Fiscal Year:	FY 2013	**Task Last Updated:**	FY 01/08/2014
PI Name:	Ritter, James A Ph.D.		
Project Title:	Development of Pressure Swing Adsorption Technology for Spaceflight Medical Oxygen Concentrators		
Division Name:	Human Research		
Program/Discipline:	NSBRI		
Program/Discipline--Element/Subdiscipline:	NSBRI--Smart Medical Systems and Technology Team		
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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City:	Columbia	**State:**	SC
Zip Code:	29208-4101	**Congressional District:**	6
Comments:			
Project Type:	Ground	**Solicitation / Funding Source:**	2008 Crew Health NNJ08ZSA002N
Start Date:	09/01/2009	**End Date:**	08/31/2013
No. of Post Docs:	1	**No. of PhD Degrees:**	1
No. of PhD Candidates:	4	**No. of Master' Degrees:**	0
No. of Master's Candidates:	0	**No. of Bachelor's Degrees:**	0
No. of Bachelor's Candidates:	2	**Monitoring Center:**	NSBRI
Contact Monitor:		**Contact Phone:**	
Contact Email:			
Flight Program:			
Flight Assignment:			
Key Personnel Changes/Previous PI:			
COI Name (Institution):	Knox, James (NASA Marshall Space Flight Center) Edwards, Paul (SeQual Technologies) LeVan, Douglas (Vanderbilt University)		
Grant/Contract No.:	NCC 9-58-SMST02002		
Performance Goal No.:			
Performance Goal Text:			
Task Description:	A source of medical oxygen will be needed at some point to keep an astronaut alive during a space mission. To meet this need, the ideal oxygen source would be a light, compact unit that uses minimal electricity, and can supply oxygen continuously for many days. No current technology meets these requirements. Traditional compressed-oxygen cylinders provide a limited amount of oxygen in a heavy, inconvenient package and are not suited for space missions. Oxygen concentrators, which extract oxygen from air using electricity, can eliminate the obvious problems with cylinder storage in space. These kinds of medical oxygen concentrators are already used in residential and military applications. However, existing systems are too big, use too much power, and are too heavy to be carried into space. For example, a unit that can produce oxygen continuously at 4 LPM (litres per minute), weigh less than 7 pounds, and use less than 100 Watts of electric power requires a two-fold reduction in weight and power consumption, compared with the most advanced oxygen concentrators now in production by SeQual. As proposed herein, this requirement may be met by combining new air compressor designs with advances in Pressure Swing Adsorption (PSA) technology. SeQual and the team of researchers from the University of South Carolina (USC), Vanderbilt University (VU), and the Marshall Space Flight Center (MSFC) are uniquely positioned to achieve this next level of performance. To determine whether the proposed technology advances are indeed possible, during the second year of this four year project, the four teams of researchers have been busy carrying out extensive mathematical modeling studies (USC), measuring equilibrium and kinetic parameters for the modeling effort (VU), performing carefully planned experiments with an Eclipse medical oxygen system modified for testing at the bench scale (SeQual), and gearing up for testing an Eclipse medical oxygen system under different environmental conditions (MSFC). Results from numerous experiments were used successfully to validate USC's Dynamic Adsorption Process Simulator (DAPS). In particular, DAPS was specially modified and calibrated against a SeQual PSA module under controlled conditions with a decoupled compressor, and the process performance was analyzed with respect to cycle speed, temperature, and high to low pressure ratio. Once validated, DAPS simulations focused on varying certain key process parameters to arrive at optimized PSA cycle designs. The learning from the design effort was implemented into a modified PSA module design operating a new PSA cycle, larger feed/exhaust ports, a backfill step, and larger recycle and purge ports. The new PSA module, associated compressor, and other components were fabricated and assembled on a breadboard. The breadboard was connected to instrumentation and tested. The new PSA design successfully delivered 4 lpm of product in about an 8 lb assembly with a compressor shaft power of 130 Watts. This was a significant outcome, especially since the new PSA design was based entirely on predictions from the DAPS. Overall, in the first two years of this four year project, this program is ahead of schedule and definitely on track for improving even further the efficiency of the PSA separation, with the project potentially culminating in a breadboard system that will supply 4 LPM of oxygen, weigh 7.2 lbs, require 106 Watts, and satisfy any new constraints imposed by NASA.		

During year 3 the task outline presented in the original proposal was followed. In this way, carefully planned experiments carried out by the folks at SeQual were used to calibrate and further validate DAPS at USC. This was done in an attempt to further improve the performance of the PSA module and to understand the effects of potential process changes on its performance. SeQual also continued to develop their medical oxygen system based, in part, on the simulation results obtained from DAPS. These developments included breadboard testing, further optimization of bed and PSA cycle design, new prototype subcomponent detailed design and fabrication, new prototype preliminary tests, and improving on their process design and mechanical design capabilities. The team at Vanderbilt continued to measure and provide equilibrium and mass transfer properties for adsorbate-adsorbent pairs of interest to NASA adsorption technology. In addition, the entire medical oxygen system was evaluated based on new constraints imposed by NASA. During year 3, testing in a vacuum chamber with an Eclipse medical oxygen system was done at the MSFC to determine how it performs under International Space Station (ISS) environmental conditions.

There were 8 tasks associated with this project. These tasks are listed below. All were completed on schedule. In the year 1, Tasks 1, 2, and 6 were initiated. In the year 2, in addition, Tasks 3 and 4 were initiated, and Task 5 was initiated ahead of schedule. In year 3, Tasks 1-6 were all underway. In year 4, Tasks 1 to 8 were either completed, or underway and completed at the end of the period.

Rationale for HRP Directed Research:

Research Impact/Earth Benefits: A major expectation of the research is the development of smaller medical oxygen concentrators, which will be of benefit not only for spaceflight but also for medica patients on Earth in need of oxygen enriched air.

Task Progress:

There were 8 tasks associated with this project. These tasks are listed below. All were completed on schedule. In the year 1, Tasks 1, 2, and 6 were initiated. In the year 2, in addition, Tasks 3 and 4 were initiated, and Task 5 was initiated ahead of schedule. In year 3, Tasks 1-6 were all underway. In year 4, Tasks 1 to 8 were either completed, or underway and completed at the end of the period. More detail about each task is provided below.
Task 1. Refine Model Parameters: Vanderbilt worked with USC to continually update the dynamic cyclic adsorption process simulator (DAPS) with the most up to date thermodynamic and kinetic parameters.

Task 2. Validate DAPS: USC worked with Chart to obtain system dimensions, operating conditions, and extensive experimental performance data of Chart's Eclipse system and then used it to calibrate and validate DAPS. Significant progress was made with respect to DAPS quantitatively predicting the performance of the Eclipse system.

Task 3. Optimize and Understand the Chart PSA Cycle: Using the refined and validated DAPS, USC, with input from Chart, carried out extensive parametric studies of Chart's PSA cycle to determine if it was possible to improve oxygen recovery, productivity, or both while maintaining the oxygen purity and without redesigning the PSA module. There were some key findings with DAPS that were recently verified experimentally by Chart.

Task 4. Examine Alternative PSA Cycles: Using the refined DAPS, USC, with input from Chart, explored new PSA cycle designs and cycle schedules to determine if it might be possible to improve the oxygen recovery, productivity, or both while maintaining the oxygen purity by redesigning the PSA module.

Task 5. Redesign and Build Improved PSA Module: Based on DAPS predictions, Chart designed a new PSA module that successfully delivered 4 lpm (litres per minute) of product in about an 8 lb assembly with a compressor shaft power of 130 Watts.

Task 6. Define Compressor Specifications and Build Feasibility Prototype for 4 LPM System: Chart developed a compressor suitable for a 3 LPM oxygen PSA system through a different funding source. Specifications and requirements were identified and a feasibility prototype was built built during this project to provide sufficient pressure and vacuum to supply a 4 LPM system.

Task 7. Assemble and Test Breadboard Systems: Chart assembled two breadboard demonstration systems that incorporated the new PSA module with the redesigned compressor. These breadboard systems are currently being tested by the MSFC and Glenn Research Center to determine new weight and performance targets and for down selection for flight development.

Task 8. Verify DAPS Predictions of New PSA Modules: Using the refined cyclic adsorption process simulator, USC carried out studies of redesigned systems and new prototypes to verify the simulation results, to determine optimum operating conditions, and to understand the performance limits of the new systems.

Bibliography Type:	Description: (Last Updated: 08/28/2015)
Articles in Peer-reviewed Journals	Giesy TJ, LeVan MD. "Mass transfer rates of oxygen, nitrogen, and argon in carbon molecular sieves determined by pressure-swing frequency response." Chemical Engineering Science. 2013 Mar 7;90:250-7. http://dx.doi.org/10.1016/j.ces.2012.12.029 , Mar-2013
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Awards	Ritter JA. "Named Fellow of the American Institute of Chemical Engineers, July 2013." Jul-2013
Awards	LeVan MD. "Honorary Session for Prof. M. Douglas LeVan, AIChE Annual Meeting, San Francisco, California, November 2013." Nov-2013
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