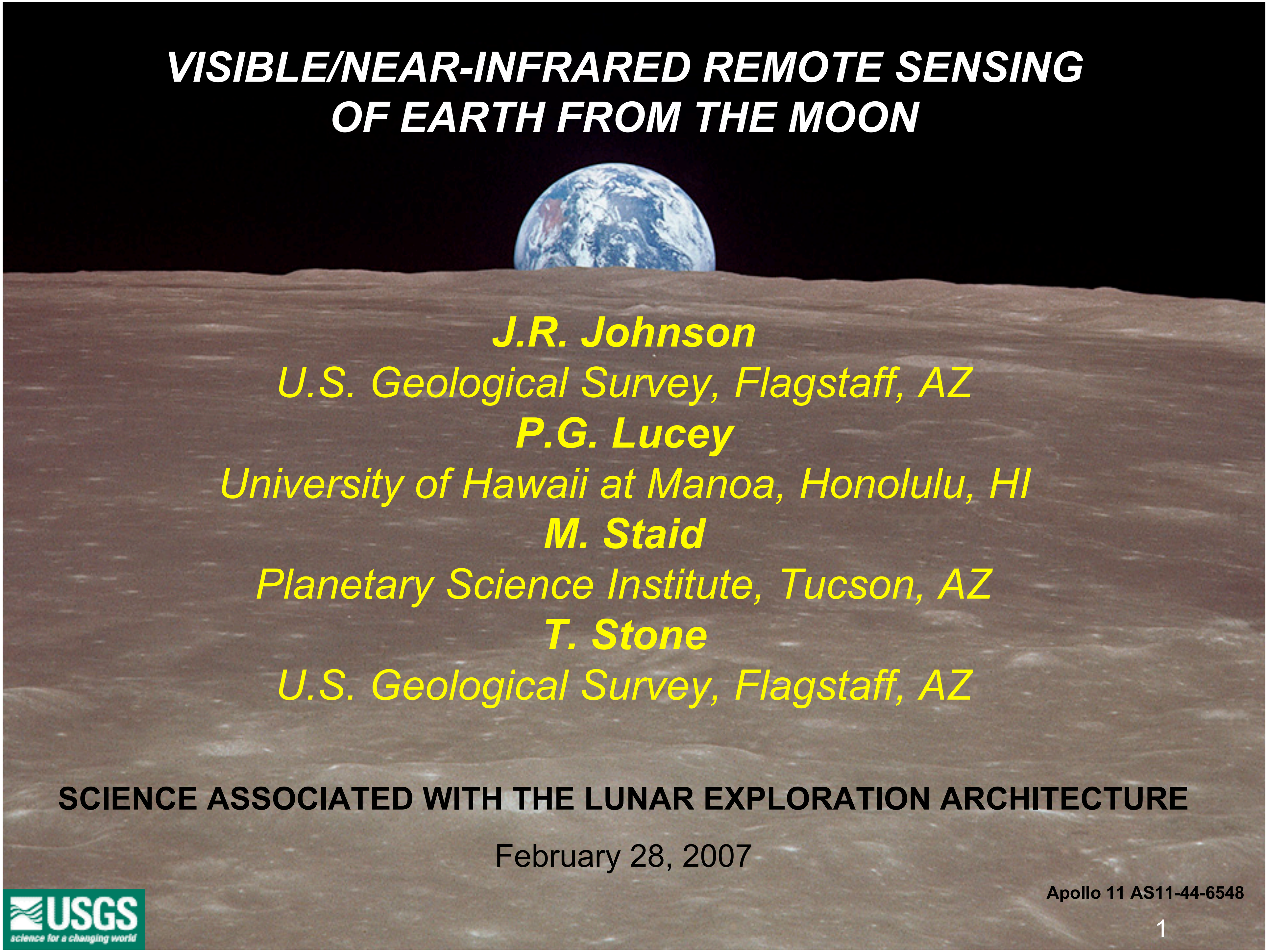

VISIBLE/NEAR-INFRARED REMOTE SENSING OF EARTH FROM THE MOON

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SCIENCE ASSOCIATED WITH THE LUNAR EXPLORATION ARCHITECTURE

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Apollo 11 AS11-44-6548

Objectives

- **Summarize (*from the perspective of someone not on Earth Science Subcommittee and most interested in planetary science*) the ESS Earth Observation Objectives relevant to visible/near-infrared wavelengths**
- **Review advantages/disadvantages of lunar-based observatory, technical constraints**
- **Discuss possible observing strategies and philosophy**

<u>ESS Earth Observation Objectives relevant to visible/near-infrared*</u>

- ***<u>mEO3</u>*** **(atmospheric composition and dynamics)**
- ***<u>mEO5</u>*** **(Earth's bidirectional reflectivity distribution function (BRDF) for climate studies)**
- ***<u>mEO7</u>*** **(synoptic surface composition)**
- ***<u>mEO9</u>*** **(ice coverage)**
- ***<u>mEO11</u>*** **(earthshine/albedo)**
- ***<u>mEO12</u>*** **(lightning distribution)**

*note revised mEO*x* numbers relative to submitted abstract

mEO3 (atmospheric composition and dynamics)

4

Multi/hyperspectral imaging at ~1 km resolution

- Monitor global-scale dynamics of dust storms, pollution
- Determine fluxes of atmospheric constituents by examining spectral features
  - H_2O (0.7, 0.8, 0.9, 1.1, 1.4, and 1.9 µm)
  - CH_4 (0.88, 1.70, and 2.40 µm)
  - CO_2 (1.06, 1.20, 1.60, 2.00, 2.06 µm)
  - O_2 (0.69, 0.76, 1.26 µm)
  - O_3 (< 0.34 µm, ~0.60 µm)

mEO5 (Earth BRDF for climate studies)

4

Hyperspectral observations at multiple incidence, emission, and phase angles

- **More fully quantify Earth's bidirectional reflectivity distribution function (BRDF)**
- **Climate studies require more precise radiative balance calculations than are currently available using data from low Earth orbiting (LEO) satellites**

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mEO7 (synoptic surface composition)

5

Hyperspectral imaging at 250-500 m spatial resolutions

- **Monitoring of surface mineralogy, vegetation, and atmospheric aerosol distributions at regional and global scales**
- **Combine with multispectral data from orbiting satellites to provide useful data for *radiometric cross-calibration***

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mEO9 (ice coverage)

5

Monitoring of regional ice masses and seasonal sea ice extent using multispectral imaging

- **Combine with data from other orbiting sensors**
- **Would add to our understanding of the response of these features to changing regional climatic conditions**

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mEO11 (earthshine/albedo)

--see Alex Ruzmaikin talk at 3:40 pm

1

Measurements of the non-sunlit portion of the Moon illuminated by light reflected from the Earth ("earthshine")

- **Have been made for nearly a century in attempts to quantify changes in Earth albedo and detect biosignatures *(Arcichovsky, 1912; Danjon, 1928)***
    - **chlorophyll "red edge" around 0.70-0.75 μm**
- **Benefits of acquiring disk-averaged Earth radiance spectra noted by others**
- **Similar techniques useful for investigating potential signs of life on extrasolar planets (cf. Turnbull et al., Thursday 10:50, Sun-Earth interactions)**
    - **Done for Earth using Galileo s/c data *(Sagan et al., 1993)***

mEO12 **(lightning distribution)** **--see Steve Goodman talk at 4 pm**

5

Continuous monitoring of lightning

- **Provide input to climate models**
- **Expand on work done by orbital sensors**
  - ➢ **Lightning Imaging Sensor (LIS) on the Tropical Rainfall Measuring Mission (TRMM)**
    - ✓ **investigated the dynamics and water content of tropical thunderstorms in relation to changes in climate**
- **Monitoring of volcanic activity using similar instruments in combination with sensors in orbit (given sufficient spatial resolution)**
  - ➢ **GOES, AVHRR, MODIS, Landsat, ASTER**

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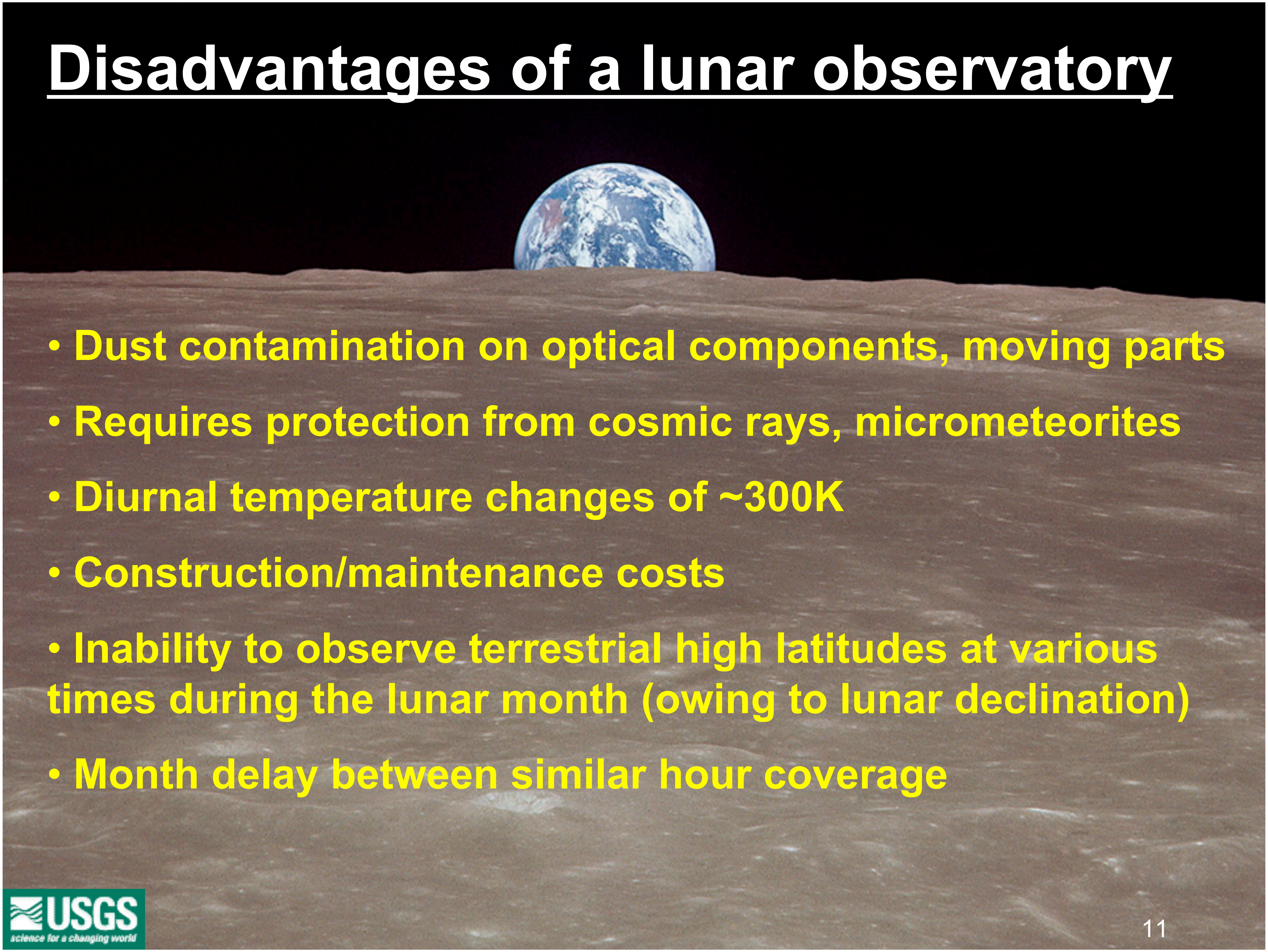
Advantages of a lunar observatory

"The Moon is a slowly rotating spacecraft….that always presents the same face to the Earth"

--NAC report, 1991

- **Absence of an appreciable atmosphere**
  - **avoids atmospherically-induced distortions ("seeing")**
  - **permits spatial resolutions limited solely by telescope size**
    - **Diffraction-limited spatial resolution *R* (km): $\boxed{R \approx \lambda / D}$**
      - **λ = wavelength (μm), *D* = telescope diameter (m)**
      - **To achieve *R* <1 km need *D* >1 m**
- **Lower lunar gravity, lack of wind**
  - **permits lighter-weight support structures compared to Earth telescopes**
- **Two weeks of thermal stability per lunation**


Disadvantages of a lunar observatory
• Dust contamination on optical components, moving parts
• Requires protection from cosmic rays, micrometeorites
• Diurnal temperature changes of ~300K
• Construction/maintenance costs
• Inability to observe terrestrial high latitudes at various times during the lunar month (owing to lunar declination)
• Month delay between similar hour coverage
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11

Final discussion points

"*a lunar astronomy program should complement the earth-orbiting satellite program*" (NAC, 1991)

- Simultaneous observations of Earth from Moon and geosynchronous Earth orbit satellites provide cross-calibration among instruments
- Monitor dynamics of volcanic eruptions, wind storms, cloud cover
  - cf. synchronized observations of planetary phenomena
    - e.g., Shoemaker Levy 9 impact; Io volcanic eruptions; Martian atmosphere (storms, dust devils, albedo changes, etc.)
- "*the scientific discoveries enabled by a lunar base are not predictable*" (Mendell, 1985)
- "*Outstanding researchers will be attracted to the lunar initiative if they [can] foresee interim scientific results being obtained*" (NAC, 1991)