Kennedy Space Center's

2016 ANNUAL Report

Success and Infusion Stories

Advanced Cryogenic Breathing Apparatus

Description

The Advanced Cryogenic Breathing Apparatus project is a joint project between NASA and the National Institute of Occupational Safety and Health, Office of Mine Safety and Health Research to develop a two hour liquid air based self-contained breathing apparatus that can be quickly refilled and used by miners exiting a mine with an immediately dangerous to life and health atmosphere. In the event of a mine emergency, miners would be able to self-evacuate using the advanced cryogenic breathing apparatus, stopping briefly to refill their pack at pre-staged filling stations every 1.5 hours along the egress path. Current compressed gas self-contained breathing apparatuses are limited to about one hour, requiring refill stations to be staged approximately every half hour along the egress path and extra refill stops means more time spent in a dangerous environment.

Comparing the advanced cryogenic breathing apparatus to traditional self-contained breathing apparatus in firefighting applications

Success Story

The KSC Biomedical Engineering and Research Laboratory partnered with a small local business, BCS Life Support, LLC, to develop and test two prototype self-contained breathing apparatuses and two filling stations. The filling stations use “zero loss” storage technology to store liquid air for an indefinite period of time. The advanced cryogenic breathing apparatuses are filled quickly by simply activating the filling station and connecting a quick disconnect. The mask does not have to be removed during filling operations, preventing dangerous mask switching operations. In addition, the advanced cryogenic breathing apparatuses have an attitude independent pickup which allows them to continue to operate when the user is within 90 degrees of vertical (i.e. laying on face or side). As of FY16 the advanced cryogenic breathing apparatus has completed both the machine testing phase and the manned testing phase demonstrating that it is capable of commercial certification. Follow-on projects will add a quantity sensor, and take advantage of the thermal properties of liquid air to provide cooling to the user via a liquid cooling garment.

Benefit

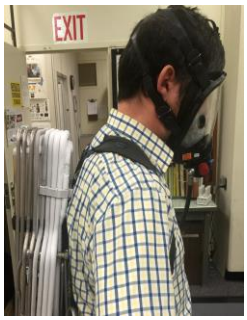
The new technology developed under this project will allow liquid-air-based systems to be commercialized, opening up a completely new sector in the life-support industry. The new designs are safer than their predecessors, provide longer duration, and they are capable of providing an array of cooling solutions to the user. This technology has many applications from crew rescue for space operations, to hazmat cleanup, Fire/Rescue, and Department of Defense.

Lead NASA Center: Kennedy Space Center
Funding Organization: National Institute of Occupational Safety and Health, National Personal Protective Technology Laboratory
For more information: techport.nasa.gov/10511

Development and Testing of an Advanced Cryogenic Breathing Apparatus for Mine Escape

Infusion

The John F. Kennedy Space Center's biomedical research team goal was to design and build a liquid air-based self-contained, refillable breathing apparatus (SCBA) that lasted 2 hours and would be used for the egress of miners during an accident. In 2016, the project was infused into the National Institute for Occupational Safety and Health (NIOSH) mine safety program and managed through a Space Act Agreement with the National Aeronautics and Space Administration (NASA) at the Kennedy Space Center (KSC).
Using KSC's long history of liquid air-based life support devices as a baseline, an improved Advanced Cryogenic Breathing Apparatus (termed the ACryoBA) was developed. A series of tests on the ACryoBA proved the concept of a backpack worn unit utilizing low pressure cryogenic liquid air instead of high pressure compressed air commonly used in most commercially available SCBA. The ACryoBA can be quickly and easily self-filled from strategically placed Cryogenic Air Storage and Fill Stations (CryoASFS). The fill stations would be placed at the initial pickup point, and strategically located along the escape route to allow for top offs every one and a half hours. Fills and top offs are a simple matter of connecting a quick disconnect and allow the user to continue breathing from the mask while filling.



NASA Team Lead David Bush Testing the ACyroBA

Benefit

The ACryoBA is proving to be safe and reliable while providing significant benefits, such as extended duration and passive cooling, not currently available in any other emergency escape ensemble. With the addition of a level indicator and proper finishing design work, there are no apparent technological hurdles remaining to commercialization. This technology provides a round the clock standby escape methodology. Cryogenic life support has many benefits to specific missions including but not limited to mining. It is hoped that this work will help bring those benefits to the broader life support industry as a whole, including Hazardous Material, Defense, Fire/Rescue, and of course flight crew rescue operations right here at KSC.

Development Team Leads

David Bush, NASA, KSC, Biomedical Engineering and Research Laboratory Rohan Fernando, National Institute of Occupational Safety and Health, National Personal Protective Technology Laboratory

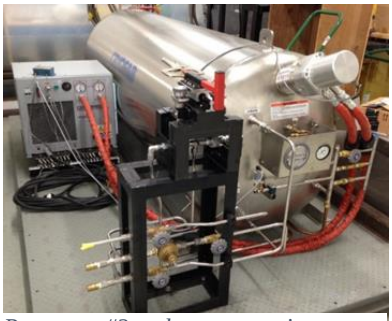
Lead NASA Center: Kennedy Space Center
Funding Organization: National Institute of Occupational Safety and Health, National Personal Protective Technology Laboratory
For more information: techport.nasa.gov/10511

Cryogenic Refuge Alternative Supply System

Description

Prototype #1 undergoing in-mine testing

The Cryogenic Refuge Alternative Supply System project is a joint project between NASA and the National Institute of Occupational Safety and Health, Office of Mine Safety and Health Research to develop an air revitalization system for emergency mine safe rooms, called “refuge alternatives”. In the event of a mine emergency, miners would shelter in these refuge alternatives for up to 96 hours while waiting for rescue. Current refuge alternative designs have problems with a build-up of metabolically generated heat and humidity, and possible safety hazards with high-pressure oxygen storage. Due to KSC’s long history with cryogenic liquid air based life support, Office of Mine Safety and Health Research requested the development of an alternative technology for these chambers.



Prototype #2 under construction

Success Story

The KSC Biomedical Engineering and Research Laboratory partnered with a small local business, BCS Life Support, LLC to develop and test two prototypes in FY16. Both prototypes use “zero loss” storage technology to store liquid air for an indefinite time. This liquid air is stored at much lower pressures (40 pounds per square inch) than current oxygen based systems reducing potential energy and flammability hazards. In addition, due to the high density of liquid air, much greater quantities of air can be stored in a similar space. In the event of a mine emergency, the cryogenic refuge alternative supply system would be activated and liquid air would begin to flow and absorb heat from the environment while being vaporized to a breathable gas. Due to the heat absorption requirements and expansion properties of liquid air, it simultaneously provides passive cooling, dehumidification, and air circulation thus reducing environmental temperature, carbon dioxide and humidity levels.

Benefit

Although initial development is targeting mine refuge chambers, this technology could be used where ever large quantities of air need to be stored indefinitely for use in an emergency. This has potential applications in emergency shelters (collective protection), military chemical, biological, radiological, and nuclear vehicles, or civilian hazmat vehicles. When compared with conventional air revitalization systems, the key advantage of this system is that it provides a variety of different systems into one (air, cooling, circulation, dehumidification, and carbon dioxide reduction) thereby reducing space and cost.

Lead NASA Center: Kennedy Space Center
Funding Organization: National Institute of Occupational Safety and Health, Office of Mine Safety and Health Research
For more information: techport.nasa.gov/10511

SEE 2016: Cooperative Collegiate Space Simulation

Description

SEE (Simulation Exploration Experience, www.exploresim.com) is a multi-university, multi-national complex space system simulation exercise. Teams from 3 continents simulated life on, under, and above a lunar base using NASA software, NASA and international standards, and commercial tools. Teams were mentored by local faculty, industry experts, and NASA simulation leaders to conceptualize, build, and simulate the operations of a future lunar base.

Success Story

DON View of SEE 2016 Simulation

The University of Liverpool Virtual Engineering Centre played host to the 2016 event. Teams from the United States, Canada, Brazil, and Europe used the JSC (Johnson Space Center) provided secure virtual network, servers, and "Environment" (Sun, Earth, Moon, Lagrange Points and associated dynamics) to build the base. Kennedy added Visualization, 3-D Model Integration, Executive Leadership, and Technical Chair. The teams developed simulations within the provided framework to share data, interact, and represent a day in the life of the lunar base. Data elements were published in NASA MPC (Model Process Control) format and displayed with DON (Distributed Observer Network), which allows participants to replay the event simulation at any time without requiring the event infrastructure or other participants to be in place.

This year's event demonstrated a number of significant "firsts."

- The most distributed ever, with at most 3 teams at any one location.
- The largest event to date (50+ students, 13 Universities / Faculty, 3 Continents)
- The first SEE with the Connections Team (NASA Kennedy group mentoring students on visual environments and complex system integration).
- The first SEE with a faculty organized coordination working group (with the goal to incorporate SEE into the research curriculum at the participating universities)

Benefits

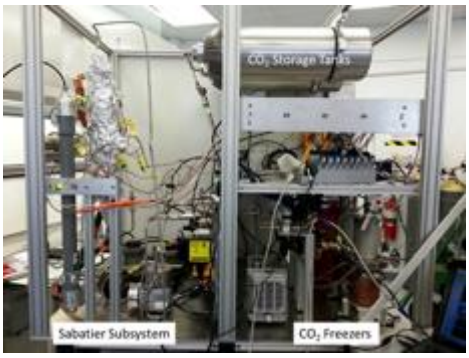
SEE 2016 Team Picture

SEE grew from standards work with Simulation Interoperability Standards Organization (SISO) and Society for Computer Simulation International (SCS) to address workforce needs for simulation professionals. SEE focuses on undergraduate and graduate education in simulation fields (STEAM – Science, Technology, Engineering, Arts and Math) within OMB (Office of Management and Budget) and NASA guidance on consensus standards (OMB A-119, NASA 7120.10). It is also an effective testbed for exploration tools, methods, and capabilities and has increased awareness of both the profession and applicability of specific degrees to the simulation profession.

Lead NASA Center: Kennedy Space Center
Funding Organization: HEOMD
For more information: techport.nasa.gov/10731

Mars Atmospheric Processing Module

Description



Mars Atmospheric Processing Module

The atmosphere of Mars, which is around 95% carbon dioxide, is a rich resource that can be used in the production of rocket propellants for Mars Ascent Vehicles, which is a critical capability for human exploration. The multi-NASA center Mars Atmosphere and Regolith COllector/PrOcessor for Lander Operations (MARCO POLO) project was initiated by NASA JSC to demonstrate a methane and oxygen propellant production system in a Mars analog environment. A NASA KSC team has focused on the Atmospheric Processing Module, which freezes carbon dioxide from a simulated Mars atmosphere by using two alternating cryocoolers. The resulting pressurized carbon dioxide is combined with hydrogen in a Sabatier reactor to make methane and water, which are purified and electrolyzed in other modules. The hydrogen is obtained via electrolysis of water acquired by heating regolith.

Success Story

The KSC Atmospheric Processing Module team has made excellent progress in developing the Atmospheric Processing Module by demonstrating that (1) the carbon dioxide freezers meet their design goal of providing 88 grams of pure carbon dioxide/hour at 50 pounds per square inch-absolute, (2) the improved Sabatier reactor produces the design goal of 32 grams methane/hour and approaches the design goal of 72 grams water/hour, (3) the two subsystems have acceptable operating ranges, and (4) integrated operations of the carbon dioxide freezers and the Sabatier subsystem are successful during four 7-hour tests that met design requirements, which is a major milestone in the FY15-16 project.

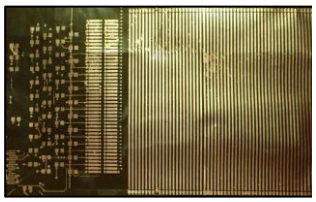
Benefit

Production of propellant on Mars is an enabling technology for human exploration missions, reducing the landed mass on Mars by greater than 30 tons. This In Situ Resource Utilization technology is greater than one-tenth scale of that needed for human missions and is a desirable option. Successful demonstration of Atmospheric Processing Module operations helps to build confidence in this approach while providing much better estimates of the mass, power, and volume of full scale systems. Measurements of the power required to freeze the carbon dioxide at Mars pressures show it is only slightly higher than theoretical calculations, allowing the specification of needed cryocooler capabilities.

Lead NASA Center: Kennedy Space Center
Funding Organization: Space Technology Mission Directorate and Kennedy Space Center
For more information: techport.nasa.gov/16846

Flexible Damage Detection and Verification System

Description



Damage detection pattern trials for in-house evaluation capability for printing flexible circuitry.

The Flexible Damage Detection and Verification System project expanded on the previously demonstrated and NASA patented Flat Surface Damage Detection System capabilities. In FY16, technology development has continued in enabling designs for damage detection software and hardware development. Development has also continued by working to decrease the number of rigid components necessary by performing a preliminary evaluation of the interfacing of flexible printed circuitry components for embedded damage detection. These could eventually be incorporated as critical parts of future inflatable or deployable vehicles and habitation structures for space exploration. The use of Kennedy Space Center's (KSC) in-house capability for printing flexible circuitry (a new capability for KSC) and the use of industry's emerging technologies in flexible printed circuitry are critical components of opportunities for project success.

Success Story

The flexible damage detection and verification project's preliminary evaluation of KSC's in-house capability for fabricating flexible printed circuitry for damage detection was successfully completed in April 2016, meeting a project milestone. The fabrication equipment, never utilized before for the creation of flexible circuitry, demonstrated that although some parts of the process are still being optimized, the current in-house capability can fabricate 2-layer flexible circuitry. Significant lessons learned, certain materials selections, and challenges in refining hardware tooling parameters to create a sufficiently complex flexible circuit board have been documented and will be provided as part of the project's final report.

Benefit

This damage detection system and flexible printed circuitry design concepts are enabling technologies and could be a game changer for NASA and the DoD for in-situ vehicle health monitoring (including detection of micrometeoroid and space debris damage effects), embedded damage technologies, and flexible printed electronics for inflatable and deployable structures, extravehicular activities, and smart wearables. There are expected new intellectual property and spin-off benefits to multiple other industries, including the energy and the shipping industries. The commercial airline industry could also benefit from in-situ damage detection monitoring for structures via technology transfer. The monitoring of impact or debris damage to critical systems such as habitation tents or aircraft, including in the military, could be a noted benefit.

Lead NASA Center: Kennedy Space Center
Funding Organization: Space Technology Mission Directorate
More information: https://techport.nasa.gov/view/16850

Integrated Display and Environmental Awareness System (IDEAS)

Description

IIntegrated Display and Environmental Awareness System Version 1 Prototype

The technology being developed for the Integrated Display and Environmental Awareness System project is a wearable computer system with an optical Heads-up Display providing various means of communication and data manipulation to the user. The wearable computer, in the form of smart glasses, allows personnel to view and modify critical information on a transparent, interactive display. The product is being designed in a modular manner so that the user can adjust the capabilities of the device depending on need. In addition, the camera and microphone allow a virtual presence by sending real-time audio and video to a third party. This technology will dramatically improve situational awareness, thus improving safety and efficiency.

Success Story

NASA Kennedy Space Center, in partnership with Abacus Technology, Florida Institute of Technology, and Purple Rock Scissors, developed the first prototype of the Integrated Display and Environmental Awareness System. In this past year, the team has integrated both hardware and software components and successfully demonstrated this technology's potential on a real operation at Kennedy's Vehicle Assembly Building. This technology takes different hardware components in the form of transparent optics, red-green-blue and infrared cameras, miniature gas sensors, and a powerful single board computer to create a practical wearable experience. At the core of this experience is custom-built software that allows the user to video conference with other users, view images in the infrared, receive live data from personal gas sensors, and a procedure viewer to walk them step by step through an operation.

Benefit

The Integrated Display and Environmental Awareness System technology has applications in a wide range of fields both at NASA and in outside industry. Initially the technology will be proven-out for launch site ground operations, but in the future it can be transitioned for use in many other areas ranging from an airplane cockpit to laboratory research on the International Space Station, to even an exploration mission on the Martian surface. Outside of the aerospace industry this type of technology can be used for work that involves equipment servicing, hardware assembly, and even medical applications.

Lead NASA Center: Kennedy Space Center
Funding Organization: Space Technology Mission Directorate
For more information: https://techport.nasa.gov/view/18917

Autonomous Flight Termination System Core Autonomous Safety Software

Description

The Autonomous Flight Termination System is a joint NASA, U. S. Air Force, and Defense Advanced Research Projects Agency project. This effort has developed an onboard autonomous flight termination system that replaces the functions of the traditional ground-based, human-in-the-loop, range safety system. The autonomous flight termination system evaluates data from onboard navigation sensors and then uses configurable rule-based algorithms to make flight termination decisions. The core autonomous safety software was originally written by NASA, then modified by the USAF 30th Space Wing to make it safety critical. It has gone through independent verification and validation, and is approved for use by the USAF space launch ranges. The core autonomous safety software is available from the USAF 30th Space Wing to any U.S. agency or international traffic in arms compliant companies.

SpaceX launch will use AFTS CASS on CRS-10 mission providing significant range cost savings

Success Story

Autonomous flight termination system core autonomous safety software has flown on several SpaceX launches in preparation for the certification flights leading to flying the autonomous flight termination system operationally. Core autonomous safety software certification flights began with the SpaceX Falcon 9 launch of the JCSAT 14 mission and continue through the CSR-9 launch, which will be the final qualification flight. Core autonomous safety software will be flown operationally on the SpaceX launch of the NASA mission, CRS-10, currently scheduled for November 10, 2016.

Benefit

Autonomous flight termination system core autonomous safety software results in reduced cost, global coverage, multiple vehicle support, and increased responsiveness. More specifically, the onboard system reduces the need for ground-based assets and eliminates the costly range safety command receivers onboard the launch vehicle; the vehicle does not have to be launched from a range; multiple vehicles (such as fly-back boosters) can be launched and tracked at the same time; and the need for the traditional ground-based range to reconfigure the Range Safety Systems for the next launch is eliminated.

Lead NASA Center: Kennedy Space Center
Funding Organization: Mission Support Directorate
For more information: techport.nasa.gov/TechPort ID

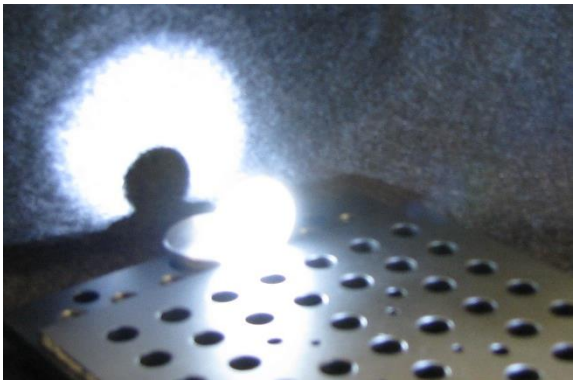
Achieving cryogenic temperatures in deep space using a novel coating

Description

We have modeled a novel coating that should be able to reflect more than 99.9% of the sun's irradiance when used in space. The current state of the art, white paints or second surface mirrors, achieves about 92% reflectance and thus prevents objects in deep space from being able to achieve cold temperatures. Our new proposed coating, if placed on a sphere at 1 Astronomical Unit from the sun should allow temperatures below 50 Kelvin to be reached. This breakthrough technology, if it can be implemented, should allow cryogenic storage in deep space and the operation of superconductors.

Success Story

We were awarded a NASA Innovative Advanced Concept (NIAC) Phase I award in June of 2015 to develop cryogenic selective surfaces, i.e. a surface that could allow a coated object to reach cryogenic temperatures in deep space. At the end of July 2015 (FY16) we had a conceptual breakthrough and realized that by placing a diffuse coating, composed of very small particles of highly transparent material, on a silver coated surface that the vast majority of the sun's energy could be scattered or reflected away. The image shows the scattering achieved by using a disk composed of pressed salt. During August and September of 2015 (FY16) we developed the theory behind this breakthrough concept, resulting in the filing of a provisional patent in early October 2015 and the presentation of the work at the Fall 2015 NIAC Symposium (Oct. 2015). We published this breakthrough in Optics Letters (March 2016) as a peer reviewed article. The Launch Service Provider Program at KSC and KSC's internal research and technology development program have both supplied follow on funding. In the spring of 2016 we were told that we had won a NIAC Phase II project to continue this development and that work began in July of 2016.



Light scatter by a disk made of pressed salt.

Benefit

Being able to achieve cryogenic temperatures in deep space will not only allow cryogenic commodities to be carried throughout the solar system and stored in deep space depots, it will also allow superconductors to operate without an active cooling system. This will open the door

for large scale magnetic operation in space, magnetic energy storage, and possibly even large scale, magnetic field based, galactic cosmic radiation shields.

Robert Youngquist and Mark Nurge are co-PIs on this work. It was funded from June 2015-March 2016 by a Phase I NIAC award. The Launch Service Program has provided funding (March 2016 to September 2016) and the KSC IR&TD program has funded this activity (April 2016-April 2017). A Phase II NIAC proposal was selected for award, which will fund this work from July 2016 to July 2018. Under that work KSC has partners at GRC and ARC.

https://www.nasa.gov/feature/cryogenic-selective-surfaces-0

Lead NASA Center: Kennedy Space Center
For more information: techport.nasa.gov/TechPort ID

A Wavefront Measurement System for Flight Window Assessment

Infusion

A new requirement, detailed in JSC 66320 Rev A, has been imposed on both flight window panes and flight window assemblies, namely that the wavefront, or optical path length, must be assessed. This measurement provides valuable information not only about possible distortions caused by the window, but also about image stress fields and manufacturing flaws. In the summer of 2013 Lockheed Martin realized that few facilities existed in the country where this assessment could be performed and these using these facilities would require shipping and handling of flight hardware. So Lockheed Martin requested that this measurement capability be established at the Kennedy Space Center both for convenience, minimization of handling, and to access KSC expertise. Unfortunately, it was not possible for Lockheed Martin to transfer Orion funds to NASA, so there was a one year delay while funding was sought.

In the summer of 2014, KSC/Orion and the NASA Engineering and Safety Center (NESC) provided funding to develop the requested capability. A phase-shifting interferometer was purchased in the fall of 2014, tested, algorithmically verified, and placed into an operational configuration by the summer of 2015. A large computer controlled X-Y scanner was constructed, along with custom window brackets to hold the Orion window panes in their proper orientation in the fall of 2015 (FY16). Software was written to automate the scanning process and customer interfaces for handling the windows and delivering the measurement data were established in FY16. The final system was brought on-line in FY16 and is shown in the figure.

Miles Skow standing in front of the wavefront measurement system.

Benefit

This system will allow wavefront measurements to be made on flight window panes and flight window assemblies at the Kennedy Space Center, near the vehicle assembly area, minimizing handling and movement of flight hardware. This assessment is required for spaceflight windows and panes and provides valuable information on window distortion, manufacturing flaws, high stress regions, and the wedge angle of the window/panes.

Development Team Leads

Robert Youngquist Optics, algorithms, documentation. Miles Skow system design and operation. Susan Danley customer interface and requirements generation. Mark Nurge software. Adam Dokos mechanical design.

Lead NASA Center: Kennedy Space Center
Funding Organization: Orion and NESC
For more information: techport.nasa.gov/TechPort ID Number