Micrometeoroids and Debris Even small micrometeoroids and debris can cause severe damage to space habitat elements or the crew itself (when on EVA). Micrometeoroids pass through space and the lunar surface at very high velocities. Since larger modules present bigger targets, they present greater hazard risks. A popular shielding strategy applies a ‘Micrometeoroid and Secondary Ejecta’ (MMSE) barrier to the external module structures, with particular attention to vulnerable top and side locations of surface modules that comprise about 3/4th of the module surface areas. A typical approach provides an exterior beta-cloth fabric layer with an interior Nextel/Kevlar blanket over the pressure shell. Estimated required MMSE shield mass is 10 kg/m2 (Table 5.11).

For the Micrometeoroid and Orbital Debris (MMOD) at the International Space Station, three shielding configurations are used (NASA [Shielding] 2003): Whipple shield: A two layer shield consisting of an outer bumper (usually Aluminum), spaced some distance from the module pressure shell wall; the bumper plate is intended to break up, melt, or vaporize a particle on impact. Stuffed Whipple shield: It consists of an outer bumper (Aluminum), spaced a distance from the module pressure shell, with a Nextel ceramic cloth and Kevlar fabric in between. Multi-layer Shields: They consist of multiple layers (fabric and/or metallic panels)

Description Front bumper Rear bumper Spacer Total Material Kevlar composite fabric 0.25 cm thick- 5 layers of 300 g/m2 Kevlar fabric Nextel 0.30 cm thick Kevlar 0.64 cm thick Area density (kg/m2) 1.5 2.8 4.0 1.7 10

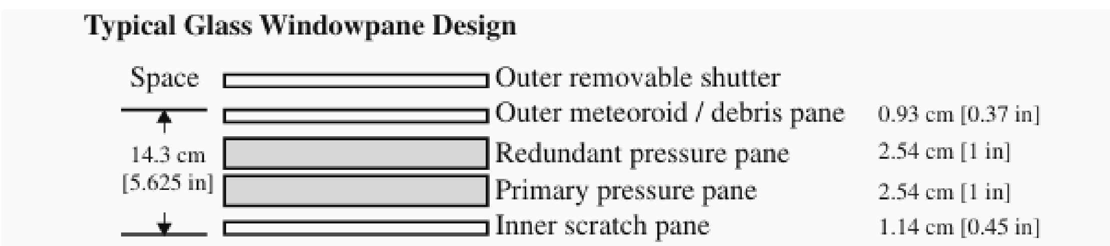
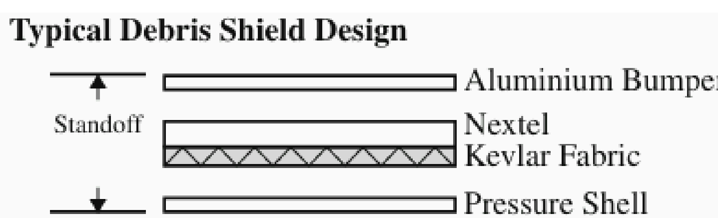


Fig. 5.16 Schematic design of glass window panel (based on NASA documentation)

Fig. 5.17 Schematic design of debris shield (based on NASA documentation)



Habitats/architecture design

Space station's configuration, orientation, and orbital flight mode critically impact planning and design options, including solar tracking for power, radiator positioning for heat rejection and space debris protection, balancing gravity gradient and aerodynamic torques for orbital stability, drag minimization to maintain efficient orbital life, outside viewing for monitoring, psychological benefits, sciences, and rendezvous and docking corridors for assembly and transfers.

Radiation Shielding:

- **Orbital Habitat:** Uses water as a possible shielding material, but it must be launched from Earth.
- **Planetary Habitat:** Can use in-situ resources (Lunar and Martian regolith) for radiation shielding, which can be attached externally or printed.
- **Mobile Habitat:** The mass of the shielding material is a relevant factor.

Pressure Ports:

- **Orbital Habitat:** Ports are often located at distal axial ends.
- **Planetary and Mobile Habitats:** Require ports with dust control.

EVA Airlock:

- **Orbital Habitat:** Incorporates an airlock and zero-gravity optimized suits.
- **Planetary Habitat:** Airlock can be landed separately and assembled on the surface; inflatable airlock is a possibility.
- **Mobile Habitat:** Inflatable airlock is a possible solution.

Countermeasures against Microgravity:

- **Orbital Habitat:** Requires diverse types of exercise equipment and countermeasures such as a small diameter, human-powered centrifuge.
- **Planetary Habitat:** In partial gravity (0.38G on Mars and 0.6G on the Moon), more spatial solutions are possible, but exercise equipment is still needed.
- **Mobile Habitat:** Less important if the mission duration is limited.

Gravity Orientation:

- **Orbital Habitat:** Optimized for 0G operations.
- **Planetary and Mobile Habitats:** Optimized for partial gravity operations.

Life Support:

- **Orbital Habitat:** Physical/chemical closed-loop system with a possible plant-growth unit.
- **Planetary Habitat:** Physical/chemical system including local resources with CELSS component; water can be extracted from Mars' CO_2 atmosphere through the Sabatier process; large greenhouse is possible.

- **Mobile Habitat:** Physical/chemical systems can connect to the main habitation system; a small portable greenhouse is optional.

Power Systems:

- **Orbital Habitat:** Uses solar panels and batteries.
- **Planetary Habitat:** Utilizes solar fields, batteries, and possibly nuclear power generators.
- **Mobile Habitat:** Employs solar cells and batteries, considering volume and mass.

Other Considerations:

- **Orbital Habitat:** Requires interior orientation and navigation cues.
- **Planetary Habitat:** Focuses on dust control and clean rooms.
- **Mobile Habitat:** Includes mobility systems, motors, and mechanisms.