Intelligent **Measure While Drilling** Development Plan

Markus Timusk, School of Engineering, Laurentian University, Sudbury, Ontario
Greg Lakanen, School of Engineering, Laurentian University, Sudbury, Ontario
Leanne Sigurdson, Northern Centre for Advanced Technology Inc., Sudbury, Ontario
Dale Boucher, Northern Centre for Advanced Technology Inc., Sudbury, Ontario

NORCAT

LaurentianUniversity
UniversitéLaurentienne

LU Mechanical Engineering

LaurentianUniversity
UniversitéLaurentienne

- Newly Implemented Mechatronics Program
- First class of graduates 2011
- NASA Lunabotics Winners!

Intelligent MWD System

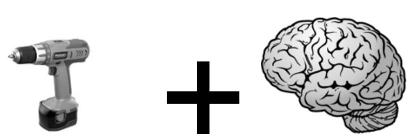
MWD Planetary Substrate Identification System

- Proposed technology is part of a larger NORCAT project involving a TRL 5 prototype of a rover-based drill
  - Can also be mounted on a fixed base (e.g. lander)
- Technology will demonstrate Canadian expertise in planetary drilling for future exploration missions
- Supports the concept of NASA's next generation RESOLVE mission.

3

Measure While Drilling: Overview

- End objective:
  - Develop additional functionality to planetary drills. From a tool for gathering core samples
    - Decision support
    - Science instrument
  - a robust system architecture that would permit a MWD system to be readily integrated into a NORCAT planetary drill system
  - develop an understanding of which parameters are most useful for MWD



4

Decision Support Scenario

- In situ substrate identification
  - Rock or ice bearing regolith
  - Decision support: continue drilling or to abort the hole
- Avoidance of Hazardous Drilling Conditions
  - Ex: drill encounters a partially exposed rock protruding into the bore hole
  - This condition can result in accelerated bit wear or damage to diamond cutters.
  - Extend equipment life

5

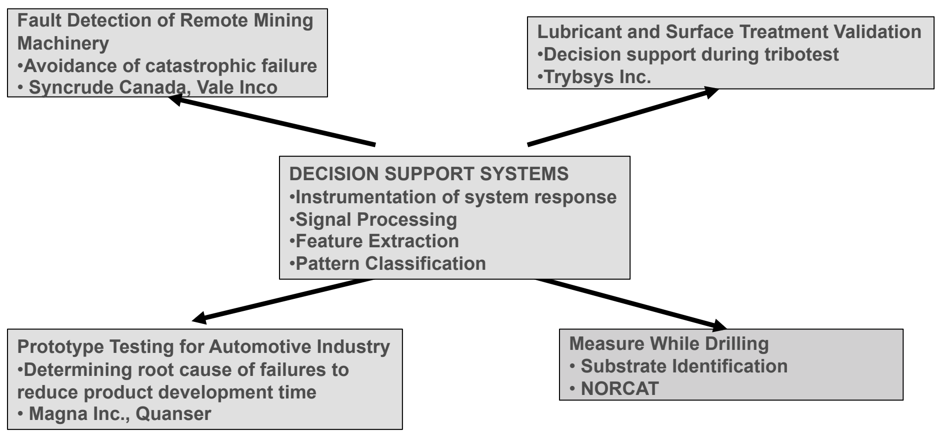
Science Instrument Scenario

- Use drill gather key geotechnical and mechanical characteristics of the material (Strength, hardness etc.)
- Data can also be stored and corroborated with data collected from sample analysis
- Data from multiple holes could be used to predict geological makeup of larger areas

6

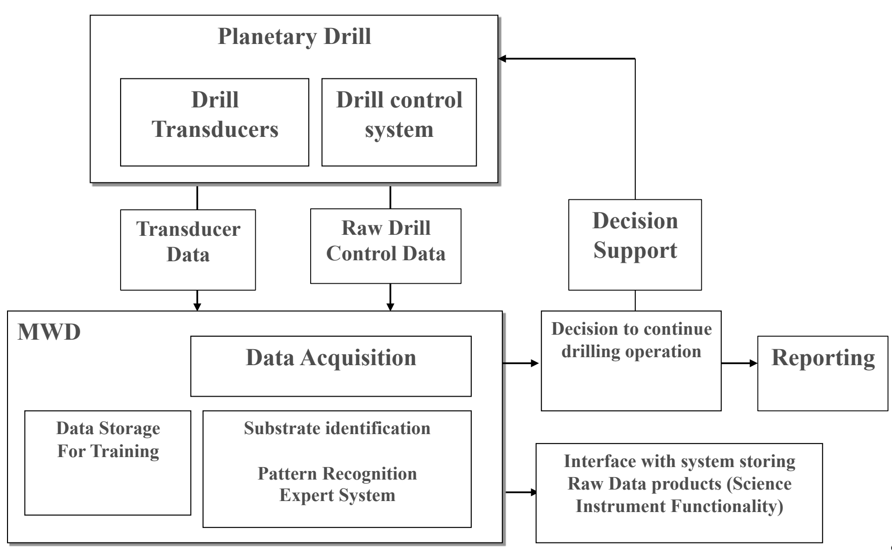
Development of Decision Support Systems

- Industrial work in other domains:



7

Implementation



8

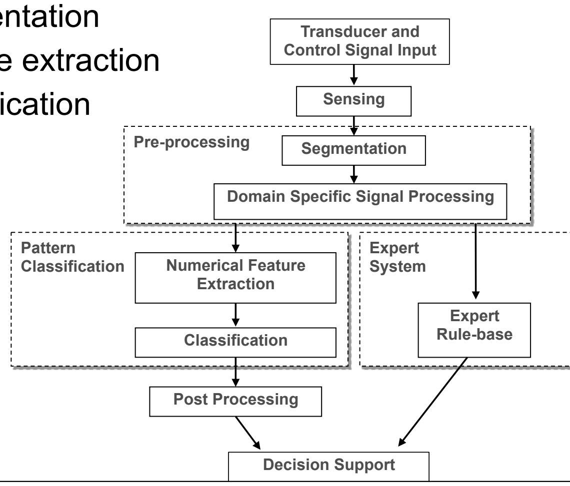
Decision Support System Development

- Various multivariate data analysis techniques are being investigated
- Will determine
  - which sensor parameters, signal processing techniques, feature extraction and classification methods best perform the task of substrate identification.
  - Performance and Reliability

9

Data Flow

- Map data from the sensor signals to the end goal of substrate identification through:
  - Segmentation
  - Feature extraction
  - Classification

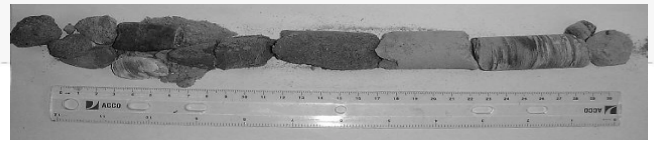


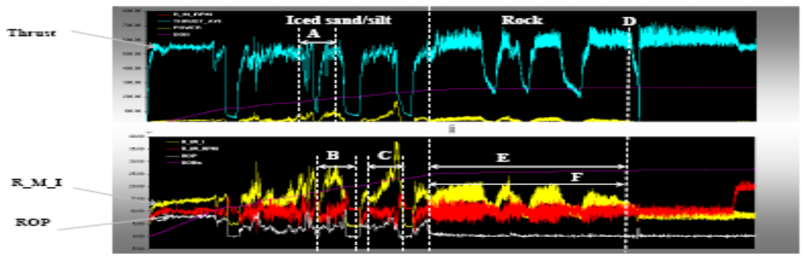
10

Is this feasible?

Is this feasible?

- Technically feasible based on:
  - Previous findings at NORCAT
  - Literature review
  - Relatively straightforward to incorporate into NORCAT's existing drill systems
- Various researchers have shown that the task of identifying substrates is possible using an instrumented drill
  - Prediction of strata in coal mine using thrust, ROP (95% confidence)
  - Characterise the structural integrity of tunnels before material is excavated
  - Statistical pattern recognition to ID rock types to optimize blasting





Parameter	Iced Sand/Silt	Rock
Thrust	Significant variations	Relatively constant
R_M_I (current)	Continually ramped up, paused to clear	Lower, comparatively flat
ROP (rate of penetration)	High	Minimal, constant

13

Phase 1 Data Collection

14

Decision Support System Development: Data Collection

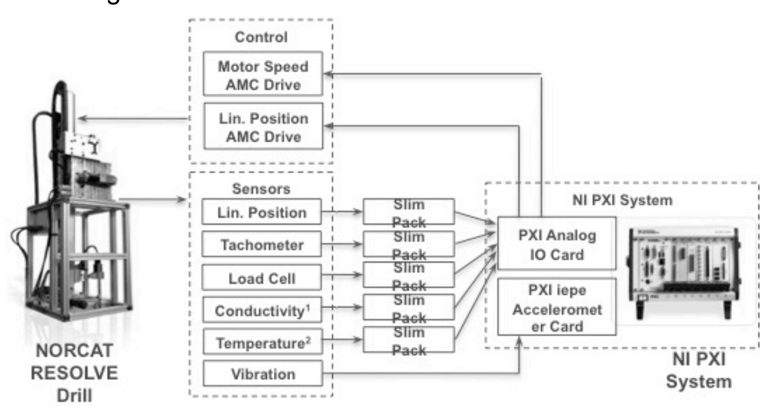
Requires Data That:

- Characterises the response of the modified NORCAT RESOLVE EBU2 drill penetrating a range of substrates under controlled conditions
- Can be used for training, optimization and testing of classification system
- can also be used to demonstrate science Instrument capability

15

Instrumentation

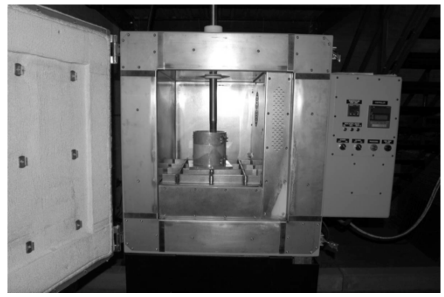
- Direct instrumentation of the control system of drill and sensors mounted on the drill
- Training data collection and analysis
  - Collection of large, time dependant multivariate data set
  - Sensory and control data will be collected during supervised drilling of known substrates



16

Primary Experimental Data Collection Phase

- Data will be collected from drilling of both consolidated and unconsolidated material



Substrates:

- Basalt
- Anorthosite
- Dolomite
- Regolith Simulant
    - compacted Chemically Enhanced OB-1 (CHENOBI) lunar highlands regolith physical simulant
    - 0%, 5%, 7.5% and 10% moisture content by weight
    - at cryogenic temperatures and standard temperature pressure.

17

Sample Preparation

- The prepared vessel containing the sample will then be placed in the cryotemper (-175°C).
- The instrumented drill will be placed on top of the cryotemper
- the drill bit and auger assembly will access the frozen CHENOBI within the chamber by means of the top port in the cryotemper.
- Drilling depth will range between 10 to 90 mm.

18

Control and Data Collection

Control of drilling process:

- The instrumented drill will penetrate the sample under specified operating conditions regulated by the MWD control system.
- With and without percussion
- Closed loop (PID) control will be used to control
  - Drill speed (encoder feedback signal)
  - Thrust (load cell feedback)

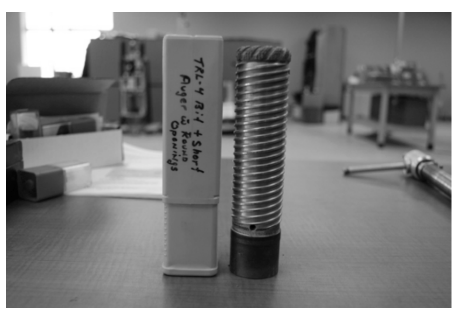
Data Collection Instrumentation:

- The data collection will be triggered by the control system of the drill
- A National Instruments PXI chassis will be used to collect data at 1kHz using two synchronized data acquisition cards.
- LabVIEW software will be used for both control and data collection.

19

Analysis

- The core sample and potentially surrounding material for consolidated substrates will then be collected and logged, linking linear position with core location.
- Collected samples will be preserved and measured for hardness at specified depths along the sample.
- Finally the ground truth and instrumented parameters will be combined into a common synchronized dataset.



20

Conclusion

- The Concept
  - Concept is technically feasible
  - Could assist with mission decision support
  - Would make a valuable science instrument
  - Could be implemented with minimal additional payload
- Next Steps
  - Data collection
  - System training
  - System Validation
- We are grateful for the support of the Canadian Space Agency and NORCAT

21

Questions?

22