Prototype Development for a Lunar Astronaut Spatial Orientation and Information System

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Research Team

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- Consultant
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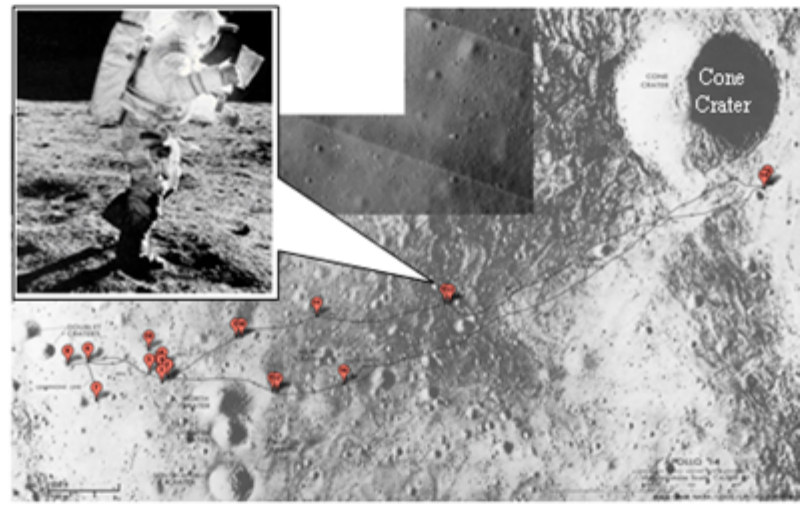
Objectives

A NASA/NSBRI (National Space Biomedical Research Institute) Project:

- **To investigate methods for removal and/or alleviation of astronaut disorientation during lunar surface operations using integrated information technology along with psychological and cognitive research on spatial orientation and navigation;**
- **To develop a Lunar Astronaut Spatial Orientation and Information System (LASOIS) that can enhance astronauts' spatial orientation capabilities and reduce sensorimotor risks during manned and landed lunar mission operations; and**
- **To train astronauts to enhance their spatial orientation capabilities in a LASOIS-supported simulated lunar environment.**



Apollo 14 traverse map

Mosaic of Apollo 17 Station 6 demonstrating the difficulty of judging distances on the lunar surface

Typical Scenarios for Astronaut Operations on the Lunar Surface

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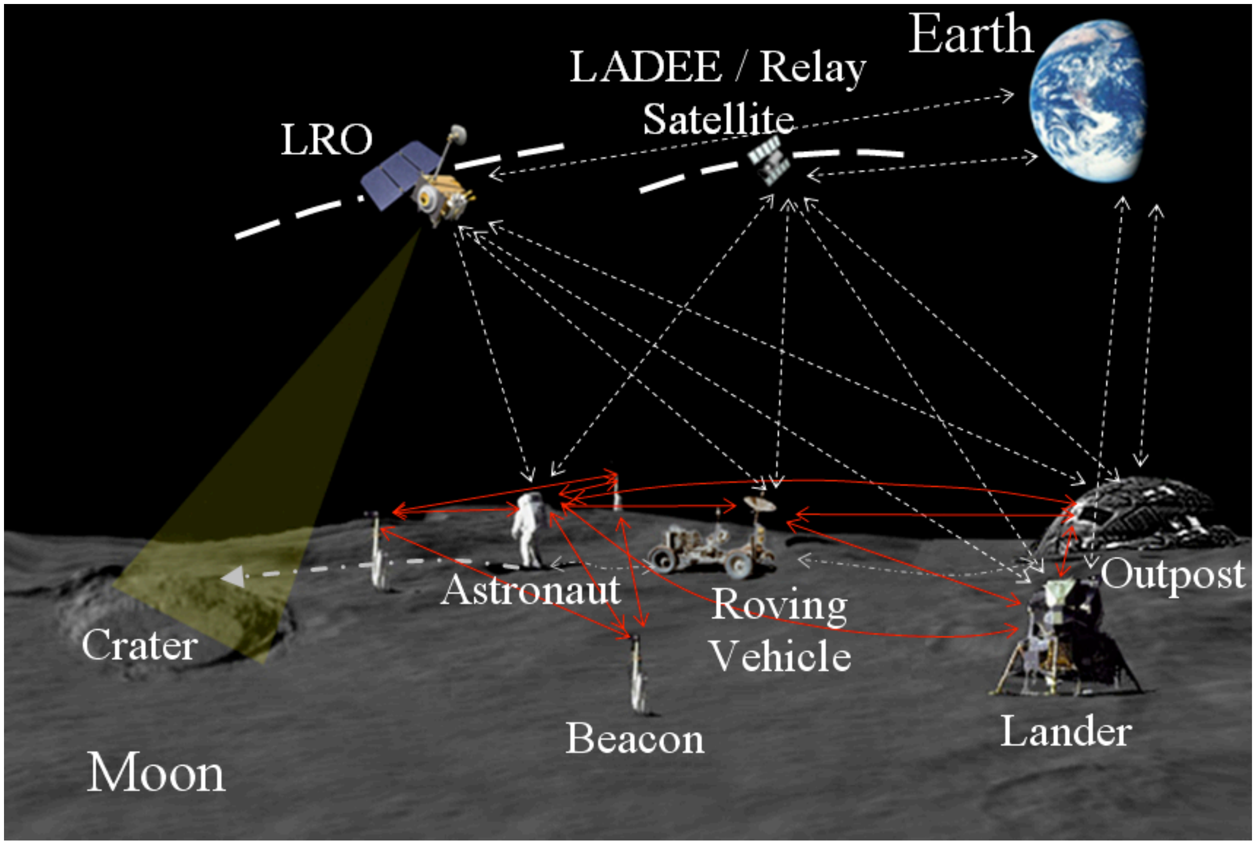
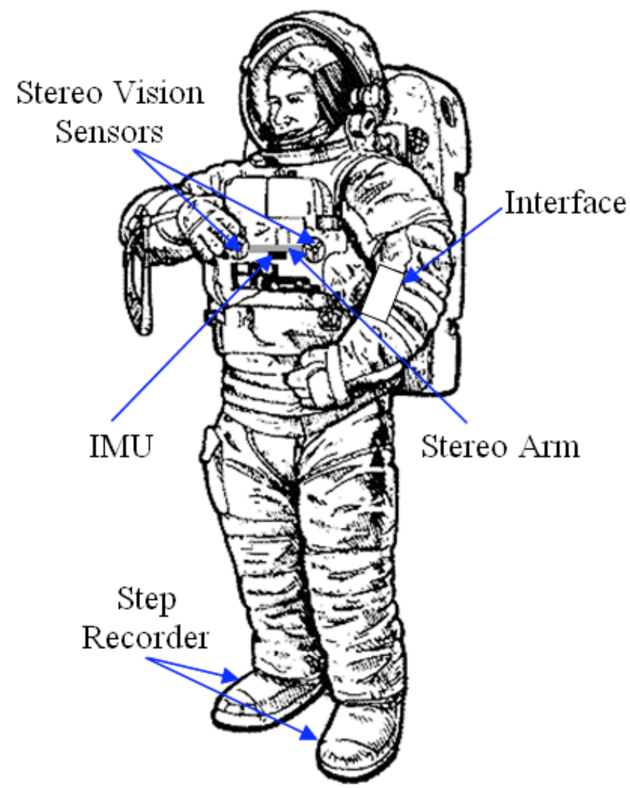
Operational Scenario	Operation Objective	Travel Distance	Operation Time/Speed	Lunar Environment Limitations
Long-range Operations	Excursions to scientific targets from the lander/outpost using LRV	100 km	Speed: ~ 10 km/h	Terrain roughness and slope; Vehicle slippage; Dust accumulated on sensors
	Excursions to scientific targets from the LRV/lander/outpost without LRV	10 km	Speed: ~ 2 km/h	Lack of reference; Terrain roughness and slope; Dust accumulated on sensors; Solar particle events
Short-range Operations	Collecting samples (rocks, soil, etc.)	30 m – 2 km	Time: < 7 hr	Lack of reference; Terrain roughness and slope; Dust accumulated on sensors; Solar particle events
	Deploying instruments	30 m – 2 km	Time: < 7 hr	Terrain roughness and slope; Lack of reference; Dust accumulated on sensors; Solar particle events
	Investigating the lunar environment, Initializing the instruments, Deploying the LRV etc.	< 30 m	Time: < 1 hr	Terrain roughness; Dust accumulated on sensors
	Capturing close-up image of the EVA station, investigating the virgin surface etc.	< 30 m	Time: < 1 hr	Undisturbed surface; Terrain roughness

[1] NASA, 2005. Exploration Systems Architecture Study - Final Report. NASA Technical Report NASA-TM-2005-214062.
[2] NASA, 2008. Navigation Concepts for NASA's Constellation Program and Human Missions to the Moon.

Integrated Sensor Network for Lunar Astronaut Spatial Orientation Enhancement

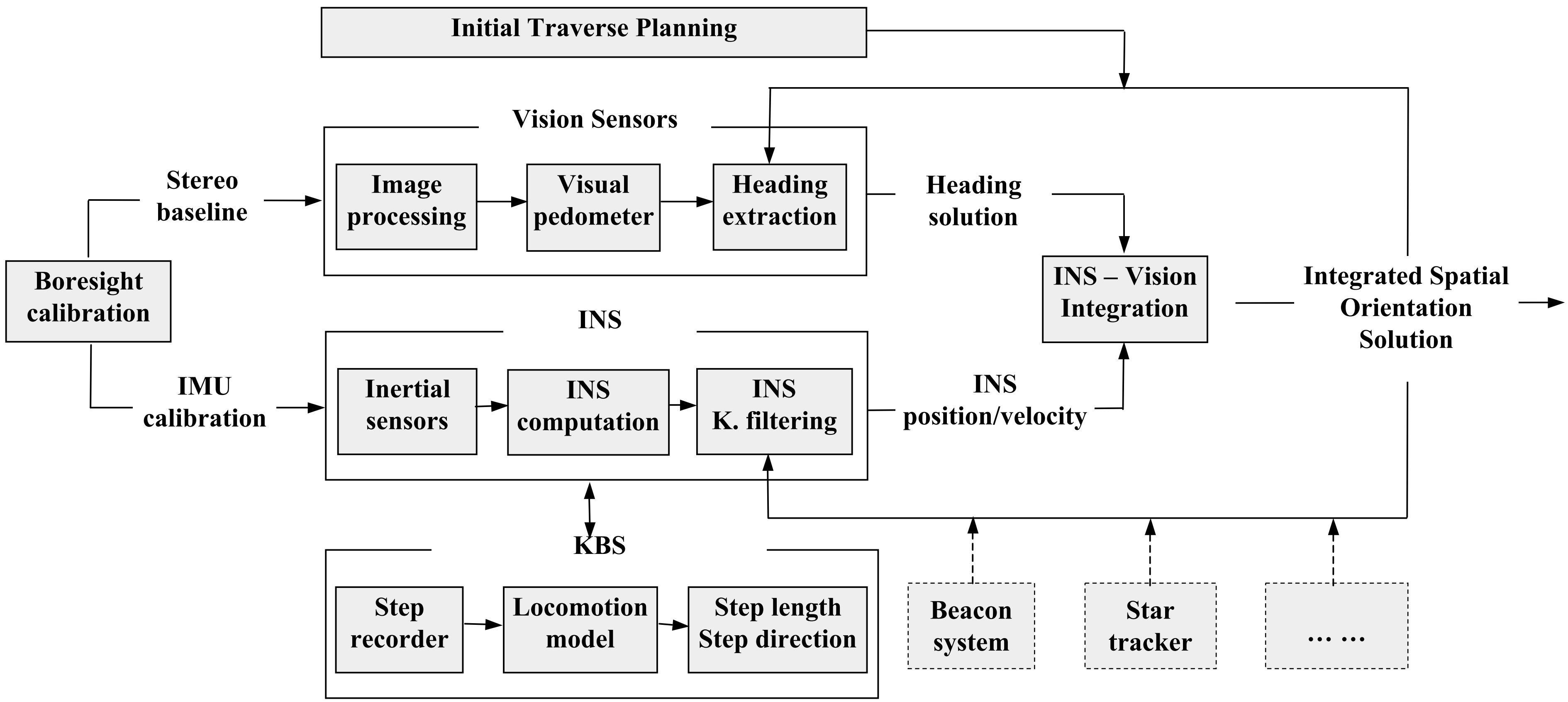


Conceptualization of the integration of orbital and surface sensors



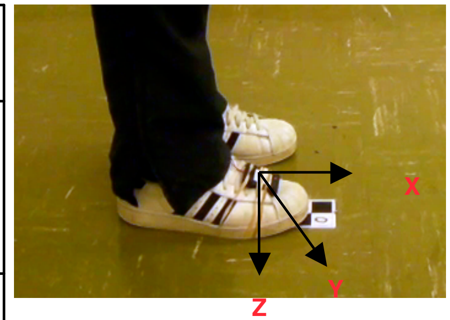
A possible configuration for on-suit sensors

Sensor Integration Solution for LASOIS

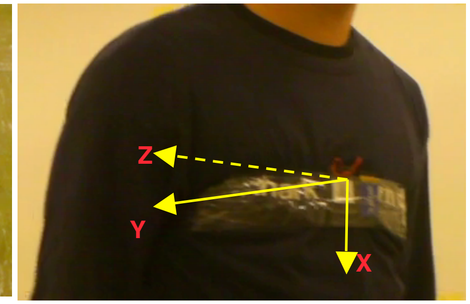


Determination of Placement of On-Suit Sensors

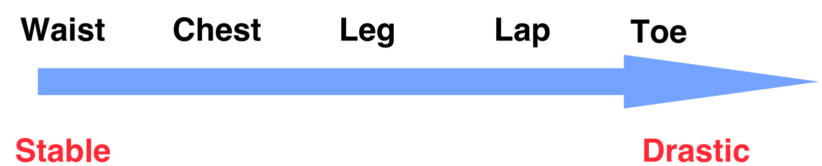
Sensor Placement	Advantages	Disadvantages
IMU on shoe Vision sensors on torso	ZUPT (Zero Velocity Update) for IMU, Longer baseline for the vision sensors	Complicated boresight calibration, Unpredicted / frequent foot movement
IMU on torso Vision sensors on torso	Simple boresight calibration, Better heading information for the IMU, Longer baseline for the vision sensors	Difficulty in employing ZUPT for IMU
IMU on shoe Vision sensors on helmet	ZUPT for IMU, More effective image tracking	Complicated boresight calibration, Unpredicted / frequent foot movement
IMU on torso Vision sensors on helmet	Better heading information for the IMU, More effective image tracking	Difficulty in employing ZUPT for IMU, Complicated boresight calibration
IMU on helmet Vision sensors on helmet	Simple boresight calibration, Better heading information from IMU, More effective image tracking	Difficulty in employing ZUPT for IMU



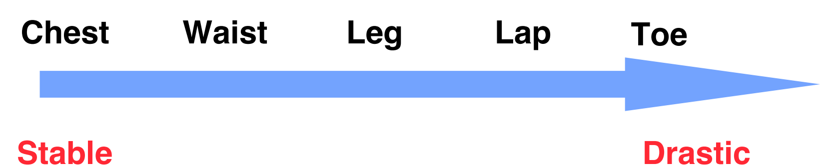
IMU on shoes



IMU on chest



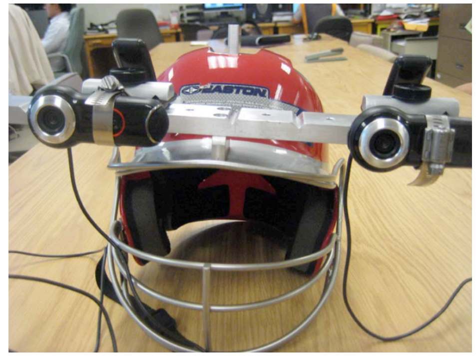
Attitude Change



Acceleration Change

Initial experimental results on IMU placement

Development of the LASOIS Prototype



Helmet Stereo Vision Sensor

Touch Screen Interface (Honeywell)

Step Recorder
FlexiForce Sensor Model A201

MEMSense Bluetooth IMU

Field Tests on Campus and at Moses Lake, WA

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NASA field test of space suits and robots on Moses Lake sand dunes in June 2008

Moses Lake, WA

- **Harsh terrestrial environment similar to the lunar environment**
- **Soft, powdery soil that is mixed with volcanic ash**

OSU field test of LASOIS prototype on Moses Lake sand dunes in July 2009

Initial Experiment Results from Field Test – more to come

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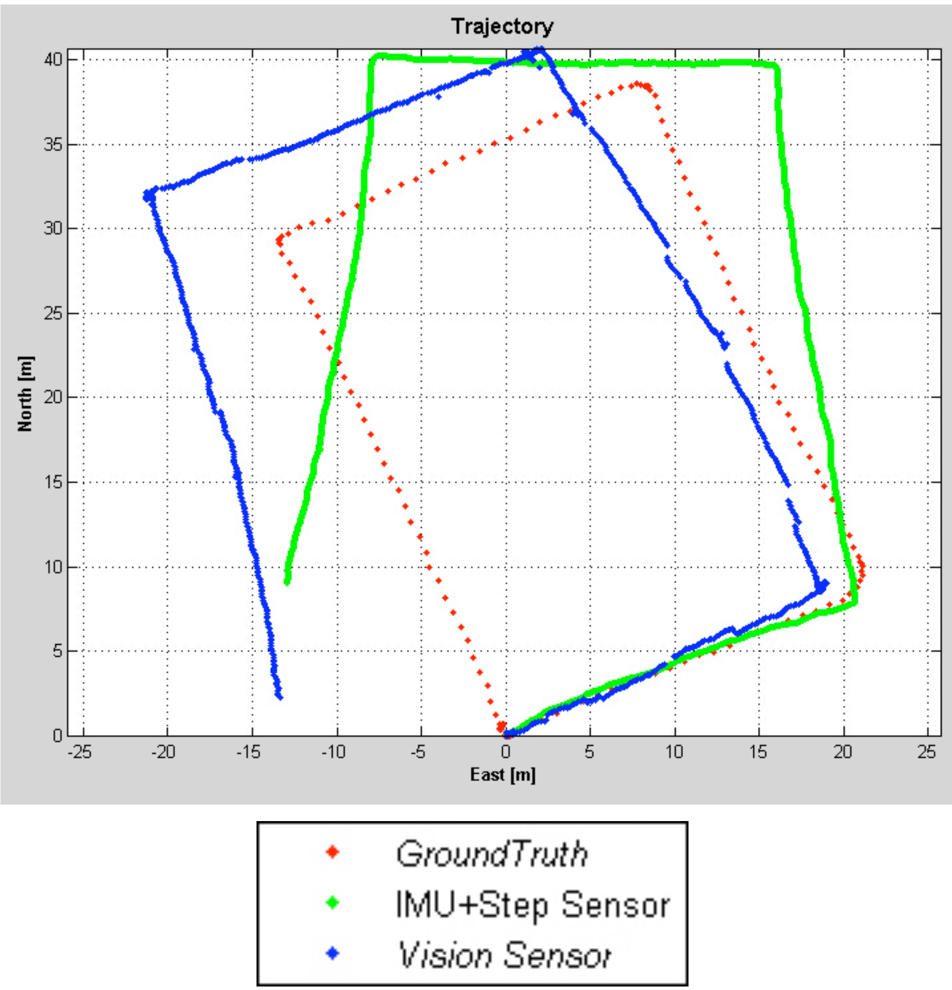
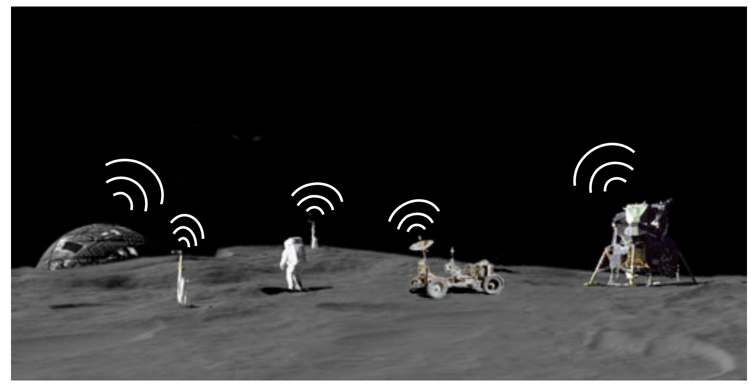
Reconstructed traverses from IMU + step sensor and vision sensors compared to ground truth (107m) for July 2009 field test



- **Traverse reconstructed from the industrial grade IMU plus the step sensor (green line) shows a distance accuracy of 2 %.**
- **Traverse reconstructed from the vision sensor alone (blue line) has a heading error of 10° (107m traverse over a 270° disclosure angle, or 4 % angle error).**
- **Experimental results demonstrate that the combination of industrial grade IMU, vision sensor and step sensor is capable of achieving an positioning accuracy of 4 % or better.**

More sensors to be used

- **Tactical IMU: Honeywell HG1900**
  - **Size: < 20 cu. in.**
  - **Gyro Bias: 1 deg/h**
  - **Accelerometer Bias: 1 mg**



- **Beacon Tracking System**
  - **Radio Frequency Identification (RFID)**
  - **Accuracy: 1 m through out 25 × 25 m**
- **Star Tracker**
  - **Determination of platform attitude**
  - **Applicable anywhere on the lunar surface**
  - **Accuracy of navigation solution: 1 arcsec (8.42 m?)**

Same as stereo cameras or separate on the back