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Advanced Environmental Control and Life Support System (ECLSS) design is critical for manned space flight beyond Earth. Current systems enable extended missions in low-Earth orbit, but for deep-space missions, not only will astronauts be outside the reach of resupply operations from Earth but they will also need to handle malfunctions and compensate for the degradation of materials. These two daunting challenges must be overcome for long-term independent space flight. In order to solve the first, separation and recycling of onboard atmosphere is required. Current systems utilize space vacuum to fully regenerate CO<sub>2</sub> sorbent beds, but this is not sustainable. The second challenge stems from material and performance degradation due to operational cycling and on-board contaminants. This report will review the recent work by the ECLSS team at Marshall Space Flight Center towards overcoming these challenges by characterizing materials via novel methods and by assessing new air revitalization systems.