ANDREW C. SCHUERGER, Ph.D.

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EDUCATION

Doctor of Philosophy in Plant Pathology, August 1991; Univ. of Florida, Gainesville, FL, GPA: 3.75; Dissertation: "Effects of Temperature and Hydrogen Ion Concentration on Disease Caused by *Fusarium solani* f. sp. *phaseoli* in *Vigna radiata* Grown in Hydroponic Nutrient Solution."

Master of Science in Plant Pathology, May 1981; University of Arizona, Tucson, AZ, GPA: 3.85; Thesis: "Ultrastructural Changes Induced by *Scutellonema brachyurum* in Potato Roots."

Bachelor of Science, double major in Plant Pathology and Entomology, May 1979; University of Arizona, Tucson, AZ, GPA: 3.45.

PROFESSIONAL EXPERIENCE

Research Assistant Professor, Mars Astrobiology and Plant Pathology, Dept. of Plant Pathology, University of Florida, Space Life Sciences Laboratory, Kennedy Space Center, FL. 2003 to present.

Responsibilities: Current research emphasis is on (a) the survival, growth, and adaptation of terrestrial microorganisms under simulated Martian conditions, (b) production and degradation of methane from the UV-degradation of carbonaceous meteorites under martian conditions, (c) biological methanogenesis under simulated Martian conditions, (d) planetary protection issues related to both forward and back contamination of planetary bodies within the Solar System, (e) the remote sensing of plant stress using spectral reflectance imaging technologies, and (f) global dispersal of pathogens in Asian and African dusts. Research has been funded by NASA's Planetary Protection Office, Mars Fundamental Research Office, Astrobiology/Exobiology Office, Jet Propulsion Lab (JPL), Office of Biological and Physical Research for NASA, Florida Space Institute, Florida Space Grant Consortium, and the US Dept. of Energy. ***The total grants received since 1997 equal $5.31 million as PI and $471K as Co-I***. Research into the survival and growth of terrestrial microorganisms in Martian environments led to the development of a planetary hypobaric chamber (see Appendix A). Astrobiology research has assisted NASA to enhance sanitation protocols for pre-launch preparations of Mars-bound spacecraft, and has demonstrated the growth of 29 bacteria under Martian conditions of 7 mbar, 0 ºC, and CO_2-enriched anoxic atmospheres.

Project Manager, Mars Astrobiology and Plant Pathology, Dynamac Corporation, Kennedy Space Center, FL. 1997 – 2003.

Responsibilities: A remote sensing research grant from the US Dept. of Energy (see Appendix B) compared spectral reflectance and laser-induced fluorescence instruments for their utility in discriminating among a diversity of abiotic and biotic plant diseases. Research plants and stressing agents were determined by DOE requirements to track heavy metals leaching from buried radioactive depositories at Savannah River, SC and Oak Ridge National Labs, TN. Two NASA projects provided the support to study the survival of terrestrial microorganisms under simulated martian conditions. Between 1999 and 2001, Schuerger participated in field work in the Canadian Arctic (Devon Island) studying microbial dispersal from human habitats into the local arctic terrains. Results from DOE remote sensing research helped develop groundwater contamination monitoring programs at several DOE sites. Results from the NASA-funded projects have identified UV irradiation thresholds for bacteria under Martian equatorial conditions. And results from the Arctic microbiology studies have supported the conclusion that microbial contamination in pristine environments does not occur immediately upon initial human traffic over the terrain.

Senior Scientist, Plant Pathology, Science & Technology Office, The Land, Epcot, Lake Buena Vista, FL. February 1982 – August 1997.

Responsibilities: The primary objective at The Land was to engage and entertain visitors on cutting-edge science topics related to sustainable agriculture. Schuerger was the chief scientist for the plant pathology Integrated Pest Management (IPM) programs for agronomic and horticultural crops grown in the 1.5 acre greenhouse exhibits. Research included projects on the following pathogen/host systems:

- tomato mosaic virus in peppers,
- *Erwinia carotovora* on cucurbits,
- *Fusarium solani* on beans,
- *Pythium myriotylum* on peppers,
- biological control of *Meloidogyne arenaria* using *Pasteuria penetrans*,
- use of filtration to control root pathogens in hydroponic systems,
- the effects of silicon on the suppression of powdery mildew on cucurbits,
- the use of composts for the suppression of soilborne pathogens in landscape beds,
- and non-chemical control methods for both soilborne and airborne pathogens.

Operational and management activities included running a disease diagnostics lab, developing sanitation programs for soilborne and airborne plant pathogens, and assisting in the co-management of the 1.5 acre greenhouse facility. Furthermore, Schuerger co-developed a science communications program at The Land that included displays on state-of-the-art hydroponic systems, co-supervision of a guided tour program including content development and staff training, student internship programs, time-lapse cinematography of biological processes for various displays, teacher and student workshops, and back-story information for journalists. Schuerger has had extensive experience with on-camera press interviews, print and radio interviews, and development of space exploration related displays (see Appendix C).

Field Research Scientist, DOW Chemical Company, Midland, MI. June 1979 – Dec. 1979.

Responsibilities: Field experiments were conducted in cotton to test the efficacy of several pesticides, with emphasis on the insecticide Lorsban (clorpyrifos). Research plots were selected in four Arizona counties based on soil profiles, cotton cultivars, and historically heavy insect-pest infestations. Activities included farmer consultations, field experimental design, pest scouting, application recommendations, collection of efficacy data, and data analysis.

Nematology and Electron Microscopy Technician, Plant Pathology Department, University of Arizona, Tucson, AZ. May 1977 – June 1979.

Responsibilities: Standard SEM and TEM techniques were used to study nematode-plant interactions. Research involved studies with ecto- and endoparsitic nematodes, but emphasized *Meloidogyne* spp., *Scutellonema brachyurum*, *Belonolaimus longicaudatus*, and *Xiphinema* spp. Electron microscopy techniques included fixation, dehydration, critical point drying, embedding, ultra-thin sectioning, and operation of SEM and TEM equipment.

Nursery and Greenhouse Technician, Plant Pathology Dept., Univ. of Arizona, Aug. 1975 – May 1977.

Responsibilities: Horticultural practices included preparation of potting media, beds, and greenhouse trials; plus watering and general plant care activities. In addition, general IPM practices included sterilization of potting soils, utilization of insect and plant disease control measures, and coordination with the UA Dept. of Plant Pathology research staff and faculty to optimize plant health of experimental crops.

SCIENCE COMMUNICATION AND TEACHING EXPERIENCE

Mars Astrobiology and Bioregenerative Life Support Systems for Human Exploration Missions (1982-2017). At Epcot (1982-2000), Schuerger developed several space exhibits including a display of bioregenerative life support systems for human missions to Mars, a robotic rover display for Science Fair events held at Epcot in 1995 and 1996, and a video-based survey on space exploration given at Epcot. He was also the Epcot-liaison to NASA for the management of a NASA/Epcot Memorandum of Understanding to develop joint space exhibits and space-based research programs at The Land. One exhibit was a system designed to demonstrate how plants might be grown in a human bioregenerative life support system (see Appendix C). A second exhibit included research into the use of remote sensing technologies to monitor plant health in over 20 plant species afflicted with 7 biological or abiological stressing agents (see Appendix B). After relocating to the Kennedy Space Center, FL in 2000, Schuerger continued hosting tours through his Mars astrobiology laboratory including frequent stops by visitors to view his Mars Simulation Chamber (see Appendix A) developed to explore the lower limits of life in hypobaric environments. Schuerger has mentored numerous graduate students from the Universities of Colorado, Central Florida (Orlando), Florida (Gainesville), and Penn State since 2000.

Press Interviews on Cutting-edge Science Topics (1982-2017). Beginning at The Land, Epcot in 1982, and continuing through to his current research position on Mars astrobiology at NASA's Kennedy Space Center, FL, Schuerger has extensive experience with TV, print, and radio press interviews on a wide range of topics in human space exploration, planetary science, astrobiology, agriculture, IPM, and plant pathology. Schuerger also prepared time-lapse footage, still photographs, and edited videos for various science communication activities at Epcot.

Children's Book on Science (2006; 2015). Schuerger co-authored a children's book (*Messages from Mars*; 3rd grade level; Holiday House Publishing) with the internationally known author and illustrator, Loreen Leedy. The story takes place on Mars in 2106 and tells of the adventure of five children who have won an international contest to go to Mars in order to visit historic robotic landing sites on the surface and harvest hydroponically grown plants in the human habitat. The book presents science results from a number of Mars missions via email messages between the traveling students and their friends and families back on Earth. Furthermore, Schuerger and Leedy published their 2nd book together in 2015 called *Amazing Plant Powers* (Holiday House Publishing) that presents the wide range of capabilities that plants exhibit, and offers insights into the ecological adaptation to plants to diverse habitats.

Epcot Integrated Pest Management Practices for Sustainable Agriculture (1982-2000). The Land, Epcot maintained a regular schedule of guided tours for day-guests and dignitaries in which sustainable IPM practices in plant pathology and entomology were seamlessly interwoven into the greenhouse exhibits. The IPM exhibits were composed of live-biological specimens and static displays, and required the preparation of display narratives with other staff scientists. Schuerger was the lead on plant pathology IPM exhibits. Schuerger was involved in developing exhibits on the guided tours, particularly those demonstrating Integrated Pest Management practices. In addition, Schuerger co-managed the students and staff at The Land during special events, tours, and daily operations.

Concepts in Advanced Life Support (ALS) Systems Microbiology and Plant Pathology (1995-2007). Guest lecturer on microbial and plant pathology issues in ALS systems for an undergraduate space biology course taught by Dr. Christopher Brown, NC State University, Raleigh, NC.

Teaching Assistant, Department of Plant Pathology, University of Arizona, Tucson (1980-1981). Prepared and maintained lab and research equipment used in three graduate plant pathology classes; and assisted in the demonstration and instruction of research hardware (e.g., electrophoresis, SEM, TEM, scientific photography).

GRANTS WON AS THE PRIMARY INVESTIGATOR (PI)

2017 NASA Planetary Protection Research Grant (#80NSSC17K0263); "Use of Stable Isotopes to Characterize Bacterial Metabolism and Growth under Simulated Martian Conditions." Grant value = $628K for 2017-2021.

Research: Recent studies by Schuerger et al. (2013; 2016) have identified 29 species of bacteria capable of metabolism and growth under simulated Martian conditions of 7 mbar, 0 °C, and CO_2-enriched anoxic atmospheres. So far, all such identified *hypobarophiles* have been culturable mesophilic or psychrophilic heterotrophs. The new research will investigate the presence of nonculturable hypobarophilic bacteria and archaea in arctic, permafrost, and alpine soils from extreme environments. The research will seek to characterize the minimum pressures and temperatures that active maintenance metabolism and/or growth of the hypobarophiles can occur under simulated Martian conditions. **Results** will establish the low pressure, low temperature, and high salt concentrations for the metabolism and growth of culturable and nonculturable hypobarophiles under simulated Martian conditions.

2017 NASA Exobiology Research Program (#NNX17AK87G); "Transcriptomics and Proteomics of Methanogens under Simulated Subsurface Conditions that Mimic Recurring Slope Lineae on Mars." Grant value = $543K for 2017-2020.

Research: Schuerger has characterized the generation of methane (CH_4) by UV irradiation under Martian conditions (Schuerger et al., 2011; 2012) and is currently working on a UV-mediated CH_4 destruction process in which UV photons interact with metal oxides in aerosols on Mars to degrade CH_4 (see below). The new research will study biological methanogenesis under Martian conditions in order to model the abiological (UV processes) and biological (methanogenic archaea) processes that might be adding CH_4 to the bulk Martian atmosphere. **Results** will demonstrate whether biological CH_4 production is possible in the shallow subsurface of the Martian terrain, and will establish the lower limits of CH_4 production relevant to low temperature, low pressure, and high salt concentrations.

2016 NASA Biodiversity Scoping Study (#NNX16AQ38G); "A Transoceanic Aerobiology Biodiversity Study (TABS) to Characterize Microorganisms in Asian and African Dust Plumes Reaching North America." Grant value = $180K for 2017.

Research: Asian and African dust plumes reach the continental USA each year depositing, respectively, up to 65 and 50 million metric tons of dust annually on the Pacific NW and the Atlantic SE. The TABS 1-year scoping study was funded by the NASA Biodiversity Office in order to constrain the range of possible research objectives required for a comprehensive 5-year field campaign into the microbial diversity of the transoceanic dust plumes. The Phase-1 study has allowed the TABS team to develop the protocols for such a field campaign. **Results** will be applied to creating future proposals for NASA, NSF, and/or USDA.

2014 NASA Mars Fundamental Research Grant (#NNX14AG45G); "A Fast Degradation Mechanism for Atmospheric Methane on Mars." Grant value = $498K for 2014-2017.

Research: Methane was detected in the martian atmosphere in 2001. Previously, Schuerger and colleagues reported on a UV/CH_4 linked model in which the UV irradiation on Mars degrades organics in accreted interplanetary dust particles (IDPs) forming CH_4. Mass balance modeling suggests that 2-4 ppbv should persist in the martian atmosphere. The MSL rover Curiosity has confirmed the presence of Mars CH_4 at concentrations consistent with the Schuerger model for the UV destruction of IDP organics (2-4 ppbv). The current study is characterizing an ultra-fast degradation model in which UV photons interact with divalent metal oxide ions in the regolith and atmospheric aerosols that act to degrade CH_4 on scales of several 100's of sols, and not 300+ years. **Results** will help constrain the CH_4 mass balance in the Martian atmosphere.

2014 Emerging Pathogens Institute (UF/EPI); "Search for Plant, Human, and Animal Pathogens in African Dust Plumes over Florida." Grant value = $88K for 2014.

Research: The Dust Atmospheric Recovery Technology (DART) system (see below and Appendix D) was redesigned for increased flight safety and sampling capability. The DART unit was also adapted to fly on the T6 Texan aircraft, a WW II army/navy propeller driven trainer. The research focused on comparing the microbial diversity in air samples at the ground (airport hangar for the T6) and sampled at 1500' above mean sea level (MSL). **Results** of DART flights on a T-6 Texan aircraft demonstrated that airborne fungal and bacterial recovery were similar between ground samples and air samples from 450 m (1500 ft).

2013 Florida Space Institute (FSI) Grant (SRI# 66014402); "The DART-2 Dust Sampler: Moving from a Prototype to an Operational System in 2013." Grant value = $75K for 2013.

Research: The grant permitted the advancement of the DART-1 prototype design into an operational DART-2 system with up to 6 individually controlled dust sampling lines and filters. Science flights in 2013 targeted the collection of aerosols over Florida to search for plant pathogens. **Results** demonstrated that the DART system was easily adapted to a propeller-driven aircraft (called the T-6 Texan), airborne fungi and bacteria were recovered up to 3.7 km (12,000 ft), and microbial diversity had an inverse relationship with altitude.

2012 Florida Space Grant Consortium (FSGC#66016015-Y3); "DART: Dust Atmospheric Recovery Technology---High Altitude Dust Sampling for the Detection of Microorganisms in Earth's Atmosphere." Grant value = $25K for 2012.

Research: Over 100 million metric tons of African and Asian dusts arrive in the continental USA each year. There are few methods to collect the microbial communities in these dust plumes. The DART system will be a wing-mounted dust sampling device capable of collecting aerosols and microorganisms up to 25 km (80,000 ft). **Results** of the DART flight tests on a F104 Starfighter jet demonstrated normal operations up to 10 km (35,000 ft) and 3.5 +G's. Airborne bacteria were recovered up to 10 km.

2012 NASA Planetary Protection Research Grant (NNX12AJ84G); "Metabolism, Growth, and Genomic Responses of *Serratia liquefaciens* under Simulated Martian Conditions." Grant value = $718K for 2012-2017.

Research: The project was designed to characterize metabolic and genomic mechanisms that contribute to the tolerance of *Serratia liquefaciens* to hypobaric conditions similar to the surface of Mars. **Results** have identified 29 species in 10 genera of heterotrophic bacteria capable of growth under simulated Martian conditions, and have helped characterize the genomic, metabolic, and morphological alterations in *S. liquefaciens* that confer fitness under low-pressure and low-temperature conditions similar to Mars.

2008 NASA Planetary Protection Research Grant (NNX08AQ81A); "Biotoxicity of Mars Soils: Compatibility of Terrestrial Microorganisms to Simulated Conditions of Special Regions on Mars." Grant value: $395K for 2008-2011.

Research: Robust simulants of potentially biotoxic Mars soils were doped with consortia of microbial species and placed within simulated Martian conditions to determine the compatibility of spacecraft microorganisms with high levels of acidity, sulfates, chlorides, bromides, perchlorates, and salts on Mars. **Results** demonstrated that most soils on Mars are not likely to be overtly biotoxic to Earth microorganisms.

2007 NASA Mars Fundamental Research Grant (NNX07AR65G); "Degradation of Organic Compounds by UV Irradiation under Martian Conditions: A Possible Source of Methane on Mars." Grant value: $340K for 2007-2011.

Research: The primary objective was to investigate whether the methane found in the atmosphere on Mars (~10 ppb) can be accounted for by the UV degradation of accreted organics in interplanetary dust particles (IDPs) and small carbonaceous meteoroids that fall on Mars.

Results were used to model the global methane budget on Mars and predict a global average mixing ratio in the atmosphere of 2.2 to 4.8 ppbv.

2006 UCF/UF Space Research Initiative Grant (20040009; jointly funded by University of Central Florida and University of Florida); "Degradation of Organic Compounds by UV Irradiation under Martian Conditions." Grant value: $186K for 2006-2007.

Research: This grant was a predecessor study to the 2007 MFR grant NNX07AR65G (see above) that conducted studies into the non-biological formation of methane in the Martian atmosphere by the UV irradiation of organics. **Results** suggest that all organics on Mars will evolve methane when exposed to UV irradiation, and that kapton tape might be a significant source of terrestrial methane contamination on the Mars Science Laboratory rover Curiosity.

2006 CACI MTL Systems (C06-060025); "Use of Spectral Reflectance Remote Sensing as an Indicator of Unique Spectral Signatures of Plant Stress." Grant value: $12K for 2006.

Research: Spectral reflectance signatures from 20 plant species were collected and analyzed for unique spectral features that would discriminate diverse plant stresses (biological and abiological stresses) from each other. **Results** supported the conclusion that spectral reflectance measurements of plant species under diverse stressing agents do not exhibit unique spectral signatures.

2004 UCF/UF Space Research Initiative (SRI) Grant (20020023/21988; jointly funded by University of Central Florida and University of Florida); "Survival, Ecology, and Detection of Endolithic Microbial Communities under Simulated Martian Environmental Conditions." Grant value: $210K for 2004.

Research: The SRI grant developed protocols used to win three NASA grants [i.e., NNX08AQ81A, NNX12AJ84G, and NNA05CS68G; see above] and studied the effects of Martian conditions on (a) the survival of terrestrial bacteria within Mars analog rocks, and (b) the internal atmospheric conditions within void spaces of rocks under Martian conditions. **Results** indicated that internal void spaces within rocks are rapidly equilibrated to Martian surface conditions, and thus, may not offer significant protection from desiccation, low pressure, and extreme temperatures on Mars.

2002 JPL/NASA (JPL-GJT-569274); "Effects of Diffuse UV Irradiation on the Survival of Terrestrial Bacteria on Spacecraft Components." Grant Value: $115K for FY2002 – FY2004.

Research: An inter-organizational team of investigators from NASA, U. of Arizona, and U. of Florida studied the effects of diffuse and reflected UV irradiation on the survival of terrestrial bacteria on spacecraft components. **Results** suggest that complete sterilization (> 6 orders-of-magnitude reductions in viable bioloads) of microbial species by UV irradiation can be achieved on the upper and lower surfaces of spacecraft on Mars within a few sols (i.e., martian days) independent of latitude, solar zenith angle, or dust loading in the martian atmosphere.

2000 NASA Research Grant (ROSS-99 NRA 99-OSS-01); "Survival of Terrestrial Microorganisms on Spacecraft Components and Analog Mars Soils under Simulated Martian Conditions." Grant Value: $ 414K for FY2000 – FY2004.

Research: The survival rates of Earth microorganisms on spacecraft materials under simulated Martian conditions were investigated as part of a program to establish cleaning and sterilization protocols for spacecraft targeted for Mars. Experimental conditions included Mars-normal atmospheric pressure and gas composition, diurnal temperature fluctuations, and the UV, VIS, and NIR fluence rates on an equatorial Martian surface (see Appendix A). **Results** indicate that gas composition and temperature have no effect, and low pressure only a minor effect, on bacterial survival under simulated Martian conditions. Greater than 99% of the biocidal activity on the surface of Mars is due to UV irradiation.

2000 NASA Research Grant (AO-99-HEDS-01-032); "Use of Induced-Fluorescence Imaging and Green Fluorescent Proteins to Monitor the Health of Terrestrial Plants under Simulated Martian Environments." Grant Value: $368K for FY2000 – FY2003.

Research: The effects of low pressure on the growth and development of *Arabidopsis thaliana* were studied to determine the range of low-pressures conducive to plant activity. Transgenic lines of *A. thaliana* were developed with green fluorescent protein (GFP) reporter genes attached to plant stress promoters sensitive to specific soil stressing agents likely to be found in actual Mars regolith. A remote sensing imaging system was developed to monitor the expression of GFP reporter genes of *A. thaliana* plants exposed to phytotoxic soil factors in martian regolith. **Results** indicate that plants can survive at pressures as low as 25 mbar (2.5% of Earth sea level pressure), but nominal plant growth was achieved at pressures closer to 100 mbar.

1997 U. S. Dept. of Energy (DOE) Grant (DE-AC08-96NV11718); "Detection of Plant Stress using Spectral Reflectance, Laser-Induced Fluorescence Imaging (LIFI), and Laser-Induced Fluorescence Spectroscopy (LIFS) Technologies." Grant Value: $516K for FY1997 – FY2001.

Research: Laser-induced fluorescence imaging (LIFI), laser-induced fluorescence spectroscopy (LIFS), and two hyperspectral imaging systems were tested for their effectiveness and sensitivities to detecting plant diseases caused by biological and non-biological stressing agents. **Results** indicate that spectral reflectance was more reliable than LIFI or LIFS for the detection of multiple stresses on different species of plants. Science communication at The Land, Epcot Center was a key goal of the work (see Appendix B).

SECONDARY GRANTS AS A CO-INVESTIGATOR (Funds indicate dollars for Schuerger)

2011 Florida Space Grant Consortium Grant (66018006-Y1); “Continuing Studies of Materials Degradation under Simulated Mars Surface Conditions.” Grant value = $7K; Dr. Melanie Correll (PI/UF); Schuerger (Co-I/UF).

2009 Florida Space Grant Consortium Grant (16296041-Y4); “Investigation into the Heat Transfer Characteristics of Mars Transparent Greenhouse Materials.” Grant value = $5K for 1 yr. Dr. Melanie Correll (PI/UF); Schuerger (Co-I/UF).

2008 NASA Astrobiology, Exobiology, and Evolutionary Biology Grant (NNX08AO15G); “Survival, Growth, and Evolution of Terrestrial Bacteria in Martian Environments.” Grant value = $153K for 2009-2011. Drs. Wayne Nicholson (PI/UF) and Andrew Schuerger (Co-I/UF).

2008 NASA Kennedy Space Center Grant (NNX07AI26G-S01); “Glow Discharge versus Solar UV Irradiation on Mars: A Comparison of the Degradation Rates of Each under Martian Conditions.” Grant value = $20K. Research team: Drs. Carlos Calle (PI/NASA), Paul Hintze (NASA), and Andrew Schuerger (Co-I/UF).

2007 NASA grant through the Kenan Institute at North Carolina State University, Rayleigh, NC; “Expression of Drought Genes in Tomato under Hypobaric Conditions.” Grant value = $13K for 1 yr. Research team: Drs. Chris Brown (PI/NCSU), Heike Sederoff (Co-I/NCSU), Mariya Khodakovskaya (Co-I/NCSU), and Andrew Schuerger (Co-I/UF).

2006 NASA Glenn Research Center CDDF Grant; “Application of Glow Discharge Plasma to Alter the Surface Properties of Materials.” Grant value = $30K for 1 yr. Research team: Dr. Carlos Calle, (PI/NASA), Dr. Steve Trigwell, (Co-I/NASA), and Dr. Andrew Schuerger (Co-I/UF).

2006 NASA Stennis Research Center CDDF Grant; “Hyperspectral Fluorescence and Reflective Based Imaging for Plant Stress Monitoring.” Grant value = $20K total for 1 yr. Research team: Drs. George May (PI/NASA Stennis), Dr. Andrew Schuerger (Co-I/UF), and Dr. Robert Ryan (Co-I/NASA Stennis).

2006 Princeton University Student Support Grant; "Survival of *Psychrobacter cryohalolentis* K5 under Extreme Conditions of Low Pressure, Low Temperature, and Low Oxygen Concentrations." Grant value = $5K for 1 yr. Research team: Mr. David Smith (PI/Princeton), Dr. T.C. Onstott (Co-I/Princeton), and Dr. Andrew Schuerger (Co-I/UF).

2005 NASA Planetary Protection Grant (NNA05CS68G); "Degradation of Biological Signature Molecules in Analogue Martian Environments." Grant value = $85K for 3 yrs. Research team: Drs. Wayne Nicholson, (PI/UF) and Andrew Schuerger (Co-I/UF).

2005 NASA Mars Fundamental Research Grant (NNX07AI26G); "Glow Discharge on Mars: Potential Factors in the Degradation of Organics in the Martian Regolith." Grant value = $53K over 3 yrs. Research team: Drs. Carlos Calle, (PI/KSC), Charles Buhler, (Co-I/KSC), and Andrew Schuerger (Co-I/UF).

2005 NASA Stennis Research Center Grant; "An Expert System for Monitoring Plant Health in Bioregenerative Life Support Modules." Grant value = $55K for 1 yr. Research team: Drs. George May, (PI/Photon Industries, LA), Andrew Schuerger (Co-I/UF), and Mark Lewis (Co-I/Photon Industries, LA).

2005 UCF/UF Space Research Initiative Grant; "Advanced, Space-Qualified, Radiometric Calibration Targets for Mars and Planetary Exploration." Grant value = $25K for 1 yr. Research team: Drs. Dan Britt (PI/UCF), Randy Duran, (Co-I/UF), and Andrew Schuerger (Co-I/UF).

PROFESSIONAL AFFILIATIONS

American Association for the Advancement of Science
American Phytopathological Society
NASA Astrobiology Institute

PERSONAL INFORMATION

Born: July 1, 1956, Cleveland, Ohio, USA.
Marital status: Married to Ms. Loreen J. Leedy, children's book author and illustrator.
Hobbies: Astronomy, paleontology, photography, woodworking, flying (private certificate), racquetball, hiking, camping, music, art, reading, scuba diving, and travel.

AWARDS

NASA 2008 Innovative Technology Award: "A Mars Simulation Chamber for the 21st Century;" July 2008.

NASA 2007 Innovative Technology Award; "UV Sterilization of Spacecraft Surfaces: New Procedures for Assuring the Sterility of Spacecraft;" August 2007.

NASA REVIEW PANELS: Multiple NASA review panels from 2007-2017.

NASA EXTERNAL REVIEWER, NASA's Mars Fundamental Research and Planetary Protection programs between 2007 to 2010; ESA's Astrobiology program in 2009; NASA Habitable Worlds program, 2016.

MANUSCRIPT REVIEWS (1985 – 2017) for the following journals: *Acta Astronautica*, *Astrobiology*, *Applied Environmental Microbiology*, *Gravitation and Space Research*, *Icarus*, *International Journal of Astrobiology*, *Journal of Botany*, *Journal of Geophysical Research*, *Phytopathology*, *Plant Disease*, and *Remote Sensing of Environment*.

<u>PEER-REVIEWED PUBLICATIONS</u> (also 100+ abstracts in astrobiology, plant pathology, plant biology, and remote sensing)

<u>2020</u>

1. Moores, J. E. and **Schuerger, A. C.** 2020. A Cruise Microbial Survival Model for calculating viable bioburdens on spacecraft on interplanetary trajectories. *Astrobiology* (submitted Dec., 2019).
2. **Schuerger, A. C.**, et al. 2019. *Fusarium oxysporum* as an opportunistic pathogen on *Zinnia elegans* grown onboard the International Space Station. *Astrobiology* (TBD).
3. **Schuerger, A. C.**, Moores, J. E., Tanner, R., and Smith, P. 2020. UV reflectance of spacecraft materials and analog soils: Implications for bioburden reductions on the undersides of rovers on Mars. *Planetary Space Sci*. (TBD).
4. **Schuerger, A. C.**, Mickol, R. L., and Schwendner, P. M. 2020. Growth of *Serratia liquefaciens* in Mars analog soils under martian conditions of 7 mbar, 0ºC, and CO2-enriched anoxic atmosphere. *Life*. (TBD).
5. Schwendner, P. M., and **Schuerger, A. C.** 2020. Addition of redox couples to solid media did not enhance growth of 125 spacecraft bacteria under simulated martian conditions. *Astrobiology* (submitted, Nov. 2019).

<u>2019</u>

6. Cortesao, M., Fuchs, F. M., Commichau, F. M., Eichenberger, P., **Schuerger, A. C.**, Nicholson, W. L., Setlow, P., and Moeller, R. 2019. *Bacillus subtilis* spore resistance to simulated Mars surface conditions. *Frontiers in Microbiology* 10:333, doi:10.3389/fmicr.2019.00333.
7. Moores, J. E., King, P. L., Smith, C. L., Martinez, G. M., Newman, C. E., Guzewich, S. D., Meslin, P.-Y., Webster, C. R., Mahaffy, P.R., Atreya, S. K., and **Schuerger, A. C.** 2019. The methane diurnal variation and micro-seepage flux at Gale Crater, Mars as constrained by the ExoMars Trace Gas Orbiter and Curiosity observations. *Geophysical Res. Letters* 46, 9430-9438, doi.org/10.1029/2019GL083800.
8. **Schuerger, A. C.**, Smith, D. J., Moores, J. E., and Guenther, R. 2019. A Lunar Microbial Survival (LMS) model for predicting the forward contamination of the Moon. *Astrobiology* 19(6), 730-756, doi:10.1089/ast2018.1952.
9. Schwendner, P. M., and **Schuerger, A. C.** 2019. Exploring microbial activity in low-pressure environments. *Extreme Microbiology.* (in press).

<u>2018</u>

10. Nicholson, W. L., **Schuerger, A. C.**, and Douki, T. 2018. The photochemistry of unprotected DNA and DNA inside *Bacillus subtilis* spores exposed to simulated Mars surface conditions of atmospheric composition, temperature, pressure, and solar radiation. *Astrobiology* 18(4), 393-402. Doi:10.1089/ast/2017.1721.
11. Peterside, D. T., Palaia, J. E., **Schuerger, A. C.**, Bucklin, R. A., and Corell, M. J. 2018. Testing of greenhouse cladding materials for space environments, Part 2: Laminates. *Appl. Engineering in Agriculture.* 34(3), 575-580. Doi.org/10.13031/aea.12465.
12. Rucker, M. A., Hood, D., Walker, M., Venkateswaran, K.J., and **Schuerger, A. C.** 2018. EVA swab tool to support planetary protection and astrobiology Evaluations on the International Space Station. *IEEE* paper 2018-05-11T19.

13. Farjardo-Cavaros, P., Morrison, M., Miller, K. M., **Schuerger, A. C., and** Nicholson, W. L. 2018. Transcriptomics of *Serratia liquefaciens* exposed to simulated Mars surface conditions near 7 mbar. *Nature Scientific Reports* 8, 149938. Doi:10.1038/s41598-018-33140-4.

14. **Schuerger, A. C.**, Smith, D. J., Griffin, D. W., Jaffe, D. A., Wawrik, B., Burrows, S. B., Christner, B. C., Gonzalez-Martin, C., Lipp, E. K., Schmale III, D. G., Yu, H. 2018. Science questions and knowledge gaps to characterize microbial transport and survival in Asian and African dust plumes reaching North America. *Aerobiologia*. 34, 425-435. Doi.org/10.1007/s10453-018-9541-7.

15. Schwendner, P. M., and **Schuerger, A. C.** 2018. Metabolic fingerprints of *Serratia liquefaciens* under simulated Martian conditions using Biolog GN2 microarrays. *Scientific Reports* 8, 15721. Doi:10.1038/s41598-018-33856-3.

16. Urbaniak, C., Massa, G., Hummerick, M., Khodada, C., **Schuerger, A.**, and Venkateswaran, K. 2018. Draft genome sequences of two *Fusarium oxysporum* isolates cultured from infected *Zinnia hybrida* plants grown on the International Space Station. *Genome Announcements* 6(20), e00326-18. Doi.org/10.1128/genomeA.00326-18.

<u>2017</u>

17. Mickol, R. L., Page, J., and **Schuerger, A. C.** 2017. Magnesium sulfate salt solutions and ices fail to protect *Serratia liquefaciens* from the biocidal effects of UV irradiation under martian conditions. *Astrobiology* 17(5), 401-412.

18. Moores, J. E., Smith, C. L., and **Schuerger, A. C.** 2017. UV production of methane from surface and sedimenting IDPs on Mars in light of the REMs data and new insights for TGO. *Planetary and Space Science* 147, 48-60.

19. **Schuerger, A. C.**, Ming, D. W., and Golden, D. C. 2017. Biotoxicity of Mars soils: 2. Survival of *Bacillus subtilis* and *Enterococcus faecalis* in aqueous extracts derived from six Mars analog soils. *Icarus* 290, 215-223.

<u>2016</u>

20. **Schuerger, A.** C., and Nicholson, W. L. 2016. Twenty species of hypobarophilic bacteria recovered from diverse soils exhibit growth under simulated martian conditions at 0.7 kPa. *Astrobiology* 16(12), 964-976.

<u>2015</u>

21. Lee, P., Schutt, J.W., Amarualik, J., Weaver, J.T., Carroll, J.T., Carroll, M., Jeauffre, J.-C., Mueller, R., Shapiro, J., Boucher, M., Braham, S., Lorber, K., Fong, T., Haas, C., Hoffman, S.J., Leonard, M., **Schuerger, A.C.**, Thomas, P. C., Thompson, W., Bonadies, T., Camblin,J. Jr., and Godbout, D. (2015) The Northwest Passage Drive Expedition: Lessons for the Human Exploration of the Moon, Mars, and Near-Earth Objects, Using Pressurized Vehicles. *Mars Inst. Tech. Pub. 2015-001*, Mars Institute, Moffett Field, CA.

22. **Schuerger, A. C.**, and Lee, P. 2015. Microbial ecology of a crewed rover traverse in the high Arctic: Low microbial dispersal and implications for planetary protection on human Mars missions. *Astrobiology* 15(6), 478-491.

<u>2014</u>

23. Moores, J. E., Mcconnochie, T. H., Ming, D. W., Archer, P. D., and **Schuerger, A. C.** 2014. The Siding Spring cometary encounter with Mars: A natural experiment for the martian atmosphere? *Geophys. Res. Lett*. 41, 4109-4117.

<u>2013</u>

24. Nicholson, W. L., Leonard, M. T., Farjardo-Cavazos, P., Panaytova, N., Farmerie, W. G., Triplett, E. W., and Schuerger, A. C. 2013. Complete genome sequence of *Serratia liquefaciens* strain ATCC 27592. Genome Announc. 1(4), e00548-13, doi:10.1128/genomeA.00548-13.

25. Nicholson, W. L., Krivushin, K., Gilichinsky, D., **Schuerger, A. C.** 2013. Growth of *Carnobacterium* spp. isolated from Siberian permafrost under simulated Mars conditions of pressure, temperature and atmosphere. *PNAS*, 110(2), 666-671.

26. **Schuerger, A. C.**, Ulrich, R., Berry, B. J., and Nicholson, W. L. 2013. Growth of *Serratia liquefaciens* under 7 mbar, 0 ^{o}C, and CO_2-enriched anoxic atmospheres. *Astrobiology* 13(2), 115-131.

2012

27. Farjardo-Cavazos, P., Waters, S. M., **Schuerger, A. C.**, George, S., and Nicholson, W. L. 2012. Evolution of *Bacillus subtilis* to enhanced growth at low pressure: Up-regulated transcription of *des-desKR*, encoding the fatty acid desaturase. *Astrobiology* 12(3), 258-270.

28. Moeller, R., **Schuerger, A. C.**, Reitz, G, and Nicholson, W. L. 2012. Protective role of spore structural components in determining Bacillus subtilis spore resistance to simulated Mars surface conditions. *Appl. Environ. Microbiol*. 78(24), 8849-8853.

29. Moores, J. E., and **Schuerger, A. C.** 2012. A meteoritic origin for the putative surface reservoir of organic carbon on Mars and relevance to the detection of methane in the martian atmosphere. *JGR, Planets*, 117(E08007), doi:10.1029/2012JE004060.

30. Nicholson, W. L., McCoy, L., E., Kerney, K. R., Ming, D. W., Golden, D. C., and **Schuerger, A. C.** 2012. Aqueous extracts of a Mars analogue soil that mimics the Phoenix landing site do not inhibit spore germination or growth of model spacecraft contaminants *Bacillus subtilis* 168 and *B. pumilus* SAFR-032. *Icarus* 220, 904-910.

31. **Schuerger, A. C**., Golden, D. C., and Ming, D. W. 2012. Biotoxicity of Mars soils: 1. Dry deposition of analog soils on microbial colonies and survival under martian conditions. *Planetary Space Science* 72, 91-101.

32. **Schuerger, A. C.**, Moores, J. E., Barlow, N., Clausen, C., and Britt, D. 2012. Methane evolution from UV-irradiated carbonaceous meteorites under simulated martian conditions. *JGR, Planets* 117(E08007), doi:10.1029/2011JE004023.

33. Smith, D. J., Jaffe, D. A., Birmele, M. N., Griffin, D. W., **Schuerger, A. C**., Hee, J., Roberts, M. S. 2012. Free tropospheric transport of microorganisms from Asia to North America. *Microbial Ecology* 64(4), 973-985.

34. Young, H. M., George, S., Naváez, D. F., Srivastava, P., **Schuerger, A. C.**, Wright, D. L., and Marois, J. J. 2012. Effect of solar irradiation on severity of soybean rust. *Phytopathology* 102, 794-803.

2011

35. Kerney, K. R., and **Schuerger, A. C.** 2011. Survival of *Bacillus subtilis* on sun-exposed spacecraft rover wheels and Mars regolith under simulated martian conditions. *Astrobiology* 11(5), 477-485.

36. Kral, T. A., Altheide, T. S., Lueders, A. E., and **Schuerger, A. C.** 2011. Low pressure and desiccation effects on methanogens: Implications for life on Mars. *Planetary Space Sci*. 59, 264-270.

37. Moeller, R., **Schuerger, A. C.**, Reitz, G., and Nicholson, W. L. 2011. Impact of two DNA repair pathways, homologous recombination and non-homologous end joining, on bacterial spore inactivation under simulated martian environmental conditions. *Icarus* 215, 204-210.

38. Sabri, F., Leventis, N., Hoskins, J., **Schuerger, A. C.**, Sinden-Redding, M., Britt, D., and Duran, R. A. 2011. Spectroscopic evaluation of polyurea crosslinked aerogels as a substitute for RTV-based chromatic calibration targets for spacecraft. *Adv. Space Res*. 47, 419-427.
39. **Schuerger, A.** C., Clausen, C., and Britt, D. 2011. Methane evolution from UV-irradiated spacecraft materials under simulated martian conditions: Implications for the Mars Science Laboratory (MSL) mission. *Icarus* 213, 393-403.
40. Smith, D. J., Griffin, D. W., McPeters, R. D., Ward, P. D. and **Schuerger, A. C.** 2011. Microbial survival in the stratosphere and implications for global dispersal. *Aerobiologia* 27, 319-332.
41. Smith, S. J., Townley, J. A., Truett, J., Stimpson, A., Palaia, J. A., **Schuerger, A. C.**, Bucklin, R. A., and Correll, M. J. 2011. Testing of greenhouse cladding materials for space environments. *Applied Engineering in Agriculture* 27(3), 449-456.

2010

42. Berry, B. J., Jenkins, D. G., and **Schuerger, A. C.** 2010. Inhibition of *Escherichia coli* and *Serratia liquefaciens* under high-salt, low-pressure, and low-temperature environments that approach surface conditions on Mars. *Appl. Environ. Micro.* 76(8), 2377-2386.
43. Fajardo-Cavazos, P., **Schuerger, A. C.**, and Nicholson, W. L. 2010. Exposure of DNA and *Bacillus subtilis* spores to simulated Mars environments: Use of quantitative PCR (qPCR) to measure inactivation rates of DNA to function as a template molecule. *Astrobiology* 10(4), 403-411.
44. Hintze, P. E ., Buhler, C. R., **Schuerger, A. C.**, Calle, L. M., and Calle, C. I. 2010. Alteration of five organic compounds to glow discharge plasma and UV light under simulated Mars conditions. *Icarus* 208, 749-757.
45. Nicholson, W. L., Fajardo-Cavazos, P., Fedenko, J., Ortiz-Lugo, J.-L., Rivas-Castillo, A., and **Schuerger, A. C.** 2010. Exploring the low-pressure growth limit: Laboratory evolution of *Bacillus subtilis* to enhanced growth at 5 kilopascals. *Appl. Environ. Micro.* 76(22), 7559-7565.
46. Smith, D. J., Griffin, D., and **Schuerger, A. C.** 2010. Stratospheric microbiology at 20 km over the Pacific Ocean. *Aerobiologia* 26, 35-46.
47. Visscher, A. M., Paul, A.-L., Kirst, M., Guy, C. L., **Schuerger, A. C.**, and Ferl, R. J. 2010. Response of wild-type Arabidopsis and ion transporter mutants to high levels of magnesium sulfate, consequences for extraterrestrial plant growth. *PLoS One* 5(8), doi:10.1371/journal. pone.0012348.

2009

48. Nicholson, W. L., Fedenko, J., and **Schuerger, A. C.** 2009. Carbon-13 (^{13}C) labeling of *Bacillus subtilis* vegetative cells and spores: Suitability for DNA stable isotope probing (DNA-SIP) of spores in soils. *Curr. Microbiol.* 59(1), 9-14.
49. Nicholson, W. L., **Schuerger, A. C.**, and Race, M. S. 2009. Migrating microbes and planetary protection. *Trends Microbiol.* 17(9), 389-392.
50. **Schuerger, A. C.**, and Hammer, W. 2009. Use of cartridge filtration to suppress root disease in hydroponic pepper plants caused by *Pythium myriotylum*. *Phytopathology* 99, 597-607.
51. Smith, D. J., **Schuerger, A. C.**, Davidson, M. M., Onstott, T. C., Pacala, S. W., and Bakermans, C. 2009. Survivability of *Psychrobacter cryohalolentis* K5 under simulated martian surface conditions. *Astrobiology* 9, 221-228.

2008

52. Fajardo-Cavazos, P., **Schuerger, A. C.**, and Nicholson, W. L. 2008. Persistence of biomarker ATP and ATP-generating capability in bacterial cells and spores contaminating spacecraft materials under Earth and simulated Mars environments. *Applied Env. Microb*. 74(16), 5159-5167.

53. Parro, V., Fernandez-Calvo, P., Rodriguez-Mafredi, J. A., Moreno-Paz, M., Tivas, L. A., Garcia-Villadangos, M., Bonaccorsi, R., Gonzales-Pastor, J. E., Prieto-Ballesteros, O., **Schuerger, A. C.**, Davidson, M., Gomez-Elvira, J., and Stoker, C. R. 2008. SOLID2: An antibody array-based life detector instrument in a Mars Drilling Simulation Experiment (MARTE). *Astrobiology* 8(5), 987-999.

54. Perkins, A. E., **Schuerger, A. C.**, and Nicholson, W. L. 2008. Isolation and characterization of *rpoB* mutations causing rifampicin resistance in *Bacillus subtilis* spores exposed to simulated Mars surface conditions. *Astrobiology* 8(6), 1159-1167.

55. Sabri, F., Werhner, T., Hoskins, J., **Schuerger, A. C.**, Britt, D. and Duran, R. A. 2008. Thin film surface treatments for lowering dust adhesion on Mars Rover Calibration Targets. *Advances in Space Res.* 41(1), 118-128.

56. **Schuerger, A. C.** and Clark, B. 2008. Viking Biology Experiments: Lessons Learned and the Role of Ecology in Future Mars Life-Detection Experiments. *Space Science Reviews* 135, 233-243.

57. **Schuerger, A. C.**, Farjardo-Cavazos, P., Clausen, C. A., Moores, J. E., Smith, P. H., and Nicholson, W.L. 2008. Slow degradation of ATP in simulated martian environments suggests long residence times for the biosignature molecule on spacecraft surfaces on Mars. *Icarus* 194(1), 86-100.

58. **Schuerger, A. C.**, Trigwell, S., and Calle, C., 2008. Use of non-thermal atmospheric plasmas to reduce the viability of *Bacillus subtilis* on spacecraft surfaces. *Intern. J. Astrobiol.* 7(1), 47-57.

59. Stoker, C. R., 28 authors; **Schuerger, A. C.**, 2008. The 2005 MARTE robotic drilling experiment in Rio Tinto Spain: Objectives, approach, and results of a simulated mission to search for life in the martian subsurface. *Astrobiology* 8(5), 921-945.

<u>2007</u>

60. Fajardo-Cavazos, P., **Schuerger, A. C.**, and Nicholson, W.L. 2007. Testing interplanetary transfer of bacteria by natural impact phenomena and human spaceflight activities. *Acta Astronautica* 60, 534-540.

61. Moores, J. E., Smith, P. H., Tanner, R., **Schuerger, A. C.**, and Venkateswaran, K. J. 2007. The shielding effect of small-scale martian surface geometry on ultraviolet flux. *Icarus* 192, 417-433.

62. Nicholson, W. L., Fajardo-Cavazos, P., and **Schuerger, A. C.** 2007. Interplanetary transport of microorganisms: Survival, growth, and adaptation. In: *Bioastronomy 2007: Molecules, Microbes, and Extraterrestrial Life.* Eds. Meech, K. J., Keane, J. V., Mumma, M. J., Siefert, J. L., and Werthimer, D. J. *Astronomical Soc. Pacific Conference Series*, 420, 381-387.

63. **Schuerger, A. C.**, Copenhaver, K., Lewis, D., Kincaid, R., and May, G. 2007. Canopy structure and imaging geometry may create unique problems during spectral reflectance measurements of crop canopies in bioregenerative Advanced Life Support systems. International Journal of Astrobiology 5(2), 109-121.

<u>2006</u>

64. Beaty, D.W.; Buxbaum, K.L.; Meyer, M.A.; Barlow, N.G.; Boynton, W.V.; Clark, B.C.; Deming, J.W.; Doran, P.T.; Edgett, K.S.; Hancock, S.L.; Head, J.W.; Hecht, M.H.; Hipkin, V.; Kieft, T.L.; Mancinelli, R.L.; McDonald, E.V.; McKay, C.P.; Mellon, M.T.; Newsom, H.; Ori, G.G.; Paige, D.A.; **Schuerger, A.C.**; Sogin, M.L.; Spry, J.A.; Steele, A.; Tanaka, K.L.; Voytek, M.A. 2006. Findings of the Special Regions Science Analysis Group. *Astrobiology* 6(5), 677-732.

65. Buhler, C. R., Hintze, P. E., Calle, C., Calle, L. M., Trigwell, S., Starnes, J. W., and **Schuerger, A. C.** 2006. Particle cleaning in the martian environment. *Proceedings of the Fifth World Congress on Particle Technology,* Orlando, FL, Paper No. 153C.

66. Calle, C. I., Hintze, P. E., Buhler, C. R., Calle, L. M., Trigwell, S., **Schuerger, A. C.** 2006. Degradation of organics due to glow discharges under simulated martian conditions. 57th

International Astronautical Congress, Valencia, Spain, October 2-6, 2006, Paper No. IAC-06-A3.P316

67. Ferl, R. J., **Schuerger, A. C.**, Paul, A. L., Dixon, M., Fluford, P., McKay, C. 2006. Mars plant biology: A workshop report and recommendations for plant biology in the era of exploration. *Habitation* 11(1/2), 1-4.

68. Richards, J. T., Wheeler, R. A., Corey, K., Paul, A-L., Ferl R.J., and **Schuerger, A. C.** 2006. Exposure of *Arabidopsis thaliana* to hypobaric environments: Implications for low-pressure bioregenerative life support systems for human exploration missions and terraforming on Mars. A*strobiology* 6(6), 851-866.

69. **Schuerger, A. C.**, and Nicholson, W. L. 2006. Interactive effects of low pressure, low temperature, and CO_2 atmospheres inhibit the growth of *Bacillus* spp. under simulated martian conditions. *Icarus* 185, 143-152.

70. **Schuerger, A. C.**, and Richards, J. T. 2006. Effects of artificial lighting on the detection of plant stress with spectral reflectance remote sensing in bioregenerative life support systems. *International J. Astrobiology* 5(2), 151-169.

71. **Schuerger, A. C.**, Richards, J. T., Newcombe, D. A., and Venkateswaran, K. J. 2006. Rapid inactivation of seven *Bacillus* spp. under simulated Mars UV irradiation suggests minimum forward contamination around Mars landing sites. *Icarus* 181, 52-62.

72. Tauscher, C., **Schuerger, A. C.**, and Nicholson, W. L. 2006. Survival and germinability of *Bacillus subtilis* spores exposed to simulated Mars solar radiation: Implications for planetary protection and lithopanspermia. *Astrobiology* 6, 592-605.

<u>2005</u>

73. Cockell, C. S., **Schuerger, A. C.**, Billi, D., Friedmann,E. I., Panitz, C. 2005. Effects of a simulated martian UV flux on the cyanobacterium, *Chroococcidiopsis* sp. 029. *Astrobiology* 5(2), 127-140.

74. Newcombe, D. A, **Schuerger, A. C.**, Benardini, J. N., Dickinson, D., Tanner, R., and Venkateswaran, K. 2005. Survival of spacecraft associated microbes under simulated martian UV irradiation. *Applied Environ. Microbiol.* 71, 8147-8156.

75. Nicholson, W. L., and **Schuerger, A. C.** 2005. *Bacillus subtilis* spore survival and expression of germination-induced bioluminescence after prolonged incubation under simulated Mars atmospheric pressure and composition: Implications for planetary protection and lithopanspermia. *Astrobiology* 5(4), 536-544.

76. Nicholson, W. L., **Schuerger, A. C.**, and Setlow, P. 2005. The solar UV environment and bacterial spore UV resistance: Considerations for Earth-to-Mars transport by natural processes and human spaceflight. *Mutation Research* 571, 249-264.

77. **Schuerger, A. C.**, Richards, J. T., Hintze, P. E., and Kern, R. 2005. Surface characteristics of spacecraft components affect the aggregation of microorganisms and may lead to different survival rates of bacteria on Mars landers. *Astrobiology* 5(4), 545-559.

<u>2004</u>

78. Paul, A-L., **Schuerger, A. C.**, Popp, M., Richards, J. T., Manak, M., and Ferl, R. J. 2004. Hypobaric biology: Arabidopsis gene expression at low atmospheric pressure. *Plant Physiol.* 134, 215-223.

79. **Schuerger, A. C.** 2004. Microbial Ecology of the Surface Exploration of Mars with Human-Operated Vehicles. <u>In</u>: Martian Expedition Planning, ed., C. S. Cockell, Univelt Publishers, Santa Barbara, CA, American Astronautical Society publication AAS 03-322, pp. 363-386.

<u>2003</u>

80. Richards, J., **Schuerger, A. C.**, Capelle, G., and Guikema, J. A. 2003. Laser-induced fluorescence spectroscopy (LIFS) of light- and dark-adapted bean (*Phaseolus vulgaris* L.) and wheat (*Triticum*

aestivum L.) plants grown under three lighting intensities and fluctuating lighting conditions. *Remote Sensing Environ*. 84(3), 323-341.

81. **Schuerger, A. C.**, Capelle, G. A., De Benedetto, J. A., Mao, C., Thai, C. N., Evans, M. D., Richards, J., Blank, T., and Stryjewski, E. C. 2003. Comparison of two hyperspectral imaging and two laser-induced fluorescence instruments for the detection of zinc stress and chlorophyll concentration in bahia grass (*Paspalum notatum* Flugge.). *Remote Sens. Environ*. 84(4), 572-588.

82. **Schuerger, A. C.**, and Hammer, W. 2003. Suppression of powdery mildew, *Sphaerotheca fuliginea*, on cucumber by the addition of silicon to hydroponic nutrient solutions. *Plant Disease* 87, 177-185.

83. **Schuerger, A. C.**, Mancinelli, R. L., Kern, R.G., Rothschild, L. J., and McKay, C P. 2003. Survival of endospores of *Bacillus subtilis* on spacecraft surfaces under simulated martian environments: Implications for the forward contamination of Mars. *Icarus* 165(2), 253-276.

2002

84. Ferl, R. J., **Schuerger, A. C.**, Paul, A. L., Gurley, W. B., Corey, K., and Bucklin, R. 2002. Plant adaptation to low pressures: Potential molecular responses. *Life Support & Biosphere Sci*. 8, 93-101.

85. **Schuerger, A. C.**, Ming, D., Newsom, H., Ferl, R. J., and McKay, C. P. 2002. Near-term lander experiments for growing plants on Mars: Requirements for information on chemical and physical properties of Mars regolith. *Life Support & Biosphere Science* 8, 137-147.

2001

86. Cockell, C. S., Lee, P., **Schuerger, A. C.**, Hidalgo, L., Jones, J., and Stokes, M. D. 2001. Microbiology and vegetation of micro-oases and polar desert, Haughton Impact Crater, Devon Island, Nunavut, Canada. *Arctic, Alpine & Antarctic Research* 33, 306-318.

2000-1983

87. Brown, C. S., **Schuerger, A. C.**, and Sager, J. C. 1995. Growth and photomorphogenesis of pepper plants grown under red light-emitting diodes with supplemental blue or far-red lighting. *J. Amer. Soc. Hort Sci*. 120(5), 808-813.

88. Gonzales, A. A., **Schuerger, A. C.**, Mitchell, R., and Barford, C. 1996. Engineering strategies for the design of plant nutrient delivery systems for use in space: Approaches to countering microbiological contamination. *Adv. Space Res*. 18(4/5), 5-20.

89. Hines, R., Prince, R., Muller, E., and **Schuerger, A. C.** 1990. A thin film hydroponic system for plant studies. *ASAE* paper No. 90-4035, Annual Meeting of the American Society of Agricultural Engineers., St. Joseph, MI.

90. Pategas, K. G., **Schuerger, A. C.**, and Wetter, C. 1989. Management of tomato mosaic virus on hydroponically grown peppers (*Capsicum annuum*). *Plant Disease* 73, 570-573.

91. **Schuerger, A. C.** 1991. Effects of temperature and hydrogen ion concentration on disease caused by *Fusarium solani* f. sp. *phaseoli* in *Vigna radiata* grown in hydroponic nutrient solution. Ph.D. dissertation. University of Florida, Gainesville. 243 pp.

92. **Schuerger, A. C.** 1992. Alternative methods for controlling root diseases in hydroponic systems. Pages 8-17 in: Proceeding of the 13th Annual Conference on Hydroponics. Hydroponic Society of America, Orlando, FL April 9-12, 1992.

93. **Schuerger, A. C.** 1998. Microbial contamination of advanced life support (ALS) systems poses a moderate threat to the long-term stability of space-based bioregenerative systems. *Life Support & Biosphere Sci.* 5, 325-337.

94. **Schuerger, A. C.**, and Batzer, J. C. 1993. Identification and host range of a bacterial stem rot of hydroponically grown plants. *Plant Disease* 77, 472-477.

95. **Schuerger, A. C.**, and Brown, C. S. 1994. Spectral quality may be used to alter plant disease development in CELSS. *Adv. Space Res*. 14, 395-398.

96. **Schuerger, A. C.**, and Brown, C. S. 1997. Spectral quality affects disease development of three pathogens on hydroponically grown plants. *HortScience* 32, 96-100.

97. **Schuerger, A. C.**, and Hammer, W. 1995. Effects of temperature on disease development of tomato mosaic virus in *Capsicum annuum* in hydroponic systems. *Plant Disease* 79, 880-885.

98. **Schuerger, A. C.**, and Laible, P. 1994. Biocompatibility of wheat (*Triticum aestivum* L.) and tomato (*Lycopersicon esculentum* Mill.) in a dual culture hydroponic system. *HortScience* 29, 1164-1165.

99. **Schuerger, A. C.**, and McClure, M. A. 1983. Ultrastructural changes induced by *Scutellonema brachyurum* in potato roots. *Phytopathology* 73, 70-81.

100. **Schuerger, A. C.**, and Mitchell, D. J. 1992. Effects of temperature, hydrogen ion concentration, humidity, and light quality on disease severity of *Fusarium solani* f. sp. *phaseoli*. *Can. J. Bot*. 70, 1798-1808.

101. **Schuerger, A. C.**, and Mitchell, D. J. 1992. Effects of temperature and hydrogen ion concentration on attachment of macroconidia of *Fusarium solani* f. sp. *phaseoli* to roots of mung bean in hydroponic nutrient solution. *Phytopathology* 82, 1311-1319.

102. **Schuerger, A. C.**, and Mitchell. D. J. 1993. Influence of mucilage secreted by macroconidia of *Fusarium solani* f. sp. *phaseoli* on spore attachment to roots of *Vigna radiata* in hydroponic nutrient solution. *Phytopathology* 83, 1162-1170.

103. **Schuerger, A. C.**, Brown, C. S., and Stryjewski, E. C. 1997. Anatomical features of pepper plants grown under red light-emitting diodes supplemented with blue or far-red lighting. *Annals of Botany* 79, 273-282.

104. **Schuerger, A. C.**, Mitchell, D. J., and Kaplan, D. T. 1993. Influence of carbon source on attachment and **germination** of macroconidia of *Fusarium solani* f. sp. *phaseoli* on roots of *Vigna radiata* grown in hydroponic nutrient solution. *Phytopathology* 83, 1171-1177.

105. Serracin, M., **Schuerger, A. C.**, and Dickson, D. W. 1997. Effects of temperature on the development of *Pasteuria penetrans* in *Meloidogyne arenaria*, race 2. *J. Nematology* 29, 228-238.

106. Thai, C. N., Evans, M. D., and **Schuerger, A. C.** 1999. Spectral imaging of bahia grass grown under different zinc and copper treatments. *ASAE* Paper #993171.

EDUCATIONAL BOOKS

107. Loreen Leedy and **Andrew C. Schuerger**, 2006. Messages from Mars. Holiday House Publishing, New York, NY. This children's book was targeted for the 2nd and 3rd grade levels, and presents the exploration of Mars through the eyes of five children who win the international student science "Go2Mars" contest in the year 2106.

108. Loreen Leedy and **Andrew Schuerger**, 2015. Amazing Plant Powers: How Plants Fly, Fight, Hide, Hunt, & Change the World. Holiday House Publishing, New York, NY. The target audience is K-3rd grade, and the book seeks to introduce the many diverse and "amazing" things that plants do to survive in a diversity of natural ecosystems.

WORKING PROJECTS AND MANUSCRIPTS

109. **Schuerger, A. C.**, and Britt, D. T. 2017. Degassing of porous rocks under simulated Mars conditions constrains the search for endolithic microbial communities on Mars. *Icarus*.

110. **Schuerger, A. C.**, Tench, B. J., Valbuena, F. 2018. Recovery of plant pathogens in the free atmosphere over Florida. *Phytopathology*.

111. **Schuerger, A. C.** and Ming, D. W. 2018. Biotoxicity of Mars: 3. Mars Sample Return bioassays must differentiate between abiotic and biotic pathogens. *Astrobiology*.

112. **Schuerger, A. C.**, Griffin, D., and Jaffe, D. 2018. Failed recovery of viable propagules of *Phytopthora*, *Pythium*, or *Rhizoctonia* spp. from trans-Pacific Asian aerosols in Oregon. *Phytopathology*.

113. **Schuerger, A. C.** and Kelley, K. 2018. Ultrastructure of *Serratia liquefaciens* grown at 0.7 kPa: Implications for an active atmospheric microbiology on Earth and Mars. *PNAS*.

114. **Schuerger, A. C.**, Valbuena, F., and Brown, L. 2018. Air-filtration and DNA-extraction efficiencies for airborne sampling of atmospheric dust. *Aerobiologia*.

115. **Schuerger, A. C.**, Ming, D., and Richards, J. T. 2019. Biotoxicity of Mars soils: 4. Effects of phytotoxic edaphic factors in Mars regolith on the growth and development of *Arabidopsis thaliana*. *Astrobiology*.

<u>SEMINARS, PRESENTATIONS, AND WORKSHOPS (2007-2017)</u>

1. 2017. *Fusarium oxysporum* as an Opportunistic Pathogen on *Zinnia hybrida* Grown Onboard the International Space Station. Invited seminar, NASA Advanced Life Support System Program, Kennedy Space Center, FL, April 7, 2017.

2. 2016. A Dust Atmospheric Recovery Technology (DART) for the Recovery of Airborne Microorganisms over Florida. Invited seminar, Space Life Sciences Lab, Kennedy Space Center, FL, April 7, 2016.

3. 2015. Hypobarophilic Bacteria Capable of Growth under Martian Conditions of 7 mbar, 0 ºC, and CO_2-enriched Anoxic Atmospheres. Invited seminar, Florida Space Institute, April 11, 2015.

4. 2015. Dust Atmospheric Recovery Technology (DART): A Dust Sampling Device for Collecting Pathogens in African and Asian Dust Plumes. Invited seminar, US Geological Survey, Sarasota, FL, April 1, 2015.

5. 2015. Ultraviolet Irradiation on the Surface of Mars: Implications for EVA Activities during Future Human Missions. Invited seminar, Workshop on Planetary Protection Knowledge Gaps for Human Missions to Mars, NASA Ames Research Center, March 19-21, 2015.

6. 2015. Low Dispersal of Human-Associated Microbes on to Pristine Snow during an Arctic Traverse on Sea Ice by the Moon-1 Planetary Surface Rover. Invited seminar, Workshop on Planetary Protection Knowledge Gaps for Human Missions to Mars, NASA Ames Research Center, March 19-21, 2015.

7. 2014. Dust Atmospheric Recovery Technology (DART): Aerial Sampling for the Detection of Airborne Plant Pathogens. Seminar to the Dept. of Plant Pathology, UF, March 2014.

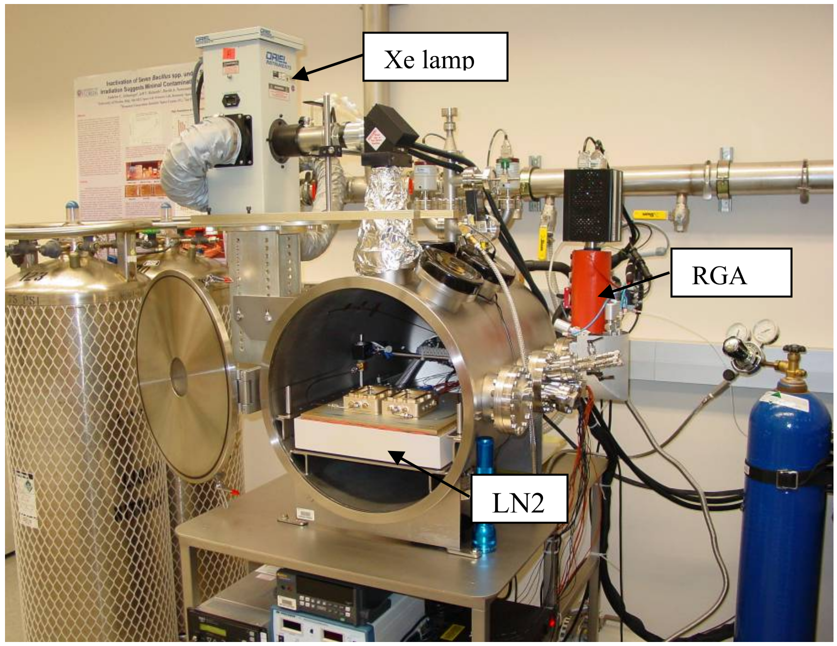
8. 2013. Atmospheric Dust Sampling for Astrobiology Research Relevant to Earth and Mars. Invited seminar at NASA Headquarters, Washington DC, on Jan. 14, 2013.

9. 2013. Survival, Growth, and Evolution of Terrestrial Bacterial under Simulated Martian Conditions. Invited seminar at NASA Headquarters Washington DC, on Jan 15, 2013.

10. 2013. Growth and Ultrastructure of Bacteria in 7 mbar, 0 ºC, and CO_2-enriched Anoxic Atmospheres: Implications for the Forward Contamination of Mars. Polycom presentation at the UCLA Mars Habitability Conference on Feb. 4, 2013.

11. 2013. Growth of Bacteria at 7 mbar: Implications for Robotic and Crewed Missions to Mars. Seminar in the UF Dept. of Plant Pathology on Feb. 26, 2013.
12. 2013. A Non-biological UV/CH_4 Linked Model for the Production of Methane in the Martian Atmosphere. Invited seminar in the Dept. of Physics at the Univ. of Hawaii on April 19, 2013.
13. 2013. Growth of Bacteria at 7 mbar: Implications for Robotic and Crewed Missions to Mars. Invited seminar in the Dept. of Microbiology at the Univ. of Hawaii on April 20, 2013.
14. 2013. DART (Dust at Altitude Recovery Technology): A Dust Sampling Device for Collecting Plant Pathogens in African and Asian Dust Plumes. Oral presentation at the statewide FL Plant Pathology conference in Ft. Lauderdale on May 7, 2013.
15. 2013. DART (Dust at Altitude Recovery Technology): A Dust Sampling Device for Collecting Plant Pathogens in African and Asian Dust Plumes. Oral presentation at the 2013 Science Writers Conference at UF on Nov. 4, 2013.
16. 2013. Growth of Terrestrial Microorganisms under Martian Conditions. Oral presentation at the ASGSR (Association of Space and Gravitational Science Research) Conference in
17. 2012. Growth of the Bacterium, *Serratia liquefaciens,* under Martian Conditions: Implications for the Robotic and Human Exploration of Mars. Florida Space Institute seminar on October 24, 2012.
18. 2012. Ecology of Terrestrial Microorganisms under Simulated Lunar and Martian Conditions. International Space University held at Florida Institute of Technology, July 6, 2012.
19. 2009. Can Terrestrial Microorganisms Survive in the Subsurface of Mars? Workshop: Cave Astrobiology Explorations, El Malpais National Monument, New Mexico, October, 2009.
20. 2008. Search for Life in the Solar System, Dept. of Microbiology & Cell Science, University of Florida, Astrobiology Class lecture, October 2008.
21. 2008. The View from Hubbert's Peak: Effects of Peak Oil on Society, Science, and Agriculture, 6 seminars given to a total of 140 people at the (i) Space Life Sciences Lab, Kennedy Space Center, FL and to student classes at the (ii) University of Florida and (iii) University of Georgia.
22. 2008. Panspermia: Is there a Biological Risk from Mars Sample Return Missions. 3rd Bi-annual meeting of the Association of Mars Explorers, San Jose, CA, April 14, 2008.
23. 2008. Panspermia: Implications for the Biosafety of Returned Samples from Mars, Dept. of Plant Pathology, University of Georgia, Athens, GA, October 20-21, 2008.
24. 2007. Survival of Terrestrial Microorganisms in Simulated Mars Environments: Implications for Aerial Transport of Pathogens in Earth's Atmosphere. 2007 Florida Phytopathology Society Conference, Quincy, FL, May 6-8th, 2007.
25. 2007. Survival and Growth of Terrestrial Microorganisms in Simulated Mars Environments. Lecture to the Plant Biology Dept., Portland State University, Portland, Oregon, October 9, 2007.
26. 2007. Microbial Ecology, Survival, and Growth of Terrestrial Bacteria on Spacecraft Surfaces during Robotic Missions to Mars. Seminar to UF Astrobiology class, March 26, 2007.
27. 2007. Effects of Tropospheric Conditions on the Survival of Plant Pathogens. 1st Annual UF Emerging Pathogens Institute Conference, Gainesville, FL, December 13, 2007.

Appendix A. Mars Simulation Chamber (MSC)

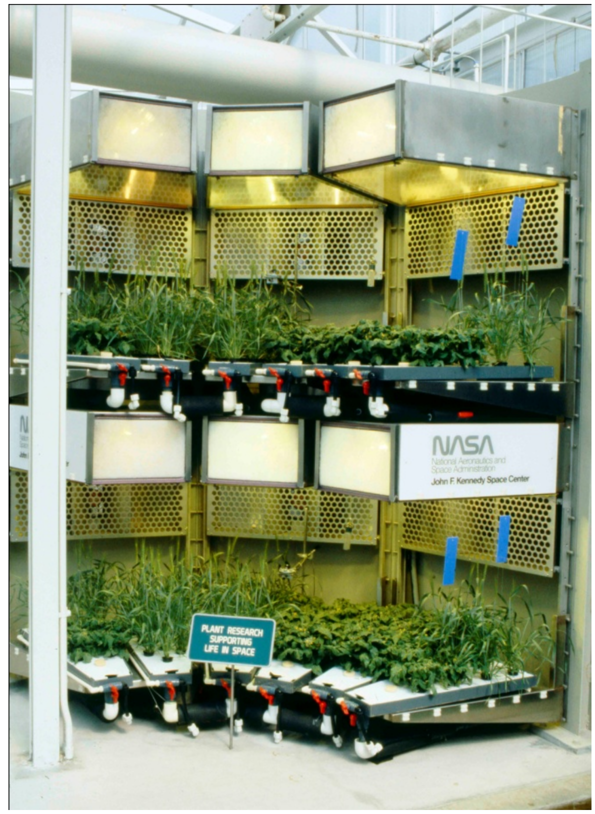


A Mars Simulation Chamber (MSC) was developed to recreate surface conditions on Mars, but can be calibrated to simulate the surface of the Moon and the upper troposphere and lower stratosphere of Earth. The MSC is a stainless steel low-pressure cylindrical chamber with internal dimensions measuring 70 cm long by 50 cm in diameter. Atmospheric gases [pure CO_2, pure N_2, Earth-normal O_2/N_2, or a Mars gas mix (see below)] are delivered to the MSC from commercially obtained tank mixes through a mass-flow controller. A liquid-nitrogen (LN2) thermal control system (model TP1265, Sigma Systems Corp., San Diego, CA) serves as the primary temperature control system for the MSC. The LN2 thermal control plate is fully programmable between –150 and +160 °C, including ramping characteristics for controlling diurnal temperature changes. Mars-normal or Earth tropospheric UV-VIS-NIR irradiation is supplied to the inside of the MSC through fused silica glass ports. Ultraviolet (UV), Visible (VIS), and near-infrared (NIR) irradiation is produced with one, 1000 W xenon-arc lamp (Xe) calibrated to deliver Mars UV fluence rates. A quadrupole mass-spectrometer Residual Gas Analyzer (RGA) can be used to track volatile gases within the hypobaric chamber from 1 to 200 atomic mass units (amu) with better than 5×10^{-7} mbar detection limits on most gases. The MSC system can accurately simulate five key components of the surface environment of Mars including: (a) pressures down to 0.1 mbar, (b) UVC, UVB, and UVA irradiation from 190 to 400 nm, (c) dust loading in the atmosphere from optical depths of 0.1 (dust-free sky) to 3.5 (global dust storm) using a series of neutral density filters, (d) temperatures from –150 to +30 °C (range based on Viking, Pathfinder, Spirit and Opportunity data), and (e) a Mars gas is composed of the top five gases in the martian atmosphere [CO_2 (95.3%), N_2 (2.7%), Ar (1.6%), O_2 (0.13%) and H_2O (0.03%)]. Schuerger designed and built the MSC system in 2004, and it has been the backbone of his astrobiology research program.

<u>Appendix B</u>. US Dept. of Energy Remote Sensing Exhibit, The Land, Epcot Center

The US Dept. of Energy (DOE) funded a series of remote sensing activities at The Land, Epcot Center between 1997 and 2000 to compare several remote sensing technologies for their effectiveness in detecting canopy changes in plants afflicted by abiological or biological pathogens. The research plots were setup in the exhibit greenhouses, and were highlighted on both the boat ride (top of photo) and walking tours (left of the display; not shown). Schuerger was the chief scientist for the project designing both the research and the science communication efforts. Shown above are several research teams from academia (Univ. of Georgia), industry (Bechtel Corp.), and NASA; each team brought their own remote sensing equipment, and all plants were measured with all four instruments. Schuerger's role was then to conduct a meta-analysis of the data to determine which instruments were more sensitive to subtle changes in canopy reflectance or laser-induced fluorescence in healthy versus diseased plants. The research was successfully conducted over 3 years with multiple changes of plants, pathogens, and remote sensing instruments.

<u>Appendix C</u>. Bioregenerative Advance Life Support (ALS) System



Bioregenerative Advanced Life Support (ALS) systems are proposed for future human missions to the Moon and Mars. The primary justification for an ALS system is the requirement to recycle food, water, and oxygen with a minimum of mass launched at the beginning of the mission. Without a bioregenerative ALS system, missions to Mars will require a prohibitively high amount of water, freeze-dried foods, and breathable oxygen. At The Land, Epcot Center, Schuerger was the chief scientist responsible for developing a hydroponic system to demonstrate the idea of bioregenerative life support systems for sustaining humans on long space missions. The modules depicted here were modeled after a hydroponic system developed at the Kennedy Space Center, FL in the early 1980’s. This approach used a nutrient flow technique (NFT) hydroponic system to recirculate a nutrient solution across a thin layer of plant roots contained within the grey trays on each level. Two ALS units were placed on either side of a boat transport system (bottom photo) that could move up to 25,000 visitors a day past the NASA-supported display.

The exhibit also combined science communication with active research. The ALS units were used to study the allelopathic interactions among various crops grown in integrated nutrient loops versus isolated nutrient loops. Allelopathy is the process in which one organism produces secondary metabolites that influence the growth and reproduction of other organisms. In this case, we tested the biocompatibility of tomato and wheat when grown in isolated or combined nutrient loops, and found a slight suppression of fruit weight in tomato plants grown in the intercropped versus isolated systems. Other research included cultivar trials of dwarf plants, use of light emitting diode (LED) arrays for optimum plant growth, effects of diverse lighting systems on plant and pathogen development, and the effects of different nutrient solutions on plant productivity.

<u>Appendix D</u>. Dust at Altitude Recovery Technology (DART) System

Dust emanates year-round from Africa and Asia and impacts air quality in North America. Asian dust plumes deliver up to 64 million tonnes of dust over the NW of the USA, and African dust storms deliver over 50 million tonnes of dust over Florida each year. Several recent studies have demonstrated that human and plant pathogens from Asian [1] African [2] aerosols can be transported to N. America in naturally occurring dust storms. What is unknown is whether these 'presumptive pathogens' impact human, plant, or animal health in the USA. In order to initiate a long-term monitoring program of pathogens in Asian and African dust plumes, we have developed a dust collection system called DART (Dust Atmospheric Recovery Technology) (red pod in figures). The DART dust sampler can be mounted on a F104 Starfighter jet (top figure; Starfighter Aerospace, Kennedy Space Center, FL) and a T6 Texan propeller driven airplane (middle figure; Warbird Adventures, Kissimmee, FL), and was test flown over FL in Dec. 2013 on the F104 and in the summer of 2014 on the T6. The DART system utilizes a high-volume pump to pass air through 6 separate filtration units where both aerosols and microbial cells are captured (bottom figure). The filtration systems exhibit flow rates from 25-142 L/min depending on the pore size and brand of filters used. Flow rates are directly correlated to increased air speed, and are inversely correlated to increased altitude. Filtration units can be turned on and off individually as required for specific science flight objectives. The DART dust sampler has performed nominally up to 10 km, 0.92 Mach, and 3.5 +G's. During initial test flights in Dec. 2013, 5 of 8 genera of fungi recovered from the lower atmosphere over FL contained plant pathogens including species in the genera: *Acremonium, Aspergillus*, *Cladosporium*, *Curvularia*, and *Fusarium*. Numbers of recovered fungi, but not bacteria, increased significantly when 5 or 10 µm were used in the DART system compared to filter pore sizes ≤ 1.2 µm. <u>References</u>: [1] Smith, D. J., et al., 2012. *Microbial Ecology* 64,973-985. [2] Griffin, D. W. 2007, *Clinical Microbiology Reviews* 20, 459-477.