Atacama Desert Trek: A Planetary Analog Field Experiment

Field Robotics Center
The Robotics Institute
Carnegie Mellon University

THE ROBOTICS INSTITUTE

NASA

Carnegie Mellon

Nomad- A planetary relevant rover

Overview

Nomad- Planetary precursor robot

Primary Objective:

Travel 200 km

Secondary Objectives:

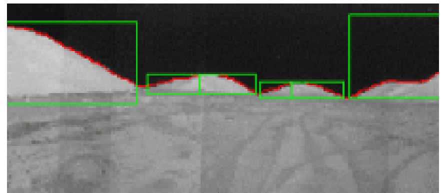
- Evaluate panospheric camera
- Demonstrate antenna pointing
- Demonstrate skyline positioning
- Autonomous safeguarding
- Evaluate locomotion
- Involve the public
- Perform remote geology
- Transcontinental Supervision

Atacama Desert, Chile

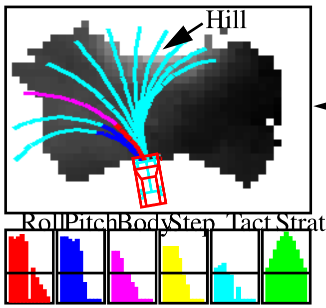
June 18- July 31, 1997

Atacama Desert Trek Technology

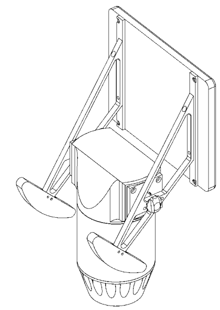
Skyline Positioning



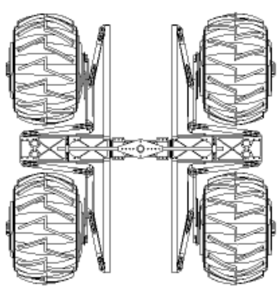
Safeguarded Teleoperation

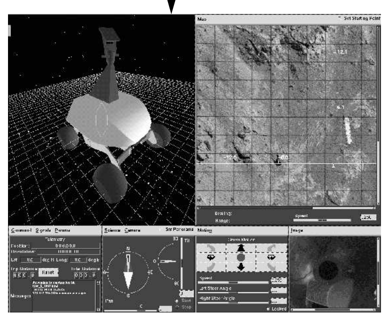


Antenna Pointing Mechanism



Transforming Chassis





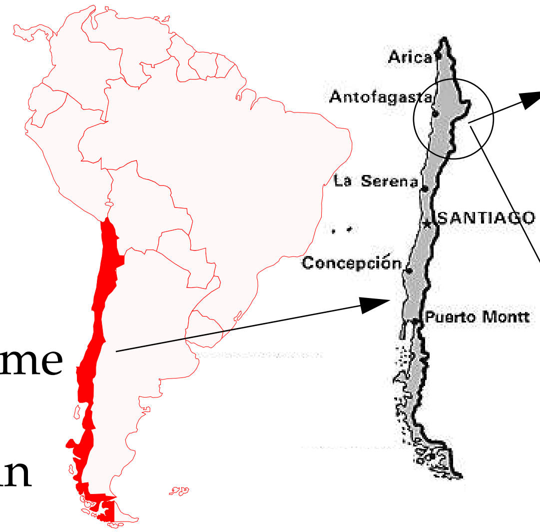
Public Outreach/Remote Science

Panospheric Camera

The Atacama Desert, Chile

Planetary Analog Terrain

- Craters, rocks and loose sand
- Complete lack of vegetation
- Varied topography



Operational Suitability

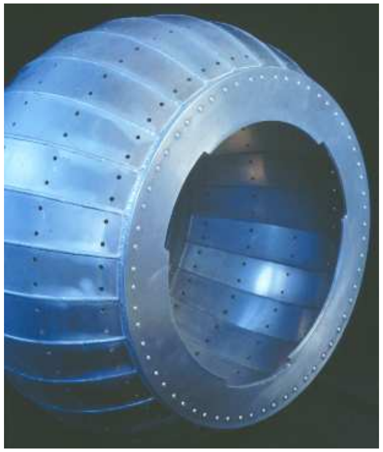
- Eastern Daylight Time
- Easy access
- Presence of NASA in Chile

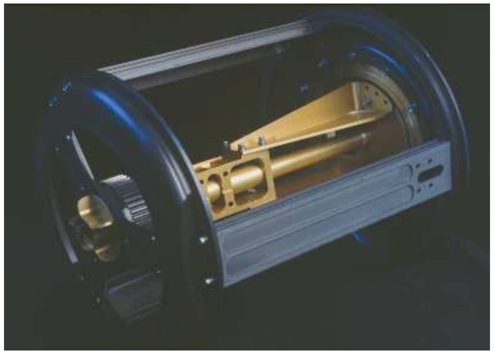
Vital Statistics

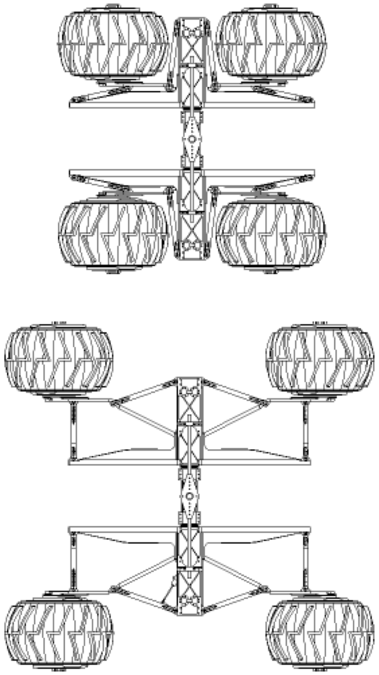
- Average elevation: 2400 m
- Temperature: $0^{o}C$ to $25^{o}C$
- Precipitation: 1 cm/year from fog
- Rainfall: once every 100 years

Locomotion Electromechanism

In-wheel independent drives for improved traction and motion control







Transforming chassis provides terrain adaptation, deployment, and steering capabilities

- An actuator drives a pair of four-bar mechanisms on each side of the rover
- Motion of the follower linkages increases rover footprint
- Wheel heading changes while deployed, enabling steering

Locomotion- Field Performance

Terrain	slope (0 deg)	slope (0 deg)	slope (10 deg)	slope (17 deg)
Test	Driving	Drawbar Pull	Driving	Driving
Predicted value	**740 W**	**975 lbf**	**1290 W**	**1665 W**
Measured value	**670 W**	**650 lbf**	**1000 W**	**1250 W**

Suspension and Steering

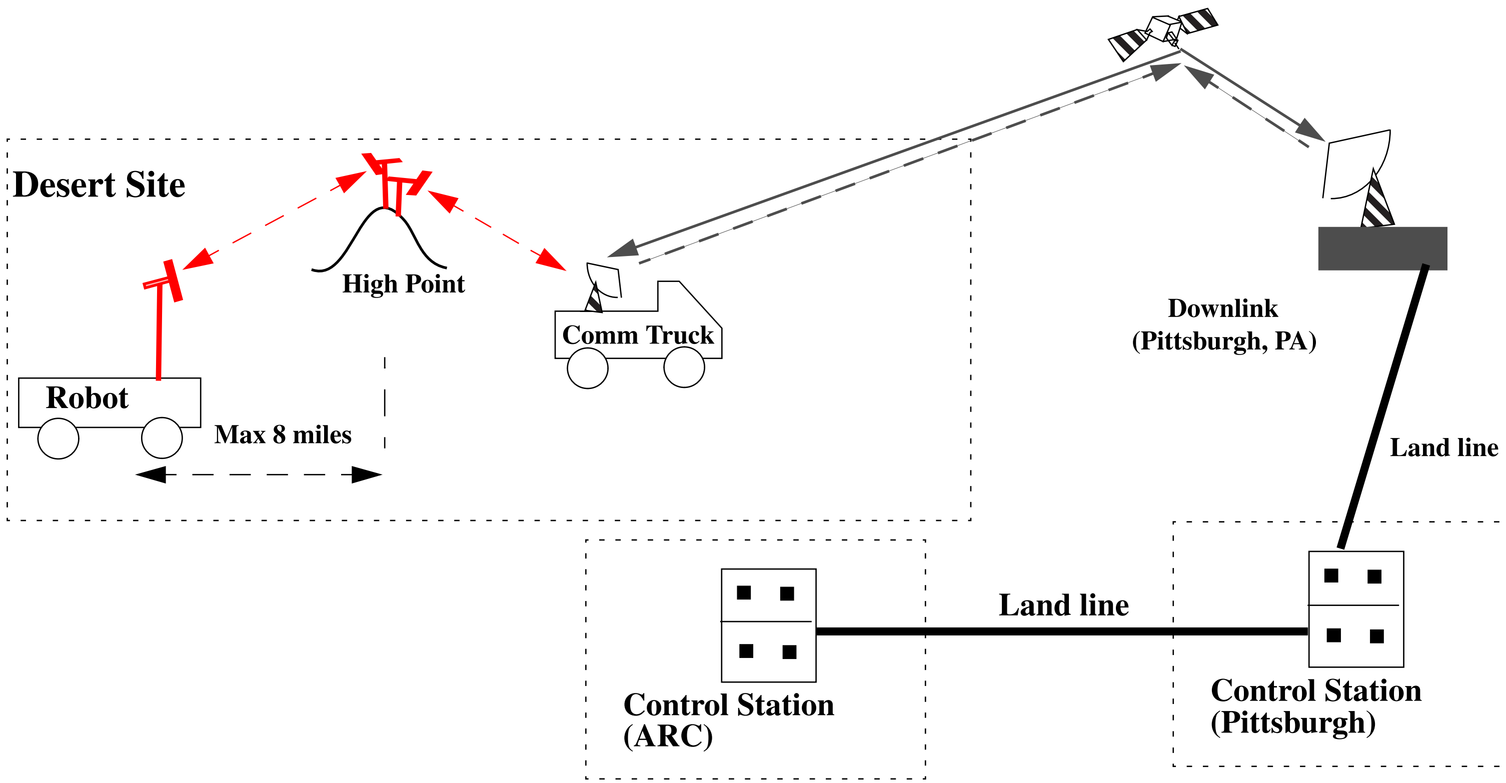
Bogey-type suspension for true body averaging

- Center of gravity moves 1/4 of the wheel elevations
- Body pitch is only 1/2 of the bogey angles
- Substantial obstacle negotiation capability

Coordinated Steering:

- Steers with mechanical linkages and few actuators
- All wheels are steered; steering angles are servoed
- Capable of both skid steering and double Ackerman

Communication



- High data rate (1.5 Mbps) required for video.
- Unprecedented from a moving robot.
- Range and rate achieved by stabilized high gain antenna.
- Pointing Mechanism and controls successfully developed.

Antenna Pointing Mechanism

- Azimuth/Elevation configuration

- less coupling

- Slip ring for elevation actuator

- continuous rotation unlike cable-wrap.
- reduces complexity (management of cables is easier)

- RF rotary joint

- to send RF signal from the transmitter to the antenna
- located co-axial with the slip ring
- RF characteristics remains constant unlike that for flexible RF cable
- Less losses (0.5 dB) compared to flexible RF cable (1.2 dB)

- *Harmonic drive and brushed motor*

- minimize backlash

- *Balanced system*

- minimizes disturbance torques

US Operations

Control centers: Carnegie Science Center (Pittsburgh, PA), and NASA Ames Research Center (Mountain View, CA)

Display: 6m diameter panoramic screen with 3 projectors at CSC, flat screen with single projector at ARC

User Interface: directional control, image pan/tilt, and heads-up overlay of instruments. [Extended interface includes low level controls of the vehicle and science instrumentation.]

Carnegie Science Center, Pittsburgh, PA

Nomad Specifications (1 of 2)

Locomotion

Type	4 wheel drive, 4 wheel steering, averaging suspension
Turning	2m minimum turn at vehicle center, sides synchronized
Speed	43 cm/s maximum, 30 cm/s average

Communications

High bandwidth telemetry	computer pointed directional antenna 1.54 Mbps continuous data rate
Low bandwidth	omni-directional, 19.2 kbps

Operation Modes

Safeguarded teleoperation	remote driver, onboard safety enabled
Autonomous	no human guidance
Direct teleoperation	remote driver, onboard safety disabled

Dimensions

Size	1.8m × 1.8m × 2.4m high (stowed) and 2.4m × 2.4m × 2.4m (deployed)
Mass	650 kg
Power consumption	2.4 kW

Nomad Specifications (2 of 2)

Sensors

Remote imaging	360° color panospheric camera
Terrain & landmark mapping	(2) stereo camera sets
Navigation	gyro compass differential GPS
Science	high resolution stereo towed metal detector weather station

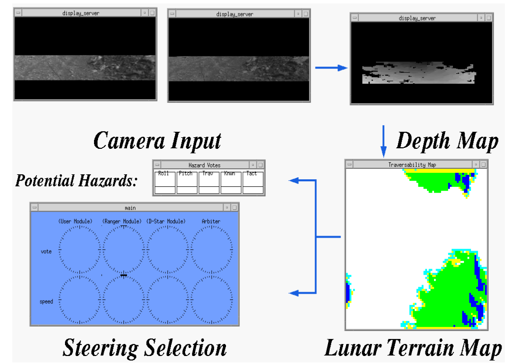
Computing

Robot control	(2) 68040 real time computers
Panoramic imaging	(1) Dual Pentium Pro
Navigation	(1) Pentium
Science	(1) Pentium Pro

Safeguarded Teleoperation

Sensors:

- 2 pairs of stereo cameras, 120 deg total FOV



Procedure:

- Range image produced from stereo and laser
- All possible paths are evaluated based on hazards along the path
- Nomad is allowed to move in a direction only if it is safe

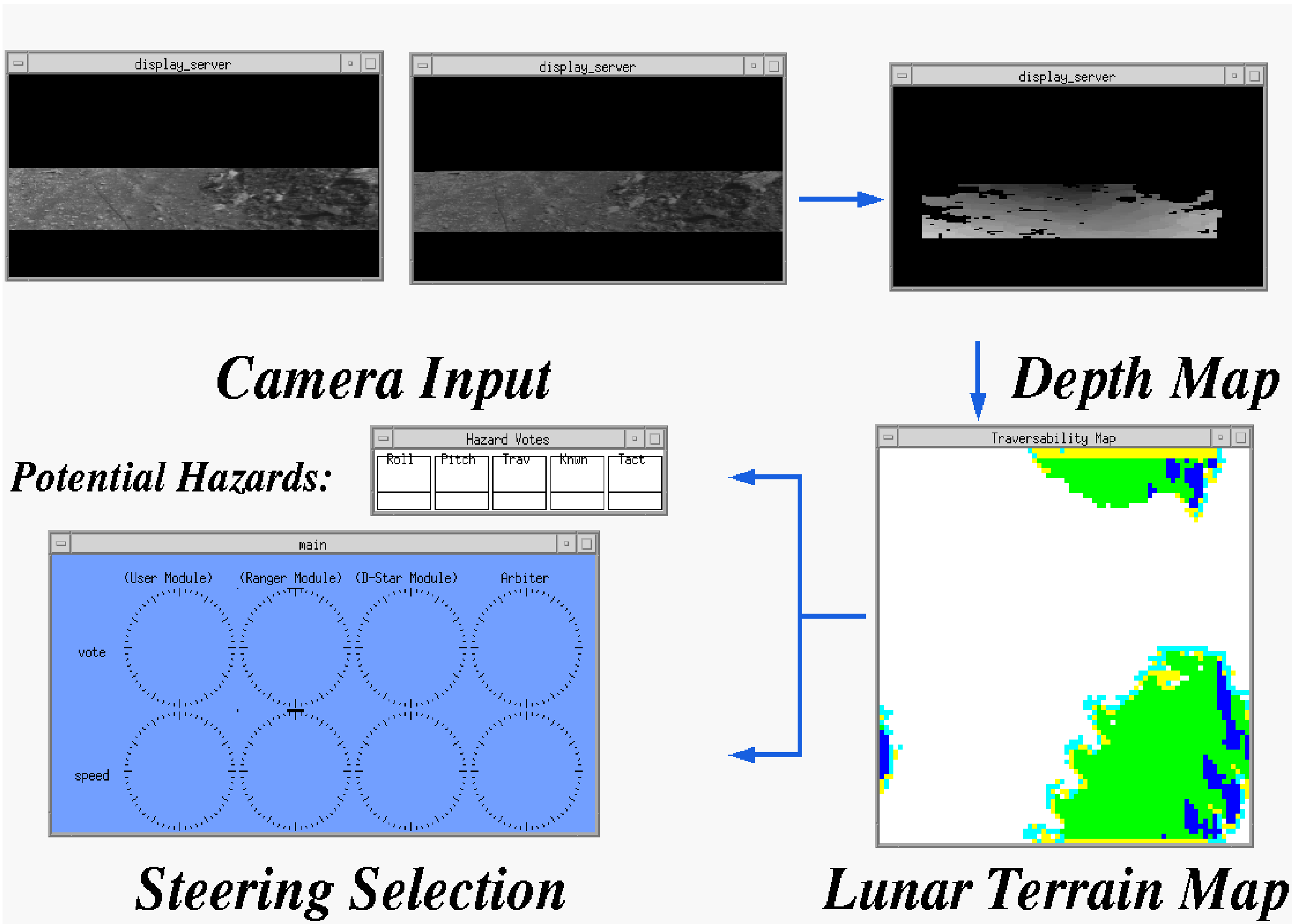
Modes:

Safeguarded teleoperation: User Issues commands, Nomad picks safest accommodating direction

Obstacle Avoidance: Nomad picks safest direction, wanders without goal

Waypoint Guidance: Nomad moves toward user-specified world point, subject to safe driving

Safeguarded Teleoperation



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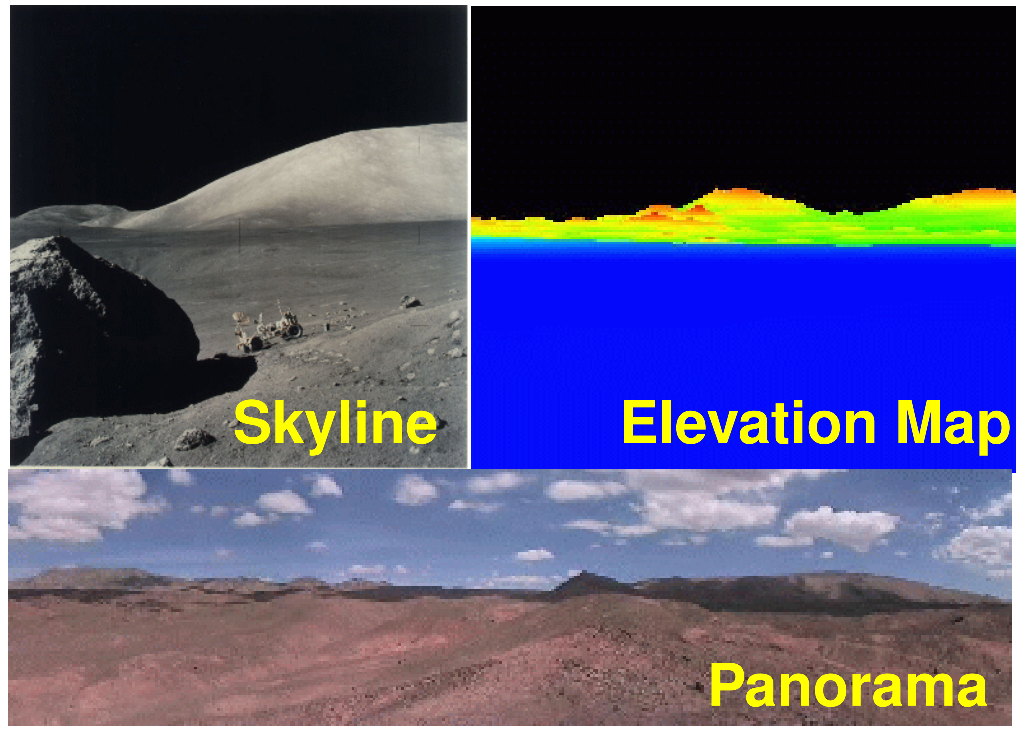
Skyline Positioning

- Combines images into a single panorama

- Skyline from the panorama matched to the skyline obtained from maps

- Accuracy between 84-300m depending on map resolution

- Accuracy achieved using data from Pittsburgh, Utah, California, Atacama and the Moon



Panospheric Imaging

Camera FOV: 360 deg Azimuth, -90 to 40 deg

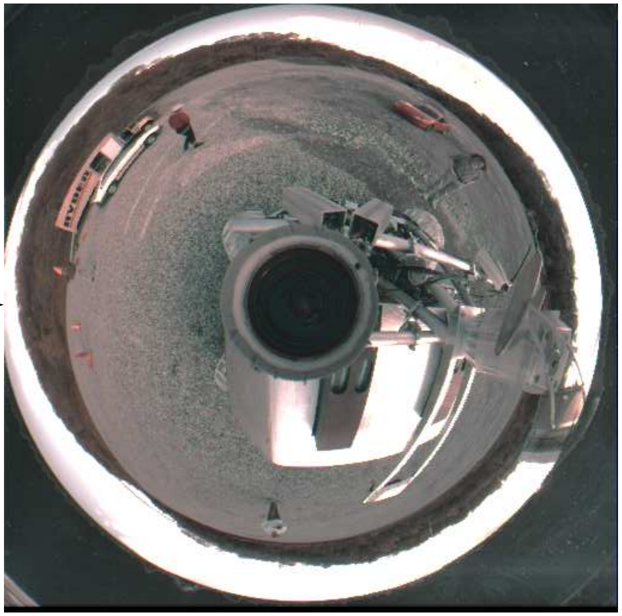
CCD: 1 k x 1k with Color filter overlay

Frame rate: 6-1 Hz possible

Compression: 1:60 using wavelet

Ultrawide FOV:

- Improves situational awareness
- Allows multiple operators independent views
- Aid scientists by giving a feel of environment
- Provides enhanced feature detection and tracking



Virtual Dashboard for Nomad

Developed by NASA Ames Research Center

- Simplify assessment of current robot state
- Reduce the number of operators and the required skill level of the operator
- Develop understanding of the environment
- Operate as effectively, in locomotion and science tasks, as if present at the site.