AIRS; An On-Demand Electromagnetic Radiation Shielding for Human Surface Habitats on Mars

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1. Why radiation is a settlement-level constraint

Radiation exposure shapes habitat architecture, operations, and long-term survivability.

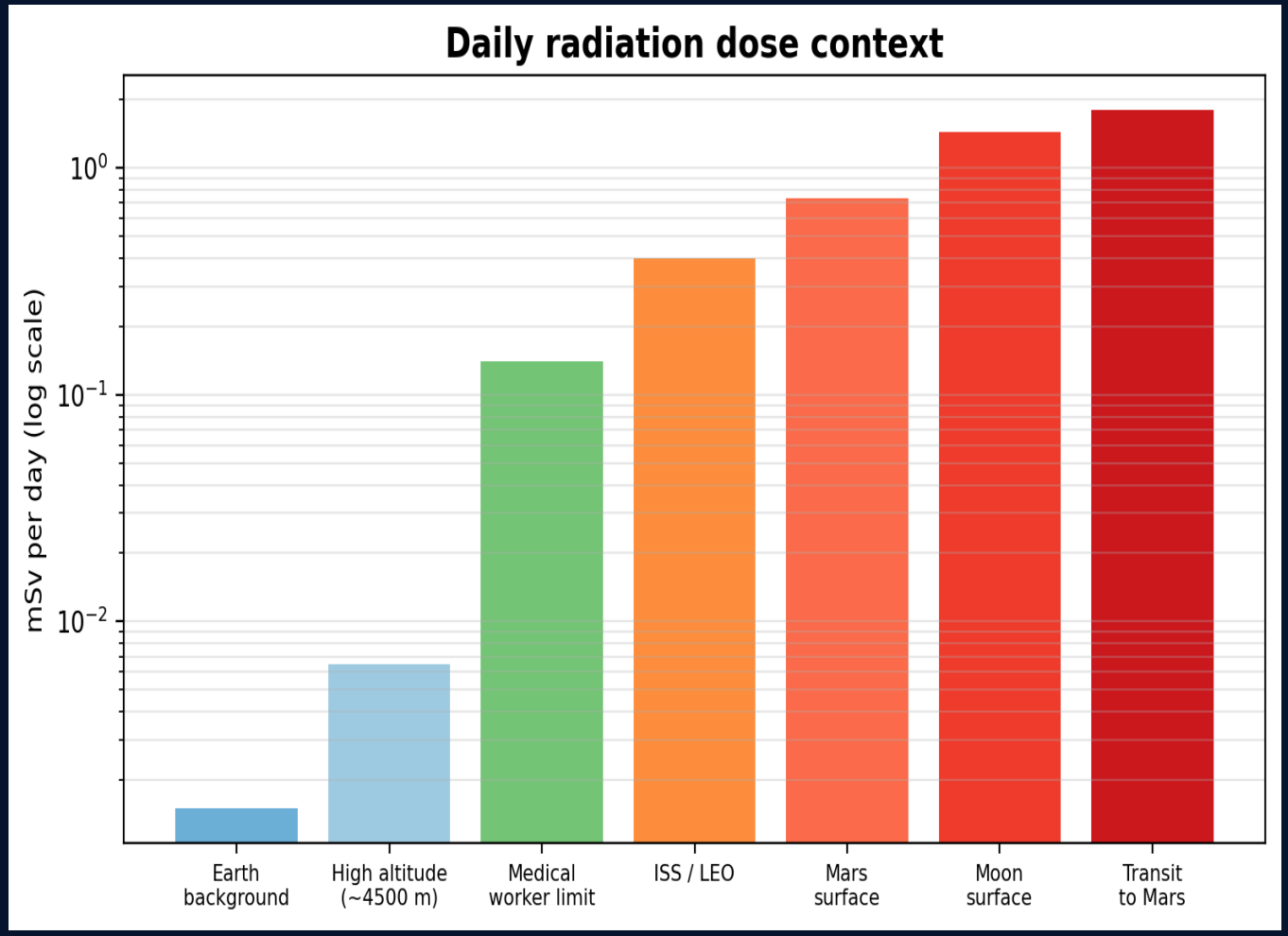
0.65 – 0.82
mSv/day
reported on Mars surface

300–1000×
higher than typical Earth background

80–95%
of Mars radiation burden attributed to GCR (Avg 0.67mSv/day)

A Mars habitat must do four things at once: maintain pressure, preserve daylight, support agriculture, and keep cumulative radiation within a survivable envelope.

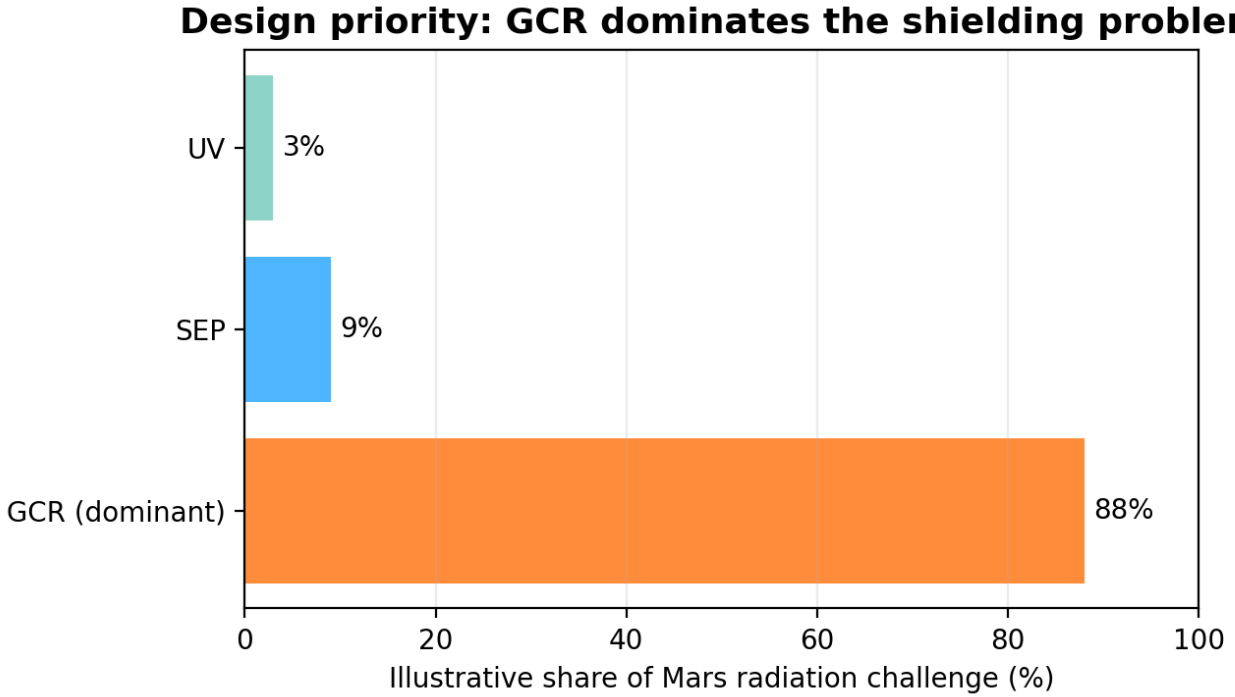
Why this matters:
- Chronic exposure raises long-term health risk.
- Surface living without protection undermines permanent settlement.
- Large city-scale habitats need a solution beyond small buried shelters.



Sources:
1. marspedia.org/Radiation
2. phys.org/news/2013-12-scientists-publish-surface-mars.html

2. What must be mitigated?

Mars radiation as a predominantly GCR problem, with SEP spikes and UV also relevant.



Design implication: a practical Mars habitat likely needs a layered strategy - UV filtering shell, active magnetic deflection for charged particles, hydrogen-rich passive materials where useful, and a dedicated storm shelter for exceptional events.

Galactic Cosmic Rays (GCR)

Deep-space, highly energetic charged particles. Creates secondary radiation. Hard to stop with thin material; the dominant design driver for AIRS.

Solar Energetic Particles (SEP)

Lower-energy, event-driven particle bursts from the Sun. Important for storm operations and emergency sheltering.

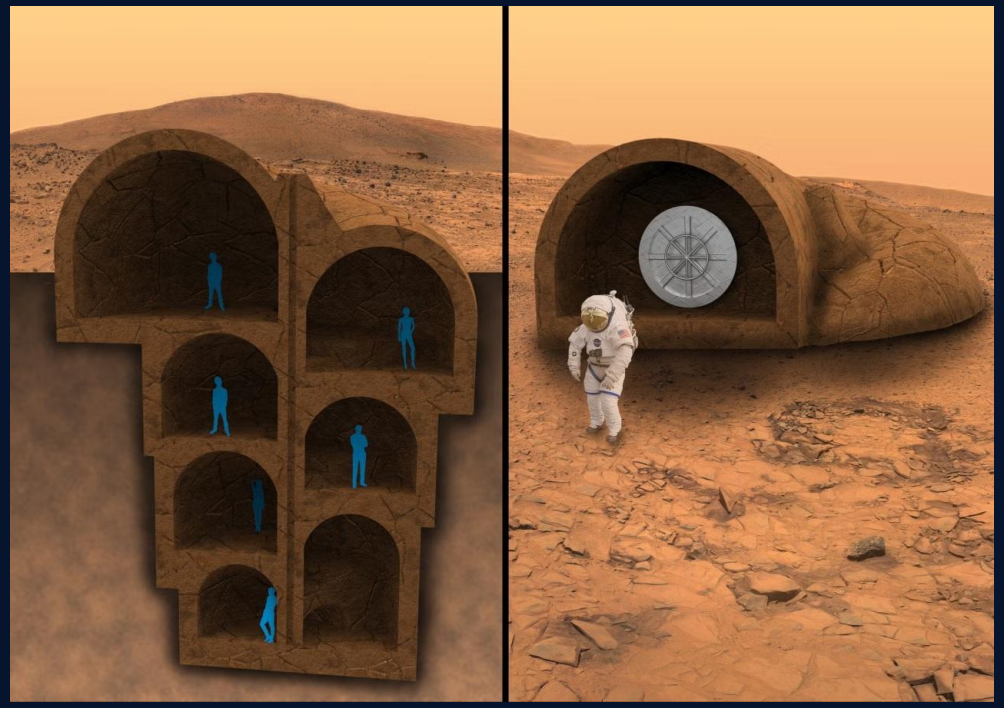
Ultraviolet (UV)

Composite material-based habitats with Polyimide coating can filter most UV, so UV is more manageable than GCR/SEP for surface habitats.

The component split is illustrative and aligned with the article’s qualitative hierarchy: GCR dominates, SEP is episodic, UV is more tractable.

3. Why passive shielding alone becomes difficult at large scale

Several meters of regolith or water work physically — but they constrain construction, daylight, and habitable volume.



Underground habitats

Excellent shielding, but weaker daylight access, more excavation, more claustrophobic living, and harder city-scale micro-terraforming.

Heavy overhead shielding

Regolith or water barriers become structurally demanding when stretched across very large, pressurized, sunlit spaces.

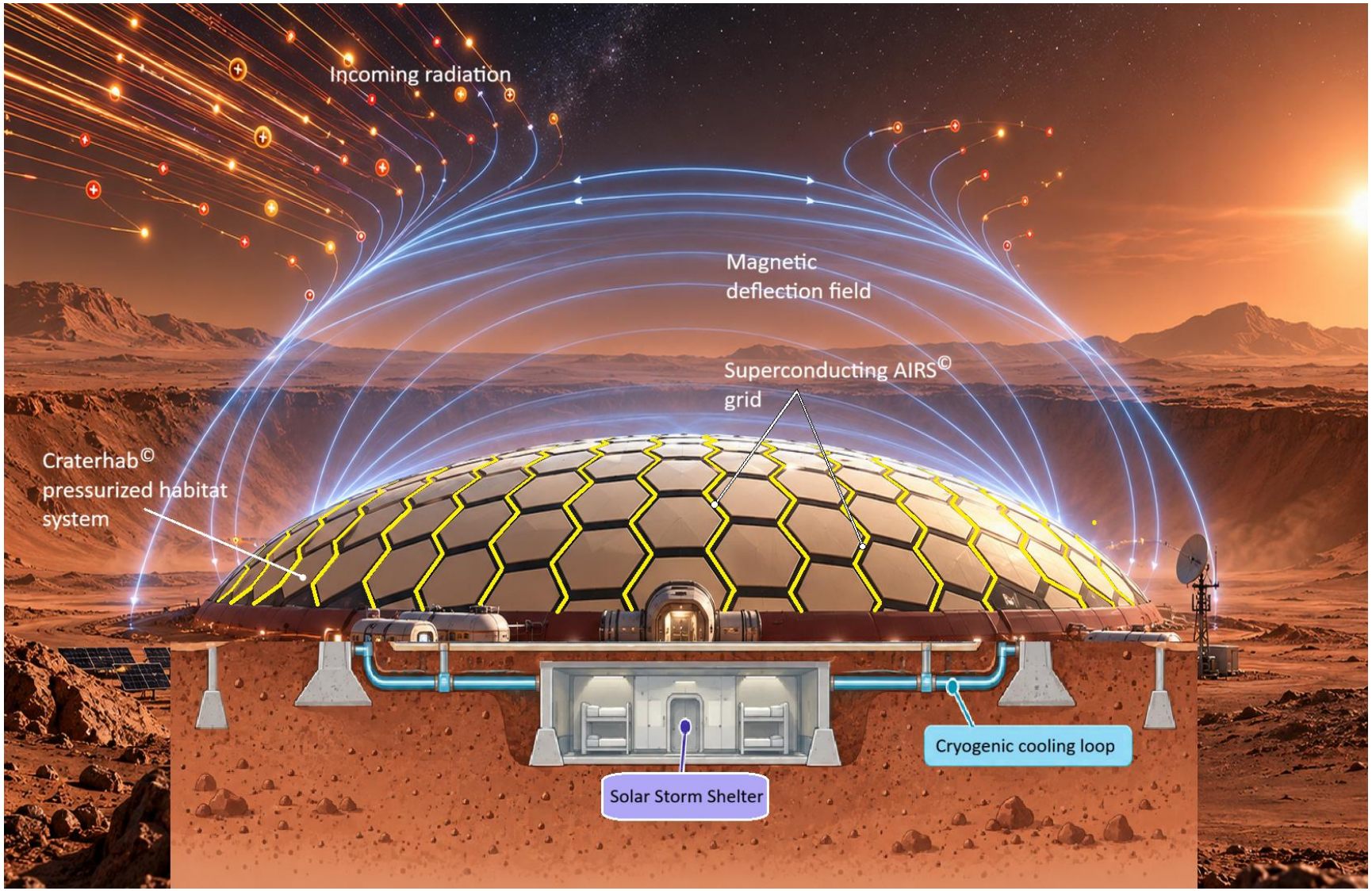
Operational consequence

If the settlement must stay on the surface and use natural light, radiation mitigation must be integrated into the habitat architecture itself.

Cross-section graphic from the article; argument summarized from the radiation and habitat architecture discussion.

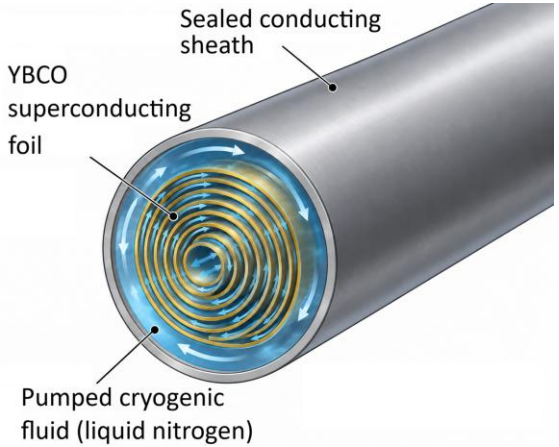
4. Active Integrated Radiation Shield (AIRS) Patent No. US 20220290422 A1

AIRS is proposed as an on-demand magnetic deflection system integrated into the Craterhab™ dome.



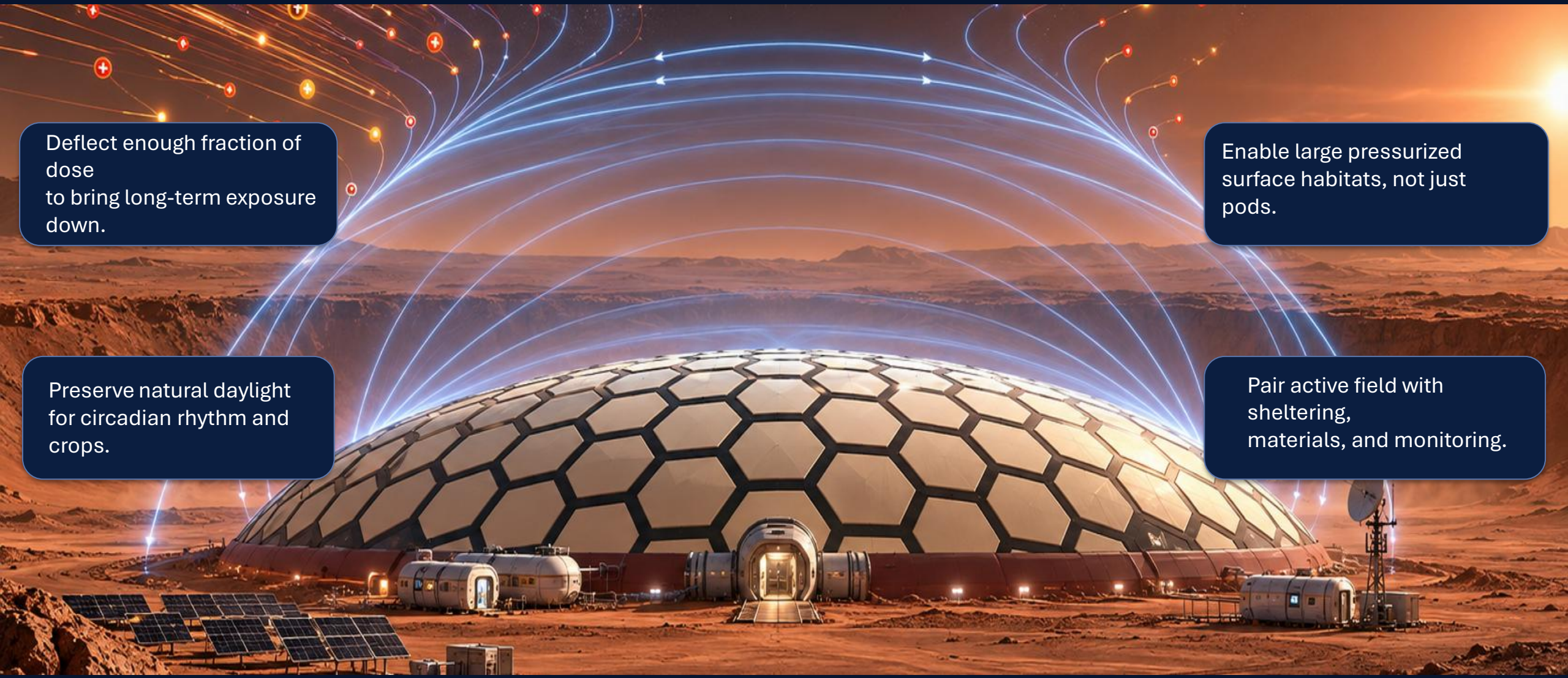
1. Conductors follow the Craterhab structural grid.
2. Direct current creates a local magnetic field over the habitat.
3. Charged particles are bent away rather than fully absorbed.
4. Cryogenic cooling enables superconducting operation.
5. A storm shelter remains as a fail-safe for extreme events.

Core principle: controlled deflection, not total absorption.



5. AIRS in action: the habitat-scale protective field

Concept image created for this deck: incoming charged particles are diverted around the dome.



This visualization is a presentation concept rendering, not a measured field map.

6. Preliminary engineering envelope

Field strength, current, and cooling input for different habitat sizes.

Selected concept values (1 GeV case)

Dome	Grid length	Field	Current	Cooling input
50 m	200 m	182.4 mT	3806 kA	7 kW
100 m	800 m	91.2 mT	3806 kA	28 kW
250 m	3330 m	45.6 mT	2040 kA	116 kW
500 m	19350 m	18.24 mT	786 kA	675 kW

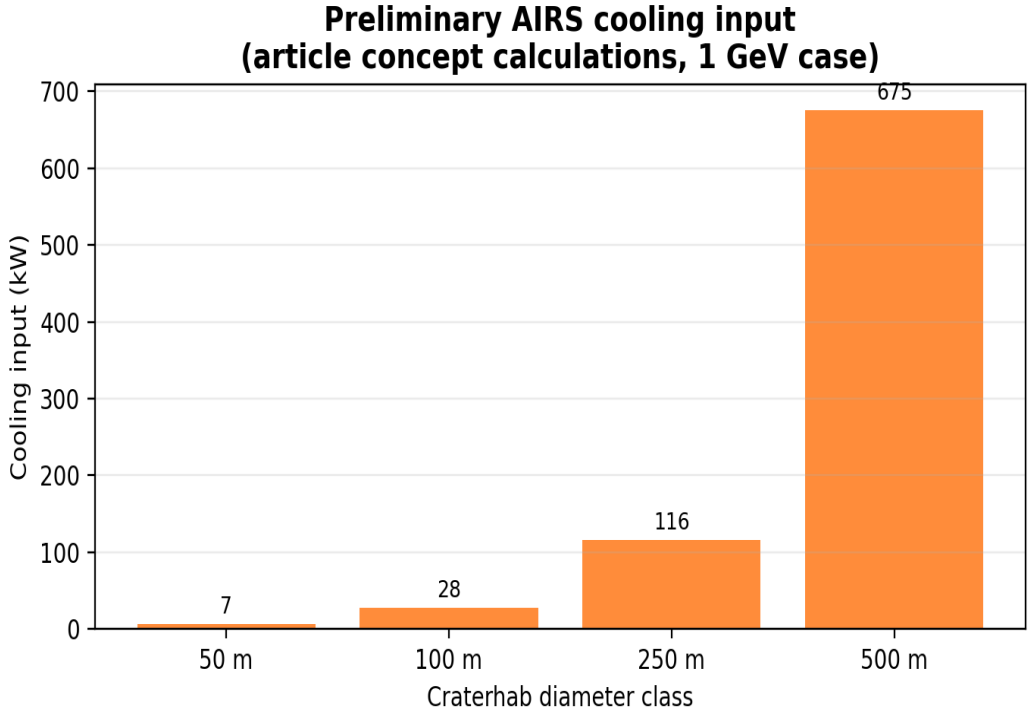
Power demand is dominated by cooling and pumping, not resistive loss.

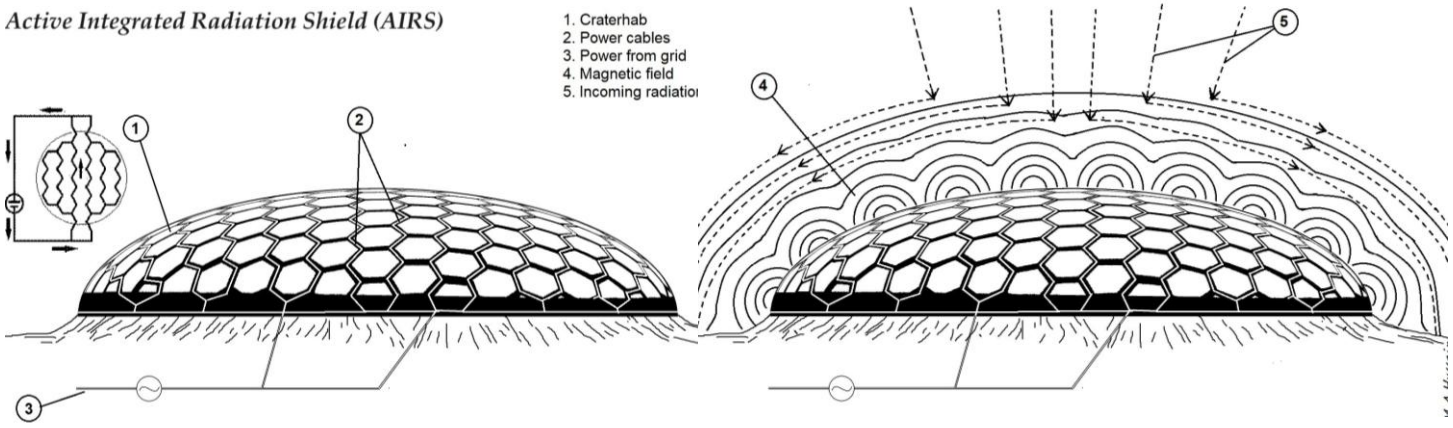
Physical framing

$F = qvB$ — *Lorentz Force Equation*

$r = mv/qB$ — *Radius of curvature of proton path*

$B = mv/qr$ — *Magnetic Field Strength*





7. AIRS Concept improvements

To strengthen the overall safety case.

1

Layered protection

Radiation protection should not rely on magnetic field alone. Combine AIRS with UV-filtering shell, hydrogen-rich liners, selective local shielding, and an underground storm shelter. Crater walls and slopes shield against part of the incoming radiation.

2

Segmented coil architecture

Independently switchable sections of the AIRS grid may enable fault isolation, staged maintenance, dynamic field shaping across the dome and improved redundancy.

3

Distributed dosimetry

Radiation sensors placed around the dome and in living zones for real-time field tuning, alarm logic, and long-term dose accounting.

4

Storm mode operations

During SEP alerts, temporarily boost protection, pause EVA, move occupants to better-shielded zones, and use shelter-on-demand protocols.

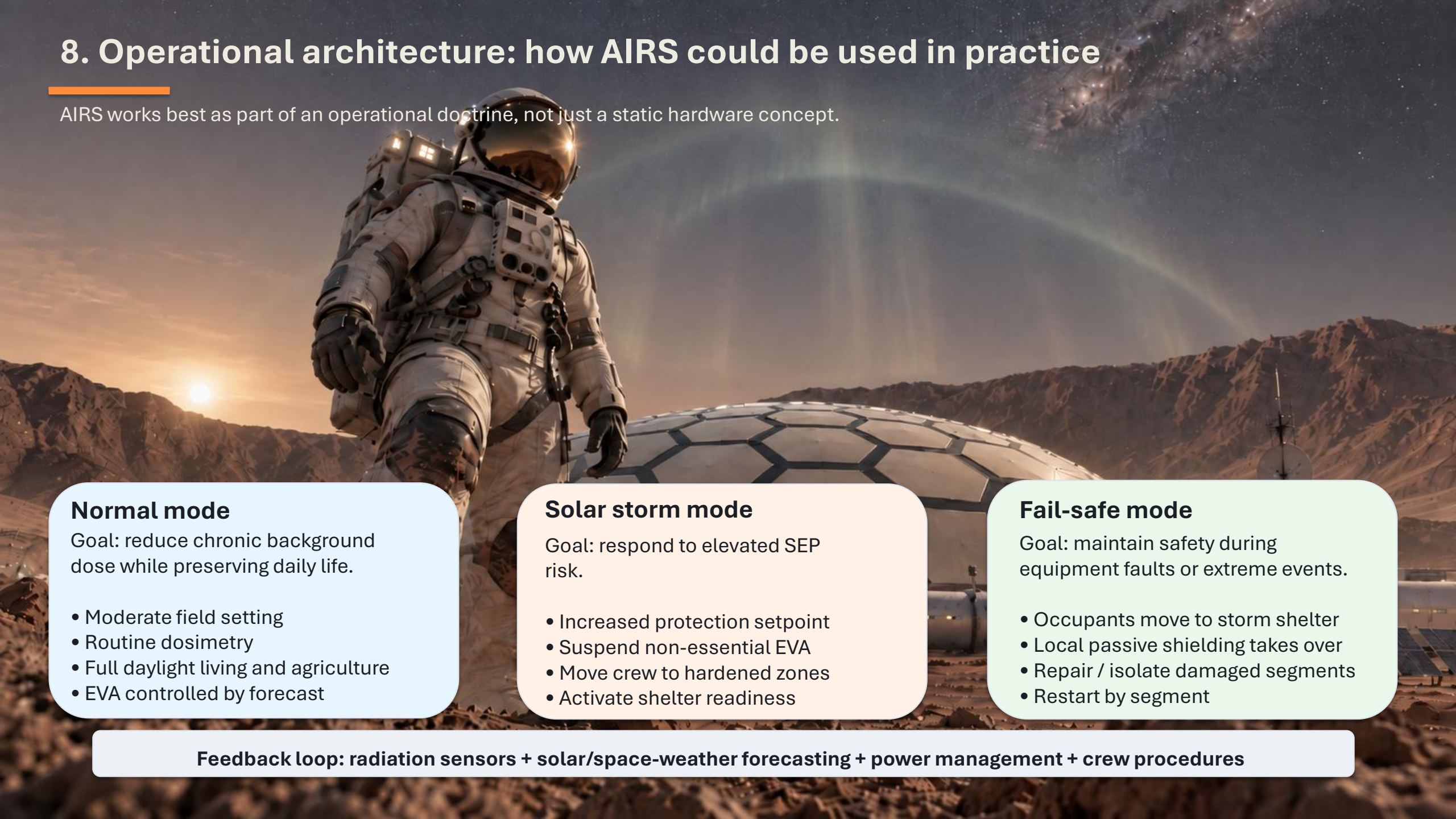
5

Hybrid habitat zoning

Shield the highest-occupancy or medically sensitive areas first: sleeping quarters, clinic, nursery, food production, and mission control.

8. Operational architecture: how AIRS could be used in practice

AIRS works best as part of an operational doctrine, not just a static hardware concept.



Normal mode

Goal: reduce chronic background dose while preserving daily life.

- Moderate field setting
- Routine dosimetry
- Full daylight living and agriculture
- EVA controlled by forecast

Solar storm mode

Goal: respond to elevated SEP risk.

- Increased protection setpoint
- Suspend non-essential EVA
- Move crew to hardened zones
- Activate shelter readiness

Fail-safe mode

Goal: maintain safety during equipment faults or extreme events.

- Occupants move to storm shelter
- Local passive shielding takes over
- Repair / isolate damaged segments
- Restart by segment

Feedback loop: radiation sensors + solar/space-weather forecasting + power management + crew procedures

9. What AIRS enables for Mars habitats

If it works, AIRS is not just a shield - it is an enabling architecture for surface civilization.

Natural light	Support human circadian rhythm, psychological health, and crop growth.
Large habitable volume	Avoid burying every living space; enable micro-terraformed habitats at city scale.
Surface dwelling	Let people live and work in shirt-sleeve environments rather than only underground.
System convergence	AIRS integrates with the Craterhab structure, habitat operations, and shelter strategy.

AIRS converts radiation mitigation from “bury the habitat” to “engineer a protective field around the habitat.”

Take-home message

Mars settlement requires habitats that are pressurized, spacious, daylight-filled, and credibly protected from radiation.

AIRS in a nutshell

AIRS is a proposed habitat-integrated, on-demand magnetic shielding architecture intended to make large surface settlements safer without sacrificing natural light and large habitable volume.

References:

- Hussain, “CRATERHAB™ TECHNOLOGY: An Engineering Overview and its Applications” (2024)
- Marspedia.org/Radiation
- Phys.org/news/2013-12-scientists-publish-surface-mars.html
- NASA Curiosity RAD mission pages for Mars surface radiation context
- Additional concept-improvement suggestions added for this ASRC 2026 presentation revision

Prepared as an improved presentation draft in PPT format.