

The Evolution and Decision-Making Process for Medical Kits in Space Medical Operations

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Abstract

- ✓ Over the last four decades, both the science of human space exploration and medicine has evolved. Space Medicine has borrowed lessons learned from space mission experience, from analog environments, and from modeling and extrapolation in order to identify the make-up of its medical suite. This has allowed an evolution of the medical kits that is based on both evidenced based medicine, lessons from research, and clinical experience. Tools such as Modified Delphi techniques, expert opinion summits, modeling with Monte Carlo analysis, and the development of a Patient Condition Database have allowed the choices for therapies and treatments to evolve along the lines of evidence-based medicine, while simultaneously relying on clinical experience where evidence is lacking. The design and content of any medical suite is always an unfinished work in progress, with continuous updating based on science, research, mission objectives, vehicle constraints, training of the caregivers and levels of desired care.

Medical Programmatic Considerations 1950's early 1960's

“The hectic pace of space activities during the late 1950”s left little time for a step by step program to develop a medical basis for manned space flight.”

“Issues of life support, safety and health had to be addressed on an *a priori* basis, building principally on the tenets of established science of aviation medicine.”

Nicogossian, Huntoon and Pool. Space Medicine and Physiology, 2nd edition. Section 1, page 5.

Project Mercury

1961 - 1963

- ✓ Medical concern to be evaluated during program
 - To prove that man could survive and function in the space environment
- ✓ Medical strategies employed
 - Voice communication
 - Physiologic monitoring
 - Rudimentary medical kit (auto injectors)
- ✓ Major medical findings (6 flights; longest 34 hrs)
 - Mild dehydration
 - Transient orthostatic intolerance
- ✓ (Note: Cosmonaut Titov experienced vestibular symptoms with nausea on his one-day mission; Vostok 8/6/1961)

Mercury 1961-1963



Mercury launch

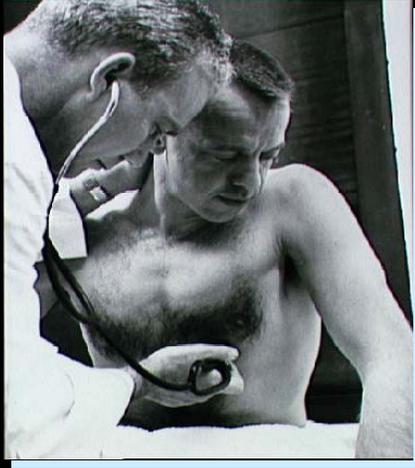
- ✓ Private medical conferences
 - Reliance on voice communication
- ✓ Vital function monitoring
 - Heart rate
 - Respiration
 - EKG
- ✓ I.M. injectors
 - Anti-motion sickness medication
 - Stimulant
 - Vasoconstrictor

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Medical maintenance for the astronauts had included routine medical care, together with annual and special physical examinations. Preflight physical examinations were given for two purposes: to allow the flight surgeon to state that the astronaut was qualified and ready for flight; and to provide a baseline for any changes resulting from exposure to the space-flight environment. Early in the Mercury program, 10 days before the scheduled mission, the flight astronaut and his backup were given a thorough evaluation. This was performed by a Department of Defense team of medical specialists providing the specialties of internal medicine, ophthalmology, neurology, psychiatry, and laboratory medicine. These specialties continued to be represented in later flights, although certain modifications were made as experience demonstrated the lack of serious effects of flight on the astronaut. Three days prior to the flight, a detailed physical examination was completed by the various medical specialists with necessary laboratory work. On the morning of the flight, a brief medical examination was made to determine the readiness of the astronaut. On the last two missions, MA-8 and MA-9, participation was reduced to that of the flight crew surgeon only. The postflight medical examinations were made initially by Department of Defense recovery physicians stationed aboard the recovery vessel, but as the flights were lengthened and experience accumulated, the pattern here too was modified. On the early missions, the astronaut was flown to Grand Turk Island where he was joined by the team of medical specialists who had made the preflight examination and by the flight crew surgeon. In the later, longer flights, when the recovery was made in the Pacific Ocean, NASA flight surgeons were predeployed aboard the recovery carrier to perform the initial postflight examination and debriefing.

Mercury 1961-1963



Bill Douglas, MD performing
preflight medical exam on
Astronaut Shepard

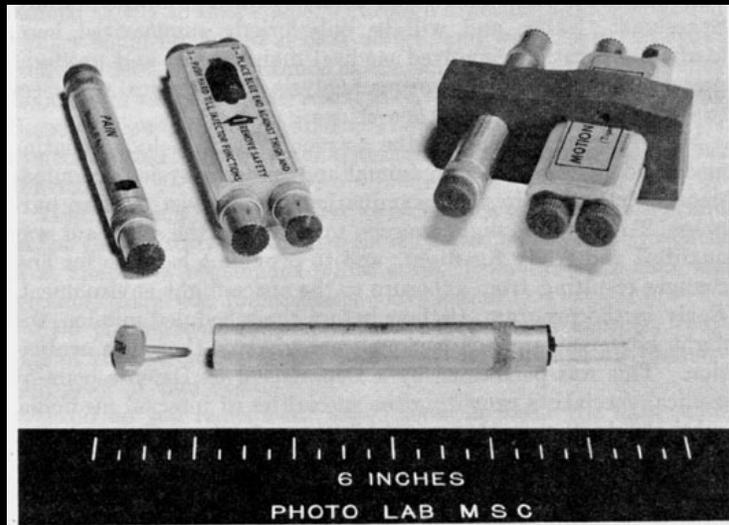
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- ✓ Drugs made available for emergency use only
- ✓ Injectors made it possible for the astronaut to self-administer drugs through the pressure suit
- ✓ First four missions these I.M. drugs included
 - Ananodyne (Anti-motion-sickness drug)
 - Stimulant
 - Vasoconstrictor for treatment of shock
- ✓ Later Changed to
 - Tigan IM
 - Demerol IM
 - Dextroamphetamine sulfate PO
- ✓ Last Mercury flight
 - Note: First use of medication on U.S flight

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For the first 4 Mercury missions, drugs included ananodyne (an anti-motion-sickness drug), a stimulant, and a vasoconstrictor for treatment of shock. In later missions, the number of medications were reduced to the anti-motion-sickness drug and an anodyne (available both in the suit and in the survival kit).

For the last Mercury flight, it was decided to make tablets of dextroamphetamine sulfate available, both in the suit and in the survival kit, and medication was taken for the first time during flight when the dextroamphetamine was taken prior to the initiation of retrosequence.



The automatic medical injectors shown above were carried by Astronaut L. Gordon Cooper on his 22-orbit flight. Two drugs were provided—Tigan, for motion sickness, and Demerol, for pain. The tubes encased in the blocks were stowed in the astronaut's survival kit; the single injection tubes were placed in a pocket of his space suit for availability in case of possible emergency during the flight.

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Experience showed that care had to be taken to prevent astronaut fatigue during the final pre-flight preparations as well as during post-flight activities. Minimum time for post-flight rest and relaxation following a 34-hour mission was between 48 and 72 hours.

Dietary control was in force for approximately 1 week prior to each mission. To prevent defecation during the mission, a low-residue diet was programmed for 3 days prior to launch, with the time extended if the launch was delayed.

In flight, food consisted of bite-size and semi-liquid tube food on early missions, although on the MA-9 mission freeze-dehydrated food was added. The bite-size food caused problems by crumbling and some difficulty was encountered in hydrating the freeze-dehydrated food.

In the early missions urine was collected in a single container within the suit, but this device became unworkable as the mission time increased.

Modifications of the suit made it possible to collect five separate and complete samples, although the system would require modification for future missions.

No blood samples were obtained during flight, and every attempt was made to combine the various blood requirements so as to minimize the number of venopunctures, both preflight and postflight.

Project Gemini 1965 –1966



Astronaut Charles "Pete"
Conrad has heart rate checked
by Dr. Howie Minners

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- ✓ Medical concern to be evaluated during program
 - Study the "long term effects" of spaceflight and EVA (intervals long enough to complete a lunar mission)
- ✓ Medical strategies employed
 - Voice communication
 - Vital sign monitoring
 - **Augmented medical kit**
- ✓ Major medical findings (longest orbital flight: 14 days)
 - Mild dehydration
 - Transient orthostatic intolerance
 - Reduced red cell mass and plasma volume
 - Bone mineral loss
 - Reduced postflight exercise tolerance
 - **Probable Type I dysbarism (Gemini 10)**
 - **NOT REPORTED**

Major medical findings in Project Gemini can be summarized as follows:

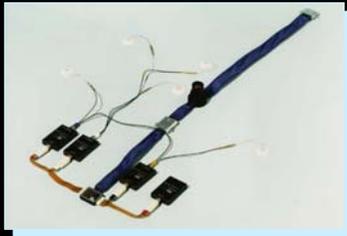
- Humans can tolerate exposure to the space environment;
- Post-flight orthostatic hypotension persisted for 50 hours when evaluated post-flight by tilt table testing;
- A 5- to 20% reduction in red blood cell mass was noted;
- Bony demineralization (bone loss) was observed as a percent change in the density of the os calcis (the calcaneous, or heel bone).
- No adverse psychological reactions were observed even during 14 days confinement in a restrictive cabin environment (on Gemini 7); and
- No vestibular disturbances were reported.

Gemini 1965-1966



Bioinstrumentation
system

- ✓ Vital sign monitoring
- ✓ Research data collected, recorded, and analyzed post-flight
- ✓ Medical monitoring during EVA
- ✓ Medical and accessory kits
- ✓ Crew preflight testing for possible drug reactions



Biobelt
assembly

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The biobelt assembly was a convenient way to wear the bioinstrumentation system inside an astronaut's spacesuit. Snap fasteners were used to attach the biobelt assembly to the midriff section of either the constant wear garment or the liquid cooling garment.

The bioinstrumentation system was used to provide physiological data to ground-based medical personnel. It consisted of an electrocardiograph (ECG; to assess the heart), an impedance pneumograph (to assess breathing), a DC-to-DC converter, a body temperature signal conditioner and appropriate electrode, a temperature probe, and interconnecting cables.

The model used during the Apollo 7 through 17 missions (the Block II configuration), consisted of only one ECG signal conditioner. The Block I configuration (pictured) differed only in that it employed two ECG signal conditioners.

Gemini VII Medical Kit

Medication	Dose	Label	Quantity
Oral Marezine	50mg	Motion Sickness	#8
Parenteral Marezine	45 mg	Motion sickness	#2
d-Amphetamine sulfate	5mg	Stimulant	#8
APC*		APC	#16
Oral Meperidine HCl	100mg	Decongestant	#16
Parenteral Meperidine	90 mg	Pain	#2
Actifed	2.5mg	Decongestant	#16
Sudafed	60mg	Decongestant	#16
Lomitil	2.5mg	Diarrhea	#16
Tetracycline HCl	250mg	Antibiotic	#16
Methyl cellulose soln	15mL	Eye drops	#1

Common with previous mission
Augmentations

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*Aspirin, Phenacetin, Caffeine

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Project Apollo

- ✓ Medical concern to be evaluated during program
 - Complete a lunar mission and bring the crew safely back to Earth
- ✓ Medical strategies employed
 - Voice communication
 - Physiologic monitoring
 - **Augmented** Apollo medical kit
 - Lunar module medical kit
- ✓ Major medical findings
 - Mild dehydration
 - Transient orthostatic intolerance
 - Reduced red cell mass
 - Bone mineral loss
 - Reduced postflight exercise tolerance
 - Space motion sickness
 - **Transient cardiac arrhythmia**

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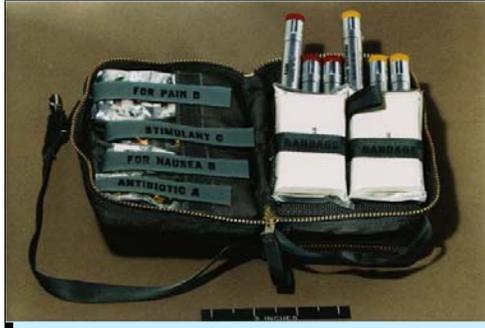
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The medical objectives of Apollo were:

- Ensuring crew safety from a medical standpoint - identify, eliminate, or minimize potential health hazards to the crew and ensuring that sufficient medical information was available for management decisions;
- Preventing terrestrial contamination from the lunar surface;
- Further the understanding of the biomedical changes incident to space flight.

Major medical findings of Apollo included the following:

- In-flight food consumption was inadequate to maintain metabolic balance (caloric intake was less than calories expended with loss of tissue fluid and electrolytes);
- Meal preparation and consumption required too much time and effort;
- Water for reconstitution of dehydrated foods was off flavor and contained large quantities of undissolved hydrogen and oxygen gas;
- Functional failures occurred in rehydratable food packages;
- Development of a system of foods and packaging that was more familiar in appearance, flavor and method of consumption was required;
- Anorexia occurred during flight (average weight loss six pounds);
- Sleep disruption due to a number of factors: cyclic noise disturbances resulting from thruster firings, communications, or movement within the spacecraft; staggered sleep periods; significant displacement of the astronaut's normal diurnal cycle; unfamiliar sleep environment; and excitement.



Apollo Medical Kits



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Apollo 1968-1972

- ✓ Introduction of video monitoring
- ✓ Use of biosensor harness
 - O₂ consumption
 - CO₂ levels
 - Temperature
 - Vital signs
- ✓ Monitoring of metabolic expenditure during EVA
- ✓ Private medical conferences
- ✓ Apollo augmented medical kit
- ✓ Lunar module medical kit

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Video monitoring was introduced during Apollo. A biosensor harness was used to monitor astronauts (measured O₂ consumption, CO₂ levels, temperature and vital statistics). There was also the ability to measure metabolic expenditure during EVA on the lunar surface. Finally, private medical conferences were also scheduled for the crew.

It is notable that the ability to monitor crew health, environmental factors, and system function ensured survival following the oxygen tank explosion during Apollo 13.

Key Medical Events and Medication Use During Apollo

Apollo 7	URI	Actifed
Apollo 8	Viral gastroenteritis: Nausea & vomiting Loose stools Difficulty with sleep	Merazine tab Lomotil Seconal
Apollo 9	Space motion sickness: Nausea & vomiting Difficulty with sleep	Merazine Seconal
Apollo 10	Fiberglass irritation: Skin, eyes, resp. tract Intestinal gas secondary to H ₂ ingestion Difficulty with sleep	"Symptomatic treatment" Self-medicated with Lomotil Seconal

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Color legend:
Common with previous mission
Augmentations

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The contents of the Apollo Inflight Medical Equipment Kit were selected based on experience gained from earlier missions. The drugs were intended for contingency situations most likely to arise. The adequacy of the kits was reviewed after each flight, and appropriate modifications were made for the next flight. The basic contents of the medical kits remained the same for each mission, but there was no "standard" kit because of mission-to-mission customization.

The Apollo astronauts received medical training to help them understand the effects of spaceflight stresses on the human body, as well as to recognize any abnormalities in their health status.

Apollo medical equipment included uncommon medications needed during flight, as well as diagnostic equipment.

Side bar note: Midway thru Apollo, pressure-related problems in medication packaging were resolved by puncturing each unit-dose medication cell with a small pin, making pressure equalization possible. Spray bottles were eliminated in favor of dropper bottles, however, this mode of delivery also proved inappropriate for the zero-G environment. Because the Space Shuttle and ISS operate under a near-normal pressure environment, spray bottles have been reintroduced into the medical kits.

Key Medical Events and Medication Use During Apollo (2)

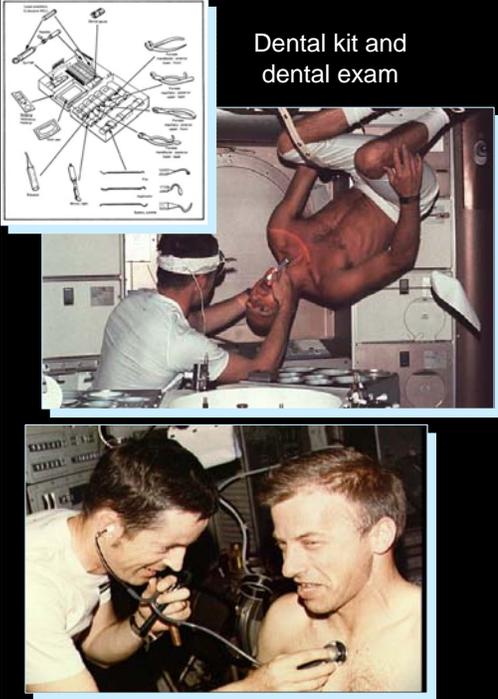
Apollo 11	No reported symptoms Prob. Type I dysbarism	Aspirin; Lomotil (prophylactic in LEM) Scop/Dex (prophylactic prior to reentry) Not reported
Apollo 12	Mild contact dermatitis Nasal congestion Difficulty with sleep	Actifed; Aspirin Seconal
Apollo 13	Space motion sickness: Headache Difficulty with sleep UTI	Marezine Aspirin Seconal No in-flight treatment
Apollo 14	Nasal congestion	Nasal decongestion used once

Key Medical Events and Medication Use During Apollo (3)

Apollo 15	Exercise-induced musculoskeletal pain in right shoulder Transient arrhythmia	Aspirin No treatment available Self-prescribed decongestant prior to entry
Apollo 16	Difficulty with sleep	Seconal
Apollo 17	Difficulty with sleep Flatulence Loose stools	Seconal Self-prescribed Simethicone Lomotil Prophylactic Scop/Dex prior to reentry

Skylab 1973-1974

Dental kit and dental exam



The diagram shows a collection of dental instruments including forceps, probes, and mirrors. The top photograph shows a dental examination of a man (Charles Conrad) who is lying upside down. The bottom photograph shows a dental examination of a man (Joe Kerwin) who is sitting upright.

- ✓ First use of data down-linking (12-24 hours after experiment)
- ✓ Telescience
- ✓ Inflight medical kit & exercise capability
- ✓ Evacuation capability (crew return vehicle)
- ✓ Inflight Medical Support System (IMSS)
- ✓ First dental kit
- ✓ First medical officer (physician-astronaut Joe Kerwin)

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This diagram shows the dental kit that was flown on the Skylab missions in the event that a dental emergency arose. Instruments and medications were provided as the Inflight Medical Support System Dental Kit (diagram.)

This kit included a manual with line drawings of complete intraoral radiographs of each crewmember as well as integrated, illustrated, diagnostic, and treatment procedures.

Skylab 2 Commander Charles Conrad is seen undergoing a dental examination by Medical Officer Joseph Kerwin in the Skylab Medical Facility. In the absence of an examination chair, Conrad simply rotated his body to an upside down position to facilitate the procedure.

Skylab Inflight Medical Support System

IMSS contained equipment and medical kits with over 1300 different items

- Necessary diagnostic, therapeutic and laboratory equipment needed to diagnose and to render first aid, resuscitative or supportive measures
- Combined weight of the IMSS was 50.85 kg (113 pounds)
- Equipment included:
 - Air Sampler
 - Incubator
 - Slide stainer
 - Splints
 - Microscope kit
 - Hematology / urinalysis kit
 - I.V. fluids kit
 - Drug kit
 - Minor surgery kit
 - Therapeutic kit
 - Dental kit
 - Diagnostic kit
 - Bandage kit
 - Resupply kit



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The Inflight Medical Support System (IMSS) for Skylab was designed to provide the onboard physician or Scientist Pilot with medical equipment adequate to make a diagnostic assessment of those injuries or illnesses most likely to occur in the Skylab environment.

The IMSS equipment was, with the exception of the microbial environmental sampling, designed to be a "contingency use only" system. However, various parts of this system were used inflight to correct other system anomalies, to obtain medical or scientific data, to launch and/or return other experiments, and to support various high school experiments and demonstrations. The IMSS contained equipment and medical kits with over 1300 different items.

The IMSS contained the necessary diagnostic, therapeutic and laboratory equipment needed to diagnose and to render first aid, resuscitative or supportive measures. The combined weight of the IMSS was 113 pounds.

Examples of the uses of the IMSS for biomedical experiments included:

- 1) *The hemoglobinometer*, used in conjunction with the drawing of blood to follow hemoglobin concentrations;
- 2) *The urine refractometer*, used to measure the specific gravity of urine;
- 3) *The sphygmomanometer and stethoscope*, used to evaluate the accuracy of the automatic blood pressure measurement system.



**Space Shuttle
1981 – present**

- ✓ Periodic vital signs monitoring
- ✓ **Wireless monitoring**
- ✓ Samples collected for postflight analysis
- ✓ Real-time telescience
- ✓ **Trained physician and/or medic on board**
- ✓ Expanding research capacity
- ✓ **SOMS Kit**

Medical kit

Inflight blood collection kit

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The Shuttle Orbiter Medical System (SOMS) is required to provide medical care in flight for minor illnesses and injuries. It also provides support for stabilizing severely injured or ill crew members until they are returned to Earth. The SOMS consists of two separate packages: the blue Medications and Bandage Kit (MBK) and the blue with red Velcro Emergency Medical Kit (EMK).

The medical kits are stowed in a modular locker in the middeck of the crew compartment. If the kits are required on orbit, they are unstowed and installed on the locker doors with Velcro.

Each kit contains pallets. The MBK pallet designators are D, E and F. The D pallet contains oral medications consisting of tablets, capsules and suppositories. The E pallet contains bandage materials for covering or immobilizing body parts. The F pallet contains medications to be administered by topical application.

The EMK pallet designators are A, B, C and G. The A pallet contains medications to be administered by injection. The B pallet contains items for performing minor surgeries. The C pallet contains diagnostic/therapeutic items including instruments for measuring and inspecting the body. The G pallet contains a microbiological test kit.

The diagnostic equipment on board and information from the flight crew has allowed diagnosis and treatment of injuries and illnesses through consultation with flight surgeons in the Mission Control Center in Houston throughout the Shuttle program.

Shuttle Orbiter Medical System (SOMS)

Adrenergic Agonist Agents (2)

- Adrenalin (3 X 1mL syringes)
- Epi-Pen (2 syringes)

Amphetamines

- Dexedrine (30 X 5mg)

Analgesic/Antipyretic (2)

- Tylenol (60 X 325 mg)
- Ascriptin (25 X 325mg)

Analgesic/Narcotic (4)

- Meperidine (50mg/mL; 2 X 1mL syringes)
- Fentanyl (2.5mg X 1 patch)
- Morphine sulfate (10mg/mL; 5 X 1mL syringe)
- Hydrocodone/Tylenol (20 X 10mg/660mg)

Antidiarrheal

- Lomotil (32 X 2mg)
- Pepto-Bismol (24)

Anesthetics-Local (2)

- Marcain (Bupivacaine) ± epinephrine)
- Xylocaine (lidocaine ± epinephrine)

Antacid (Ca carbonate/Mg sulfate)

Antimicrobials (10)

- Amikacin
- Metronidazole
- Imipnem/Cilastatin
- Cefadroxil
- Azithromycin
- Augmentin
- Ciprofloxacin
- Bactrim
- Famciclovir
- Fluconazole

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A representative inventory of medications carried in the SOMS are listed in this slide and the next 3 slides. Medications are organized by intended use or therapeutic category.

The process used in selecting medications for the SOMS kit was based on the medical acumen obtained from Mercury, Gemini and Sky Lab. Weight and volume considerations were paramount in drug selection.

SOMS (2)

Antidote – Narcotics

- Narcan (0.4mg/mL; 2 X 1mL syringes)
- Antiemetic (oral & suppository)
 - Promethazine (30 X 25mg tabs, 14 X 25mg supp)
 - Promethazine (50mg/mL; 2 X 1mL syringes)

Antihistamines

- ✓ Sedating
 - Benadryl (20 X 25mg cap)
 - Benadryl (50mg/mL, 2 X 1mL syringes)
- ✓ Nonsedating
 - Claritin (20 X 10mg caps)
 - Antipsychotic
 - Haloperidol/Haldol (5mg/mL, 2 X 1mL syringes)

Antitussive

- Dextromethorphan lozenges (15 X 5mg)

Cardiotropics

- ✓ Adrenergics
 - Adrenalin (1:10,000; 5 X 10mL syringes)
 - Nitroglycerin (tabs & patches)
- ✓ Antiarrhythmics
 - Adenosine (3mg/mL, 2 X 4mL syringes)
 - Lidocaine (20mg/mL, 2 X 5mL syringes)
 - Propranolol (24 X 40mg tabs)
 - Verapamil (2.5mg/mL, 2 X 2mL syringes)
 - Metoprolol (1mg/mL; 3 X 5mL syringes)
 - Procainamide (100mg/mL; 1 X 10mL syringes)

Anticholinergic agent

- Atropine (1mg/mL; 2 X 2mL syringes)

SOMS (3)

Electrolyte supplements

- Ca Gluconate
- Mg Sulphate
- Potassium Chloride

Corticosteroids

- Dental- Kenalog in Orabase
- Anusol HC (6 supps)
- Systemic
 - Decadron (10mg/mL, 2 X 1mL syringes)
 - prednisone (30 X 20mg tabs)

Decongestants

- ✓ Oral
 - Pseudoephedrine/ Guaifensin
- ✓ Nasal
 - Afrin (6 X 3mL containers)

Dermatology medications

- ✓ Antibiotic – topical
 - Bactroban (2%; 15gm tube)
 - Neosporin/Lidocaine
 - Silvadene (1%, 20gms)
 - Topicort (0.25%, 15gms)
- ✓ Antifungal – topical
 - Lotrimin (1%; 15gm tube)

Hormone therapy – female

- Ovral 21

✓ Hypnotics/Sedatives

- Restoril (40 X 15mg tabs)
- Valium (30 X 5mg tabs)
- Versed (1 mg/mL; 1 X 5mL syringes)
- Ambien (75 X 10mg tabs)

Laxative

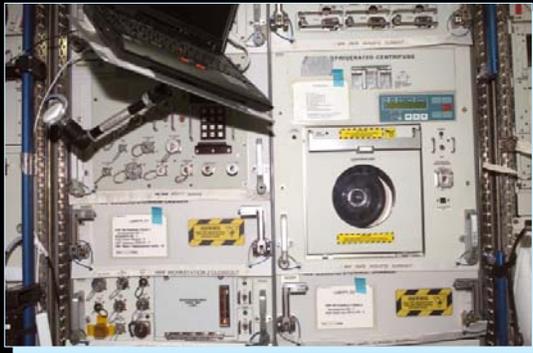
- Dulcolax (5mg and 10mg supps)

SOMS (4)

Ophthalmics

- ✓ Anesthetic, local
 - Alcaine 0.50%
- ✓ Antibiotic
 - Ciloxan 0.3%
 - Cortisporin
 - Genoptic 0.3%
- ✓ Antiviral
 - Vira-A 3.0%
- ✓ Mydriatic (pupillary dilator)
 - Cyclogyl 1.0%

International Space Station 1998 - present



Human research facility (HRF)

Rack 2 with refrigerated centrifuge



Continuous blood pressure
measurement device

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- ✓ Test protocols and procedures
 - Medical
 - Systems
- ✓ New technologies
 - Monitoring
 - Ultrasound device

View of the center of the Human Research Facility (HRF).
Rack 2 with the Refrigerated Centrifuge visible at location code
LAB1P4_G2 in the Destiny laboratory module as
photographed by the Expedition 14 crew.

ISS Medications

RUSSIAN SEGMENT

- ✓ Anti-Inflammatory Agents (Kits 1, 2, 3, 4)
- ✓ Antiseptic Remedies Kit
- ✓ Aspro Medical Kit
- ✓ Burns and Wounds Kit
- ✓ Cardiovascular Remedies Kit
- ✓ Gastrointestinal and Urological Kit
- ✓ Ointment Kit
- ✓ Preventive Remedies (Kits 1, 2, 3, 4)
- ✓ Psychotropic Remedies Kit

U.S. SEGMENT

- ✓ Tylenol (oral)
- ✓ Acetazolamide (oral Diamox)
- ✓ Acyclovir (ointment)

***etc,etc,etc...24 pages...191
meds***

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Medical kits are maintained by the two primary ISS partners and are located in each partner's area on the station.

The U.S. ISS kit is similar in organization to the SOMS, but has an expanded array of medications.

Medications in both kits are labeled in English and Russian.

Inflight Medical Events

Event	Program	Mission impact
Nitrogen Tetroxide leaked into capsule on reentry	Apollo Soyuz Test Project	Crew hospitalized postflight for chemical pneumonia
Intractable headaches after probable combustion event	Salyut Space Station	Abandoned Salyut
Urinary tract infection	Salyut Space Station	Evacuation
Cardiac dysrhythmia	Mir Space Station	Evacuation
Acute grief reaction	Mir Space Station	Crew withdrew for 1 week
Urinary retention (4 cases)	Shuttle Program	Bladder catheterization
Acute behavioral change	Shuttle Program	Crew concerned about dangerous behavior
Excessive medication use prior to EVA	Shuttle Program	Performance impacts
Misuse of on-orbit medications	Shuttle Program	Performance impacts
Unexpected reaction to medications	Shuttle Program	Caused urinary retention
Cardiac abnormalities detected	ISS Program	Crew member pulled from EVA
Crew-crew interpersonal conflicts	All Programs	
Crew-ground interpersonal conflicts	All Programs	
Cardiac ischemic event treated w/aspirin & beta blocker	Russian Program	MI 6 weeks postflight

Ground Medical Events

Cardiovascular

- Ventricular tachycardia, exercise induced
- Angina
- Atrial fibrillation
- Stroke (2)

Gastro-Intestinal

- Appendicitis (2)
- Diverticulitis
- Choledocholithiasis
- Pancreatitis
- Lower GI bleeding
- Duodenal ulcer with upper GI bleeding
- Clostridium difficile infection
- Gastroenteritis/ Colitis
- Inguinal hernia (4)

Musculo-skeletal

- Cervical disk herniation with impingement on spinal cord
- Hand bacterial tenosynovitis

Ophthalmological

- Corneal ulcer
- Retinal detachment (2)

Gynecological

- Right ovarian cyst
- Dysmenorrhea
- Hemorrhagic cyst

Other

- Allergic reaction – severe
- Sudden hearing loss (2)
- Malignant melanoma
- Pneumonia (2)
- Kidney stone (14)
- Severe epistaxis

Environmental Events

Event	Program	Mission impact
Frequent leaks of ethylene glycol from cooling loops	Mir	Contaminated air and water
Formaldehyde escaped containment	Mir	Contaminated air
Oxygen candle fire	Mir	Contaminated air (Benzene)
Overheating Catalytic Oxidizer	Mir	CO Levels elevated
Progress Mir Collision	Mir	Loss of Module
Combustion events (5)	Shuttle	TBD
LiOH dust escaped from CO ₂ removal canisters	Shuttle	TBD
Microbial production of methyl sulfides from liquid waste	Shuttle	TBD
Freon 218 leaks from SM air conditioner	ISS	Timeline impact to troubleshoot
METOX canister regeneration	ISS	Noxious air
Formaldehyde levels periodically exceed long-term limits, especially when debris restricted ventilation	ISS	Timeline impact to troubleshoot
Strong solvent-like odor from Elektron oxygen generator after repair work	ISS	Timeline impact to troubleshoot
Potential acid preservative aerosol escape (Russian urinal)	ISS	Timeline impact to troubleshoot
ISS Window Leak	ISS	Lost research time to troubleshoot

PROGRESS FROM MERCURY TO ISS

- ✓ 3 MEDICATIONS TO 191
- ✓ ORAL PREPARATIONS
- ✓ I.M. PREPARATIONS
- ✓ SUPPOSITORIES
- ✓ OPHTHALMIC PREPARATIONS

CAPABILITY TO TREAT WIDE RANGE
OF MEDICAL CONDITIONS

Future Medical Recommendations for Exploration Class Missions

- ✓ Need more medication shelf life data
- ✓ Need extensive pharmacokinetic studies
- ✓ Need a more robust autonomous medical system
 - On board physician with appropriate skill set and current medical practice experience
 - Expanded surgical capability
 - Better understanding of general anesthesia in space
 - On board tutorial capability to maintain physician currency