Slide Sentinel: Designing Remote Sensor Systems to Estimate Landslide Potential in Oregon Landscapes

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Abstract

A system capable of reliably detecting catastrophic landslides and centimeter movement in land mass could save lives and offers landowners valuable information about gradual changes in soil displacement on their land. With precise acceleration and relative positioning data collected from an accelerometer and a set of GPS receivers, a system can be designed to detect subtle changes in sensor position due to land movement. With the rapid production of new microprocessors and greater memory storage capabilities the limits of microcontroller systems are continually expanding. The Slide Sentinel project offers landowners a low-cost alternative to commercial equipment consisting of a network of remote low power sensors that detect fast linear slides and eventually lower soil movements such as creep. Long range low-power (LoRa) radio connections on these sensor nodes wirelessly transmit three-dimensional acceleration, Real Time Kinematic (RTK) GPS coordinates, and sudden shift alerts to a common base station where they are exported to an online spreadsheet to be processed remotely.

Slide Sentinel

Remote Sensors to Monitor and Evaluate Landslides

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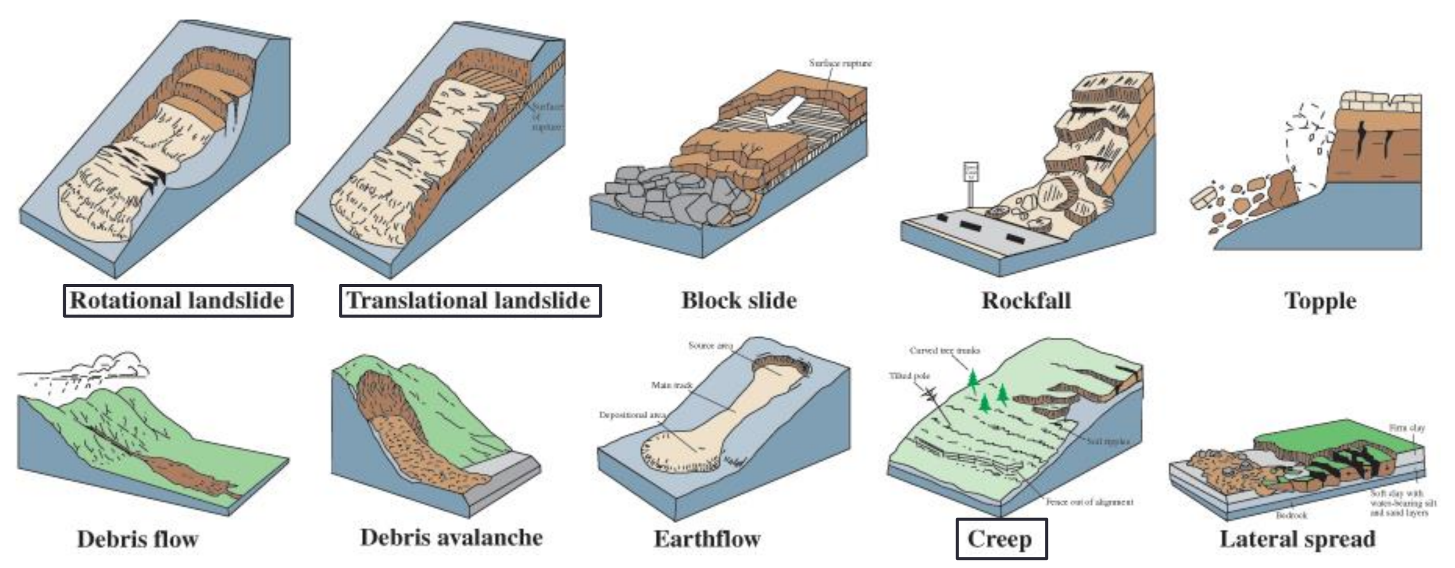
OPEnS

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**

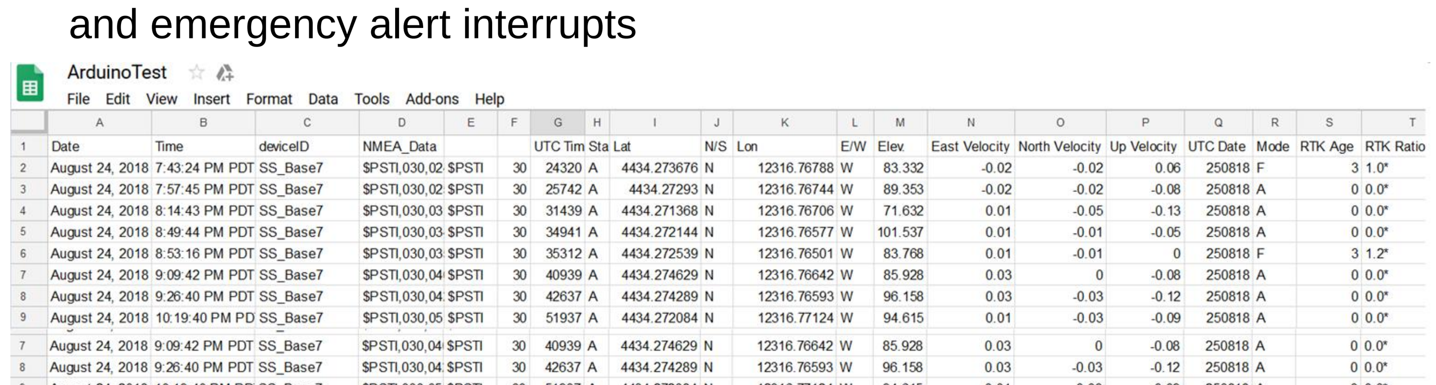


Landslide Types, Courtesy of the USGS[1]

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



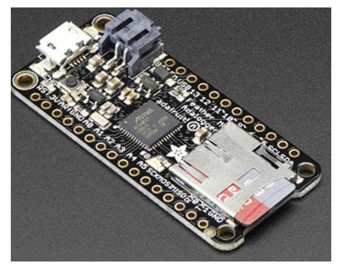
Sample position data uploaded from base station

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

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

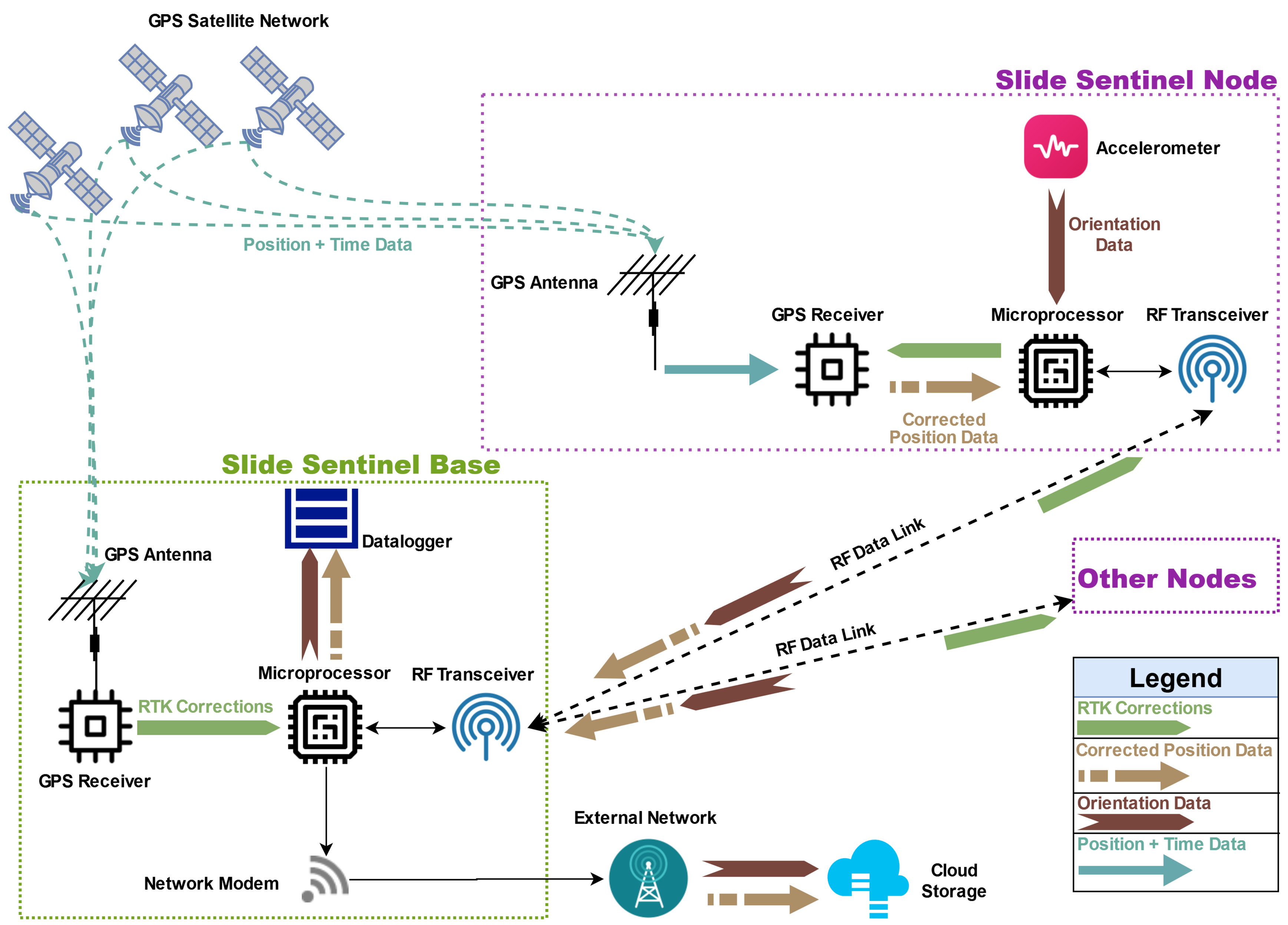
I^{2}C devices (nodes)
- **MMA8451** Accelerometer, ±0.01 m/s^2
- **SHT31-D** Temperature sensor, for correction of acceleration measurements
- **DS3231** High precision real time clock

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

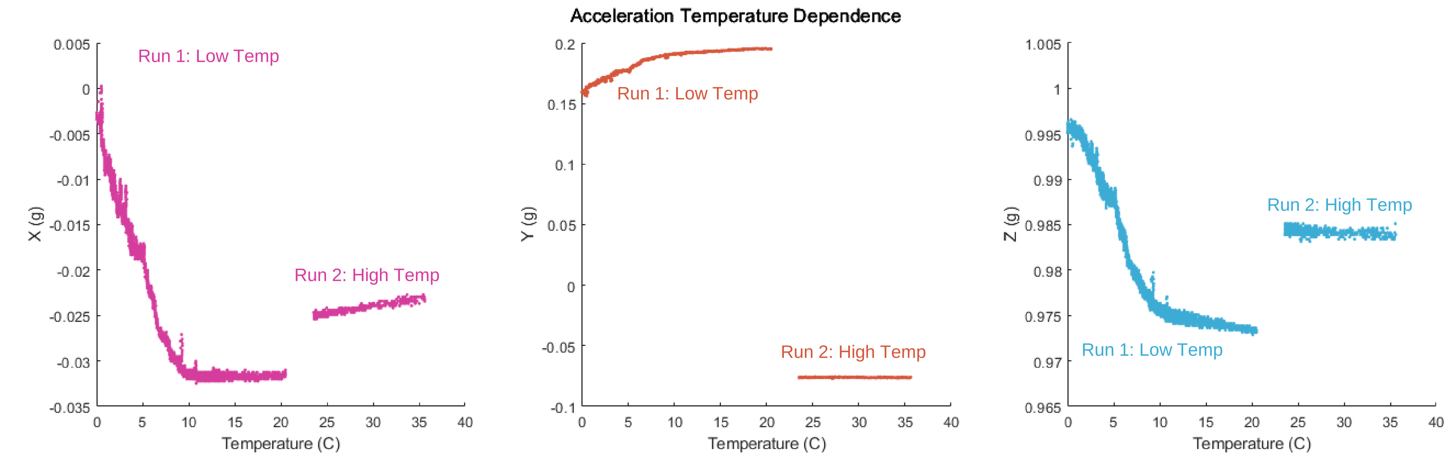
Other Components
- **Feather Latching Relay (nodes)** Cuts off power to the high-draw GPS units and radios
- **Power System (both)** TBD, will require solar power and LiPo batteries

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

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

[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