

Pharmacy, medical stocks and diagnostics far from Earth



Conceptual visualization — medical autonomy depends on trained people, diagnostics, consumables, pharmaceuticals, equipment, records and contingency planning.

Plan medicines, consumables, diagnostics, cold chain and substitutions when a Mars crew cannot be rapidly resupplied or evacuated.

Before starting — reconnect emergency medicine, probability and logistics before translating shelf inventory into clinical capability over a long resupply delay. Important quantities and assumptions are stated at first use.

Mastery objectives

- translate clinical scenarios into usable treatment capability rather than raw pharmaceutical counts
- connect diagnostics, cold chain, equipment, consumables and trained staff to medication availability
- use pre-authorised substitution logic without erasing contraindications, monitoring needs or clinical authority
- measure stock by treatment courses, expiry exposure, diagnostic throughput and delayed-resupply consequence

1. A Mars pharmacy is a system, not a cabinet

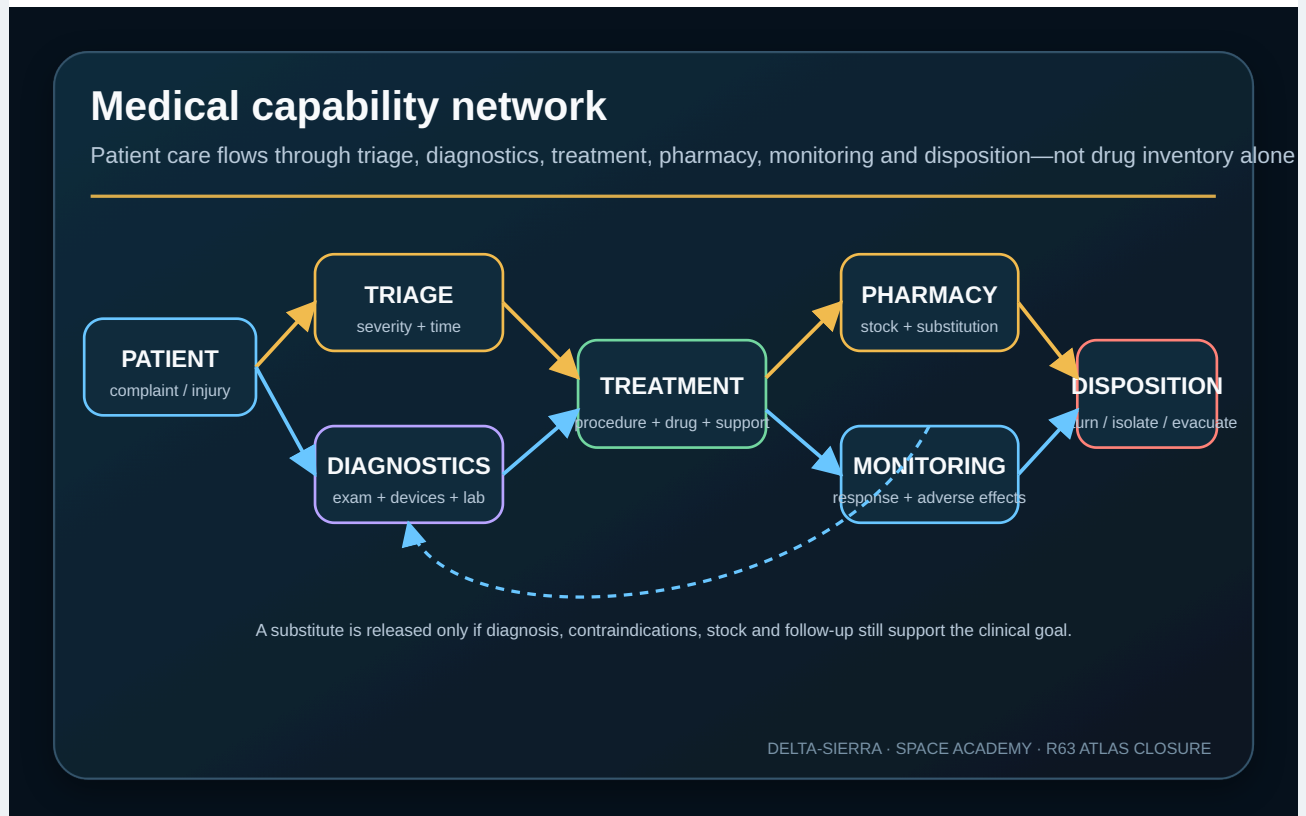
Medical stores must cover common illness, trauma, dental care, emergencies, behavioral health and spaceflight-specific risks. Every drug also has storage conditions, expiry, protocols and sometimes a delivery device. A long inventory is not automatically robust; the settlement needs to know which scenarios are covered, what alternatives exist and what becomes impossible after a consumable is depleted.

2. Start from clinical scenarios

Planning begins with events such as pain, infection, allergy, trauma, burns, dehydration, respiratory problems and dental emergencies. For each scenario the team defines minimum diagnosis, first-line treatment, backup treatment, required equipment and escalation criteria. This reveals common dependencies such as one pump, one sterile item or one diagnostic reagent used across many conditions.

3. Expiry and stability

The printed expiry date is only part of stability. Temperature, humidity, radiation and packaging matter. FEFO rotation reduces waste, but Earth-Mars logistics require replacement planning long before a product expires. Critical stock therefore tracks quantity, date, storage history, confidence and the contingency if the item becomes unavailable.



Medical readiness exists only when information, medicines, equipment and qualified clinicians are simultaneously usable. Pedagogical synthesis by Delta-Sierra from the primary sources cited in this course; schematic, not to scale.

4. Cold chain and power

Some medicines and diagnostic reagents require controlled temperature. A medical refrigerator is therefore a critical load with independent sensing, temperature logging, alarms and a power-loss procedure. The key question is not merely wattage but how long the contents remain acceptable without cooling and which backup power source protects that interval.

5. Diagnostics: information before treatment

Empirical treatment can be necessary, but long missions benefit from reducing uncertainty. Compact imaging, blood analysis, targeted microbiology, ultrasound and physiological sensors can change clinical decisions. Every instrument also requires consumables, calibration, software, maintenance and trained operators. The best test is one whose result can actually change what the crew does next.

6. Sterility and consumables

Gloves, drapes, syringes, needles, sampling kits and dressings can become limiting resources. Some can be sterilized or reused; others cannot. Medical planning therefore connects pharmacy, sterilization, waste handling and logistics. A claimed surgical capability without sterile consumables is only a theoretical capability.

7. Substitution and formularies

Resilience improves when clinically validated alternatives cover overlapping needs without creating an unmanageable inventory. Substitutions must be prepared in advance with contraindications and dosing rules. The goal is never to improvise pharmacology during a crisis but to preserve acceptable options when the preferred product is gone.

8. Skills, telemedicine and delay

Earth remains an important source of specialist expertise, yet time delay prevents synchronous telemedicine. The crew must stabilize a patient, collect structured data, follow procedures and continue care while waiting for advice. Medical protocols therefore need offline usability and clear decision points.

Deepening: population and stock size

Medical stock does not always scale linearly with population. Some equipment is shared, while drugs and consumables scale more directly. Rare events also become more likely across a larger population and longer duration. Inventory planning combines expected frequency, severity, mission duration and the inability to resupply quickly.

Deepening: medical learning loop

Every major case updates the model: actual consumption, effectiveness, adverse effects, operator difficulty and recovery time. Those data inform the next manifest and training cycle. Medical records therefore contribute to logistics engineering as well as care, under strict privacy and access controls.

9. Worked example: stock margin

A medicine is used at an average of 14 doses per month. Covering 26 months requires $14 \times 26 = 364$ doses. A 30% logistics margin raises this to $364 \times 1.30 = 473.2$, so at least 474 whole doses. If 80 doses will expire before the end of the period, the initial stock must increase or a more stable formulation must be chosen.

Calculated case study: diagnostic-test stock

TEACHING ASSUMPTION — Planned average use is 120 diagnostic tests per month. The autonomous logistics period is 18 months and the safety reserve is 15%.

Let q be monthly use in tests/month; d duration in months; N number of tests; and r reserve, dimensionless.

$N_{\text{base}} = q \times d = 120 \times 18 = 2,160$ tests. With a 15% reserve: $N_{\text{plan}} = 2,160 \times 1.15 = 2,484$ tests.

The result is a unit count, not a pharmacy composition. The total must then be allocated by indication, shelf life, storage temperature and criticality.

10. Exercise

A settlement has 900 units of a consumable used 28 times per month. The next possible resupply is 30 months away. Calculate the current margin and propose two actions if observed demand increases by 20%.

11. Reasoned solution

Nominal demand is $28 \times 30 = 840$ units, leaving only 60 units or about 7.1% margin. At 20% higher demand, monthly use becomes 33.6 and 30-month demand becomes 1,008 units. The stock is inadequate, so avoidable uses must be reduced, an alternative qualified or the next manifest increased.

12. Mini-project

Build a simplified medical formulary for 30 people over 30 months: ten clinical scenarios, associated drugs and consumables, expiry dates, cold-chain needs, two diagnostic devices and three preplanned substitutions. Identify the five dependencies that still cannot be replaced locally.

Medical autonomy depends on information, stock, equipment and trained people at the same time

A Mars pharmacy is not an oversized medicine cabinet. It is a logistics and clinical-support system operating far from rapid resupply. Medicines, sterile consumables, diagnostic cartridges, dressings, oxygen interfaces, refrigeration, records and trained crew all have different shelf lives and storage constraints. A treatment option is operationally available only when the required product, equipment, consumable and competence are present together.

Stock planning therefore begins with clinical functions rather than a long product list. The settlement asks what capabilities it must sustain: first response, wound care, infection evaluation, pain control under medical protocols, stabilization, dental emergencies, monitoring and diagnostics. Specific medical choices require qualified clinical governance; the engineering task is to make approved capabilities logistically reliable.

Communication with Earth can support decision-making, but delay and outages mean the crew must gather high-quality local information and perform immediate stabilization without assuming real-time remote control. Diagnostic availability and crew training can therefore be as important as the number of stored medications.

Ten principles for medical logistics far from Earth

1. Build inventory around clinical functions

Group stock by what it enables rather than only by product name. A wound-care function may depend on cleaning supplies, sterile materials, closure equipment, analgesia, documentation and trained personnel. If one unique consumable is missing, the whole function may degrade.

This functional view also reveals substitution opportunities. Several approved products may support the same function, reducing reliance on one item, but substitutions must remain within mission medical protocols rather than being invented during an emergency.

2. Shelf life must be tied to storage history

Expiry information assumes specified conditions. Temperature excursions, radiation, humidity or packaging damage may change confidence in a product. The inventory should therefore retain storage history and quarantine items whose condition is uncertain until they are evaluated under the mission's medical quality process.

Rotation policy should consider both expiry and resupply windows. An item that expires shortly after the next cargo arrival may be manageable; the same item becomes a serious risk if the next credible replacement is years away.

3. Cold-chain stock is coupled to the microgrid

Refrigerated medical inventory needs monitored temperature, backup power and an alternate storage plan. A refrigerator is not a self-contained medical asset if it loses power when the grid sheds non-critical loads. Medical refrigeration should be classified according to the consequence of losing its contents.

Temperature logs should support action after an excursion. The crew needs a defined process for identifying affected items and seeking medical or manufacturer guidance where communication permits, rather than guessing that everything is either safe or ruined.

Apply diagnostic evidence to treatment triage

The core diagnostic principle is now applied to triage: use a test only when its result can change treatment, isolation or monitoring. A scarce cartridge that does not alter the decision consumes inventory without buying useful information.

The capability matrix should therefore track equipment availability and consumable coverage together. Redundant methods are valuable when they provide independent information rather than duplicating the same failure mode.

5. Sterility is a supply-chain constraint

Sterile single-use items can become limiting during repeated procedures. Reusable instruments shift burden toward cleaning, sterilization equipment, validation and packaging. A Mars medical system needs an intentional mix based on mission risk and available infrastructure.

Stock records should distinguish sterile integrity from physical presence. Damaged packaging or uncertain sterilization means an item may no longer count toward a sterile procedure kit.

Apply formulary substitution during delayed resupply

The general substitution rule becomes an operational problem here. For each substitute, the formulary records clinical indication, dose conversion, contraindications, monitoring, authority to approve the change and the condition that forces consultation or escalation.

From a logistics perspective, substitution can reduce the number of unique items, but excessive consolidation can create a new single point of failure. The balance belongs to clinical governance and supply engineering together.

7. Crew skills are part of inventory

A procedure may require two trained people, or one operator plus a second person capable of assisting. Skill coverage should be tracked like hardware readiness. Cross-training reduces dependence on one specialist, especially if that specialist is the patient.

Training also degrades without practice. Simulation, drills and supervised refreshers should be scheduled so critical skills remain usable over a multi-year mission.

8. Stock uncertainty needs margins, not optimism

Consumption is variable because injuries and illness are stochastic. Planning should therefore use expected demand plus a margin informed by consequence, resupply interval and variability. High-consequence low-mass items can justify relatively large reserves.

Margins should not be applied mechanically to every product. Some supplies have high usage variability, others have predictable scheduled replacement, and some are limited mainly by expiry rather than consumption.

9. Prioritization should be explicit before scarcity

If a diagnostic consumable becomes scarce, the crew needs a rule for prioritizing use based on clinical consequence and alternative methods. Creating that rule before the shortage reduces cognitive load and conflict during an emergency.

Prioritization is not purely numerical. A scoring tool can support consistency, but qualified medical authority remains responsible for patient-specific decisions.

10. Resupply planning is a moving forecast

The medical inventory should project stock through the next credible resupply, including losses, expiries and expected consumption. A cargo manifest planned months earlier can become outdated after an injury cluster or refrigerator failure. Forecasts should therefore be updated after every significant event.

Earth dependence remains visible even when most routine care is locally possible. Many advanced drugs, sensors and sterile consumables may continue to require Earth manufacture. Autonomy means managing those dependencies honestly, not pretending they have disappeared.

Calculation laboratory: coverage, stability, equipment availability and priority

Stock coverage

$$\text{Coverage} = \text{Stock_usable} / \text{Planned_consumption_rate}$$

If 240 test cartridges are usable and expected planning consumption is 20 per month, simple coverage is 12 months. The number is meaningful only if cartridges remain within validated storage life over that horizon and the analyzer itself is available.

Storage-compliance fraction

$$f_{\text{compliant}} = t_{\text{within_limits}} / t_{\text{total}}$$

If a refrigerator stayed within required limits for 718 of 720 monitored hours, time-compliance is 99.72%. This metric alone does not decide whether products are usable: the duration and magnitude of the two-hour excursion matter and must be evaluated against product-specific guidance.

Loss rate

$$\text{Loss_rate} = \text{Units_lost} / \text{Units_managed}$$

If 12 of 600 sterile units are lost to damaged packaging or other non-use events, loss rate is 2%. Tracking the cause can support better packaging, handling or storage rather than merely increasing future orders.

Target stock

$$\text{Stock_target} = \text{Average_demand} \times \text{Horizon} \times (1 + \text{margin})$$

If a consumable averages 15 units/month, resupply horizon is 18 months and planning margin is 30%, target is $15 \times 18 \times 1.30 = 351$ units. Shelf life and storage capacity must then be checked; stocking more than can remain usable is not resilience.

Diagnostic equipment availability

$$A_{\text{diag}} = \text{MTBF} / (\text{MTBF} + \text{MTTR})$$

MTBF means mean time between failures and MTTR mean time to repair. If a device has an illustrative MTBF of 1,000 hours and MTTR of 20 hours, inherent availability from this simplified relation is about 98.0%. Real mission availability also depends on spares, calibration and consumables.

Skill coverage

$$\text{Skill_coverage} = N_{\text{competent}} / N_{\text{required}}$$

If a critical procedure requires at least three independently capable crew members and four are currently competent, coverage ratio is $4/3 = 1.33$. If illness removes two trained people, the ratio falls below one and the capability is no longer fully staffed.

Inventory forecast

$$\text{Stock_end} = \text{Stock_start} + \text{Deliveries} - \text{Consumption} - \text{Losses}$$

This simple balance should be projected across time and repeated after significant events. It makes shortages visible early enough to adjust resupply, training or approved alternatives.

Worked case: diagnostic cartridges through a delayed resupply

A device has 360 usable cartridges. Planning consumption is 18 per month and the next nominal resupply is 16 months away. Simple demand is 288 cartridges, leaving 72 units. That appears comfortable, but a six-month launch delay would raise demand to 396 cartridges and create a projected shortage of 36 units before accounting for losses or expiry.

The operations response is to update the forecast, not to ration blindly. Medical authority can identify which tests have alternatives, which clinical scenarios require the cartridges most strongly, and whether the resupply manifest can be changed. Engineering verifies device reliability and whether the inventory remains within storage limits.

If 5% of the cartridges are later quarantined because of a storage incident, usable stock becomes 342. The forecast is recalculated immediately. This example shows why physical count, usable count and projected coverage are separate fields.

Failure scenario: medical refrigerator loses cooling

The crew confirms temperature history and transfers stock to an alternate validated cold location if available. Power operations protect the replacement cooling load. Affected items are identified by batch and storage history so only the relevant inventory is quarantined.

The medical team then determines, using approved guidance and Earth consultation when available, whether exposed items remain suitable. The logistics system simultaneously projects the consequences of any losses through the next resupply. This turns a hardware fault into a controlled clinical-supply decision rather than a panicked discard of the entire pharmacy.

Progressive exercises with solutions

- ▶ Exercise 1 - Coverage
- ▶ Exercise 2 - Target stock
- ▶ Exercise 3 - Equipment availability
- ▶ Exercise 4 - Inventory forecast

Interactive beginner glossary

- formulary - approved medical stock framework.
- shelf life - validated usable storage period.
- cold chain - controlled-temperature supply path.
- diagnostic cartridge - single-use or limited-use test consumable.
- quarantine - hold pending evaluation.
- MTBF - mean time between failures.

- MTTR - mean time to repair.
- capability availability - readiness of the whole clinical function.

Medical autonomy is a capability network, not a pharmacy cupboard

A remote settlement cannot equate medical readiness with the number of medicines carried. Diagnosis, stabilization, monitoring, sterile technique, procedures, rehabilitation, mental-health support, records, training and logistics interact. A medication is useful only when the correct indication is recognized, contraindications are considered, dose and route can be delivered, storage has remained valid and the patient can be monitored for response and adverse effects.

Start with clinical functions

The medical plan should list functions such as triage, basic examination, airway support, bleeding control, fracture management, infection assessment, laboratory testing, imaging where available, dental care, medication administration, isolation and rehabilitation. For each function, identify equipment, consumables, power, water, sterile supplies, software, trained roles and backup methods.

This approach reveals hidden dependencies. A diagnostic analyzer may require reagents with shorter shelf life than the instrument, calibration material, clean electrical power and temperature control. A surgical capability may depend on sterilization capacity and post-procedure monitoring. A drug that is stable for years can still become unusable if its delivery device, diluent or compatible diagnostic pathway is unavailable.

Inventory must distinguish count from capability

Two hundred tablets do not equal two hundred treatment-days unless dose, treatment duration and indication are defined. Stock systems should therefore record unit count, strength, formulation, lot, expiry, storage conditions, protected reserve, substitute products and the clinical function supported.

Treatment-course coverage

$$N_{\text{courses}} = N_{\text{units,usable}} / N_{\text{units,per-course}}$$

Suppose a hypothetical medicine has 600 usable units and one modeled treatment course consumes 20 units. Ideal coverage is $600/20 = 30$ complete courses. If only 19 units remain after partial consumption, the count “19” may have much less operational value than one complete course. This is a stock-accounting example only; it does not prescribe any medication.

Expiry creates a moving boundary

Coverage should be calculated against time, not treated as static inventory. Material expiring before the next plausible replacement opportunity cannot be counted the same way as long-lived stock. Rotation, environmental monitoring and periodic inspection therefore belong to the medical logistics system.

A useful dashboard can show stock in three layers: immediately usable, usable but approaching a planning threshold, and quarantined or unavailable. Quarantine matters because uncertain storage history should not silently become usable inventory during a crisis.

Model false confidence, false positives and test unavailability

A diagnostic result is evidence, not truth. This application adds test sensitivity, specificity, calibration state, specimen quality and equipment availability to the decision so that a confident-looking number cannot silently replace clinical reasoning.

The same logic used elsewhere in Space Academy applies: distinguish observation from interpretation. “Instrument reports value X” is an observation. “The patient has condition Y” is an interpretation supported by the measurement and clinical context. That distinction protects the team when two indicators disagree.

Diagnostic capacity workload

$$U_{\text{lab}} = T_{\text{required}} / T_{\text{available}}$$

If a laboratory can provide 10 technician-hours in a shift but urgent testing requires an estimated 14 technician-hours, utilization demand is $14/10 = 1.4$. The settlement cannot solve that overload by optimism. It must prioritize, defer low-value testing, cross-train staff, use validated rapid methods or add capacity.

Cold-chain failures need a decision tree

When temperature-controlled stock experiences an excursion, the response should preserve evidence: duration, maximum and minimum temperature, packaging state, monitoring record and product identity. The default should not be “use everything” or “discard everything.” Product-specific stability evidence is needed. If evidence cannot establish suitability, the stock may need quarantine, and the medical plan must show what alternative capability remains.

Human skills are a consumable resource too

A small settlement can be vulnerable if one clinician or technician is the only person capable of a critical procedure. Cross-training does not make everyone a physician, but it can provide structured support for monitoring, equipment setup, sterile preparation, documentation and emergency assistance. Training plans should identify which skills require frequent practice because they decay when unused.

Medical contingency drill

Design a scenario in which a crew member requires urgent evaluation while one diagnostic instrument is unavailable and a second crew member has a minor injury. The student must allocate trained staff, choose which measurements are essential, identify which consumables are spent, record what uncertainty remains, and decide what information is sent to Earth. Then add a cold-storage alarm and repeat the plan. The objective is to show how the medical system degrades gracefully rather than collapsing when one device is missing.

A Mars medical system should therefore be audited like any other critical engineering system: functions, dependencies, limits, detection, backup, time to consequence, recovery and evidence. The ethical stakes are different, but the discipline of exposing assumptions is the same.

Medical-stock calculation laboratory: convert inventory into coverage and decision triggers

Counting boxes is not enough. Medical autonomy requires knowing usable quantity, consumption rate, shelf life, substitution options and the time until replenishment or local replacement can exist.

Simple stock coverage

$$D_cover = N_usable / q_daily$$

In a teaching scenario, 240 usable doses remain and average modeled consumption is 6 doses/day. Ideal coverage is $240/6 = 40$ days. If the expected demand doubles during an outbreak or injury cluster, coverage falls to 20 days.

Limit. Average consumption can hide rare high-demand events. Drugs are not interchangeable merely because they share a count unit, and expiry/storage conditions may reduce usable stock.

Planning trigger stock

$$N_trigger = q_daily \times (t_lead + t_buffer)$$

For a purely pedagogical case, assume 6 units/day, a 180-day effective replacement lead time and a 60-day protected buffer. Trigger stock = $6 \times (180+60) = 1,440$ units. The point is not the number; it is that long logistics lead times push inventory decisions far earlier than on Earth.

► Exercise — demand surge

Clinical decision studio: turn limited diagnostics and finite stock into safe choices

Medical autonomy on Mars is not obtained by carrying more boxes. It comes from reducing uncertainty and preserving options. The same symptom can have different causes, and the wrong treatment can consume scarce stock while delaying the correct intervention. A settlement therefore needs a structured chain from symptom to measurement to interpretation to treatment, with clear thresholds for when telemedicine, isolation, procedure, watchful waiting or emergency resource use is justified.

Sensitivity and specificity are not the probability that a patient has a disease

A diagnostic test can perform well and still produce many false alarms when the condition is rare. Sensitivity is the fraction of truly affected patients who test positive. Specificity is the fraction of unaffected patients who test negative. Neither number alone tells the clinician the probability that a particular positive result represents true disease. That also depends on the pre-test probability, which comes from symptoms, exposure, prevalence and clinical context.

Positive predictive value in a teaching cohort

$$\text{PPV} = \text{TP} / (\text{TP} + \text{FP})$$

Question. Among all positive test results, what fraction are true positives?

Symbols. TP means true positives; FP means false positives; PPV is a fraction or percentage.

Worked cohort. Imagine 1,000 screening events where 20 truly have the condition. A test with 90% sensitivity detects 18 of those 20. If specificity is 95%, then 5% of the 980 unaffected cases test falsely positive: 49 false positives. $\text{PPV} = 18/(18+49) = 18/67 \approx 0.269$, or about 27%.

Interpretation. A positive result in this low-prevalence screening example is not a diagnosis by itself. Clinical context or confirmatory testing is valuable.

Limit. The numbers are a teaching scenario, not performance claims for a particular medical device. Real test characteristics depend on device, specimen, operator and patient population.

Cold-chain autonomy can be calculated as time

Some medicines, reagents and biological materials require controlled temperatures. A refrigerator therefore depends on electrical power, thermal insulation, monitoring and an excursion procedure. The useful emergency quantity is often “how long until the stored product leaves its allowable range?” rather than battery percentage alone.

First-pass thermal holdover

$$t_{\text{hold}} \approx C_{\text{th}} \times \Delta T_{\text{allow}} / \dot{Q}_{\text{leak}}$$

C_{th} is effective thermal capacitance in joules per kelvin; ΔT_{allow} is allowable temperature rise in kelvins; $\dot{Q}_{\text{leak}}$ is net heat entering the cooled volume in watts. If $C_{\text{th}} = 180,000 \text{ J/K}$, allowable rise is 4 K and heat leak during a power loss is 60 W, stored thermal capacity is 720,000 J. Divide by 60 J/s to obtain 12,000 s, about 3.3 hours.

Sanity check. Better insulation lowers $\dot{Q}_{\text{leak}}$ and must increase holdover time. A formula producing the opposite trend would be wrong.

Limit. Door opening, internal fans, phase-change packs, product mass and non-uniform temperature can change the result substantially. Actual storage decisions must follow validated product and equipment limits.

Stock policy should preserve complete treatment courses

Counting tablets or cartridges can mislead. If a treatment requires a sequence of doses, partial courses may not preserve the intended capability. Inventory should therefore be expressed in clinically meaningful units: complete courses, sterile procedures, diagnostic panels, litres of infusion fluid, hours of oxygen therapy or number of patients supportable under a defined scenario.

Expiry management should also distinguish calendar expiry from actual storage history. A package that remained inside its validated environmental envelope is not equivalent to one that experienced an undocumented heat excursion. Digital stock records therefore need lot identity, arrival date, storage conditions, opened/closed state, calibration or control status where relevant, and the decision authority for quarantine or release.

Medical capability includes trained backups

A one-person skill is a single-point failure. The settlement should map critical clinical skills such as airway management, ultrasound, wound care, dental emergencies, laboratory operation, sterilization and medication preparation against primary and backup personnel. Cross-training does not turn every resident into a physician, but it reduces the risk that one injury removes the only operator of a life-critical capability.

Diagnostic scarcity drill

A respiratory syndrome appears in four residents. Only twelve confirmatory cartridges remain before the next plausible resupply. Propose a testing strategy that uses symptom severity, exposure links and the consequence of missing a true case. State what information you would collect before consuming a cartridge and how you would preserve a reserve for future emergencies.

► Reasoned solution

First-Man medical readiness: a pharmacy is a network of decisions, not shelves

Medical capability on Mars is constrained by distance, communication delay, finite crew skills and finite stocks. The important question is not how many medicines are stored but which clinical capabilities the settlement can deliver from recognition to diagnosis, treatment, monitoring and recovery. A sealed box of medication is useless if nobody can identify the condition, if a diagnostic consumable has expired, if the drug requires refrigeration that has failed, or if the only trained operator is the patient.

For planning purposes, organise stocks by capability bundles: wound care, pain control, infection management, airway and breathing support, dental care, eye care, allergy response, gastrointestinal illness, fractures and immobilisation, selected chronic needs, diagnostics and sterilisation. The exact contents belong to medical governance and mission-specific standards; the systems lesson is that each capability depends on people, equipment, consumables, storage conditions and procedures simultaneously.

Convert inventory into complete courses, not tablet counts

$$N_{\text{courses}} = Q_{\text{usable}} / q_{\text{course}}$$

Starting question

How many complete treatment courses can a stock support when partial courses cannot be counted as equivalent capability?

Read aloud

Read: “number of courses equals usable stock quantity divided by quantity required per complete course.”

Symbols, pronunciation and meaning

Q_{usable} is stock that is in date, correctly stored and available; q_{course} is the quantity needed for one full treatment course under the approved protocol; N_{courses} is the number of complete courses supported.

Units

If both quantities are expressed in the same units, they cancel and the result is a count.

Origin and status of values

Usable stock comes from controlled inventory. Course quantity comes from the medically approved protocol; this educational module does not prescribe it.

Why this operation

The division asks how many full bundles of required quantity fit in the usable inventory.

Substitution and calculation

Teaching inventory example only: 240 units are usable and the approved course would consume 18 units. $240/18 = 13.3$, so the inventory supports 13 complete courses with 6 units left over.

Calculator entry

Enter $240 \div 18$. For complete-course planning, round down rather than treating 13.3 as fourteen.

Mental estimate

$18 \times 10 = 180$ and $18 \times 3 = 54$, giving 234 for thirteen courses, leaving 6.

Independent check

$13 \times 18 = 234 \leq 240$, while $14 \times 18 = 252 > 240$.

Physical or operational interpretation

The stock can support thirteen complete protocol-defined courses under the assumed storage and expiry status.

Plain-English translation

A remaining handful of units may have little value if it cannot complete the next required treatment bundle.

Variation / sensitivity

If 36 units become unusable after a storage excursion, Q_{usable} falls to 204 and capacity becomes only 11 complete courses.

Limit / assumption

This inventory equation ignores patient-specific dosing, contraindications, alternative therapies and clinical judgement. Those belong to medical professionals and mission protocols.

What this does not prove

A numerical stock of courses does not prove diagnostic accuracy, medical staffing, treatment effectiveness or patient safety.

Boundary case to test

If the required diagnostic test or trained clinician is unavailable, treatment capability may be effectively zero even while physical medication remains on the shelf.

Budget diagnostic cartridges, analyzer time and operator attention

This is a resource-accounting application of the diagnostic workflow. A test consumes a cartridge or reagent, analyzer time, power, maintenance capacity and qualified human attention; all of those can become the limiting resource before the medicine itself does.

Recognise

symptoms, vitals,
exposure history

Differentiate

tests, examination,
uncertainty

Treat

trained person,
equipment, complete
stock

Monitor

response, adverse
effects, recovery

Skill redundancy is medical inventory

Training is a stored capability that cannot be resupplied quickly. For each high-consequence procedure, identify the primary operator, at least one backup and the minimum equipment needed to practise. Cross-training should consider correlated unavailability: two specialists assigned to the same EVA can be lost or injured together. Human redundancy should therefore be distributed across teams and shifts where possible.

Cold-chain monitoring must support a release decision

Temperature-sensitive stock needs continuous or adequately sampled records, alarm thresholds, backup power and an explicit rule for quarantine after an excursion. The purpose of the record is not administrative completeness; it is to answer a later question: can this stock still be trusted? If the evidence cannot support that decision, the inventory should not be silently returned to service.

Scenario: two patients, one diagnostic cartridge

One crew member has a minor, stable complaint; another has rapidly changing vital signs after a known exposure. Only one cartridge remains for a specific analyser. The systems response is to preserve the scarce test for the decision where it can change urgent management, while using

lower-resource observations for the stable case if medically appropriate. The important lesson is not a clinical prescription; it is that diagnostic scarcity must be represented in operational triage and inventory policy before the emergency.

A substitution is a clinical decision with eligibility, monitoring and authority gates, not a simple inventory swap. Pedagogical synthesis by Delta-Sierra from the primary sources cited in this course; schematic, not to scale.

Medical logistics qualification lab: preserve treatment options when resupply is months away

A remote pharmacy is not a box of medicines. It is a managed capability that combines indication, dose form, shelf life, storage conditions, diagnostic confidence, contraindications, substitution rules and the time required to obtain more stock. The same number of tablets can represent very different medical resilience depending on which conditions they can treat and whether suitable alternatives exist.

Count complete courses, not loose units

For therapies used as defined courses, inventory should be translated into the number of complete usable courses after expired, quarantined or damaged units are removed. Partial courses can be clinically useless or inappropriate. For chronic treatment, the relevant unit may instead be patient-days. The inventory system should therefore store both physical units and the medical capability those units represent.

Complete usable treatment courses

$$N_{\text{courses}} = \text{floor}(N_{\text{units,usable}} / N_{\text{units,course}})$$

1 – Concrete question

How many complete treatment courses can be delivered from the units that remain usable?

2 – Intuition

Divide the usable number of doses by the doses required for one complete course, then round down.

3 – Quantities

Count only units that are within the accepted storage/expiry status and define the full course under the applicable medical protocol.

4 – Formula

Complete courses equal usable units divided by units per course, rounded down to a whole course.

5 – Read aloud

“N courses equals the floor of usable units divided by units per course.”

6 – Symbols

N is a count. The floor function removes any incomplete remainder.

7 – Pronunciation

“floor” means take the greatest whole number not exceeding the ratio.

8 – Units

Units divided by units per course gives courses.

9 – Convention

Do not count quarantined stock as usable until release criteria are met.

10 – Why this relationship

A complete treatment requires a fixed number of units; incomplete leftovers do not create another complete course.

11 – Assumptions

The teaching calculation assumes one standard course size. Real dosing can depend on diagnosis, body mass, organ function and protocol.

12 – Unit check

$\text{unit} \div (\text{unit/course}) = \text{course}.$

13 – Numerical case

Usable inventory: $N_{\text{units,usable}} = 215$ units.

Defined full course: $N_{\text{units,course}} = 24$ units/course.

$215 \div 24 = 8.958\dots$

$N_{\text{courses}} = \text{floor}(8.958\dots) = 8$ complete courses.

Units remaining after eight complete courses = $215 - (8 \times 24) = 23$ units.

14 – Operations

Divide first, then floor. Rounding to nearest would falsely claim nine courses.

15 – Algebra check

Eight complete courses consume 144 units; nine would require 162, which exceeds stock.

16 – Mental estimate

$18 \times 8 = 144$, immediately showing eight courses are possible.

17 – Interpretation

The pharmacy has eight complete standard courses under the stated assumptions.

18 – What it does not prove

It does not prove the drug is appropriate for eight future patients, nor that diagnostic capability can identify the right indication.

19 – Sensitivity

If 20 units are quarantined after a storage excursion, usable stock becomes 126 and coverage falls to seven complete courses.

20 – Practice

Guided exercise. Compute complete treatment courses from 215 usable units when each course requires 24 units.

Detailed guided correction.

1. $215 \div 24 = 8.958\dots$

2. Only complete courses count, so $\text{floor}(8.958\dots) = 8$ courses.

3. Eight courses consume $8 \times 24 = 192$ units.

4. Units remaining $= 215 - 192 = 23$, which is not enough for a ninth complete course.

Autonomous exercise. Medicine A has 180 usable units and requires 20 units/course. Medicine B can substitute for the same defined indication in this teaching scenario, has 126 usable units and requires 18 units/course, but

36 units are at elevated storage risk. Compute immediately secure complete courses for each and explain how the risky stock should be treated.

► Autonomous correction – open after attempting the exercise

21 – Mission decision

Use complete-course coverage and resupply lead time to trigger conservation, substitution review or local diagnostic restrictions before stock becomes critical.

Forecast diagnostic depletion beside treatment-stock depletion

Carry diagnostic demand into the stock forecast explicitly. If the diagnostic pathway will be exhausted first, the nominal number of treatment courses overstates clinical capability because the crew may no longer be able to allocate those treatments safely.

When uncertainty is high, treatment decisions may consume scarce stock without resolving the underlying diagnosis. Protocols should identify when remote consultation, repeat measurement or a higher-specificity test is worth the delay. The goal is not to ration care mechanically but to protect future treatment capability while making defensible decisions for the patient in front of the crew.

Qualification drill

Create a capability inventory for five medical problems rather than a simple drug list. Include diagnostic tests, medicine, sterile supplies, storage constraint and substitute pathways. Inject a refrigerator excursion that quarantines one drug and a six-month resupply delay. Identify which treatment capabilities disappear first and what operational restrictions or substitutions preserve the most medical coverage.

Source context. NASA medical operations, Human Research Program hazards and NASA-STD-3001 provide the operational human-health context. Medication quantities above are teaching examples only. [NASA — Medical Operations](#).

Lead-time planning: order before the shelf is visibly empty

For Earth-dependent items, resupply planning should combine consumption, uncertainty and transport delay. The trigger cannot be “order when only one course remains” if the next feasible cargo opportunity is many months away. Maintain a protected buffer that covers lead time, expected use and plausible surges. For low-frequency but high-consequence medicines, average consumption may be a poor predictor; scenario coverage matters more.

Stock rotation on Mars should also minimise expiry waste. New deliveries do not automatically belong at the front of the shelf. Use earliest-expiry-first principles where medically appropriate, preserve lot traceability and keep enough metadata to identify which patients received which lot if a quality issue emerges.

Diagnostic capacity as a throughput system

A diagnostic instrument can become a bottleneck when several crew members are ill or when repeat testing is needed. Record assay time, preparation time, operator qualification, consumables per test, calibration frequency and failure recovery. A single analyser that needs one specialist can be less resilient than two simpler pathways with broader crew competence.

False positives and false negatives have different consequences. A screening test that is useful for one prevalence context may perform differently when the condition is rare. The course’s earlier sensitivity/specificity and predictive-value material should therefore be tied to a decision pathway: what action follows a positive result, what confirmatory test exists, and what is the cost of unnecessary treatment or isolation?

Cold-chain failure drill

Assume a medical refrigerator rises outside its validated temperature range for an uncertain period. The correct action is not automatically “discard everything” or “use it anyway.”

Quarantine the affected inventory, preserve temperature logs, identify products with relevant stability information, seek authoritative guidance where available, and separate medications whose quality can be established from those whose status remains uncertain. Meanwhile, recalculate treatment capability using only verified stock.

Now add a second constraint: the backup refrigerator shares the same power circuit. The lesson is architectural—the cold chain depends on electrical redundancy, monitoring and physical distribution, not only on buying more medicine.

R59 medical-capability board: inventory is useful only when diagnosis, competence and time align

A remote settlement can possess thousands of medical items and still lack a treatment capability. Capability exists only when the crew can recognise the condition, obtain enough diagnostic evidence, select an appropriate intervention, deliver it with the available skills and equipment, monitor the response, and continue care through the expected duration. The medical ledger should therefore be organised by capability and failure mode, not merely by shelf location.

Separate “units on hand” from usable courses

Expiry date is only one filter. A stock can be unusable because of temperature excursion, packaging damage, missing diluent, missing administration hardware, incompatible formulation, uncertain identity or lack of a trained operator. Quarantined stock should remain visible in the inventory but should not be silently counted as available capability. The same principle applies to diagnostics: a device without valid controls, calibration material or a compatible consumable is not a working diagnostic chain.

Use substitution trees with explicit medical authority

Supply planning can identify categories in which more than one product might support the same mission capability, but arithmetic cannot decide clinical interchangeability. A substitution tree should therefore contain a medical decision gate. It can show which stock might be considered, what additional information is required, what contraindications matter and which specialist authority must approve the substitution. This prevents a logistics model from turning into an unsafe prescribing engine.

Diagnostics are a consumable workflow

For each high-consequence scenario, list specimen container, collection tool, analyser or test method, calibration/control material, power, software, cleaning requirement, interpretation skill and waste path. The weakest item can limit the entire chain. A settlement that can perform one test today but has no control material for the next month has a demonstration, not a sustainable capability.

Clinical autonomy is also a communications problem

Mars communication delay means that Earth can provide expertise but may not provide real-time control. Procedures should distinguish actions that must be initiated locally from decisions that can wait for consultation. Telemedicine packages should transmit the data needed for a remote specialist to reason effectively: trend, images, waveforms, medication history, environmental exposures and previous interventions, not merely a one-line symptom description.

Medical logistics exercise

A settlement lists nine complete courses of treatment A and five verified courses of substitute B. Two people may require treatment at the same time, and the next resupply window is uncertain. Build a capability board that shows verified courses, quarantined stock, diagnostic prerequisites, trained operators and lead time to replenish. Then inject a refrigerator excursion and decide which capabilities should immediately change state from green to conditional. The goal is not to diagnose a patient; it is to show how a distant settlement keeps medical capability honest under supply uncertainty.

Primary-source bridge. NASA's Human Research Program studies health and performance risks for exploration missions, while NASA medical-operations material provides operational context for spaceflight medical support. The capability-board method here is an educational synthesis. [NASA — Human Research Program](#).

R60 medical logistics: pharmacy resilience is a clinical system, not a stockpile

A Mars pharmacy cannot be managed as a list of boxes with expiry dates. It is a coupled clinical and logistics system in which diagnosis, indication, formulation, storage conditions, trained prescribers, interactions, replacement options and resupply delay all matter. The operational question is therefore not “how many tablets remain?” but “which clinical capabilities remain available, for how many plausible patients, under the present diagnostic certainty and storage history?”

Count treatment capability, not only units

Inventory should be translated into complete treatment courses for defined indications. Two hundred tablets can represent many short courses or only a few long ones. The ledger should therefore connect each item to dose, duration, route, patient restrictions and substitution options. When the drug has multiple uses, the settlement may need protected allocations so that treating a common low-severity condition does not consume the only stock needed for a rarer but life-threatening indication.

Primary-source bridge. NASA's exploration medical operations material provides context for medical planning and care in remote spaceflight. The treatment-course ledger here is a Delta-Sierra teaching method for making stock capability explicit. [NASA — Medical Operations](#).

Storage history belongs to the clinical record

A labelled expiry date assumes a storage envelope. Temperature excursions, radiation exposure, damaged packaging, humidity or repeated opening can change confidence in a product. Critical items should therefore have a storage-history record linked to the lot. If an excursion occurs, quarantine the lot until a qualified decision is made; do not silently return it to usable inventory because the printed date has not passed.

Use targeted diagnostics to protect scarce treatment stock

This section applies the diagnostic workflow to stewardship: reserve tests for decisions where better information avoids unnecessary treatment, identifies a contraindication or changes isolation. The purpose is not to test more; it is to spend information where it preserves options.

Primary source at use. NASA Medical Operations provides the operational context for diagnosis, treatment and medical support in human spaceflight; here it supports the claim that diagnostic capability protects scarce treatment options rather than merely consuming inventory. [NASA Medical Operations](#).

Exercise the pre-authorised substitution tree under scarcity

Use the substitution tree as a rehearsed decision aid rather than inventing an alternative during a crisis. A valid branch identifies who may authorise it, what monitoring changes, which patient factors block it and how the inventory ledger is updated after the decision.

Protect the cold chain as a powered medical subsystem

Temperature-controlled drugs, reagents and biological materials need monitored storage, alarm routing and contingency power. The pharmacy plan should state how long a refrigerator can remain in range after a power loss, where stock is moved if the unit fails, how transfer temperature is verified, and which items become unusable after an excursion. Backup cooling that shares the same failed power branch does not constitute an independent contingency.

Medical staffing is part of stock usability

A sophisticated inventory has little value if only one person can prescribe, prepare or interpret it. Cross-training should focus on bounded, protocol-driven capabilities: emergency medication access, inventory quarantine, point-of-care testing, sterile technique, documentation and communication with remote specialists when delay permits. The capstone should also test the uncomfortable case in which the senior clinician is ill or injured.

Scenario exercise — the stock count says eight courses, the capability is lower

A drug inventory contains 215 usable units and a full course requires 24 units, giving eight complete courses with 23 units left. Now add two operational facts: one patient has a contraindication to that drug, and the only alternative formulation has enough stock for two complete courses. The settlement does not possess “ten interchangeable courses.” It possesses eight courses for eligible patients plus two alternative courses under a different clinical pathway. Capability must remain tied to the patient and indication boundaries that make the calculation meaningful.

Primary-source bridge. NASA-STD-3001 Volume 2 provides human-system requirements relevant to crew health and medical care. The pharmacy examples here are educational architecture, not prescribing guidance. [NASA-STD-3001 Volume 2](#).

R60 clinical-stock drill: force the pharmacy model to make a hard allocation decision

Choose three medications that compete for storage, monitoring or resupply priority and create a scenario in which demand rises unexpectedly. The trainee should not solve the problem by ranking drugs from “important” to “unimportant.” Instead, define the conditions each medicine

treats, the severity and frequency of those conditions, substitutions, diagnostic requirements, expiry/storage vulnerability and whether a stockout removes a unique treatment capability.

Then quarantine one lot because its storage history is uncertain. The inventory system should immediately reduce usable treatment-course coverage and identify which patients or indications are affected. A mature system keeps quarantined stock physically and digitally distinct from usable stock so that emergency pressure does not cause an operator to treat “present on shelf” as “clinically available.”

Finally, make the primary clinician unavailable. The exercise should reveal which actions are protocolised and cross-trained and which decisions genuinely require higher medical expertise. The correct architecture reduces avoidable dependency while respecting the boundary between trained emergency action and clinical judgement. A Mars pharmacy should expand the crew’s resilience, not create false confidence that a stocked cabinet substitutes for medical competence.

Diagnostics protect scarce treatment options when they are targeted to decisions that actually change care. Pedagogical synthesis by Delta-Sierra from the primary sources cited in this course; schematic, not to scale.