MARS ECG HOLSTER CHALLENGE

Student Project Brief

Wearable ECG Holster Challenge | NASA-Inspired Engineering Design

Biomedical Engineering | Space Medicine | Human-Centered Design

GRADE LEVEL	SUBJECT AREA	PROJECT TYPE
High School	**STEM / Engineering**	**Design & Prototype**

1. Challenge Overview

You are living in 2035. A crew of six astronauts is on a 900-day mission to Mars, over 250 million miles from Earth. There are no hospitals. There are no emergency services. There is no way to send a replacement crew. When a medical emergency happens, the six crewmates are all each other have.

One day, a crewmember collapses. The onboard flight surgeon suspects a cardiac event. The only available diagnostic tool is the KardiaMobile 6-Lead ECG device — a pocket-sized, FDA-cleared instrument that captures clinical-grade heart rhythm data. But there is a critical problem: the device requires the patient to press their thumbs onto two electrodes. An unconscious patient cannot cooperate.

Your mission: design a wearable ECG holster that allows a single caregiver to deploy the KardiaMobile on an incapacitated patient in under 60 seconds, without any patient cooperation.

> **DESIGN CHALLENGE:** How do you take an ECG reading on a patient who CANNOT move their own thumbs or cooperate with the test?

2. The KardiaMobile 6-Lead Device

Before designing your holster, you must deeply understand the tool you are designing around.

Feature	Details
6-Lead ECG	Captures the same cardiac data as a hospital-grade ECG machine — not a consumer fitness tracker.
Wireless Bluetooth	Transmits ECG data wirelessly to a smartphone or tablet. No cables required.
Thumb Electrodes	Two electrodes on the top of the device require direct thumb skin contact to complete 6 leads.
Leg Electrode	One electrode on the bottom must contact bare skin on the thigh/leg to complete the 6-lead circuit.
30-Second Test	Captures a full cardiac rhythm strip in just 30 seconds.

FDA Cleared	Medically approved for detecting AFib, bradycardia, tachycardia, and normal sinus rhythm.
Compact Size	Roughly the size of a large USB drive — portable and lightweight.

KEY INSIGHT: Your holster must maintain all three electrode contact points simultaneously without patient cooperation: two thumb contacts on top, one leg contact on bottom.

3. Medical Scenarios — When Could This Happen?

Understanding why a crewmember might be incapacitated helps you design a more effective and empathetic solution. Below are five realistic cardiac emergencies that could occur during a Mars mission, and why each one creates a critical need for your ECG holster.

3.1 Sudden Cardiac Arrest (SCA)

Sudden cardiac arrest occurs when the heart abruptly stops beating effectively due to an electrical malfunction — typically ventricular fibrillation (VF) or pulseless ventricular tachycardia (VT). The person collapses without warning, loses consciousness instantly, and has no pulse. In space, the risk is significant: microgravity causes cardiovascular deconditioning, fluid shifts toward the head, and potential coronary artery changes over a 900-day mission.

WHAT THE CAREGIVER FACES: The patient is completely limp and unresponsive. The flight surgeon needs to confirm the cardiac rhythm via ECG before deciding whether to defibrillate. Your holster must function while the patient is flat on the floor, possibly in a confined spacecraft corridor, with the caregiver simultaneously managing CPR protocols.

DESIGN IMPLICATION: The holster must be compatible with AED defibrillator pad placement on the chest. It cannot obstruct the anterior chest wall or prevent immediate defibrillation.

3.2 Acute Myocardial Infarction (Heart Attack)

A heart attack occurs when blood flow to part of the heart muscle is blocked, usually by a blood clot in a coronary artery. Unlike cardiac arrest, the heart is still beating — but may be doing so dangerously and irregularly. The patient may experience crushing chest pain, shortness of breath, sweating, and nausea, and may lose consciousness if the infarction is severe.

WHAT THE CAREGIVER FACES: There is a time-critical window. The faster an ECG confirms an ST-elevation myocardial infarction (STEMI) pattern, the faster the flight surgeon can begin thrombolytic (clot-busting) medication. In a hospital this triggers a Code STEMI. On Mars, the caregiver is the entire cardiac team.

> **DESIGN IMPLICATION:** Speed matters. Your 60-second deployment requirement directly corresponds to the cardiac treatment window. Every second of fumbling with your device is heart muscle being lost.

3.3 Severe Arrhythmia — AFib with Rapid Ventricular Response

Atrial fibrillation (AFib) is an irregular heart rhythm in which the upper chambers quiver instead of contracting normally. In most people, AFib is manageable. But in space, after months of microgravity-induced cardiac deconditioning, AFib with a very fast ventricular rate can cause blood pressure to drop dangerously, resulting in sudden loss of consciousness (syncope).

WHAT THE CAREGIVER FACES: AFib requires completely different drug treatment than ventricular fibrillation. Giving the wrong medication because of an incorrect diagnosis could be fatal. An accurate ECG diagnosis is non-negotiable.

> **DESIGN IMPLICATION:** The holster must work even if the patient has collapsed in a narrow equipment bay, on a sleeping berth, or near a suit doffing station. Adaptability to confined spaces is essential.

3.4 Vasovagal Syncope (Fainting) with Monitoring Need

Vasovagal syncope is the most common cause of fainting — the nervous system briefly overreacts to pain, fear, or dehydration, causing a sudden drop in heart rate and blood pressure. In space, chronic dehydration from microgravity fluid shifts makes fainting episodes more likely. While usually benign, the flight surgeon must rule out dangerous cardiac arrhythmias masquerading as a simple faint.

WHAT THE CAREGIVER FACES: The patient is unconscious but may wake during the test. A frightening device strapped to their leg could cause the patient to tear it off, ruining the 30-second recording window.

> **DESIGN IMPLICATION:** Comfort and intuitive design matter even for brief episodes. A patient who wakes mid-test should not panic. Clearly label your device — consider the patient's perspective when they open their eyes and see it.

3.5 Cardiovascular Deconditioning After Long-Duration Spaceflight

Extended spaceflight causes the heart to work less against gravity, gradually weakening cardiovascular function. After 900 days in microgravity, a crewmember transitioning to Martian gravity (38% of Earth's) could experience orthostatic intolerance — the heart beats erratically when the person tries to stand, causing confusion, dizziness, or sudden collapse during critical landing and surface operations.

WHAT THE CAREGIVER FACES: This is a chronic scenario requiring repeated ECG monitoring over weeks, not a single emergency. Your holster may need to be deployed dozens of times on the same patient across the mission.

> **DESIGN IMPLICATION:** Design for durability and repeated use. A holster that degrades after 20 cycles fails a mission measured in hundreds of days. Material longevity is a primary engineering constraint.

4. Functional Requirements (What Your Design Must Do)

These are engineering specifications, not suggestions. Think of them as the checklist a NASA engineer would use to accept or reject your design.

4.1 Mechanical Design & Skin Interface

- **FR-3.1.1** Thigh strap secures the device to the mid-to-lower thigh with stable positioning during movement and medical procedures.
- **FR-3.1.2** A posterior aperture allows the KardiaMobile rear electrode continuous direct contact with bare skin.
- **FR-3.1.3** Mechanical holders secure the patient's thumbs against the top electrodes, compensating for lack of muscle tone.
- **FR-3.1.4** All materials are non-irritating and compatible with medical-grade disinfection for multi-use cycles over 900+ days.

4.2 Operational & Assisted Donning

- **FR-3.2.1** A single caregiver must fully deploy the device and position the patient's limbs in under 60 seconds — no instruction booklet allowed.
- **FR-3.2.2** Visual alignment markers allow correct thigh positioning even under extreme stress.

4.3 Data Acquisition & Patient Safety

- **FR-3.3.1** Holster materials must NOT block or interfere with Bluetooth wireless ECG data transmission.
- **FR-3.3.2** Device placement must not block AED defibrillator pads or blood pressure cuffs applied simultaneously.
- **FR-4.1** The patient must be safely transportable through the spacecraft without the ECG device dislodging or causing pressure injuries.

5. Design Constraints

Your Design MUST Include	Your Design MUST NOT Do
Secure thigh mount (no caregiver hands required)	Block Bluetooth transmission
Rear electrode contact with bare skin	Cause pressure sores during patient transport

Passive thumb electrode holders	Require any patient cooperation
60-second solo deployment	Require more than one caregiver to deploy
Skin-safe and disinfectable materials	Allow the device to dislodge during movement
Clear AED chest pad access	Degrade over 900+ days of mission use

6. NASA Standards You Must Meet

Your design must comply with NASA-STD-3001, the Human Integration Design Handbook governing crew health and safety in spaceflight.

NASA-STD-3001 Section 9027 — Restraint Systems

Any device that restrains or positions a crewmember must be comfortable, adjustable for different body sizes, and must not restrict circulation or cause skin breakdown. Your strap system must be designed around this standard.

NASA-STD-3001 Section 6110 — Microbial Contamination

In a closed spacecraft, infections spread quickly with no access to external medical care. All medical equipment must be fully disinfectable with standard medical-grade disinfectants without degrading material properties. Porous materials that trap bacteria require a specific disinfection strategy to be acceptable.

> **THINK LIKE AN ENGINEER:** Standards are not bureaucracy. They exist because real people were injured without them. When you follow NASA-STD-3001, you are building on lessons from 60 years of human spaceflight.

7. Suggestions for Innovation & Excellence

Meeting the base requirements earns a passing design. These ideas can elevate your project to genuinely innovative territory. You don't need to implement all of them — choose those that excite you and that you can feasibly prototype and test.

7.1 Advanced Electrode Interface Ideas

- **Hydrogel Electrode Pads:** Replace bare-skin contact with pre-attached hydrogel pads (like hospital ECG stickers). Hydrogel conforms to skin, improves signal quality, and reduces motion artifact. Could your holster incorporate a replaceable hydrogel cartridge?
- **Conductive Fabric Aperture:** Instead of a hard aperture, design a flexible conductive fabric zone that maintains electrode contact even as the patient is repositioned — more forgiving than rigid materials in emergency scenarios.
- **Spring-Loaded Thumb Mechanism:** A controlled spring mechanism lightly but consistently presses the patient's thumbs onto electrodes. The spring provides just enough force without crushing tissue during transport.
- **Integrated Alignment Grid:** Add a printed or embossed positioning grid on the thigh surface. Like targeting crosshairs, this helps the caregiver achieve reproducible positioning under stress.

7.2 Structural & Wearability Innovations

- **Universal Sizing System:** Astronauts range significantly in height and thigh circumference. Design a single holster frame with modular interchangeable size liners rather than carrying three separate size holsters on a 900-day mission.
- **One-Handed Deployment:** Most designs require two hands. Can the caregiver deploy and secure the holster with one hand? This matters if the other hand is occupied with CPR compressions or airway management.
- **Confirmation Indicator:** Add a simple mechanism — a click, color-change indicator, or tactile bump — that tells the caregiver when the device is properly seated and all electrodes are making contact. Eliminate ambiguity under extreme stress.
- **Modular Emergency Kit Integration:** Design the holster to clip directly to the spacecraft emergency medical kit. Zero time is wasted searching for the device at the start of a crisis.

7.3 Material Science Excellence

- **Shape Memory Polymer Frame:** Shape memory polymers conform to a new shape when warmed to body temperature. A frame from SMP could self-conform to the patient's thigh without manual adjustment — the body's warmth does the fitting.
- **Antimicrobial Coating:** Specify silver-ion or copper-ion antimicrobial surface treatment on all skin-contact components. This directly addresses NASA-STD-3001 Section 6110 and demonstrates deep understanding of spacecraft medicine constraints.

- **Radiation Resistance Analysis:** In deep space, materials are exposed to high-energy cosmic radiation for 900+ days. Many common polymers degrade under radiation. Research which materials maintain their properties and justify your choices in your design document.

7.4 Data & Connectivity Innovations

- **Bluetooth Signal Optimization:** Document which materials in your design are transparent to 2.4 GHz Bluetooth signals. Avoid dense metal frames over the ECG device. Include a brief materials analysis in your design justification — this is real RF engineering.
- **Redundant Data Path:** What happens if Bluetooth fails? Consider adding a wired data port as a backup connection to the medical tablet. A simple addition that dramatically improves mission-critical reliability.
- **Multi-Modal Sensing Mount:** Could your holster simultaneously position a pulse oximetry sensor or skin temperature sensor alongside the ECG device? A multi-modal mount gives the flight surgeon more diagnostic information from a single deployment.

7.5 Human Factors & Usability Excellence

- **Stress-Proof Deployment:** Under acute stress, humans lose fine motor control and working memory. Design so deployment requires zero reading. Use color coding, tactile cues, and a single logical action sequence — like an aviation emergency checklist.
- **Microgravity Adaptation:** Mars has gravity (38% of Earth's), but could this design be adapted for true microgravity on the ISS? Velcro loses effectiveness when floating debris coats the hooks. How would your fastening system perform in weightlessness?
- **Inclusive Design:** Does your design work equally well on crewmembers of very different body compositions? A holster optimized for one body type fails a diverse crew on a multi-year mission.

8. Your Design Process

Follow the engineering design cycle. Your process documentation is as important as your final prototype.

Phase	What You Do
1. DEFINE	Re-read all requirements. Who is the user? What does success look like? Write a one-sentence problem statement in your own words.
2. RESEARCH	Study medical holsters, orthopedic braces, climbing harnesses, prosthetic sockets, phone

	mounts. Ask: what holds things securely under stress? Fill an inspiration board.
3. IDEATE	Sketch 10+ ideas. No bad ideas at this stage. Think about velcro, buckles, hinges, foam, magnets, 3D printing. Combine ideas from unexpected sources.
4. PROTOTYPE	Build a low-fidelity model from cardboard, tape, straps, foam, or clay. Test it on your own leg first. An AD8232 sensor board (~$5) can capture real ECG signals.
5. TEST	Have a partner play the role of an unconscious patient. Can you deploy in under 60 seconds? Do thumbs stay in position? Does the device shift when the patient is moved?
6. ITERATE	What failed? What worked? Improve your design. Repeat until all functional requirements are met. Document every iteration.

9. Materials to Consider

Category	Options
Straps & Closure	Hook-and-loop (Velcro), medical-grade elastic, neoprene, ratcheting buckle straps, cam buckles, magnetic closures
Structural Frame	Thermoplastic (ABS, PLA via 3D printing), flexible TPU, carbon fiber composite, medical-grade aluminum, HDPE
Electrode Interface	Conductive fabric/mesh, open-cell foam aperture, silicone gasket, hydrogel electrode pads, silver-coated fabric
Thumb Holders	Molded silicone cup, padded finger cradle, spring-loaded clamp, adjustable loop strap, foam-lined rigid channel
Padding & Comfort	Medical-grade neoprene, memory foam, gel pad inserts, breathable mesh liner
Disinfectable Surfaces	Silicone (autoclavable), sealed ABS/PLA, anodized aluminum, powder-coated metals

10. Project Deliverables

You will be evaluated on all five deliverables. A brilliant prototype with no documentation will not earn full marks.

Deliverable	Requirements
01 — Annotated Sketches	At least 3 design concepts with labels identifying key components, materials, and design rationale. Show your thinking, not just a polished drawing.
02 — Physical Prototype	A functional low-fidelity model (cardboard, tape, foam, straps) that can be demonstrated on a person. Optional: include an AD8232 sensor for real ECG signal capture.
03 — Test Results	Documented data: deployment time in seconds, whether thumbs stayed in position, what failed, what worked, how you responded. Minimum 3 test runs.
04 — Design Justification	One-page written explanation of how your design meets each functional requirement (FR-3.1.1 through FR-4.1). Be specific — cite your exact design decisions.
05 — Class Presentation	5-minute pitch explaining your design choices, test results, and what you would improve in Version 2. Practice under time pressure.

11. Student Resources

All resources below are publicly accessible. Use them to build your understanding of the engineering problem, the medical context, and available tools.

11.1 Understanding the KardiaMobile Device

- **KardiaMobile 6L official product page:** alivecor.com/kardiamobile6l — specifications, dimensions, electrode positions, Bluetooth specs
- **FDA 510(k) Clearance Database:** fda.gov/medical-devices — search "KardiaMobile" to read the actual FDA clearance documentation
- **Book:** "12-Lead ECG Made Easy" — Hampton & Hampton (widely available in school and public libraries)

11.2 Space Medicine & NASA Standards

- **NASA Human Research Program:** humanresearchroadmap.nasa.gov — research on health risks in spaceflight
- **NASA-STD-3001 (free PDF):** Search "NASA-STD-3001 PDF" on nasa.gov — the actual engineering standard you must comply with
- **NASA Space Medicine Division:** nasa.gov/space-medicine — overview of medical challenges in human spaceflight
- **YouTube — NASA Official Channel:** Search "NASA space medicine" for short documentary videos on medical care in space
- **Book:** "Into That Silent Sea" — Burgess & Doolan (history of early space medicine)

11.3 Cardiac Physiology & ECG Basics

- **Khan Academy — Cardiac Physiology (free):** khanacademy.org — search "circulatory system" for clear animated video lessons
- **StatPearls (NCBI) — free peer-reviewed article:** ncbi.nlm.nih.gov/books/NBK549803/ — "Electrocardiography" clinical reference
- **American Heart Association:** cpr.heart.org — free online modules on how to read a basic ECG
- **YouTube:** Search "6-Lead ECG explained" for multiple free clinical tutorials aimed at nurses and EMTs — ideal level for this project
- **Book:** "ECG in 10 Days" — Desai & Bhatt — concise beginner guide to reading cardiac rhythms

11.4 Biomedical Engineering & Device Design

- **Biomedical Engineering Society (BMES):** bmes.org/students — student resources and career information
- **NIH NIBIB:** nibib.nih.gov — "What is Biomedical Engineering?" short explainer videos
- **Engineer Girl (National Academy of Engineering):** engineergirl.org — biomedical project ideas and profiles of biomedical engineers
- **Book:** "Design of Biomedical Devices and Systems" — King & Fries (check school library)

11.5 Prototyping & Maker Tools

- **Tinkercad (free, browser-based 3D CAD):** tinkercad.com — no software installation, works in any browser
- **Autodesk Fusion 360 (free for students):** autodesk.com/products/fusion-360/students — professional-grade CAD tool
- **AD8232 Heart Rate Monitor:** sparkfun.com — search "AD8232" for a ~$5 sensor board that captures real ECG signals for testing

- **Instructables.com:** Search "ECG Arduino" for step-by-step low-cost sensor project tutorials
- **McMaster-Carr:** mcmaster.com — industrial materials catalog, excellent for identifying real straps, buckles, and hardware options

11.6 Human Factors & Ergonomics

- **NASA Human Factors Design Standard:** Search "NASA-HFDS" on hq.nasa.gov for free PDF
- **Human Factors and Ergonomics Society:** hfes.org — student resources and design guidelines
- **Book:** "Designing with the Mind in Mind" — Jeff Johnson (how humans process information and make errors under stress — directly relevant to your design)

11.7 Real-World Design Inspiration

- **Holter Monitor Holster Systems:** Search "ambulatory ECG holster" on Google Images and medline.com for professional examples
- **Ottobock Prosthetics:** ottobock.com — technical documentation on prosthetic limb socket design and secure body attachment
- **Wilderness Medicine Institute:** nols.edu/wmi — emergency medicine protocols in austere environments, analogous to space medicine
- **Search:** "sports GPS vest holster design" for examples of wearable technology mounting on active bodies

12. Evaluation Rubric

Criteria	Excellence Looks Like
Functional Requirements Met (30%)	All FRs addressed in prototype and written justification. No requirements ignored.
Prototype Quality (25%)	Testable prototype demonstrates all core mechanisms and shows clear engineering intent — not just an art project.
Test Documentation (20%)	Multiple runs documented with real timing data. Failures analyzed honestly. Iterations shown with evidence of learning.
Innovation & Design Thinking (15%)	Solution goes beyond the obvious. Edge cases considered, multiple user scenarios explored, genuine insight from research applied.

Presentation (10%)	Clear, confident, within time limit. Design choices justified with engineering reasoning, not just aesthetics.

13. Final Tips from the Engineering Team

TIP 1: Do not try to make it look pretty first. Make it work first. A cardboard prototype that deploys in 58 seconds beats a beautifully 3D-printed one that takes 3 minutes.

TIP 2: Test on real people, not mannequins or pillows. Human thighs are irregular, warm, and move unexpectedly. Your device must handle all of this.

TIP 3: Read the KardiaMobile manual and look up its exact dimensions, electrode positions, and Bluetooth specs. You cannot design a holster for a device you do not fully understand.

TIP 4: Think about what happens in 5 years of use. Will the elastic stretch out? Will velcro get clogged with lint? Will plastic crack from repeated sterilization? Design for durability.

TIP 5: Failure is information. When something breaks or does not work, write it down immediately. The most compelling presentations show honest failure analysis and genuine iteration.

TIP 6: Ask yourself: could a stressed, sleep-deprived person deploy this device correctly at 3am after being woken by an alarm? That is your real usability test.

Good luck. Lives depend on engineers like you.