Slide Sentinel
Remote Sensors to Monitor and Evaluate Landslides

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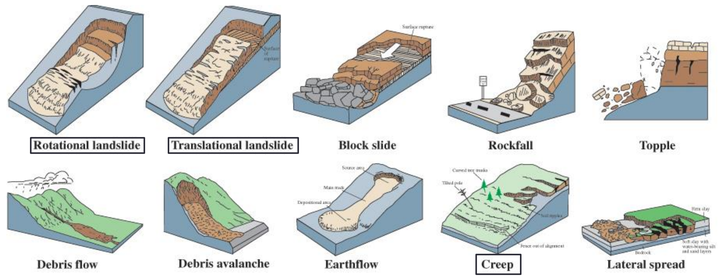
Abstract

- Landslides are a threat to forest workers and homeowners in the Pacific Northwest and areas with large annual rainfall
- Monitoring slides can be dangerous and expensive for landowners, making precise measurement of known slides a challenge
- **Slide Sentinel is a low cost alternative to current monitoring strategies**
- Uses Real Time Kinematic GPS and high-precision orientation measurement
- Slide Sentinel will support **3 month deployments with remotely available data** to decrease need for servicing and maintenance
- **Monitor known active creep, translational and rotational slides**



Landslide Types, Courtesy of the USGS[1]

Purpose: Alerts and Monitoring

GPS Position Monitoring: 1cm Accuracy

- **Nodes reduce position error from 3m to 1cm** using correction data
- **Real Time Kinematic** (RTK) GPS correction data generated at nearby base station and forwarded to all nodes in the network
- Nodes forward corrected position and orientation data to the base station which uploads a portion of that data to a cloud server using a satellite transceiver or cellular connection
- Provides updates and **long term knowledge of surface level slide activity**
- An accelerometer is used for both high-precision orientation measurements and emergency alert interrupts

ArduinoTest

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	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Date	Time	deviceID	NMEA_Data			UTC Tim	Sta	Lat	N/S	Lon	E/W	Elev	East Velocity	North Velocity	Up Velocity	UTC Date	Mode	RTK Age	RTK Ratio
2	August 24, 2018	7:43:24 PM PDT	SS_Base7	$PSTI,030,02	$PSTI	30	24320	A	4434.273676	N	12316.76788	W	83.332	-0.02	-0.02	0.06	250818	F		3 1.0*
3	August 24, 2018	7:57:45 PM PDT	SS_Base7	$PSTI,030,02	$PSTI	30	25742	A	4434.27293	N	12316.76744	W	89.353	-0.02	-0.02	-0.08	250818	A		0 0.0*
4	August 24, 2018	8:14:43 PM PDT	SS_Base7	$PSTI,030,03	$PSTI	30	31439	A	4434.271368	N	12316.76706	W	71.632	0.01	-0.05	-0.13	250818	A		0 0.0*
5	August 24, 2018	8:49:44 PM PDT	SS_Base7	$PSTI,030,03	$PSTI	30	34941	A	4434.272144	N	12316.76577	W	101.537	0.01	-0.01	-0.05	250818	A		0 0.0*
6	August 24, 2018	8:53:16 PM PDT	SS_Base7	$PSTI,030,03	$PSTI	30	35312	A	4434.272539	N	12316.76501	W	83.768	0.01	-0.01	0	250818	F		3 1.2*
7	August 24, 2018	9:09:42 PM PDT	SS_Base7	$PSTI,030,04	$PSTI	30	40939	A	4434.274629	N	12316.76642	W	85.928	0.03	0	-0.08	250818	A		0 0.0*
8	August 24, 2018	9:26:40 PM PDT	SS_Base7	$PSTI,030,04	$PSTI	30	42637	A	4434.274289	N	12316.76593	W	96.158	0.03	-0.03	-0.12	250818	A		0 0.0*
9	August 24, 2018	10:19:40 PM PDT	SS_Base7	$PSTI,030,05	$PSTI	30	51937	A	4434.272084	N	12316.77124	W	94.615	0.01	-0.03	-0.09	250818	A		0 0.0*
7	August 24, 2018	9:09:42 PM PDT	SS_Base7	$PSTI,030,04	$PSTI	30	40939	A	4434.274629	N	12316.76642	W	85.928	0.03	0	-0.08	250818	A		0 0.0*
8	August 24, 2018	9:26:40 PM PDT	SS_Base7	$PSTI,030,04	$PSTI	30	42637	A	4434.274289	N	12316.76593	W	96.158	0.03	-0.03	-0.12	250818	A		0 0.0*
9	August 24, 2018	10:19:40 PM PDT	SS_Base7	$PSTI,030,05	$PSTI	30	51937	A	4434.272084	N	12316.77124	W	94.615	0.01	-0.03	-0.09	250818	A		0 0.0*

Sample position data uploaded from base station

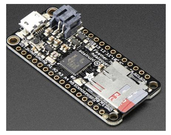
Emergency and Event Alerts

- Nodes are in a low-power standby mode during normal duty cycle, having no functions active and consuming 2mA of current
- Accelerometer wakes the device if a high acceleration event is detected, triggering an alert state
- Alert threshold is programmable and can be as sensitive as 0.016g
- Special alert behaviors include taking measurements more often, to sending emergency SMS alerts to the nearby area
- More behaviors are possible

[1]United States Geological Survey. (2004, July). Landslide Types and Processes. Retrieved December, 2018, from https://pubs.usgs.gov/fs/2004/3072/fs-2004-3072.html

Design: Electronics and Network

Electronic Components



Microcontroller (base and nodes)
- Adafruit Feather M0
- Can easily add 915MHz Radio or SD
- Built-in battery monitor, charging circuit

GPS (base and nodes)
- Navspark S2525F8-GL-RTK
- Base sends correction data to nodes, node sends RTK corrected position back

GPS Receiver

GPS Antenna

DS3231

MMA8451

SHT31-D

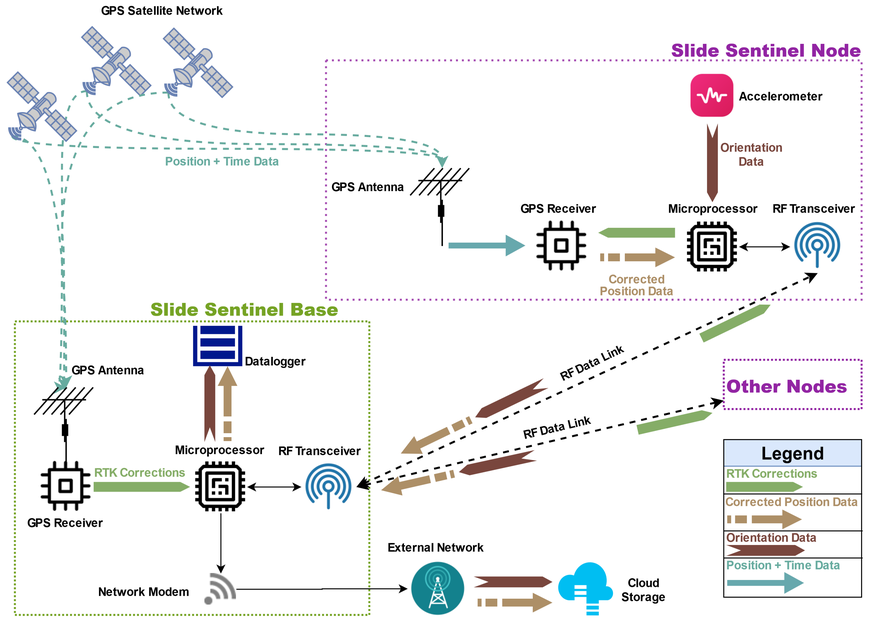
I²C devices (nodes)
- **MMA8451** Accelerometer, ±0.01 m/s²
- **SHT31-D** Temperature sensor, for correction of acceleration measurements
- **DS3231** High precision real time clock

Network Modem Options (base)
- **RockBLOCK+** Satellite transceiver for uploading small packets of data to the cloud;
- **Pycom FiPy** LTE network capability and greater bandwidth; or
- **SIM808** 2G network capability and integration with OPEnS LOOM library

Base-Node Communication Options, (base and nodes)
- **Nordic NRF-24LO1+** 2.4GHz Wi-Fi band transceiver: high bandwidth and limited range
- **Freewave Z9-T** 915MHz transceiver: medium bandwidth and long range, high power

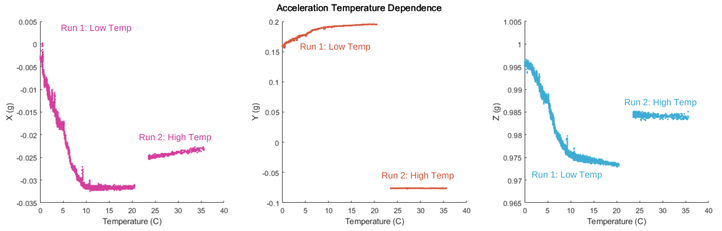
Other Components
- **Feather Latching Relay (nodes)** Cuts off power to the high-draw GPS units and radios
- **Power System (both)** TBD, will require solar power and LiPo batteries

Network Design: From the Field to Your Screen



Results: First Phase and Tests

- Initial tests show variation in acceleration readings with temperature and indicate need for a temperature sensor on each node



Accelerometer xyz low and high temperature tests, note differing scale on Y-acceleration y-axis

- **RTK transmission requires ~15Kbps bandwidth**, LoRa tests with Feather M0 gave max range of 100 meters at this data rate
- **A radio with longer range, 2-5 km, is necessary going forward**
- Tests run on accelerometer to find best combination of precision and interrupt sensitivity for alerts
- Selected 14-bit MMA8451 with 0.016g interrupt threshold
- Tests run for data upload to a Google Sheet show that OPEnS Lab developed LOOM sensor library supports 100 kb/day uploads

Sample Base and Node

24 Hour RTK GPS Test

Future: Testing and Development

Evaluate in Canopied Environment

- GPS satellite signals are extremely weak by the time they reach a receiver, effects of attenuation on the RTK fix are yet to be determined
- Potential alternatives/solutions are dual frequency GPS receivers from Piksi or the addition of a low noise amplifier (LNA) to the signal chain
- Calibrate accelerometer data received and determine significance of fluctuations in measurements due to temperature

RF Transceiver: Range and Data Rate

- The corrections from base to **nodes must have a robust and dependable broadcast link** because RTK corrections are large packets
- Future tests include line-of-sight range test, attenuated range test alongside a bandwidth test in the forested environment where these transceivers will be used

Acknowledgements

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To learn more about Slide Sentinel or follow the project, scan the QR Code