The first telescopes at the lunar outpost will be observing the Sun.

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Overview

- The need for an operational solar telescope
  - In situ space weather forecasting / nowcasting
    • What is the longest time out of contact?
    • Learning about how to build and operate telescopes on the moon
- Scope
  - Radio, Optical, UV, EUV, X-ray
  - Not particles, hard X-ray, gamma-ray
- Operational observations
  - Basic instrument compliment
    • GOES X-Ray Sensor
    • WIND/WAVES Radio Receiver
    • GOES SXI
    • Imaging magnetograph (vector?)
  - Mass and power limitations
- Science
  - Define the requirements for the integrated space weather system
  - What are the key unknowns
- Space weather system on Mars
Operational Space Weather Requirements

• Why Forecasts?
  – People in extreme environments don’t like surprises

• Forecasts from Earth
  – Far side imaging, interior imaging (weeks - days)
  – Near side active region evolution models (days - hours)
  – Real time active region monitoring (multi wavelength) (days - hours - minutes)

• Lunar contribution
  – Need depends on continuity of contact with the Earth
    • The fastest CMEs arrive in about 18hrs
    • The fastest particles arrive with observation of the flare
  – Real time active region monitoring (days - hours - minutes)
Why are lunar observations required?

- Communication with Earth may be disrupted.
- Space weather is the most significant environmental variable at the lunar outpost.
- Individuals in an extreme environment will want to have direct access to the instruments that inform them about that environment.
Other benefits of the a solar forecast telescope suite

• Prepare for Mars
  – Earth based forecasts won’t work for Mars
  – A combination of orbiting and ground based telescopes will be needed for Mars
  – Operating a telescope in a hash environment requires practice.

• Simple telescopes
  – Small, low power, low weight instruments (based on GOES designs)
  – Bright target

• Determine the impact of dust on seeing.
  – Multi-wavelength observations show sensitivity from optical to X-ray wavelengths.
  – Grazing incidence optics are sensitive to dust - Is cleaning possible?
  – Or EUV?
Baseline instrument package

- GOES X-Ray Sensor
- WAVEs RAD2 Radio Receiver
- GOES Soft X-Ray Imager
- Magnetograph
- Coronagraph
Baseline Mass & Power

- **GOES XRS** (Disk integrated X-ray sensor using two ion chamber detectors):
  - 3-4W; 10Kg; 0.2m length

- **WIND/WAVE RAD2** (Disk integrated radio receiver 1-14 MHz):
  - 28W; 43Kg; 0.5m length

- **GOES SXI** (grazing incident X-ray telescope backside thinned CCD):
  - 30W; 27Kg; 0.8m length

- **XRT**:
  - 30W; 48Kg; 3m length

- **MDI**:
  - 60W; 58Kg; 1.1m

- **Coronagraph**:
  - 100W, 25Kg; 2m
Infrastructure

- **Mounting**
  - On a south pole ridge the telescopes will scan the horizon over the course of a lunar day.

- **Power**
  - Power requirements not a driver

- **Computing resources/displays**
  - Full sun images may require high resolution displays
  - Need to be hardened.
Where is the science?

- **HelioPhysics community needs to:**
  - Improve the space weather forecasts
    - Instrumentation, theoretical understanding, models, simulations
  - Define the baseline instrumentation and associated infrastructure
    - What physical quantities need to be measured? Where do we need to measure them (mag field in photosphere or chromosphere; vector or scalar …)?
    - What tools need to be developed to use new understandings in operational forecasts?
    - Define the minimum set of observations for forecasts on time scales from weeks to minutes?
  - Implement the program in a timely manner
Implementation

• Transition scientific understanding to improved operational tools
  – Improve the communication between research scientists and forecast scientists

• Develop the analysis tools that will allow for accurate forecasts with the given instrumentation.
  – Having defined the instrument package the associated software and hardware to use the data needs to be developed.
  – Training of users using archival data.
Timeline

- Timeline (L = date of lunar habitation ~ 2018)
  - (L - 1 year) Instrument package and associated hardware and software delivered.
  - (L - 5 years) Begin phase C/D construction of telescopes.
  - (L - 8 years) AO for telescopes and analysis hardware/software released.
  - (L - 10 years) Science definition team for lunar space weather analysis system formed.

NOTE: These operational telescopes have no scientific usefulness; the cost of construction can not come out of SMD/HP.
The Mars site will require a stand alone space weather system.
- Direct connection to data from satellite assets in Mars orbit
  - Ground stations on Mars
  - Connection to Earth based information
  - Local telescopes and sensors

The Martian atmosphere
- Absorption of EUV and soft X-rays
- Wind blown dust reduces seeing in visible light
- Hard X-ray telescope may be usable from the surface, but dust....?