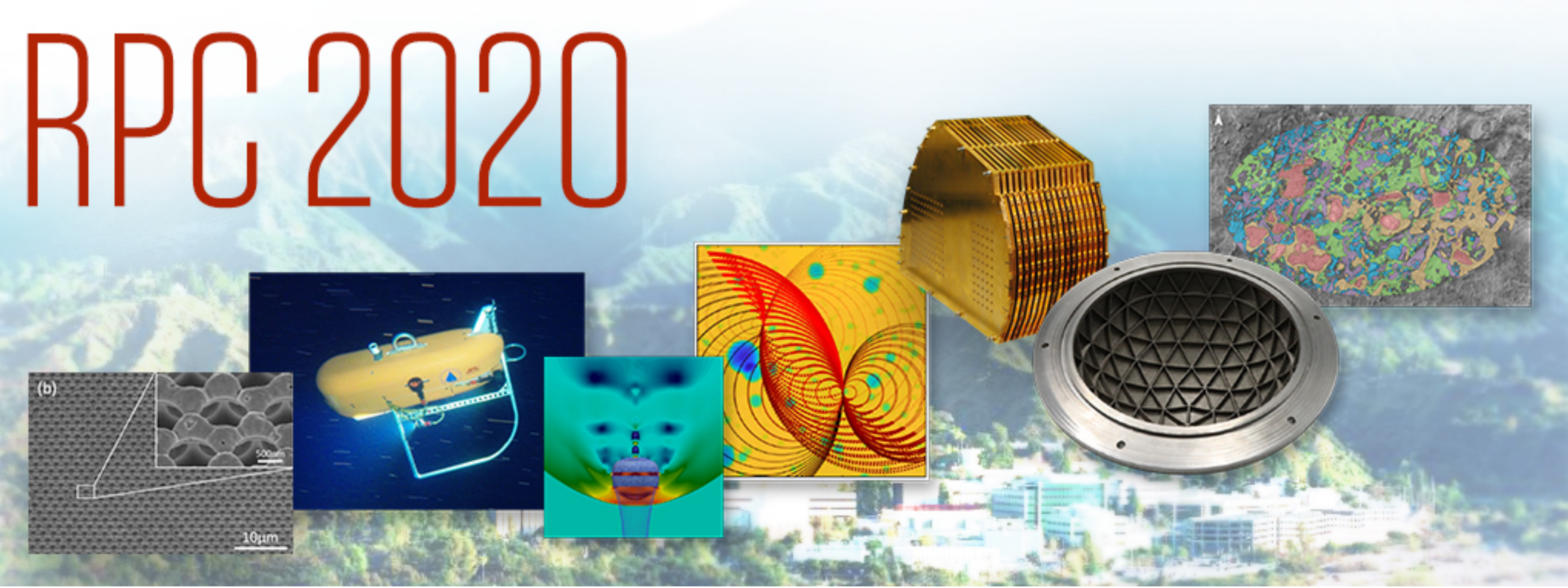

Virtual Research Presentation Conference

Precision North Finding

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Program: Spontaneous Concept

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Tutorial Introduction

Abstract

A precise knowledge of the North direction is critical for a multitude of applications such as attitude initialization for ascent/launch vehicles on planetary or terrestrial bodies, navigation in cluttered environments, and precision pointing of antennae and telescopes. Conventionally, North finding is performed via a combination of gyro-compassing using navigation grades inertial measurement units (IMUs) and/or using a magnetic compass to determine the magnetic North and knowing the location/time co-ordinates. Magnetic compasses are prone to interference from stray EM fields and ferro-magnetic structures, while nav grade IMUs are typically bulky and expensive, and therefore not amenable to implementation on size, weight and power (SWAP) constrained systems such as ascent vehicles or high mobility small platforms. Thus, an alternate method of North finding is required to estimate precise knowledge (<0.1deg error) in a low-SWAP form factor. If such a sensor system were to be available for special applications such as the Mars Ascent Vehicle, it would enable the use of a much smaller SWAP IMU for the ascent trajectory thereby resulting in a much lighter to-be-landed mass (6kg of landed mass is required for every 1kg of ascent mass) on the Martian surface.

Problem Description

Precise knowledge of the North direction is critical for a multitude of applications

- Attitude initialization for ascent/launch vehicles
- Navigation in cluttered or GPS denied environments
- Precision pointing of antennae and telescopes

State-of-the-Art Approaches:

- Gyro-compassing using navigation grade IMU
  - Typically nav-grade IMUs are large, bulky and expensive, and therefore face SWAP challenges
- Magnetic compass to determine magnetic North, coupled with location/time information
  - Magnetic compass is prone to interference from stray EM fields and ferro-magnetic structures

Relevance to NASA and JPL

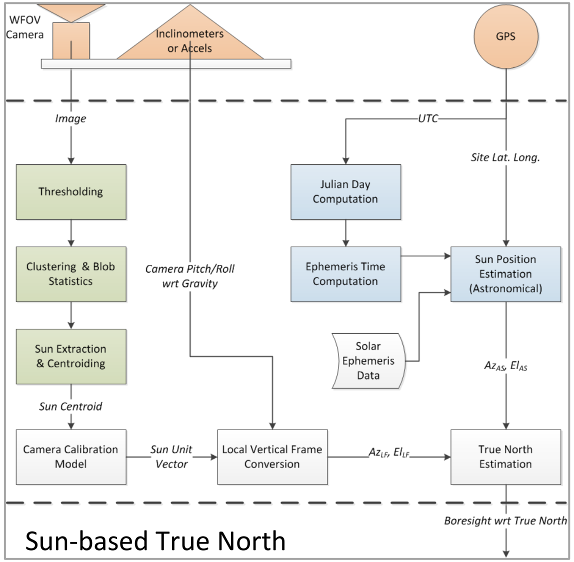
- An alternate low-SWAP, high precision North finding approach is therefore essential
- Immediate applications to NASA/JPL missions include:
  - Azimuth finding for the Mars Ascent Vehicle (MAV) for Sample Return Mission => would allow for a much smaller SWAP IMU on the MAV
  - Any surface based applications such as landers, rovers for Moon, Mars, and other bodies for azimuth/heading determination

Methodology

Primary Objectives of this short spontaneous effort were to identify and select optimal sensing solutions for North determination

Possible solutions to be looked at were:

- Dual field-of-view camera based approach using Solar-arc tracing
  - Combined with location of the vehicle on the surface this would provide North direction
  - To minimize transfer errors from the camera frame to MAV frame, the same camera with its second field-of-view would image fiducials on the MAV to continuously estimate and update the pose relative to the MAV
- Day/night star tracker with narrow spectral filters
  - Identify spectral bands that would allow for imaging through the atmosphere even in day-time
  - High accuracy method but is constrained to requiring at-least a partially cloud-free portion of the sky
- Nav-grade IMU on Lander (not ascent vehicle) for gyro-compassing
  - Active alignment using camera that is simultaneously imaging fiducials both on the IMU and the ascent vehicle

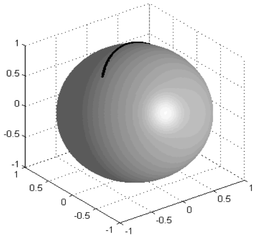


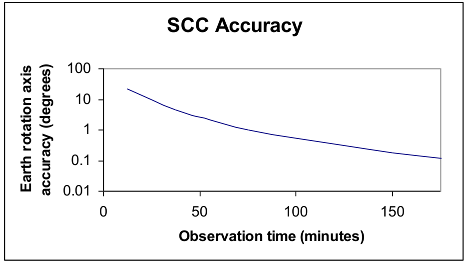
Lab-closures due to Covid-19 have significantly impacted work on this task, and therefore prevented any actual tests of acquired sensors

Results

Solar Arc-Tracing

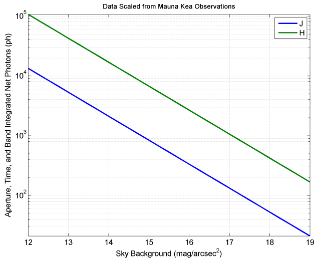
- Wide FOV of camera image sun at intermittent intervals
- High accuracy centroiding (~0.25pixel) on Sun performed
- Arc fit to the centroid positions
- Local vertical can be determined through accelerometers
- Simulations show that the azimuth accuracy reaches <0.5deg in 2hrs

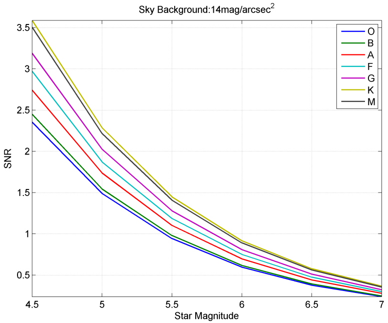




Day-night Star Imaging

- Based upon atmospheric transmission data, J-band (1.6um) short-wave-infra-red band is optimal for imaging stars in daytime for Earth applications
- NIR could be used in situations where ambient lighting from man-made light sources is low
- SNR of 2 is achievable for stars as faint as visual magnitude 5 on a bright daytime background
- For Earth applications, off-the-shelf SWIR imaging cameras coupled with the requisite optics for field-of-view and aperture, would provide the imaging capability





Significance: Two methods have been identified that could provide required accuracy for North finding

Next Steps: More experimental data needs to be acquired to fully quantify accuracy. Atmospheric transparency for Mars needs to be analyzed to identify optimal operating band for Mars

Publications and References