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Author: Dr. Azita Valinia
NASA Engineering and Safety Center (NESC), United States, Azita.Valinia@nasa.gov

Mr. David C. Folta
National Aeronautics and Space Administration (NASA), Goddard Space Flight Center, United States, david.c.folta@nasa.gov
Dr. Kyle Hughes
NASA Goddard Space Flight Center Greenbelt MD 20771, United States, kyle.m.hughes@nasa.gov
Dr. Noble Hatten
National Aeronautics and Space Administration (NASA), Goddard Space Flight Center, United States, noble.hatten@nasa.gov
Dr. Alonso Vera
NASA Ames Research Center, United States, alonso.vera@nasa.gov
Ms. Megan Parisi
NASA Ames Research Center, United States, megan.e.parisi@nasa.gov
Ms. Kaitlin McTigue
NASA Ames Research Center, United States, kaitlin.r.mctigue@nasa.gov
Ms. Tina Panontin
San Jose State University at NASA Ames Research Center, United States, tina.l.panontin@nasa.gov

ARCHITECTURE REQUIREMENTS FOR SAFE HUMAN EXPEDITIONS TO MARS

Abstract

We performed an integrated health risk assessment to crews on long-duration missions to Mars. By using a systems approach rather than individual countermeasures, we examined the trade space of a subset of human health risks to identify potential engineering solutions to mitigate the risks to crew health. As such, our assessment informed characteristics of those Mars mission architectures that render the lowest integrated human health risks. The key findings of our assessment is that fast Mars round-trip mission duration of approximately 1 year brings many benefits: 1) it reduces cumulative radiation exposure and associated shielding requirements; 2) it reduces microgravity exposure and is within bounds of 12 months of microgravity experience on the International Space Station (ISS); 3) it reduces the possible number of time-driven vehicle failures; and 4) it enables sustainable deployment of humans and infrastructure to Mars on a regular cadence, allowing steady exploration and colonization of Mars. The study performed used an innovative flight dynamics approach to quantify the minimum total mission energy required for a fast Mars transit with total mission duration less than 400 days. The results of this feasibility study show promise for sending humans to Mars and returning them safely with acceptable exposure to microgravity and minimal exposure to radiation using current or near-term technology. Furthermore, we found that a new paradigm for designing Human-Systems Integration Architecture (HSIA) on long-duration missions beyond Low Earth Orbit (LEO) is needed. The LEO mission operations paradigm has been one of near-complete real-time dependence on experts at Mission Control to manage the combined state of the mission, vehicle, and crew. Based on historical trends, we found that the likelihood of high-consequence problems of uncertain origin occurring during long-duration spaceflight is high (conservatively, exceeding 50 percent during Mars transit) and that attempting to use the LEO operational paradigm with communication and

resupply delays is high risk. It is possible to reduce anomaly rates through improved reliability analysis and testing and anomaly impacts through added robustness,but such mitigations addressonly known failure modes and known uncertainties. Therefore, a radical shift in operational paradigm, systems design, and human/system integration approaches is the only viable approach to improve the risk posture.