NASA-STD-3001 Technical Brief

Fire Protection

OCHMO-TB-008
Rev A

Relevant Technical Requirements

NASA-STD-3001 Volume 1, Rev C
[V1 3004] In-Mission Medical Care
[V1 3009] Palliative Comfort Care

NASA-STD-3001 Volume 2, Rev D
[V2 6024] Combustion Monitoring and Alerting
[V2 6025] Contamination Monitoring and Alerting
[V2 6049] Chemical Decomposition
[V2 6050] Atmosphere Contamination Limit
[V2 6107] Nominal Vehicle/Habitat Atmospheric Ventilation
[V2 7083] Cleaning Materials
[V2 9028] Isolation of Crew from Spacecraft Equipment
[V2 9053] Protective Equipment
[V2 9055] Protective Equipment Automation
[V2 9059] Fire Detecting, Warning, and Extinguishing
[V2 9060] Fire Protection System Health and Status
[V2 9061] Fire Protection System Failure Alerting
[V2 9062] Fire Protection System Activation
[V2 9063] Portable Fire Extinguishers
[V2 9064] Emergency Equipment Accessibility
[V2 10114] Distinguishable and Consistent Alerts

Executive Summary

Throughout the history of spaceflight, there have been numerous combustion events that have ranged in severity. Besides injury due to fire itself, a secondary hazard of fires is the inhalation of toxic combustion products. During and after a fire event, combustion products can present an immediate threat to the life of the crew due to the limited escape options, the fragility of the atmosphere, and the crew's immediate need for safe air. The major approach to fire protection in current human-crew spacecraft is through prevention. Thus, fire safety relies strongly on the selection of materials proven to be fire-resistant through analysis and testing. During the design of new spacecrafts, trade studies for fire detection, fire suppression, crew response, crew protection, and post-fire clean-up and monitoring systems must be conducted. Improvements in the current fire-safety technology are necessary for future human-crew missions beyond low-Earth orbit. Deep Space exploration will challenge the existing tools and concepts of spacecraft fire safety.

Overview

Understanding how fire spreads in space is crucial for the safety of the crew. Changes in gravity and airflow can alter the way fire behaves in space, making it harder to extinguish.

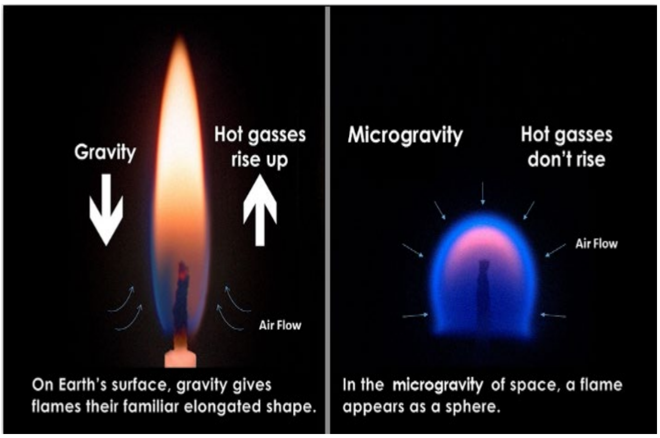
In gravity, fire is the result of the reaction between a fuel and oxygen in the air. As hot gasses from the flame rise, gravity pulls cooler, denser air to the bottom of the flame which regulates its speed and size. This also creates both the shape of the flame, as well as a flickering effect.

In microgravity, this flow doesn't occur. This reduces the variables in combustion events, making them simpler and creating spherical-shaped flames. In low gravity situations, there is no buoyancy from flames; the flame burns equally in all directions.

Ventilation fans on space vehicles replace natural convection and can supply the air a fire needs to burn. Under these circumstances, the fire can spread in any direction, rather than just upward. The flame's unusual shape creates different amounts of soot, smoke, or harmful gases.

Ventilation is not the only source of flame stimulating flow. Some burning plastic materials may induce flow to continue combustion through the action of boiling and vapor-jet ejection.

In systems or environments with higher oxygen content and/or pressure, materials that normally do not burn have a lower ignition temperature, are more vigorously combustible, and have a higher flame temperature if they do burn.



Flames in near quiescent or low-oxygen environments are often pale blue and almost invisible. *Photo Credit: NASA*

Detecting a fire in space is also different. On Earth, smoke detectors are installed on the ceiling or upper section of a wall because that's the direction in which smoke travels. In space, smoke doesn't rise, so detectors are placed within the ventilation system.

An additional source of early warning in the case of a fire event is the rate of buildup of atmospheric gasses. This particularly includes carbon monoxide concentrations. The ISS uses continuous atmospheric sampling of air-quality monitoring. This has the potential to detect the buildup of carbon monoxide as the confirmation of a fire event.

The basic approach to minimizing fire hazards in space is through prevention, which implies the elimination of one of the three fire-causing factors: fuel, oxygen, and ignition energy. Prevention is never absolute; thus, the overall strategy of fire safety must include fire detection, response, and suppression.

Background

ISS Fire Safety Strategy
For a fire on ISS, the following actions will be taken sequentially by the crew until the fire is extinguished:

1. Fire detection and warning ***[V2 6024] Combustion Monitoring and Alerting, [V2 9059] Detecting, Warning and Extinguishing***.

2. Terminate ventilation in the affected module to slow the spread of fire. For fires detected by smoke detectors, software response automatically terminates intra-module ventilation within the affected module, terminates inter-module ventilation between that module and the rest of ISS, and closes powered inter-module ventilation valves in the affected and adjacent modules ***[V2 9062] Protective System Activation***.

3. Don protective masks ***[V2 9053] Protective Equipment, [V2 9054] Protective Equipment Use, [V2 9055] Protective Equipment Automation, [V2 9064] Emergency Equipment Accessibility***.

4. Manually remove electrical power: Removing electrical power from hardware within the affected module should cease any continuous ignition sources ***[V2 9062] Protective System Activation***.

5. Use fire extinguishers to put out the flames: The ISS has a portable CO_2 extinguisher for use in the U.S. modules, and two types of water-based extinguishers for the Russian modules ***[V2 9063] Portable Fire Extinguishers***.

6. If obvious signs of fire continue, the crew will power down the module ***[V2 9062] Protective System Activation***.

U.S. Portable Fire Extinguisher on ISS

Russian water-based foam fire extinguisher

7. After the fire has been extinguished, if breathing protection is required due to atmospheric contaminants from the fire or if a CO_2 portable fire extinguisher was discharged, the crew will egress and isolate the affected module by closing the hatches. This action is performed to prevent the migration of atmospheric contaminants into the other modules of the ISS.

8. If atmospheric contaminants are present and require breathing protection, the affected module will remain isolated until atmospheric scrubbing has reduced monitored contaminants in the atmosphere (CO, HCN, HCL) to admissible concentrations. The crew may use flexible vapor barriers instead of hatches to isolate the affected modules, especially for hatchways that are between a U.S. vehicle and its crew ***[V2 6024] Combustion monitoring and Alerting, [V2 6050] Atmosphere Contamination Limit***.

Background

Health and Medical Management of an ISS Fire

- During a fire event, contaminant readings are taken frequently (several per hour) per Emer-1 SODF procedures. This frequent sampling allows the crew and ground to have insight into whether contaminant levels are quickly rising and approaching (or at) levels requiring masks to be donned. These measurements are necessary to ensure that the crew does not experience acute exposure to contaminants that may pose a risk to crew health.

- A crewmember in smoke, near the flame, or experiencing symptoms of exposure to combustion products are considered adequate criteria for mask donning. Contaminant Level readings are not required prior to mask donning because taking readings from different devices or modalities would delay the crew from getting to the important steps of donning a mask (if necessary) and addressing the fire.

- To protect crewmembers from toxicological injury, Personal Protective Equipment (PPE) must be donned when in smoke/near fire or when preparing to enter that environment. If a crewmember is experiencing symptom(s), the affected crewmember should be treated using a supplemental breathing source with eye protection (i.e., portable breathing apparatus (PBA) or ИПК-1М) and consultation with a Flight Surgeon should occur.

- Protection of the eyes and respiratory tract is achieved by donning the PBA, ИПК-1М or the Emergency Mask with fire cartridge.

- Goggles are required when using the Russian Half Mask to ensure the crew is not unnecessarily exposed while preserving full gas masks.

- If the crew experiences symptoms while on the Russian Half Mask and goggles, the crew can don a new PBA or ИПК-1М.

PBA

ИПК (IPK)

First Response Masks located throughout station

- Protection of the skin is also recommended since it is unknown what other products have escaped into the environment that may cause irritation.

Relevant NASA-STD-3001 Volume 2 Technical Requirements

[V2 6024] Combustion Monitoring and Alerting, [V2 9059] Detecting, Warning and Extinguishing, [V2 9062] Protective System Activation, [V2 9053] Protective Equipment, [V2 9054] Protective Equipment Use, [V2 9055] Protective Equipment Automation, [V2 9064] Emergency Equipment Accessibility, [V2 9063] Portable Fire Extinguishers, [V2 9062] Protective System Activation, [V2 6050] Atmosphere Contamination Limit

Background

Challenges of Deep Space Exploration

Venturing past low-earth orbit brings a host of additional risks with the specific fire safety procedures and equipment depending greatly on the mission details:

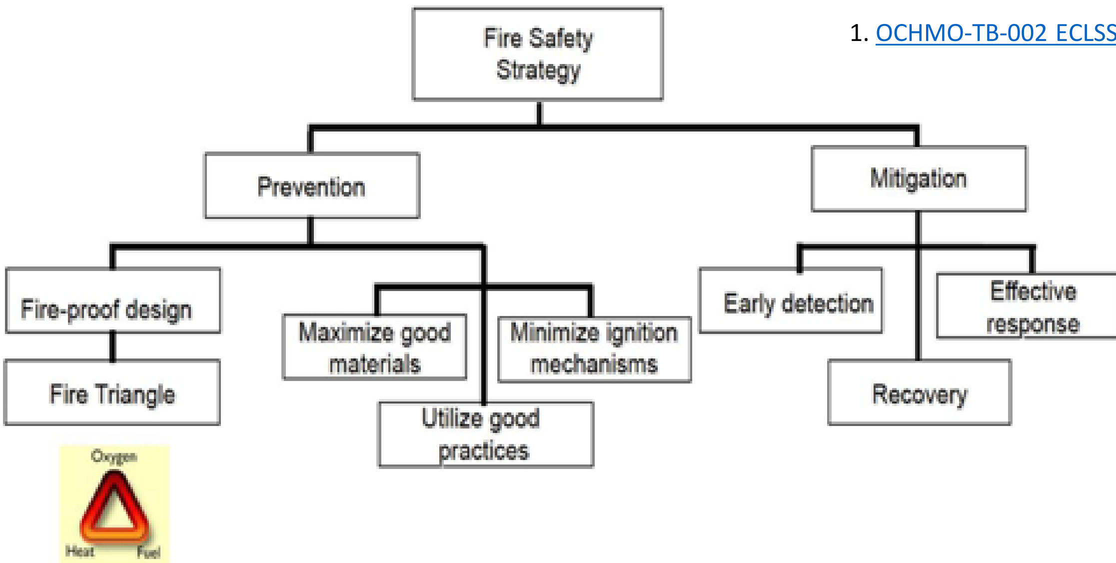
- Partial gravity levels affect the whole chain of the fire safety strategy, with expected consequences on flammability, flame spread rate, smoke production, detection, mitigation, and clean-up.
- Surface operations on the Moon or on Mars will introduce intermediate buoyancy conditions which haven't been investigated.
- Long-term exposure to radiation will also generate indirect fire safety issues. There is a lack of knowledge regarding the impact of long-duration radiation exposure on material flammability and coating efficiency.
- Material flammability in partial gravity remains a major gap for exploration missions. Ground-based flammability tests have proven relatively effective for low-gravity screening of material flammability based on decades of practice. There is no terrestrial facility that can confirm these results are relevant for partial gravity.
- In the habitat phase, the influences of celestial dust on surfaces or entering the atmosphere on flammability and smoke detection are presently unknown.
- Handheld fire suppression devices will be expected to meet requirements for operation in microgravity.
- Suppression devices need to operate in both microgravity and partial gravity.
- Stowage of suppressant and atmospheric diluents is more limited.
- Consultation and emergency communications with the ground may be of poor quality and delayed.
- The technical solutions presently implemented on the ISS are not designed for long-duration missions.

Deep Space expeditions featuring no emergency resupply, increased oxygen content in a low-pressure atmosphere, intermediate gravity levels, radiation exposure, and changes in the nature of the missions call for a cautious upgrade of present protocols to ensure the safe development of space exploration.

Application

Fire safety is divided into capability areas that include: (1) fire prevention and material flammability, (2) fire detection, (3) fire suppression, and (4) post-fire clean-up. It is key that these areas work together, not only with each other but with the Environmental Control and Life Support System (ECLSS)[1] and other systems on the spacecraft. The connectivity between these procedures and systems requires an integrated approach that includes crew response to the fire alarm, fire suppression, clean-up, and monitoring of the event.

NASA-STD-3001 Volume 2 includes many requirements dedicated to the appropriate design and implementation of an integrated fire protection system. The system is comprised of detecting, warning, and extinguishing devices that shall be provided to all spacecraft volumes during all mission phases without creating a hazardous environment ***[V2 9059] Fire Detecting, Warning, and Extinguishing***.



1. OCHMO-TB-002 ECLSS Technical Brief

Fire Prevention and Material Flammability

- Design requirements are to ensure that the crew has the capability of determining the health and status of the fire protection system ***[V2 9060] Fire Protection System Health and Status***. The crew is to be aware as soon as possible when the fire protection system has failed or is unreliable ***[V2 9061] Fire Protection System Failure Alerting***.

- The system design must provide the crew with a fire protection system that allows for manual activation and deactivation ***[V2 9062] Fire Protection System Activation***.

- Design requirements need to specify pressure and % O_2 combinations permitted in the habitable volume: The potential for fire in a spacecraft can be reduced by maintaining the oxygen level below hazardous levels and by carefully selecting materials for compatibility with the O_2 atmosphere.

Application

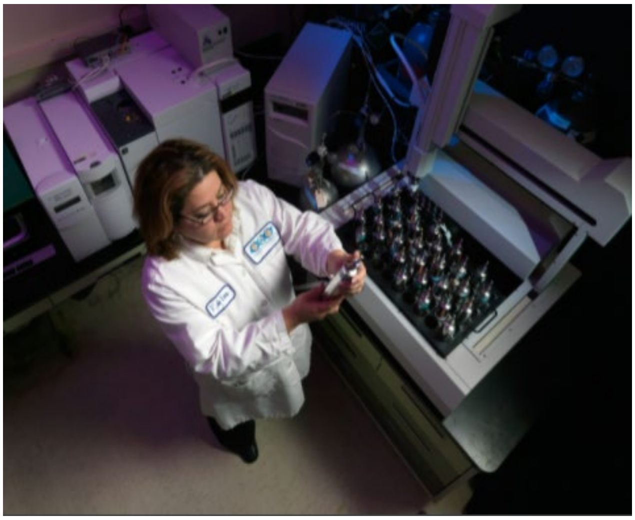
- Monitoring systems must provide real-time capability for the measurement and display of atmospheric concentrations of toxic combustion products. The gaseous combustion products that are to be monitored must be identified.

- Fire response scenarios must be defined and evaluated for the exploration of spacecraft and habitats.

- Gravity material flammability tests must be defined and verified to evaluate reduced gravity flammability. Material flammability must be assessed in relevant cabin atmospheres and gravity levels for exploration transit vehicles and habitats.

- Hazardous Materials Summary Tables (HMSTs) are required by Safety for all Programs (Reference Document JSC 26895 – Guidelines for Assessing the Toxic Hazard of Spacecraft Chemicals and Test Materials for additional information).

- Materials used in pressurized cabins of spacecrafts must have high ignition temperatures, slow combustion rates, and low potential for explosion. Some materials that have been approved as having a low risk of flammability for spaceflight are Nomex and GORE-TEX®.



Hazardous Materials Summary Tables (HMSTs) are a compilation of the chemical, biological, and flammability hazards of materials on a given flight or mission. Johnson Space Center (JSC) toxicologists evaluate the toxic hazard level of all liquids, gases, particles, or gels flown on or to any manned U.S. spacecraft.

Relevant NASA-STD-3001 Volume 2 Technical Requirements
[V2 9059] Fire Detecting, Warning, and Extinguishing, [V2 9060] Fire Protection System Health and Status, [V2 9061] Fire Protection System Failure Alerting, [V2 9062] Fire Protection System Activation
Relevant Technical Brief: OCHMO-TB-015 Spaceflight Toxicology Technical Brief

Application

Fire Detection

- Human-crew spacecraft require automated detectors that respond to fire "signatures“. Typical signatures are temperature rise, combustion gases, light and other radiation, particulates (smoke), pressure rise, and acoustic waves.
- The conditions on a spacecraft require rapid detection of fires with limited false alarms.
- Detection also depends on knowledge of where a fire detector should be located and the associated time to detection.

U.S. Smoke Detector (optical sensing)

- When designing fire-detection systems, consider the following features:
  - ✓ Smoke detectors should be located in equipment bays, the cabin, and nearby ventilation return ducts.
  - ✓ Airflow must be provided in occupied areas to make smoke visible and/or cause its odor to be detected.
  - ✓ The fire detection system must be capable of operating independently of other components of a caution and warning system in the event of a triggered power failure or failure of an associated system.
  - ✓ Failures of the fire warning system must be annunciated to the crew; due to the extreme danger a fire presents.
  - ✓ Since the first detection of the fire may be a visual or olfactory indication to a nearby crewmember, the fire-detection system must be capable of being manually activated in the event a fire is detected by a crewmember.

Relevant NASA-STD-3001 Volume 2 Technical Requirements
[V2 10114] Visual and Audio Annunciations, [V2 10055] Distinguishable and Consistent Alarms

Application

Fire Suppression

- Once a fire is detected, crewmembers need to act quickly to extinguish it. In microgravity, the extinguishing system must be usable without assistance from gravity conditions. Per NASA-STD-3001 Volume 2, the design of the spacecraft and its components must provide for rapid access to fire-extinguishing equipment. The fire suppression equipment must be clearly identified, accessible, and useable to extinguish the fire in the time required during all mission phases. All extinguishing systems are not to create any additional hazardous conditions for the crew per **[V2 9053] Protective Equipment** and **[V2 9063] Portable Fire Extinguishers** .
- PPE must be donned when in smoke/near fire or when preparing to enter that environment since even small concentrations of some combustion products can be immediately harmful.
- Portable fire extinguishers must be provided for extinguishing fires in open areas, as well as areas behind panels per **[V2 9063] Portable Fire Extinguishers** and **[V2 9064] Emergency Equipment Accessibility.**

- Portable breathing apparatuses are needed to protect the crew from smoke and combustion products and must allow communication between crewmembers and ground personnel per **[V2 9053] Protective Equipment**.
- The selected extinguishing agent must not:
  - ✓ Support combustion in an O_2 enriched environment
  - ✓ Contain toxic agents
  - ✓ Emit toxic products when applied to a fire
  - ✓ Interfere with visual observation
  - ✓ Be difficult or time-consuming to initiate
- Design rules for the suppressant system must be able to stop the flow of O_2 into the cabin. If loss of O_2 in an unoccupied area or isolated compartment can be tolerated, then the use of depressurization for fire control or clean-up should be considered.

Astronaut Marsha Ivins performing a Zero-G evaluation of orbiter fire extinguishers while onboard the KC-135

Relevant NASA-STD-3001 Volume 1 Technical Requirements

[V1 3004] In-Mission Medical Care, [V1 3009] Palliative Comfort Care

Relevant NASA-STD-3001 Volume 2 Technical Requirements

[V2 9028] Isolation of Crew from Spacecraft Equipment, [V2 9053] Protective Equipment, [V2 9055] Protective Equipment Automation, [V2 9063] Portable Fire Extinguishers, [V2 9064] Emergency Equipment Accessibility

Application

- The characteristics of the fire and the burning agent determine how to handle the fire in terms of airflow distribution and pressurization. Cabin depressurization may be useful in addressing a fire but may initially accelerate flame propagation depending on the location of depressurization valves (i.e., they may increase airflow to the fire).
- Automated systems are to be used where crews are not capable of extinguishing fires (large fires or fires where the crew could be absent, or fires in volumes inaccessible to the crew). Other systems may be effectively protected with portable extinguishers per ***[V2 9059] Fire Detecting, Warning, and Extinguishing.***
- Hand-operated extinguishers are to be clearly labeled and easily accessed by the crew. All extinguishing systems are not to create any additional hazardous conditions for the crew per ***[V2 9059] Fire Detecting, Warning, and Extinguishing.***
- Fire suppression is intimately linked to the post-fire response. The crew must clean up the cabin atmosphere from any smoke or gaseous combustion products as well as clean up any fire suppression agent that was discharged.

Post-Fire Monitoring and Response

- Considerable clean-up will be required after all fire events, minor or major. The most important requirement in developing a post-fire clean-up process is to specify the state of the environment to be scrubbed: pressure, temperature, and composition.
- Resources for recovering from the fire must include proper procedures for removal of contaminants from the atmosphere, and the ability of the crew to determine if the atmosphere is safe enough for them to remove their breathing apparatuses.
- The ventilation system may need to be shut down to protect the safety of the crew.
- Atmospheric revitalization to remove even trace quantities of fire and extinguishment contamination may tax the environmental controls and require the use of portable air-breathing equipment for lengthy periods of time. The crew must be wearing a breathing apparatus or filtering respirators to provide protection for the duration of the clean-up process.
- After nominal conditions are restored, the subtle toxic and corrosive aftereffects of the fire on equipment, systems, and payloads must be recognized and appropriately mitigated.

Relevant NASA-STD-3001 Volume 2 Technical Requirements

[V2 7083] Cleaning Materials, [V2 6024] Combustion Monitoring and Alerting, [V2 6025] Contamination Monitoring and Alerting, [V2 6050] Atmosphere Contamination Limit, [V2 6049] Chemical Decomposition, [V2 6050] Atmosphere Contamination Limit, [V2 6107] Nominal Vehicle/Habitat Atmospheric Ventilation

Relevant Technical Brief: OCHMO-TB-002 ECLSS Technical Brief

Lessons Learned

Apollo 1 (1967)

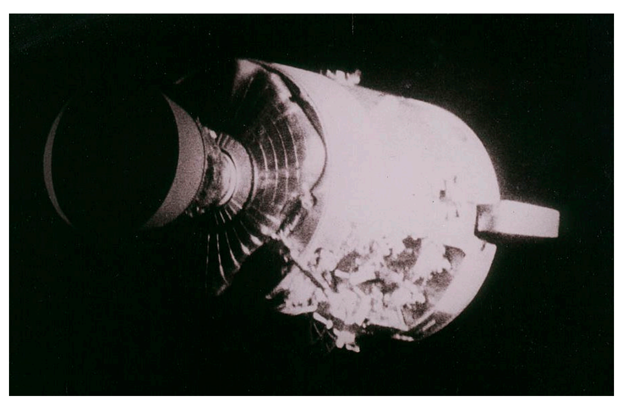
- On January 27th, a fire killed three astronauts aboard Apollo 1 during a launch rehearsal test.
- An unidentified ignition event led to the rapid spread of fire in the closed cabin, and astronauts trapped inside could not escape in time. The electric wiring and plumbing carrying a combustible and corrosive coolant were considered the most probable ignition sources.
- Material and atmospheric choices in the module were revised after the accident to reduce the magnitude of any accidental fire.
- Flammability tests were conducted to limit fire hazards associated with individual components in an oxygen-enriched atmosphere, and more than 100 full-scale mock-up fire growth tests were carried out on the ground to investigate under which atmospheric conditions a fire may propagate beyond its incipient region of ignition in the redesigned spacecraft interior.

Apollo 13 (1970)

- A malfunction was caused by an explosion and rupture of oxygen tank no. 2 in the service module. It was the first recorded fire-related accident in the absence of buoyant flow. The shock of the explosion put two extra oxygen tanks out of commission, crippling the Command and Service Module.
- All oxygen stores were lost within about 3 hours, along with loss of water, electrical power, and use of the propulsion system. The mission was consequently aborted, and the crew retreated into the Lunar Module for the trip back to Earth.
- Numerous design changes were made to the Apollo service module and command module on subsequent missions in the Apollo program following the incident.

Damage after the Apollo 1 fire

Wreckage of the Apollo 1 command module



The damaged Apollo 13 service module after separation

Lessons Learned

Mir (1997)

- A fire erupted on the Russian Space Station Mir after an astronaut routinely ignited a perchlorate canister that produced oxygen to supplement the space station's air supply. The fire came from an oxygen generator, where the oxygen supplied a ready source of fuel. Tests showed that the generator had to run out of oxygen for the fire to burn out. The fire caused little damage and no injuries, but it was difficult to control.

- The trace contaminant control fire on Mir showed that carbon monoxide, which can be generated in large quantities from a small fire, can cause serious effects on crew health. Lesser fires have shown that the crew needs immediate assurance of the limited threat to their health when they smell combustion products. This requires a carefully planned monitoring strategy, which includes volatile gases as well as smoke.

- Fire detection was based on optical smoke detectors and mitigation relied first on portable extinguishers, releasing a water-based foamy solution expanded by Halon 1301.

- Based on lessons learned during the incident, Russian space officials instituted changes in how crewmembers trained for similar emergencies, and how ground controllers responded to aid the onboard crew. Eventual knowledge of the cause of the fire enabled them to implement changes in the ground preparation of the solid-fuel oxygen generator canisters.

- Ground investigations of ignited generators, induced by cassette contamination or steel-shell failure, showed that water-based foam, the agent used in the Mir incident, is the most effective extinguishing agent, somewhat superior to water alone. The foam must be applied directly to the surface of the generating cassette.

NASA Astronaut Jerry Linenger wearing a respirator following the fire aboard the Mir space station

Charred remains of the solid fuel oxygen generator returned from space station Mir

Back-Up

Referenced Technical Requirements

View the current versions of NASA-STD-3001 Volume 1 & Volume 2 on the [OCHMO Standards website]

NASA-STD-3001 Volume 1 Revision C
[V1 3004] In-Mission Medical Care All programs shall provide training, in-mission medical capabilities, and resources to diagnose and treat potential medical conditions based on epidemiological evidence-based PRA, individual crewmember needs, clinical practice guidelines, flight surgeon expertise, historical review, mission parameters, and vehicle-derived limitations. These analyses consider the needs and limitations of each specific vehicle and design reference mission (DRM) with particular attention to parameters such as mission duration, expected return time to Earth, mission route and destination, expected radiation profile, concept of operations, and more. In-mission capabilities (including hardware and software), resources (including consumables), and training to enable in-mission medical care, and behavioral care, are to include, but are not limited to: (see NASA-STD-3001, Volume 1 Rev C for full requirement).

[V1 3009] Palliative Comfort Care The program shall provide in-mission palliative comfort care capabilities for medical scenarios where onboard medical resources have been exhausted, or a timely return to Earth (or another location of higher medical capability) is not feasible, and survival of the crewmember has been determined to be impossible.

NASA-STD-3001 Volume 2 Revision D
[V2 6024] Combustion Monitoring and Alerting The system shall monitor in real-time the toxic atmospheric components listed in Table 6.2-3—Recommended Combustion Product (CP) Monitoring Ranges, that would result from pre-combustion and combustion events in the ranges and with the accuracy and resolution specified in the table, and alert the crew locally and remotely in sufficient time for them to take appropriate action.

[V2 6049] Chemical Decomposition The system shall use only chemicals that, if released into the habitable volume, do not decompose into hazardous compounds that would threaten health during any phase of operations.

[**V2 6050] Atmosphere Contamination Limit** The system shall limit gaseous pollutant accumulation in the habitable atmosphere below individual chemical concentration limits specified in JSC-20584, Spacecraft Maximum Allowable Concentrations for Airborne Contaminants (SMACs).

[V2 6107] Nominal Vehicle/Habitat Atmospheric Ventilation The system shall maintain a ventilation rate within the internal atmosphere that is sufficient to provide circulation that prevents CO2 and thermal pockets from forming, except during suited operations, toxic cabin events, or when the crew is not inhabiting the vehicle.

[V2 7083] Cleaning Materials The system shall provide cleaning materials that are effective, safe for human use, and compatible with system water reclamation, air revitalization, waste management systems, spacesuits and other spacecraft materials.

[V2 9028] Isolation of Crew from Spacecraft Equipment Protective provisions, e.g., close-out panels, shall be provided to isolate and separate equipment from the crew within the habitable volume.

Referenced Technical Requirements

View the current versions of NASA-STD-3001 Volume 1 & Volume 2 on the OCHMO Standards website

NASA-STD-3001 Volume 2 Revision D

[V2 9053] Protective Equipment Protective equipment shall be provided to protect the crew from expected hazards.

[V2 9055] Equipment Automation of Rescue Aids Automation of protective equipment rescue aids shall be provided when the crew cannot perform assigned life-saving tasks.

[V2 9059] Fire Detecting, Warning, and Extinguishing The vehicle shall have a fire protection system composed of detecting, warning, and extinguishing devices that do not create a hazardous environment to all spacecraft volumes during all mission phases.

[V2 9060] Fire Protection System Health and Status The fire protection system health and status data shall be provided to the crew and other mission systems.

[V2 9061] Fire Protection System Failure Alerting The crew shall be alerted to failures of the fire protection system.

[V2 9062] Fire Protection System Activation The fire protection system shall be capable of being manually activated and deactivated.

[V2 9063] **Portable Fire Extinguishers** A fire protection system shall include manually operated portable fire extinguishers usable while wearing the most encumbering equipment and clothing anticipated.

[V2 9064] Emergency Equipment Accessibility Emergency equipment shall be clearly identified, accessible, and useable to complete emergency response in the time required during all mission phases where the corresponding emergency may occur while wearing the most encumbering equipment and clothing anticipated.

[V2 10114] Distinguishable and Consistent Alerts The system shall provide distinct visual and audio annunciations to the human operators for emergency, warning, and caution events which require human operator action, and advisory alerts that are necessary for human operator situation awareness as specified in Table 10.3-1—Table Alert Type and Annunciation Table.

All referenced tables and figures are available in NASA-STD-3001 Volume 2 Revision D.

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