

GROVER: An Autonomous Vehicle for Ice Sheet Research

April 17, 2014

Introduction

What is GROVER?

- ▶ Goddard Remotely Operated Vehicle for Exploration and Research
- ▶ Developed closely with **Lora Koenig**



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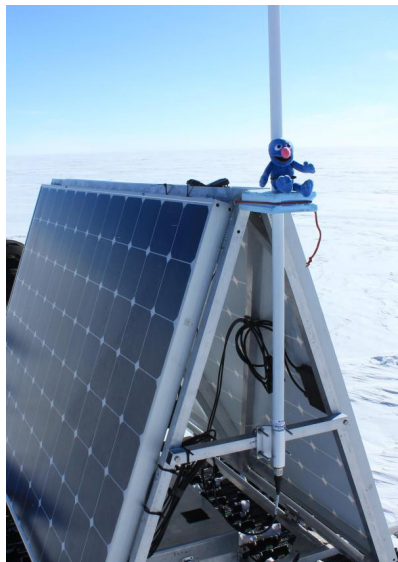


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Sesame Workshop

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- ▶ Controlled via **satellite** or line-of-sight **radio** (WiFi)



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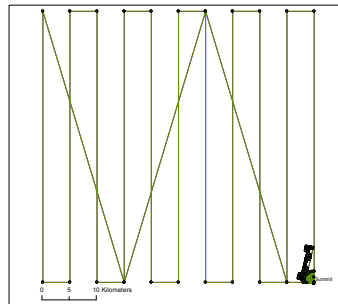
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- ▶ Controlled via **satellite** or line-of-sight **radio** (WiFi)
- ▶ Tested in the field in May/June 2013

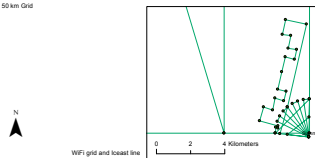


Original Mission

- ▶ Demonstrate that it could:
 - ▶ Operate 24/7, in harsh environment
 - ▶ Complete track within **two weeks**



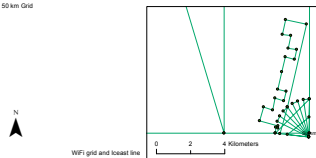
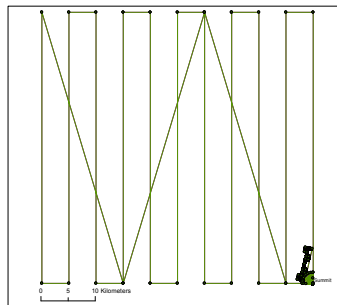
50 km Grid



WF1 grid and least line

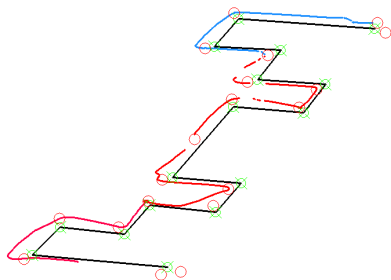
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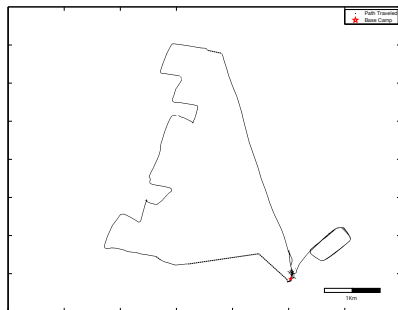
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 - ▶ Go over same point to maximize crossover
- ▶ Successfully completed stage 2
- ▶ Performed additional power failure tests



Hardware

Requirements

- Zero emissions vehicle



Hardware

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- Running 24/7



Hardware

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- Running 24/7
- Operational in the **extreme cold**

- ▶ High efficiency **solar** panels
(300W, 20%)



Hardware

Requirements

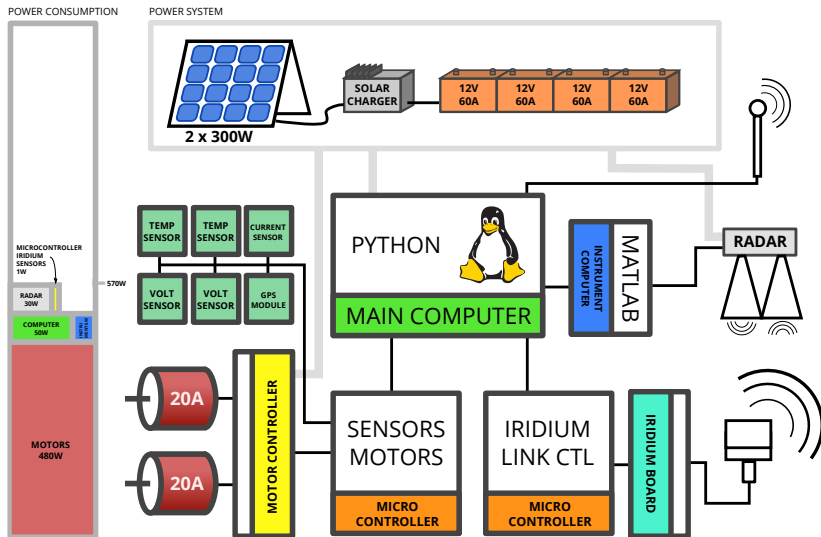
- Zero emissions vehicle
- Running 24/7
- Operational in the **extreme cold**

- ▶ High efficiency **solar** panels (300W, 20%)
- ▶ Constant sensor monitoring
 - ▶ GPS
 - ▶ 2 × Temperature
 - ▶ 2 × Voltage
 - ▶ 1 × Current

- ▶ Two 20 Amp motors, travel over powder and **sastrugi**

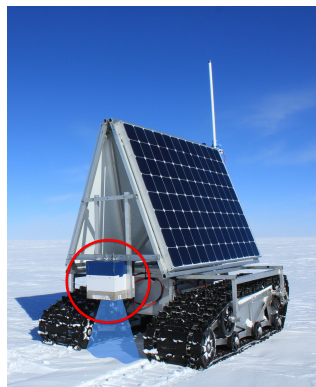


Hardware



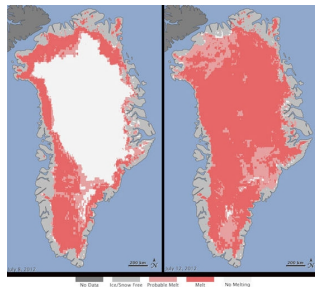
Instrument

- ▶ FMCW radar, low-power
- ▶ 4GHz - 10GHz
- ▶ Footprint between tracks



Instrument

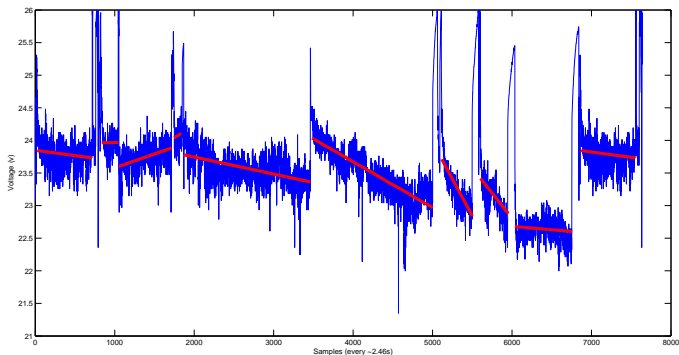
- ▶ FMCW radar, low-power
- ▶ 4GHz - 10GHz
- ▶ Footprint between tracks
- ▶ Ice layer present between 50cm-100cm



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Power Consumption

- ▶ Autonomy of 6 hours (14Km) recharges in 6 hours.
- ▶ Total power consumption 570W
- ▶ Can power on-board or external instruments



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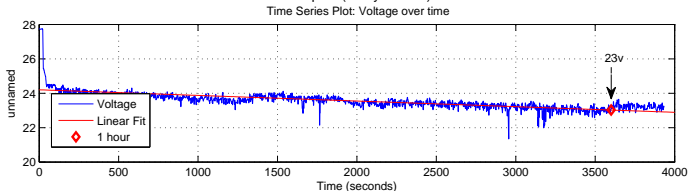
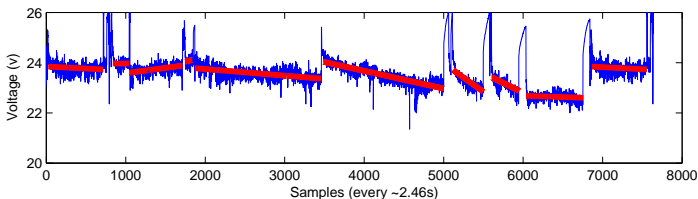
Sensor malfunction (disclaimer)

- ▶ Current sensor failed within 48 hours
- ▶ Had no replacement
- ▶ Took us days to figure it out
- ▶ Computer battery failed as well

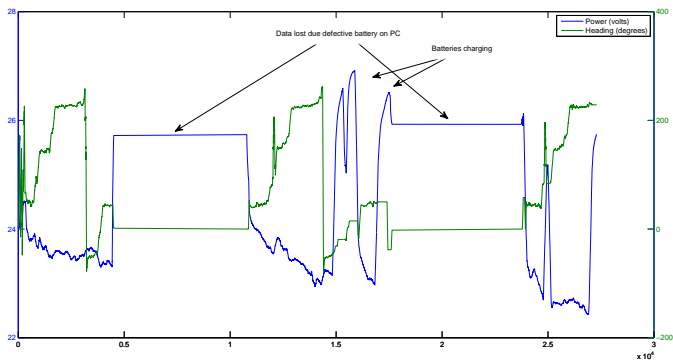


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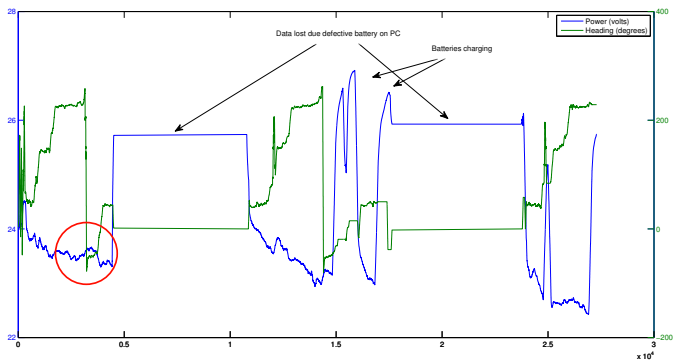
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Hardware



Hardware



Software

- ▶ Designed to be used in many applications

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from grover.core.configurationloader import ConfigurationLoader
from grover.core.message import Message
from grover.core.messagemanagers.basemessagemanager import BaseMessageManager
from grover.core.messagemanagers.messagemanager import MessageManager
from socket import socket as Socket
from threading import Thread
from util.logger import Logger
import random
import select
import socket as SocketPkg
import time

```

```

class NetworkMessageManager(BaseMessageManager):

```

```

    def __init__(self, connect_to=None):
        super(NetworkMessageManager, self).__init__()

        self.name = "NetworkMessageManager"
        self.sender_name = self.name+str(random.randint(0, 999))
        self.domain = "#"Domain"+str(random.randint(0, 999))

        Logger.log_red(self.name, "Domain Name: {}".format(self.domain))

        self.connect_to = connect_to
        self.connection_threads = []

        self.connected = False

        Logger.log_gray(self.name, "Initializing...")

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Software

- ▶ Designed to be used in many applications
- ▶ **Publisher/Subscriber** design pattern

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Software

- ▶ Designed to be used in many applications
- ▶ **Publisher/Subscriber** design pattern
- ▶ Written in **Python**
 - ▶ `gpscomponent.py`
 - ▶ `headingcomponent.py`
 - ▶ `iridiumcomponent.py`
 - ▶ `motorcomponent.py`
 - ▶ `navigationcomponent.py`
 - ▶ `radarcomputercomponent.py`
 - ▶ `telemetrycomponent.py`

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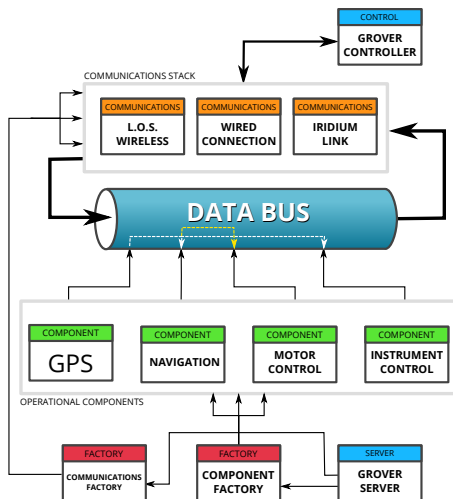
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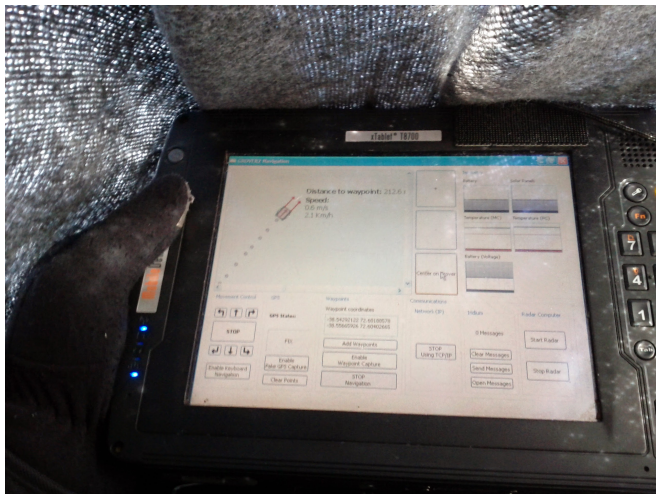
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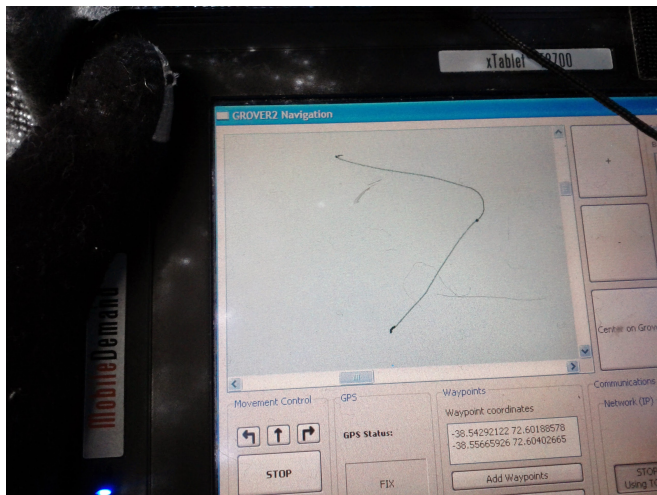
Software



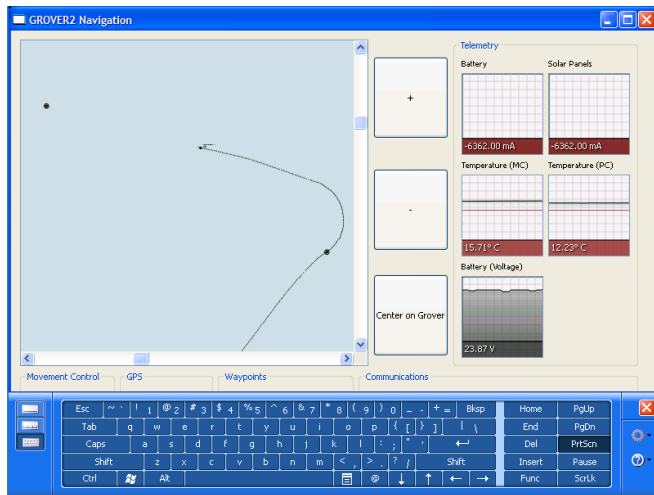
GUI



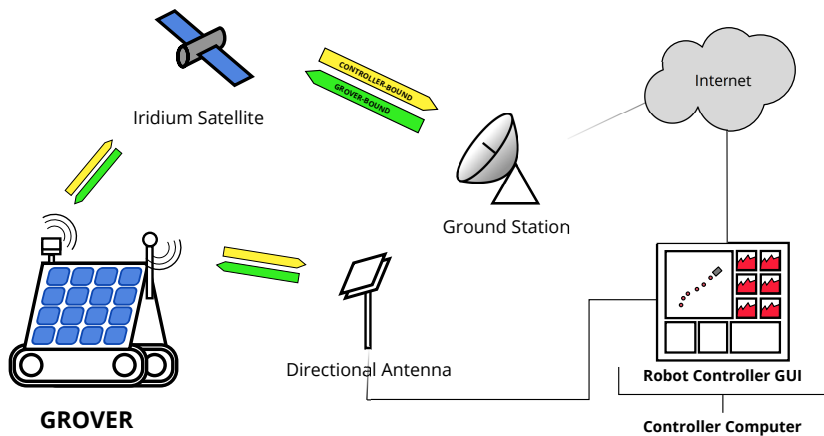
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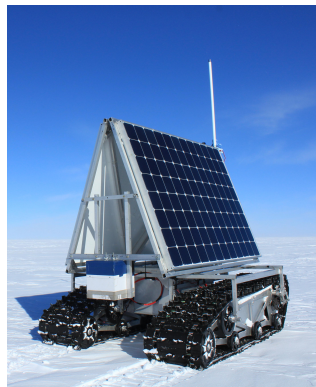


Communications



Field Performance

- ▶ Collected **20GB** of data



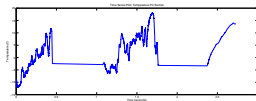
Field Performance

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- ▶ Covered **30+ Km**



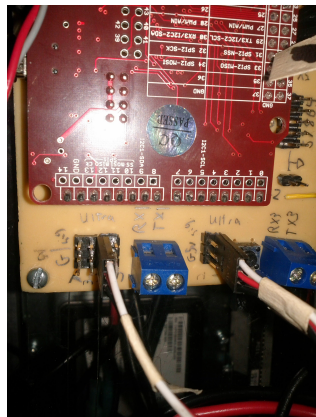
Field Performance

- ▶ Collected **20GB** of data
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Field Performance

- ▶ Collected **20GB** of data
- ▶ Covered **30+ Km**
- ▶ Found that temperature didn't affect performance
- ▶ Simple engineering mistakes were very expensive
- ▶ yet...



Conclusion

- ▶ GROVER demonstrates that autonomous rovers can be a **revolutionary** tool in polar research



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- ▶ GROVER demonstrates that autonomous rovers can be a **revolutionary** tool in polar research
- ▶ The technology and the software are **available and ready** to be implemented
- ▶ Exciting new opportunities using this platform for scientific data collection.



Future/Current Work

- ▶ Working with **Alberto Behar**
- ▶ Bigger/better solar panels
- ▶ **Redundancy** in sensors
- ▶ Rewiring electrical systems
- ▶ Optimize travel path to maximize **exposure** to the Sun
- ▶ Add visual indicators to facilitate the localization of the robot in **poor visibility** conditions



Conclusion

References

Gary Koh, James H. Lever, Steven A. Arcone, Hans-Peter Marshall, and Laura E. Ray. "Autonomous FMCW Radar Survey of Antarctic Shear Zone" 13th International Conference on Ground Penetrating Radar (2010): 1-5.

J.H. Lever and L.R. Ray, *Revised Solar-Power Budget for Cool Robot Polar Science Campaigns*, Cold Regions Science and Technology, 52(2), (2008): 177-190.

C.M. Gifford, E.L. Akers, R.S. Stansbury, and A. Agah, "Mobile Robots for Polar Remote Sensing," In Guarav S. Sukhatme (Ed.), *The Path to Autonomous Robots*, Springer-Verlag, Heidelberg, Germany, (2009): 1-22.

Acknowledgements

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CH2M HILL Polar Field Services Logistics support and invaluable help in the field

NASA's Engineering Bootcamp Michael Comberiate and students who prototyped and built GROVER

Contact Information

► gabrieltrisca@boisestate.edu



