

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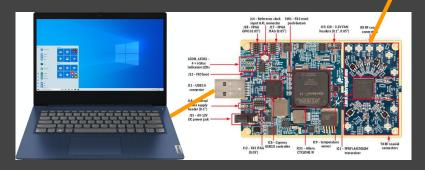


Bits 0 0 1 0 1 1 1 1 0 1 0 0 0 0 1 0

NRZ

USB Connection sends .txt as bits to LimeSDR

Wired from TX to RX sending bits



Bits converted to .txt and compared to initial file

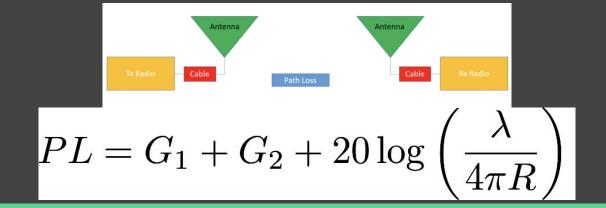


Antenna test

Demonstrate that the antennas used can supply the proper gain for the design

DR

- Measure loss between a two radio/antenna setup running multiple trials at various distances
- Use least squares calculate the gain of the antennas(they are the same)







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Transmitter/Receiver Set up



Each transmitter and receiver will feature a casing for the electronics that will hold the LimeSDR, Raspberry Pi, a battery pack, and space for wiring and a connection to the antenna. The electronics casing will be thread-mounted to a camera tripod.



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Modulation Scheme

LimeSDR receiver positioned 100m away from LimeSDR transmitter

- Transmitter modulates 100 bit .txt file to 2.48 GHz carrier frequency using GNU Radio PSK modulator
- LimeSDR receiver receives signal and demodulates it using GNU radio PSK demodulator
- Signal is re-output as .txt file and compared to initial file



Using Laptop and GNURadio send .txt file to LimeSDR



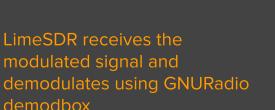








GNURadio modbox modulates bits using BPSK modulation scheme



demodbox

LimeSDR receives the modulated signal and





Bits are converted to .txt file and compared to original .txt







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Multiplexing and Wireless Transmission

Receiver can distinguish CDMA codes and process the desired signal

3 transmitters generate and transmit signals of different 100 bit .txt files

DR

- o For each file, send preamble and .txt file using GNU radio PSK modulator
- LimeSDR receiver positioned 100m away receives the signals and listens for specific preamble
 - o Based on desired preamble, receiver demodulates and converts desired signal to .txt
- Received .txt file is compared to original 3 to verify proper signal was processed



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HDOP and Positioning Accuracy

LimeSDR demonstrate positioning accuracy within 10 m

- Have 3 transmitting set ups spaced out in an equilateral triangle
 - o GNU radio with a LimeSDR and an antenna on a tripod
- Have a receiver set up in sensitive areas inside the triangle of transmitters:center of triangle, close to corner(near far problem)
- Receive signals from the transmitter stations to calculate position of receiver

DR

 Verify that receiver position calculated from transmitters is within 10 m of expected position (from GPS)



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DR

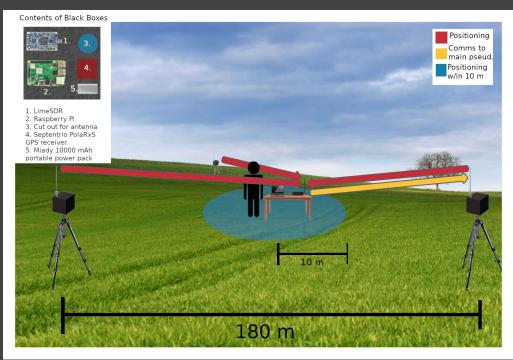
Risk & M

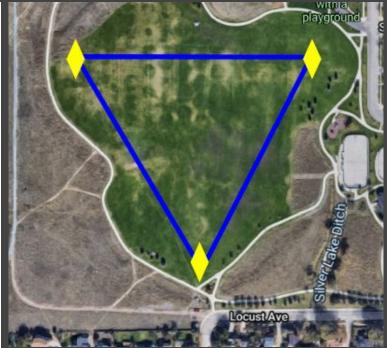
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Planning



Multiplexing & HDOP Test Setup









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Test Checklist

- 1. Walk transmitters to their positions
- 2. Sync transmitters and receiver with GPS
 - a. Sync up clocks to GPS (as well as to each other)
 - b. Record "true" position of each transmitter and receiver
- Verify all stations ready
- 4. Run communications/positioning test



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Testing site: Foothills Park

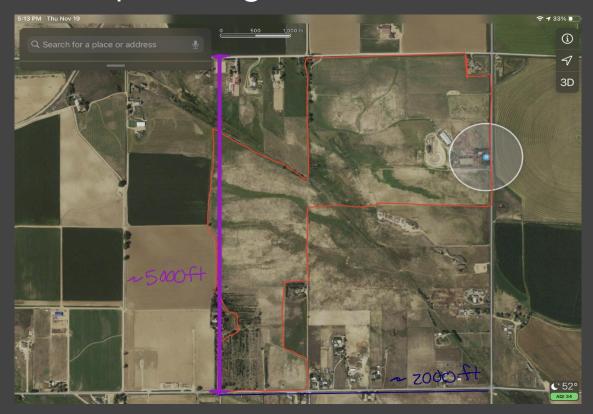


DR





Back-Up Testing Area

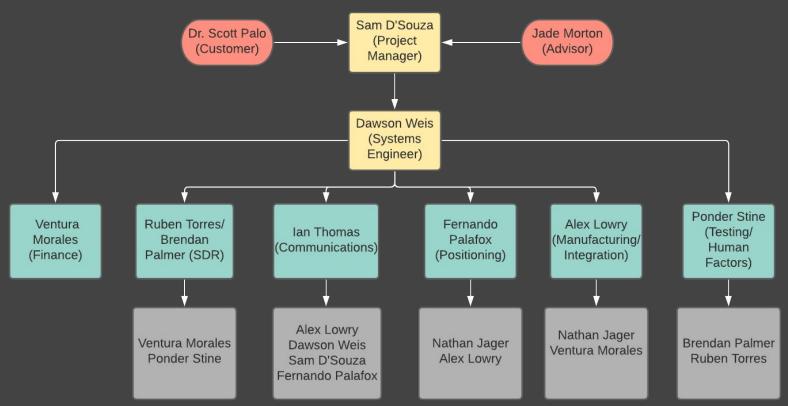




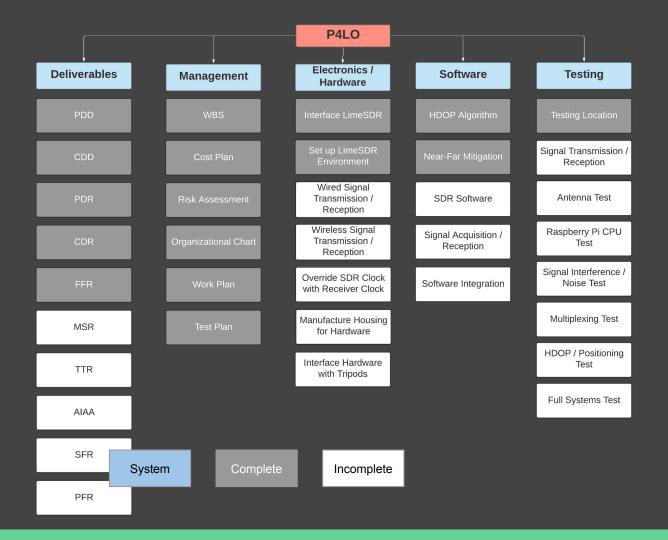
Project Planning



Organizational Chart





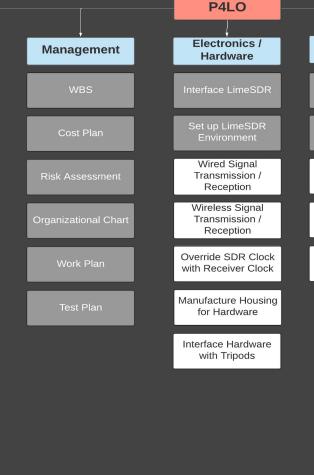




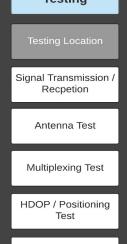


Work Breakdown **Structure** (WBS)









Full Systems Test

SDR Software

Signal Acquisition /

Reception

Software Integration

System

Incomplete

144



Overview Solution

CPE

DF

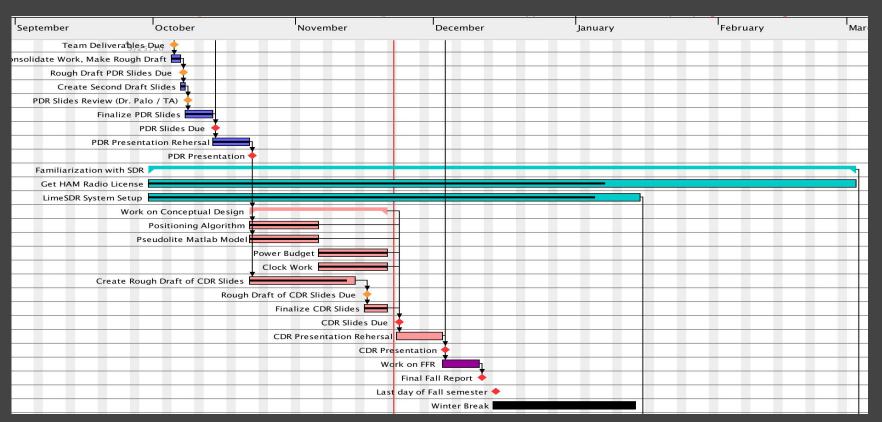
Risk & M

V&V

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Work Plan





Overview Solution

CPE >

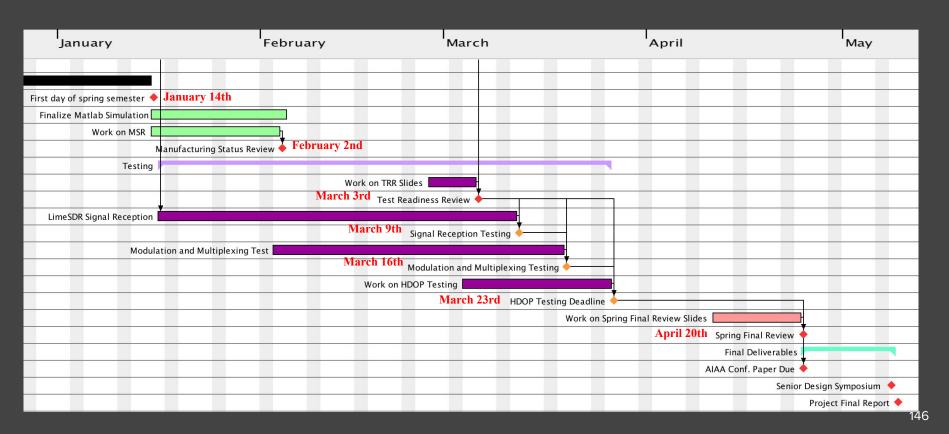
>

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Planning



Work Plan







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Test Plan

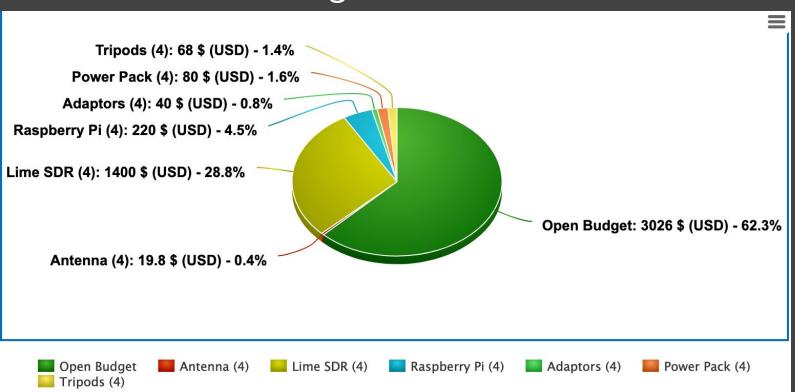
Testing Procedure	Date Scheduled	Location	
Signal Reception Test	March 9th	Foothills Park	
Modulation and Multiplexing Test	March 15th	Foothills Park	
HDOP Test	March 23rd	Foothills Park	
Full Scale Test	March 25th	Foothills Park	



Budget



Budget Pie Chart





Expense Budget & Margin



Team P4LO Budget								
Allowable Budget	\$5,000.00							
	Communications Hardware							
Item	Individual Cost	# of Items	Subtotal Per Set	Supplier	Item Link			
Antenna	\$4.95	4	\$19.80	SparkFun	https://www.sparkfun.com/products/11320			
Lime SDR	\$349.95	4	\$1,399.80	SparkFun	https://www.sparkfun.com/products/15027			
Raspberry Pi	\$55.00	4	\$220.00	SparkFun	https://www.sparkfun.com/products/15447			
Hardware Adapators	\$9.95	4	\$39.80	SparkFun	https://www.sparkfun.com/products/9145			
Power Pack	\$19.99	4	\$79.96	Amazon	https://www.amazon.com/Miady-10000mAh-Portabl			
Testing Tripods (6ft)	\$16.99	4	\$67.96		https://www.continentalphoto.com/itemdetails.asp?r			
			Budget Ba	alance				
Sub-total Balance	\$1,827.32							
Sales Tax Total	\$146.19							
Total Cost	\$1,973.51							
Budget Balance	\$3,026.49							





LimeSuiteGUI - GNU Radio - Gr-LimeSDR Plugin

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