NASA

Human Health &
Performance Group

IV Fluid Administration Device

Student Project Brief — Microgravity Medical Systems

PRESENTED TO NASA HUMAN HEALTH AND PERFORMANCE · HIGH SCHOOL ENGINEERING DESIGN PROJECT

Project Overview

What we are asking student engineers to do

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THE MISSION

High school engineering teams will apply the full engineering design process to design, build, and test a working prototype of an IV fluid administration system capable of operating in a microgravity environment.

At the end of the semester, teams present their prototypes and test data to the NASA Human Health and Performance Group for review.

PROJECT STRUCTURE

1. **Team size:** 3–5 students per team
2. **Duration:** Full semester (~16 weeks)
3. **Process:** NASA engineering design process
4. **Deliverable:** Working prototype + test data
5. **Final review:** Presentation to NASA HH&P

The Problem in Microgravity

Why Earth-standard IV systems cannot be used in space

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No Gravity-Fed Drip

On Earth, IV fluid flows by gravity. In microgravity there is no gravitational force to drive flow. Fluid must be actively pressurized from source to patient.

Air Bubbles Don't Rise

On Earth, air bubbles float to the top of the line and can be managed. In microgravity, bubbles travel wherever fluid goes — directly to the patient, causing potential gas embolism.

No Buoyancy for Separation

Standard air-elimination filters rely on buoyancy to separate gas from liquid. That mechanism does not exist in microgravity, requiring phase-separation technology.

Crew Autonomy Required

With communication delays to Earth of up to 24 minutes each way on deep-space missions, the crew must be able to set up and operate the system entirely without ground support.

System Requirements at a Glance

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Key performance targets from the functional requirements scope

1 L	5 L	< 90s	0
in ≤ 15 min	minimum	prime time	air to patient
Emergency flow rate	**Volume per medical event**	**System ready for use**	**Air bubbles tolerated**

FR-3.1	**Fluid Delivery**	Programmable flow rates; ≥5 L per event; ≤90 sec prime; filters must not impede emergency flow
FR-3.2	**Air Elimination**	Continuous gas-liquid separation; passive, gravity-independent; single-use disposable line with replaceable inline filters
FR-3.3	**Patient Safety**	Type CF electrical safety (≤0.01 mA); occlusion detection; mismate-proof fluid-sealed connectors; autonomous crew setup
FR-4	**Operational**	Onboard maintainability for 900+ day missions; withstands panic-force handling without failure

Design Priorities

How students must resolve competing constraints

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1. **Zero air to patient — no design trade-off may compromise this requirement.**
2. Single-use, fully disposable fluid path with individually replaceable inline filters.
3. Full system prime in under 90 seconds using a pressure infuser.
4. Emergency flow rate (1 L / 15 min) must not be degraded by filter placement. Push vs. pull configurations shall be tested.
5. Fluid-sealed, mismate-proof connectors throughout — no free fluid enters the cabin.
6. Minimal-part, fail-proof assembly operable by one crewmember under stress.

Key Technology: Pressure Infuser

The mechanism replacing gravity in microgravity IV delivery

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HOW IT WORKS

1 The Sleeve

The IV bag is placed inside a durable inflatable sleeve designed to apply even, uniform pressure across the bag surface.

2 The Pump

A manual inflation bulb is connected to the sleeve via a tube. The crew squeezes the bulb to increase pressure.

3 The Pressure

Inflating the sleeve squeezes the bag, pushing fluid through the line at rates exceeding gravity-fed flow — up to 4,000 mL/hr.

SAFETY REQUIREMENTS

▲ Pressure Monitoring

Device must include a pressure indicator. Pressure must remain within manufacturer-specified and clinically approved limits.

▲ Air Embolism Risk

Increased pressure can drive air into the line faster. Monitoring for bubbles at the outlet is a critical step during operation.

▲ Prime in < 90 seconds

The pressure infuser is the primary priming mechanism. Students must demonstrate full prime under 90 seconds using this device.

▲ Emergency Handling

Hardware must withstand panic-force application by crew without loss of integrity or fluid containment (FR-4.2).

Critical Requirement: Air Elimination

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Phase separation in the absence of buoyancy

On Earth, buoyancy causes air bubbles to rise to the top of an IV line where they can be caught or vented. In microgravity, this does not happen. Any air entering the fluid path travels directly toward the patient — making passive phase-separation the most critical system requirement.

FR-3.2 REQUIREMENTS

FR-3.2.1	Continuous gas-liquid separation mechanism — air removed before reaching patient
FR-3.2.2	Mechanism functions without buoyancy — entirely gravity-independent
FR-3.2.3	No accumulated gas may be released into the patient's circulatory system
FR-3.2.4	Passive operation — no active bubble-detection sensor required to trigger elimination
FR-3.2.5	Single-use disposable line with individually removable and replaceable inline filters

STUDENT TESTING NOTE

An open engineering question students must investigate:

Some inline filters perform differently depending on whether fluid is pushed through them (pressure from behind) vs. pulled through (suction from ahead).

Students must test both configurations and report data on which meets the emergency flow rate requirement without allowing air passage.

Student Deliverables

What NASA will receive at the end of the semester

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Phase 1–2	**Problem Statement & Design Concept**	Written problem statement grounded in NASA requirements. Concept decision matrix showing all ideas considered and rationale for selected design.
Phase 3	**Design Package**	Labeled system diagram, materials list, assembly sequence, test plan with defined success metrics, and risk log.
Phase 4	**Working Prototype**	Physical IV fluid system: IV bag, pressure infuser, inline filter(s), fluid-sealed luer-lock connectors, flow regulator, and collection vessel.
Phase 5	**Test Data & Iteration Log**	Quantitative results for flow rate, prime time, air elimination (push & pull config), and occlusion detection. Lab notebook documenting all decisions and changes.
Phase 6	**NASA Review Presentation**	5-minute live demo + 10-slide deck + Q&A with the panel. Team defends design choices with data.

Bonus Objectives (FR-3.4)

Advanced requirements for teams that meet all core criteria

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Teams that successfully meet all FR-3.1 through FR-4 requirements may pursue these advanced objectives for additional recognition.

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, Section 5).

HOW STUDENTS ADDRESS THIS:

Students document how connector and line geometry would not obstruct ultrasound probe access.

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).

HOW STUDENTS ADDRESS THIS:

Typically implemented with an Arduino microcontroller and inline flow sensor. Teams demonstrate live readout during the final review.

How Teams Are Evaluated

NASA review criteria and grading framework

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Phase	Pts	NASA Evaluation Criteria
Define & Research	15	Problem statement accuracy; requirements annotation; no premature solution language
Ideate & Specify	15	Number of concepts generated; rigor of decision matrix; traceability to requirements
Design & Plan	20	System diagram completeness; feasibility; explicit safety considerations; test plan quality
Build Prototype	25	System functions; craftsmanship; lab notebook documentation; component replaceability
Test & Iterate	15	Data quality; number of iterations; conclusions tied to NASA requirements
Present to NASA	10	Data-driven defense; clarity; team collaboration; honest acknowledgment of limitations

Total: 100 points · Bonus available for FR-3.4 objectives

Semester Timeline

Six-phase design cycle across 16 weeks

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1	Define & Research	Wk 1–2
2	Ideate & Specify	Wk 3–4
3	Design & Plan	Wk 5–6
4	Build Prototype	Wk 7–10
5	Test & Iterate	Wk 11–14
6	NASA Review	Wk 15–16

NASA HH&P review panel attends Phase 6. Teams present live demo + test data + Q&A. Failures honestly reported are valued as engineering evidence.

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Partnering with the next generation of space medicine engineers.

The systems students prototype this semester may directly inform the medical equipment carried aboard future crewed missions to the Moon and Mars.

Scope Document · Grading Rubric · Lab Safety Rules

Available upon request from the project coordinator.