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APOLLO EXPERIENCE REPORT - CREW STATION INTEGRATION

Volume IV - Stowage and the Support Team Concept

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16. Abstract

Crew equipment stowage and stowage arrangement in spacecraft require configuration control in order to maximize crew equipment operational performance, stowage density, and available stowage volume. The NASA crew equipment stowage control process requires a support team concept to coordinate the integration of crew equipment into the spacecraft.

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FOREWORD

This technical note documents experience gained in the area of spacecraft crew-station design and operations during the Apollo Program. Emphasis is given to the time period ranging from early 1964 up to, and including, the Apollo 11 lunar landing mission of July 1969 — an era that covers three important phases of the Apollo Program: the design phase, hardware construction, and mission operations.

This technical note consists of five volumes. Volume I, "Crew Station Design and Development," gives an overview of the total crew station integration task. Volumes II, III, IV, and V are specialized volumes, each of which is devoted to a basic functional area within the Apollo crew station. The subject of each volume is indicated by its title, as follows.

Volume II, "Crew Station Displays and Controls"

Volume III, "Spacecraft Hand Controller Development"

Volume IV, "Stowage and the Support Team Concept"

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APOLLO EXPERIENCE REPORT

CREW STATION INTEGRATION

VOLUME IV - STOWAGE AND THE SUPPORT TEAM CONCEPT

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SUMMARY

Stowage arrangement for spacecraft has evolved from an unsophisticated process used during the first manned space flights to the exact and complex skill involved in landing on the moon.

Within weight limitations, crew equipment design required operational endurance and performance. Also, the stowage density of crew equipment in the spacecraft had to provide maximum available stowage volume. Configuration control of crew equipment from mission requirements to launch has been adopted as a result of these important requirements. The NASA crew equipment stowage control process requires a team concept to assure the integration of crew equipment into the spacecraft in a timely manner.

The crew station team successfully managed and ensured that spacecraft crew equipment supported the operational phase of space flights during the Apollo Program. Working with the stowage contractor personnel and crew equipment suppliers, the support team was able to meet all objectives of equipment performance, stowage packaging, and stowage volume utilization.

The development of crew equipment and crew station stowage arrangements was directed toward minimizing the crew tasks in retrieving and using crew equipment in zero g. It is desirable to do as many one-handed operations as possible in zero g and to leave one hand free to grasp handholds and to counteract body torques generated by removing, replacing, or using certain crew equipment.

INTRODUCTION

The increase in the amount of crew equipment flown on the Gemini and Apollo Programs over that flown on Project Mercury created a need for crew equipment stowage lists and techniques for more rigid configuration control. The Flight Crew Support Team implemented the stowage list requirements and assured configuration control of the crew equipment. As more manned space flight experience was gained, four broad concepts in the crew equipment and crew station stowage arrangement evolved as the criteria to be applied in manned spacecraft working environments. These concepts are modular stowage, frequency of crew equipment use, zero-g handling procedures, and equipment control. The spacecraft mockups, "top" (overall) stowage drawings, and crew equipment stowage lists were developed to help implement the concepts.

DISCUSSION

Operational Considerations

The expense of repeating aircraft flights is negligible when compared with the launch-to-return expense of Apollo space flights. Whereas malfunctioning crew equipment in aircraft can be readily replaced or repaired after a flight, malfunctioned spacecraft crew equipment cannot be replaced and the mission reflown. Therefore, the nature of manned space flights required maximum attention to crew equipment functional endurance and performance. Careful quality control had to be maintained to preclude errors and malfunctions in crew equipment before stowage for launch.

Control and stowage of the crew equipment became full-time tasks. Controlled areas for maintaining crew equipment were developed, and flight equipment inspection and documentation became a major task in quality control functions (fig. 1).

To successfully manage and ensure that spacecraft crew equipment supported the operational phase of space flights, the crew station team support concept was implemented at the beginning of the Gemini Program and was expanded for the Apollo Program.

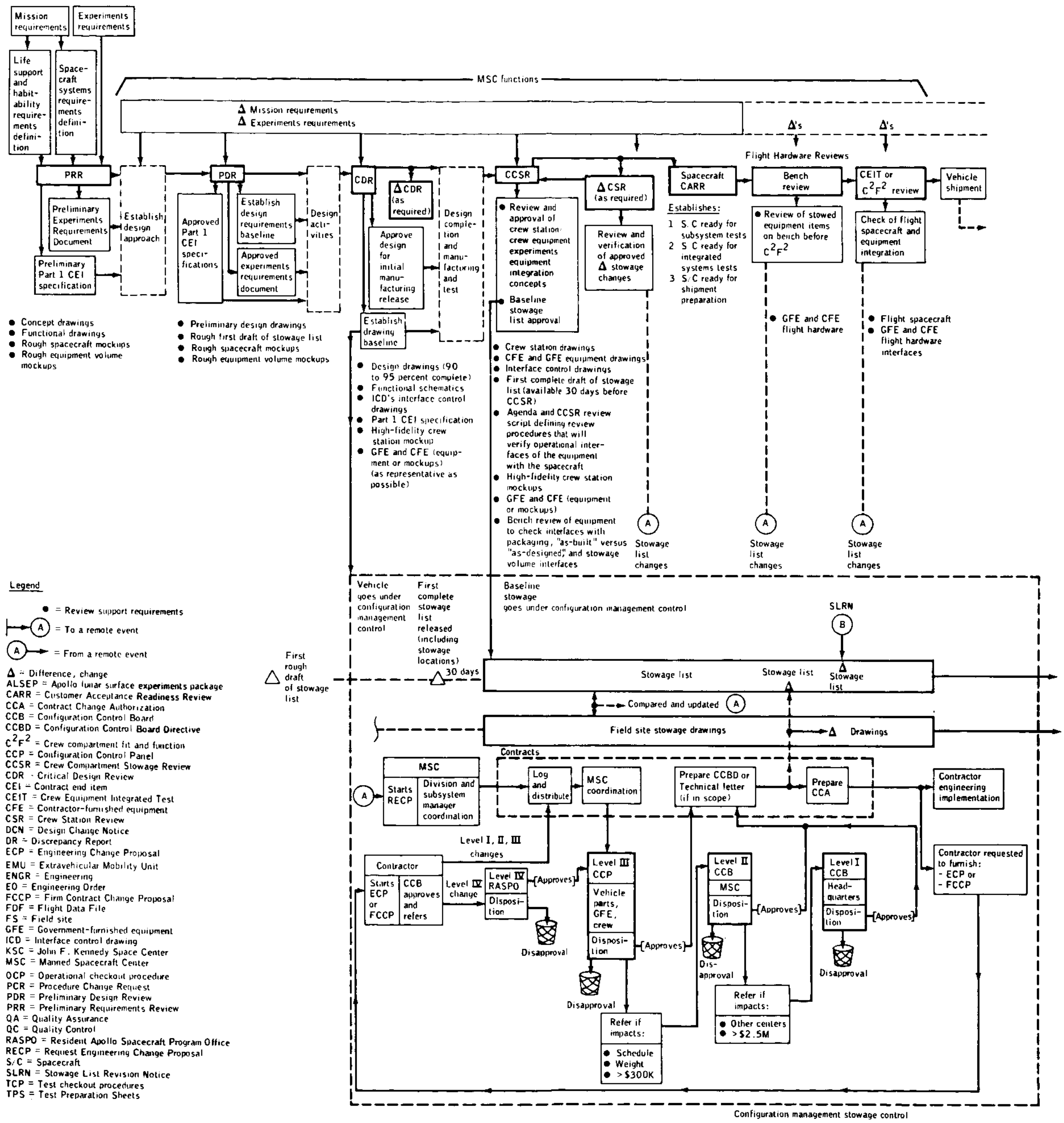

Figure 1. - The NASA stowage process.

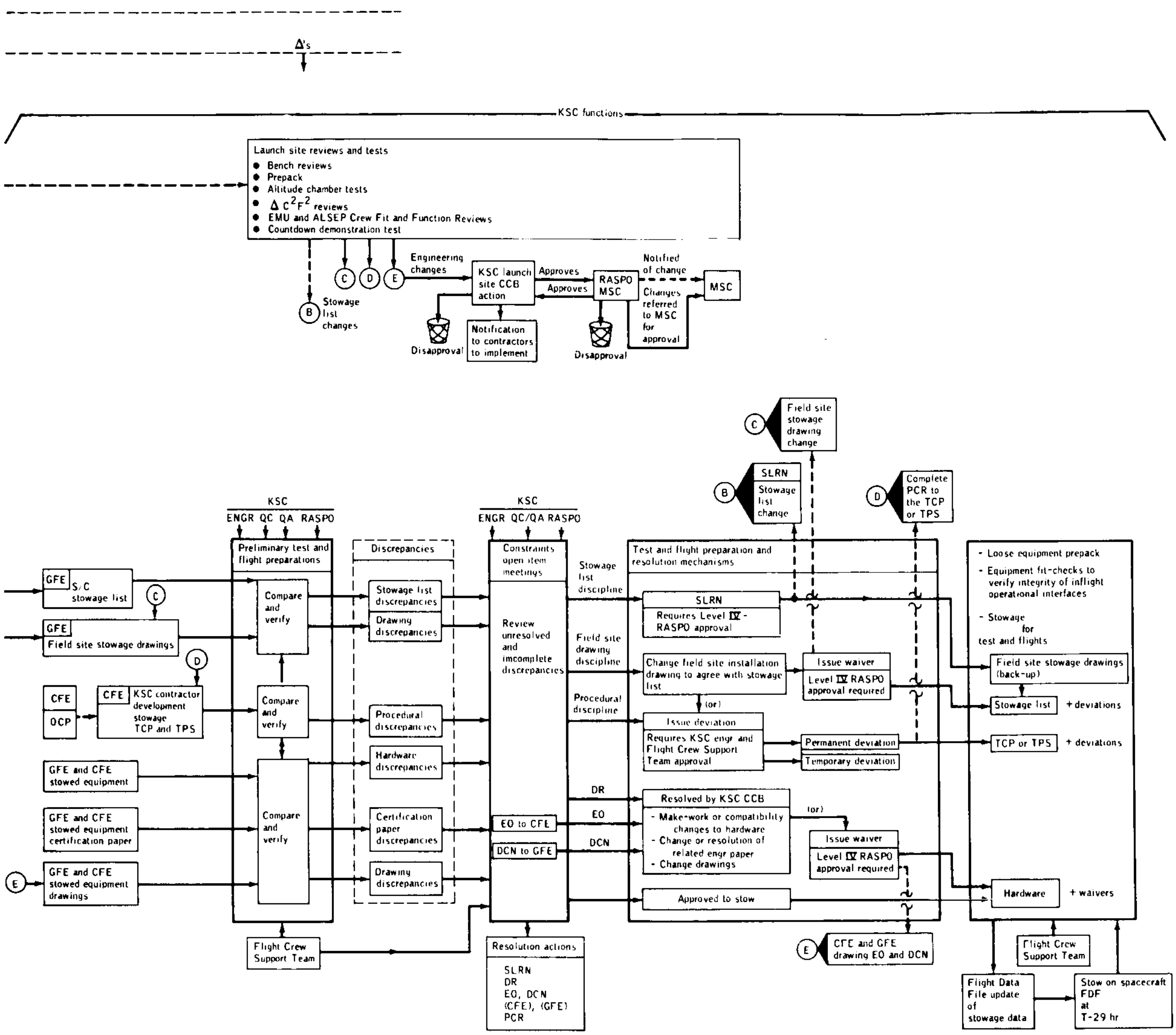

Figure 1.- Concluded.

Flight Crew Support Team

The Flight Crew Support Team provides technical and operational support to the flight crew during crew training, spacecraft reviews, and checkout tests at the contractor facilities and at the NASA John F. Kennedy Space Center. Personnel assigned to each support team were designated 10 months before launch. Duties and crew support functions of the team are described in the Apollo Crew Integration Plan, which was released to the NASA management and to Apollo hardware contractors. Basically, the team duties encompass all areas associated with crew equipment stowage in the spacecraft for launch. These duties include working with the assigned flight crews in training to assure that stowage in the simulators and the mockups is in the same configuration as that in the spacecraft. Maintaining mockups to the current spacecraft configuration is a constant problem caused by the continuously changing flight crew equipment. The team member who is familiar with the spacecraft configuration provides consultation to the crewmen as they practice the tasks of unstowing equipment in orbit and restowing for entry. These tasks are practiced in authentic mockups in the same sequence as planned for flight. To further assure successful launch or return stowage, including temporary stowage, the team coordinates flight-hardware-to-spacecraft interface fit checks. Furthermore, the team provides liaison among the flight crews, the Apollo Spacecraft Program Office, and other groups associated with crew training and crew participation in spacecraft checkout. Launch day preparation for the crew, up to the time of crew insertion into the spacecraft, is handled by the Flight Crew Support Team.

Apollo Couch and Crew Restraints

The design criteria used for the Apollo command module couch and restraint system relative to crew equipment stowage were as follows.

1. To provide crew restraint in the correct position for all mission phases

2. To allow performance of mission-required crew activities, including stowing the tunnel probe, hatch, and drogue; donning the portable life support system (PLSS) for extravehicular activity (EVA); performing an EVA through the side hatch; and operating the guidance and control console

3. To allow access to all crew station control panels and stowed equipment

To satisfy the design criteria, the center couch was constructed so that it could be folded out of the way and could allow the crewmen to move about and perform various activities, such as those previously discussed.

The couches were designed primarily to accommodate three suited crewmen during entry. Difficulty was encountered during entry, when crewmen were unsuited, because the heel-clip half of the foot restraint was in the suit boot heel. This problem was solved with heel clips that the crewman could strap on, much like sandals with metal heels. These heel clips were stowed for launch and then unstowed for entry. Additionally, the headrest was designed primarily to support the helmet of the suited crewman during entry. The headrest problem was solved for the unsuited crewman by headrest pads that could be stowed for launch and installed before entry.

Stowage-Arrangement Experience

During Project Mercury and the Gemini Program, experience was gained in crew station concepts in terms of modular stowage, frequency of crew equipment use, zero-g handling procedures, and interface control of equipment. The use of Velcro hooks, bonded to loose equipment and mated to bonded Velcro pile in the spacecraft, was devised for temporary inflight stowage during Project Mercury and continued to be used in subsequent programs. The Gemini Program was the first in which the concept of modular container stowage was used, and the concept was applied more extensively in the Apollo Program. This concept involved standardized containers or boxes filled with a plastic-foam material molded to fit the contours of the items stowed within the container.

Two distinct advantages were realized with the adoption of this stowage concept. First, standardized containers with different interiors made it possible to use the same basic stowage arrangements for widely varying mission requirements. When mission requirements changed, only the interior container inserts had to be changed to accommodate the new stowage arrangement. Second, spacecraft checkout serial time required for prelaunch stowage was reduced greatly because equipment could be prepacked in controlled areas away from the spacecraft.

CREW EQUIPMENT SOURCES

Equipment stowed on board the spacecraft was serialized for tracking purposes and was categorized. The categories were Government-furnished equipment (GFE), contractor-furnished equipment (CFE), and experimental equipment.

Government-Furnished Equipment

Government-furnished equipment is defined as equipment supplied by the Government. Some equipment supplied by the Government is manufactured in Government-owned-and-operated shops; however, this type of supplied equipment is kept to a minimum to avoid the connotation of a competitive business enterprise. Most GFE is purchased from selected contractors on a competitive basis. After delivery of GFE to the NASA, the hardware is processed for spacecraft installation or stowage, as described in figure 1.

Contractor-Furnished Equipment

Contractor-furnished equipment is defined as equipment supplied by a spacecraft contractor. This equipment may be manufactured in contractor shops or purchased through a vendor. Where circumstances dictated, the contractor was given directions from NASA to purchase CFE from a specific vendor when a certain item was common to both the command and service module (CSM) and the lunar module (LM).

Experiment Equipment

Most scientific experimental equipment is built or purchased by the Government and could be classified as GFE. Although this experiment equipment is not placed on board to support the crew, the crew must deploy the equipment to perform the experiments.

SPACECRAFT MOCKUPS

The quantity of changes or modifications in crew equipment led to real-time problems in spacecraft fit tolerances and spacecraft environmental compatibility. Crewmen were provided with additional training aids for familiarization with existing hardware stowage locations and updates to hardware changes. The problem of assuring that the mockups were up to date with the changing hardware was solved by directing the module contractor to provide modification kits for the mockups. The modification kits were flight-production units identical to those to be used for the flight module installation.

Consequently, spacecraft mockups became a necessary, expedient tool in determining the best use of the available spacecraft stowage volume. These mockups provided the flight crews with a quick, ready reference to pending changes and a complete spacecraft-interior-configuration likeness for training with crew equipment and for experiment equipment handling.

TOP STOWAGE DRAWINGS

Crew equipment stowage orientation inside a volume within a spacecraft has become a controlled sequence. When one group of people stows equipment a certain way in the mockup and another group of people stows the equipment differently in the spacecraft, confusion concerning crew equipment location and usage in flight results.

Because of the large quantity of crew equipment, the top stowage drawings were developed and have become mandatory to aid in the proper stowage of equipment. The spacecraft stowage drawings consist of a top assembly drawing divided into four main categories: a listing of all the loose crew equipment (defined as that crew equipment which can be removed, without tools, from one location and placed in another location by a crewman); three-dimensional views of the crew equipment arrangement in a modular container; three-dimensional views of the crew equipment arrangement within a spacecraft crew station volume; and modular container location within the spacecraft.

MODULAR STOWAGE

Modular container stowage has been proved to be the best method of handling crew equipment for installation into the flight spacecraft. However, some areas of the spacecraft are not suitable for the use of a modular container, and not all the crew equipment can be stowed in a modular container. For instance, the lunar-boot overshoes are large and dimensionally unsuitable to be stowed in this manner.

Modular container stowage involves the use of volumetric boxes with cushion inserts designed to hold various pieces of crew equipment. For example, one container may contain cameras, film magazines, lenses of various focal lengths, brackets, and power cables. The box containing these items is coded B3, denoting the spacecraft location as the third box from left to right in the lower equipment bay. Similar designations are applicable to other sectionalized areas in the spacecraft (fig. 2 and table I).

The use of modular container stowage has several advantages that extend from the time of receipt of crew equipment in a controlled area to final spacecraft installation. The primary advantages are reduced time in crew equipment preparation in the bond room, capability to review the crew equipment before installation in the spacecraft, and reduced serial time in spacecraft installation.

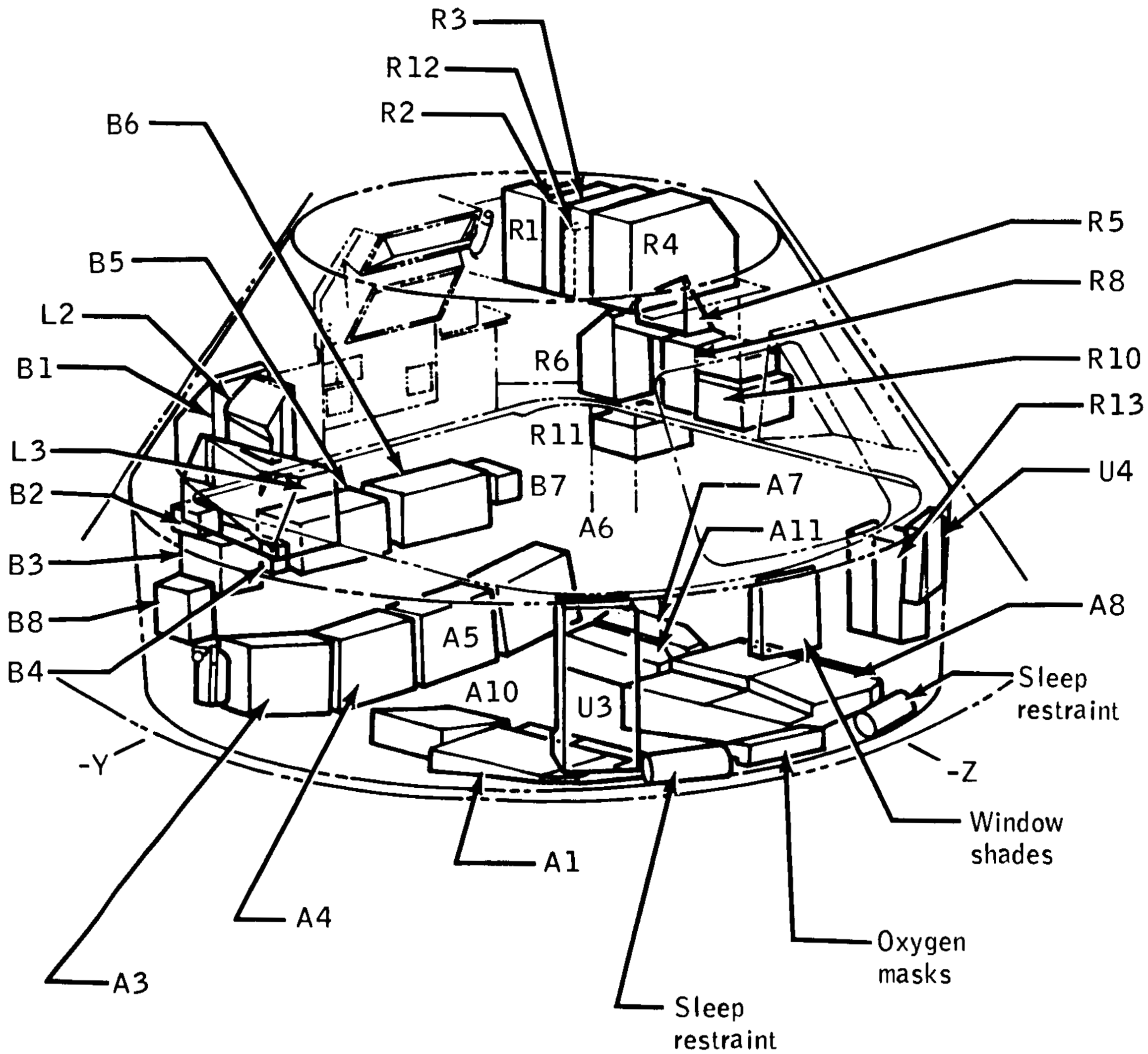

Figure 2. - Command module crew station stowage geometry, according to sectionalized areas.

TABLE I. - COMMAND MODULE CREW STATION STOWAGE LIST

Stowage location (a)	Equipment	Quantity
A1	Penlights with bag	2
	Utility towel assembly	3
	Tissue dispensers	5
	Snag line with container and strap	1
	Temporary stowage containers	3
	Gas separators with bag	2
	Postlanding ventilation ducts with container	3
	Pressure garment assembly oxygen interconnects with container	3
	Sea dye marker	1
	Probe stowage straps	2
	Chlorination ampule container	1
	Chlorination ampules	4
	Buffer ampules	3
	Hasselblad camera adapter	1
	Tool kit	1
	Utility strap	1
A3	Carbon dioxide absorbers	4
A4	Carbon dioxide absorbers	4

[a]See figure 2.

Stowage location (a)	Equipment	Quantity
A5	Headrest pads	3
	Heel restraints	3 pair
	Sleep restraint ropes	5
	Sextant adapter for 16-mm camera	1
	Spotmeter	1
	Two-speed timer	1
A6	Carbon dioxide absorbers	2
	Television monitor with cable and strap	1
	12-foot television cable with strap	1
	Television-camera bracket	1
A7	Television color camera with zoom lens	1
	Television ringsight	1
A8	Liquid-cooled garments	2
	Fecal containment system	3
	Extravehicular mobility unit maintenance kit	1
	Pilot preference kits	3
	Inflight exerciser	1
	Lightweight headsets (two with earmold installation)	3
	Relief receptacle in container with straps	1
	Constant-wear-garment GFE adapters in bag	4

[a]See figure 2.

TABLE I. - COMMAND MODULE CREW STATION STOWAGE LIST - Continued

Stowage location (a)	Equipment	Quantity
A8	Tissue dispensers	2
	Constant-wear garments	3
	Decontamination bags	7
	70-mm magazines in bag	2
A10	S-158 experimental assembly:	
	70-mm electric Hasselblads	4
	70-mm magazines	7
	Photar filters - blue, red, orange, and 87C	1 each
	Intervalometer	1
	Camera mount	1
A11	50-mm lens	1
	Remote-control cable	1
	70-mm camera-bracket assembly	1
B1	Food and hygiene equipment	1
B2	16-mm magazines in bag	4
B3	18-mm lens	1
	16-mm power cable with strap	1
	Right-angle mirror	1
	5-mm lens with cover	1

[a]See figure 2.

TABLE I. - COMMAND MODULE CREW STATION STOWAGE LIST - Continued

Stowage location (a)	Equipment	Quantity
B3	75-mm lens	1
	16-mm data acquisition camera with magazine installed	1
	70-mm electric Hasselblad with 80-mm lens and magazine installed	1
B4	Chlorination ampules	3
	Buffer ampules	3
	Chlorination needle	1
	Chlorination syringe casing	1
	Chlorination syringe knob	1
	Chlorination-equipment container	1
B5	Carbon dioxide absorbers	4
B6	Carbon dioxide absorbers	4
B7	Chlorination ampules	3
	Buffer ampules	4
	Chlorination-ampule container	1
B8	Voice recorder with battery and tape cassette	1
	16-mm magazines	5
L2	Electrostatic ground cable	1
	Adapter tool E with strap	1

[a]See figure 2.

TABLE I. - COMMAND MODULE CREW STATION STOWAGE LIST - Continued

Stowage location (a)	Equipment	Quantity
L2	Camera control unit control head (spare) with container	1
	Camera control unit spare cable with strap	1
L3	Food packages with food restrainer pouches and contingency feeding valve adapter	NA[b]
R1	Flight data file books	NA
	Guidance and navigation handles	2
	High-density sun filters (guidance and navigation)	2
	Glare shields (display and keyboard, and so forth) with four straps	1
R3	Flight data file books	NA
	Flight data card kit	1
	Stowed in data card kit:	
	Floodlight glare shield	1
	Eye patch	1
	Meter covers	2
	Fuse for 16-mm camera	1
	Flight data file clips	6
	Guidance and navigation alinement procedures	1
R4	Survival kits	2

[a]See figure 2.

[b]Not available.

TABLE I. - COMMAND MODULE CREW STATION STOWAGE LIST - Continued

Stowage location (a)	Equipment	Quantity
R5	Gas and liquid waste management system quick-disconnect filter assemblies	2
	Inflight retainer straps	3
	Back-to-back straps	6
R6	Helmet bags	3
	Accessory bags	3
	Tape	1
	Cabin vent quick-disconnect	1
R8	Medical kit (with urine collection transfer assembly roll-ons)	1
R10	Fecal collection assemblies	30
	Sanitation supply box (aft)	1
	Sanitation supply box (forward)	1
	Coupling assembly water panel	1
	Water panel quick-disconnect	1
	Waste management system pressure cap quick-disconnect	1
	Waste management system power cable	1
R11	Roll-on cuffs (red, white, blue)	1 package each
	Urine transfer systems with roll-ons	3
	Urine receiver (spare)	1

[a]See figure 2.

TABLE I. - COMMAND MODULE CREW STATION STOWAGE LIST - Continued

Stowage location (a)	Equipment	Quantity
Guidance and navigation panel, lower equipment bay	Radiation survey meter	1
Aft bulkhead, under A6	Urine Hose assembly with container	1
	Inflight retainer strap	1
	Urine collection transfer assembly transfer adapter	1
On camera control unit	Camera control unit control heads	3
On upper equipment bay oxygen repressurization system	Shades with container	5
On side of A3	Fire extinguisher	1
Above left-hand window	Crew optical alinement sight with bulb	1
In environmental control unit	Carbon dioxide absorbers	2
Oxygen repressurization	Oxygen mask and hose with utility straps and container	3
Aft upper equipment bay	Rest restraints (left, right, and center)	3
R12	Flight data file books	NA

[a]See figure 2.

TABLE I. - COMMAND MODULE CREW STATION STOWAGE LIST - Continued

Stowage location (a)	Equipment	Quantity
R13	16-mm magazines in bag	6
	Passive dosimeter (in 16-mm magazine bag)	1
	70-mm magazines in bag	3
	70-mm magazines in bag	2
	Jettison stowage bag	1
U3	Docking target adapter	1
	16-mm camera bracket	1
	LM docking target	1
	Crew optical alinement sight light bulbs	2
	Crew optical alinement sight filter	1
U4	Tape recorder cassettes	4
	Recorder battery packs	4
	Monocular	1
	Intervalometer	1
	250-mm lens	1
Under left-hand couch	Forward hatch container	1

[a]See figure 2.

TABLE I. - COMMAND MODULE CREW STATION STOWAGE LIST - Concluded

Stowage location (a)	Equipment	Quantity
In pressure garment assembly bag under center couch	Urine collection transfer assembly clamps	3
	Oxygen screen clamps	3
	Couch straps	3
	Pressure garment assembly electrical connector covers	3
	Helmet shield	1
On guidance and navigation panel	Verb and noun list (guidance and navigation)	1
On B5 and B6	Closeout curtains, B-5 and B-6	1 each
Under A3	Acoustic tone booster in bag	1
Side of A8	Vacuum brushes in bag	2
	Vacuum hose in bag	1
Right and left lower equipment bay	Calfax adapter plate assemblies, right and left	2 each
Closeout curtain pockets, in pouches	Data retention snap assemblies, hook assemblies, snap clamps, and spring clips	NA
On B1 door	Snap adapters, food compartment	6
On translational and rotational hand controllers	Harness straps	3

[a]See figure 2.

Display/Bench Check

The first milestone in the preparation of crew equipment for stowage is a bench check. A full complement of flight equipment is laid out on a table in the bonded storage room for crew inspection and familiarity before a major event (for example, altitude-chamber testing). The bench check gives the crew an opportunity to compare the training equipment (with which they are familiar) to the flight equipment (which they may be seeing for the first time). Flight equipment that is modified after a bench check and items that are not available for the bench check are stowed in the spacecraft for the next major test in which the crewmen participate. The equipment is examined by the flight crew at that time.

Crew Equipment Modifications

Crew equipment modifications affecting external dimensions can be worked and fitted into a modular container box on a timely basis without impacting a spacecraft checkout and flow schedule.

Crew Equipment Inspection

Crew equipment can be quality-control inspected before it is installed in modular containers because this activity takes place in work areas outside the spacecraft. Top assembly stowage drawings must be available for reference when questions on equipment orientation arise. Such questions are solved more readily in the bonded storage room than during peak periods of activity in the spacecraft.

Prepack Operations

Prepack operations consist of placing the crew equipment to be flown in its respective modular container. As each item is inspected for damage and cleanliness, it is placed into its respective cushioned area in the container; the top assembly stowage drawings are used to ensure that the container is packed properly.

Modular Container Transport

Packed modular containers are sealed in plastic to maintain the cleanliness necessary during transport from the bonded storage area to the spacecraft. Modules also prevent crew equipment damage that could occur if the equipment were handled separately or were improperly cushioned.

Modular Container Installation

Modular container installation in the spacecraft minimizes stowage time. Container installation consists of visual inspection, as a final quality-control measure to verify that no damage to the equipment has occurred during transport; placement of the module into the prefitted, checked location; and securement of the module with pip pins or Calfax fasteners.

FREQUENCY OF CREW EQUIPMENT USE

Just as in any aircraft cockpit that has provisions for stowed equipment, some areas in a spacecraft are more accessible than others. Because of pressure-suit bulk and the zero-g environment, prime consideration is given to allocating high-use crew equipment to the most accessible locations and low-use equipment to the least accessible areas. Food and camera equipment are examples of crew equipment that occupy the most accessible locations in the stowage arrangement. Equipment that is used periodically or that can be retrieved with minimum effort can be categorized as secondary stowed equipment. A generalized matrix of stowed crew equipment could be classified as follows.

Primary	Secondary	Tertiary
Food	Medical kit	Survival kits
Personal-hygiene equipment	Lithium hydroxide cartridges	EVA equipment
Cameras and equipment	Tethers	Tool kits
Flight data file		

ZERO-GRAVITY HANDLING PROCEDURES

The natural law of physics, "... to each action there is an equal and opposite reaction," is very pronounced and applicable in zero g. Inside the spacecraft, the crewmen use strategically located handholds to aid in their maneuverability. Primary and secondary stowage of equipment is justified further on the basis of limiting body maneuvers needed for retrieval.

Temporary retention methods that satisfy the temporary stowage requirements have been developed, tried, and proved. Four different methods have been used for temporary retention of high-use crew equipment. These are Velcro, metal snaps, utility straps, and bungee cords.

Velcro

Velcro has proved to be a very effective general-purpose temporary retention device and was used as the only retention device in Project Mercury and the Gemini Program. Patches of Velcro hook were bonded to areas on spacecraft bulkheads conveniently within reach of the crewmen. Small patches of Velcro pile were bonded to the crew equipment. The mating of Velcro pile to Velcro hook provided the necessary retention and ease of retrieval as the equipment was used.

However, the Velcro was made of nylon and had a high burn rate. After the Apollo fire, a new Velcro material was developed that was less combustible but less effective. Consequently, the use of Velcro became limited and other methods of retention were investigated.

Metal Snaps

Metal snaps have become second to Velcro in frequency of usage for equipment retention. The snaps are nonflammable and have become the prime method for retention of debris guards and container flaps throughout the spacecraft. One side of a snap, either male or female, must be mounted to a hard surface in the spacecraft. Snaps also are used to secure covers on Beta-cloth bags, in which the male portion of the snap is attached to a hard surface. Apollo flight crews have found that separation of soft-backed snaps is very difficult to perform while in space suits and in a zero-g environment.

The two types of snaps in spacecraft use are unidirectional and omnidirectional. Unidirectional snaps are used when the holding requirement is subjected to the forces of lift-off and landing. These snaps are designed so that when the two portions are mated, the force acting on the snap cannot separate them. However, if separation forces are applied on the opposite side from the acting forces, the mating snaps release easily. Omnidirectional snaps are separated easily and are used to hold against light forces, mostly by shear. This is the type of snap used to hold the spacecraft debris guards.

Utility Straps

Utility straps were developed to supplement the limited amount of Velcro placed in the spacecraft. These straps were approximately 12 inches long, with mating snaps and a tab of Velcro pile at each end. This configuration enabled the strap to be snapped around a handhold or on another snap within the spacecraft, and the Velcro at the opposite end was used to retain crew equipment.

Bungee Cords

Bungee-cord retention is the newest technique used for temporary stowage of crew equipment in zero g. Bungee cords were suggested by the Apollo 10 crew and were carried on the Apollo 11 and subsequent missions. Bungee cords are metal "screen door" springs with snaps attached to each end. These bungee cords are slightly stretched between mating snaps, strategically located in the crew compartment. This method provides a retention scheme whereby loose items such as gloves, food packs, books, and pens may be pressed behind the expanded spring. The use of bungee cords has proved to be the best supplement to Velcro for loose equipment in the spacecraft.

INTERFACE CONTROL

The interface control of crew equipment is the biggest task to accomplish in crew station stowage arrangement. Interface control of equipment becomes very involved when several different contractors are selected to provide crew equipment. Each source must be familiar with the interface to which that equipment must fit for the crew station stowage arrangement to integrate all equipment into the spacecraft. Further emphasis is placed on crew equipment serialization. The serialized equipment is fit checked to the launch and in-use configuration to assure that interface control has not been violated and that dimensional problems have been solved. After a serialized piece of equipment is fit checked, it is documented and assigned to the respective spacecraft. Principally, interface control becomes necessary between flight crews and crew equipment, flight crews and spacecraft, crew equipment and spacecraft, and spacecraft and spacecraft.

Flight-Crew-to-Crew-Equipment Interface

The interface between flight crew and crew equipment is the most difficult to control. Probably the most difficult item of crew equipment to fit is the suit. Obviously, the element of human feeling and comfort is a prime factor in achieving peak operational performance. Other factors are the suit and crewman mobility and operational efficiency that are affected by the PLSS, penlight, pens, and other equipment. Mobility, comfort, and operational efficiency cannot be measured by volume or width and depth. This interface can be controlled only by the individual to whom the equipment has been fitted.

Flight-Crew-to-Spacecraft Interface

Two design reviews (milestones) have been implemented, in phase II of the Apollo Program and in the Skylab Program, for primary stowage design and identification of flight crew interface problems with spacecraft hardware. These reviews are the Preliminary Design Review (PDR) and the Critical Design Review (CDR).

The PDR is concerned with the contractor sketches in terms of proposed stowage concepts and methods of crew equipment retrieval and use. The NASA crew representatives familiar with stowage concepts and crew station arrangements review the stowage sketches and propose changes to drawings and concepts.

The CDR is the final contractor-drawing review with NASA representatives before drawing release. After drawing release, manufacturing and flight-hardware production is begun. Verification of the stowage design and redesign (or both) usually is performed in the contractor-facility mockup by a NASA flight crew and then again in the actual spacecraft.

Crew-Equipment-to-Spacecraft Interface

Experience has shown that control of the crew-equipment-to-spacecraft interface is a very difficult task. Of the crew equipment items flown, a small percentage was manufactured by the spacecraft contractor. Therefore, it was necessary to implement a contractual document, known as an interface control drawing (ICD), that describes an agreement among all participating parties (that is, spacecraft contractor, crew equipment contractor, and NASA). The drawings were signed by all parties, and the crew equipment was designed within the basic criteria set forth in these drawings. For example, a dimensional drawing of the PLSS is submitted by the crew equipment contractor for NASA approval. The spacecraft contractor must approve the ICD because the PLSS interfaces with stowage provisions in the LM. The suit manufacturer must approve the ICD because the PLSS attaches to the crewman space suit. The NASA must approve the ICD because the crewman must fly the spacecraft, wear the suit, wear the PLSS, and rely on the PLSS for life support. Obviously, any small change in detail in any one of the points of interface could affect the fit and function of the equipment. Therefore, all concerned must agree on a change before it can be implemented.

After the flight hardware had been manufactured and serialized, it is fit checked to its respective in-use position in the spacecraft. These checks eliminate the misfits that sometimes occur because of tolerance buildup or dimensional errors.

Spacecraft-to-Spacecraft Interface

Some crew equipment is stowed in the LM at earth launch, then transferred into the command module (CM) before lunar-orbit separation. One example of the interchangeability requirements is the requirement for interchanging the lunar-rock boxes with the CM lithium hydroxide boxes. This interchange requires that the ICD be agreed on by both spacecraft contractors and NASA.

CONCLUDING REMARKS

Experience with crew equipment and crew station stowage arrangements emphasizes the necessity for minimal crew effort in retrieving and using crew equipment in zero g. It is desirable to do as many one-handed operations as possible in zero g. This procedure leaves one hand free to grasp handholds and to counteract body torques generated by removing, replacing, or using certain crew equipment.

Rigid control of crew equipment, both for interface fits and for functional reliability, is necessary. The cost per pound of placing equipment in earth orbit and beyond justifies the effort required to assure usable crew equipment.

The support team, in close coordination with the assigned flight crews, supports all operational phases of space flights with respect to management of crew equipment, including astronaut training in crew equipment stowage and usage.

Spacecraft mockups and crew equipment mockups are required early in a manned spacecraft program to develop crew equipment familiarity and handling procedures before final flight-hardware delivery. The most important lesson learned concerning flight crew equipment is the need for early definition of requirements and for the timely delivery of hardware on a schedule compatible with the spacecraft-testing sequence.

Lyndon B. Johnson Space Center
National Aeronautics and Space Administration
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