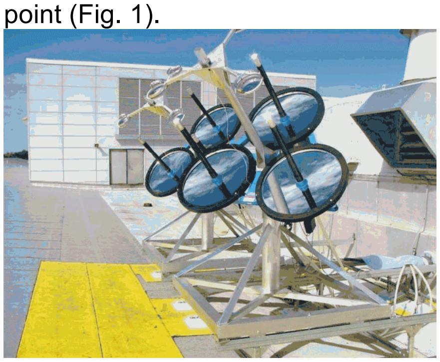
Energy-Efficient Plant-Growth Lighting: Key to Sustainability of the Lunar Base and Beyond. Cary A. Mitchell[1], Gioia D. Massa[1], Raymond M. Wheeler[2], Gary W. Stutte[2], Neil C. Yorio[2], Oscar A. Monje[2], C. Michael Bourget[3], and Robert C. Morrow[3], [1]Purdue University, West Lafayette, IN 47907. cmitchel@purdue.edu, [2]Kennedy Space Center, FL 32899. Raymond.m.wheeler@nasa.gov, [3]Orbital Technologies, Inc., Madison, WI 53717. bourgetm@orbitec.com

Introduction: Long-duration habitation of the Moon will be sustainable only when food becomes independent of resupply. Reasonable cropping area can provide the calories, nutrients, and oxygen needed to sustain human crews in space habitats [1, 2]. The main obstacle to food production in space is the high energy required for electric lamps and heat rejection [3]. Reduction of energy for crop lighting is required for food production in space. Availability of solar radiation for crop growth is temporally limited at most locations on the Moon. Reliable sources of energy and effective methods to deliver photosynthetically active radiation (PAR: 400-700 nm) to crops growing in protected locations on the Moon are the grand challenges to food sustainability.

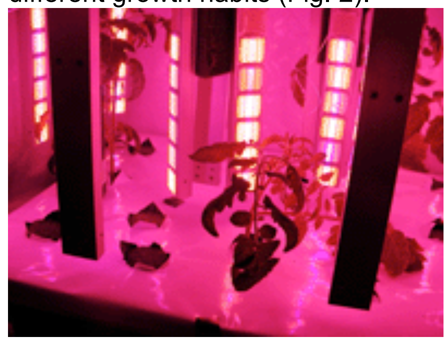
Experimental approach:

Solar collection/PAR transmission: The Kennedy Space Center (KSC) has a device that tracks the sun with six primary-collection mirrors and concentrates solar radiation on dichroic mirrors that allow long-wave radiation to pass through while reflecting PAR to a fiber-optic collection point (Fig. 1).



Collected PAR is transmitted through 10-m-long fiber-optic bundles that deliver 40-50% of the original solar radiation to overhead emitters in a growth chamber.

LED lighting: Both KSC and Purdue University have investigated light-emitting diodes (LEDs) for crop lighting with many advantages over conventional lamps, including durability, lifetime, selectable wavelengths, and relatively cool emitter surfaces. KSC is defining spectral requirements for food crops with LEDs, while Purdue and ORBITEC are developing methods for distributing PAR to crops with different growth habits (Fig. 2).



Results & Discussion: During solar maximum, 350-400 Watts of PAR have been delivered from the 2 m^2 of primary collector surface. This power would be adequate to light a 2 m^2 "salad machine" at the lunar base. Near the lunar south pole, sunlight could be collected most of the time, although how much energy could be collected at oblique angles of incidence is unknown. Intracanopy and close-canopy crop lighting with LEDs have saved considerable energy compared to traditional overhead lighting. During the lunar night or when solar collection alone cannot provide enough PAR, LEDs would provide PAR for crop production, and this would require either stored electrical energy from previous solar collection or an alternative energy source.

Future work: The long-wave solar radiation passing through the cold mirror will be collected by photovoltaic cells to generate electrical current that can power LEDs immediately or be stored in high-capacity batteries for use when PAR is absent. LED lighting will be developed as "smart" lighting systems that target leaves only.

References:

[1] Kim H.H. et al. (2007). Acta Hort. 761:193-202.
[2] Massa, G.D. et al. (2008). HortScience 43(7): 1951-1956.
[3] Nakamura, T. et al.(2006). NASA TP—2006 (SBIR Report).