IV Fluid Administration Device

Functional Requirements Scope — Microgravity Environment

NASA Human Health and Performance Group

1.0 Scope

This document defines the functional requirements for an IV Fluid Administration Device designed for microgravity environments. The system is intended to provide IV fluid to crewmembers — including but not limited to resuscitation — while ensuring the absolute elimination of air from the fluid path to prevent gas emboli.

2.0 System Overview

The device shall provide a controlled interface between an IV fluid reservoir (bag) and the patient for a variety of clinical needs, ranging from medication titration to rapid volume expansion. Because buoyancy-driven gas separation is absent in microgravity, the system shall utilize phase-separation technology to ensure a bubble-free fluid stream.

The device must support both rapid delivery for medical emergencies and precision delivery for routine care within a deep-space habitat. The system is intended for use by trained crewmembers operating autonomously, without real-time support from Earth.

3.0 Functional Requirements

3.1 Fluid Delivery and Performance

ID	Requirement	Reference
FR-3.1.1	**Maximum emergency flow rate:** The system shall deliver IV fluids at a maximum rate of 1 liter per 15 minutes (4,000 mL/hr) to support emergency resuscitation. Crew may need to visually gauge this delivery rate by applying manual pressure to the bag via the pressure infuser.	*NASA-STD-3001 V2 6110*
FR-3.1.2	**Programmable flow rates:** The device shall provide selectable flow rates to support non-emergent care, including maintenance fluids and medication titration.	*EIMO-L2-Prog-1*
FR-3.1.3	**Minimum volume capacity:** The system shall provide a minimum total volume delivery of 5 liters per medical event.	*NASA-STD-3001 V2 6110*

FR-3.1.4	**Rapid priming:** The system shall be fully primed and ready for use in under 90 seconds. Priming shall be accomplished using the pressure infuser to force fluid from the source bag through the entire line, purging air before reaching the patient.	*Sec. 5.0 Priority*
FR-3.1.5	**Filters shall not impede emergency flow rate:** Inline filter selection and placement shall be validated to confirm no reduction in maximum flow rate (FR-3.1.1) under emergency conditions. Filter push-versus-pull flow performance shall be characterized during testing, as performance may vary by configuration.	*Sec. 5.0 Priority*

3.2 Air Elimination (Phase Separation)

Critical constraint: In microgravity, buoyancy cannot be used to float air bubbles to the top of the IV line. Any air that enters the fluid path will travel directly to the patient. The phase-separation mechanism must be entirely passive and gravity-independent.

ID	Requirement	Reference
FR-3.2.1	**Continuous gas-liquid separation:** The system shall provide a continuous gas-liquid separation mechanism to ensure all air is removed from the fluid stream before it reaches the patient.	*NASA-STD-3001 V2 9026*
FR-3.2.2	**Microgravity-compatible mechanism:** The air elimination mechanism shall function effectively in a microgravity environment where buoyancy cannot be used for bubble separation.	*NASA-STD-3001 V2 9026*
FR-3.2.3	**No accumulated gas release:** The system shall prevent the release of any stored or accumulated gases into the patient's circulatory system.	*NASA-STD-3001 V2 9024*
FR-3.2.4	**Passive bubble handling:** The device shall be designed to handle the transition of air-fluid mixtures from the source bag without requiring active bubble detection sensors to trigger the elimination process.	*Sec. 5.0 Priority*
FR-3.2.5	**Single-use line with replaceable filters:** The complete fluid path from IV bag to patient — including all inline filters and components — shall be single-use and fully disposable. All components shall be individually removable and replaceable.	*Sec. 5.0 Priority*

3.3 Patient Safety and Monitoring

ID	Requirement	Reference

FR-3.3.1	**Electrical safety:** The system shall adhere to Type CF (Cardiac Floating) electrical safety standards, with leakage current not exceeding 0.01 mA in normal operation.	*NASA-STD-3001 V2 9023*
FR-3.3.2	**Occlusion detection:** The device shall include an occlusion detection mechanism to ensure fluid delivery is not interrupted by downstream resistance without crew awareness.	*NASA-STD-3001 V2 9026*
FR-3.3.3	**Mismate-proof connectors:** All fluid connectors shall be designed to prevent accidental cross-connection with non-medical systems. Connector geometry, color-coding, or keying shall make incorrect mating physically impossible. All connectors shall be fluid-sealed to prevent the escape of free fluids into the spacecraft cabin environment.	*NASA-STD-3001 V2 9032 / V2 9026*
FR-3.3.4	**Autonomous crew operation:** The system shall support autonomous setup and operation by the crew during communication delays with Earth. Setup shall be achievable by a single crewmember, rapidly, under stress, with minimal parts to assemble. The design shall be fail-proof — wrong assembly shall be physically prevented, not merely discouraged.	*EIMO-L2-Prog-1 / Sec. 5.0*

3.4 Integration and Autonomy (BONUS Section)

Requirements in this section are bonus objectives. Meeting them earns additional credit but is not required for a passing prototype. Any updates to initial prototype must be compact, ease of use, and not require more time for set up.

ID	Requirement	Reference
FR-3.4.1	**Ultrasound compatibility:** The device shall be compatible with ultrasound imaging protocols used for confirming correct placement of exogenous IV lines.	*ExMC ConOps 5*
FR-3.4.2	**Digital status interface:** The system shall provide a digital interface for the crew to monitor volume infused, current flow rate, and device status in real time.	*EIMO-L2-Prog-1*

4.0 Operational Considerations

ID	Requirement	Reference
FR-4.1	**Onboard maintainability:** The device shall be designed for onboard maintenance and component-level repair to support missions	*EIMO-L2-Prog-11*

	exceeding 900 days. Replacement parts shall be storable and accessible without specialized tools.	
FR-4.2	**Structural integrity under panic loads:** All hardware shall withstand forces applied by the crew during emergency or 'panic' conditions without loss of structural or functional integrity. The system shall remain fully operational after rough handling consistent with a high-stress medical event.	*NASA-STD-3001 V2 9027*

5.0 Design Priorities Summary

The following priorities synthesize the most critical design constraints across all sections. These drive trade-off decisions when requirements compete.

#	Priority
1	Zero air to patient — non-negotiable. No design trade-off may compromise this.
2	Single-use, fully disposable fluid path with individually replaceable inline filters.
3	Line primed in under 90 seconds using a pressure infuser to force fluid from the source bag.
4	Maximum emergency flow rate (1 L / 15 min) must not be degraded by filter placement. Test both push and pull configurations — performance varies.
5	Fluid-sealed, mismate-proof connectors throughout. No free fluid may enter the cabin.
6	Minimal-part, fail-proof assembly (FR-3.3.4) — any crewmember must be able to set up the system quickly under emergency conditions without real-time Earth support.

6.0 Reference Standards

Reference	Description
NASA-STD-3001, Vol. 2	Human Integration Design Handbook — covers human health and performance requirements for spaceflight systems
EIMO-L2-Prog-1, -11	Exploration Infrastructure and Medical Operations — Level 2 programmatic requirements for crew medical capability
ExMC ConOps, Section 5	Exploration Medical Capability Concepts of Operations — IV line placement and ultrasound guidance protocols
NASA-STD-3001 V2 9023	Type CF electrical safety standard — cardiac floating, leakage current ≤ 0.01 mA
NASA-STD-3001 V2 9024	Prevention of accumulated gas release into circulatory system

NASA-STD-3001 V2 9026	Fluid-sealed connectors; phase-separation and bubble elimination requirements
NASA-STD-3001 V2 9027	Structural integrity under crew-applied emergency loads
NASA-STD-3001 V2 9032	Mismate-proof connector requirements