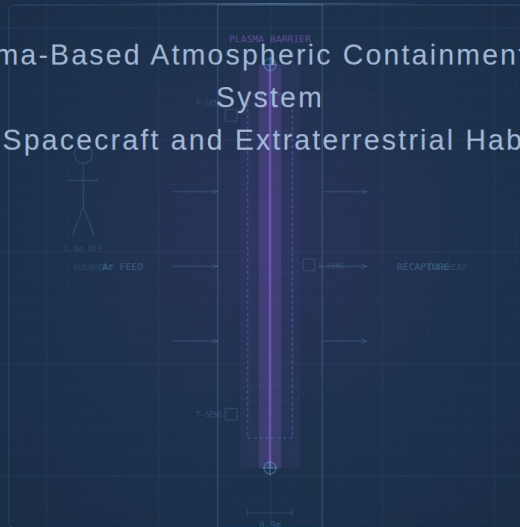


THE NOLAN SAFETY CURTAIN

A Plasma-Based Atmospheric Containment Barrier
System
for Spacecraft and Extraterrestrial Habitats



PLASMA-BASED ATMOSPHERIC CONTAINMENT // PUBLIC DOMAIN DISCLOSURE

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A Public Technical Disclosure

Patrick Nolan

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*The space safety application described in this work is dedicated
to the public domain. This publication constitutes a deliberate
public disclosure intended to establish prior art and ensure
that life-safety technology for space exploration remains
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“If it keeps people alive, it should be free.”

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1. Introduction and Purpose

This paper describes a plasma-based atmospheric containment barrier system designed for emergency decompression compartmentalization in crewed spacecraft, space stations, and extraterrestrial surface habitats including lunar and Martian bases. The system uses magnetically confined cold atmospheric plasma to create passable barriers at bulkhead junctions, replacing or supplementing mechanical hatches for emergency compartmentalization.

The core enabling technology—the plasma window—was invented by Ady Hershcovitch at Brookhaven National Laboratory and patented in 1995. That patent demonstrated a plasma barrier capable of maintaining pressure differentials up to nine atmospheres across small apertures. The original patents are approximately 30 years old and have expired or are expiring under standard 20-year patent terms.

This document takes the known physics of plasma windows and cold atmospheric plasma and applies them to a specific, critical, and currently unsolved problem in space habitat design: how to compartmentalize pressurized volumes during emergency decompression events while still allowing crew passage through the barrier.

The space safety application described in this paper is dedicated to the public domain. No patent will be filed for this application. This publication is intended to establish prior art, ensuring that no entity can patent these concepts and restrict access to technology designed to save human lives in space.

2. The Problem: Emergency Decompression in Space

Every pressurized crewed volume in space faces the same existential threat: a hull breach that causes rapid atmospheric loss. Whether from micrometeorite impact, structural fatigue, seal failure, or collision, decompression events are among the most dangerous scenarios in crewed spaceflight. The standard engineering response is compartmentalization—dividing the pressurized volume into isolated sections that can be sealed independently, so a breach in one section does not depressurize the entire habitat.

Current compartmentalization relies entirely on mechanical hatches: heavy, rigid doors with elastomeric or metallic seals that physically close to isolate sections. These systems work, but they carry significant limitations in the environments where next-generation habitats will operate.

Mechanical Hatch Failure Modes

- **Dust contamination:** Lunar regolith is abrasive, electrostatically charged, and pervasive. It degrades elastomeric seals and can physically prevent hatch closure. Martian fines present similar problems over extended mission durations.
- **Thermal cycling:** Lunar surface temperatures range from approximately +127°C (sunlit) to -173°C (shadow). Repeated thermal cycling causes material fatigue, warping, and seal degradation in mechanical systems with tight tolerances.
- **Structural deformation:** Moonquakes, Marsquakes, and micrometeorite impacts can cause structural flex that jams mechanical hatches or prevents full seal engagement.
- **Moving parts in vacuum-adjacent environments:** Lubricants outgas in low-pressure environments. Mechanisms designed for Earth-atmosphere operation degrade without continuous maintenance.

- Crew passage limitation: A sealed mechanical hatch is, by definition, impassable. In an emergency where crew must move between compartments while maintaining atmospheric containment, mechanical hatches offer no solution.

A plasma-based containment barrier addresses every one of these failure modes through a fundamentally different physical mechanism. It has no moving parts, no seals to degrade, no mechanisms to jam—and critically, it allows human passage while maintaining atmospheric containment.

3. Underlying Physics

3.1 Plasma Fundamentals

Plasma—ionized gas—is the fourth state of matter and constitutes over 99% of the visible universe. For the purposes of atmospheric containment, plasma has a critical exploitable property: at sufficient temperature and density, it becomes highly viscous, capable of preventing gas flow across a boundary. This is not a theoretical property; it was demonstrated experimentally by Hershcovitch in 1995 using argon plasma heated to approximately 12,000–15,000 K, achieving ionization fractions of 15–20% in compact channels.

Plasma also interacts with electromagnetic radiation in a frequency-dependent manner. It reflects electromagnetic waves below its characteristic plasma frequency while transmitting waves above it. This is the same mechanism by which Earth’s ionosphere reflects radio signals. The plasma frequency is determined by electron density; by controlling electron density, the barrier’s interaction with specific frequency ranges can be tuned. This property has additional applications beyond atmospheric containment.

3.2 The Plasma Window

The plasma window, as demonstrated by Hershcovitch, generates a stabilized plasma arc that serves as a virtual interface between regions of differing pressures without requiring a solid barrier. Key demonstrated capabilities include: maintenance of pressure differentials exceeding 2.5 atmospheres (tested up to 9 atmospheres); particle beam and electromagnetic radiation transmission with negligible attenuation; operation at atmospheric pressure; and millisecond-scale activation times.

The related plasma valve technology (US Patent 6,528,948) demonstrated that plasma seals could be activated within nanoseconds, ionizing gas nearly instantaneously to form a barrier. This rapid activation capability is critical for emergency decompression scenarios where seconds determine survival.

3.3 The Plasma Shield Extension

Hershcovitch subsequently developed the plasma shield concept, which extends a vortex-stabilized arc to engulf a target area, shielding it from surrounding atmospheric or liquid environments. This demonstrated that plasma containment could be projected beyond a fixed aperture into a shaped barrier configuration—a critical step toward corridor-scale barriers.

3.4 Cold Atmospheric Plasma

Cold atmospheric plasma (CAP) operates at near-ambient temperatures—29–32°C at the point of application—while maintaining ionization sufficient for electromagnetic interaction. CAP is already in clinical medical use for wound treatment and sterilization, with FDA-pathway approvals. Multiple feed

gases are viable: argon (producing a violet/purple glow), helium (red to purple), nitrogen (red to yellow), and various mixtures. Gas selection controls both the functional properties and the visual appearance of the barrier.

Researchers at Tsinghua University have demonstrated cold atmospheric plasma jets at 1-meter scale, confirming that CAP generation is not limited to laboratory-scale apertures.

4. Prior Art and Existing Technology

A thorough review of existing patents and published research confirms that no existing intellectual property covers the specific system described in this paper. The following represents the closest existing work:

4.1 Hershcovitch Plasma Window Patents (Expired/Expiring)

US Patent 5,578,831 (1995) describes the plasma window as a vacuum-atmosphere interface for particle beam applications. US Patent 6,528,948 describes the plasma valve for rapid-activation plasma sealing in particle accelerator breach protection. These patents cover the base technology for industrial applications. They do not address spacecraft compartmentalization, human passage, breach detection integration, or closed-loop gas recapture. The primary patent was filed in 1995 and has expired under the standard 20-year term.

4.2 Boeing Shock Wave Attenuation Patent (2015)

Boeing was granted a patent for a method using electromagnetic arcs to generate transient plasma that attenuates shock waves from explosions. This covers shock wave protection, not atmospheric containment. No working models have been demonstrated. The patent is limited to shock wave attenuation and does not claim atmospheric pressure maintenance or compartmentalization.

4.3 Spacecraft Radiation Shielding (US20110049303A1)

This patent application describes magnetic field and plasma-based shielding against energetic charged particles from solar events. It covers external radiation protection using a mini-magnetosphere—a fundamentally different physics problem, application, and engineering challenge from internal atmospheric containment.

4.4 StarTram MHD Window

The StarTram proposal described using a magnetohydrodynamic window over a multi-meter diameter launch tube to prevent vacuum loss during hypervelocity spacecraft launch. This is the closest conceptual relative to the Nolan Safety Curtain but is limited to a fixed ground-based launch infrastructure application, not portable or spacecraft/habitat emergency systems.

4.5 Gap Summary

No existing patent or published system covers: plasma barriers specifically designed for emergency decompression compartmentalization in crewed spacecraft or habitats; plasma barriers sized for human passage during emergency events; integration with breach detection sensor systems for automatic activation; closed-loop noble gas recapture systems for sustained operation in resource-constrained environments; redundant compartmentalization systems pairing plasma barriers with mechanical

hatches; or plasma barriers powered by onboard nuclear reactors or next-generation solar arrays in extraterrestrial habitats.

5. The Nolan Safety Curtain: System Design

5.1 Architecture Overview

The Nolan Safety Curtain consists of plasma generation assemblies integrated into bulkhead junction frames at compartmentalization points throughout a spacecraft or habitat. Each assembly includes the following components:

- Plasma generation electrodes and magnetic confinement system built into the doorframe or corridor junction structure.
- Noble gas supply manifold and closed-loop recapture system providing feed gas (primarily argon) and recovering spent gas for filtration, purification, and recirculation.
- Breach detection sensors (pressure differential, acoustic, thermal) tied to automated activation logic.
- Power conditioning and switching for rapid activation from the station or habitat power bus.
- Independent emergency power comprising high-capacity capacitor banks for immediate plasma initiation and battery backup for sustained barrier operation when primary power is unavailable.
- Visual status indication via inherent plasma glow color—the barrier itself provides an unmistakable visual warning that a pressure differential exists.

5.2 Feed Gas Selection

Argon is recommended as the primary feed gas for the following reasons: it achieves sufficient electron density for atmospheric pressure containment; as a noble gas, it has minimal chemical reactivity, dramatically reducing ozone and reactive species generation compared to air-fed plasma; it produces a distinctive violet/purple visible glow providing clear visual indication of barrier status; it is relatively low cost and easy to store; and its behavior in plasma physics is extensively characterized in the scientific literature.

Helium is a viable alternative or supplementary feed gas, producing a red-to-purple glow at even lower operating temperatures (approximately 29°C surface temperature). Gas mixtures could be engineered to optimize specific barrier properties.

5.3 Closed-Loop Gas Recapture

Closed-loop noble gas recapture is critical for sustained operation in resource-constrained space environments. The doorframe or corridor junction serves as both delivery and recapture infrastructure: gas feeds from one side, plasma is generated across the opening, and a low-pressure recovery manifold on the opposite side recaptures spent gas for filtration, purification, and recirculation.

Industry-standard recapture systems in semiconductor fabrication and MRI facilities routinely achieve recovery rates exceeding 90%. Engineering targets for the Nolan Safety Curtain should exceed 95% recovery, which is achievable with current industrial recapture technology adapted for the closed-environment conditions of a spacecraft or habitat.

5.4 Breach Detection and Automatic Activation

The system integrates with a sensor array capable of detecting atmospheric breach events through multiple independent channels: pressure differential sensors detect rapid pressure drops between adjacent compartments; acoustic sensors detect the characteristic sound signatures of hull breach events; and thermal sensors detect rapid temperature changes associated with atmospheric venting.

Sensor fusion logic processes inputs from all channels to distinguish actual breach events from false positives (e.g., airlock cycling, normal pressure adjustments). Upon confirmed breach detection, the plasma barrier activates automatically. Given the nanosecond-scale ionization capability demonstrated by the plasma valve technology, activation latency is dominated by sensor processing time, not plasma generation time.

5.5 Corridor-Scale Plasma Generation

The system is designed for human-passage-sized corridor openings, approximately 0.5 to 2.0 meters in diameter. This represents a significant scaling challenge beyond laboratory plasma window demonstrations, which have typically operated at apertures of a few centimeters. However, the StarTram proposal and Tsinghua University CAP jet research both confirm that plasma generation at multi-meter scales is physically feasible. The engineering challenge is optimization for the specific pressure differential (approximately 1 atmosphere), power efficiency, and sustained operation requirements of this application.

6. Human Safety Assessment

6.1 Medical-Grade Safety Data

Cold atmospheric plasma is already used directly on human skin and wounds in clinical medicine. A five-year follow-up study on medical CAP application found no therapy-associated cancerous or precancerous lesions and classified CAP as safe for clinical use. Multiple independent studies confirmed no mutagenic effects from CAP exposure. Treatment times of up to two minutes showed only slight reduction in mucosal cell viability while achieving high bactericidal effect.

6.2 Thermal Safety

Cold atmospheric plasma operates at near-ambient temperatures. Argon-fed plasma surfaces have been measured at approximately 32°C; helium-fed at approximately 29°C. Human passage through a plasma curtain—approximately one second of exposure—represents orders of magnitude less exposure than the clinically proven safe medical applications that involve sustained direct contact.

6.3 Reactive Species Management

Primary concerns for sustained operation are ozone generation and reactive oxygen/nitrogen species in ambient air. These concerns are substantially mitigated by three factors: use of noble gas feeds (argon, helium) rather than air, which dramatically reduces reactive species production; closed-loop gas recapture, which contains the plasma chemistry within the barrier system rather than releasing it into habitat air; and standard ventilation and atmospheric processing systems already required in spacecraft and habitat life support systems.

6.4 Emergency Context

In an emergency decompression scenario, the biological risk of brief plasma barrier passage is negligible compared to the risk of decompression injury or death. The barrier exists to save lives. Any minimal biological effect from passage is vastly outweighed by the protective function. This is analogous to fire doors that may cause minor contact burns during emergency evacuation—the alternative is worse.

7. Power Requirements, Emergency Backup, and Feasibility

7.1 Baseline Power Estimates

The original Hershcovitch plasma window consumed approximately 20 kilowatts per inch of aperture diameter. For a human-passage-sized corridor of approximately 36 inches (0.9 meters), this suggests approximately 720 kW at full containment. However, this figure is based on 1990s technology maintaining a full vacuum-to-atmosphere differential at 15,000 K.

The Nolan Safety Curtain has substantially less demanding requirements: it needs to maintain a one-atmosphere differential (not vacuum-to-atmosphere); it can employ cold plasma approaches at much lower temperatures; and three decades of advances in power electronics, magnetic confinement, and plasma physics offer significant optimization opportunities. A reasonable engineering estimate for an optimized system is 100–400 kW per barrier, with further reduction possible through continued development.

7.2 Emergency Power Independence

A critical design requirement is that the Nolan Safety Curtain must be capable of activation and sustained operation even when the primary habitat or station power bus is damaged or destroyed—precisely because the same event that causes a hull breach (collision, micrometeorite strike, structural failure) may also damage power distribution infrastructure. A barrier that depends entirely on station power fails at the exact moment it is needed most.

Each barrier assembly therefore incorporates independent emergency power in the form of high-capacity capacitor banks and battery backup systems integrated into the bulkhead junction frame. Capacitor banks provide the high-current pulse required for immediate plasma initiation—capacitors can discharge stored energy in milliseconds, matching the rapid-activation capability of the plasma valve technology. Battery backup systems (lithium-ion or solid-state cells) sustain barrier operation for a defined holdover period, providing time for crew evacuation, damage assessment, and either restoration of primary power or orderly compartment abandonment.

The capacitor bank sizing is driven by the initiation energy requirement: the burst power needed to ionize the feed gas and establish the plasma barrier across the full aperture. Once established, sustained barrier maintenance requires less power than initiation, and the battery backup system assumes the load. Engineering targets for the holdover period should be a minimum of 30 minutes on battery power alone, consistent with emergency evacuation timelines in spacecraft safety standards.

7.3 Available Power Sources (Normal Operation)

Next-generation spacecraft and lunar habitat power systems make these requirements viable. NASA's Fission Surface Power project targets 40 kW reactors for lunar surface operations, with multiple reactors per base as the baseline architecture. Full-scale space-rated fission reactors are projected to reach

megawatt-class output. The DARPA DRACO program is developing nuclear thermal propulsion systems that could provide substantial surplus electrical capacity during transit and orbital operations. Advanced solar arrays, including NASA's Roll-Out Solar Array (ROSA) technology, continue to increase power-to-mass ratios.

Dedicating 2–5% of total station or habitat power capacity to plasma safety systems is a reasonable engineering allocation, particularly given that barriers only operate at full power during actual emergency events. Standby power consumption for sensor monitoring and gas system pressurization is minimal.

8. Application Domains

8.1 Orbital Spacecraft and Stations

Emergency decompression compartmentalization at corridor junctions in space stations and transit vehicles. Advantages over mechanical hatches include: no moving parts subject to micro-debris damage; millisecond activation; crew can pass through during emergency; and no structural reinforcement requirements for hatch mounting points, reducing station mass.

8.2 Lunar Surface Habitats

Compartmentalization across pressurized tunnel junctions connecting habitat modules. Lunar-specific advantages include immunity to lunar regolith contamination that degrades mechanical seals; no thermal cycling stress on moving parts across the extreme lunar temperature range; tolerance to moonquake-induced structural flex that could jam mechanical hatches; and scalability to large greenhouse dome and mining corridor access points.

8.3 Martian Habitats

Similar advantages to the lunar application with additional tolerance to Martian dust storms and fines that would degrade mechanical systems over extended mission durations measured in years.

8.4 Vehicle Airlocks

Secondary containment at airlock junctions for rover garages and EVA access points, providing backup containment if a primary airlock seal fails during cycling.

9. Redundancy and Failure Modes

The Nolan Safety Curtain is explicitly designed as a complementary system alongside traditional mechanical hatches, not a replacement. The two systems provide true redundancy through completely independent failure modes:

Mechanical hatch failure causes—dust contamination, thermal warping, seal degradation, structural deformation—do not affect plasma barrier operation. Plasma barrier failure causes—gas supply depletion, electronics failure—do not affect mechanical hatch operation. Primary power loss, which would previously have been a plasma barrier failure mode, is mitigated by independent capacitor bank and battery backup systems integrated into each barrier assembly, providing autonomous initiation and holdover capability independent of the station power bus.

This dual-mode approach satisfies spacecraft safety design philosophy requiring independent redundant systems with non-overlapping failure modes. The probability of simultaneous failure of both systems is the product of their individual failure probabilities—dramatically lower than either system alone.

10. Public Domain Dedication

The space safety application of plasma-based atmospheric containment barriers as described in this paper—the Nolan Safety Curtain—is hereby dedicated to the public domain.

This publication constitutes a deliberate and permanent public disclosure intended to:

- Establish prior art preventing any entity from obtaining patent protection over plasma-based emergency decompression compartmentalization systems for spacecraft and extraterrestrial habitats;
- Ensure that life-safety technology for space exploration remains freely available to all nations, agencies, and commercial entities engaged in human spaceflight;
- Encourage development, refinement, and implementation of this technology by any party with the engineering capability to build it.

No license is required. No royalty is owed. No permission need be sought. Build it. Use it. Keep people alive.

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About the Author

Patrick Nolan is an attorney, U.S. Army veteran, and technologist based in Kirksville, Missouri. He has no financial interest in the space safety application described in this paper and has dedicated it to the public domain. He can be reached through the Nolan Law Firm at nemolegal.com.

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