Fiscal Year:	FY 2015	**Task Last Updated:**	FY 03/25/2015
PI Name:	Olson, Sandra Ph.D.		
Project Title:	Oxygen Delivery System		
Division Name:	Human Research		
Program/Discipline:	HUMAN RESEARCH		
Program/Discipline--Element/Subdiscipline:	HUMAN RESEARCH--Operational and clinical research		
Joint Agency Name:		**TechPort:**	Yes
Human Research Program Elements:	(1) **ExMC**:Exploration Medical Capabilities		
Human Research Program Risks:	(1) **Medical Conditions**:Risk of Adverse Health Outcomes and Decrements in Performance Due to Medical Conditions that occur in Mission, as well as Long Term Health Outcomes Due to Mission Exposures		
Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
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Organization Name:	NASA Glenn Research Center		
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City:	Cleveland	**State:**	OH
Zip Code:	44135	**Congressional District:**	9
Comments:			
Project Type:	FLIGHT,GROUND	**Solicitation / Funding Source:**	Directed Research
Start Date:	10/02/2008	**End Date:**	12/31/2017
No. of Post Docs:	2	**No. of PhD Degrees:**	2
No. of PhD Candidates:	2	**No. of Master' Degrees:**	0
No. of Master's Candidates:	0	**No. of Bachelor's Degrees:**	0
No. of Bachelor's Candidates:	0	**Monitoring Center:**	NASA JSC
Contact Monitor:	Antonsen, Erik	**Contact Phone:**	281.483.4961
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Flight Program:	ISS		
Flight Assignment:	NOTE: End date changed to 12/31/2017 per transfer to ECLSS; information from ExMC element/JSC (Ed., 3/12/18) NOTE: End date changed to 9/30/2019 per HRP Technology Pipeline spreadsheet sent by B. Corbin (Ed., 9/9/14) NOTE: Title change to Oxygen Delivery System (previously Medical Oxygen Fire Safety), per M. Covington/JSC via S. Watkins/ExMC/JSC (Ed., 9/23/13) NOTE: End date changed to 12/31/17 per PI information (Ed., 7/26/13)		
Key Personnel Changes/Previous PI:			
COI Name (Institution):			
Grant/Contract No.:	Directed Research		
Performance Goal No.:			
Performance Goal Text:			

Task Description:	Future space missions will take astronauts beyond Earth's orbit. The spacecraft that will be used for these missions is currently envisioned to have an internal atmosphere that is at a reduced pressure and elevated oxygen percentage, which assists with extra-vehicular activities. These exploration missions may be long in duration (e.g., 36 months), which requires that medical support be available for the crew. This medical support will include advanced life support equipment, which includes patient ventilation with oxygen. There are many medical conditions listed on the Space Medicine Exploration Medicine Conditions List (SMEMCL) that involve either treatment with supplemental oxygen or full ventilator support. Medical conditions that the Oxygen Concentrator Module must address per decision of NASA's Exploration Medical Capabilities Advisory Board include those which may require oxygen or ventilation use, including: smoke inhalation, sepsis, angina/myocardial infarction, hypovolemic shock, medication overdose, decompression sickness, stroke, head injury, choking/obstructed airway, chest injury, sudden cardiac arrest, altitude sickness, seizures, cardiogenic shock, radiation syndrome, neurogenic shock, toxic exposure to ammonia, and anaphylaxis. There are two US oxygen delivery systems currently used onboard the International Space Station (ISS)--the Respiratory Support Pack (RSP) and the Portable Breathing Apparatus (PBA). The RSP uses the ISS 120 psi oxygen lines and delivers pure oxygen up to 12 L/min. The RSP is for medical O2 usage. The PBA consists of a non-refillable portable oxygen bottle that provides 15 minutes of oxygen and also includes a 30 foot hose to attach to the ISS oxygen lines for long term oxygen supply. The PBAs are distributed throughout the ISS, and a few are available in each module or node. Both the PBAs and the RSP can obtain their oxygen supply from high pressure tanks located on the ISS. The PBAs also attached to the ISS oxygen line for use during the pre-Extravehicular Activity (EVA) pre-breathe protocol (a method of decreasing the body's nitrogen load and the risk of decompression sickness). The PBAs are also used for emergency oxygen usage (e.g., in a tox hazard or fire situation). An alternative to the US oxygen mask is the Russian isolating gas mask that can be used during fire or atmospheric contamination events. It provides 70 minutes of oxygen, but has been reported to be bulky, hot, and uncomfortable to wear for long periods of time. The main challenge with the current systems is that when using either the RSP or PBAs, the cabin oxygen concentration is elevated which increases the fire hazard. Modeling results have shown that when a patient is receiving oxygen, the oxygen concentration aboard the ISS rises very slowly secondary to the large volume and good mixing due to ventilation. In a much smaller spacecraft, the oxygen concentration increases much more rapidly and the risk of fire increases accordingly. Even in the ISS well-mixed scenario there is a pocket of elevated oxygen around the astronaut's head and chest area that creates a high risk situation. If an ignition source is introduced into this area, the resulting fire can rapidly spread through the oxygen-saturated clothing and hair as well as to other astronauts who may be treating the patient. For exploration atmospheres, the ambient atmosphere may be at elevated oxygen and reduced pressure as the norm, increasing the flammability of materials in general. Ignition hazards for medical operations during future space flights may be similar to those encountered in a typical operating room: defibrillators, laser beams, and fiber optic light sources are already available on the ISS. These tools can cause sparks when the energy impacts a metallic surface. The sparks or even the glowing embers of charring materials can provide enough initial heat to ignite some fuels, especially in oxygen enriched atmospheres. Hot electrical components in an oxygen enriched environment can be a source of ignition also. The ignition hazard may exist for a few minutes after deactivation of the source. Heat transfer is different in microgravity. Hot surfaces are hotter in the absence of gravity, and cooling times are longer.
Rationale for HRP Directed Research:	This research is directed because it contains highly constrained research, which requires focused and constrained data gathering and analysis that is more appropriately obtained through a non-competitive proposal.
Research Impact/Earth Benefits:	Long duration exploration missions require that medical support be available for the crew. This medical support will include advanced life support equipment, which includes patient ventilation with oxygen. The current medical oxygen requirement onboard the International Space Station (ISS) is met using 100 percent oxygen from high pressure oxygen tanks. Using 100 percent oxygen can increase the risk of fire. Providing a method of oxygen therapy that keeps the oxygen levels below the vehicle fire limit will allow extended duration of oxygen therapy without intervention required to reduce the cabin oxygen levels. Improved oxygen concentration technology could also find wide application on Earth.
	At the completion of an NSBRI (National Space Biomedical Research Institute) grant to develop an Oxygen Concentrator, Dr. Ritter and his team incorporated a new PSA module with a redesigned compressor into a prototype oxygen concentrator, and these systems have been delivered to NASA's Marshall Space Flight Center (MSFC) and Glenn Research Center (GRC) in 2014. Long-term testing and review of performance data at MSFC will indicate any degradation of the adsorbent materials due to trace contaminant poisoning. The prototype delivered to GRC was tested in the Exploration Atmospheres Lab. The Exploration Atmospheres Lab includes the test chamber, a vacuum exhaust system, a gas supply rack, chiller, power supplies, and data acquisition system. The test chamber is a 60 cm x 60 cm x 60 cm vacuum chamber with a cold plate at the floor level. A chiller is used to provide temperature-conditioned water to the cold plate in the bottom of the chamber. This is used primarily for heat rejection to maintain the chamber temperature at near-ambient conditions. Saturated salts are used to control the initial humidity in the chamber. A vacuum system is used to evacuate the chamber so it can be filled with the desired gas mixture. If the concentrator cannot withstand a hard vacuum, the chamber is partially evacuated and filled with the desired gas mixture repeatedly to obtain the desired ambient oxygen concentration and total pressure. The chamber is filled from the bottle rack, which contains different O2-N2 blends of 21% O2, 30% O2, and 34% O2. In addition, a combustion products 'air' blend is present that contains 1% CO2 and 55 ppm of CO. Additional bottles of 95% O2 and 100% N2 are used to calibrate and purge the oxygen sensor before and after each test, respectively. The oxygen concentrator is placed in the test chamber, draws in the ambient atmosphere from the chamber, and separates the gases to a waste stream that is predominantly nitrogen, and a product stream which is predominantly oxygen. Each of the three flow streams is measured for pressure, flow rate, temperature, humidity, and the oxygen concentration of the product stream is also measured. In addition, the voltage and current draw of the prototype was measured, and CO and CO2 sensors were used in some tests that used a gas mixture with these contaminants present. At the end of the testing, a report was finished comparing the Ritter PSA Prototype to the Lynntech Electrochemical

Task Progress:	Prototype we received and tested in 2012. This report serves as our annual report this year. Both prototypes were tested in the same lab, and were judged against the current flight oxygen concentrator requirements. Both prototypes met some of the requirements, but not all of them, since these are prototype units and not high TRL (technology readiness level). The PSA prototype successfully met 12 of 23 requirements, and the electrochemical prototype met 8 of 23 requirements. Based on this evaluation, the PSA technology had a clear technical advantage over the electrochemical technology. In addition, in 2014, two Phase I SBIRs (Small Business Innovation Research) were awarded pursuing two different technologies (Vacuum Swing Adsorption - VSA, and a different electrochemical design). The TDA, Inc. SBIR Phase I developed an oxygen generator based on a vacuum swing adsorption (VSA) to produce concentrated medical oxygen. They designed and built and evaluated the performance of the sorbent in a breadboard bench-scale prototype. The unit uses ambient vehicle cabin air as the feed and delivers high purity oxygen. TDA's VSA system uses a modified version of the lithium exchanged low silica X zeolite (Li-LSX), a state-of-the-art air separation sorbent extensively used in commercial Portable Oxygen Concentrators (POCs) to enhance the N2 adsorption capacity. The Reactive Innovations SBIR Phase I developed a modular electrochemical subscale concentrator and performed a preliminary design based on the performance of their arrangement of modular separation units. They demonstrated that modular separation units could be manufactured that separated oxygen from exploration atmospheres to produce pure oxygen. The modular separation units were compact, light-weight, and low cost serving both NASA needs and Reactive Innovation's commercial pursuits. Lastly, a technology development plan was updated this year, and the Oxygen Concentrator Module (OCM) project has had extensive discussions with Johnson Space Center (JSC) and NASA Headquarters (HQ) personnel regarding synergy with EVA high pressure, high purity oxygen requirements for exploration missions. We also identified oxygen needs for pre-breathing prior to EVA and in the event of a toxic spill or fire.
Bibliography Type:	Description: (Last Updated: 04/04/2024)
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