BIOLOGICAL WASTEWATER PROCESSOR EXPERIMENT DEFINITION

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INTRODUCTION
The primary objective of the biological wastewater processor experiment definition NRA was to conduct preparatory ground-based research to enable development and optimization of future space flight experiments. Research tasks encompassed performing a comparative bioprocessor study to examine adaptation of existing bioprocessing technology for use in microgravity, microbiological consortium evaluation to characterize the bacteria used for degrading wastewater, bench-top testing to investigate surrogate parameters for monitoring bioprocessor performance, computer modeling to investigate start up of the reactors and scaling laws, and prototype infrastructure development to address form, fit and function requirements for designing a space flight-qualified payload.

CURRENT STATUS OF RESEARCH
Methods
A systematic process was used to define the space flight experiment. A versatile modular design that can be scaled to meet the constraints of either the space shuttle or the international space station (ISS) was developed for the ground-based experiment. The infrastructure for the ground-based research was designed to be as generic as possible so that it would be adaptable to accommodate other types of small-scale biological experiments requiring similar operating conditions.

The feasibility of monitoring bioprocessor performance using a surrogate parameter such as oxidation reduction potential (ORP) was investigated by correlating real-time measurements of ORP with chemical analyses of TOC, ammonia, nitrite, and nitrate. Scaled comparisons were made using 5-L and 500-mL reactors. Two experiments were performed on the 500-mL reactor to assess the response of an anoxic bioprocessor to failure of two key components: the feed pump and the internal liquid recirculation pump. Each failure event lasted 24 hours. Bioprocessor response was measured using on-line ORP sensing and periodic discrete sampling for nitrate and nitrite.

Characterization of the microbial species found in a bioprocessor processing a human-donated ISS wastestream was performed at two different intervals. Consortia samples collected from a bioprocessor that had been in operation for several weeks were compared to samples collected a year later from the same operating bioprocessor.

Results
ORP and pH data collected in bench-top testing indicate that on-line sensing of ORP and pH can provide useful insight into rate variations in denitrification and nitrification in a bioprocessor system. Data from the feed pump failure test performed on the 500-mL reactor indicated a good correlation between ORP profile and the ambient nitrate and nitrite concentrations. The strong decrease in the ORP value shortly after shutdown of the feed pump was evidence that ORP might be a reliable surrogate parameter for bioprocessor monitoring. In addition the bioprocessor recovered very quickly from the feed pump shutdown, returning to the pre-failure level of treatment within several hours. Results of the mixing pump failure, however, did not show a clear change in either ORP or nitrate/nitrite indicating that the short-term bioprocessor performance has less reliance on internal mixing within the reactor.

Twenty-three microbial strains were identified in the samples initially taken from the bioprocessor. However, only 15 strains were identified in the samples taken after one year of operation and all of the later strains were different from those previously isolated. Some of the strains isolated from the year one samples appeared to be facultatively heterotrophic and autotrophic bacteria that have only recently been isolated and documented in the literature. It is possible that our technology is simply allowing us to see strains that previously could not be cultivated, but which may have always been present and active in bioprocessing consortia processing similar wastewater streams.
Conclusions
The ability to monitor bioprocessor performance in real time offers significant advantages for a space flight experiment by minimizing required astronaut time and increasing understanding of continuous operational conditions including potential biological upsets and subsequent recovery events. Process stability, and the ability to recover from off-nominal perturbations, are essential attributes of human-rated space flight systems. The rapid recovery of functional performance following the pump failure tests demonstrated the inherent stability of this bioprocessor configuration.

FUTURE PLANS
Ground-based experiment definition and testing has created a solid foundation on which to propose a well-defined flight experiment. Scientific investigations of biological wastewater processing in microgravity are required not only to increase understanding of microorganisms in the long-term absence of gravity, but also to mitigate risks associated with life support hardware development.

INDEX TERMS
Bioprocessing, wastewater, on-line performance monitoring, modeling, advanced life support