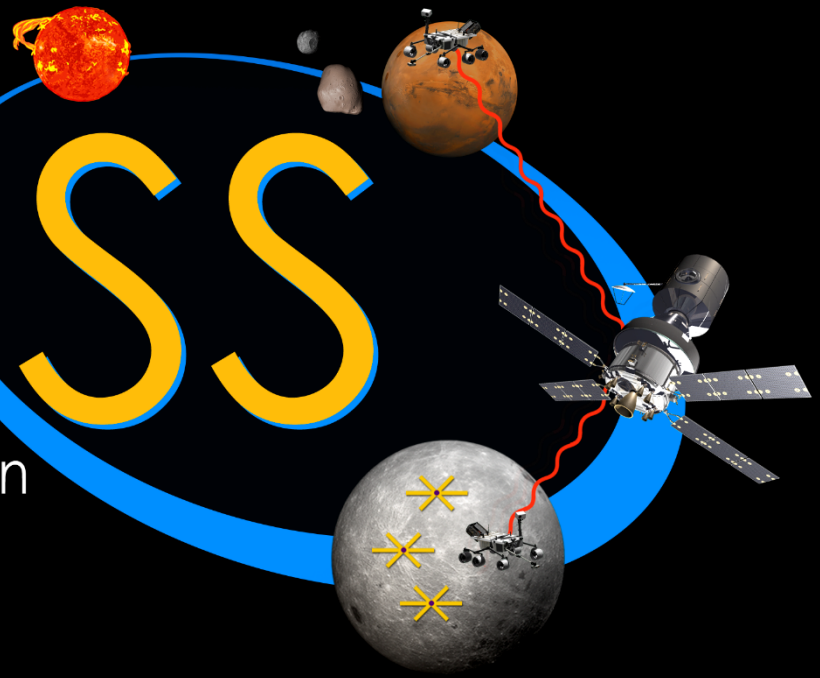
NESS

Network for Exploration and Space Science



SERVI — Solar System Exploration Research Virtual Institute

University of Colorado Boulder

NASA

University of Michigan

UCLA

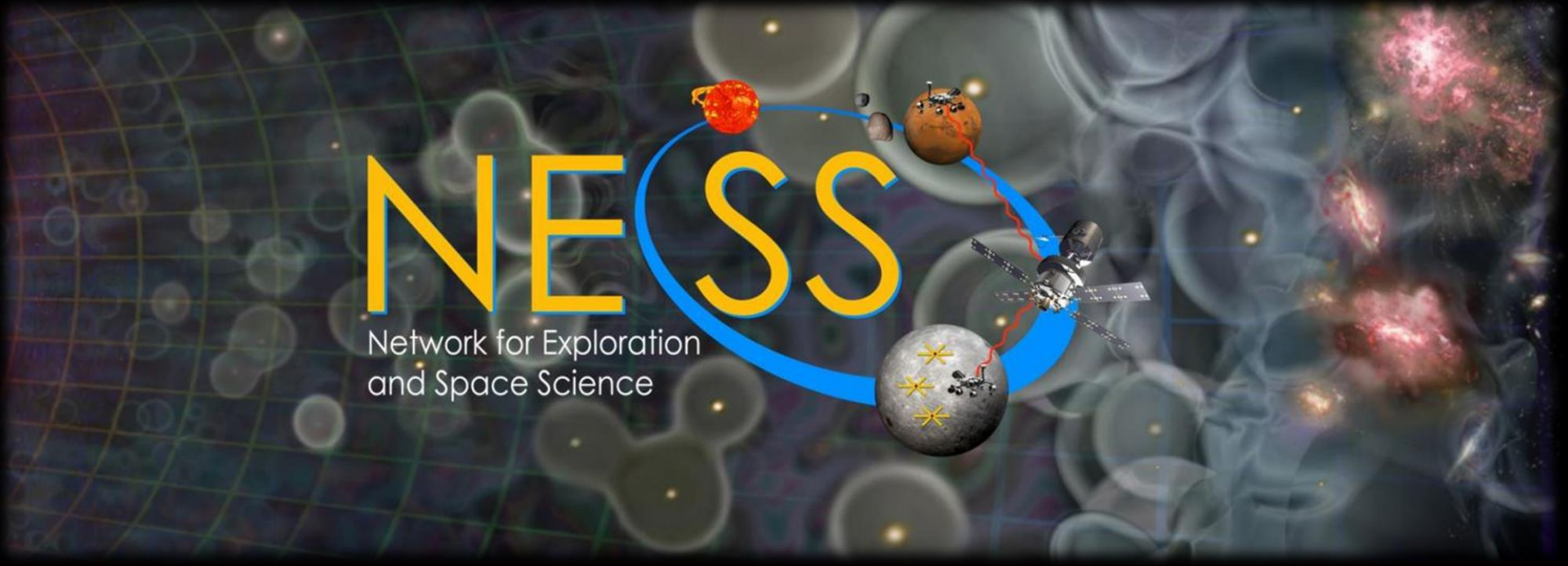
NRAO

ASU

Caltech

Ball Aerospace

Lockheed Martin



The Network for Exploration and Space Science (NESS) is a multifaceted and multidisciplinary investigation in the space sciences, including the areas of astrophysics and heliophysics, that foster innovative instrument platforms enabled through human and robotic exploration of the target bodies.

NESS website: http://www.colorado.edu/ness/

NESS Steering Committee

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Bob MacDowell, Deputy
NASA GSFC
Co-lead Radio Heliophysics

Jack Burns, PI
U. Colorado
Co-lead Telerobotics

David Rapetti, Assistant Dir.
U. Colorado
Cosmic Dawn

Judd Bowman
Arizona State
Cosmic Dawn

Steve Furlanetto
UCLA
Cosmic Dawn

Rich Bradley
NRAO
Cosmic Dawn

Gregg Hallinan
Caltech
Extrasolar Weather

Terry Fong
NASA Ames
Surface Telerobotics

Justin Kasper
U. Michigan
Radio Heliophysics

Industry Collaborators:

Bill Purcell
Ball Aerospace

Scott Norris
Lockheed Martin

NESS Collaborators & Students

Collaborators

- Dan Baker, University of Colorado
- Tim Cichan, Lockheed Martin
- Heino Falcke, Radbound University, The Netherlands
- Bill Farrell, NASA GSFC
- Joshua Hopkins, Lockheed Martin
- Brian Jones, Lockheed Martin
- Dayton Jones, Space Science Institute
- Leon Koopmans, Kapteyn Astronomical Institute, The Netherlands
- David Kring, LPI
- Milan Maksimovic, Observatorie de Paris
- Nicole Meyer-Vernet, Observatorie de Paris
- Jordan Mirocha, UCLA, postdoc
- Raul Monsalve, U. Colorado, postdoc
- Chris Norman, Lockheed Martin
- Arnaud Zaslavsky, Observatorie de Paris

Students

- University of Colorado:
  - Graduate students - Keith Tauscher, Bang Nhan
  - Undergraduates - Ben Mellinkoff, Matt Spydell
- Arizona State: Ms. Nivedita Mahesh
- Caltech: Ms. Marin Anderson
- University of Michigan: Alex Hegedus, Ms. Janelle Holmes, Chris Bert.

Collaborations with other SSERVI Teams

SSERVI SOLAR SYSTEM EXPLORATION RESEARCH VIRTUAL INSTITUTE

- Institute for the Science of Exploration Targets – Bill Bottke, PI, SwRI.

- Dynamic Response of Environments at Asteroids, the Moon, and moons of Mars (DREAM2) – Bill Farrell, PI, NASA GSFC.

- Institute for Modeling Plasma, Atmospheres and Cosmic Dust (IMPACT) – Mihaly Horanyi, PI, University of Colorado.

- Inner Solar System Impact Processes – David Kring, PI, LPI.

NESS Science

NESS science is derived from the recommendations of three space science Decadal Surveys, the NASA Astrophysics Roadmap, and the Global Exploration Roadmap.

NESS undertakes investigations in space science and exploration including:

- Generation and monitoring of energetic solar particle events that are potentially harmful to life in interplanetary space and in extrasolar systems;
- Dust environments of space and exploration target bodies;
- Detection of the first stars and galaxies in the early universe;
- Characterization of habitable exoplanets.
- Human-assisted telerobotic operation of planetary surface science and exploration assets from platforms orbiting the Moon and Mars;

Our technical approach includes humans and robots working in tandem to explore at target bodies as well as building, operating, and servicing scientific instrumentation by using cis-lunar space as a science-enabling stepping-stone towards a "Journey to Mars."

Science & Exploration Themes

The significance of the partnership between science and exploration is reflected in the overarching questions that we pursue:

- **Radio Heliophysics**
  - How do variations in the Sun's activity, interplanetary plasmas, and inputs from the interstellar medium influence the energetic particle and dust environment of space and exploration target bodies?
- **Cosmic Dawn**
  - What were the first objects to light up the universe and when did they do it?
- **Extrasolar Space Weather**
  - How can lunar radio arrays enable the detection and characterization of exoplanets and their magnetic environments?
- **Science & Exploration enabled by Surface Telerobotics**
  - How can exploration infrastructure facilitate space science at target destinations?

Radio Heliophysics

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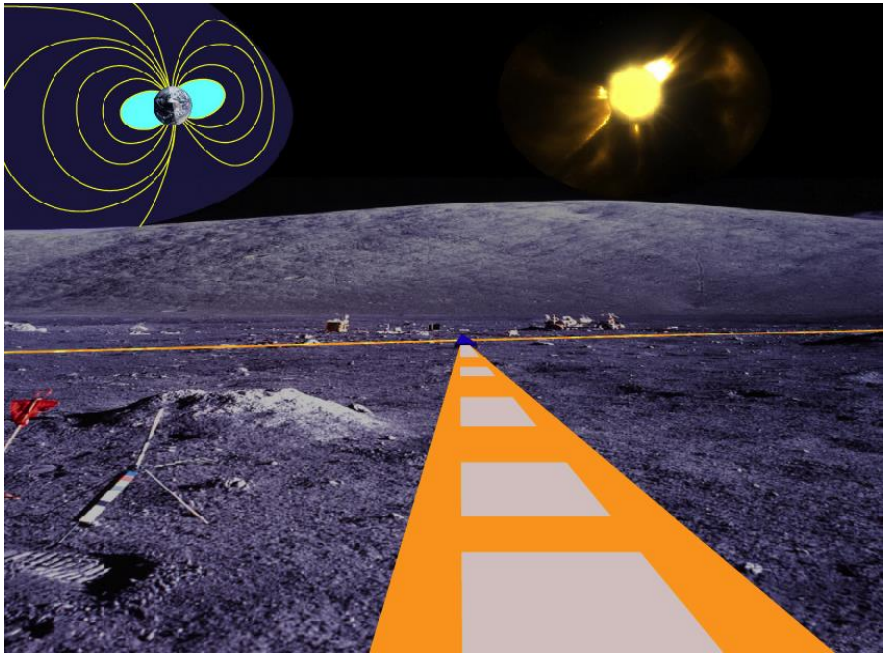
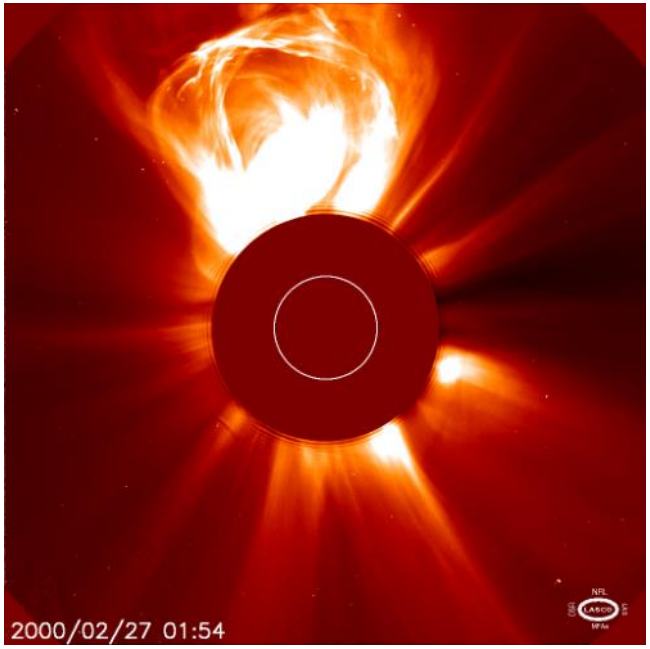
- How do variations in the Sun's activity, interplanetary plasmas, and inputs from the interstellar medium influence the energetic particle and dust environment of space and exploration target bodies?
- What observational capabilities are needed to maximize the application of solar and other radio bursts to facilitate improved monitoring of solar particle events?





Cosmic Dawn

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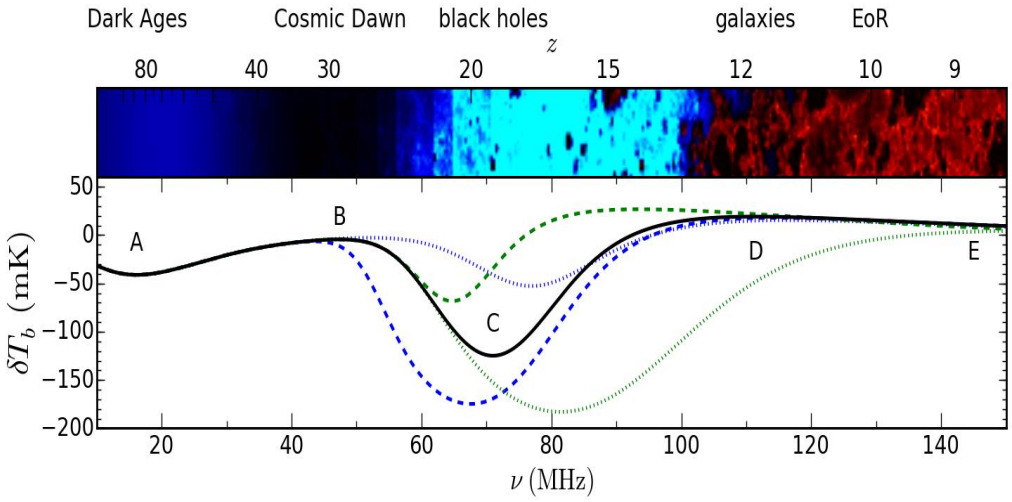
- What are optimal low-frequency antenna technologies for a lunar farside low frequency array?
- What are the key astrophysical processes driving the low-frequency radio signal from the Cosmic Dawn?
- How can we extract astrophysical parameters from low-frequency radio measurements of the Cosmic Dawn, alone and in combination with other future investigations?



Extrasolar Space Weather

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- Can we find another planet like Earth orbiting a nearby star?
- How can lunar radio arrays enable the detection and characterization of exoplanets and their magnetic environments?

Science & Exploration Enabled by Surface Telerobotics

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- What new systems should be added to Orion/Habitat, and what crew training strategies are needed to support telerobotic deployment of a low frequency telescope array?
- What are the operational requirements for deployment of radio antenna arrays from landers and rovers, possibly in conjunction with an astronaut-assisted lunar sample return?
- How do telerobotic laboratory simulations improve the realism and effectiveness of student training?

Participation in Exploration Science Activities

- Steering Committee for *Human Exploration Deep Space Gateway Workshop.* J. Burns is on the Science Advisory Group. Initiative led by Ben Bussey (HEOMD) & Paul Niles (JSC). Workshop expected in early 2018.
- *Community Technical Interchange Meeting on Future Priorities in Astrophysics Enabled by In-Space Servicing and Assembly*, NASA GSFC, November 1 – 3, 2017. J. Burns expected to participate on surface telerobotics.
- NASA Astrophysics *Cosmic Origins Technical Interest Group.* J. Burns participated in technology gap analysis providing input on lunar low frequency radio telescopes.
- *LEAG Advances in Science on the Moon Special Action Team [ASM-SAT].* J. Burns participating in two-day working meeting at JSC on Aug. 7-8. Organized by Sam Lawrence and Clive Neal.

SSERVI Monthly Report
NESS/PI Burns - July, 2017

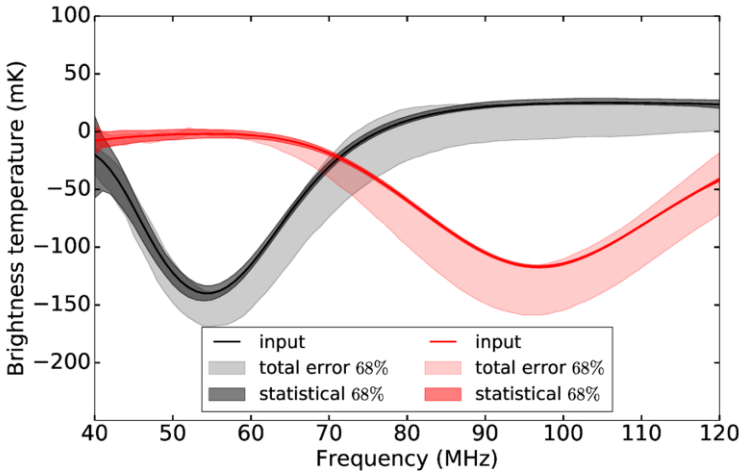
Progress Report

- In Burns et al. 2017, we have shown how the 21-cm spectrum can be measured and astrophysical parameters of the first stars can be constrained in the presence of large foregrounds using a low-frequency radio antenna in lunar orbit.
- Mirocha and Furlanetto are exploring unique signatures from the first generations of stars in the universe that could be observable from a lunar low-frequency radio observatory.
- MacDowall is working on the design of a potential Low-frequency Radio Observatory on the Lunar Surface.
- Papers: Burns et al. (2017), ApJ in press (arXiv: 1704.02651), "A Space-Based Observational Strategy for Characterizing the First Stars and Galaxies Using the Redshifted 21-cm Global Spectrum"; Burns et al. (2017), conference proceedings (arXiv:1705.09692), "Science and Exploration at the Moon and Mars Enabled by Surface Telerobotics"; Mellinkoff et al. (2017), arXiv:1706.03752, "Investigation of minimum frame rate for low-latency planetary surface teleoperations"; Monsalve et al. (2017), submitted to ApJ; Tauscher, Rapetti et al. (2017a, 2017b), in preparation; Mirocha, Furlanetto et al. (2017), in preparation.
- NESS website recently released: http://www.colorado.edu/ness/
- Steering Committee (SC) kick-off meeting, May 25, 2017.
- Burns presented invited plenary talk on Space Telerobotics at conference on Bridging the Gap in Space Robotics at MIT on July 15, and invited talk to IAA Symposium on Space Exploration in Torino, Italy on June 28.
- The invited talk in Italy by Burns and the corresponding conference proceedings were co-authored with Kring, who is the PI of the CLSE SSERVI team.

Upcoming Events

- NASA Exploration Science Forum (NESF), July 18-20; 15 talks & posters to be presented by team members.
- NESS Steering Committee meeting at NESF, July 19, 2017.
- Monsalve invited to give seminar at UC Berkeley on July 17 on the status of 21-cm cosmology measurements; and invited to U Richmond to talk about diffuse foregrounds in the context of 21-cm science on July 21.
- Burns will present invited talk on "Lunar Low Frequency Radio Observations" at the U.S. Radio Futures III conference at UC Berkeley on Aug. 3; Bowman will also present invited talk at this conference (Aug 2-4), reviewing the status of global 21-cm experiments.

A Moment of Science



Burns et al. (2017): The extracted 21-cm spectra with 68% confidence intervals for models with primordial Pop II (red) and Pop III (black) stars expected using instrument parameters for a low-frequency radiometer in lunar orbit and 800 hours of observation.