Development of an On the Spot Proximal Soil Sensing Platform for Subsurface Measurement of Soil Properties

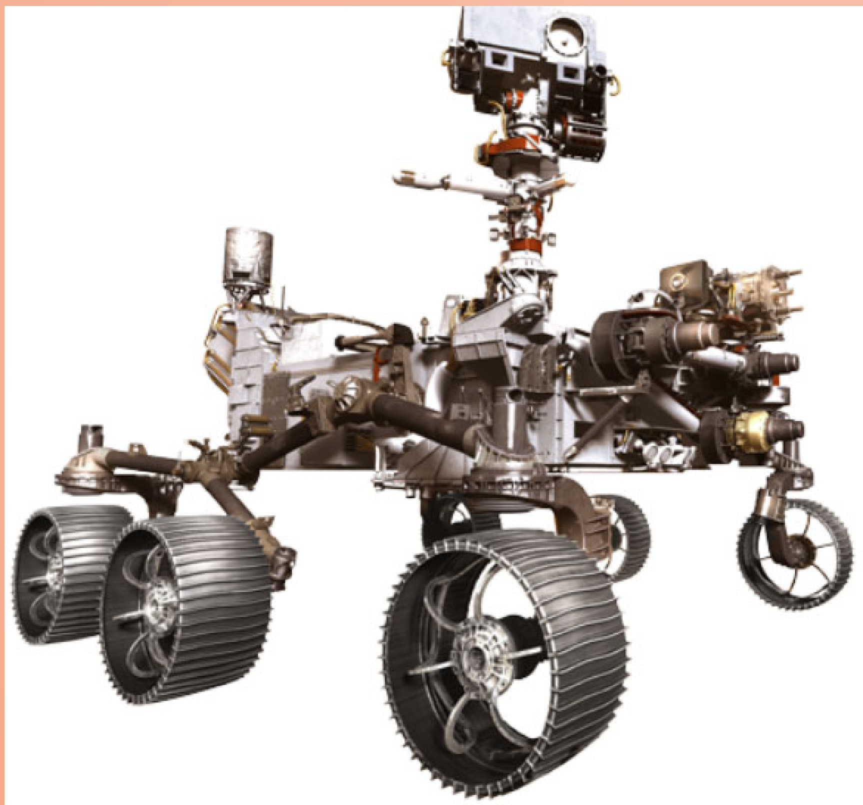
Eko Leksono, Viacheslav Adamchuk, Maxime Leclerc, Roberto Buelvas, Connor Miller, Jaesung Park

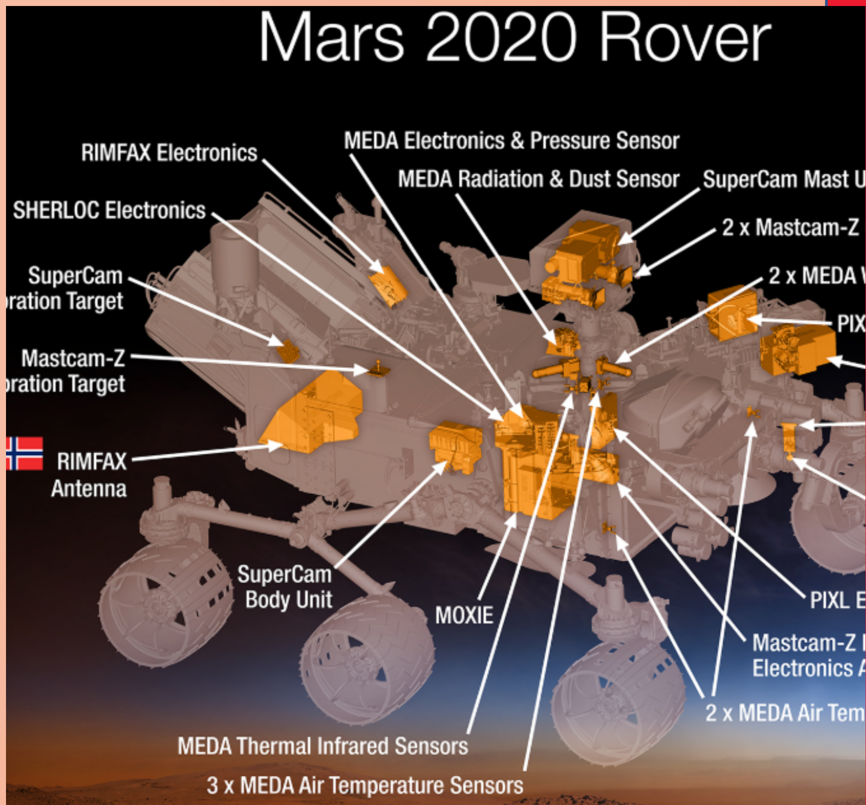
Bioresource Engineering Dept., McGill University, Ste-Anne-de-Bellevue, QC, Canada

Introduction

- Proximal Soil Sensing (PSS) involves the ***use of portable soil sensors*** mounted on a mobile platform → ***on-the-go soil mapping***
- Vs. Grid sampling :
  - Produce higher soil measurement density
  - Reduces overall errors of thematic soil maps (Adamchuk et al., 2004)
- Development of geostatistics :
  - representative soil sampling locations (spots) can be selected effectively
  - reducing the need to sample the entire field
- ***Requires a reliable platform*** to gather various *in situ* soil measurement

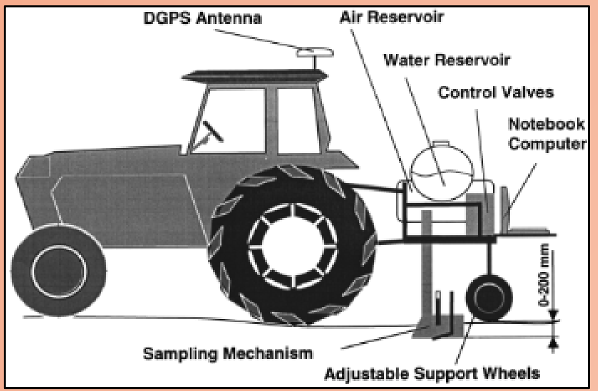
Introduction





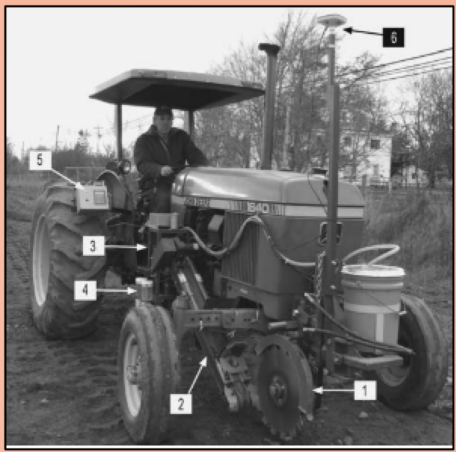
McGill lpdp NSERC CRSNG https://mars.jpl.nasa.gov/mars2020/

Introduction : On-the-Go Platform



Adamchuk et al. (1999)

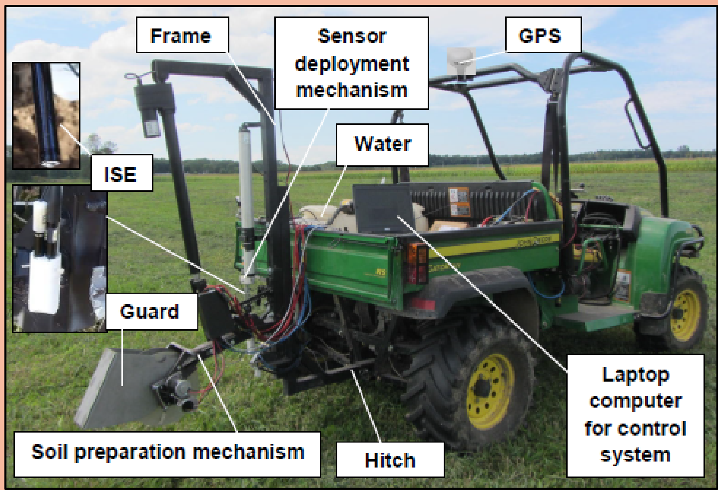
- Three-point hitch
- Movable shank (20cm deep)
- Single pH ISE



Sibley et al. (2008)

- Vertical wood saw blade & conveyor
- Water spray unit to moisten the sample
- Single Nitrate ISE

Adamchuk et al. (2007)



First Generation OSA (Adamchuk et al., 2014)

Research Objective

To develop a robust automatic OSA platform that would efficiently prepare the soil, perform multiple ISE measurements and restore effect of soil disturbance.

Methodology :

- SolidWorks (Dassault Systemes
optimized the On-the-spot Soil
- The new design features :

1. Two sets of parallel linkages:
    - reduce digging curvature
    - reduce platform vibration
    - reduce sampling footprint

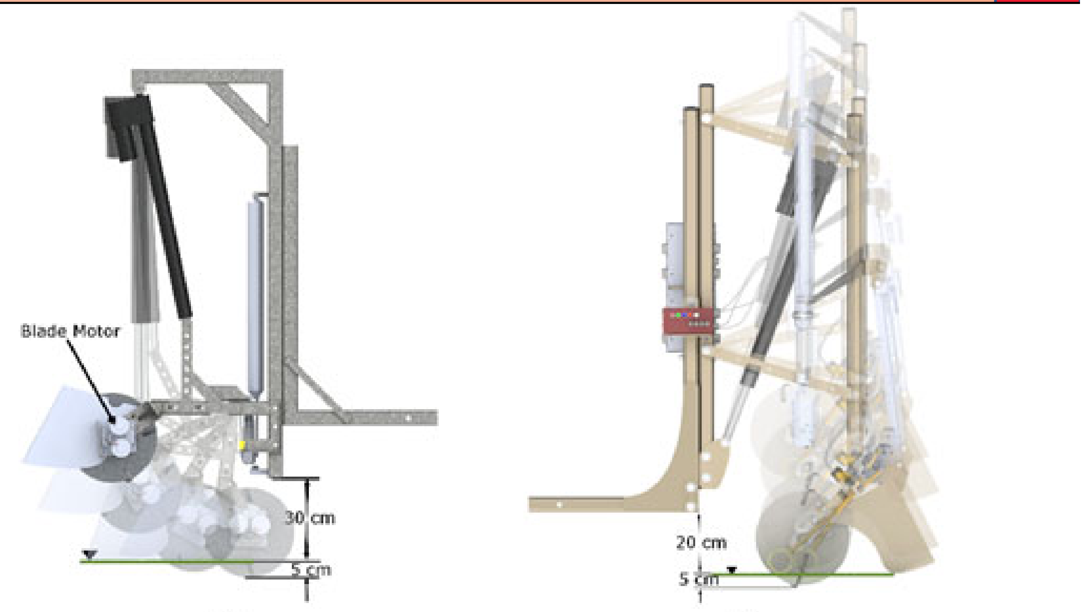


Fig. 1. Digging curvature comparison between (a) the old and (b) the new OSA design

2. Sprocket-chain mechanism to drive the blades:
    - minimize electrical noise
    - provided more ground clearance
3. A linear actuator for automatic covering of the sampling hole.
4. Three Teejet XR11002VK nozzles for a better ISEs cleaning

Methodology : OSA Electronics

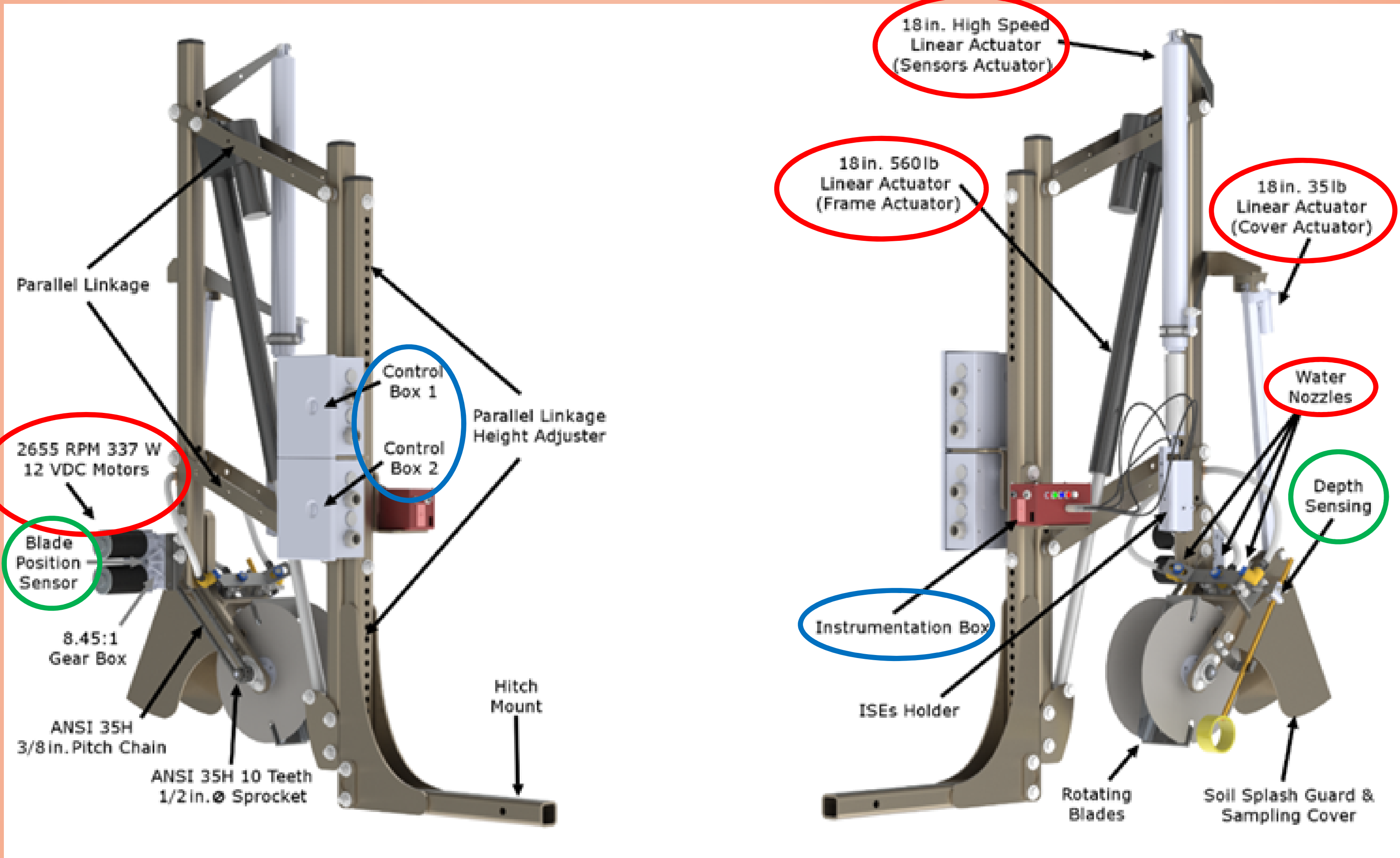
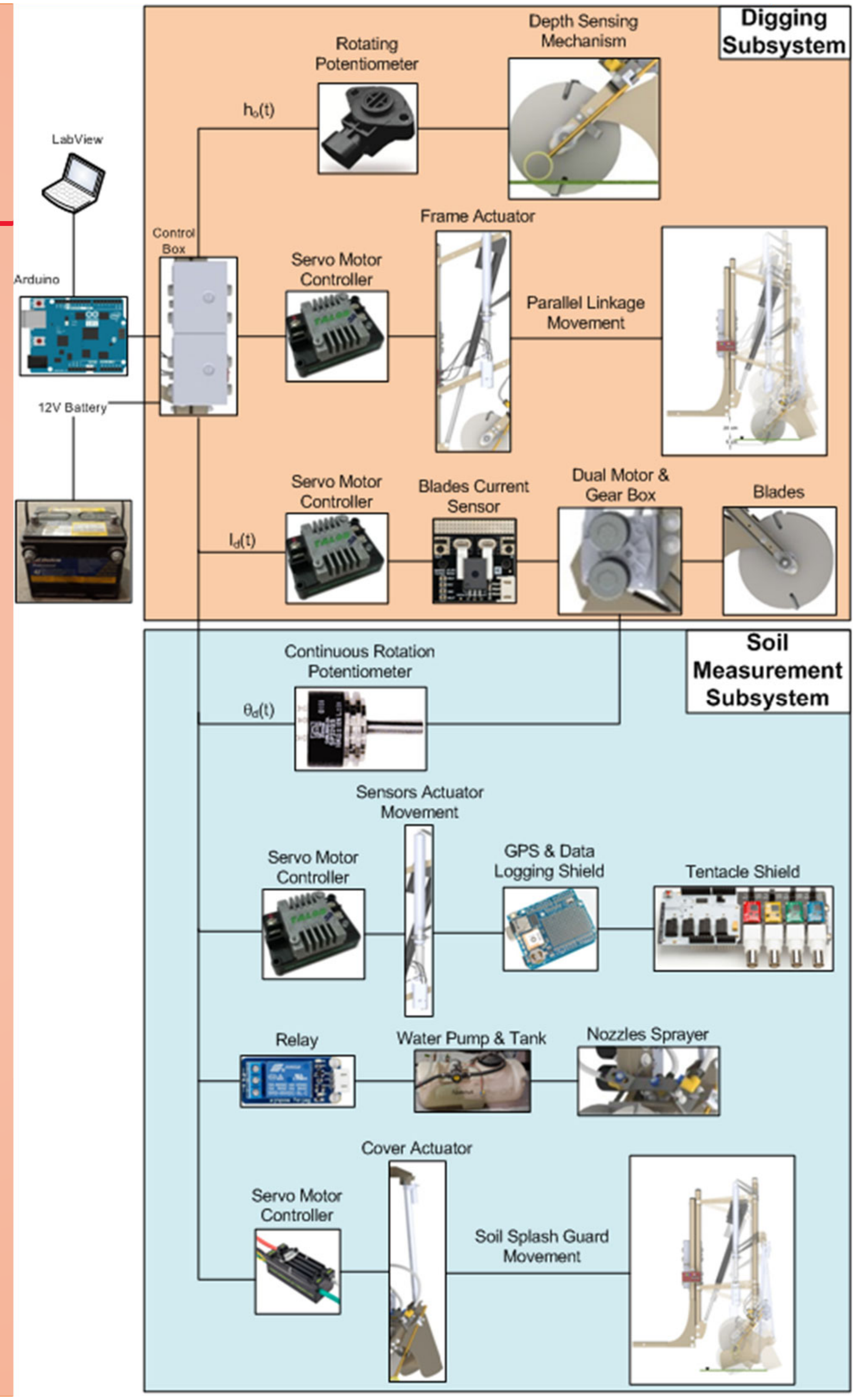


Fig. 2. The new OSA design

Methodology : OSA Control Design

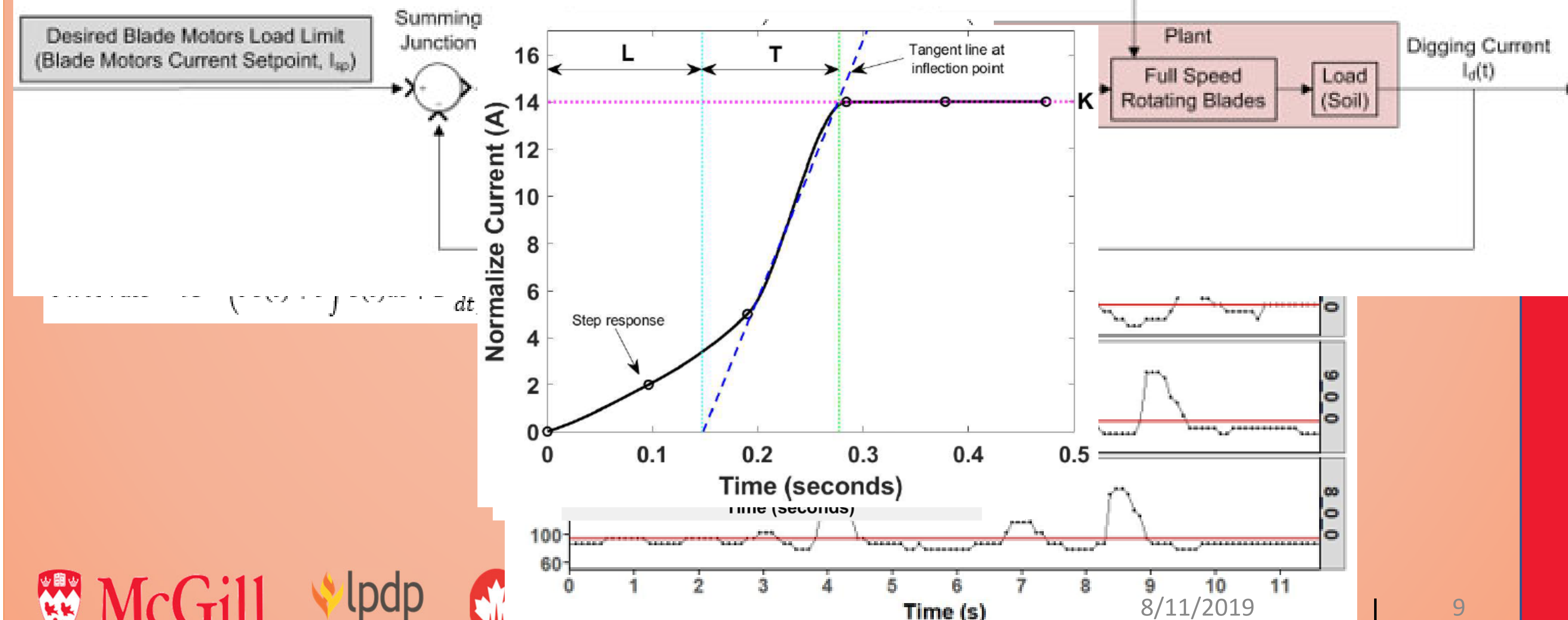
- Control Design Requirements:
  - Stop when desired digging depth reached
  - Cannot exceed the blade motor digging current setpoint
- Control Design Objectives:
  - Producing desired transient response (< 300ms)
  - Reducing steady-state error
  - Attain stability
- Focus on the digging control
  - Design and compare white-box vs. black-box PID control modelling



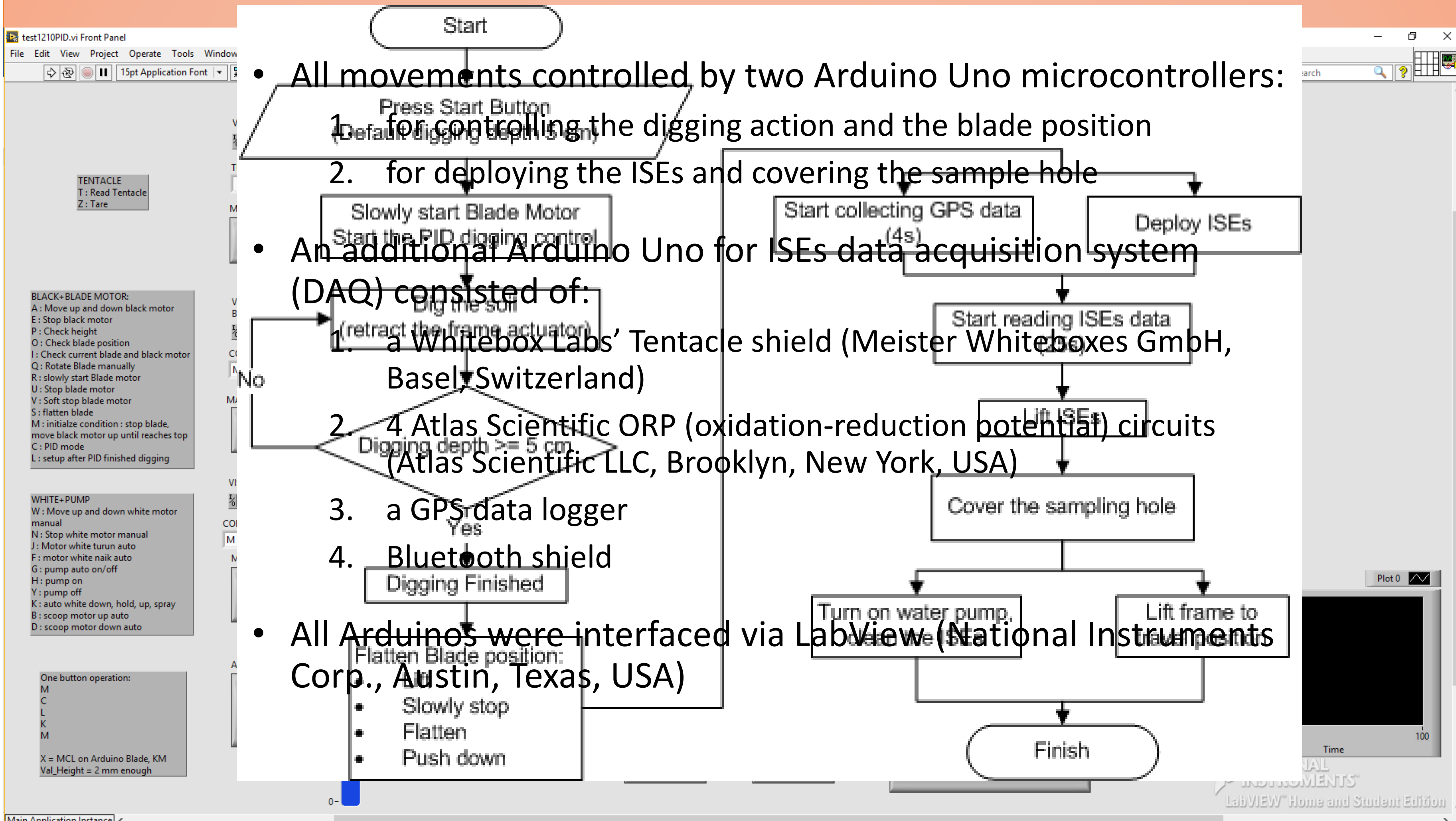
McGill lpdp lembaga pengelola dana pendidikan NSERC CRSNG

Methodology : OSA Digging Control

Method	P	I	D	N
White-Box Matlab Simulink® modelling	164.9	0	5.74	1915
Black-Box second-order system	4.7	0	0.07	-
Black-Box Ziegler-Nichols	1.12	3.73	0.08	-
Field Tuning	9	0	2	-



Methodology : OSA DAQ and GUI



- All movements controlled by two Arduino Uno microcontrollers:
  1. for controlling the digging action and the blade position
  2. for deploying the ISEs and covering the sample hole
- An additional Arduino Uno for ISEs data acquisition system (DAQ) consisted of:
  1. a Whitebox Labs' Tentacle shield (Meister Whiteboxes GmbH, Basel, Switzerland)
  2. 4 Atlas Scientific ORP (oxidation-reduction potential) circuits (Atlas Scientific LLC, Brooklyn, New York, USA)
  3. a GPS data logger
  4. Bluetooth shield
- All Arduinos were interfaced via LabView (National Instruments Corp., Austin, Texas, USA)

McGill lpdp lembaga pengelola dana pendidikan NSERC CRSNG

Methodology : Field Test

Sampling

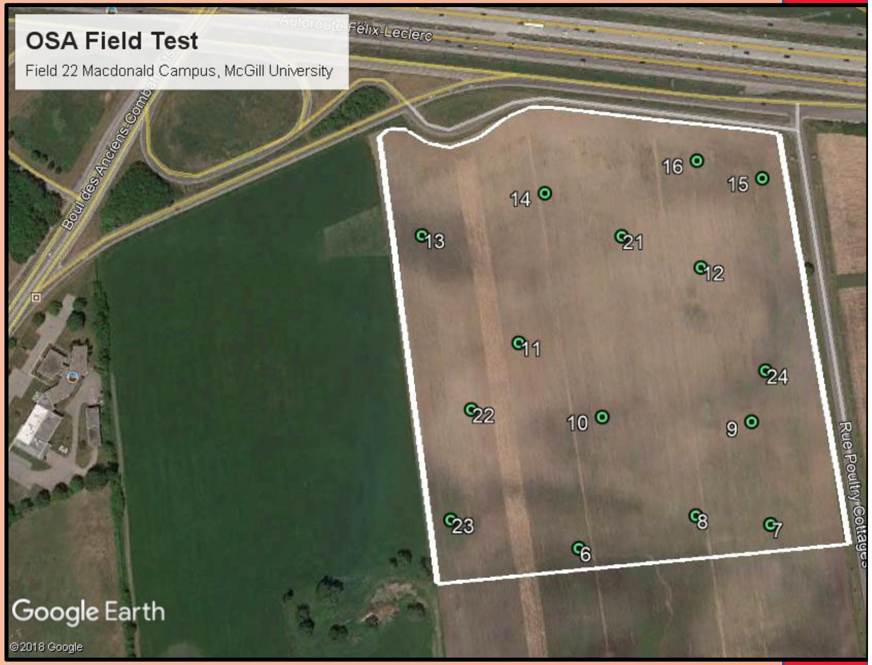
- Measure soil soluble nitrate, phosphate and pH
- 15 locations in a 12-ha sandy loam field in November 2018 a few days after soybean harvesting

Calibration

- Soil soluble nitrate (2M KCl ext.) and orthophosphate (Mehlich 3 ext.): using Lachat QuikChem® 8500 FIA+ (Lachat Instruments, Milwaukee, Wisconsin, USA)
- Soil pH 1:1 using glass pH combination ISE

Data filtering

- Questionable soil-ISE contact and/or inefficient ISE cleaning) were removed from the dataset



Results

covering sampling hole

Fig. 5. The USA field operation

Results

- Digging <10 s on average
- 60 s to complete entire operation
- Spike current → impact with compacted soil or with stone
- Oscillating digging action → slow blade motor current sensor acquisition speed (84 ms)
- Robust control system:
  - able to limit the maximum digging load to less than 30 A
  - provide a decent response

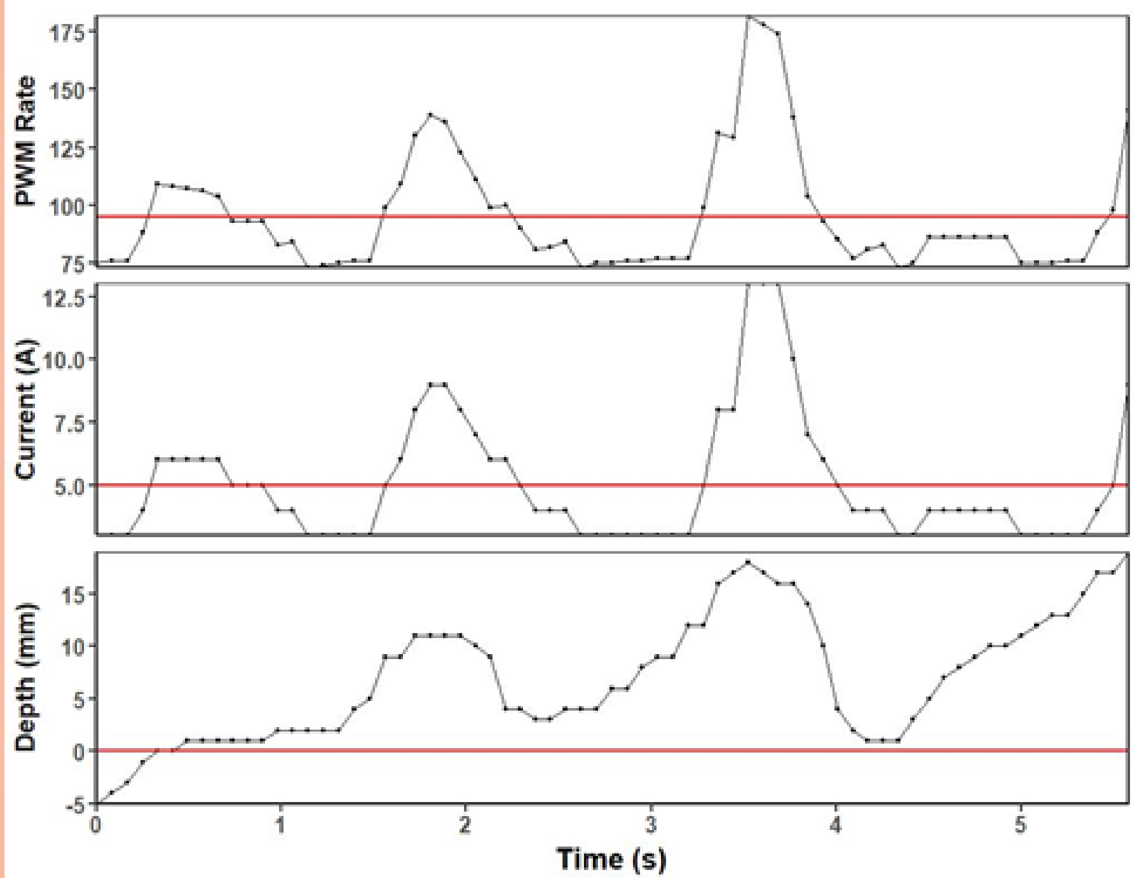


Fig. 6. Typical OSA digging control output

Results

- Sand particles stuck t
glass pH ISE → break
glass membrane
- The Sb ISE performed
sufficiently (R^2 = 0.55
- Nitrate and Phospha
did not show strong
correlation :
  - Relatively low ion
  - No chemical ion
  extraction took pla
  the field (DSM vs l
- Future testing is sche
to cover greater rang
field conditions

McGill lpdp lembaga pengelola dana pendidikan NSERC CRSNG

Conclusion

- The optimized OSA successfully conducted the DSM of multiple soil chemical properties
- The digging control was able to manage the digging load
- Average digging time was <10 s at 2-cm depth, 60 s to complete whole operation
- The Sb pH ISE was able to predict soil pH with R^2 of 0.55
- Future testing is scheduled to cover greater range of field conditions

Acknowledgement

This research was supported in part by funds from Indonesia Endowment Fund for Education (LPDP) and the National Science and Engineering Research of Canada (NSERC) Discovery Grant

lembaga pengelola dana pendidikan

Thank You!