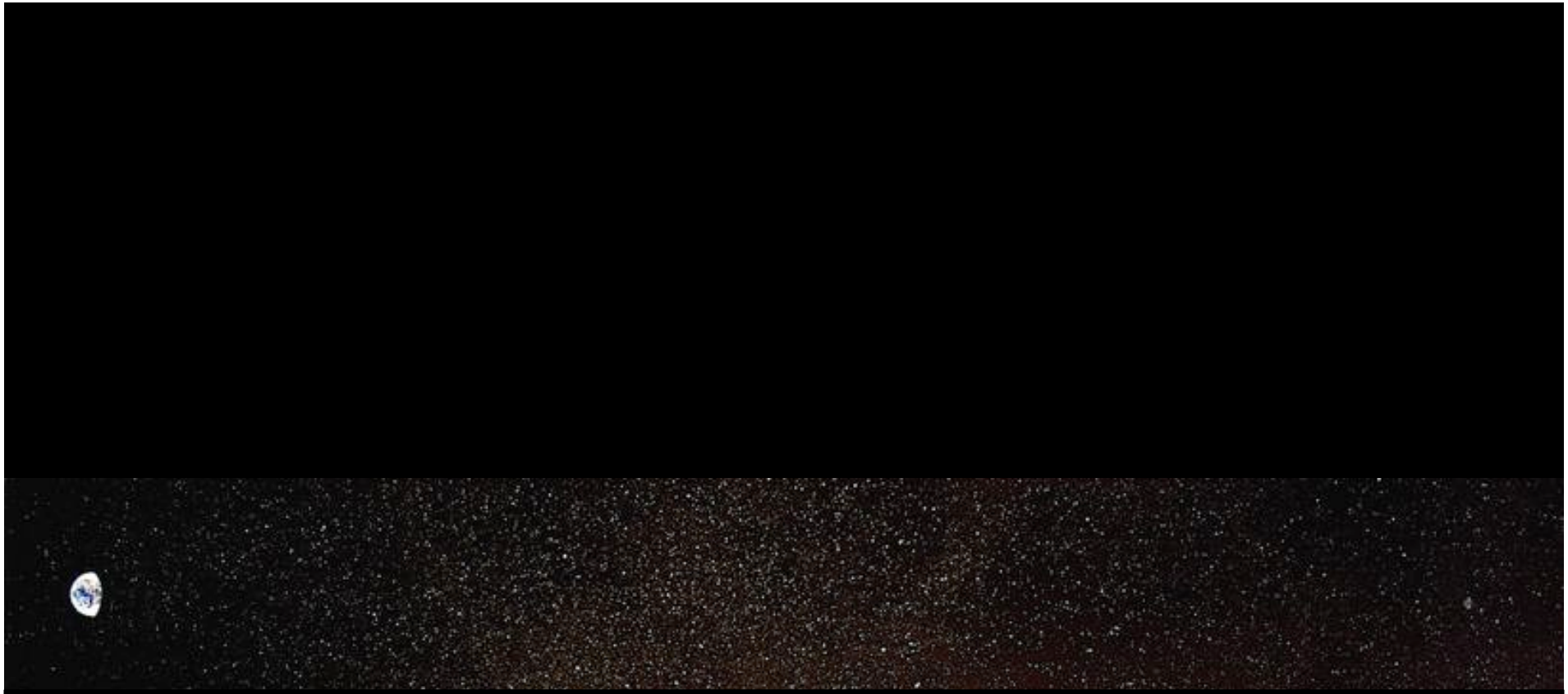

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Why Go To Mars?

Or to the Moon for That Matter?

Science	Spin-offs
Exploration	Store Waste
Adventure	Migration/Colonization/Space Settlement
The Journey	Start a New Branch of Human Civilization
Look Back at the Earth	Become a Multiplanet Species
Save the Earth	Human Destiny
Human Experience	"*Because we need the Challenge*"
Education	"*Because we've already been to the Moon*"
Jobs	"*Because the Chinese are going*"
National Prestige	"*Because the Europeans are trying*"
National Security	"*Because it is there*" (Malory on Mt. Everest)
Technological Leadership	"*Because it is clean*" (Mawson on Antarctica)
Executive Legacy	"*Because it'd be cool*" (Anonymous School Kid)
International Cooperation	"*Why Not?"* (JFK on going to the Moon and doing the other things)
Resources	"*To Boldly go…"* (Capt. James T. Kirk)
Commerce	*"Establish a new colony of prisoners/convicts"* (Australians)

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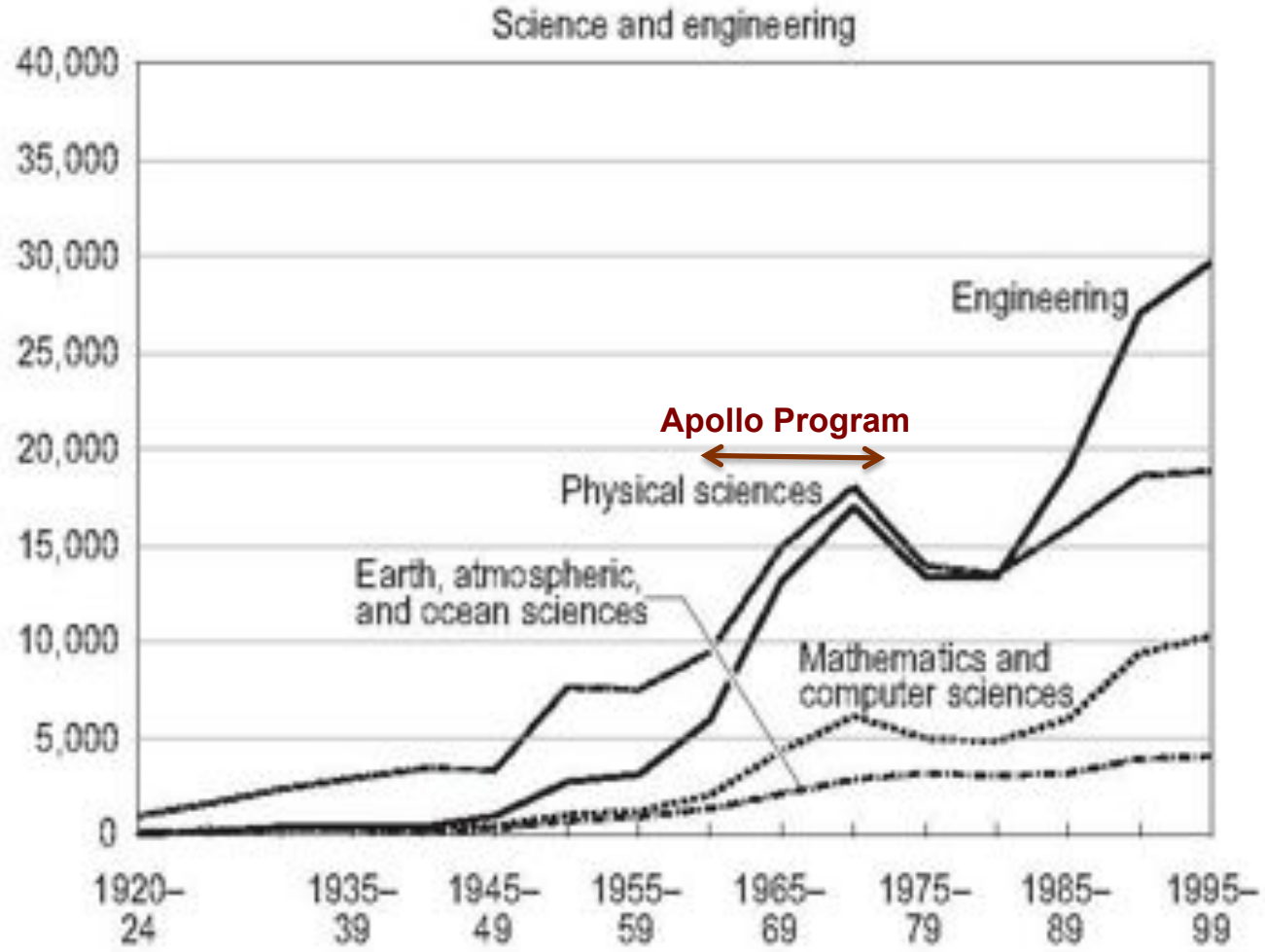
For Nations: *CRITICAL NATIONAL INTEREST.*

Apollo had a **Compelling Motivation**: *Show the World the US could beat Soviets at Space.*

Constellation had a List of Good Things to do on the Moon, but no **Compelling Motivation.**
The Critical National Interest in going to the Moon - if there was one -, was not conveyed.

Why?

Apollo Was a Huge Boost to Science and Engineering Education in America



NSF 2006

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Developing Terrestrial Analogs For Settlements Beyond LEO

Pascal Lee

Mars Institute, SETI Institute, & NASA Ames Research Center

JUSTSAP-2010 Meeting

Hawaii

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Definitions

Definitions are important, because they are associated with *Requirements.*

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- **residence**: the act or fact of *dwelling in a place* for *some time.*

This Talk:

Space Settlement:

Continuous Occupation of a Localized Infrastructure Off Earth for ≥ 1 Earth yr.

Sustainable:

Able to meet present needs while ensuring that next gen's needs will also be met.

Is the ISS a *Sustainable* Space Settlement? ?

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More Definitions

This Talk:

Outpost: *Infrastructure intended to support ≤ 10 people.*

Base: *Infrastructure intended to support > 10 people.*

Station: *Outpost or Base.*

Examples of Exploration Infrastructure	Outpost	Base	Station	Settlement	Space Settlement
HMP Research Station, Arctic		X	X		
McMurdo Station (USA), Antarctica		X	X	X	
Syowa Station (Japan), Antarctica		X	X	X	
Dome Fuji (Japan), Antarctica	X		X	X	
Tranquility *Base* (Apollo 11), Moon	X		X		
Skylab	X		X		
Salyut 7	X		X		
Mir	X		X	X	X
ISS		X	X	X	X

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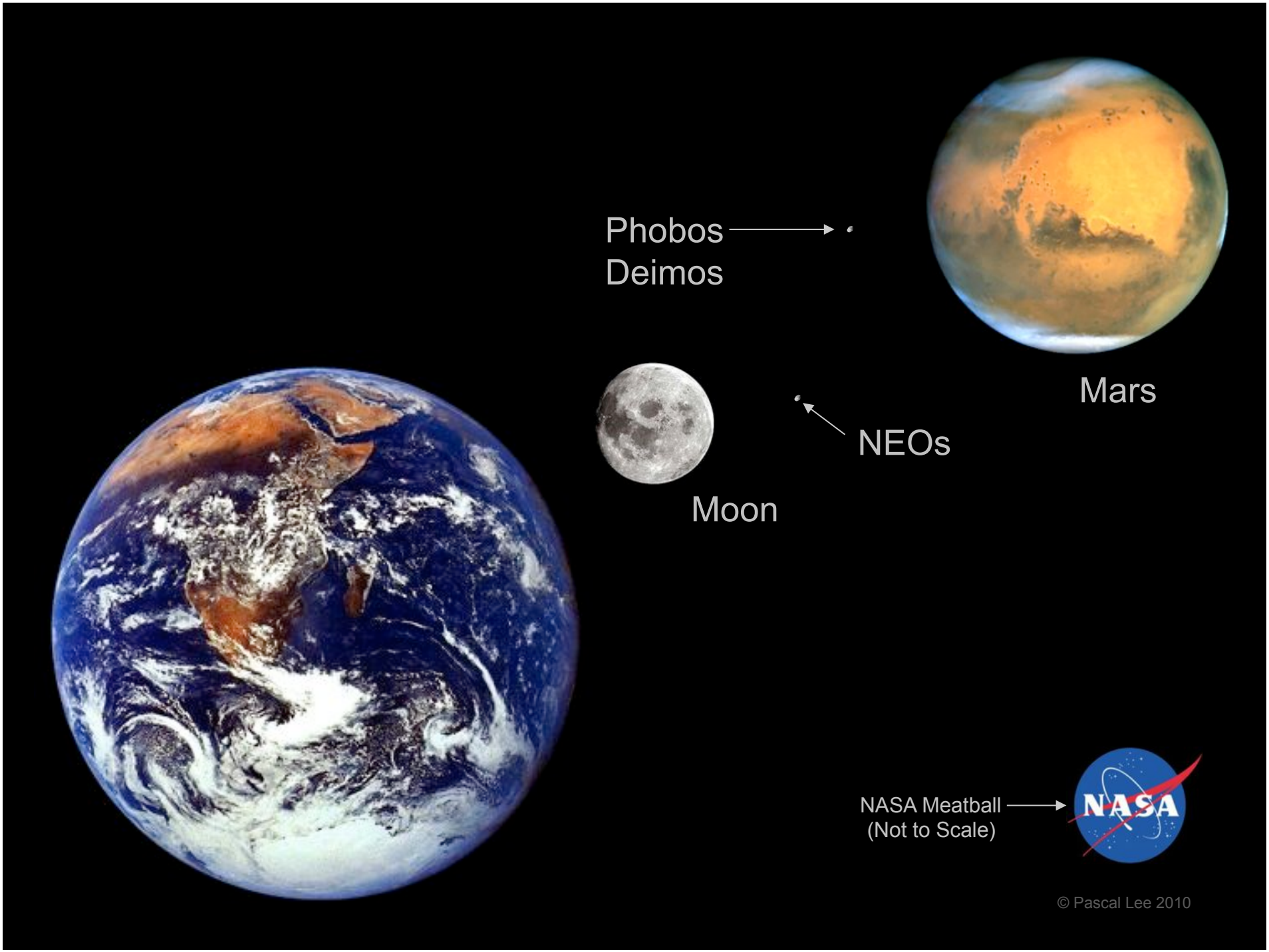
Why *Settle* Space?

- **In Nature**, Occupying and Settling is *a Winning Evolutionary Strategy* to:
  - Efficiently Gain Access to, "Control", and Transform New Territories
  - Exploit Their Resources
  - Prosper There and Expand Beyond.

- **In the Military**: *Beachheads, Garrisons, and Bases*.

- **In Antarctica**: *Research Stations*.

- **In Space Exploration**: *Habitats and Research Stations*.
  Good Strategy to:
  - Efficiently Gain Access to, "Control", and Begin Transforming, Planetary Bodies
  - Exploit Their Resources (Including Science Data)
  - Expand and Prosper There and Beyond.



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Terrestrial Analogs

PLANETS ON EARTH

Principal Moon-Mars Analog Sites used by NASA

Map by Pascal Lee – Oct 2010

CAVEAT EMPTOR

- Analogy is a Powerful, Universal Analytical Approach.
- *No Place on Earth is like the Moon or Mars.*
- Some Sites offer Relevant *Aspects*: Terrestrial *Analogs*.
- Analogs are *Approximations* → Error Bars!
  Analogs will mislead if Error Bars are ignored.
- Many Sites are Good for Focused Field Tests.
- Need to Go to Real Exploration Environments for Real Exploration Integrated Operations Simulations.

ANALOG VALUE

Several Criteria Determine the Value of a Terrestrial Analog:

CRITERIA	DETAILS
APPLICATION	Science and/or Exploration
FUNCTION	1-*Learn*, 2-*Test*, 3-*Train*, 4-*Engage* (Int'l Partners, Public, Students)
ASPECT	Climate, Temperature, Pressure, Gravity, Geology, Biology, Terrain, Remoteness, Isolation, Logistics, Comms, Ops, *Exploration*, etc.
FIDELITY OF EACH ASPECT	Low, Adequate, High. Can also be: Irrelevant, Insufficient, even Adverse!
ACCESS	Cost, Management, Politics, Socio-Economics, Other Users.

Lee et al. 2005

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MAURITANIA: TENOUMER

Tenoumer Impact Crater, Mauritania. Diameter: 1.9 km. Age: 21,000 ± 10,000 years

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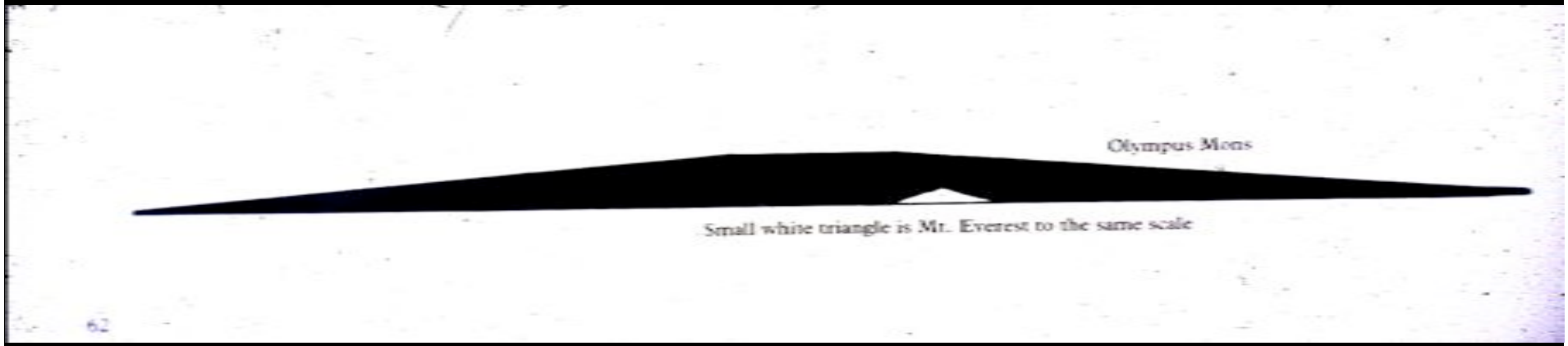
Hawaii: Mars Analog



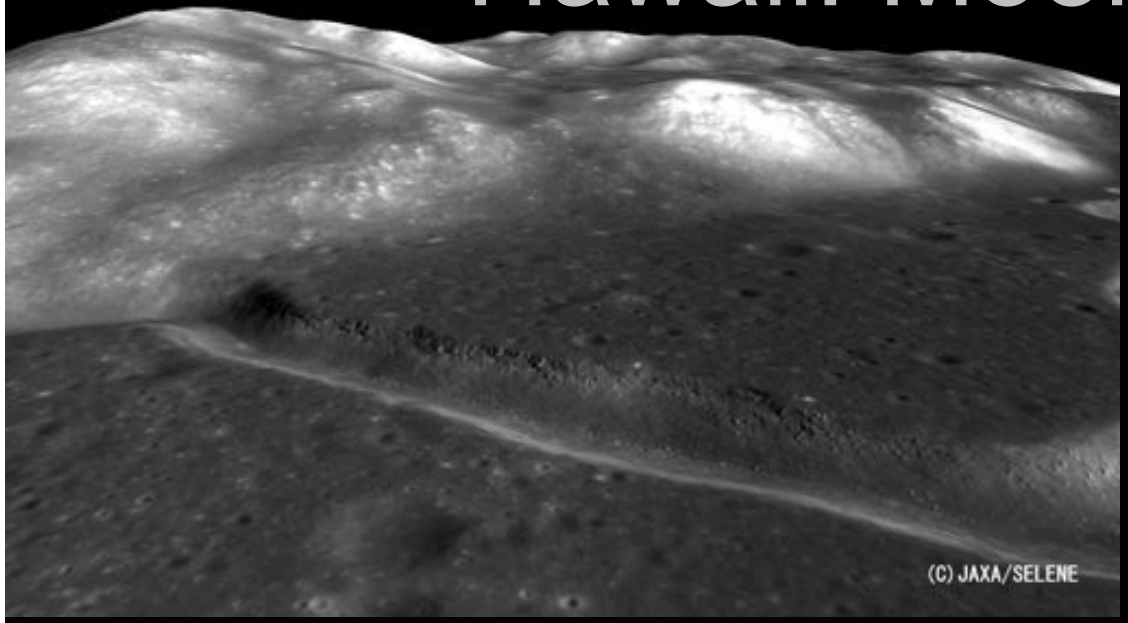
Terrestrial Analogs

Hawaii: Mars Analog

Painting by William K. Hartmann

Terrestrial Analogs

Hawaii: Moon Analog

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Terrestrial Analogs
Hawaii: NEO Analog
NASA
Small Radius of Curvature, Topography, and Terrain of Hawaii's Volcanoes offer Unique Analogs for Human and Robotic Exploration of Small Bodies.
- Small Body Science: Geologic Sampling, Geologic Mapping, Geophysics, Network Science
- Small Body Exploration: Comms Networks, Navigation, ISRU

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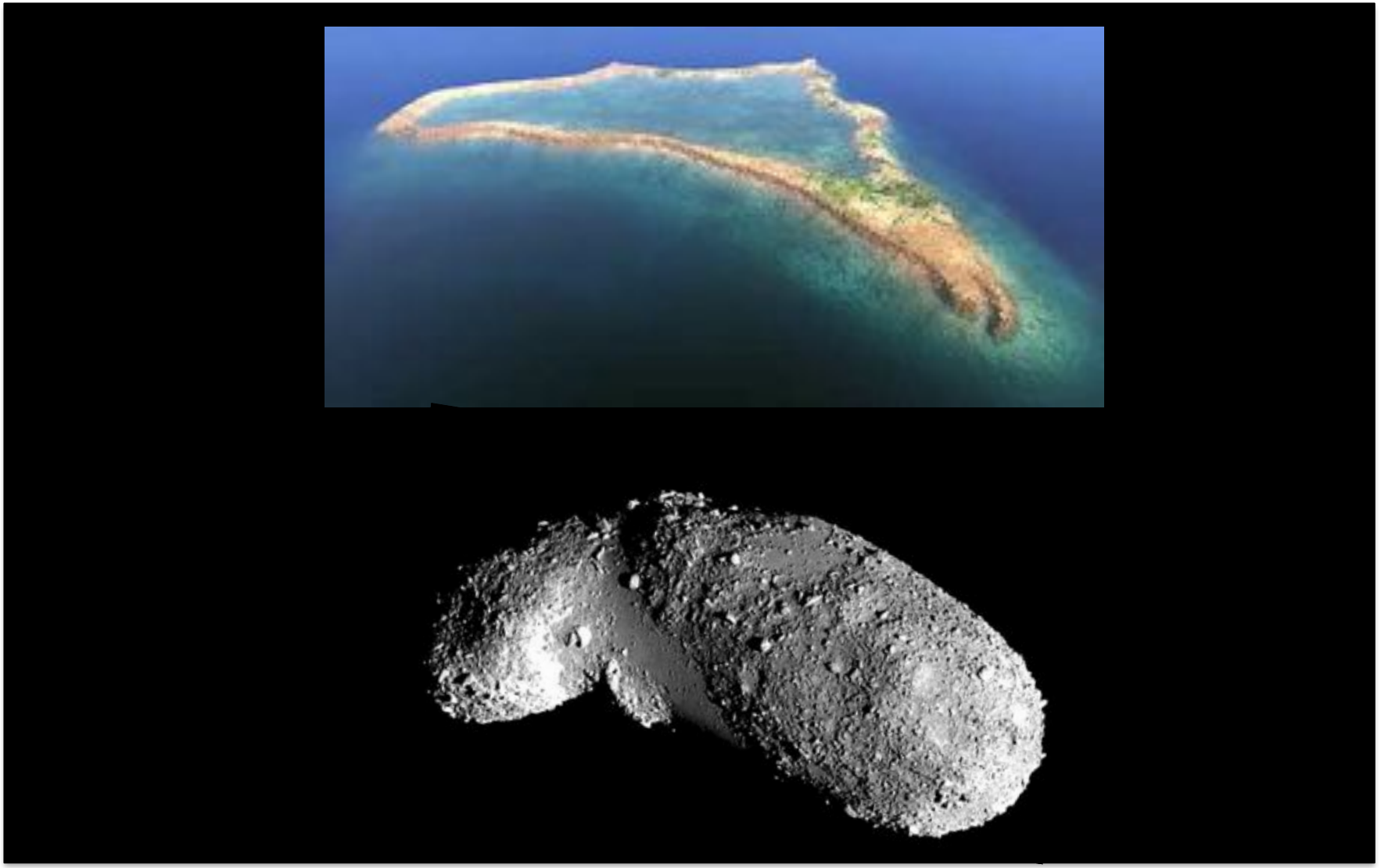
NEO ANALOGS: ATOLLS



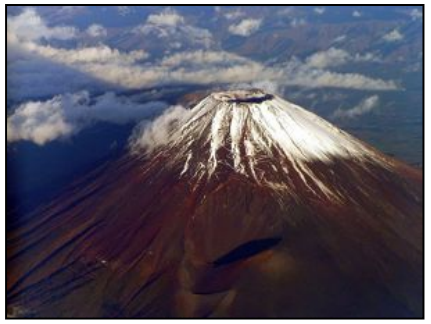
JAPAN'S ANALOGS

Daisetsu Mountains Asahi-Dake Summit
Rocky Terrain, Volcanics
Permafrost

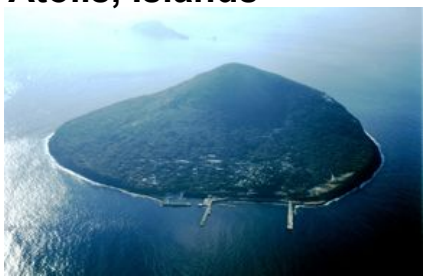
Tottori Sand Dunes
Sand Dunes

Mt. Aso
Rocky Terrain, Volcanics

Mt Fuji Summit
Rocky Terrain, Volcanics
Permafrost



Atolls, Islands



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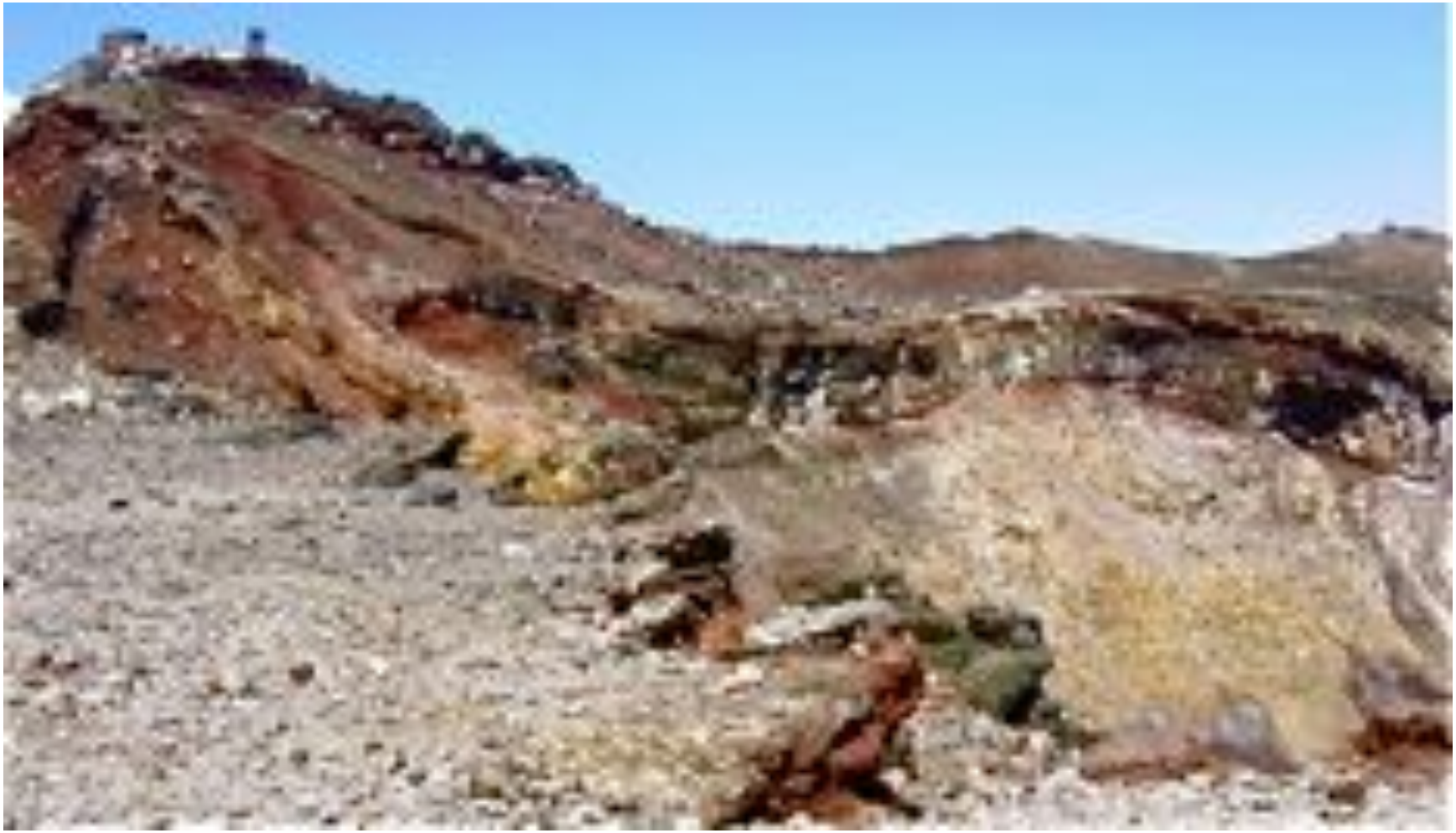
JAPAN: MT. FUJI



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JAPAN: DAISETSU MTN.

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JAPAN: MT. ASO

JAPAN: TOTTORI DUNES

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JAPAN: ATOLLS, ISLANDS

Polar Analogs

"Outside one is in touch with the sternest of Nature - one might be a lone soul standing in Precambrian times or on Mars - all is desolation and hard in the durest"

Sir Douglas Mawson
The Home of the Blizzard
9 April 1912

Devon Island

Devon Island is the largest uninhabited island on Earth.

ANG Airlift

The bulk of HMP's core personnel and cargo is airlifted each year from NASA Ames Research Center at Moffett Field, CA to Resolute Bay, High Arctic, and back, on Air National Guard (ANG) C-130 *Hercules* transport planes. *HMP-2011 will be supported again by the ANG.*

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Twin Otter Airlift

Personnel and cargo are transported between Resolute Bay and the HMPRS, Devon Island, on chartered Twin Otters planes.

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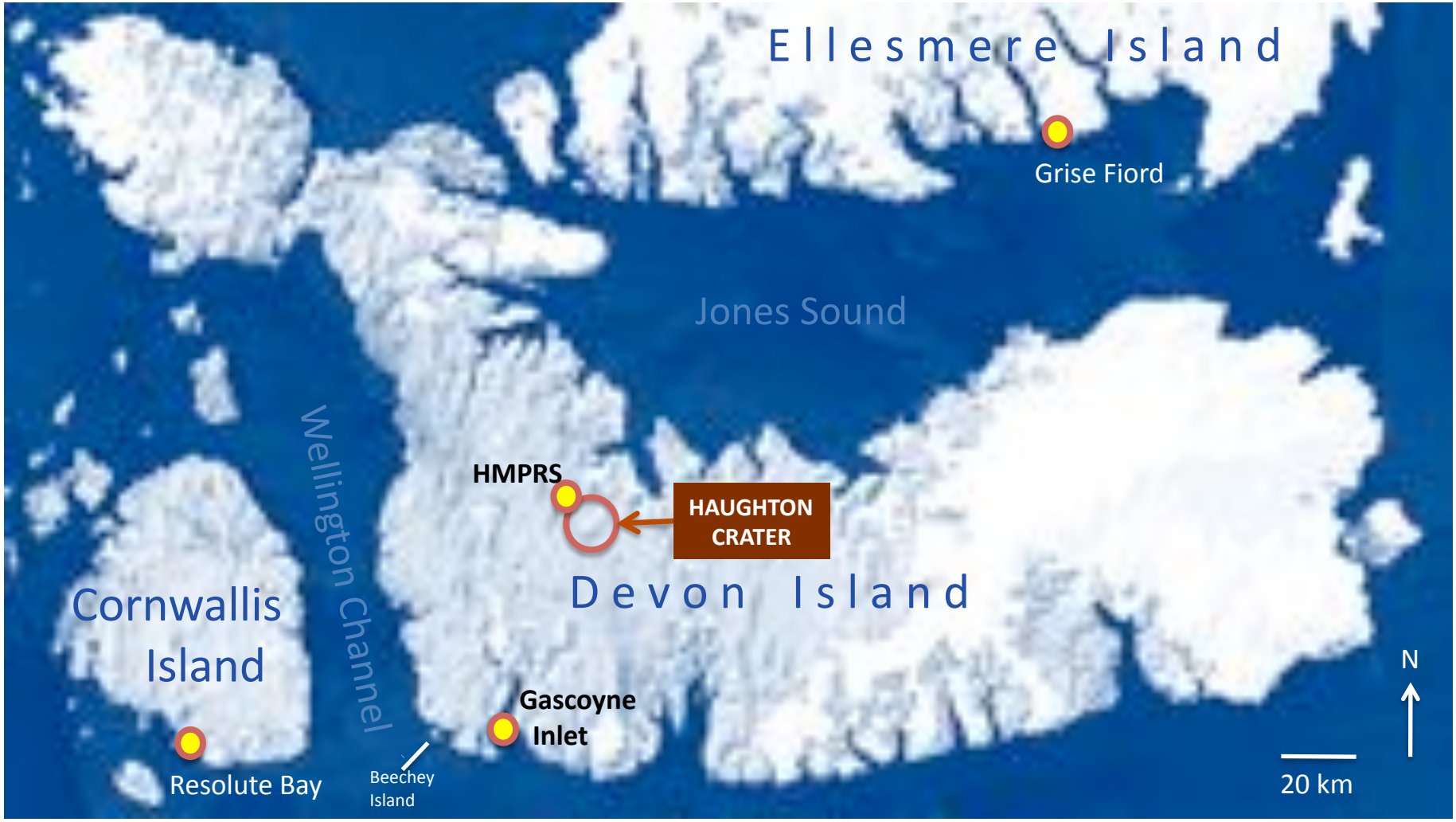
Haughton-Mars Project

Devon Island



HMPRS = Haughton-Mars Project Research Station

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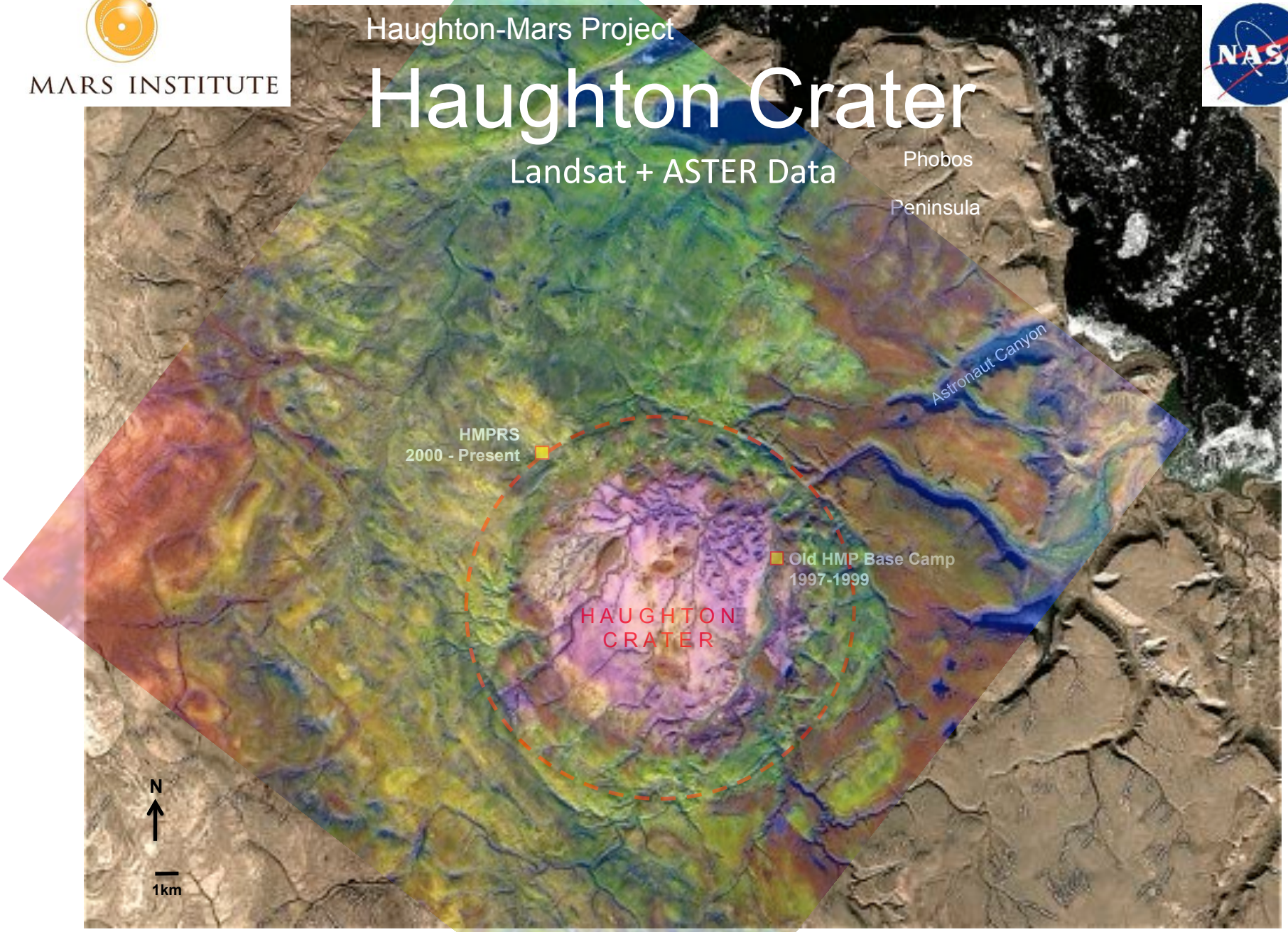
Haughton-Mars Project

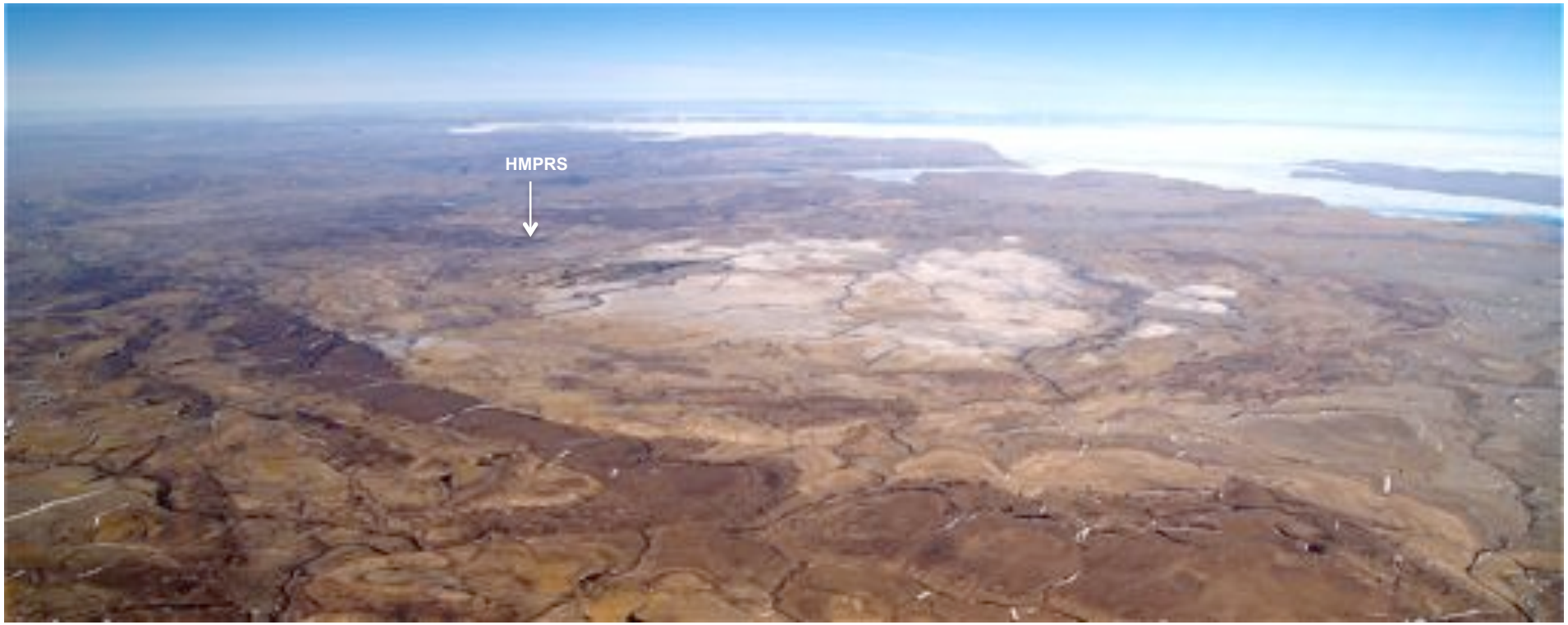
Haughton Crater

Landsat + ASTER Data



NASA

Haughton Crater



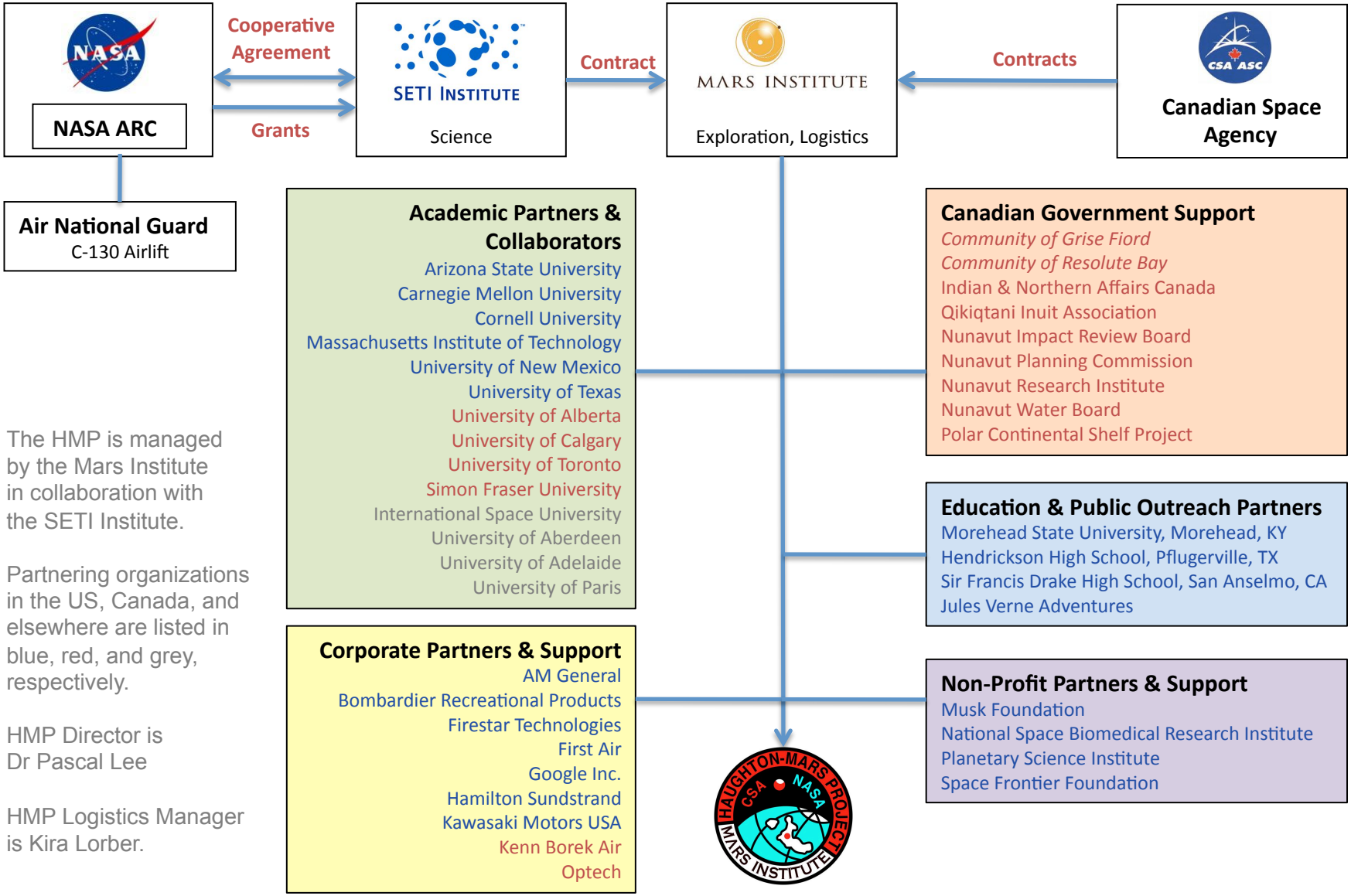
Haughton Crater from 10,000 ft (view looking North).

Haughton Crater formed 39 million years ago (redated by the the HMP from the previous published age of 23 Ma).

The Haughton-Mars Project Research Station (HMPRS) is located on the northwestern rim of the impact structure.

Haughton-Mars Project

Organization



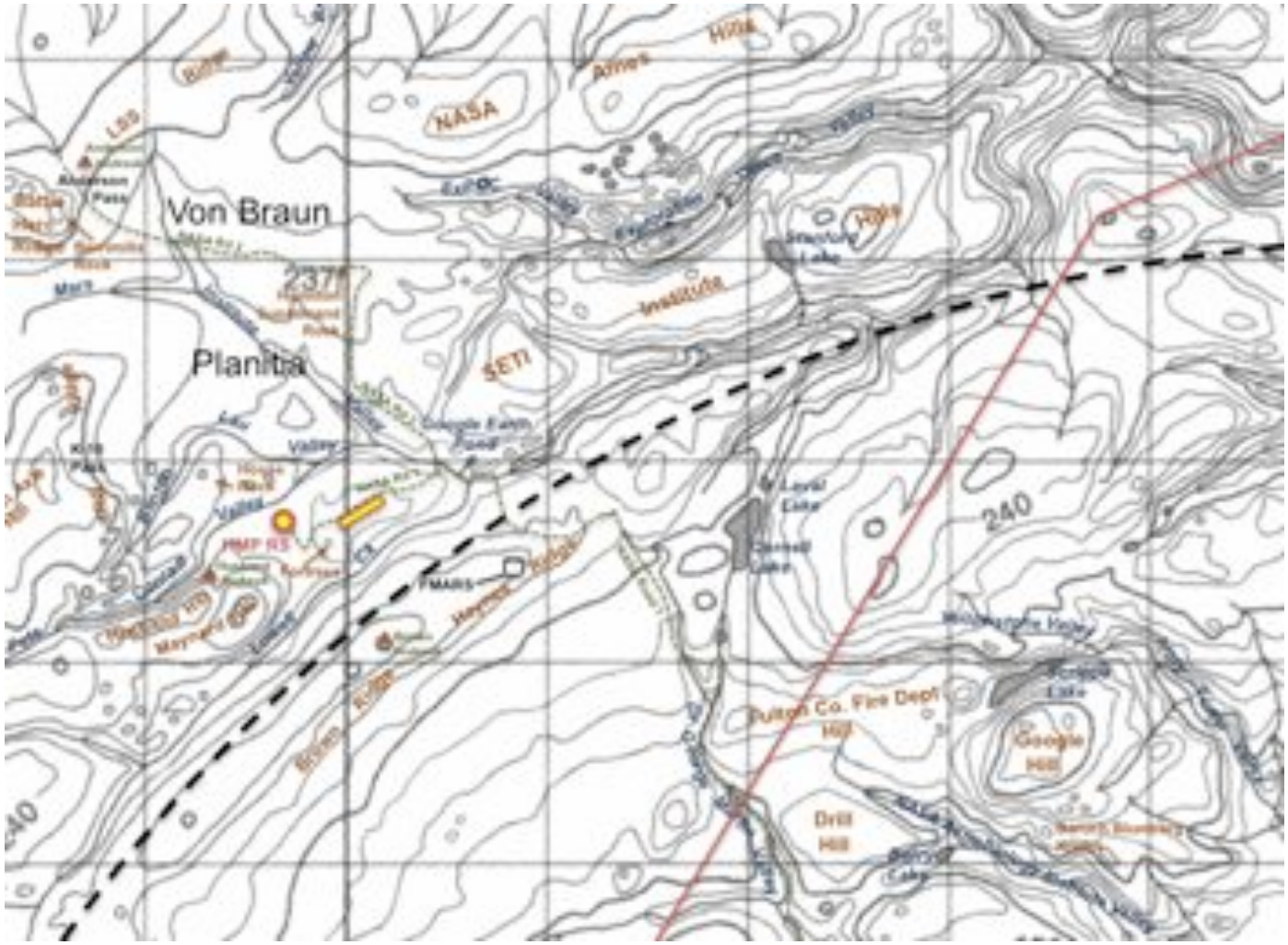
The HMP is managed by the Mars Institute in collaboration with the SETI Institute.

Partnering organizations in the US, Canada, and elsewhere are listed in blue, red, and grey, respectively.

HMP Director is Dr Pascal Lee

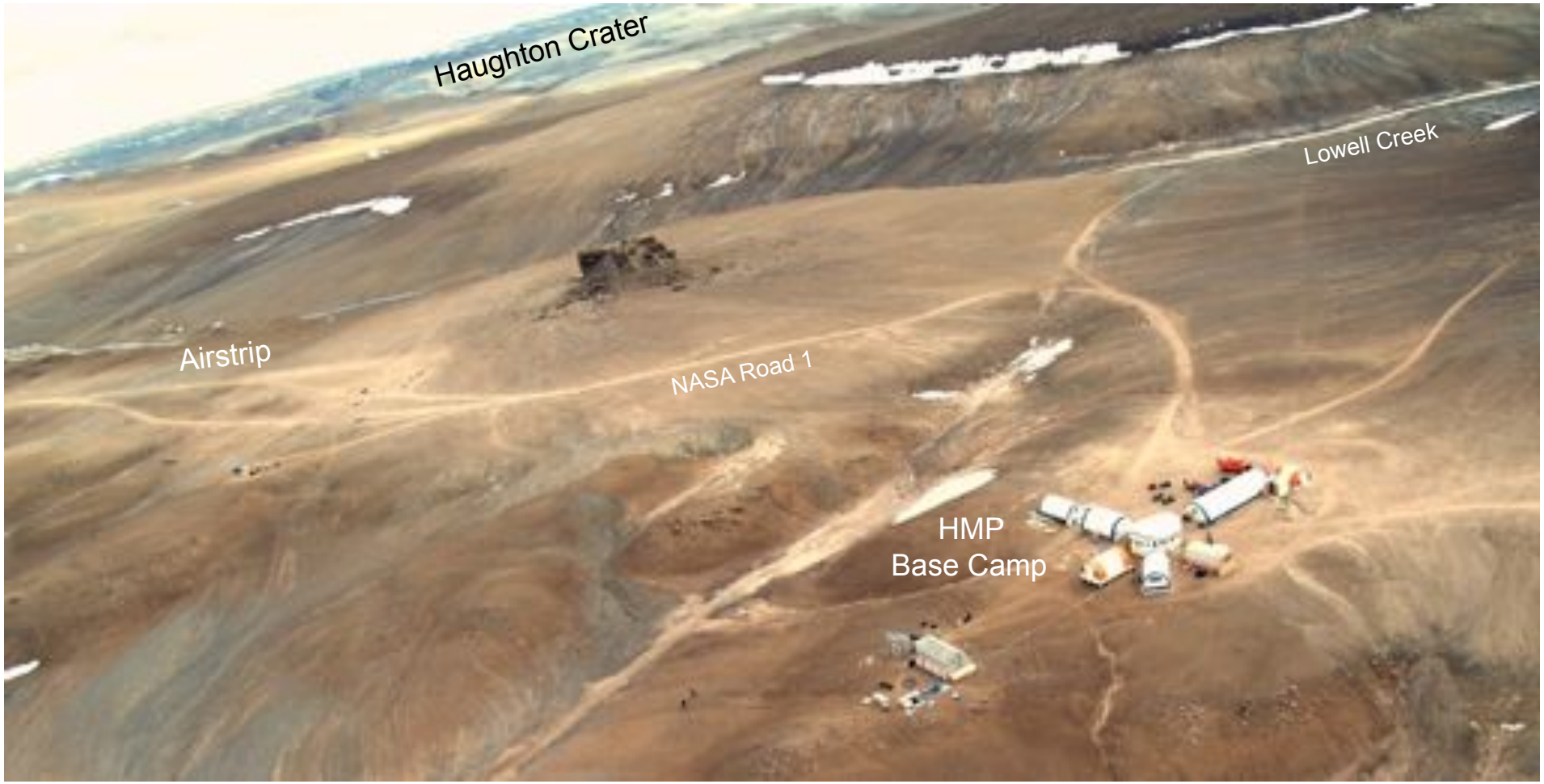
HMP Logistics Manager is Kira Lorber.

Local Map



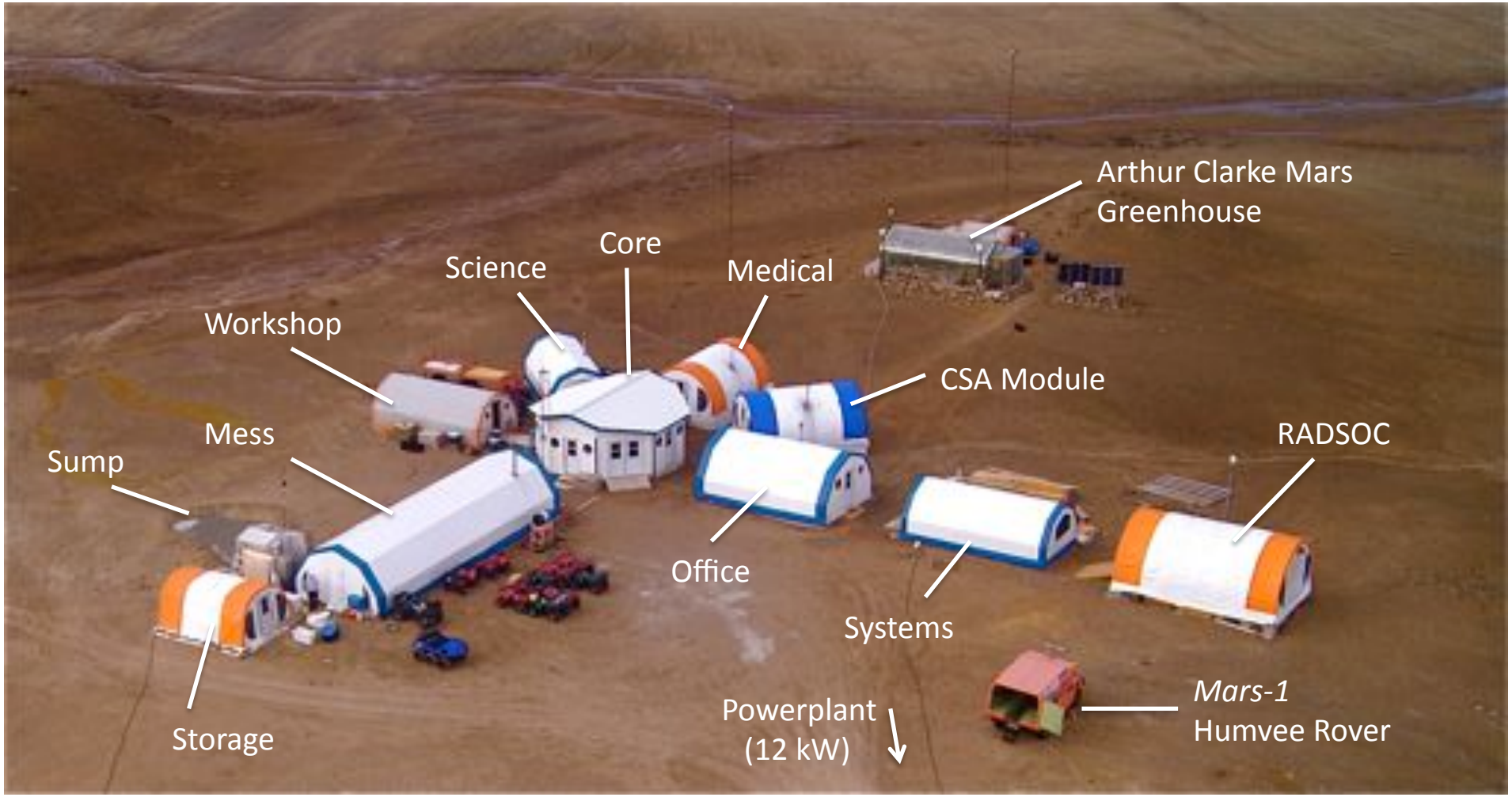
The HMPRS and Airstrip (shown in yellow) are located on Crown Land leased by the Mars Institute until 2018. Dashed line is outline of Haughton Crater rim. Red line indicates *Inuit Owned Land* (aboriginal lands) boundary. Each square is 1 km on its side. North is up.

Haughton-Mars Project Research Station



The Haughton-Mars Project Research Station (HMPRS) is the **largest privately operated polar research station in the world**.

HMPRS



HMP Research Station – July 2010

RADSOC = Remote Advanced Destination Systems Operations Center

ATVs

The HMP operates a fleet of 22 ATVs (Kawasaki Bayou 220 and 250) and 2 Mules (Kawasaki Mules). ATVs form part of the HMP's core research tools, as they allow efficient access to remote field sites.

Haughton-Mars Project

HMPRS in Winter

The HMPRS is available to NASA and CSA for winter research and operations, including crew isolation experiments.

Haughton-Mars Project

Top 10 Reasons To Go To HMP

• Science

1. Real Field Science

Real Field Science research is being done at HMP.
International Science Team is Truly Engaged in the Science.
Peer-Reviewed Research Publications are coming out of HMP (over 75 in 15 years).

2. Planetary Relevance

Field investigations at HMP are relevant to Moon, Mars and/or Planetary Sciences (eg., impact cratering, ground ice, fluvio-glacial processes, paleo-lakes, gully & valley formation, etc).
Field investigations at HMP trace back to NRC and NASA Strategic Plan and SS Roadmap Goals.
NASA SMD MMAMA, ASTID, and ASTEP programs fund several HMP investigations each year.
Canadian Space Agency also funds several Space Science investigations at HMP each year.

• Exploration

3. Real Exploration

HMP is a Real Exploration Environment, with Real Risks and Operational Challenges.
Crews in the Field and Remote Support Teams are faced with Constant & Real Decision Pressures.

4. Planetary Ops Fidelity

Many Aspects of Science and Exploration *Operations* at HMP are Critically Relevant to Planetary Exploration, e.g., isolation, remoteness, 24h daylight in Summer (which allows ANY planetary day/night cycling to be simulated), large (D~20 km) impact crater, diverse terrain types, "virgin" territory, large sample set collection and management, predominance of float *vs* outcrops, etc.

5. Comms Fidelity

Dry, hilly, rocky, unvegetated, and EM quiet desert at HMP is a high-fidelity analog for simulating realistic Moon and Mars surface comms multipath problem, unlike lower latitude vegetated sites.

• Infrastructure, Logistics, and Safety

6. Infrastructure

HMPRS is an existing field infrastructure established largely with NASA Support.
HMP has on site a fleet of 22 ATVs, 2 mules, 2 Humvees, field science equipment, etc.
HMPRS serves as a paradigm for a privately-operated international space station on the ground.

7. Proven Logistics

HMP in operation for 15 years, with proven, low-risk logistics: e.g. Air National Guard airlift.

8. Safety Procedures

HMP has solid safety record. No serious injury in 15 years of high-exposure field operations.

• E/PO, Participatory Exploration, & Media

9. E/PO & PE Value

Considerable public and student interest in NASA research and PE at HMP over the years.
HMP hosts student interns each year and has trained a generation of analog researchers.
HMP has hosted Artists and Writers at HMP every year since 1998.

10. Media Appeal

Over 15 international documentaries filmed at HMP in 15 years, > at any other analog site in that time.

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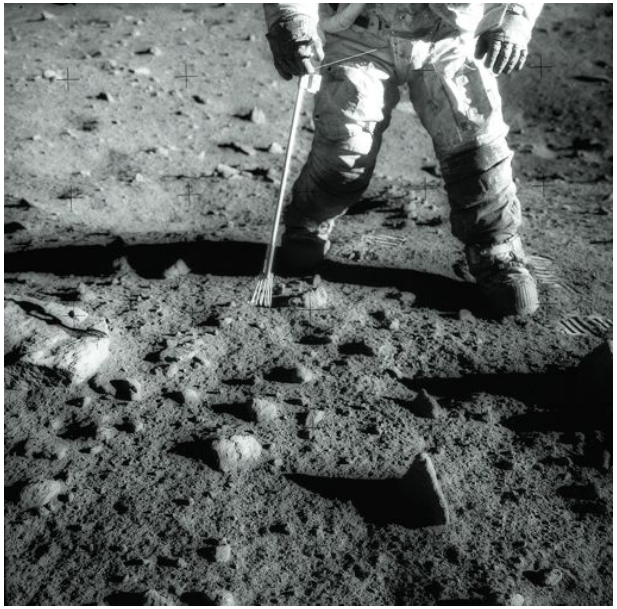
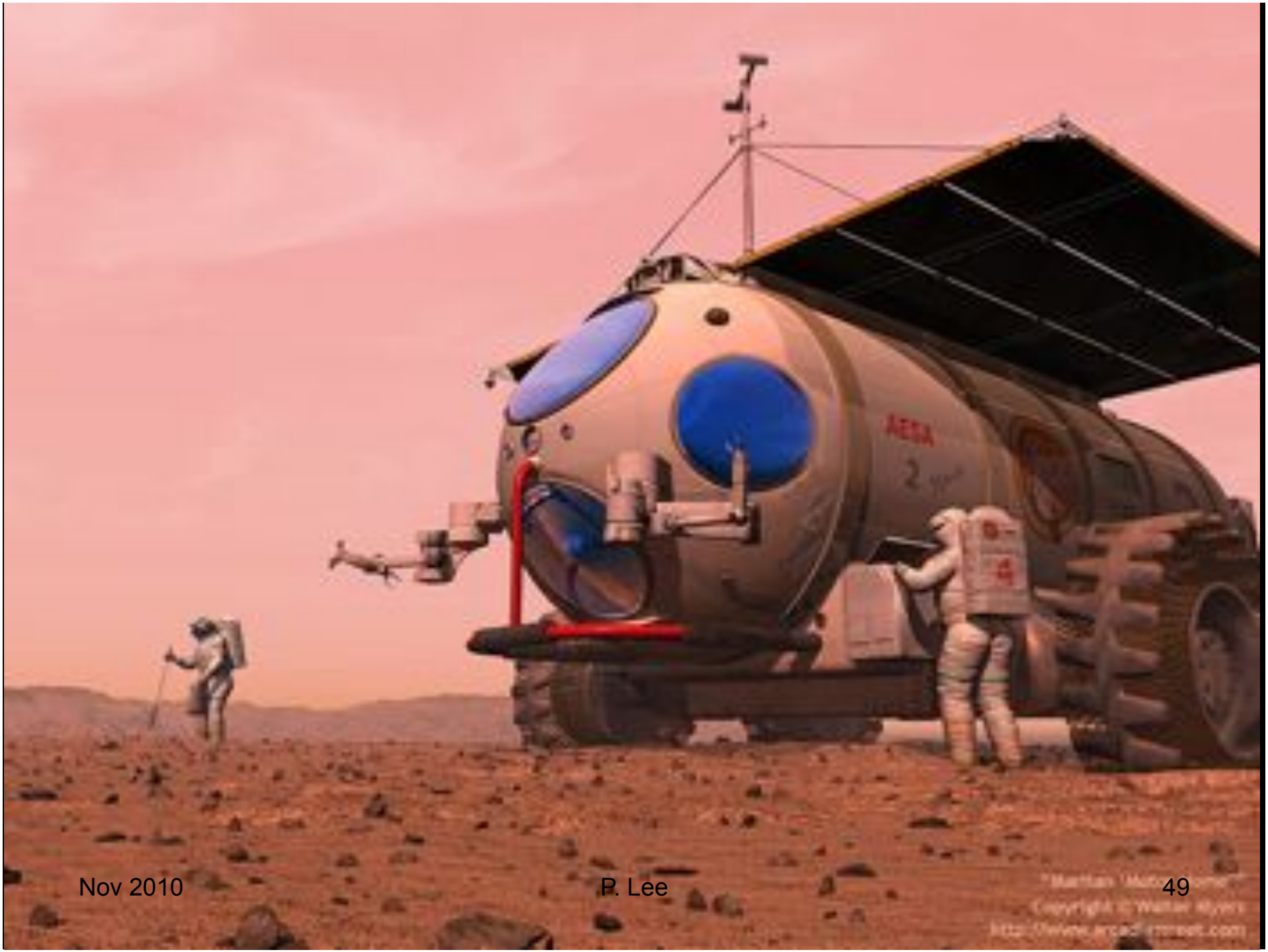
FLOAT vs OUTCROP



For Science Ops, need a site with few *outcrops* and a lot of *float*:
Glacial deposits, Periglacial Rubble Zone, Impact Craters


AM General
HUMVEE



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VEGETATION

Multipath comms problem is eliminated in vegetated areas. Such sites are *Too Easy*!
Comms infrastructure needed is ~4th power of multipath delay and 3rd power of data rate!
For Science Ops, need to go to dry, *unvegetated, hilly sites*.

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REAL EXPLORATION

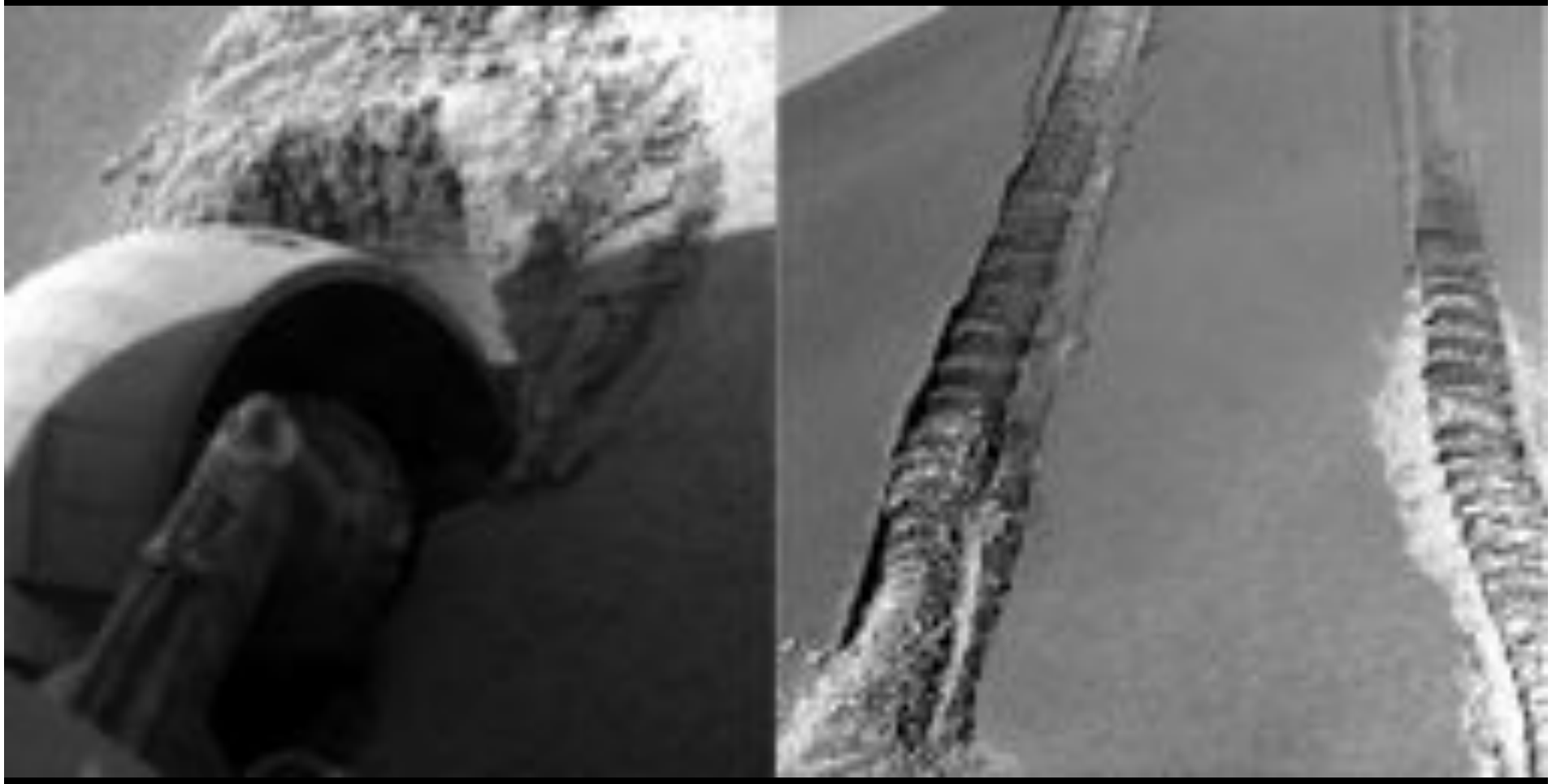
- The Greatest Challenges to Planetary Field Geology, as for Field Geology in Remote Areas on Earth, are Logistics and Safety.

  Without these Challenges, we are Learning Wrong Science Ops Lessons.

- In Real Exploration Environments:
  - *Crew is Alone*
  - *Limited Resources (Power, Time, People, $$)*
  - *Real and Unforgiving Risks*
  - *Constant Critical Decision-Making*
  - *Real Science that Engages Scientists with Driving Investigations (not Visitors who may already know the Answer or part of it).*

- Lessons from Haughton-Mars Project's Northwest Passage Drive Expedition.

Mars: The Harsh Reality



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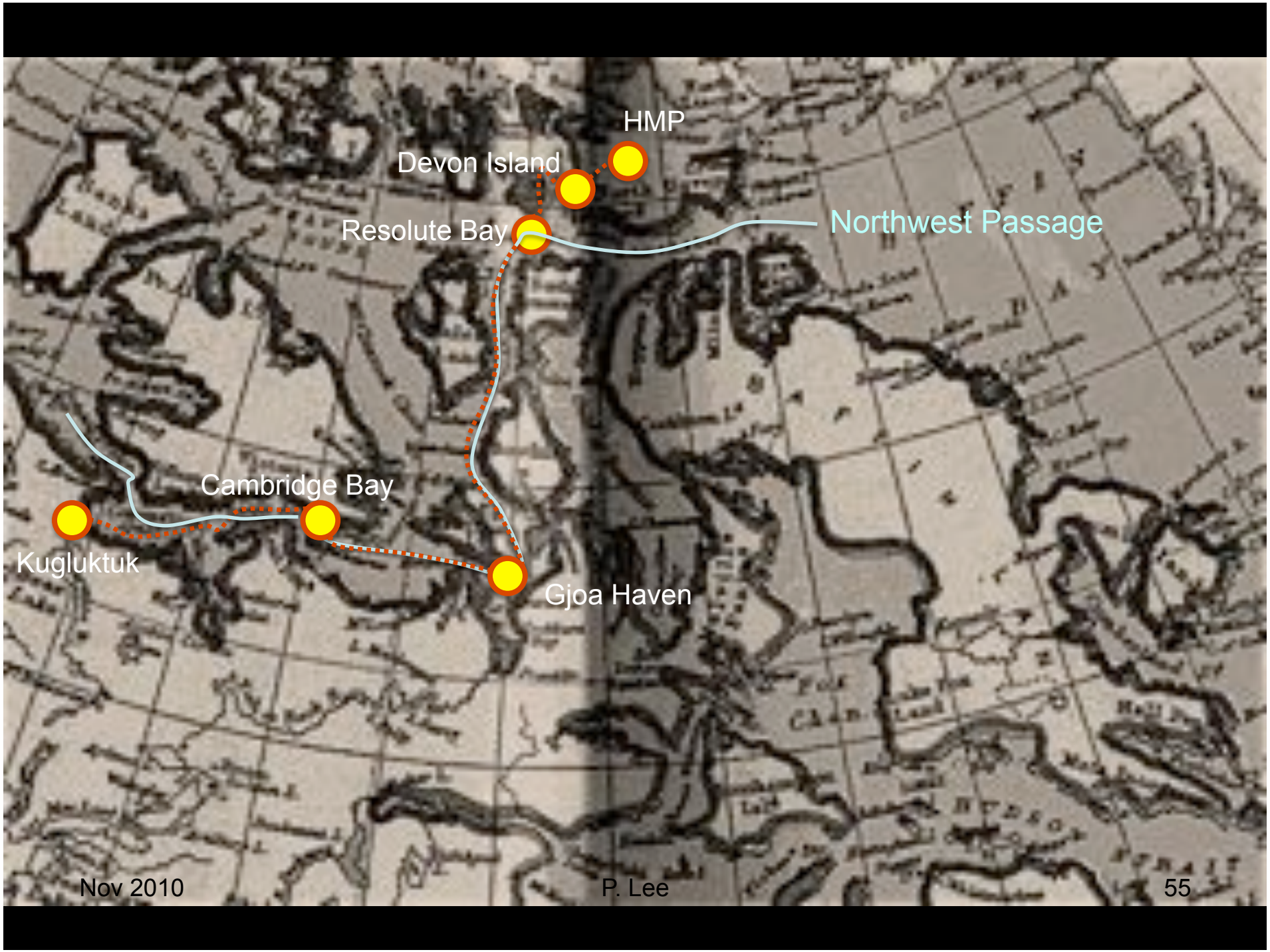
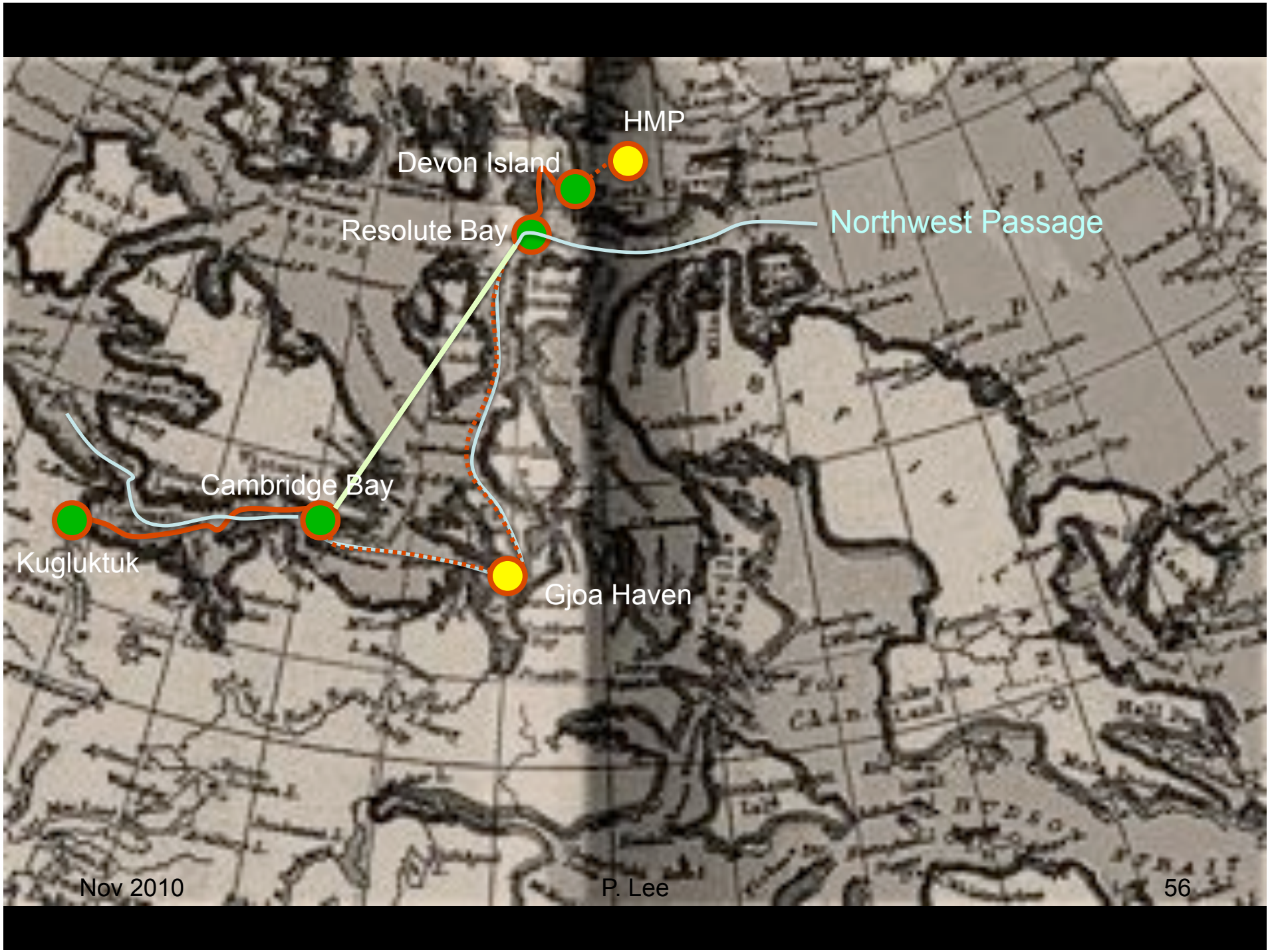
Northwest Passage


HMP
Devon Island
Resolute Bay
Northwest Passage
Cambridge Bay
Kugluktuk
Gjoa Haven


HMP
Devon Island
Resolute Bay
Northwest Passage
Cambridge Bay
Kugluktuk
Gjoa Haven


Haughton-Mars Project
Northwest Passage Drive Expedition - 2009
Victoria
Island
Cambridge Bay
6
16 Apr
Dease Strait
Finlayson
Islands
Kent
Peninsula
5
15 Apr
N
Cape Flinders
Wilmot
Islands
4
14
Apr
Coronation
Gulf
3
12-13 Apr
Jameson
Islands
Kugluktuk
2
11 Apr
1
10 Apr
Hepburn
Island
0
100 km

Snow

Sea-Ice

Lead

Seawater

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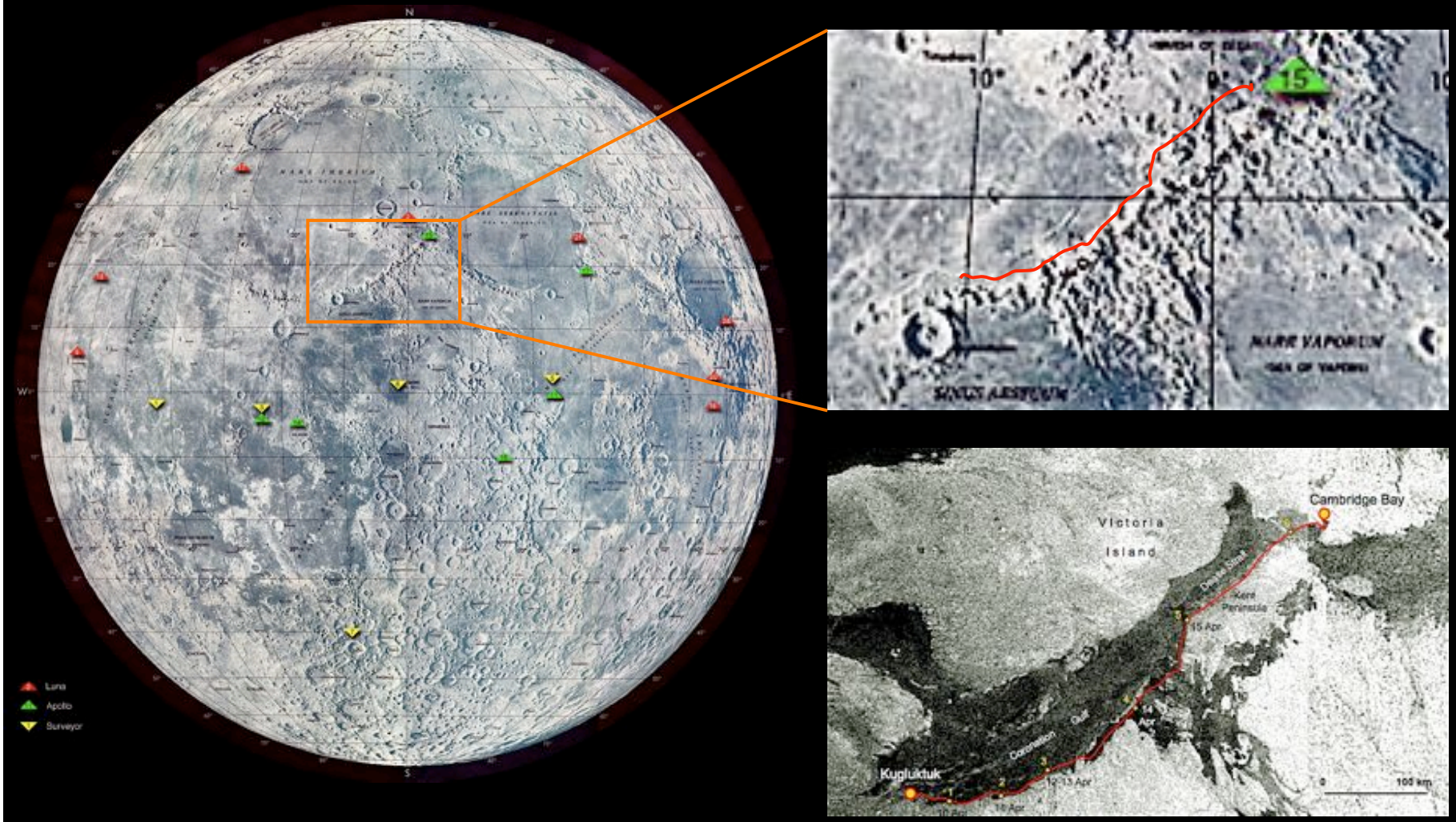
Northwest Passage Drive Expedition - 2009

Equivalent Distance Traversed on Moon



Distance traversed by *Moon-1 Humvee Rover* on Northwest Passage Drive Expedition from Kugluktuk to Cambridge Bay (494 km) is approximately equivalent to a traverse from Crater Eratosthenes to the Apollo 15 Landing site along Montes Apenninus on the Moon.

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Northwest Passage Drive Expedition - 2009

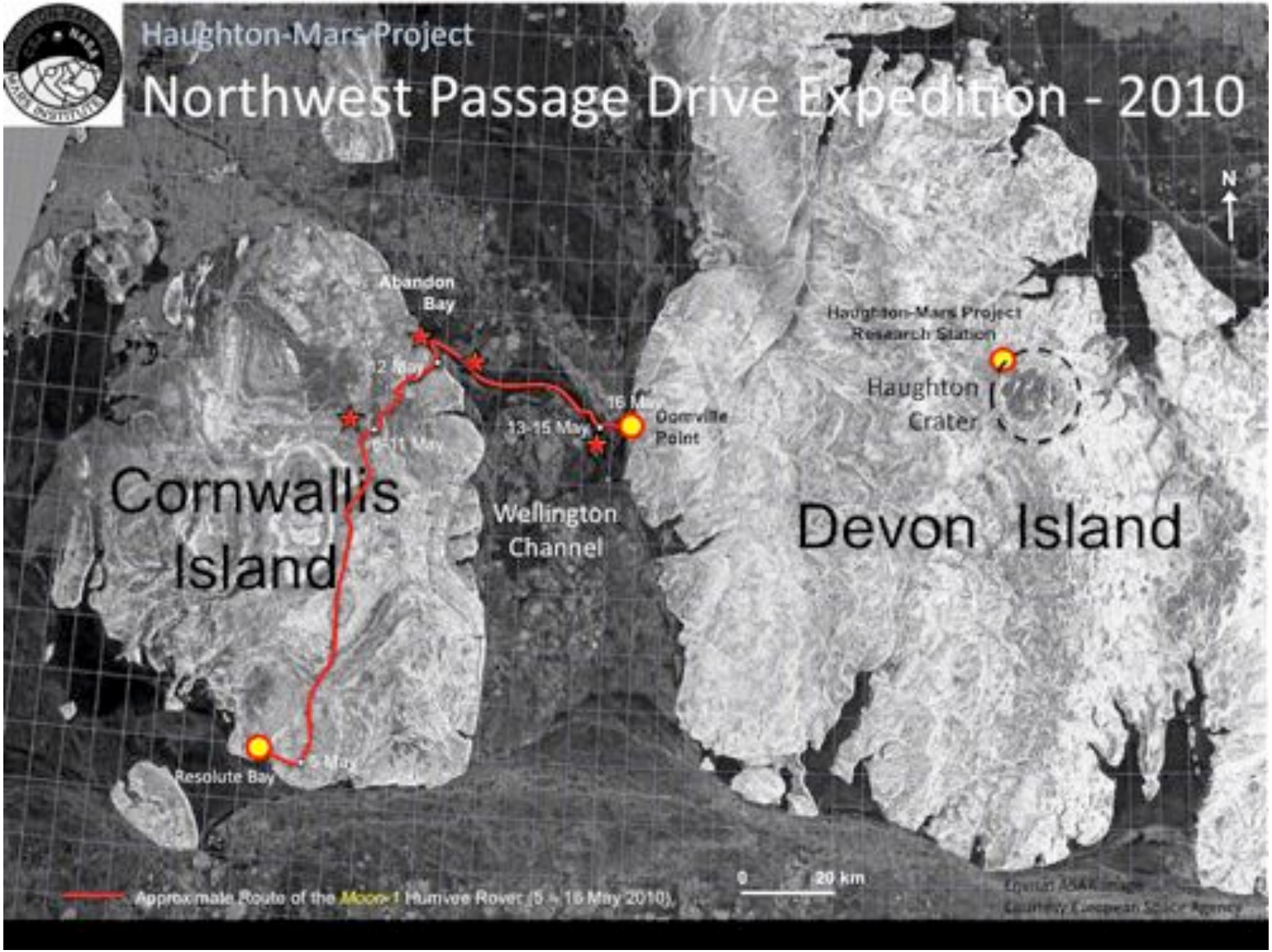
Moon-1 Humvee Rover Time & Consumables

Total Range	436.5 km		
Total Distance Traversed	494 km		
Total Time	170 hrs		
Speed Made Good	2.91 kph		70.5 km/day
Average Speed Driving	12 kph		
Time Driving	41.17 hrs	**24.22% of Total Time**	5.81 hrs/day
Total Fuel at Start	305 gal		
Fuel Used	256 gal	83.93% of Total Fuel	
Fuel Unused	49 gal	16.07% of Total Fuel	
Average Fuel Burn Rate	1.51 gal/hr		
Fuel Burn Rate Driving	2.81 km/gal		
Fuel Used Driving	175.5 gal	57.54% of Total Fuel	
Fuel Burn Rate Driving	4.26 gal/hr		
Fuel Used Idling	80.5 gal		
Fuel Burn Rate Idling	0.625 gal/hr		
Time Idling	128.83 hrs	75.78% of Total Time	18.19 hrs/day
Boots on Ground Time (per person)	24.5 hrs	14.41% of Total Time	3.5 hrs/day
Comms Time (Satcom Time)	5 hrs	**2.94% of Total Time**	0.71 hr/day
Research Time (per person)	14 hrs	**8.24% of Total Time**	2 hrs/day

SETI INSTITUTE

SFU SIMON FRASER UNIVERSITY THINKING OF THE WORLD

(Lee et al. 2009)


Haughton-Mars Project
Northwest Passage Drive Expedition - 2010
N
Abandon Bay
12 May
11 May
16 M
13-15 May
Cornwallis Island
Wellington Channel
Devon Island
Haughton-Mars Project Research Station
Haughton Crater
Resolute Bay
0
20 km
Approximate Route of the Mars-1 Humvee Rover (5 - 16 May 2010).


AM General


AM General
HUMVEE


AM General
NASA
AM General
MARS INSTITUTE
SETI INSTITUTE
SFU
Moon-1
HUMVEE
HUMVEE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MATTRACKS
www.marsone


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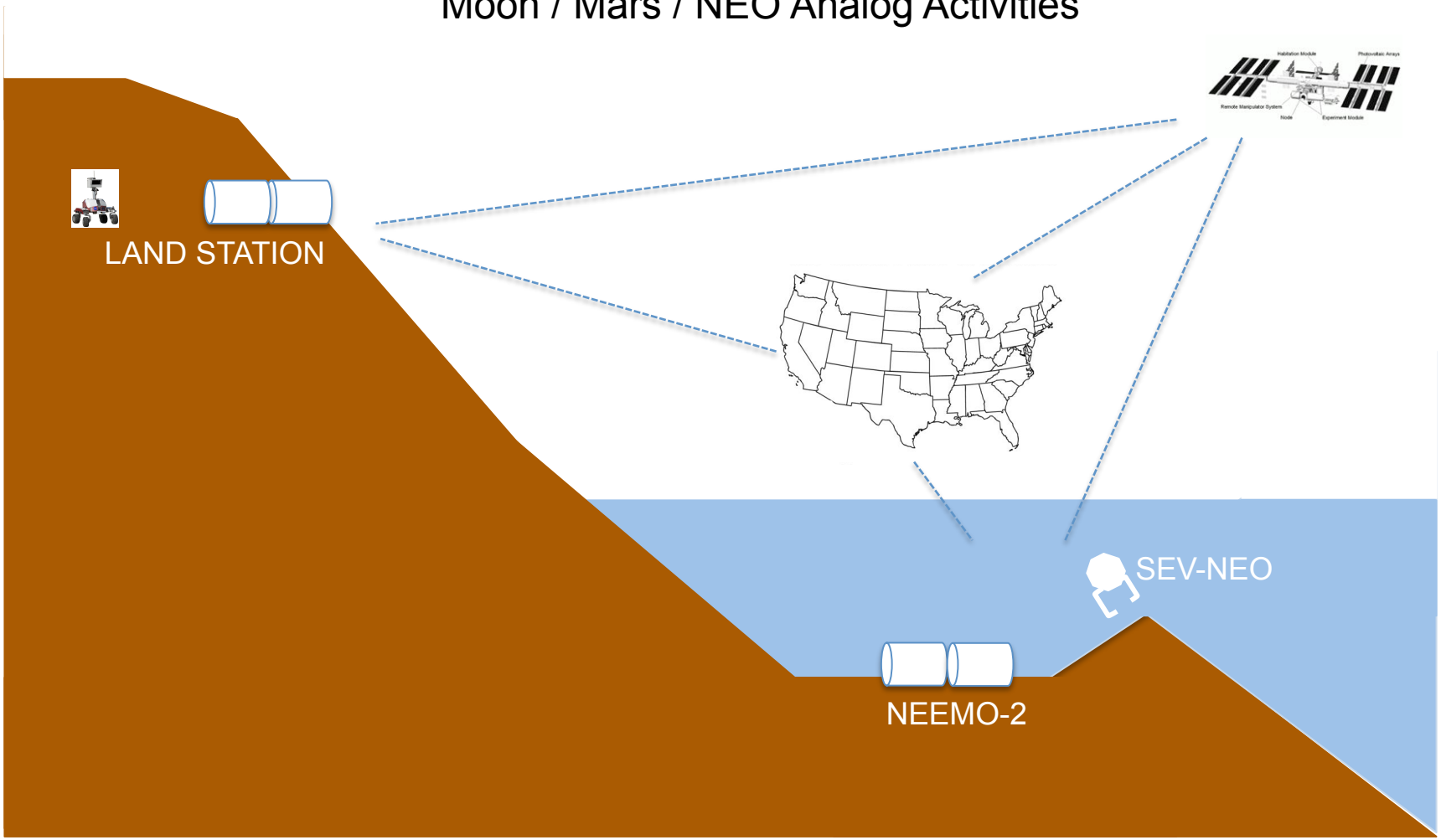
Hawaii Analog System

Moon / Mars / NEO Analog Activities



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Recommendations

- *Build the Lunar (Planetary) R&D Park / University in Hawaii.*
- *Build It, And They will Come.*
- Keep Doing What You Are Doing.
  Best way to Promote Hawaii's Value as an Analog is to Continue Projects and to Host as many Good Analog Activities as Possible.
- Keep it Flexible, Adaptable, Universally Relevant.
- Hawaii is Good Not Just for the Moon and Mars, but Also NEOs
  Summit Areas + Underwater Environments.