Planetary Protection & Biosecurity

1) First Principles: No-First-Harm, Dual-Use Risks, and the Commons Ethic

1. **State the pledge: no-first-harm, no hidden data, no hype—who signs and how enforced.**
2. **Define “planetary protection” vs. “biosecurity” and where they overlap/diverge.**
3. **Identify dual-use risks (tools that help care can also harm); set guardrails.**
4. **Draw the ethical boundary between exploration, terraforming, and restraint.**
5. **Clarify public-interest tests for any biological deployment on/off-world.**
6. **Set bright-line prohibitions (e.g., unvetted release, covert field trials, data concealment).**
7. **Publish the transparency stack: truth boards, audits, independent ombuds.**
8. **Create annual renewal rituals and consent briefings for all staff/partners.**
9. **Define breach ladders (warn → remediate → suspend → replace operator).**

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2) Forward vs. Backward Contamination: Boundaries, Scenarios, and Risk Classes

1. **Define forward (Earth → celestial body) vs. backward (space → Earth) contamination.**
2. **Create risk classes by mission type (flyby, orbiter, lander, sample return, crewed).**
3. **Map plausible contamination vectors (dust, ice, aerosols, fluids, hardware).**
4. **Write boundary conditions for “clean zones” vs. “contact zones”.**

5. **Set allowable bioburden thresholds and measurement methods.**
6. **Draft decision trees for unexpected bio-signals (halt? retreat? isolate?).**
7. **Specify containment levels for sample return vs. in-situ use.**
8. **Assign responsibilities (PI, biosafety officer, mission ombud) and escalation clocks.**
9. **Tabletop scenarios: near-misses and "unknown unknowns" drills.**

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3) Governance Stack: COSPAR Alignment, Treaties, Licenses, and Local Protocols

1. **Summarize COSPAR categories and how your projects align.**
2. **Trace treaty obligations (Outer Space Treaty, Moon Agreement—where relevant).**
3. **List licensing/permit routes for national jurisdictions.**
4. **Build local protocols for field sites, ports, and labs (Earth & off-world).**
5. **Create pre-mission compliance checklists and document retention rules.**
6. **Establish change-control for scope shifts mid-mission.**
7. **Define joint governance with partners/consortia; who holds vetoes.**
8. **Publish public summaries of compliance and inspection outcomes.**
9. **Plan periodic policy reviews as science/regulation evolves.**

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4) Clean Materials, Clean Assembly: Plastic-Free, Low-Shedding, and Bioinert Standards

1. **Set a banned list (PFAS, shedding plastics/foams) and approved materials palette.**
2. **Define bioinert surfaces and cleanability criteria.**
3. **Specify low-shedding textiles, seals, and gaskets; test methods.**
4. **Create clean assembly SOPs (wipe-downs, bake-outs, particle counts).**
5. **Establish dedicated clean benches & tool control (no cross-contamination).**
6. **Document acceptance tests (emissions, particles, residues).**
7. **Track lot/serial traceability via parts passports.**
8. **Build refurb cycles that maintain cleanliness ratings.**
9. **Publish nonconformance handling and re-work rules.**

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5) Sterilization & Bioburden Control: Heat, Dry-Heat, VHP, UV-C, Gamma, Compatibility Maps

1. **Compare sterilization options and compatibility with your materials.**
2. **Define target log-reductions for risk classes.**
3. **Map process windows (temp, dose, dwell) and sensors to validate.**
4. **Write load configuration rules (shadowing, venting, indicators).**
5. **Establish environmental monitoring before/after cycles.**

6. **Manage residues (e.g., VHP aeration) to protect downstream habitats.**
7. **Qualify vendors/equipment and calibration intervals.**
8. **Build re-sterilization limits by component life.**
9. **Record chain-of-custody and release criteria before shipment.**

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6) Cleanrooms & Aseptic Field Ops: Gowning, Flow, Zoning, and Tool-in-Glove Procedures

1. **Design room classes, pressure cascades, and unidirectional flow.**
2. **Write gowning sequences and material staging rules.**
3. **Zone tools and carts; bar cross-zone traffic without re-prep.**
4. **Establish aseptic technique for field assembly (tents, bubbles, air knives).**
5. **Define routine and terminal cleaning schedules; allowed agents.**
6. **Implement access control and personnel training logs.**
7. **Perform settle plates/air sampling and action levels.**
8. **Capture deviations, corrective actions, and retraining triggers.**
9. **Drill “loss of containment” events and recovery steps.**

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7) Microbiome Management: Allowed Consortia, Sentinel Organisms, and Drift Monitoring

1. **Define permitted consortia (soil, algae, fungi) by habitat zone and purpose.**
2. **Select sentinel organisms and indicators for drift/toxicity.**
3. **Create inoculation SOPs and quarantine for new biota.**
4. **Establish routine assays (qPCR panels, ORP/EC trends, respiration).**
5. **Set thresholds for re-balance interventions (re-inoculate, rest, flush).**
6. **Manage antagonists (antibiotics, disinfectants, metals) with detection/response.**
7. **Log provenance, storage, and expiry for all cultures.**
8. **Maintain a genetic library with barcodes and access controls.**
9. **Publish microbiome health dashboards (aggregate, privacy-safe).**

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8) Genetic Safeguards: Kill-Switches, Auxotrophy, Barcodes, and Containment Levels (Bio^0→Bio^3)

1. **Choose safeguards per application (kill-switch, auxotrophy, dependency).**
2. **Define containment levels for living systems (Bio^0 to Bio^3) by risk/use.**
3. **Include barcoding/tagging for traceability; verify stability.**
4. **Model failure modes and layered safeguards (defense in depth).**
5. **Write field-disable procedures and “dead-man” conditions.**

6. **Test safeguard efficacy under environmental extremes.**
7. **Document ethical review and consent for any genetic work.**
8. **Set decommissioning protocols for genetic constructs.**
9. **Publish non-release guarantees and auditability.**

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9) Life-Support Biosecurity: Water/Air Loops, Biofilm Control, Pathogen Modes, Plant-Polish Validation

1. **Color-code/segregate water streams; air pressure zoning.**
2. **Write sanitation pulses (heat/UV) and post-pulse validation.**
3. **Map biofilm risks and maintenance cycles.**
4. **Define outbreak modes (ACH surge, recirc limits, safe rooms).**
5. **Validate plant-polish beds (residence time, contaminants to ppb).**
6. **Draft cross-connection prevention and test protocols.**
7. **Integrate lab QA/QC and chain-of-custody for samples.**
8. **Establish re-occupancy criteria after an incident.**
9. **Log KPIs on Truth Boards (aggregate, privacy-safe).**

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10) Sample Handling & Planetary Quarantine: Chain-of-Custody, Cold Traps, and Return Facilities

1. **Design chain-of-custody forms, seals, and time stamps.**
2. **Select containment levels for sample types (gas, dust, ice, rock).**
3. **Define cold traps/cryogenic holds and monitoring.**
4. **Build quarantine facility flows (dirty → decon → analysis → archive).**
5. **Establish destructive vs. non-destructive analysis balances.**
6. **Write personnel protection and decon exits.**
7. **Simulate "alarm" events (unexpected growth/biomarkers).**
8. **Publish release criteria for samples and data.**
9. **Archive metadata and shareable records for future science.**

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11) ISRU & Bioprocesses: Soil/Regolith Contact Rules, Bioreactors, and Waste Pathways

1. **Set contact rules for regolith/ice (tools, liners, pre-sterilization).**
2. **Choose closed bioreactors vs. open beds for process goals.**
3. **Prevent cross-contamination between ISRU and life-support loops.**
4. **Validate effluents (gas/liquid/solid) before release/reuse.**
5. **Define waste routing: mineralize, incinerate, reprocess.**
6. **Monitor process microbes and off-gas safely.**

7. **Integrate with energy/thermal cascades for efficiency.**

8. **Run failure drills (contamination, spill, runaway growth).**

9. **Track performance and publish audit summaries.**

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12) Waste & EOL Protocols: Red/Yellow/Green Streams, Incineration, Mineralization, and Audit Trails

1. **Classify waste streams with color coding and handling rules.**

2. **Specify containment for biohazard vs. non-bio hazard materials.**

3. **Choose EOL methods (incineration, mineralization, sterilize→recycle).**

4. **Document transport routes and custody logs.**

5. **Define on-site vs. off-site processing with permits.**

6. **Train staff on spills, sharps, and PPE disposal.**

7. **Audit downstream handlers; ban unsafe export.**

8. **Publish annual EOL reports (recovery %, incidents, fixes).**

9. **Reserve funding for remediation escrow.**

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13) Environmental Sensing & Truth Boards: Dose, Particulates, Bioaerosols, and Public Telemetry

1. **Select sensors (dose, $PM_1/_{2.5}/_{10}$, bioaerosols, VOCs) and placements.**
2. **Calibrate and drift-check schedules; acceptance tests.**
3. **Build tamper-evident pipelines and signed logs.**
4. **Design public dashboards (WCAG, multilingual) with context cards.**
5. **Set alert thresholds and automatic actions.**
6. **Enable citizen science kits and calibration days.**
7. **Archive time series and publish audits.**
8. **Protect privacy (aggregate, anonymize) while preserving safety value.**
9. **Track KPI health (data completeness, alert latency).**

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14) Incident Command for Bioevents: Detect → Isolate → Stabilize → Repair

1. **Define red-flag triggers (sensor + symptom + observation).**
2. **Write isolation steps (zones, valves, shutters, locks).**
3. **Stabilize with safe set-points; list allowed agents.**
4. **Assign roles (lead, scribe, runner, safety, comms).**
5. **Set SLAs for each phase; log evidence.**
6. **Transition to postmortem (5 Whys/FMEA) within fixed time.**

7. **Run quarterly cross-team drills and publish results.**
8. **Update SOPs after every event; time-box closeouts.**
9. **Offer restorative support to affected teams/residents.**

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15) Human Factors & Medical: Crew Screening, Vaccination, Mental Health, and Privacy

1. **Pre-deployment screening and vaccination baselines.**
2. **Daily symptom logs and “stay home” incentives.**
3. **Quiet/rest spaces and COLORVISION scenes for recovery.**
4. **Confidential care access and telehealth privacy.**
5. **De-stigmatize reporting; protect leave/pay.**
6. **Post-incident monitoring and fit-for-duty checks.**
7. **Store minimal medical data; role-based access only.**
8. **Publish de-identified health trends to the Truth Board.**
9. **Train leads in trauma-informed responses.**

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16) Field Logistics & Mobility: Sterile Transport, Staging Caches, and Decon Corridors

1. **Plan sterile transport packaging and seals.**

2. **Stage caches (PPE, wipes, swabs, bags) at entry points.**
3. **Build decon corridors (dirty → clean) for people/gear.**
4. **Route maps that avoid sensitive ecologies/sacred sites.**
5. **Define cold-chain for bio samples; logging and alarms.**
6. **Train drivers/porters; spill and breach drills.**
7. **Maintain chain-of-custody at every handoff.**
8. **Coordinate with emergency services and mutual aid.**
9. **Track logistics KPIs (on-time %, breach incidents).**

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17) Ethics & Indigenous Partnership: Sacred Sites, Cultural Consent, and Benefit-Sharing

1. **Map Indigenous territories and obtain free, prior, informed consent (FPIC).**
2. **Include cultural monitors in field teams; respect protocols.**
3. **Define no-go zones and seasonal restrictions.**
4. **Share benefits (jobs, training, royalties, data access).**
5. **Translate materials and provide public briefings.**
6. **Establish grievance lines co-managed with partners.**
7. **Co-author findings where appropriate; credit TEK contributions.**

8. **Annual renewal ceremonies and public commitments.**

9. **Publish partnership scorecards and remedies.**

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18) Algorithmic Risk & Data Dignity: Model Bias, Human Override, Tamper-Evident Logs

1. **Inventory algorithmic uses (triage, detection, routing).**

2. **Run bias audits across groups and environments; publish results.**

3. **Require explainability; offer simple appeals/overrides.**

4. **Track model drift and retraining cadence.**

5. **Protect against adversarial data injection; sign streams.**

6. **Limit data collection to minimal purpose; retention windows.**

7. **Independent audits of code and datasets.**

8. **Log every access and change; display model version on dashboards.**

9. **Sunset models that fail fairness or safety bars.**

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19) Audits, Verification & Certification: Third-Party Checks, Citizen Science, and Transparency Reports

1. **Set audit calendars (internal, external) and rotate firms.**

2. **Publish scopes and sampling plans before audits.**

3. **Collect corrective actions with owners and deadlines.**
4. **Invite citizen scientists; calibrate their kits.**
5. **Release audit summaries and raw (de-identified) data.**
6. **Track recurrence and sanction chronic failures.**
7. **Certify operators and revoke for misconduct.**
8. **Maintain an open repository of reports, searchable by site.**
9. **Celebrate improvements and lessons learned.**

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20) Education & Drills: Competency Ladders, Sims/Live Runs, and After-Action Loops

1. **Define competency ladders for all bio-critical roles.**
2. **Build curricula (classroom, sim, live) with recert cycles.**
3. **Run mixed-discipline table-tops; escalate to live runs.**
4. **Use objective SLAs and scorecards for drills.**
5. **Capture after-action reviews; assign fixes.**
6. **Track training hours and privileges tied to competency.**
7. **Share drill videos and quick-reference cards.**
8. **Reward near-miss reporting and proactive risk reduction.**

9. **Update training after each real incident.**

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21) Design for Disassembly: Hot-Swap Biocontainment, Sealed Interfaces, and Tool Unification

1. **Standardize sealed collars/quick-disconnects for bio loops.**
2. **Prove hot-swap times for pumps, filters, UV modules.**
3. **Provide single-tool service kits for gloved operation.**
4. **Ensure repair clearances and ergonomic access.**
5. **Use captive fasteners and loss-proof features.**
6. **Color-code flow directions and hazard levels.**
7. **Validate seals with pressure/trace-gas tests.**
8. **Track MTTR and feed improvements back into design.**
9. **Publish exploded diagrams and QR-linked repair videos.**

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22) Planetary Parks & No-Go Zones: Habitat Buffers, Wilderness Reserves, and Temporal Moratoria

1. **Define criteria for parks and reserves on/off-world.**
2. **Set buffer distances and activity constraints.**

3. **Establish temporal moratoria for sensitive seasons or science windows.**
4. **Implement permit systems and ranger roles.**
5. **Build sensing to detect intrusions or degradation.**
6. **Align with international bodies and COSPAR guidance.**
7. **Post clear maps/signage and public education.**
8. **Review zones annually; expand or relax with evidence.**
9. **Sanction violations and fund restoration.**

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23) Debris, Dust & Non-Bio Contaminants: Particulate Control, Propellant Residues, and Cleanup Rules

1. **Classify non-bio contaminants (metals, propellants, lubes, micro-fragments).**
2. **Create dust control methods (tack mats, electrostatic/air curtains).**
3. **Define propellant residue cleanup SOPs and waste routing.**
4. **Monitor particulates and residues; set action levels.**
5. **Protect sensitive habitats and instruments from abrasion/fouling.**
6. **Audit EVA/vehicle shed protocols for debris control.**
7. **Record spills/releases and remediation timelines.**

8. **Publish non-bio contamination dashboards.**

9. **Tie contractor payments to verified cleanup KPIs.**

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24) Finance & Liability: Insurance, Bonds, Performance Clauses, and Remediation Escrow

1. **Price risk: insurance levels for bio events by class.**

2. **Require bonds/performance guarantees for contractors.**

3. **Define KPI-linked payments and penalties.**

4. **Create remediation escrow funds with release criteria.**

5. **Publish cost-of-care and cost-of-failure transparently.**

6. **Standardize indemnification and sub-tier liability.**

7. **Align finance with “no-first-harm” and open telemetry clauses.**

8. **Audit financial readiness annually; simulate loss scenarios.**

9. **Report to councils and the public on financial posture.**

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25) Scaling & Replication: Open Standards, Training Networks, and Global Alignment Roadmap

1. **Package an open, certifiable standard others can adopt.**

2. **Build training networks (academies, apprenticeships, online sims).**
3. **Create a franchise-of-care kit (contracts, rituals, dashboards).**
4. **Form regional federations for mutual aid and audits.**
5. **Align with international standards bodies; contribute test suites.**
6. **Track scale metrics (sites, uptime, incidents, audit pass rates).**
7. **Publish an annual roadmap and lessons learned.**
8. **Seed funding models for new communities to join.**
9. **Maintain a living playbook with public change logs.**