ENGINEERING DESIGN PROJECT

Lunar Splint

Design Challenge

3D Printing Medical Devices for the Moon

Space Medicine · Biomechanics · Additive Manufacturing

The Key Assumption

Without on-site printing

- Pre-made splints launched from Earth
- Fixed sizes — poor fit for bone-density-depleted limbs
- Launch mass ~$1M per kg — every gram counts
- No adaptation possible once on the Moon

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With on-site 3D printing

- Printer + filament launched instead of pre-made splints
- Custom fit from patient scans — ideal for any limb
- On-demand fabrication — no stockpiling every size
- Designs updated from Earth and re-printed as needed
- Novel lunar-specific designs impossible to ship pre-made

Design assumption: The lunar base has an FDM or SLA printer stocked with PEEK and TPU filament, and can print a custom splint within 4–8 hours of injury.

Why the Moon Changes Everything

Four constraints that make lunar splint design a fundamentally different problem

1/6 gravity

Lower axial bone load — but falls still happen in bulky suits. Fracture forces differ; healing mechanics are not well understood in lunar gravity.

Bone density loss

Astronauts lose 1–2% bone mass per month in transit. Crew arrive on the Moon more fracture-prone and may heal more slowly.

No hospital for months

Earth return takes days at minimum. Splints must be wearable for weeks — with adjustability for swelling and long-term hygiene.

Regolith hazard

Lunar dust is razor-sharp crystalline glass. It destroys velcro, fouls any mechanism, and is present everywhere on the surface.

Injury Scenarios Requiring Splinting

Injury	Site	Lunar risk factor	Design difficulty
Stress fracture	Tibia / fibula / metatarsals	**HIGH — bone density loss in transit**	Intermediate
Acute fall fracture	Wrist, forearm, ankle, clavicle	**HIGH — rocky terrain + suit bulk**	Beginner–Intermediate
Finger fracture / dislocation	PIP / DIP joints	**MOD–HIGH — EVA glove snag risk**	Beginner
Lateral ankle ligament tear	Lateral ankle	MODERATE — stiff EVA boots	Intermediate
Achilles partial tear	Posterior ankle	MODERATE — repetitive boot loading	Advanced

Students select one injury. Difficulty determines project complexity requirements.

The On-Site Printing Advantage

1
Injury occurs
EVA or habitat

2
Limb scan
X-Ray or Ultrasound

3
Design adapted
From Earth or on-base

4
Splint printed
PEEK or TPU filament
Prototypes can be different filament

5
Custom fit
Applied within hours

Recommended materials for on-base printing

PEEK
Gold standard

- Stable −200 °C to +250 °C
- Biocompatible
- High strength-to-weight
- Radiation resistant

TPU
Flexible layer

- Absorbs impact loads
- Skin-contact comfort
- Can become brittle below −40 °C
- Best used in habitat

CF-PEEK
Advanced

- Carbon fibre reinforced
- Extreme rigidity
- Lightest option
- Higher print complexity

Regolith+
Novel / research

- Sintered lunar dust + binder
- Zero mass from Earth
- Brittle — needs careful design
- Active research area

Required Novelty — Lunar-Specific Innovations

Students must incorporate at least one of these innovations — Earth splint copies will not be accepted

A

Thermal phase design

Uses shape-memory polymer or TPU lattice that transitions between rigid (cold / shadow) and semi-flexible (warm / sunlit) — both states must immobilize adequately.

B

Single-piece ratchet closure

No loose parts that could become habitat hazards. Printed friction-lock geometry replaces velcro (which lunar regolith destroys) and separate screws.

C

Swelling-adaptive lattice

Variable-density gyroid or honeycomb infill that compresses gently as post-injury swelling occurs, eliminating repeated adjustments by medical staff.

D

Rehab-progressive locking

Full immobilization with locking pins in place; controlled range-of-motion when pins are removed. One splint serves the entire recovery arc — no second device needed.

E

Regolith-resistant geometry

All grooves, hinges, and closures are sealed or self-clearing. No surface trap for lunar dust, which is razor-sharp glass at the micro scale.

Lunar Biomechanics for Splint Designers

Gravity & load distribution

- Axial load on long bones is ~83% lower than Earth
- Lateral forces from stumbles remain nearly the same
- Splint stiffness can be lower along the bone axis
- Lateral / torsional reinforcement still critical
- Gait is different due to 1/6 gravity — very different from walking

Bone density considerations

- 1–2% bone mineral density loss per month in transit
- 6-month mission= potential 6–12% density reduction
- Callus formation during healing may be impaired
- Splint must account for longer immobilization
- Stress fracture risk remains high even post-fracture

Your Design Challenge

Design requirements

1. Immobilizes the assigned injury adequately for the lunar environment

2. Printable with ABS, PLA or other 3D print material. Although your prototype can be printed in common material, explain what kind of 3D print material you would use for flight.

3. Accounts for long-term habitat wear

4. Incorporates at least one lunar-specific novel innovation (A–E)

5. Justifies material choice against thermal and radiation requirements

6. Mass budget: calculate filament mass and justify against ~$1M/kg launch cost

Deliverables

01 **Biomechanics rationale**
1–2 pages: how does the Moon change your design?

02 **Annotated concept sketch**
Every design decision labeled with its reason

03 **CAD model or detail drawing**
Geometry, wall thickness, closure, material

04 **Mass & print-time estimate**
Filament mass vs launch cost justification

05 **Design review (5 min)**
Present as if to a lunar base medical officer

Grading Rubric- only a suggestion for teachers

100 points total

Biomechanics accuracy

Does the design correctly address 1/6 g, bone density loss, temperature, and suit constraints for the specific injury chosen?

25 pts

Novelty & justification

Is the chosen lunar-specific innovation (A–G) well-reasoned, clearly described, and integrated into the design rather than just mentioned?

25 pts

Design completeness

Are geometry, wall thickness, closure mechanism, material selection, and fit all addressed? No critical design gaps.

20 pts

Mass & printability

Realistic filament mass estimate, print time considered, material selection justified against thermal and radiation environment.

15 pts

Presentation & defense

Clear communication, confident answers under questioning, presented as if speaking to a lunar base medical officer.

15 pts

Resources

Research	Lunar biomechanics, bone density literature, injury selection
Concept	Annotated sketches, novelty feature selected, initial material specification
Design	CAD model or detailed drawings, closure mechanism worked out, mass estimate
Review prep	Biomechanics rationale written, mass budget finalized, presentation prepared
Presentation	5-minute design defense to class as lunar base medical review panel

Key reference topics

- NASA Human Research Program — bone loss in spaceflight
- Apollo program EVA suit design lessons (regolith / dust)
- ISS medical procedures — remote medicine protocols
- PEEK biocompatibility & thermal properties (literature)
- Shape-memory polymers for orthopedic applications
- Lunar regolith sintering research (ESA / NASA)
- 3D-printed splints in emergency medicine (terrestrial baseline)

Mission briefing complete.

Your crew is counting on you.

Design a splint that works in the most hostile environment humans have ever inhabited.
Make it light enough to justify the launch cost. Make it smart enough for the Moon.

Questions? Select your injury. Begin your research. Good luck.