This document outlines the works required for BLASTSCOUT to develop a proof of concept for void measurements, volume measurements and basic temperature readings.

Background

BLASTSCOUT PROBE is a tool used to measure the depth and water of blast holes on open pit mines. PROBE utilises a custom cable to pass data and power from the UPHOLE (top unit) to the DOWNHOLE (In hole unit). The UPHOLE unit logs depth as it obtains data from the downhole unit, and hence events occurring in the downhole are communicated to the uphole, allowing logging of them versus the current depth of the cable.

The existing BLASTSCOUT system connects from the Uphole to the Downhole via custom made and fit for purpose cable. This cable features metallic crimps, 11mm long, every 0.2m. The UPHOLE utilises 3 induction sensors measuring at high frequencies to capture the crimp change and direction, and an algorithm on the UPHOLE translates this to a counting structure. The UPHOLE also contains a GNSS antenna connected to a UBlox ZED-F9P, E22900T30S for LORA (868 or 915 MHz) and a Raytac MDBT42Q-512KV2 for BLE communications. The LORA provides RTCM corrections from a Base Station to enable RTK corrections and hence accurate GPS locations. The current firmware assumes connection to a Watch and Phone for core functionality, with events passing to the end user to make decisions. The Downhole PCB communicates to the UPHOLE via RS485 half-duplex through a proprietary messaging implementation. The Downhole PCB features a STM, two water detection circuits for voltage-based water detection externally, and 2 ports on it for future expansion which have not been utilised insofar.

MTi Group has completed Proof of Concept work using mmWave RADAR sensors for void detection previously with success. The POC previously generated focused on feasibility of the concept through manual data analysis. These mmWave RADAR sensors (RS-1843AOPC) utilise CAN for all messaging. A variety of profiles have been developed over the years, including 50m and 100m variations for depth sensing, and a historic 5m profile for void sensing. The sensors have a FOV of 120 degrees total. The advantage of these radar sensors is their ability to see through materials, meaning lenses are not needed a robust radome can be constructed for the harsh environments. A historic dead-zone was documented of 0.1m for RADAR but further testing of the implications algorithmically has not been done. It is expected the RADAR has a dead-zone of 0.1-0.3m but the implications of this require investigation and testing. Each sensor has a measurement rate of 10 Hz, and depth readings contain several depths as well as the SNR of each depth value.

BLASTSCOUT is deployed into holes that may be from 100mm diameter to 350mm diameter. These holes will contain significant dirt, mud, and water, and may be anywhere from 5m deep to 70m deep. Voids are characterised by deviations in the ground that are >0.5m. One sensor detecting this is sufficient to trigger a void, but it is expected the entire hole may have wall deviation in this situation.

Scope of Works

The goal of this development is to create a custom PROBE system which will identify and measure hole volume, void location and temperature. This system shall also retain the existing capacity for bottom detection and water detection, though these may take other forms if deemed necessary.

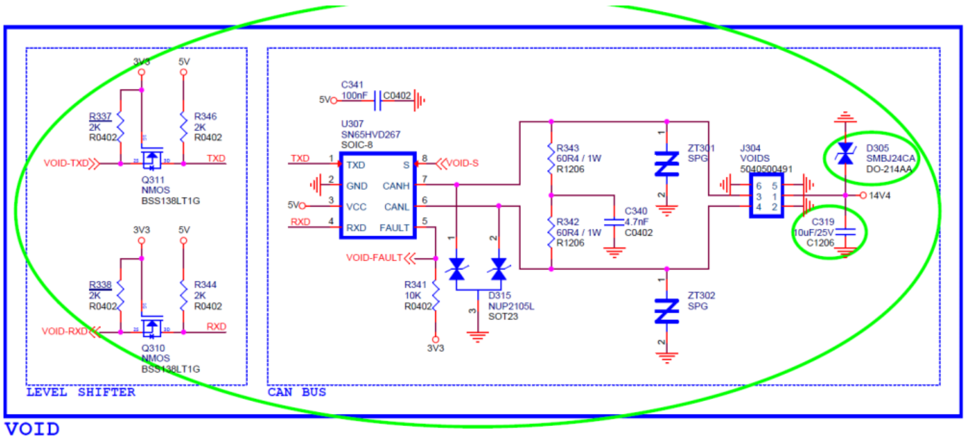
The scope is an MVP in software for the void/volume and temperature product, while a POC for the physical dynamics of the system.

This scope assumes that the system will be fitted to a MINESCOUT **only**, and hence phone app, watch and other export mechanisms are not part of the scope. The UPHOLE PCB will hand-off to a computer on MINESCOUT for all processing, such that this scope does not require automatic creation of fully formed data that is user-friendly.

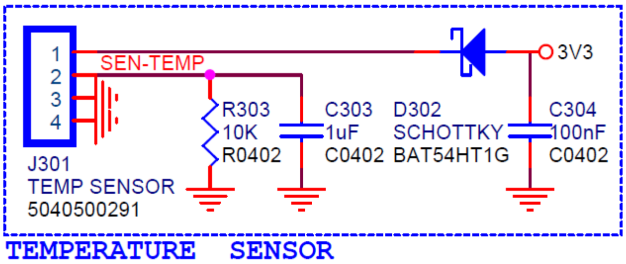
The following shall be the requirements for the development.

<u>Electrical/Software Work:</u>

1. Development of a Downhole PCB electrical/software system that can take data from:
    a. 3-4 RADAR sensors at once utilising CAN in the VOID header.
        i. Testing shall evaluate and decide if 3 or 4 sensors are required.
        ii. These sensors shall be polled at a fast enough rate to allow for a message to be sent to the uphole for each crimp reading (0.2m) when the cable is travelling at 3m/s. If this is not possible, a speed limit shall be applied and advised.
        iii. The reading of these sensors should be tuned such that they can output a value as a minimum, and the dead-zone will not impact an output reading negatively that would affect functionality.



    b. 1 temperature sensor using the ADC to find the temperature reading.
        i. This sensor shall be polled at a fast enough rate for each crimp reading (0.2m) when the cable is travelling at 3m/s. If this is not possible, a speed limit shall be applied and advised.
        ii. The sensor choice itself is outside the scope, but it may be emulated via other mechanisms for development.



   c. Both temperature and void sensors may function at the same time, meaning messaging congestion may not impact operation of the system.
   d. The expected hole diameter may be saved to Downhole PCB for use in calculation of voids or hole size if it is of benefit. This may be provided to the uphole via a serial command in the UPHOLE PCB.
2. Development of a Downhole-Uphole software communication to allow messaging to be sent from the downhole to the uphole for relevant events identification, including:
   a. Void/Volume:
      i. Void detection flag (given a void size definition set prior that may be stored in the downhole PCB), as well as an exit state flag.
      ii. Instantaneous Hole size as detected by each RADAR sensor.
   b. Temperature:
      i. Temperature exceeding flag (given a temperature limit definition set prior that may be stored in the downhole PCB) as well as an exit state flag.
      ii. Instantaneous Temperature reading as detected by the temperature sensor.
   c. Each of these messages may be switched on and off as required through a message from the Uphole PCB.
   d. Continue to prompt for bottom detection given an impact per the current algorithm.
   e. Evaluate if Water sensing may be completed through use of RADAR sensors all measuring within dead-zone, instead of an external water sensor.
      i. If this is found possible Downhole PCB and communications will be updated to use this technology instead of external ADC based water detection.
3. Development of the RADAR firmware to be suited to void detection:
   a. Namely a maximum distance output of 5M shall be suitable, with a minimum output of 0.1m
   b. CAN messaging can be modified if required from standard as this firmware is specific to void usage.
4. Development of Uphole software algorithms to:
   1. Tie the void detection event to a height of the detection.
      a. The largest void measurement readings, for a given depth region, shall be taken as the maximum void height for a given depth.
   2. Tie each progressive volume value to the height and thereby provide a complete dataset of distance values versus hole depth.
      a. The largest volume measurement, for a given depth region, shall be taken as the maximum volume for a given depth.
   3. Tie the temperature detection exceed event to a height of the detection.

4. Tie each progressive temperature measurement to a height and thereby provide a complete dataset of temperature versus hole depth.
5. A serial log output of the progressive measurements may be presented for POC evaluation. This data can take the form for example of [Depth, Void_1, Void_2, Void_3, Temp_1] where the chosen values correspond to the maximum obtained value within the depth count region.
6. The sensors may need to not broadcast when coupled to comply with legislation
    a. RADAR is required to be aiming at the ground, and a coupled PROBE may not meet this requirement.
    b. Temperature may be a hazard due to emitting an infrared laser when coupled, so it may need to be disabled during coupling.

<u>Mechanical/Physical Work:</u>

1. Prototyping of a Downhole concept housing to:
    a. Correct for dead zone in the RADAR sensors, if required, through 3D printing and a 'centraliser' design, but only if required.
    b. Provide a proposed RADAR sensor arrangement that allows for a hole to be measured and volume to be calculated from these measurements.
    c. Evaluate if a TPU boot, such as that being 3D printed, will impact these RADAR sensors in measuring the hole.
2. Simulation of a temperature sensor on the Temperature sensor header to validate the sensor would function if plugged in along with void sensors.
    a. An example sensor, or electronics simulating the sensor, may be used for testing and prototyping.
    b. The sensor would be expected to output temperatures in C from 0 deg C to 110 deg C as a baseline, but this should be customisable for the actual sourced sensor.

Proposed Requirements & Assumptions

The target hole will be a 250mm hole with a 22.5M cable, and a target 17M hole depth typically.

1. The POC shall only go into mechanical development insofar as to enable a practical demonstration in the office and to test concepts, specifically for void/volume sensing.
2. A mechanical conceptual design allowing for the temperature sensor is not required or within scope.
3. No requirement is necessary for waterproofing, and the system will not be suitable for field usage within this scope.
4. The maximum 32.5M cable will be used to power the Downhole, which has a ~3A-5A current limitation, but the actual test cable will be 22.5M.
5. The 0.1m void sensor resolution will generate an accurate enough volume calculation to be practically usable, and if not, a new firmware will need to be developed to enable usable value. This new firmware is out of the current scope, so if this is a limit, volume work would proceed assuming the accuracy is sufficient.
    a. At the time, an evaluation may be made with SMT to decide if new firmware shall be developed in house or externally to meet this requirement.
    b. The old void test firmware (5m) shall be workable and updated to current standards for use in this purpose of testing and development.

6. The system will be used in environments in <50 degrees C and physically is not suited to deployment in hot ground, so future development outside this scope will make the hardware suitable to this.
7. Holes will be 100mm diameter or greater, with a typical target hole being 250mm diameter.
8. RADAR sensors are assumed to be able to withstand the necessary Gs for a bottom detection function without failure.
9. This system will be used as a combo bottom detection/Water detection/void detection/temperature detection system, with all systems at once being available.
    a. Optionally, only bottom and water are available (as current design)
    b. Optionally, only void, bottom and water are available (no temperature is available).
10. Backwards compatibility to current functions is required (An older cable with only bottom and water, 9a, may be connected to the uphole PCB).
11. Readings may be obtained on the way up from the bottom of the hole, rather than solely on the way down the hole, should this prove advantageous.
12. Void sensors may be able to provide a water detection through all sensors seeing a minimum distance at the same time, correlating to a DOWNHOLE submerged in water.
13. The algorithm only needs to expect a single up and down pass – dynamic up/down movements are not part of the scope of a MINESCOUT measurement system. However, at the bottom of the hole, the PROBE may be raised and lowered for a clean 'bottom detection' if required automatically, which shall be factored into the algorithm (but data may not be used depending on programmers' requirements).
14. The processing shall be offloaded to a MINESCOUT computer for volume calculation, or other computationally intensive calculations. Unnecessary processing should not be done on the embedded systems unless absolutely required for operation.

Future Work

Following work from this scope would include:

1. RADAR sensor firmware development for higher resolution, if deemed required.
2. Practical temperature sensor development including choosing a sensor and mechanical development of a downhole arrangement to support this at the appropriate temperature ratings, as well as void/volume.
3. New cable development for a cable that supports elevated temperatures.
4. MINESCOUT software development to support the void/temperature development.
5. A downhole MVP/Commercial product supporting void/volume measurement mechanically for commercial rollout.