2010 Robotic Follow-up Field Test

Haughton Crater, Devon Island, Canada

http://lunarscience.nasa.gov/robots

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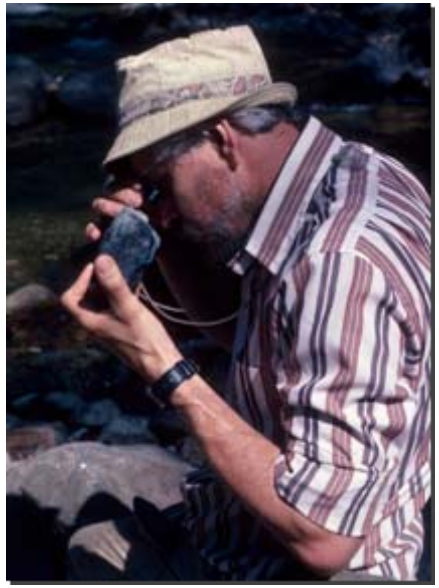
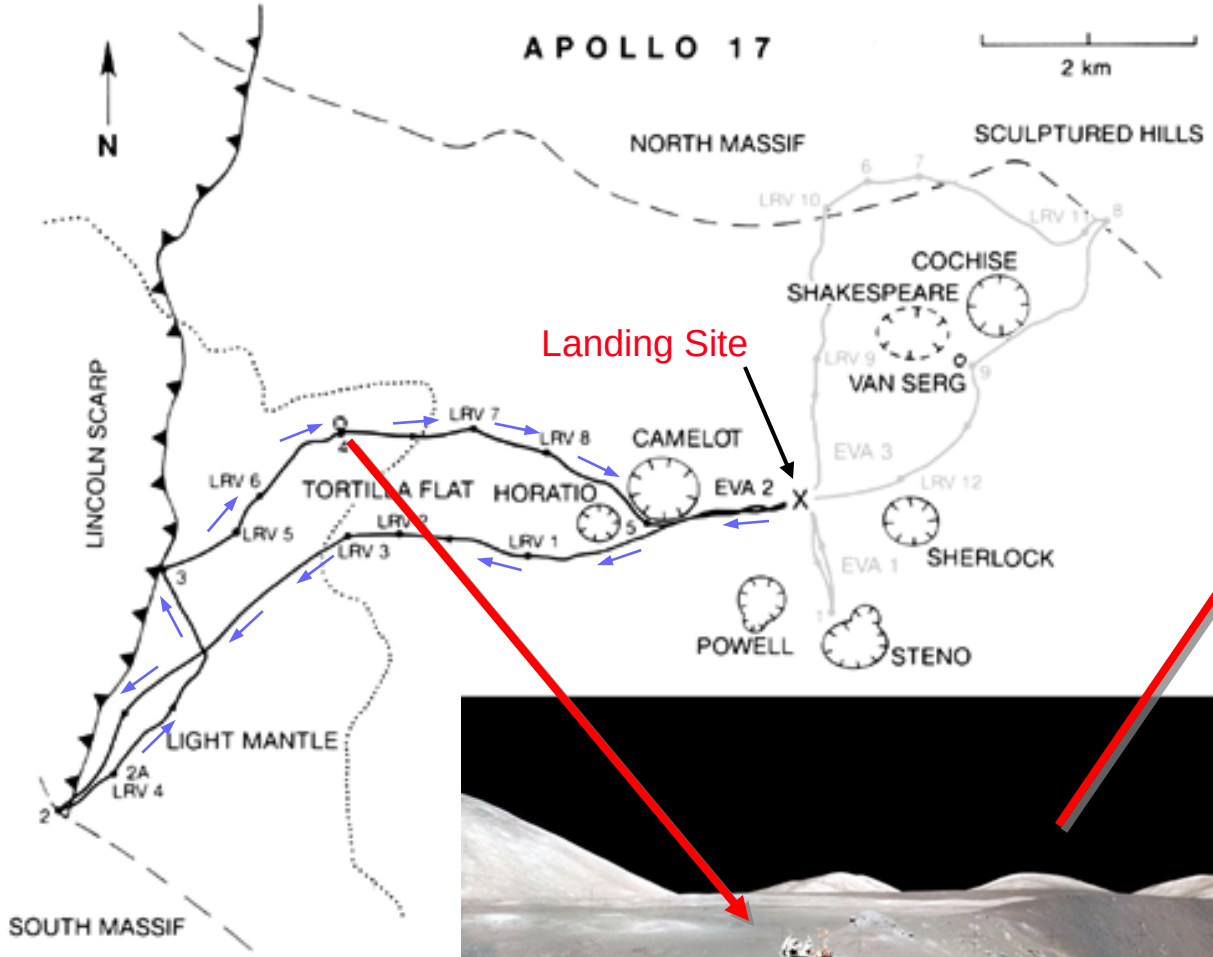
An Exploration Problem

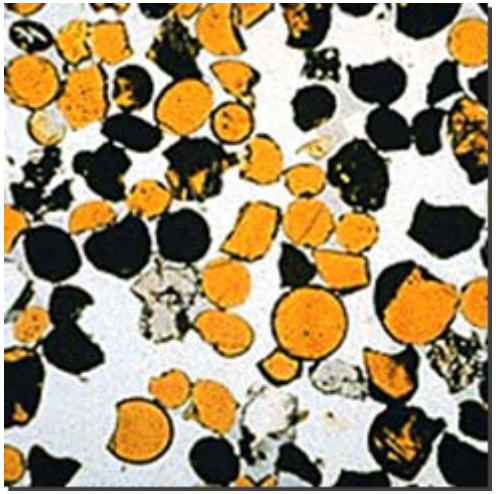
"If only I could have …"

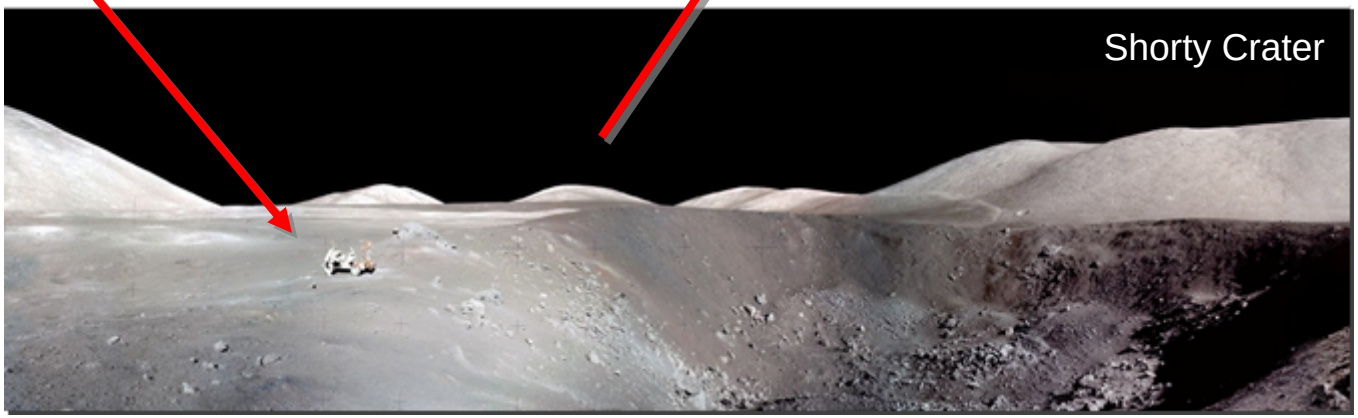
- Explorers often cannot do everything during a mission
  - More observations to make
  - More samples to collect
- Field geologists routinely face this problem on Earth
- The problem is worse in space or on other worlds
  - Limited work time & resources
  - High-risk environment
  - Extremely difficult to return



Case in Point: Apollo 17







Robotic Follow-up

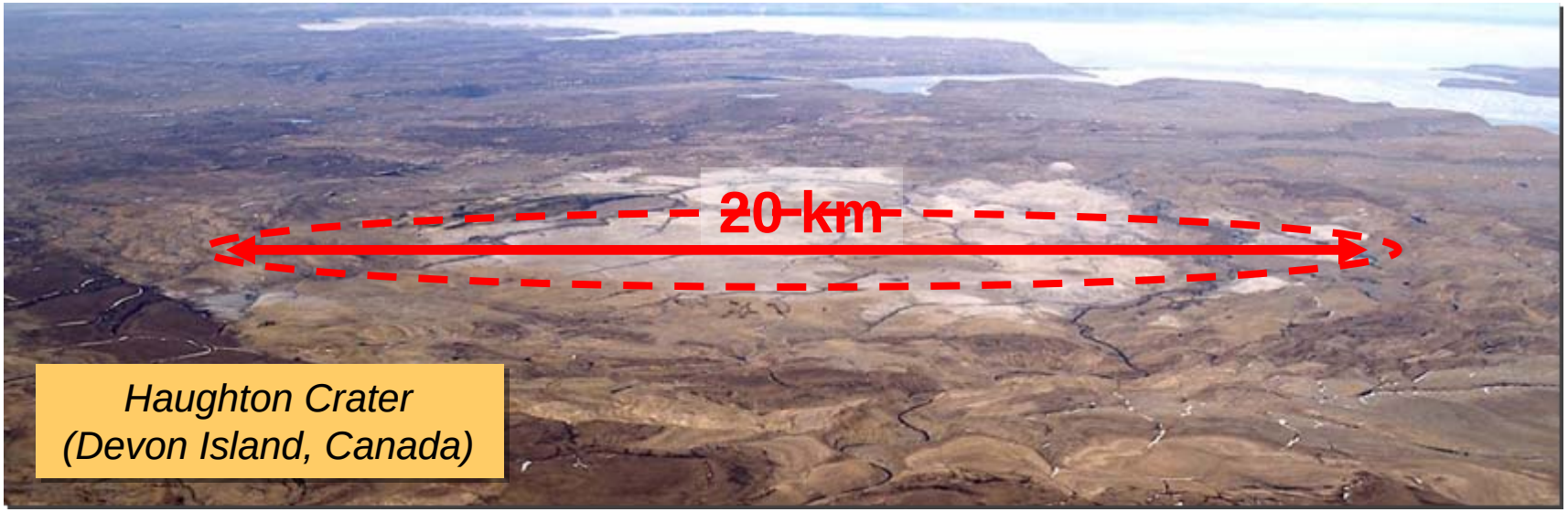
A new field exploration technique

- Augment human field work with subsequent robot activity
- Use robots for work that is tedious or unproductive for humans to do
- Collect supplementary and complementary data

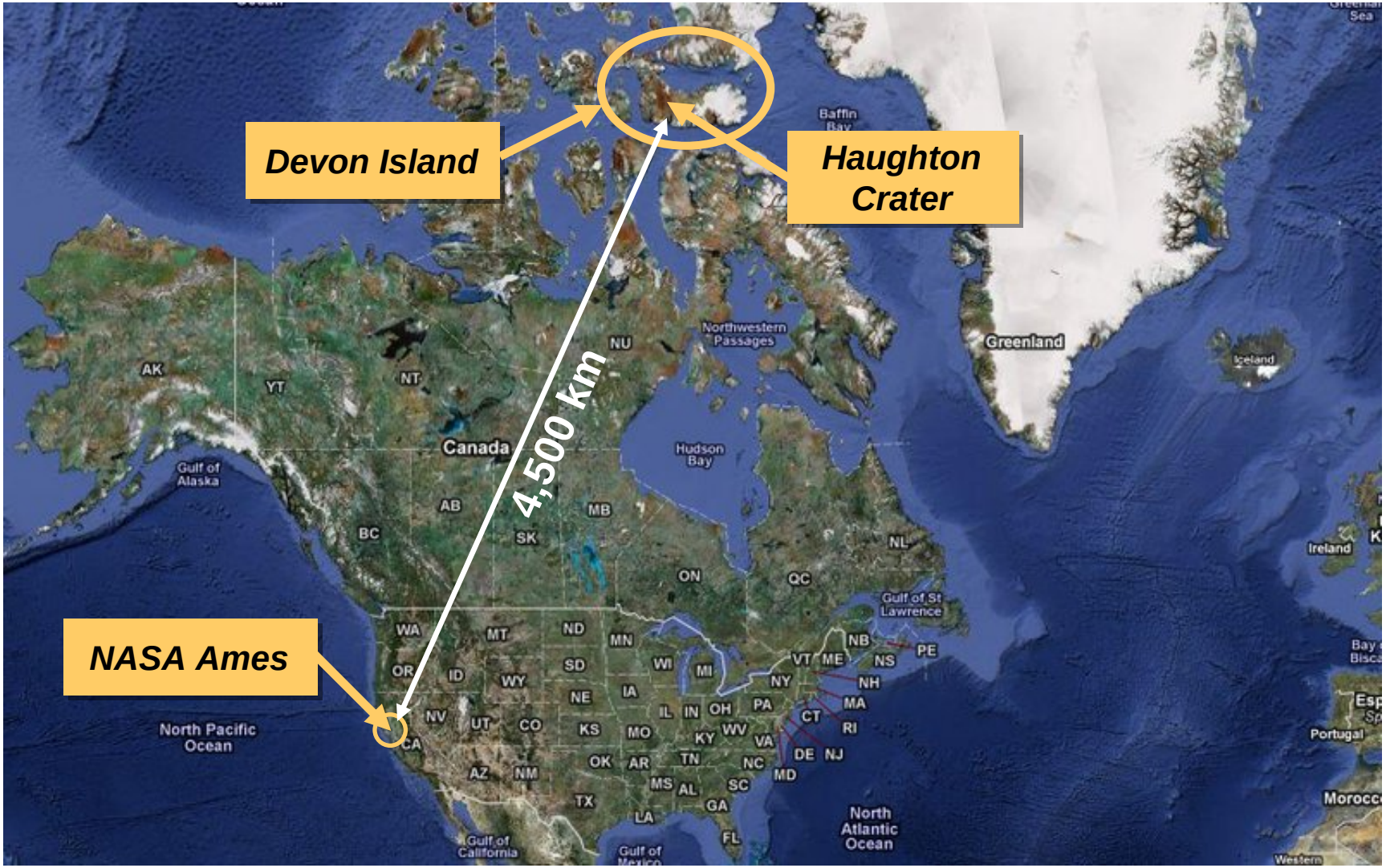
2010 Robotic Follow-up Field Test

July 12 – August 13, 2010

- Use robots to “follow-up” after humans
  - Geologic mapping & subsurface survey
  - K10 robots remotely operated from NASA Ames
  - Variety of sites in and around Haughton Crater
- Follows 2009 crew mission simulation (by Mark Helper, EssamHeggy& Pascal Lee)
- Funded by NASA MMAMA (SMD) & ETDP (ESMD)



Locations



Devon Island
Haughton Crater
NASA Ames
4,500 km
Baffin Bay
Northwestern Passages
Greenland
Iceland
Canada
Hudson Bay
Gulf of Alaska
Gulf of St Lawrence
Ireland
North Pacific Ocean
North Atlantic Ocean
Portugal
Gulf of California
Gulf of Mexico
AK
YT
NT
NU
AB
BC
SK
MB
ON
QC
NL
WA
MT
ND
MN
OR
ID
WY
SD
WI
MI
NE
IA
NV
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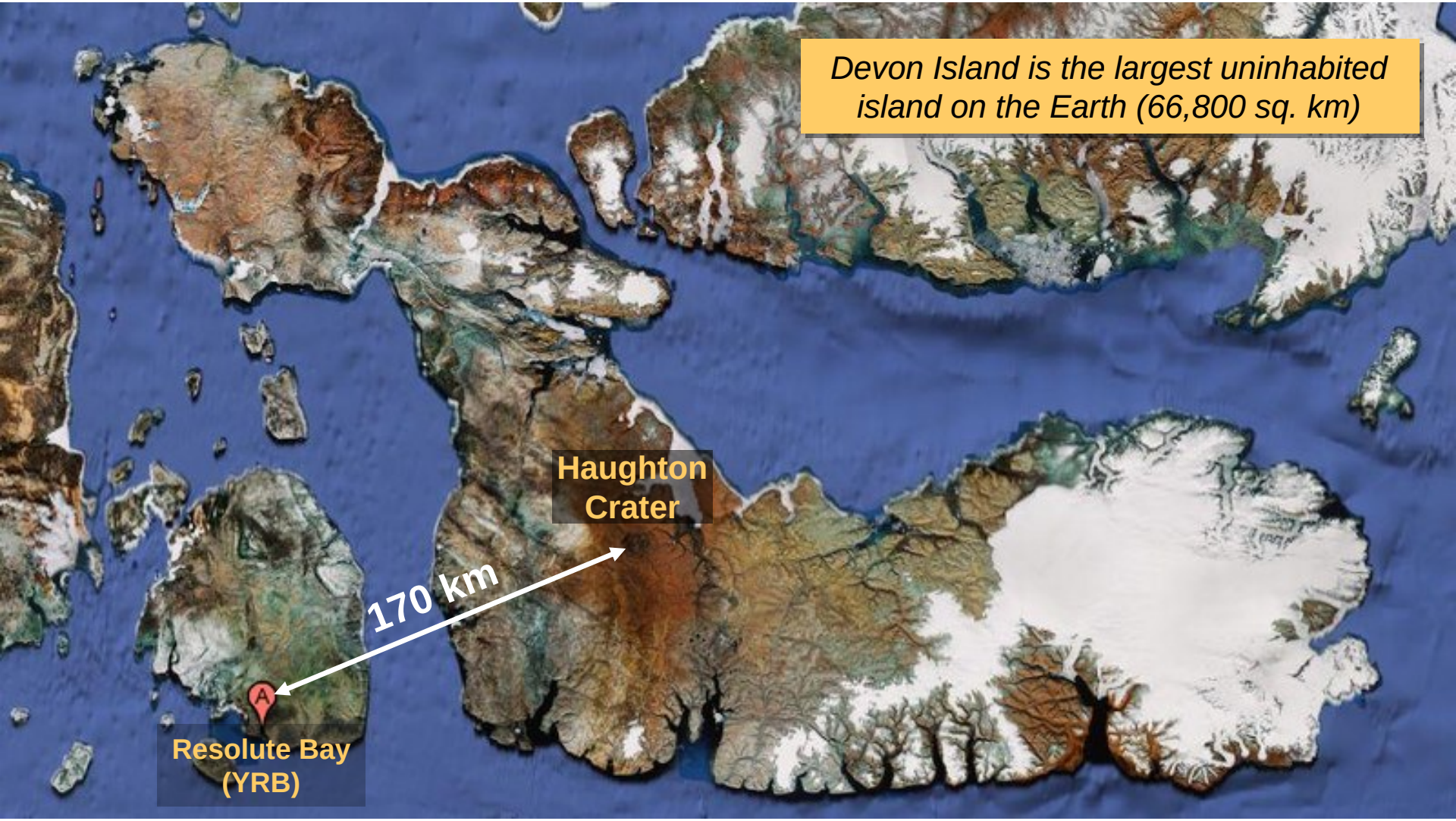
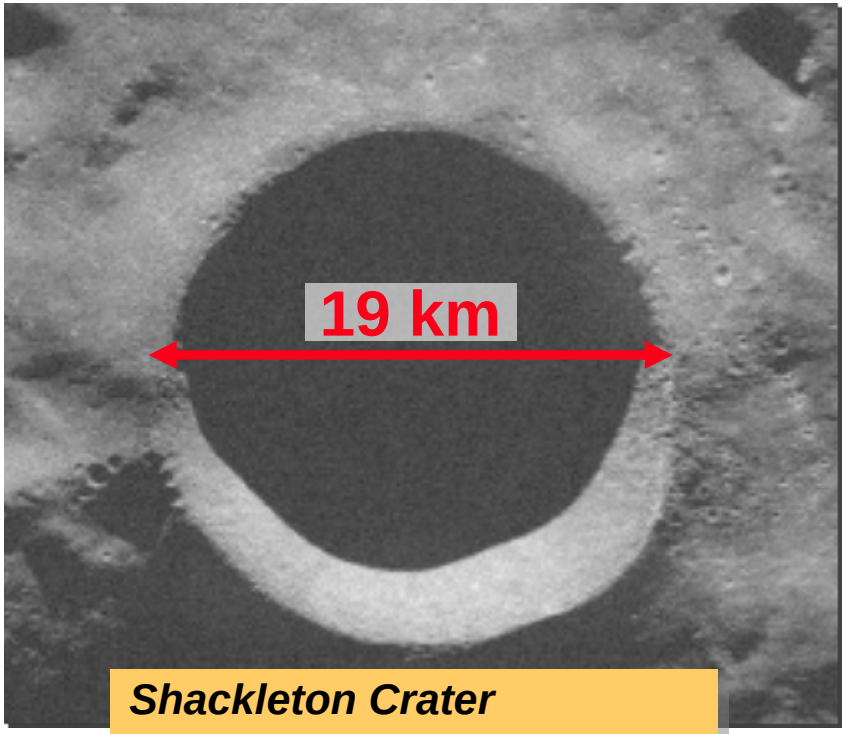
Devon Island

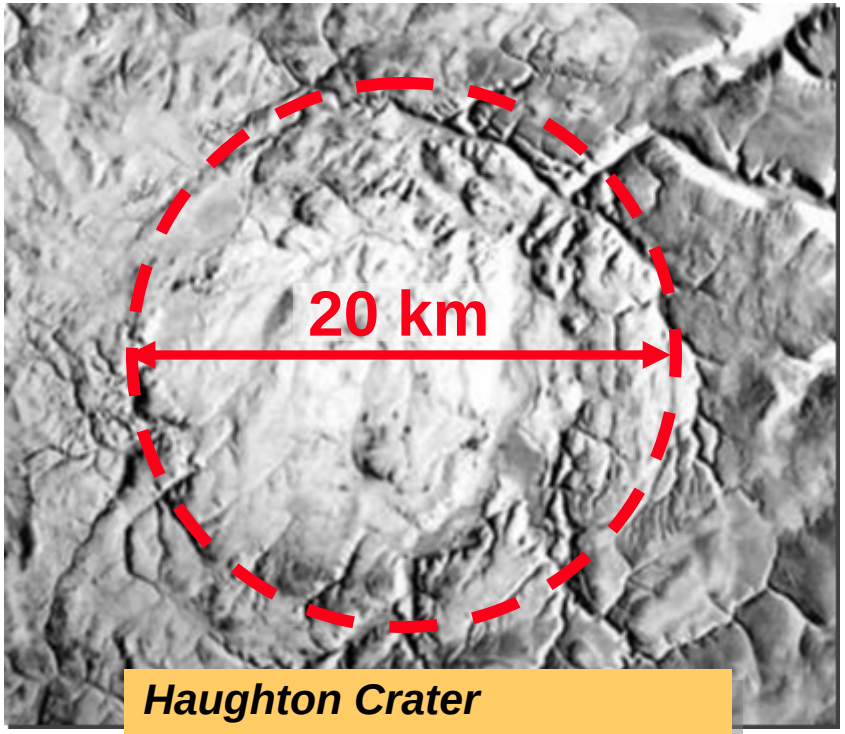


Haughton Crater: A Lunar Analog

Shackleton Crater at the South Pole of the Moon is 19 km in diameter and might present H_2O ice in surrounding shadowed zones. It is a prime candidate site for human exploration. Haughton Crater, also ~ 20 km in size, is by far the best preserved impact structure of its class on Earth and is located in a H_2O ground ice–rich rocky desert. Haughton may be the best overall ***scientific and operational analog for lunar craters such as Shackleton***.



Shackleton Crater
(lunar South Pole)
2005 Arecibo radar image



Haughton Crater
(Devon Island, Canada)
radar image

NASA “Robotic Follow-up” Project

Objectives

- Identify surface science scenarios for human explorers to draw maximum benefit from robotic follow-up to vehicular traverses &EVAs
- Identify science operations requirements for conducting robotic follow-up on planetary surfaces after human exploration
- Identify mission operations protocols for optimizing human field work and robotic follow-up activities

Simulated multi-mission campaign

	May 2009	Define science objectives
	June 2009	Plan crew mission #1
cycle 1	July 2009	Crew mission #1 (Mark Helper &EssamHeggy)
cycle 1	Oct 2009	Develop robotic follow-up #1
cycle 1	July 2010	Robotic follow-up #1
cycle 2	Aug 2010	Crew mission #2 (Kelsey Young)
cycle 2	Dec 2010	Develop robotic follow-up #2
cycle 2	July 2011	Robotic follow-up #2

Key Questions

Robotic rover

- How do we adapt follow-up work to specific sites, science and tasks?
- What scientific field work can be effectively performed by robots following humans?

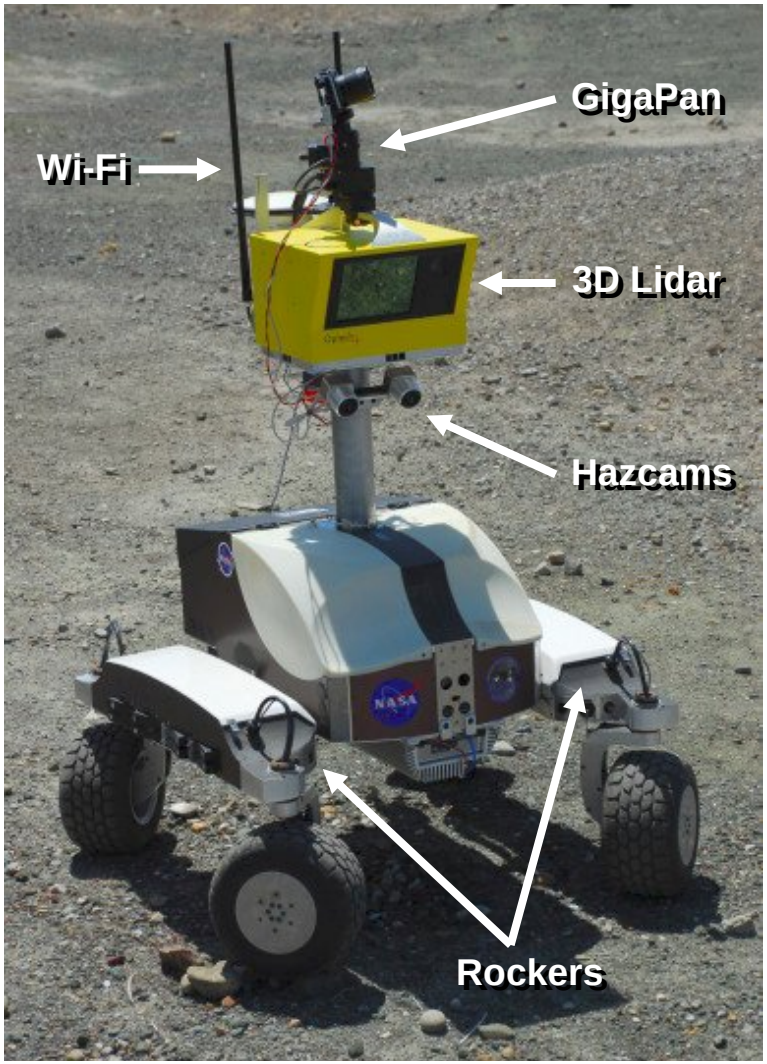
Ground control

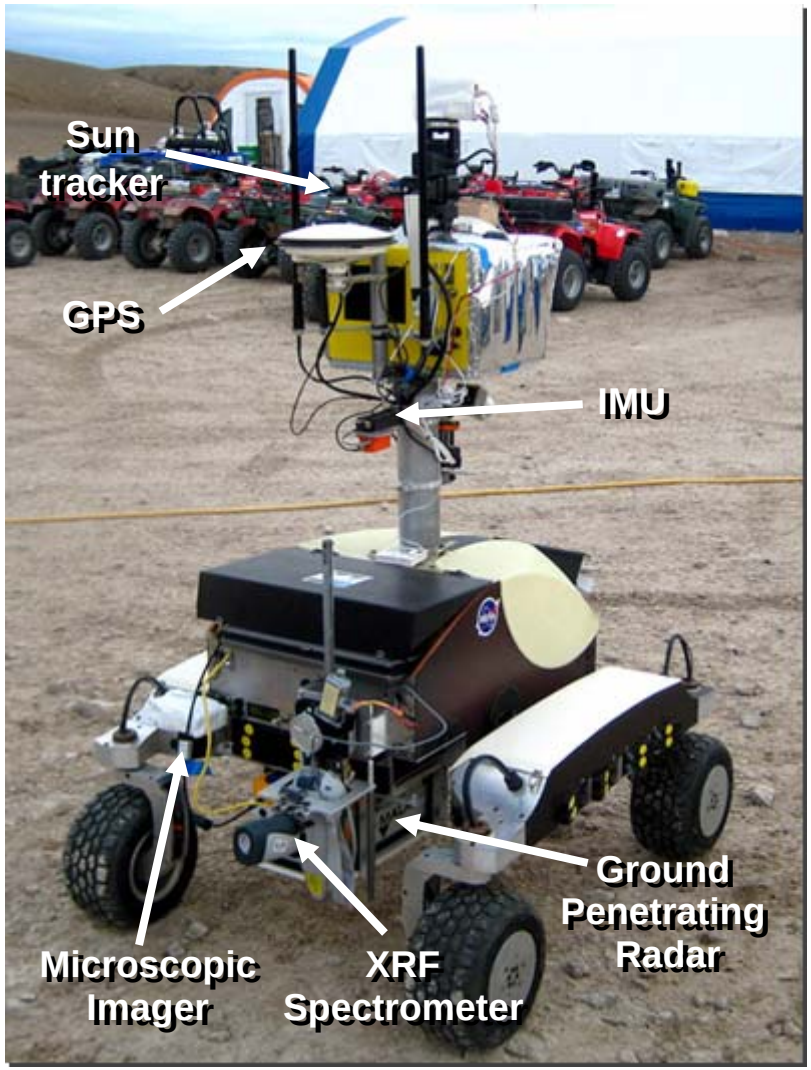
- What ground control structure (including science team) is needed to support robotic follow-up activities?
- How much time and resources are required for planning and executing a robotic follow-up mission?

Human-robot exploration

- How should robotic follow-up be incorporated into campaign planning?
- How can we optimize human productivity, given what robots can do afterwards?

K10 Robot


GigaPan
Wi-Fi
3D Lidar
Hazcams
Rockers


Sun tracker
GPS
IMU
Ground Penetrating Radar
Microscopic Imager
XRF Spectrometer

K10 Instruments (1)

3D Scanning Lidar

- Optech ILRIS-3D
- 3D topography measurements
- 5mm @ 500m

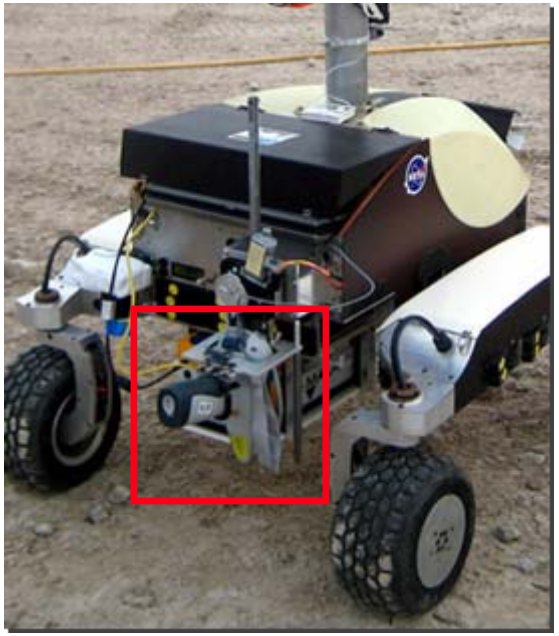
GigaPan (Pancam)

- Canon G9 + pan-tilt
- Oblique, wide-angle, color, context views
- 60x180 deg

Microscopic Imager (MI)

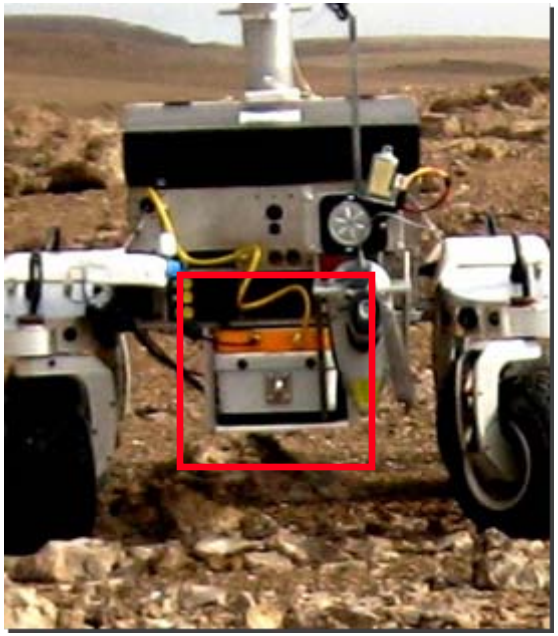
- Canon G9
- High-res, close-up, color, terrain views
- 33 micron / pixel

K10 Instruments (2)



XRF Spectrometer

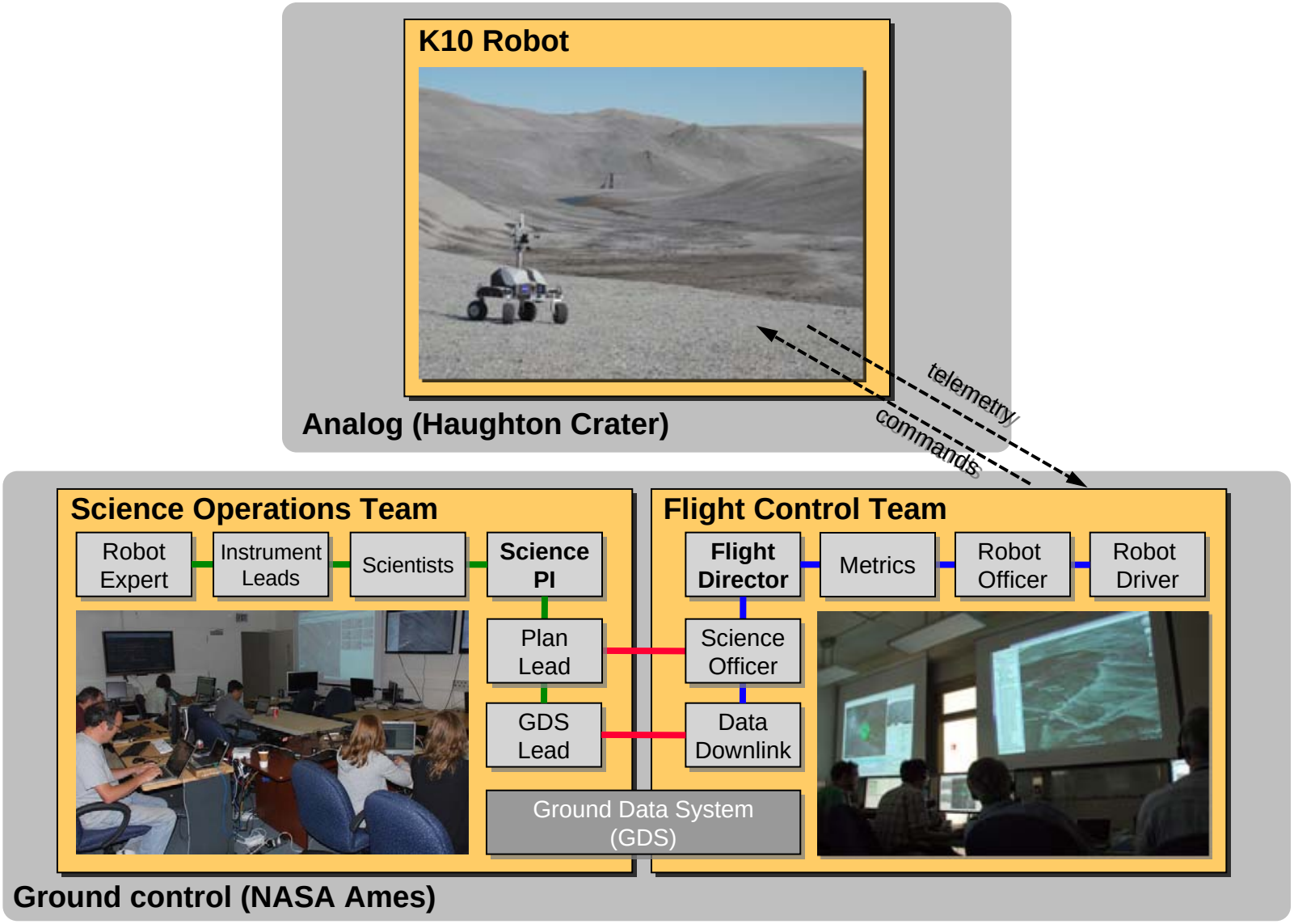
- Niton XL3t 900
- Bulk analysis of geologic materials
- Identify light elements



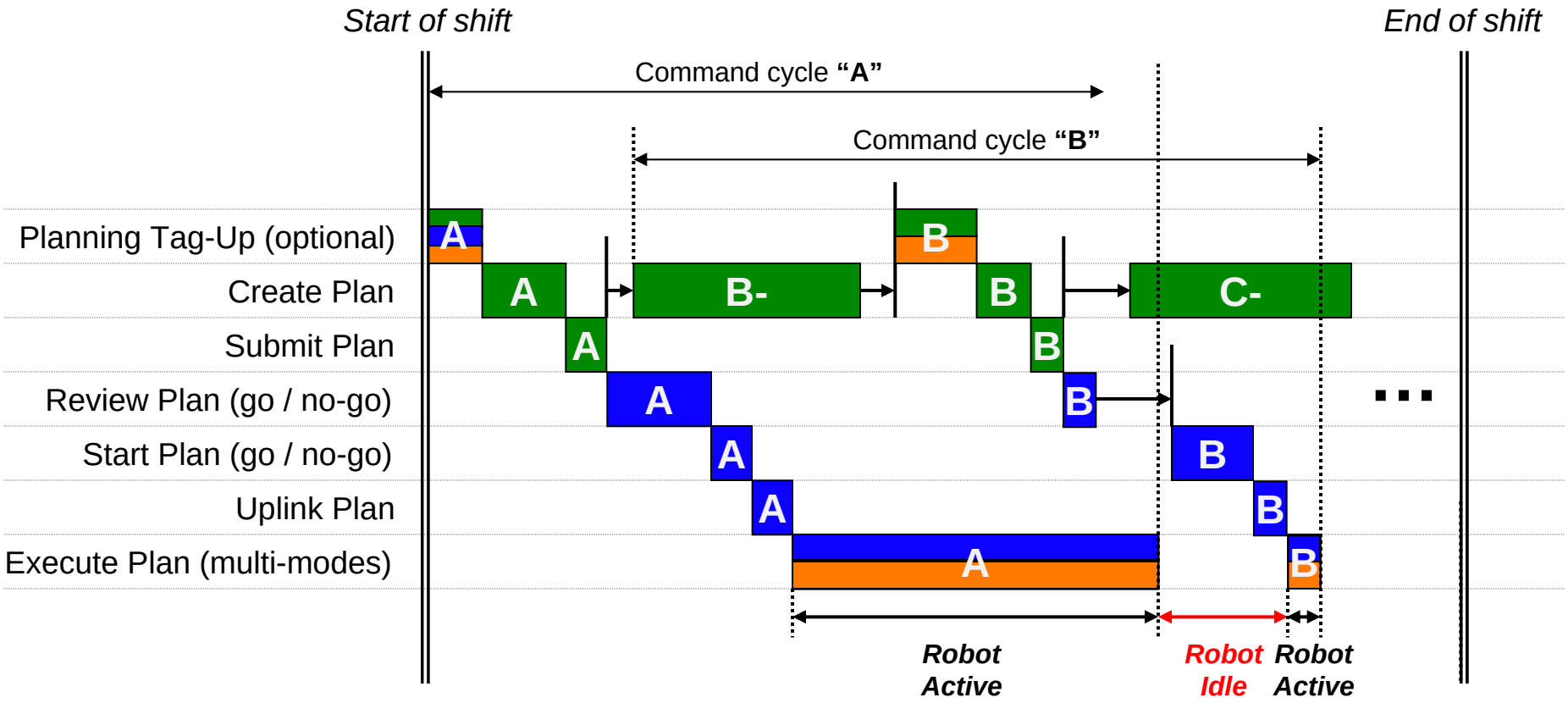
Ground-penetrating radar

- Mala X3M
- 800 MHz antenna
- Suitable for shallow depth mapping

Ground Control Structure



Operations Timeline

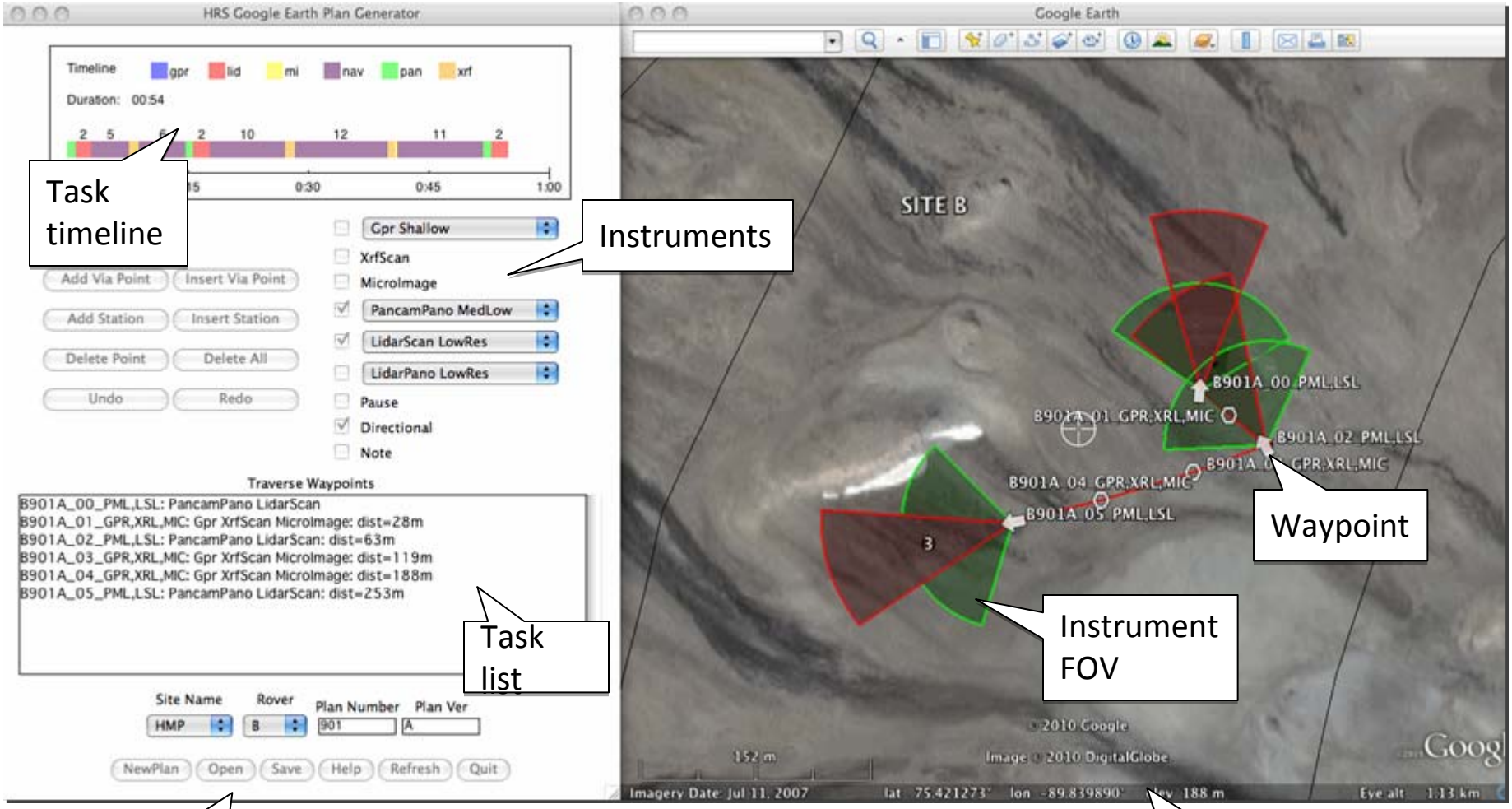


Science Operations Team

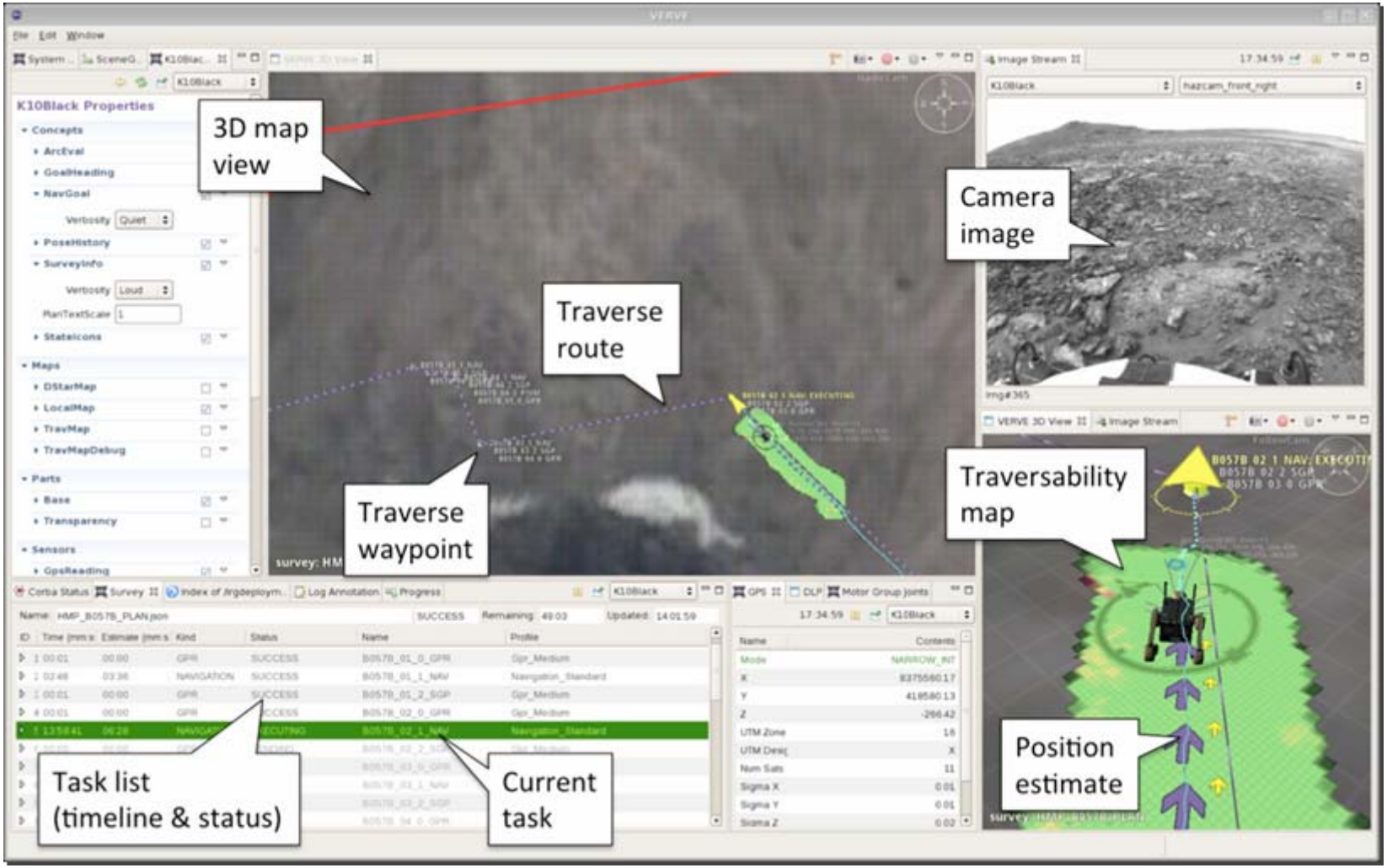
Flight Control Team

Robot Operations Team

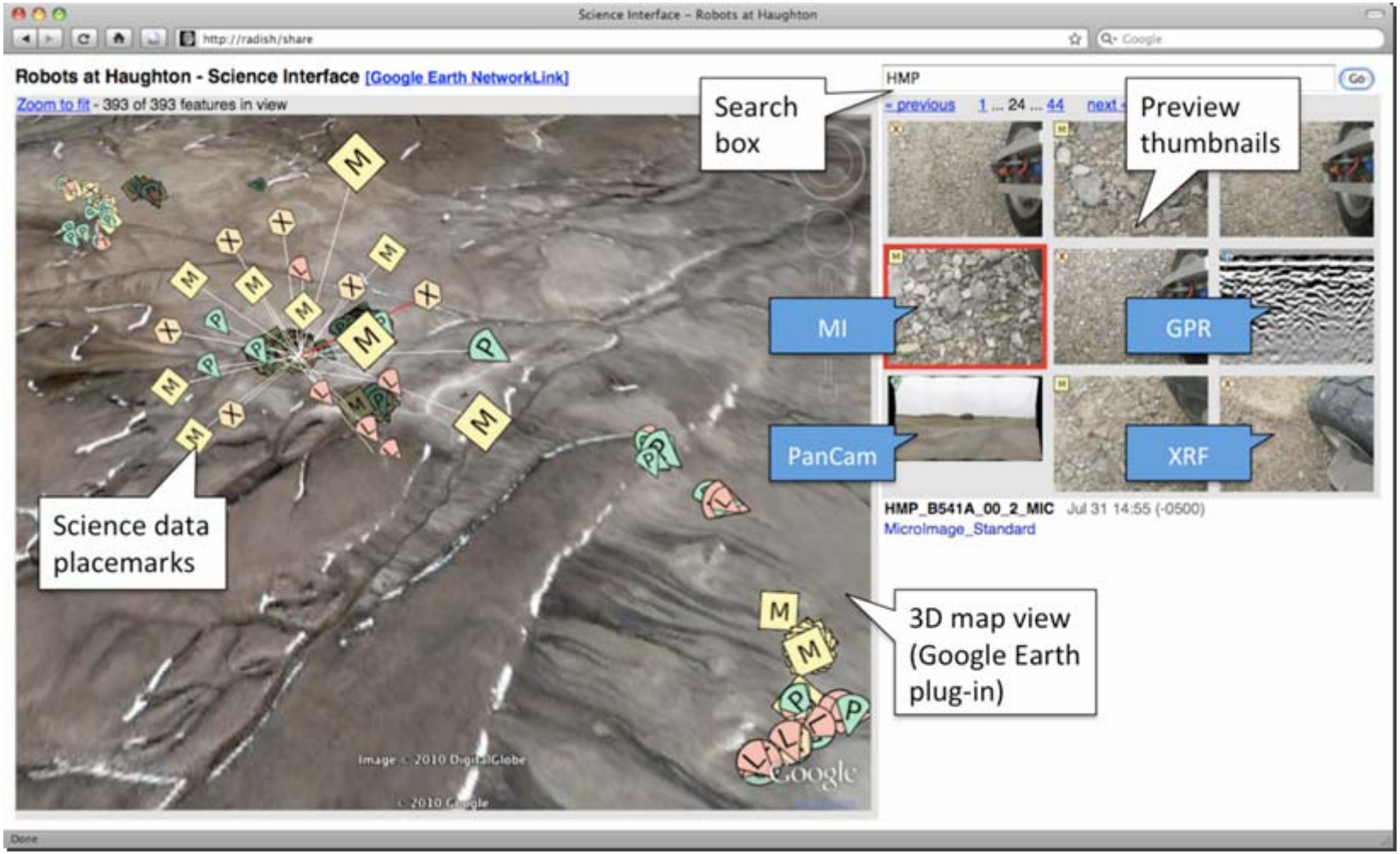
Google Earth Ops (GEOps)



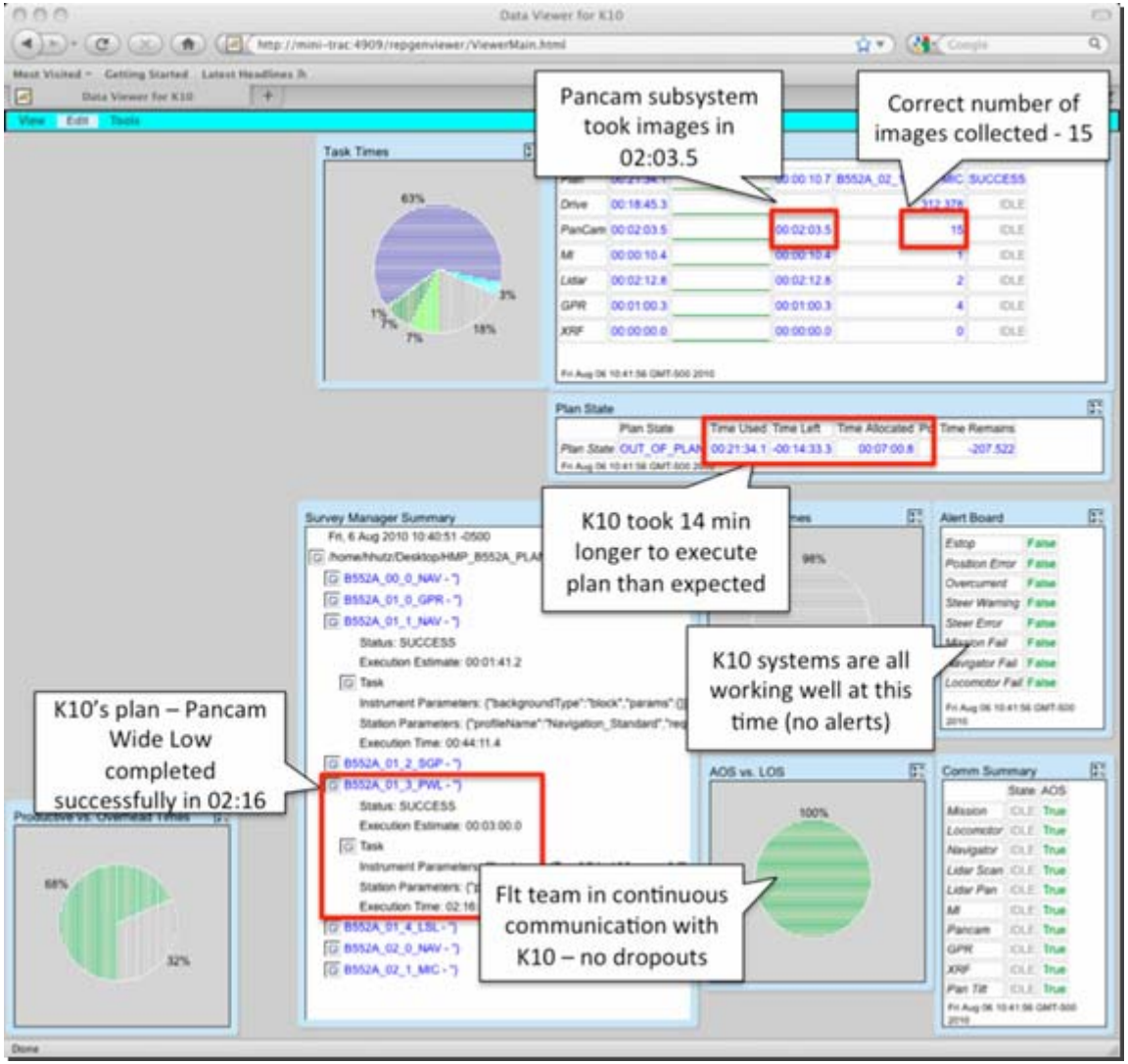
VERVE


3D map view
Camera image
Traverse route
Traverse waypoint
Traversability map
Position estimate
Task list (timeline & status)
Current task

Science Data Interface



Performance Monitoring



Crew Mission (2009)

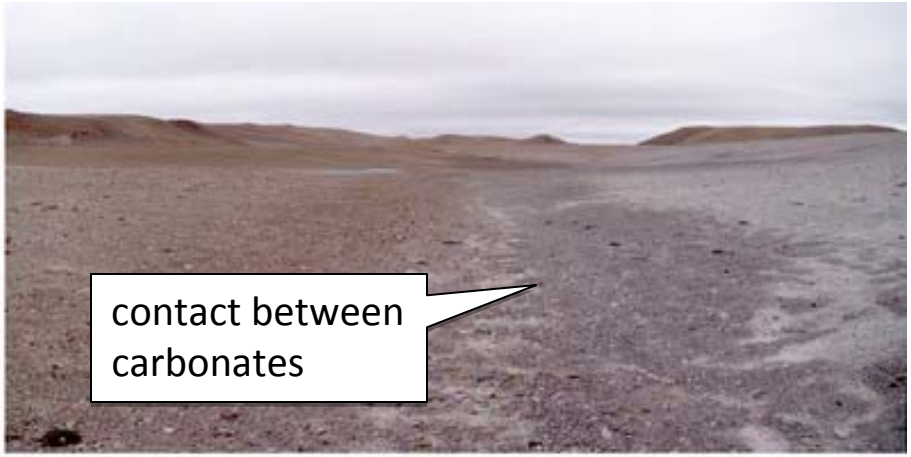
Geologic Mapping

- Document geologic history, structural geometry & major units
- Example impact breccia&clasts
- Take photos & collect samples

Geophysical Survey

- Examine subsurface structure
- 3D distribution of buried ground ice in permafrost layer
- Ground-penetrating radar: manual deploy, 400/900 MHz

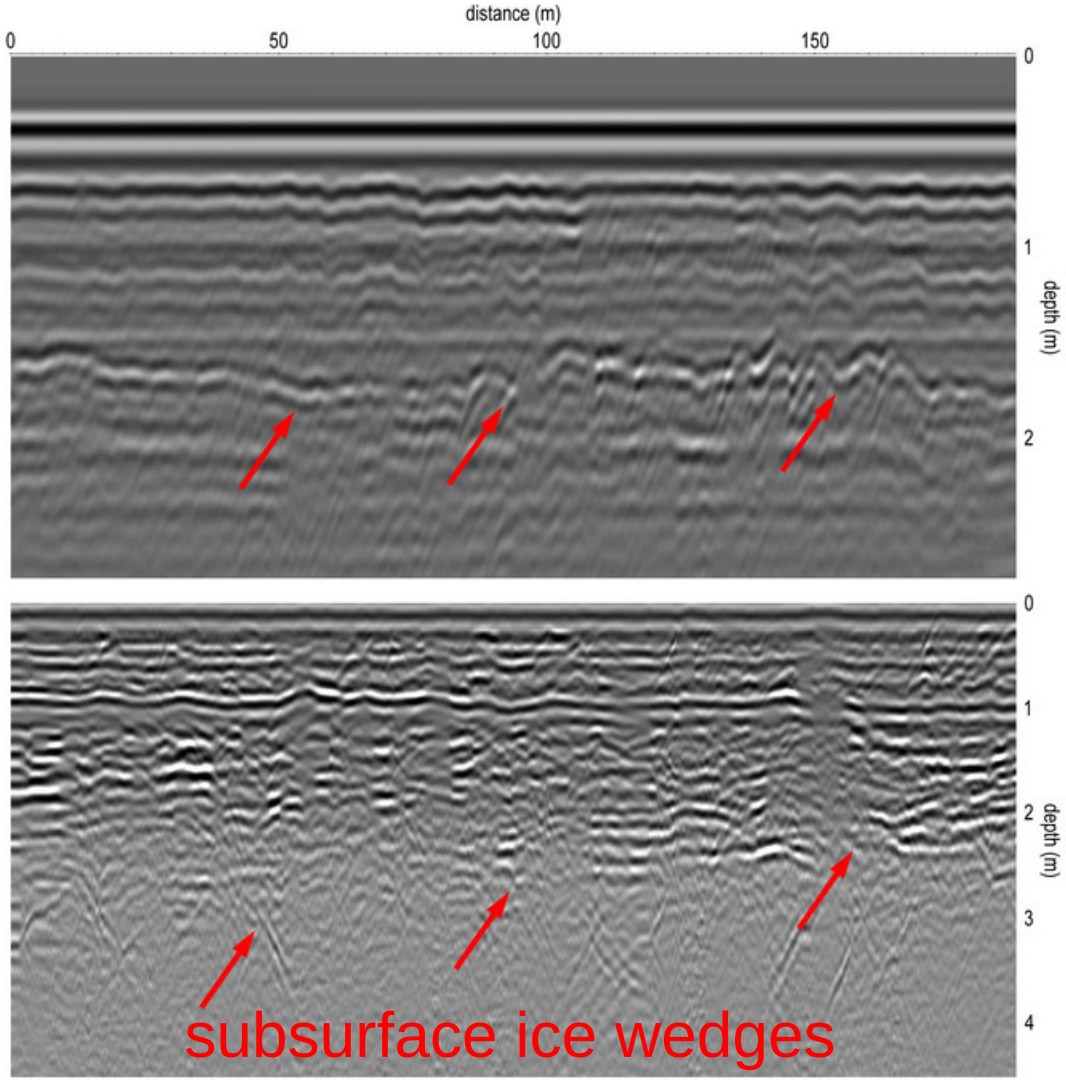
Geologic Mapping



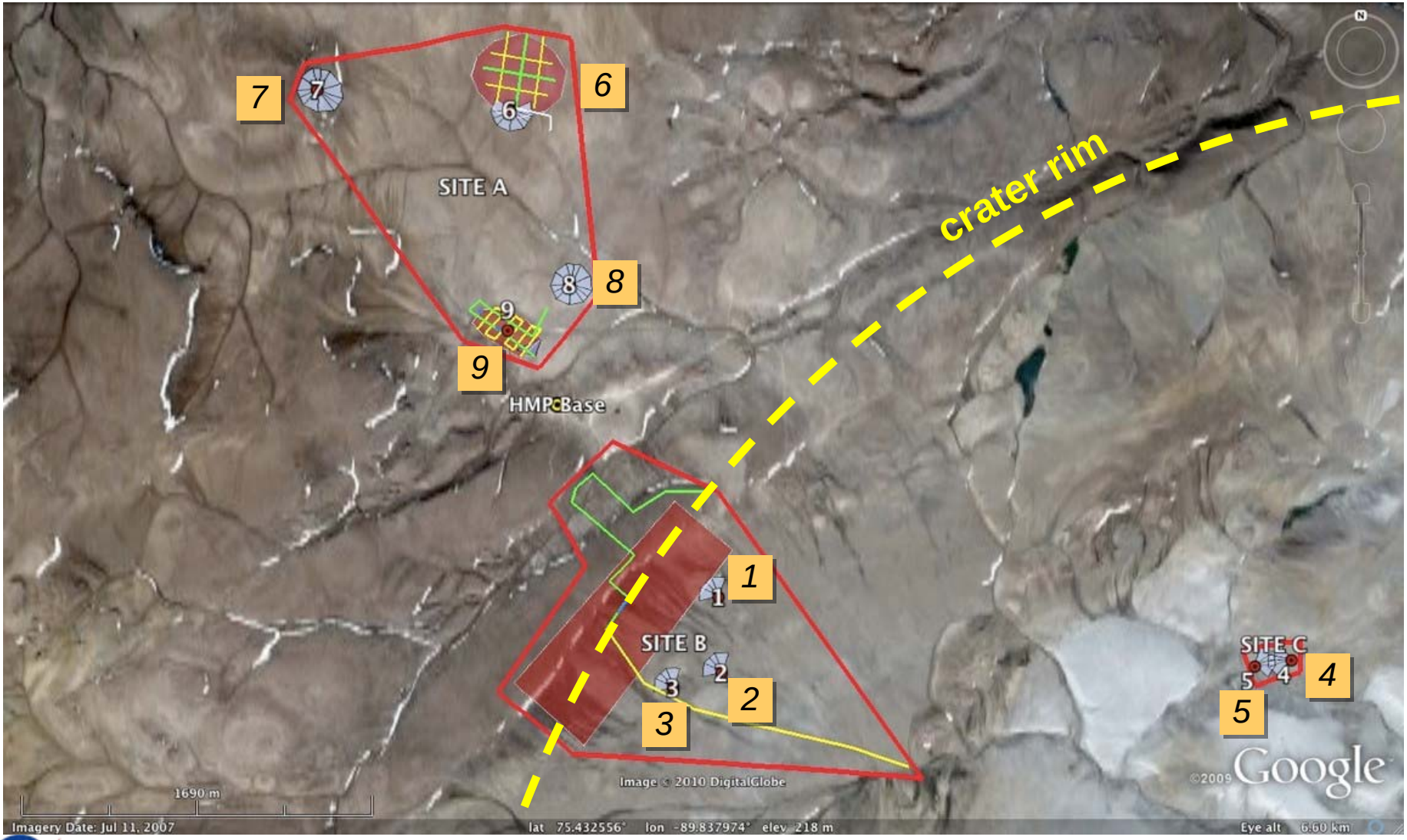
Geologic Mapping

***top row**: shock metamorphosed basement clasts*
***bottom**: shatter cone, polymict gray breccia, "vesicular" carbonate*

Geophysical Survey



Robotic Follow-up Plan



Robotic Follow-up Mission (2010)

Schedule

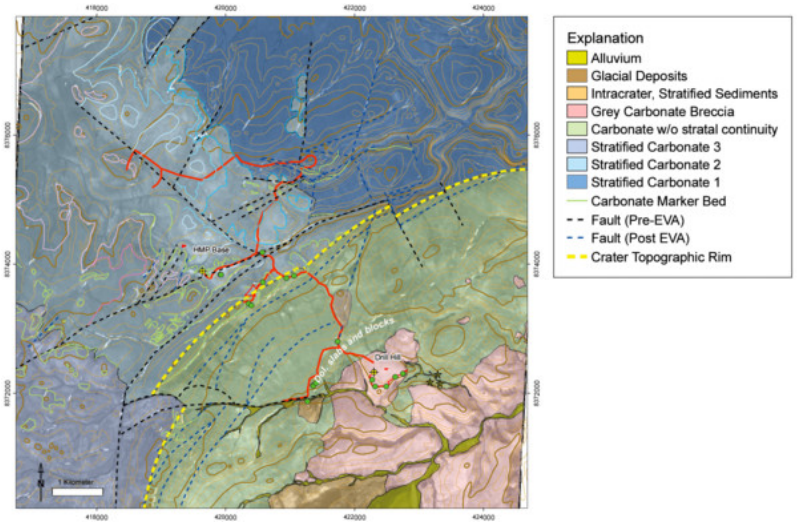
July 16	Field team departs NASA Ames
July 21	Complete K10 check-out
July 22 - 23	Geologic mapping (locale **8**)
July 24 - 28	Subsurface mapping (locales **1**, **2**&**3**)
July 29 - Aug 1	Complete remote ops check-out
July 29 - Aug 2	Subsurface mapping (locale **9**)
Aug 3 - 5	Geologic mapping (locale **7**)

K10 Robot at Haughton Crater

Results: Science

Geologic Mapping

- Robot data enabled verifying and amending the geologic map in several locations
- In some places, robot data was ambiguous, or lacked sufficient detail to re-interpret the map



Geophysical Survey

- Robot data enabled study of “polygon” features and determination of the average depth of the buried ice layer

Lessons Learned

Benefits

- Robotic follow-up can support geologic mapping & geophysical survey
- Robotic follow-up can provide quantitative data that complements and supplements data previously collected by humans
- Robotic follow-up can improve the coverage, completeness and quality of planetary exploration

Requirements

- Planning for human missions needs to consider what robots will do:
  - Must consider robot capabilities (instruments, mobility, etc.)
  - Must consider how long robot mission will operate
- Consistent localization (including orientation) is needed to co-register and coordinate data between missions
- Orbital remote sensing, human field work and robotic follow-up are highly complementary
  - Each provides different types of data, viewpoints, and resolution
  - None is fully sufficient to completely explore planetary surfaces

Robotic Follow-up Team

Experiment Team

- **PI** : Terry Fong
- **Test Manager**: Linda Kobayashi
- **Sim Sup:** EstrellinaPacis, Maria Bualat

Flight Control Team

- **Flight Directors**: Tim Kennedy (JSC), Rob Landis (ARC), Frank Jurgens (JSC)
- **Controllers**: Mark Allan, Xavier Bouyssounouse, Lorenzo Fluckiger, Jason Lum, Mike Lundy

Science Operations Team

- **Plan Leads:**EssamHeggy (JPL), Mark Helper (UT Austin), Jose Hurtado (UTEP)
- **Scientists**: Martha Altobelli (UT Austin), Joshua Garber (UC Davis), Elizabeth Palmer (Case), Tim Shin (UT Austin)
- **GDS**: Tamar Cohen, Dave Lees
- **K10 Expert**: DW Wheeler, Liam Petersen

K10 Robot Team (at HMP)

- **Field Lead:** Matt Deans
- **Robot System Lead:** Hans Utz
- **Robot Engineers:** Susan Lee, Eric Park, Vinh To
- **Data Systems:** Trey Smith
- **Science:** Byron Adams (ASU), Kelsey Young (ASU)

Support Team (at HMP)

- **HMP Manager:** Pascal Lee
- **Logistics:** KiraLorber
- **Communications:** Steve Braham
- and many others …

Questions?

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