Fiscal Year:	FY 2016	**Task Last Updated:**	FY 08/20/2015
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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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
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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:			

NASA’s Exploration Medical Capability (ExMC) is charged to reduce the risk of adverse health and mission outcomes due to limitations of in-flight medical capabilities. They have identified a number of technology gaps, one of which is:
ExMC Gap 4.04: We do not have the capability to deliver supplemental oxygen to crewmembers while minimizing local and cabin oxygen build-up during exploration missions.

Current spaceflight oxygen delivery systems deliver pure oxygen to the crewmember from high pressure oxygen tanks, which results in a gradual increase in cabin oxygen levels and a localized area of increased oxygen concentration in the vicinity of the crewmember, posing an increased fire hazard.

The Oxygen Concentrator Module (OCM) project is tasked with developing an oxygen delivery system with variable oxygen capability that minimizes localized oxygen build-up and meets the commercial crew vehicle evacuation requirements.

Work under this gap focuses on the development of a supplemental oxygen delivery system for crewmembers that pulls oxygen out of the ambient environment instead of using compressed oxygen. This provides better resource optimization and reduces fire hazard by preventing the formation of localized pockets of increased oxygen concentration within the vehicle. The system will provide oxygen support in a closed cabin environment where the atmosphere may be at a reduced pressure and elevated oxygen percentage (compared to terrestrial standard atmosphere composition and pressure). Reference (http://humanresearchroadmap.nasa.gov/) for additional information on this gap.

Future space missions will take astronauts beyond Earth’s orbit. These exploration missions may be long in duration (e.g., 36 months) and will have limited resources. It is vital that each piece of equipment serve as many functions as possible, with built in redundancy. A modular oxygen concentrator that uses the ambient cabin air can serve a number of functions (medical emergency, pre-breathing, atmospheric contamination, or leak) without taxing other spacecraft systems to compensate for an increase in ambient oxygen. This improves mission safety by not exacerbating fire risk, and minimizing system interdependencies.

Task Description:	This gap aligns well with the International Space Station (ISS) Health Maintenance System (HMS) because HMS currently has no oxygen delivery system that can meet commercial crew vehicle evacuation requirements. Concentrating oxygen from cabin air eliminates the up mass associated with oxygen tanks and reduces fire hazard, as it prevents the formation of localized pockets of increased oxygen levels within the vehicle. An oxygen concentrator for crew medical support is considered vital to provide an ill crewmember with ventilation with oxygen. Providing a method of oxygen therapy that uses cabin air keeps the oxygen levels stable and avoids Environmental Control and Life Support System (ECLSS) intervention required to maintain the cabin oxygen levels. The medical conditions requiring oxygen supplementation include: Altitude sickness, Anaphylaxis, Burns, Choking/obstructed airway, Cough–URI (upper respiratory infection), bronchitis, pneumonia, inhalation, De Novo cardiac arrhythmia, Decompression sickness, Headache (CO2, SAS, other), Infection – sepsis, Medication overdose/misuse, Neck injury, Radiation sickness, Seizure, Smoke inhalation, and Toxic exposure. The final flight system for an oxygen delivery system needs to be Food & Drug Administration (FDA) clearable device and should be designed to minimize mass, volume, and power. A demonstration unit for the International Space Station (ISS) should verify the technology and provide oxygen capability for ISS. There are two US oxygen delivery systems currently used onboard the 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 spaceflights 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 environmental control intervention required to reduce the cabin oxygen levels. Improved oxygen concentration technology could also find wide application on Earth.
Task Progress:	A continuous stirred-tank reactor (CSTR) model was applied to predict how quickly the atmosphere inside a spacecraft would rise if pure oxygen from pressurized tanks was used for oxygen therapy. Small vehicles like commercial crew vehicles or the Multi-Purpose Crew Vehicle (MPCV) will see a rapid rise in ambient oxygen concentration if bottled oxygen is used at the required 15 LPM to treat an ill crewmember. A very ill crewmember requires a significant flow of oxygen, up to 15 LPM, but lower flow rates can be adequate for less ill crewmembers or as respiratory supply of healthy crew. To address these multiple flow ranges, a parallel architecture approach was applied this year to the technology development. In this system design, a set of 4 redundant lower flow concentrators (4 LPM each) is envisioned that could be used separately as needed or combined for the high flow need. The lower flow modules can be run off batteries for a reasonable period of time, or plugged in if the crew is relatively stationary. The oxygen concentrator could be used in a portable mode at 4 LPM as an option for pre-breathing protocol by the crew in preparation for Extravehicular Activities (EVA). The portability of the system could allow the astronaut the ability to move around and perform other activities while completing the pre-breathing protocol. This may be needed during the long transit to Mars, where the spacecraft cabin is still normal atmospheric air, for example. The portable, distributed oxygen concentrator could also be used to protect healthy crewmembers if there is an atmospheric contamination event such as a toxic spill or a fire, to avoid toxic gas or smoke inhalation. A replaceable inlet filter on the unit would remove toxic gases from the oxygen delivery stream, allowing the user to breathe in the enriched ambient oxygen free of smoke, dust, or other contaminates. The concentrator could also be used to provide an adequate partial pressure of oxygen in the event of an emergency leak, allowing the crew to find and stop the leak while ensuring an adequate oxygen supply as the spacecraft pressure drops. In 2015, a two year Phase II SBIR (Small Business Innovation Research) was awarded for a Vacuum Swing Adsorption – VSA system that will utilize this parallel architecture. The TDA, Inc. SBIR Phase II is continuing the development of an oxygen generator based on a vacuum swing adsorption (VSA) to produce concentrated medical oxygen. In Phase I 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. In Phase II, they will build and deliver two units so that the units can be tested individually, or in parallel.
Bibliography Type:	Description: (Last Updated: 04/17/2024)
NASA Technical Documents	Gilkey KM, Olson SL. "Evaluation of the Oxygen Concentrator Prototypes: Pressure Swing Adsorption Prototype and Electrochemical Prototype." Cleveland, OH: NASA Glenn Research Center, 2015 Mar. 42 p. NASA Technical Memorandum TM-2015-218709. http://ntrs.nasa.gov/search.jsp?R=20150011038&hterms=20150011038&qs=N%3D0%26Ntk%3DAll%26Ntx%3Dmode%2Bmatchallany%26Ntt%3D20150011038 , Mar-2015