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STUDY OF PERSONAL HYGIENE CONCEPTS FOR FUTURE MANNED MISSIONS

FINAL REPORT

APPROVED BY NASA

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FOREWORD

This document was prepared by the Grumman Aerospace Corporation under Contract NAS 9-10455 "Study of Personal Hygiene Concepts for Future Manned Missions", for the Manned Spacecraft Center of the National Aeronautics and Space Administration. The work was performed under the technical direction of the Habitability Technology Section, Spacecraft Design Office of the Manned Spacecraft Center. Mr. Dean C. Glenn served as both Technical Monitor and Contracting Officer's Representative.

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INTRODUCTION

Although man's basic physiological needs with respect to the elimination of body wastes remain essentially constant and comparable to his normal terrestrial experience, the space environment and its attendant constraints pose waste collection and management problems whose solutions require unique approaches.

Personal hygiene in this context has three major components: man, vehicle, and physical environment, each of which exerts a unique influence on the problems.

Man is subject to stress situations which can cause increased frequency of vomiting, due to Coriolis' effects, and increased flatus and diarrhea, due to stress and altered diet. These changes in waste output, however, are not so great as to create serious difficulties from the viewpoint of waste management system design.

The vehicle, in turn, imposes limitations on the personal hygiene system's size, weight, and the consumables such as power, water, etc., used in its operation. Although of major importance in the immediate past, these limitations are not unduly severe and are becoming increasingly less significant with each succeeding generation of vehicles.

The third component, physical environment, constitutes the personal hygiene system's most serious difficulty: the lack of a gravitational force sufficient for taking the wastes away from the body. Hence, a gravity-substitute force must be employed. In the absence of a natural transport mode also, the expelled waste lacks a predictable direction, i.e., it will not fall into a container such as the water closet or shower stall, etc. The waste matter must therefore be immediately contained at the point of expulsion, to avoid soiling both body and equipment and to preclude atmospheric contamination.

The process of defecation, for example, is normal only up to the point where the fecal bolus is expelled from the body. At that point a gravity-substitute force must be employed to separate the bolus from contact with the body and remove it in a controlled fashion to the waste management system. In the case of diarrhea, on the other hand, the propulsive force generated by the intestinal tract is generally sufficient to obviate this problem--except for containment. In any event, a positive transport force must be employed once the waste matter has entered the disposal system.

In the case of internal waste discharges, which can generally be characterized as being foul and of considerable bulk, immediate containment, removal and deactivation is imperative from the standpoint of health, comfort, and esthetics. In the case of external wastes such as hair clippings, nail clippings, desquamated epidermal cells, etc., which we might regard as comparatively clean, the problem is to contain essentially particulate matter, to avoid atmospheric contamination. In either case, this poses man/equipment interface problems of considerable complexity such as accurate positioning of body orifices with respect to equipment, the establishment of a positive body-equipment seal, etc.

With respect to the waste management system itself, the major problem area may again be defined as environmental, i.e., the necessity to dispose of wastes in a closed environment system. It must be noted, however, that this is a manufactured problem, not one which arises out of a natural phenomenon. In our normal terrestrial waste management systems, we, in effect, jettison our wastes overboard. Since this is unacceptable in space, we are faced with the necessity of treating and storing wastes on board the vehicle. Depending upon the particular mission, certain waste products, such as internal discharges, may have to be sampled for biomedical purposes before disposal, or, wastes may have to be recycled for water, or 0_2, or fuel production. In any event, a particular waste management system's design depends upon acceptable procedures and whatever requirements may exist for the utilization of waste products.

In summary, the principal problems associated with personal hygiene in space are the need for:

- A gravity-substitute transport force
- Immediate containment and deactivation of wastes
- Complex man/equipment interfaces

The objectives of this study were to:

- Evaluate the applicability of existing and/or proposed concepts for personal hygiene systems to long-duration manned spacecraft.
- Develop new concepts for personal hygiene systems applicable to long-duration manned spacecraft.
- Bring together all available information into a single source manual.
- Establish a basis for determining areas requiring future development.

The scope of the study included:

- Body waste collection and processing: urine; feces; vomitus.
- Body waste specimen collection and processing: urine; feces.
- Grooming and personal care: body cleaning; removal of excess hair and nails.

This study was limited to applications for space vehicles:

- Operating at an altitude of 200 to 300 nautical miles
- Providing a gravity field from zero to one earth gravity
- Containing a mixed gas atmosphere (total pressure 10 to 14.7 psia, oxygen partial pressure 3.5 psi)
- Manned by an all male crew (10 to 100 men)
- Launched by 1976 for a ten year mission with six months resupply

The study was conducted during the seven month period from January 7, 1970 to August 7, 1970. The contract effort included implementation of the following major study tasks to meet the study objectives:

- Conduct literature search
- Establish personal hygiene requirements
- Synthesize and develop candidate concepts
- Evaluate and select concepts
- Develop parametric data
- Assess concepts
- Prepare study results

SUMMARY OF RESULTS

CONCEPT REQUIREMENTS

Requirements for personal hygiene concepts imposed by man, his vehicle and its environment were established. They are presented in a document entitled "Requirements for Personal Hygiene Concepts for Future Manned Missions" which is included in the Personal Hygiene Manual for Designers (SMA-14S-001). These requirements include the combined thinking of representatives of many diverse but germane engineering and life sciences disciplines.

The document is organized to present mandatory requirements first, and highly desirable requirements second, in each of several categories. The first category includes general considerations, such as:

- Crew Acceptability
- Safety
- Reliability/Maintainability
- Logistics
- Schedule

Requirements in other categories are presented for each of three aspects, i.e., Function, Spacecraft Interface, and Crew Interface. These categories are:

- Feces and Vomitus Collection and Processing
- Urine Collection and Processing
- Feces and Urine Specimen Collection and Processing
- Grooming and Personal Care
  - Body Cleaning
  - Hair and Nails
  - Oral Hygiene

RECOMMENDED CONCEPTS

The study resulted in the selection of 29 concepts, within 19 personal hygiene functions, for inclusion in the Personal Hygiene Manual for Designers (SMA-14S-001).

The manual contains an engineering description, a functional diagram with explanation, an objective assessment, and pertinent parametric data for each concept. A brief description of each of these concepts follows.

Feces Collection and Processing

Three concepts for the collection and processing of feces were selected and are analyzed in detail in the Manual for Designers:

- "Dry John" System
- Chemical Toilet System
- Automated Bag System

The "Dry John" System incorporates a stationary toilet seat, formed to the lower buttocks (to exclude the collection of urine). Air is used to transport the feces to a slinger/separator which coats it on the wall of an expendable container where it is microbiologically deactivated by vacuum dehydration. Filled containers are periodically returned to earth. A possible configuration of this concept is depicted in Figure 1.

The Chemical Toilet System is identical to the "Dry John" System except that microbiological deactivation of the feces is accomplished by chemical treatment instead of vacuum dehydration.

The Automated Bag System uses the stationary toilet seat formed to the lower buttocks, but transports the feces by air into a collection bag. The bag is automatically transferred to the processor where it is microbiologically deactivated by vacuum dehydration and subsequently returned to earth by shuttle. An artist's rendition of this concept is illustrated in Figure 2.

In addition, two feces collection concepts were recommended for consideration for emergency or back-up use. They are:

- Diapers (disposable or reusable)
- Fecal collection bag sealed to inner buttocks

The former may be used while the crewman is wearing a pressure suit; the latter, if the primary collection system is inoperative or unavailable.

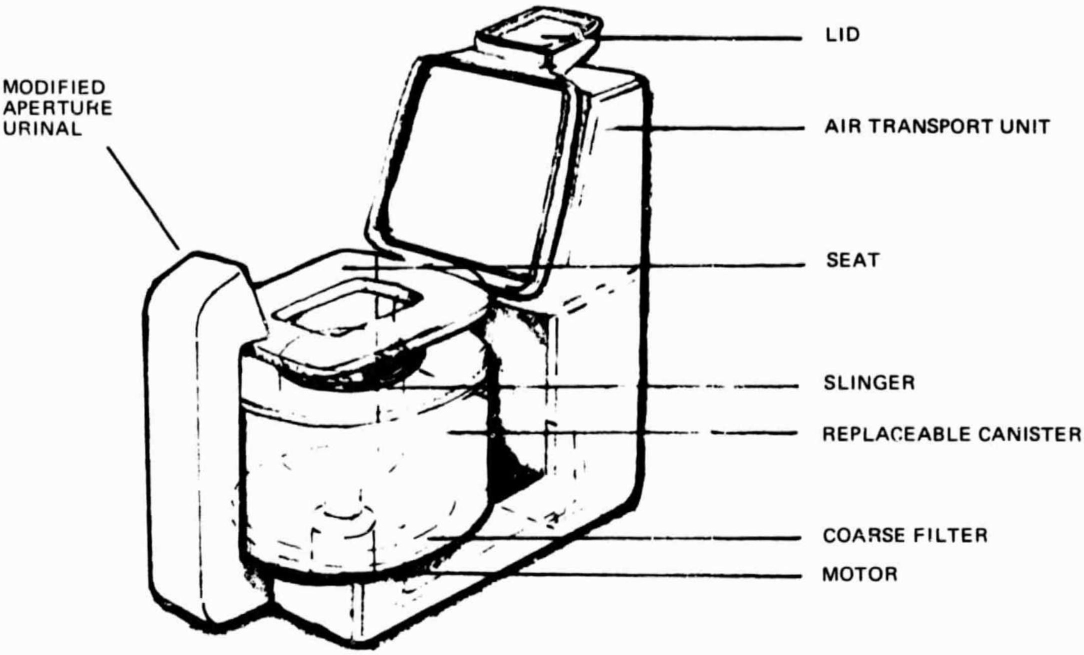


FIG. 1 "DRY JOHN" SYSTEM

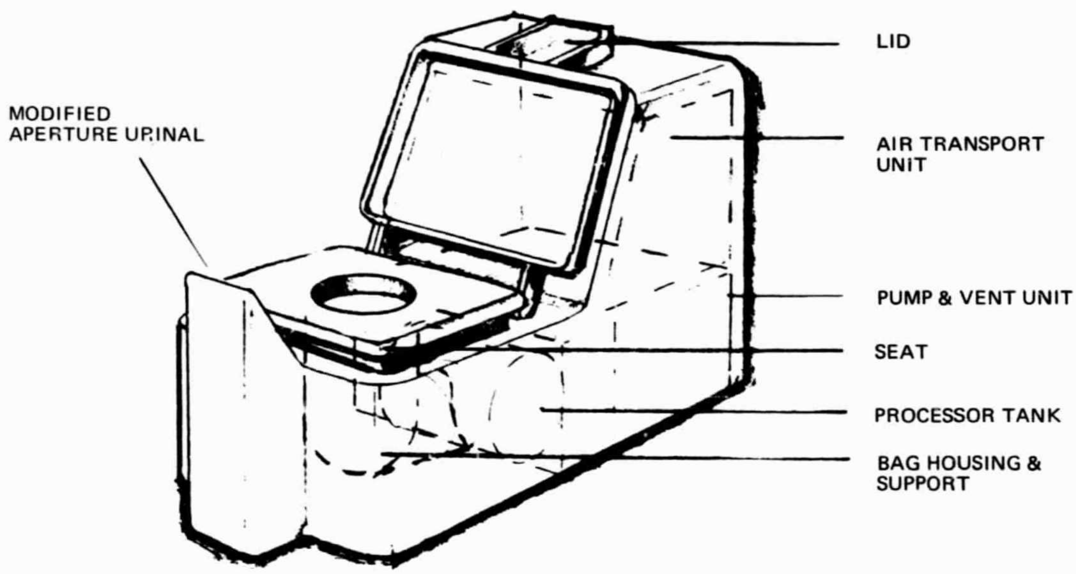


FIG. 2 AUTOMATED BAG SYSTEM

Anal Cleansing

A single concept for anal cleansing was selected. It comprises manual separation of the fecal bolus after defecation by means of dry wipes, removal of the fecal smear by means of wet wipes, followed by manual drying of the anal area by means of dry wipes.

Vomitus Collection and Processing

Two concepts for the collection of vomitus are included in the Manual for Designers. They are:

- Disposable type toilet adaptor
- Lined type toilet adaptor

Both concepts (see Figure 3) involve an adaptor which attaches to the feces collection system and directs the vomitus into the collector by air transport. The used adaptors are processed together with food wrappings. The lined adaptor is reusable, but features an expendable liner which is disposed of via the feces collection unit after use.

In both cases, the vomitus is processed in the same manner as feces.

Urine Collection

Two concepts for the collection of urine are included in the Manual for Designers. They are:

- Seal for penis with air transport of urine to centrifugal separator (See Figure 4).
- Direct urine stream into adequately sized aperture, with air transport (See Figure 5) of urine to centrifugal separator.

Each of these concepts includes a water flush of the ducting and separator after use. Penis seals, required for the former concept, are issued to each crewman for his individual use.

An alternate concept is recommended for consideration for emergency or back-up use, when the primary urine collection system is inoperative or unavailable. This concept consists of disposable urine bags, with positive attachment to the penis by either a condom-like sleeve or by an elastomeric seal.

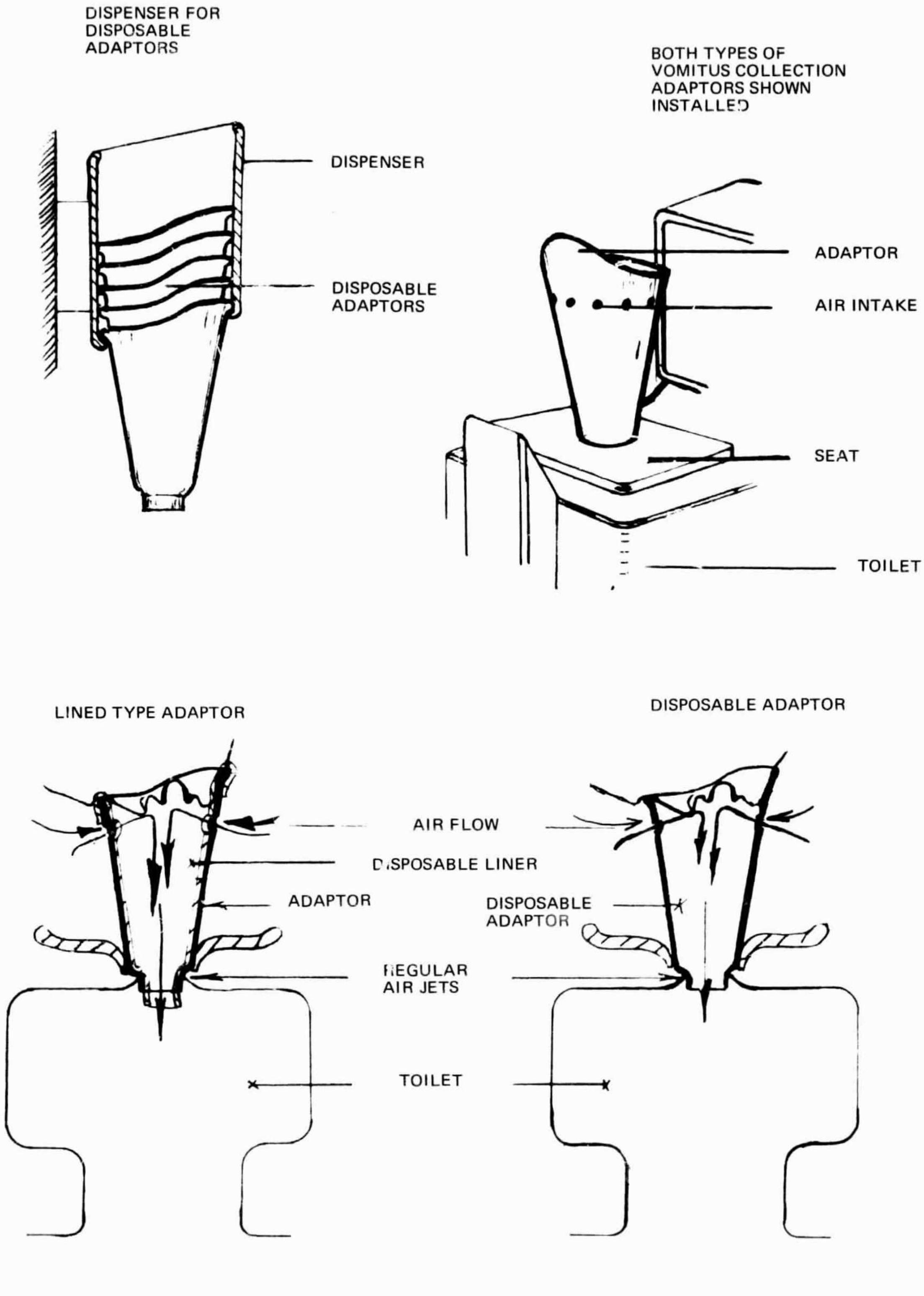


FIG. 3 VOMITUS COLLECTION TOILET ADAPTOR SYSTEMS

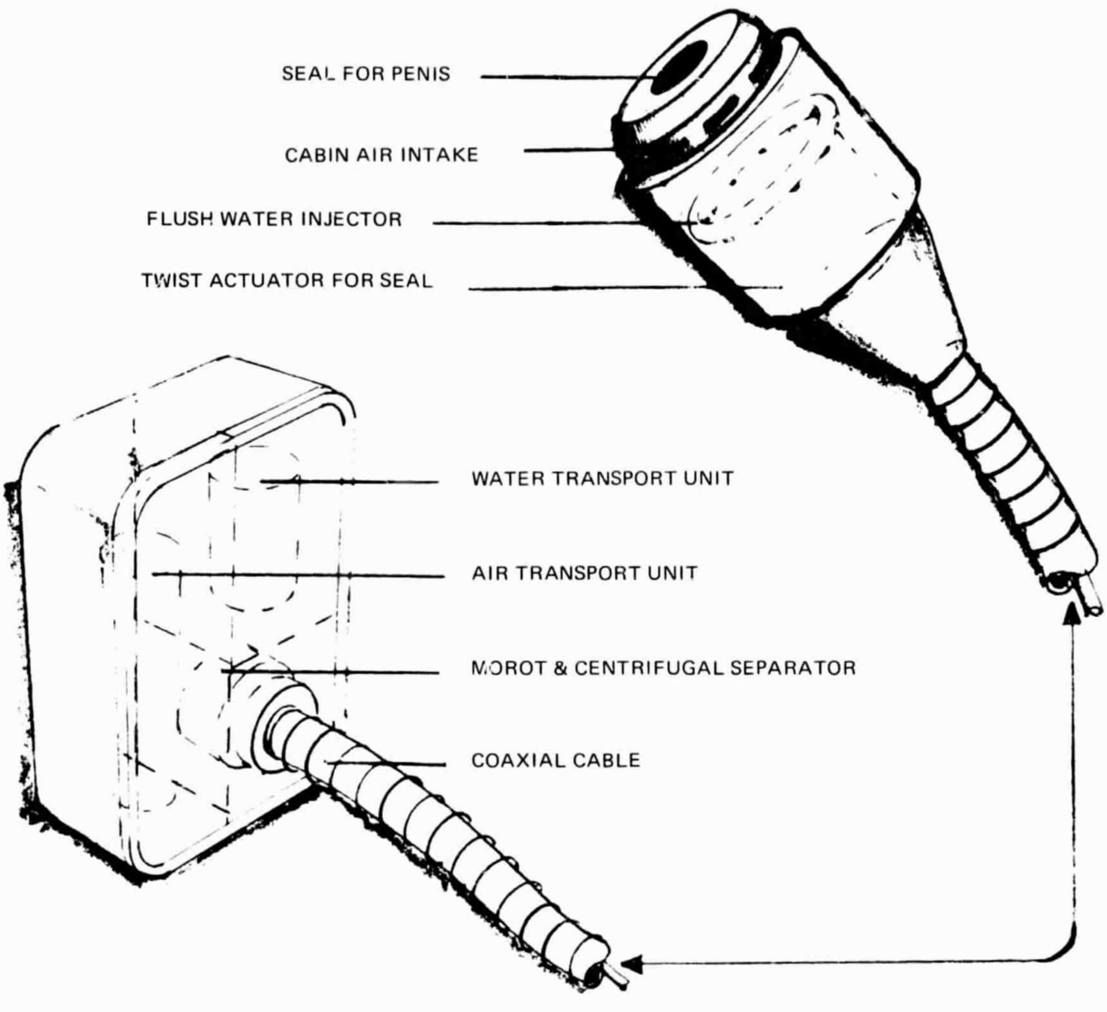


FIG. 4 "PENIS-SEAL" URINAL

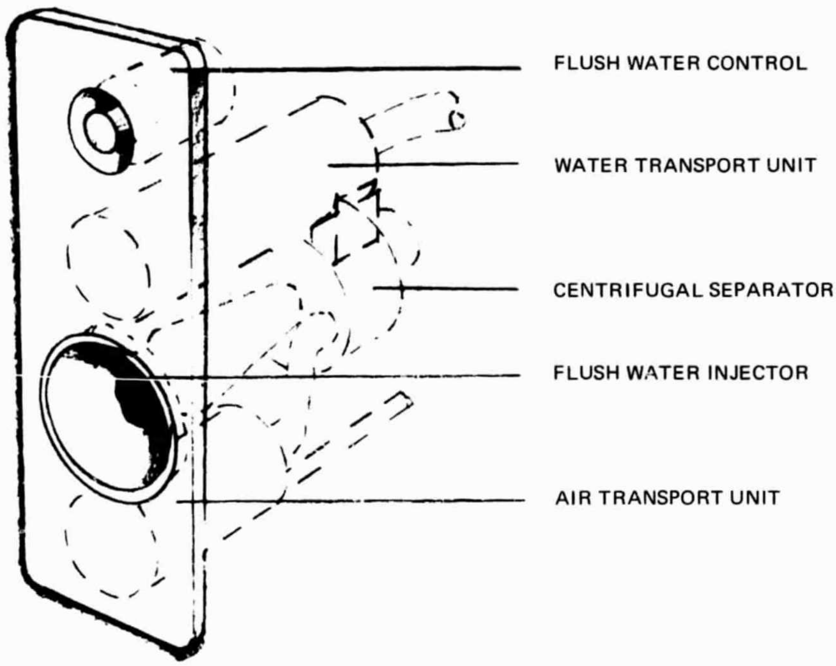


FIG. 5 APERTURE URINAL

Urine Processing

Trade-off studies, performed by Grumman and others which evaluated many water reclamation systems, have shown that it is cost-effective to recover potable water from urine on long duration missions.

Potable water is usually reclaimed from urine by means of a primary process which is coupled with pretreatment and post treatment. Successful candidates for the primary process fall into two basic categories: distillation and membrane technology. These primary processes can be modified to permit incorporation of specialized equipment for heat transport, mass transport and/or phase separation.

Pretreatment can be accomplished by the addition of chemicals or the application of electricity; post treatment by pyrolysis, catalysis and/or filtration. For post treatment, several processes can be combined.

Figure 6 delineates the approaches which are considered eligible candidates for post 1975 applications. The evaluation of these approaches was not within the scope of this study.

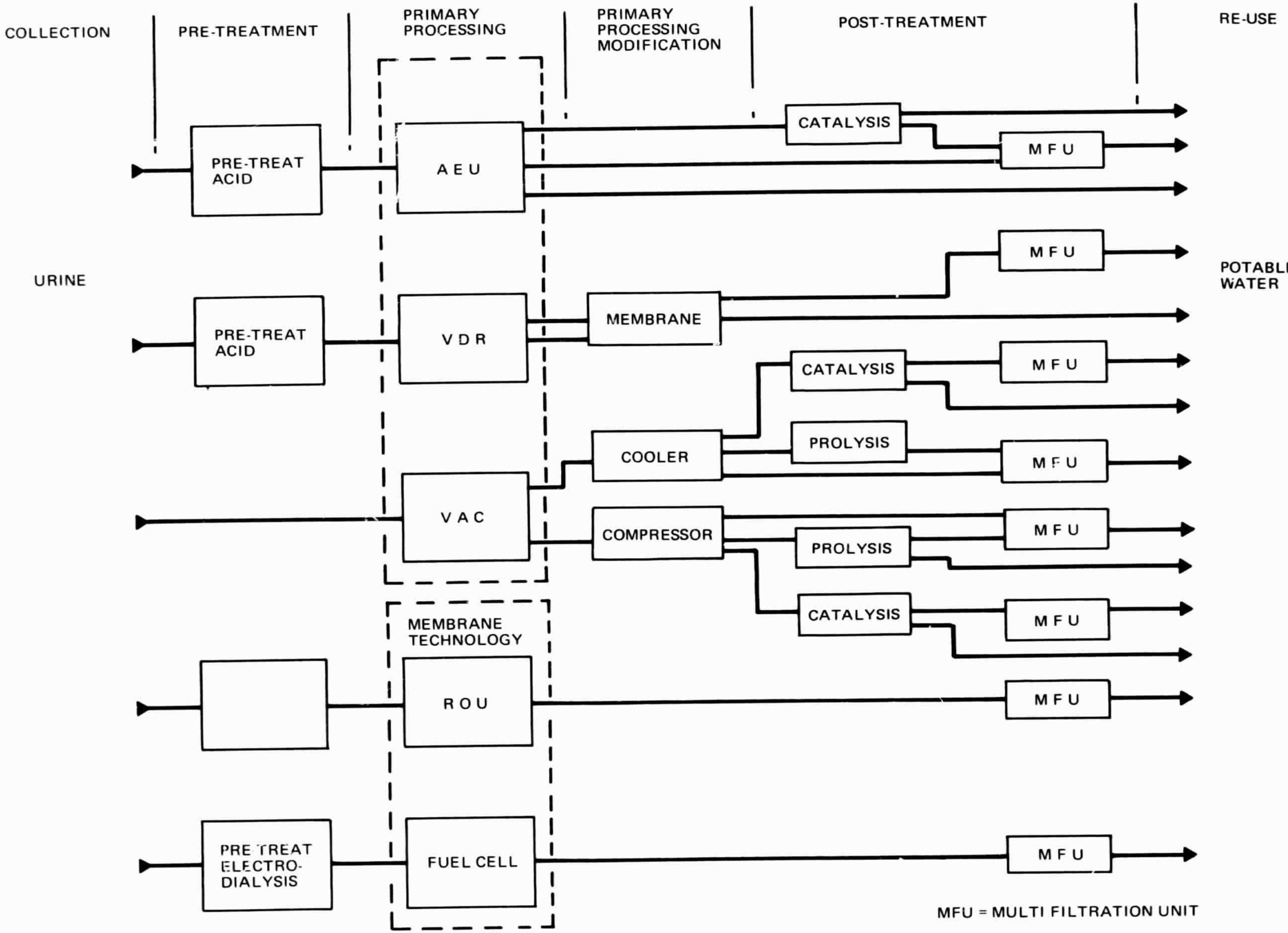
An alternate concept, recommended for emergency use when the primary urine processing system is inoperative concerns the use of urine, in a boiler or sublimator, to supply auxiliary cooling. Water vapor released to outer space would not violate existing international treaties.

Feces Specimen Collection

One concept, compatible with any of the selected feces collection concepts, is recommended. In this concept the specimen is collected in a bag attached to the toilet seat. The feces collection system's air transport is used to transport the feces into the bag. After anal cleansing, which is accomplished in the manner previously recommended, the bag is sealed and manually transferred to the processor.

Urine Specimen Collection

The concept recommended for primary use involves the manual direction of the urine stream into an aperture. Air flow is used to control and transport the stream into a specimen collection bag.



AEU = AIR EVAPORATION UNIT
VDR = VAPOR DIFFUSION RECLAMATION
VAC = VACUUM DISTILLATION
ROU = REVERSE OSMOSIS UNIT

FIG. 6 SYSTEMS FOR RECLAIMING WATER FROM URINE

After micturition, the bag is removed from the collection unit, sealed, and manually transported to the processing unit. The disposable urine bag, previously recommended for emergency use in lieu of the primary urine collection system, is also recommended as an emergency back-up system for urine specimen collection.

Urine and Feces Specimen Processing

One concept is recommended for the processing of both urine and feces specimens. In this concept, specimens are refrigerated, as collected, at a temperature between 1°C and 4°C. This temperature range is attained in less than one hour, and analysis of the specimens is completed onboard the spacecraft within 48 hours of collection.

After analysis, the specimens are disposed of in the primary urine and feces collection units, respectively.

Full Body Cleaning

Two full body cleaning concepts are included in the Manual for Designers. They are:

- Stall shower
- Hand-held scrubber, with water feed and air transport ("Astro Vac")

The stall shower (Figure 7) is used in conjunction with air transport to direct the water flow. The "Astro Vac" (Figure 8) scrubber has a removable sponge, to which water is supplied through a tube. A water collection ring surrounds the sponge. Water is collected by induced air flow into the collection ring. Sponges are issued to each individual crewman.

Local Body Cleaning

Two local body cleaning concepts are recommended:

- Reusable wet wipes
- Disposable wet wipes

Both of these concepts involve the use of a wetting and soaping unit (See Figure 9), and are detailed in the Manual for Designers. Water and soap are applied to the wipe inside the wetting and soaping unit.

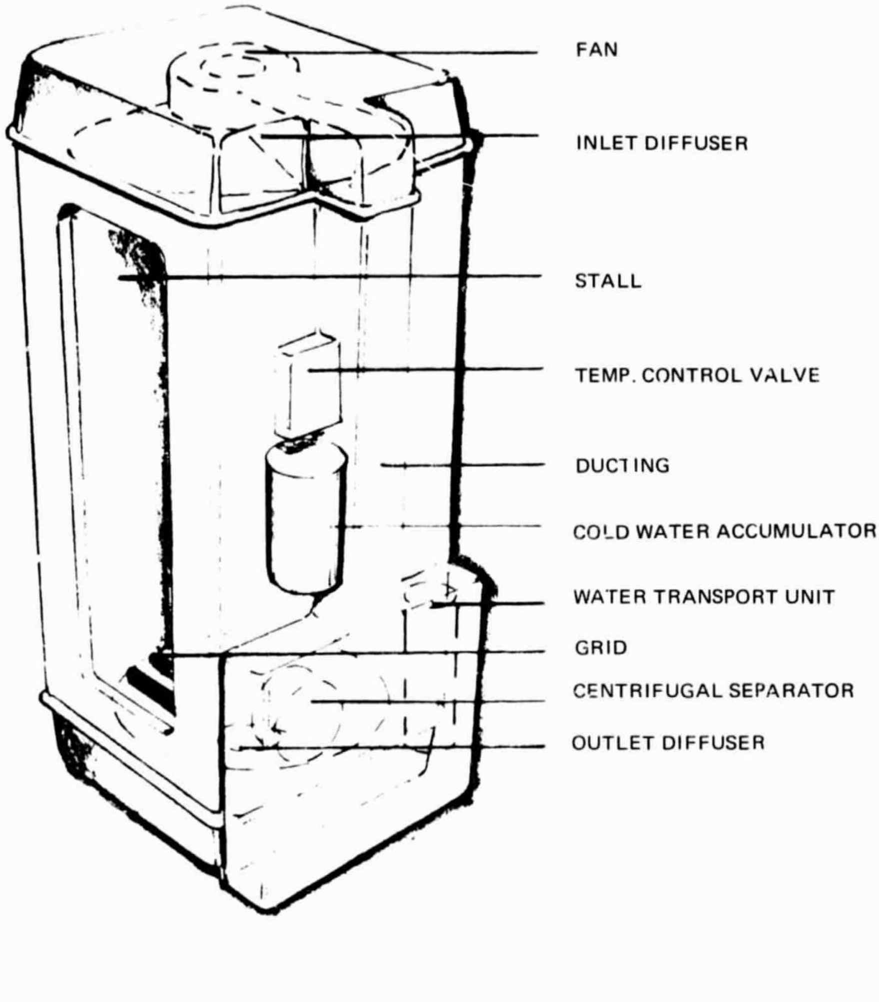


FIG. 7 STALL SHOWER

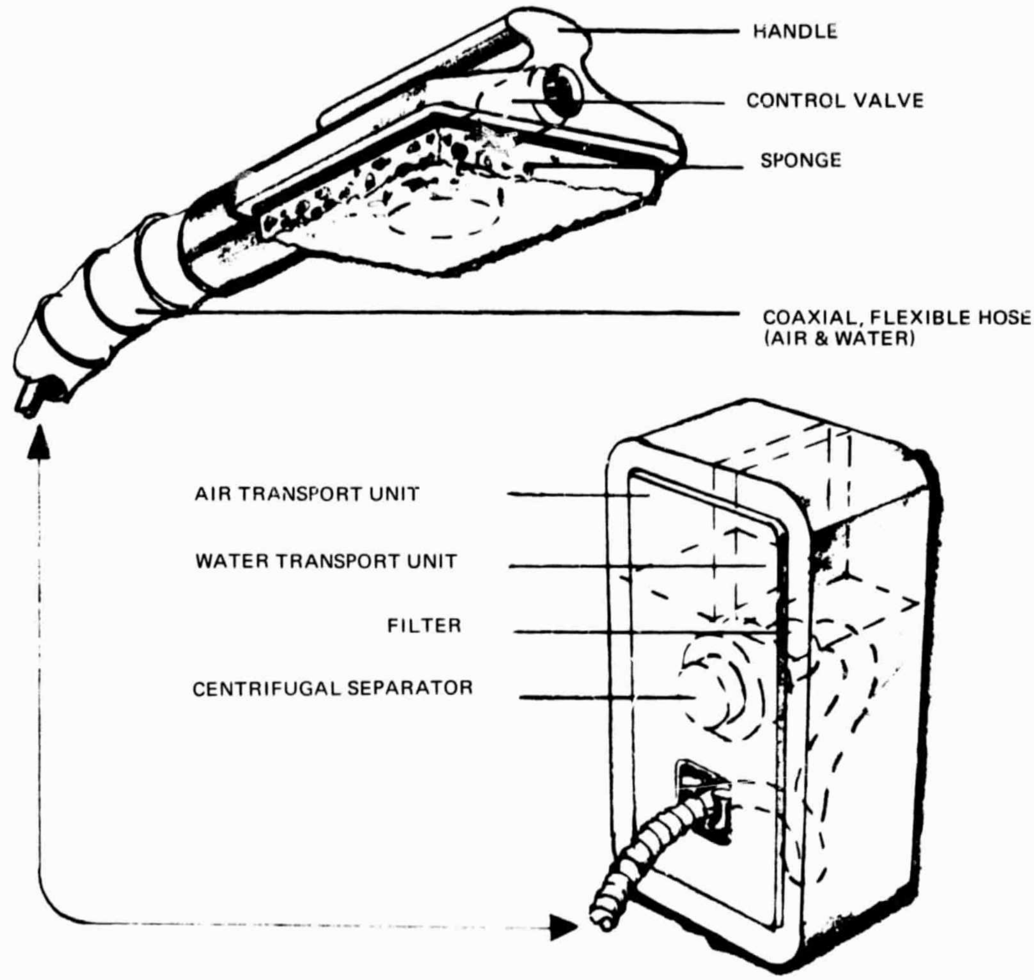


FIG. 8 ASTRO VAC SYSTEM

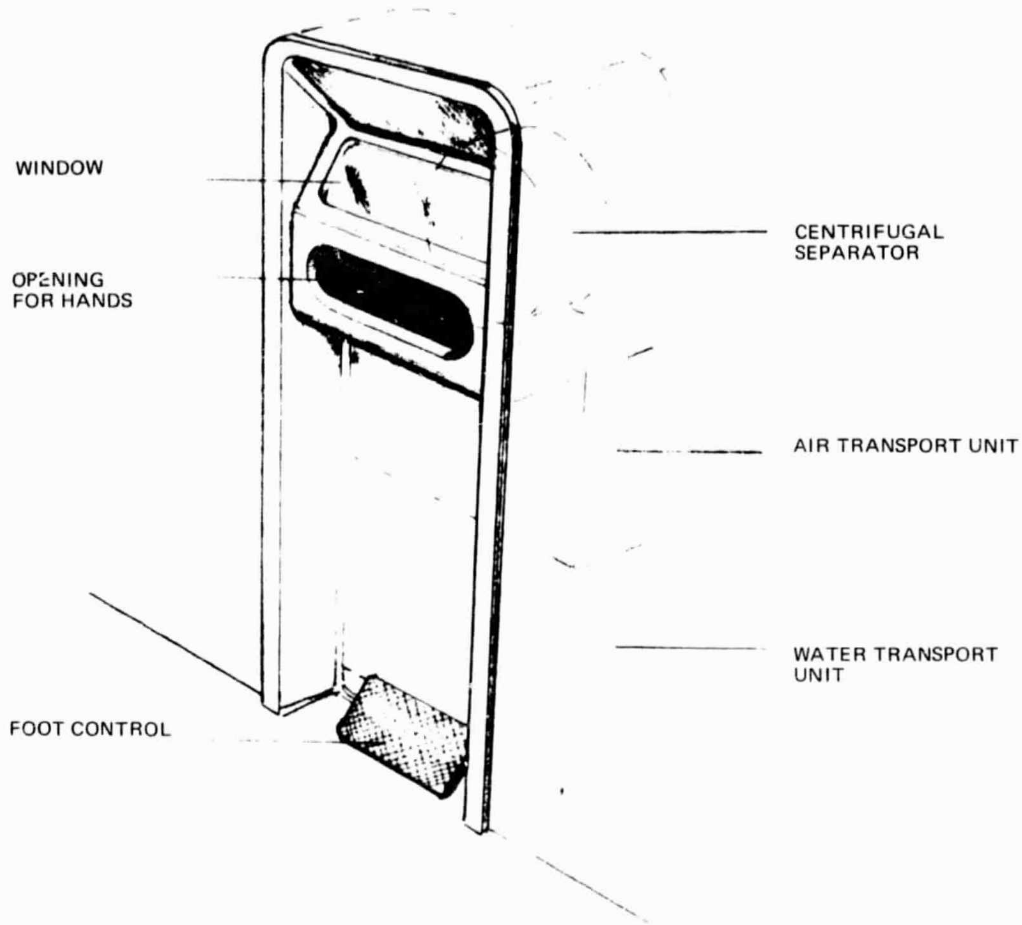


FIG. 9 WIPE WETTING SYSTEM

The soapy wet wipes are used to clean the desired local body area and are then rinsed within the unit. The rinsed wipe is used to remove excess soap from the body.

Reusable wipes are cleaned in a washer/dryer and stored for reuse; disposable wipes are vacuum dried and returned to earth.

Full Body Drying

Reusable dry wipes, similar to bath towels, are recommended for full body drying. After each use, the wipe is washed in the clothes washer. After 60 washings the wipes are discarded.

Local Body Drying

Two concepts for local body drying are recommended:

- Reusable dry wipes
- Disposable dry wipes

Reusable dry wipes, similar to hand towels, are washed in the clothes washer and are discarded after 60 washings.

Disposable dry wipes, similar to paper towels, are vacuum dried after use and stored for return to earth.

Body Cleansing Agents

The general class of non-ionic detergents (i. e., isotonic or amphiprotic), dispensed in paste form from tubes, is selected for use. The Manual for Designers (SMA-14S-001) contains the full rationale for this selection, including requirements. The non-ionic detergent entsufon (sodium octylphenoxyethoxyethyl ether sulfonate), in pHisoHex, was used to develop the parametric data found therein. However, hexachlorophene, which is contained in pHisoHex as a bactericide, is specifically not recommended because of its deleterious effect on semipermeable membranes.

Tubes of detergent in paste form are recommended because of the relative simplicity of dispensing, stowage, and control in zero-g.

Scalp Hair Cutting and Collection

Two concepts for cutting scalp hair are included in the Manual for Designers:

- Powered clipper (Figure 10)
- Razor comb (Figure 11)

In both cases, the hair clippings are collected by an air stream induced by the vacuum from the normal debris collector.

The powered clipper, similar to those used in barber shops, has a vacuum hood to collect hair clippings. The razor comb is used on wet hair; cuttings are collected with a hand-held vacuum inlet.

Removal of Excess Facial Hair

Two concepts for the removal of excess facial hair are included in the Manual for Designers:

- Wet shave using a safety razor and cream
- Dry shave using an electric razor with vacuum hair collection hood.

A safety razor and cream are used in conjunction with one of the wet wipe concepts previously described under Local Body Cleaning. One such razor with a blade-cleaning feature is depicted in Figure 12. The wet wipe is used to moisten the beard prior to application of the shaving cream, and to remove excess cream after shaving. The shaving cream mechanically entraps the shaved whiskers. When shaving is completed, the local body drying concepts may be used to dry the face.

An electric razor is used for dry shaving. A vacuum collection hood, connected to the debris collector, is used to collect hair clippings (see Figure 10). Local body washing and drying procedures may be used by the crewman before and/or after shaving in accordance with individual preference.

Finger and Toe Nail Care and Trimming

Two concepts are included in the Manual for Designers:

- Manual nail clipper with attached clippings bag
- Metal nail file with vacuum collection hood.

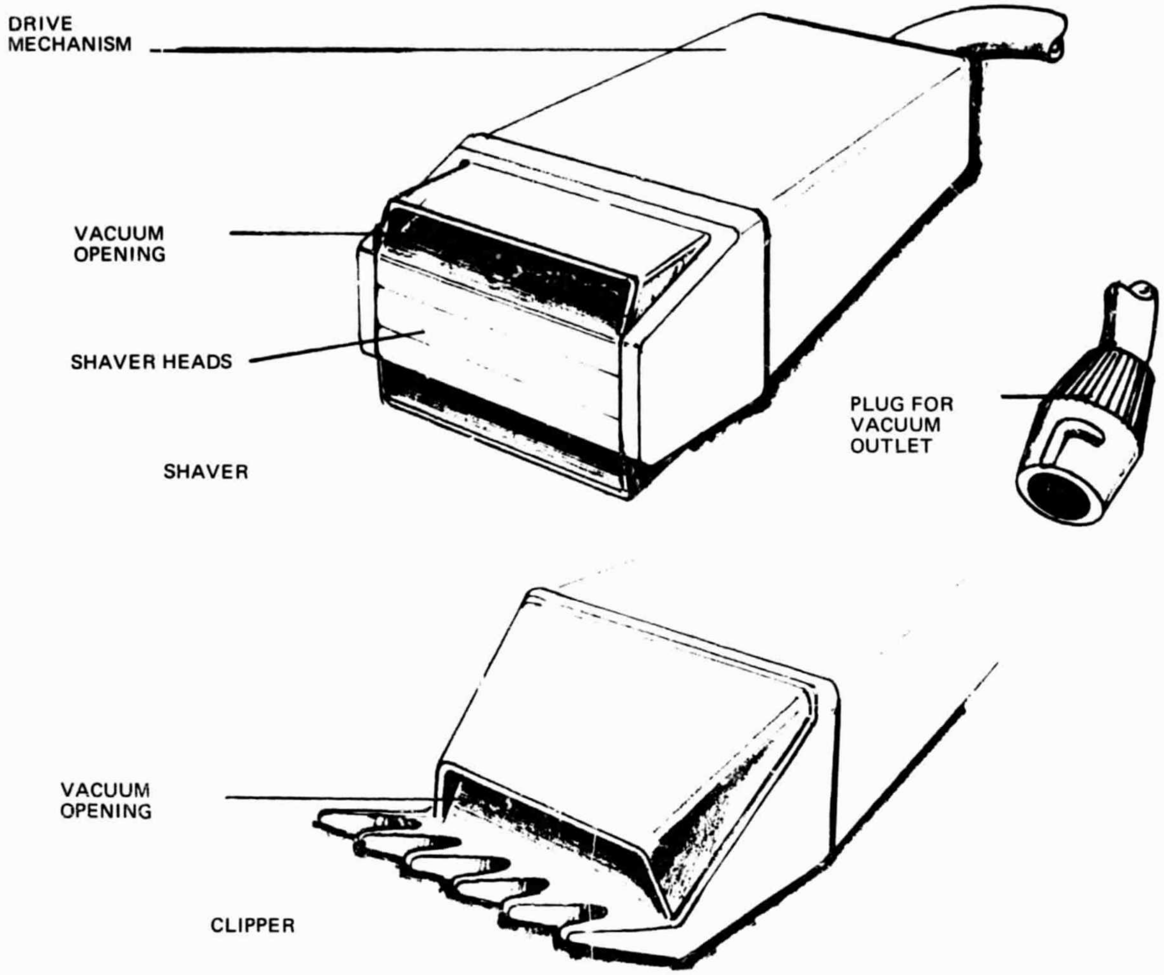


FIG. 10 HAIR CLIPPER - ELECTRIC SHAVER

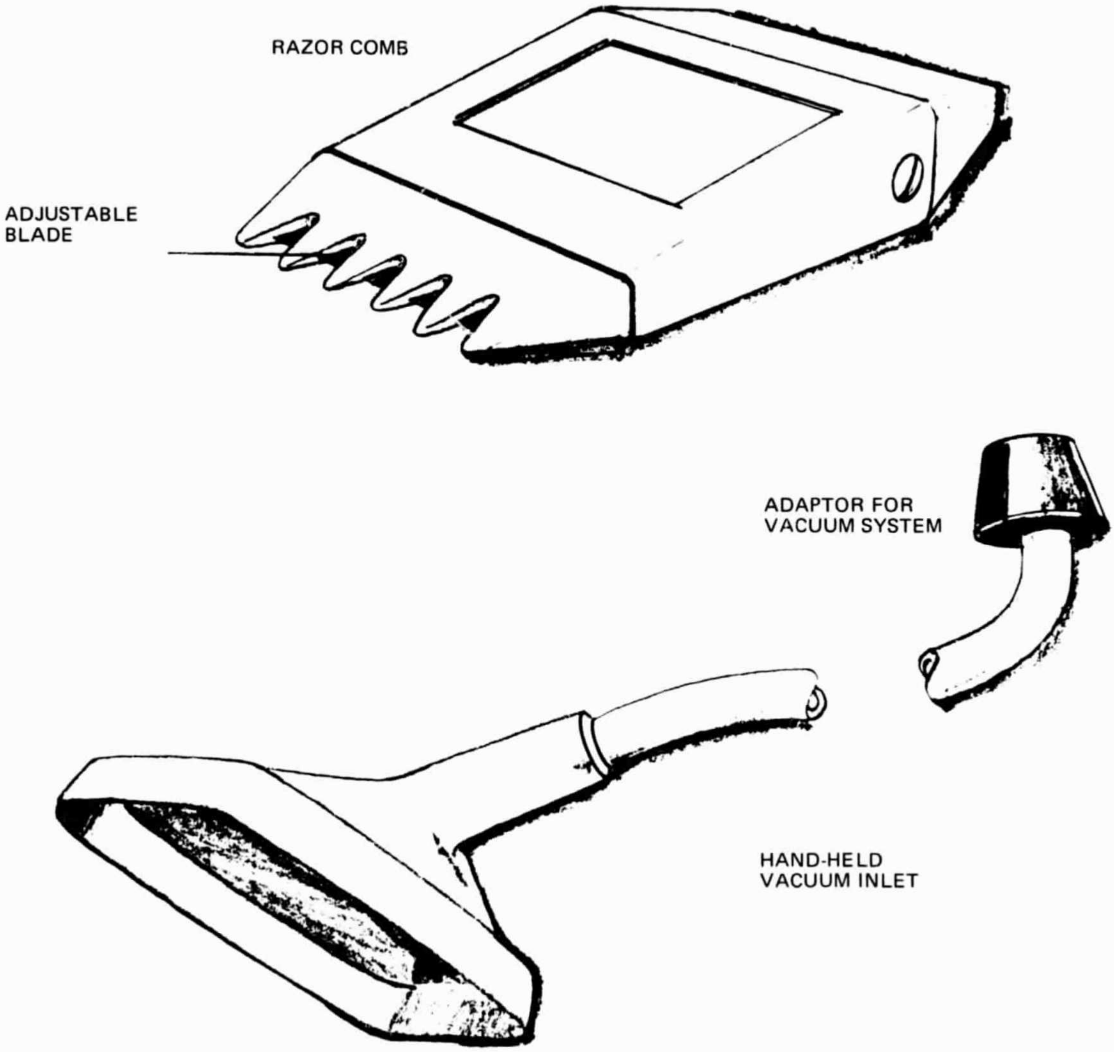


FIG. 11 RAZOR COMB AND VACUUM COLLECTOR

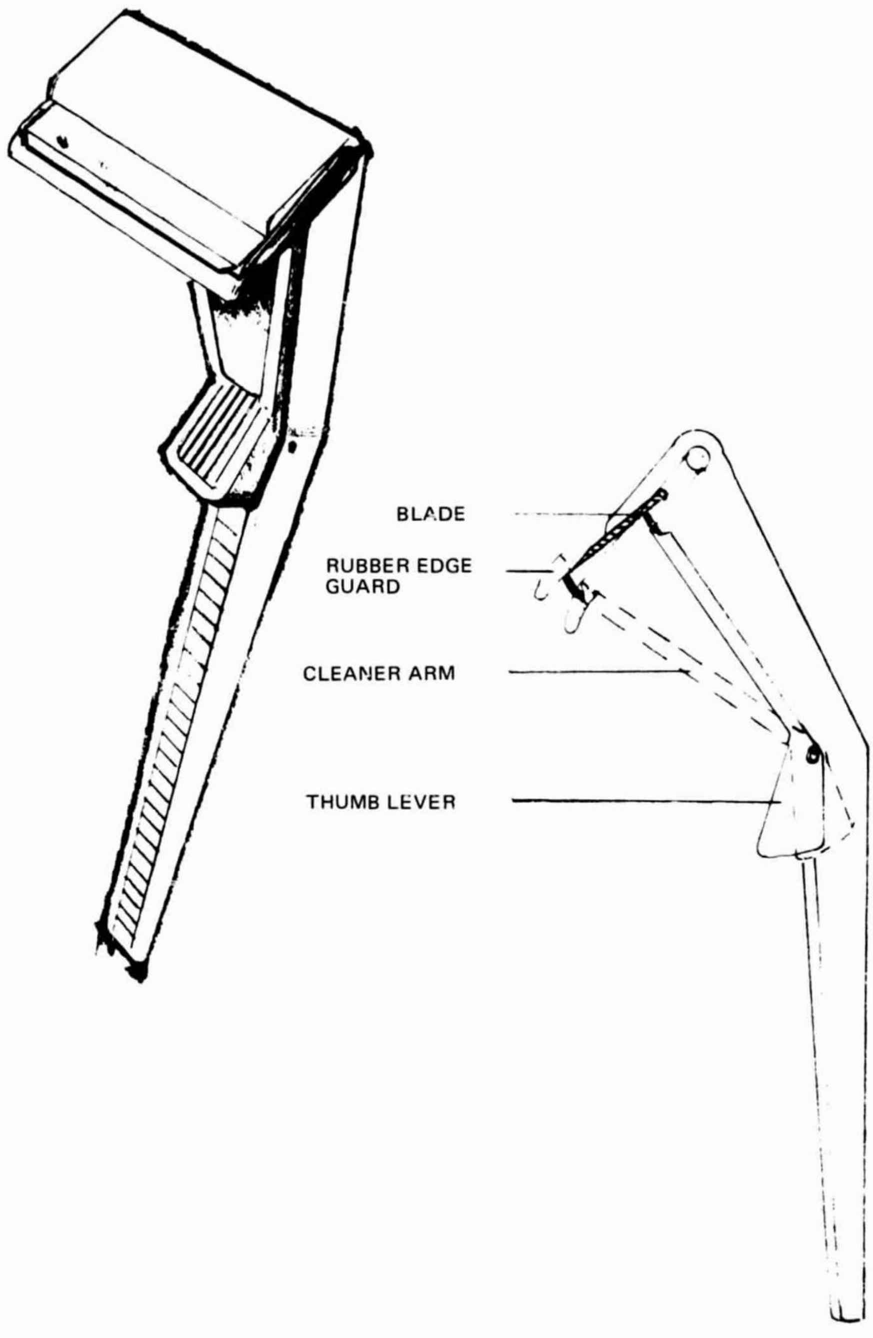


FIG. 12 WIPE CLEAN SAFETY RAZOR

Both of these concepts are closely related to their terrestrial counterparts. The clippings bag, attached to the nail clipper, is used to contain the nail parings. The vacuum collection hood, attached to the vacuum debris collector by a flexible vacuum hose, collects the nail filings by induced air flow.

Tooth Surface Cleaning

The recommended concept for tooth surface cleaning is the use of a toothbrush followed by a mouthwash flush. An ingestible dentifrice is recommended to avoid hazard in the event that it is inadvertently swallowed. The teeth are brushed in the conventional manner, but with the mouth closed to contain the dentifrice. The mouthwash is dispensed from soft plastic squeeze bottles, and is expelled from the mouth into an appropriate receptacle.

Tooth Crevice Cleaning

Two concepts for tooth crevice cleaning are included in the Manual for Designers:

- Dental floss
- High-velocity water spray ("Water Pik")

The used dental floss is disposed of in a debris collection can.

A "Water Pik" (See Figure 13) unit is located in each personal hygiene area for use by multiple crewmen. Each user attaches the personal tip issued to him. The device creates a high velocity water spray which is manually directed at the tooth crevices to loosen debris. The water is swallowed periodically during use.

Plaque and Tartar Removal

The use of an ultrasonic cleaning device, similar to terrestrial units, is recommended for the removal of accumulated plaque and tartar from the teeth. It is anticipated that these deposits will accumulate in sufficient amounts as to require removal when a crewman stays more than 180 days on board the spacecraft.

The operation of the unit will be similar to that on earth and will be restricted to trained dental technicians.

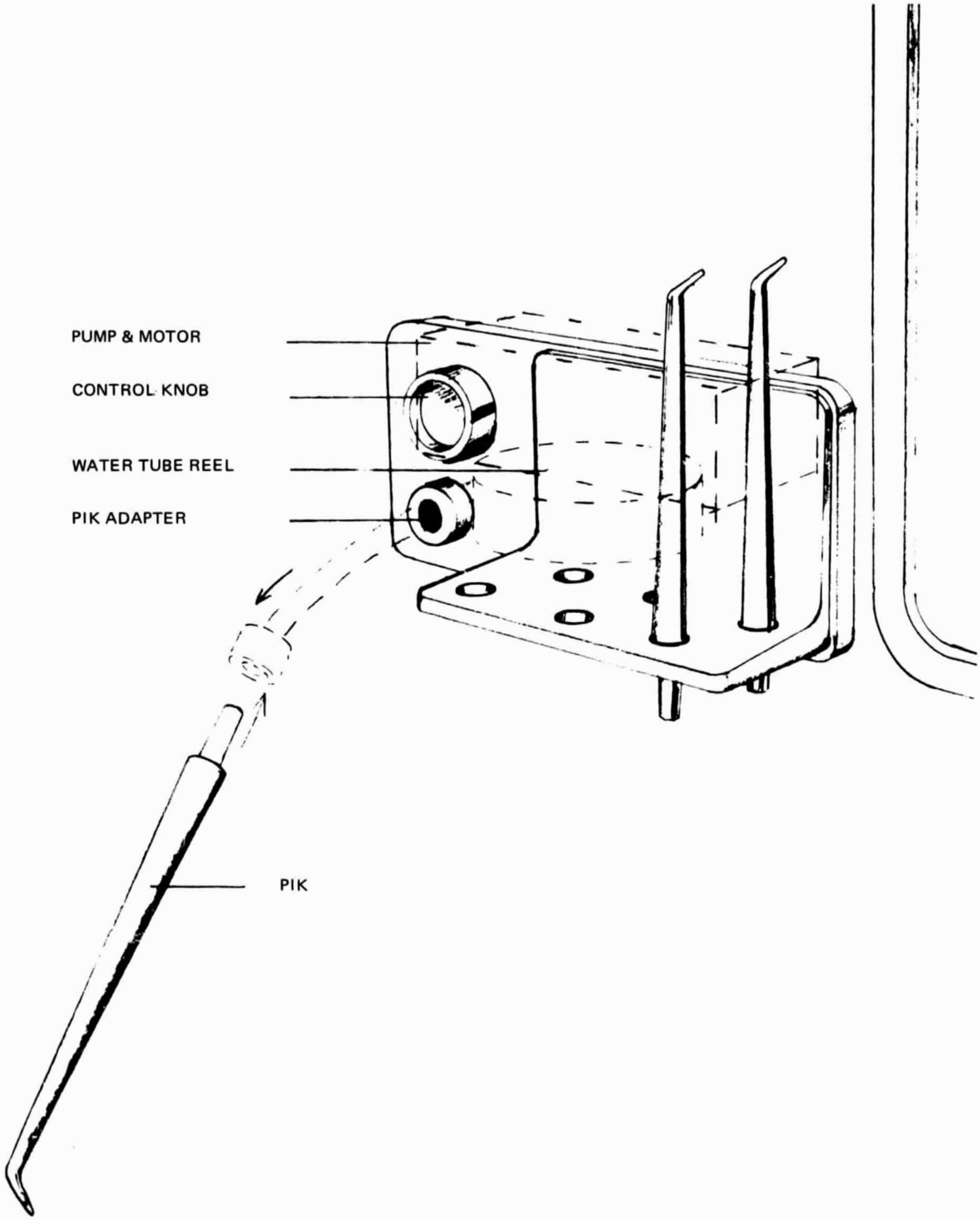


FIG. 13 WATER PIK

RECOMMENDATIONS FOR FURTHER DEVELOPMENT

This "Study of Personal Hygiene Concepts for Future Manned Missions" has focussed on broad concepts for management of body wastes for one specific type of mission, i. e., low earth orbit with an all male crew. Recommendations for further development fall into three major categories:

- Preliminary design of integrated personal hygiene systems
- Accommodation of female crewmembers
- Application of personal hygiene systems for future missions

PRELIMINARY DESIGN OF INTEGRATED PERSONAL HYGIENE SYSTEMS

The current study provides the initial technology development for future space missions, with primary reference to two requirements: suitability to man and his physiological needs in as "normal" a way as possible, and feasibility with respect to engineering and schedule constraints. Further development of personal hygiene technology should be on a total spacecraft systems basis; i. e., the integration of personal hygiene concepts identified during this study into utilitarian facilities designed for use in various specific areas (such as: working areas, sleeping and living areas, and various service areas) of candidate spacecraft configurations. A study should be conducted to:

- Define system requirements
- Synthesize and define system concepts
- Evaluate and select systems
- Establish preliminary systems design

This effort should yield:

- Systems requirements
- Preliminary design
- Systems analyses
- Support requirements
- Preliminary test requirements
- Required future development
- Selection rationale

ACCOMMODATION OF FEMALE CREWMEMBERS

It is quite possible that women will be onboard a Space Station/Base in the 1980 time frame, at least for brief periods and probably as principal investigators of scientific experiments.

The successful space flight of the Russian woman cosmonaut, Valentina V. Tereshkova, in June 1963, demonstrated that women can endure the stresses of space flight. Her subsequent marriage to cosmonaut Andrian Nikolayev, and the birth of their normal, healthy daughter, Alyonka, indicates that space flight apparently has no harmful effects on women's reproductive capabilities. The obvious physiological differences between men and women make it apparent that the presence of women on a spacecraft will have a profound impact on the vehicle's personal hygiene systems.

A study similar to this one should be conducted to:

- Establish requirements
- Identify problem areas
- Synthesize concepts in these areas
- Evaluate and select concepts

This study should generate recommended concepts for:

- Urine collection
- Separate collection of urine and feces
- Menses management
- Long hair management

APPLICATION OF PERSONAL HYGIENE SYSTEMS FOR FUTURE MISSIONS

This study has been restricted to personal hygiene concepts to support future manned missions in the 1970 time frame, comprising space stations/bases in low earth orbit, and having logistic support at finite resupply intervals via shuttle from earth. However, other missions, which should be investigated, have different mission parameters, e.g.,

- Mars Mission
- Synchronous Earth Orbit
- Low Lunar Orbit
- Synchronous Lunar Orbit
- Lunar Base

The differences between the mission parameters of the above missions and the mission parameters of this study may impact the selection of concepts since mission parameters were a factor in developing

- Weighting factors of selection criteria
- Relative worth of candidate concepts with respect to the various selection criteria

As an example, the weighting factors for selection criteria used in the conduct of this study were developed considering a resupply period of from 90 to 360 days. Consideration of a Mars mission, with no resupply possible, would probably result in higher weighting factors for certain criteria, e.g., complexity, maintainability, etc. These differences in the weighting factors for at least some of the selection criteria, combined with possible differences in the scales used to rank the candidate concepts, would yield different "worths" for the concepts evaluated and might result in the selection of different concepts.

Although the schedule for some of these missions may be such that there is no apparent urgency to investigate their personal hygiene accommodations, the complexity of the problem indicates that a preliminary analysis should be initiated in the near future.

CONDUCT OF THE STUDY

STUDY APPROACH

The study was conducted by a Study Team, with the support of an Advisory Panel and a consultant.

The Study Team searched the literature, compiled data, established concept requirements, developed candidate concepts, evaluated and selected concepts, developed parametric data, assessed recommended concepts, conducted Advisory Panel meetings, and prepared reports.

The Advisory Panel, which included many diverse but germane life sciences and engineering disciplines, supported the establishment of concept requirements and candidate concepts. The consultant provided support in the establishment of concept requirements, the generation and synthesis of candidate concepts, the subjective evaluation of candidate concepts, as well as an objective critique of the entire program.

The Study Team comprised:

G. Frankel	Study Manager
L. Flocke	Environmental Control Engineering
M. Pereira, Ph.D.	Physiology

The Advisory Panel comprised:

C. R. Bassano	Consulting Pilot
S. Campbell	Psychology
R. DelVecchio, Ph.D.	Physiology
R. Fagin, M.D.	Medicine
K. Feindler	Biotechnology
A. Giotta (Republic Aviation Division/Fairchild-Hiller Corporation)	Equipment Element Design
E. Hansberry	Crew and Equipment Integration
P. Hodge	Reliability/Maintainability
A. Reed	Biochemical Engineering
L. Slote, Eng. Sc. D.	Environmental Engineering

D. Valentine	Microbiology
H. Wolf	Safety Engineering

The consultant was:

Alexander Kira	Professor of Architecture, Cornell University. Author of "The Bathroom-Criteria for Design". Consultant to the Battelle-NASA-AF Conference on Waste Management for Manned Space Operation.

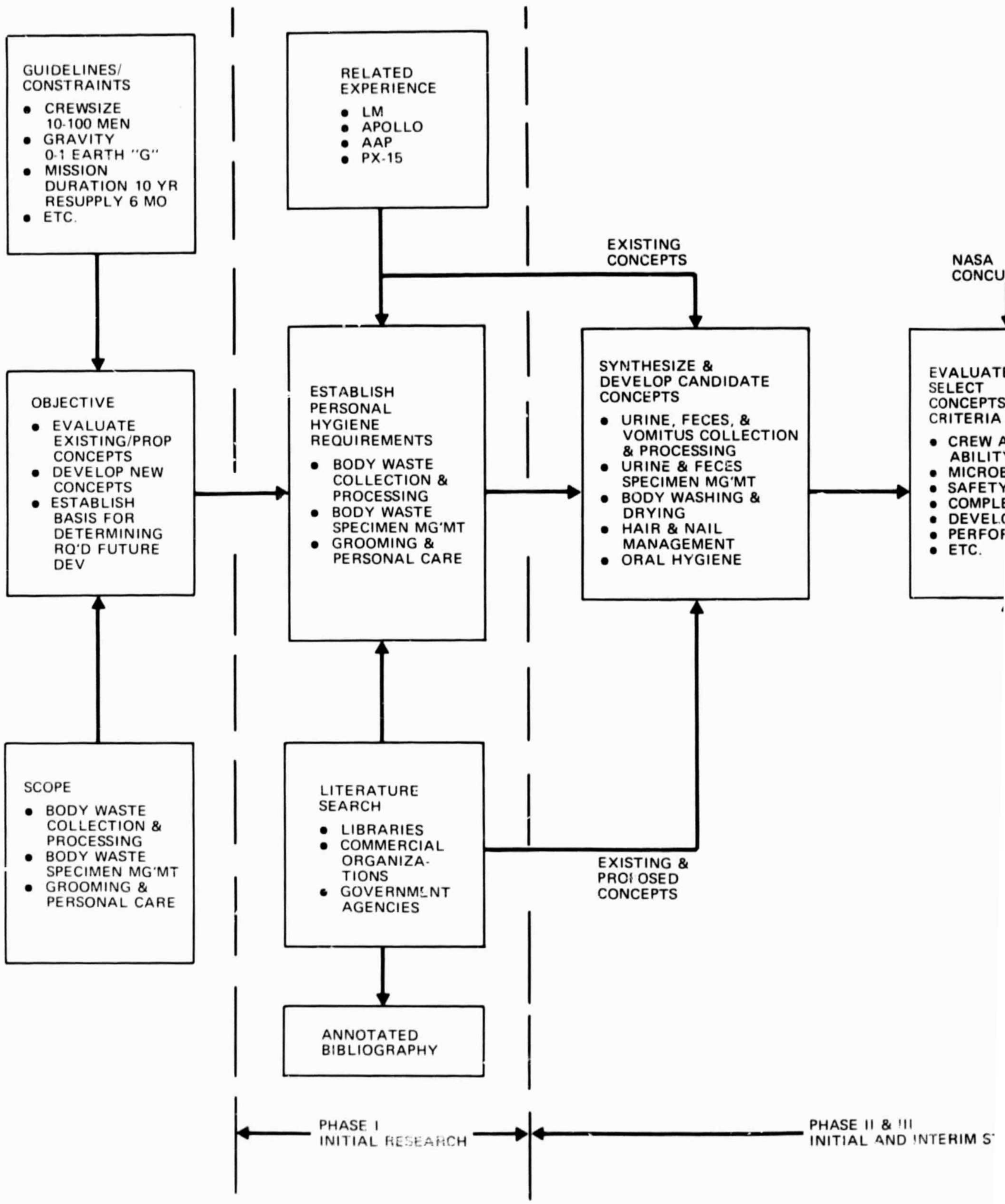
During the course of the study, the Advisory Panel met formally 24 times, including three meetings with the consultant, Prof. Kira. These meetings were scheduled on a regular weekly basis for the first five months of the study. Formal minutes of each meeting were prepared and issued. A copy of each was transmitted to Mr. Dean C. Glenn (MSC-EW64), the NASA Technical Monitor and Contracting Officer's Representative.

STUDY METHODS

The study was conducted during the seven month period from January 7, 1970 to August 7, 1970. The major study tasks which were performed to meet the study objectives were:

- Literature Search
- Establishment of Personal Hygiene Concept Requirements
- Synthesis and Development of Candidate Concepts
- Evaluation and Selection of Concepts
- Development of Parametric Data
- Assessment of concepts

The Study Flow Plan, Figure 14, shows the interrelationship of these tasks. The Program Schedule, Figure 15, shows the time schedule for documentation and each task.



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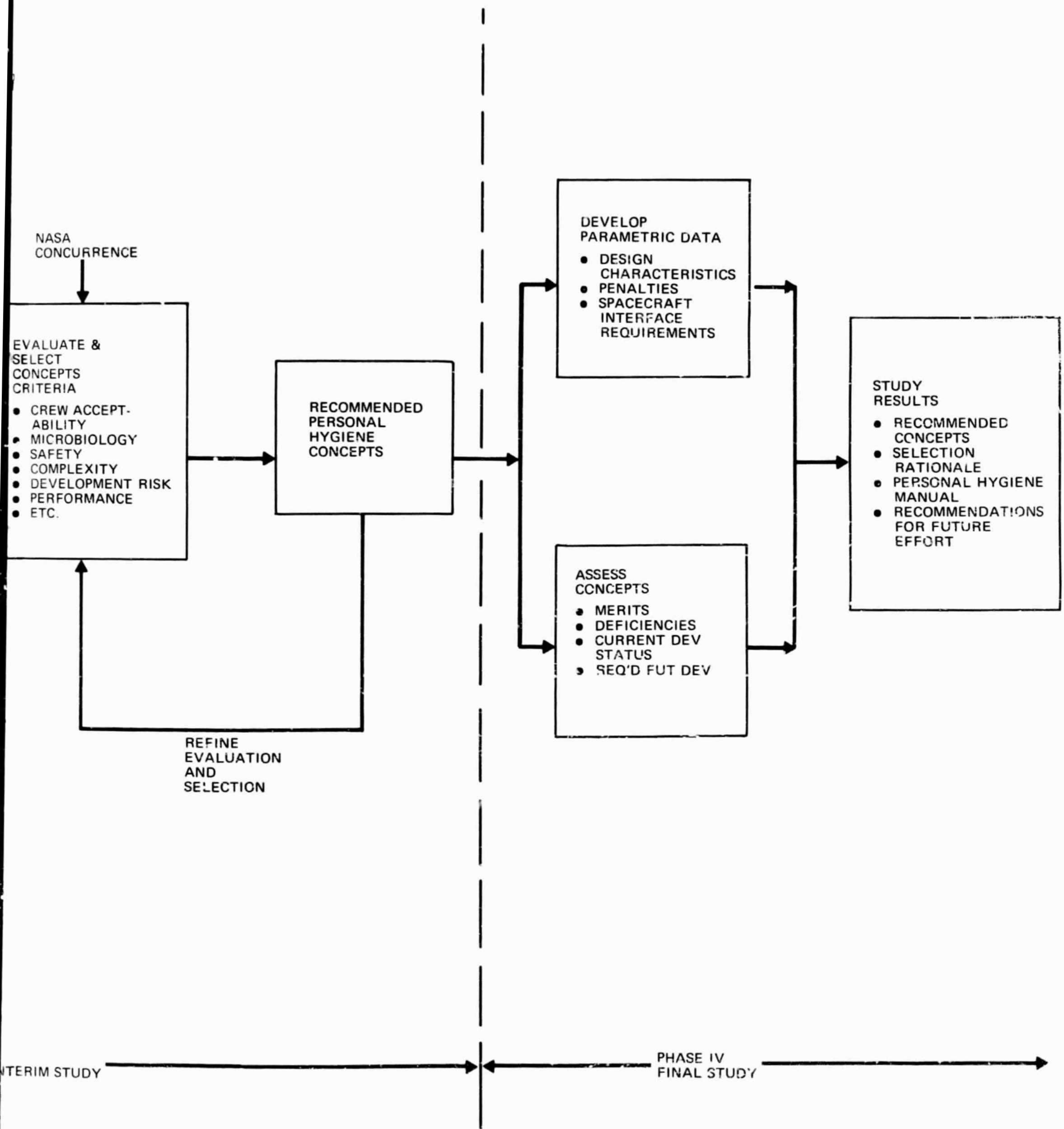

FIG. 14 FLOW PLAN - STUDY OF PERSONAL HYGIENE CONCEPTS FOR FUTURE MANNED MISSIONS

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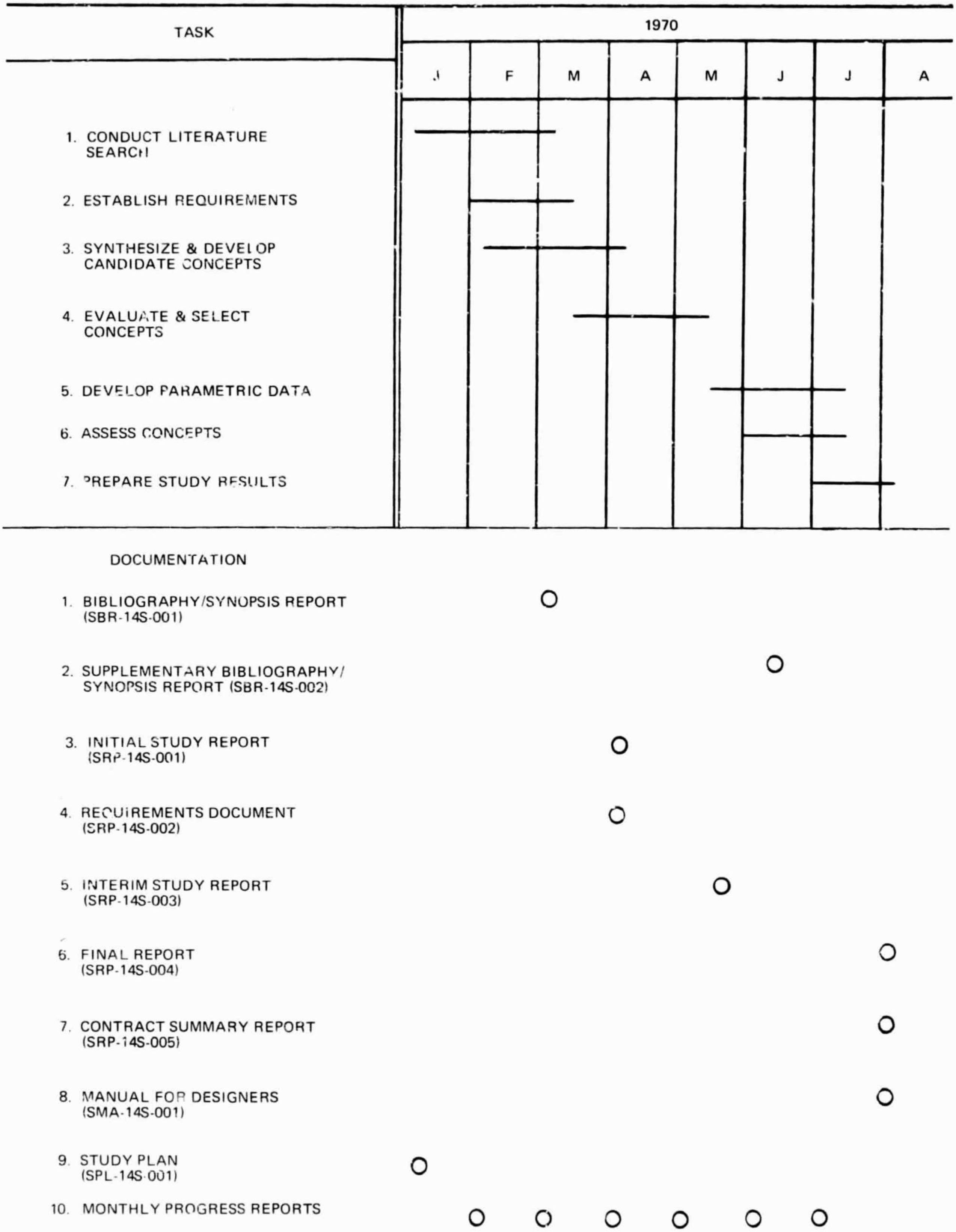

FIG. 15 SCHEDULE - STUDY OF PERSONAL HYGIENE CONCEPTS FOR FUTURE MANNED MISSIONS

LITERATURE SEARCH

A literature search was conducted to consolidate documents applicable to the subject of personal hygiene on future manned missions. These documents were identified by means of the computerized information retrieval services of the Defense Documentation Center, the NASA Scientific and Technical Information Facility, and the National Library of Medicine, as well as by the Grumman Engineering Library and the personal resources of the Study Team and Advisory Panel.

The results of the literature search were submitted in two reports:

Bibliography/Synopsis Report, (SBR-14S-001), and Supplementary Bibliography/Synopsis Report, (SBR-14S-002).

The Study Team used these reports to identify requirements and concepts for personal hygiene.

ESTABLISHMENT OF PERSONAL HYGIENE CONCEPT REQUIREMENTS

Requirements for personal hygiene concepts were generated by each member of the Advisory Panel with respect to his individual discipline. These were supplemented by requirements gleaned from the literature search (Bibliography/Synopsis Report SBR-14S-001) by the Study Team. They were organized into two categories: mandatory, and highly desirable. All requirements were iteratively reviewed by the Advisory Panel and our consultant prior to issuance.

The Requirement Document, "Requirements for Personal Hygiene Concepts for Future Manned Mission", (SRP-14S-002), presents both mandatory and highly desirable functional, spacecraft interface, and crew interface requirements for each personal hygiene function. This document appears in the Personal Hygiene Manual for Designers as well as in the Initial Study Report (SRP-14S-001).

SYNTHESIS AND DEVELOPMENT OF CANDIDATE CONCEPTS

Candidate concepts for each personal hygiene function were synthesized by the Study Team from the literature (Bibliography/Synopsis Report SBR-14S-001) and from ideas contributed by the Advisory Panel. A concerted effort was made to think freely, unencumbered by earthbound conventions.

Personal hygiene functions were analyzed, and reduced to their elementary forms. Concepts were synthesized for each of the elements. These concept elements, which were displayed in Section II of the Initial Study Report (SRP-14S-001), were subsequently used to develop candidate personal hygiene concepts.

Prior to the development of these candidate concepts, however, each concept element was initially evaluated by the Study Team, with the support of the Advisory Panel, with respect to four absolute criteria:

- Safety
- Performance
- Crew Acceptance
- Development Risk

The results of this initial evaluation are displayed in Part A, Section II of the Interim Study Report (SRP-14S-003). If the concept element was rejected, the rationale for rejection was displayed; otherwise, the concept element was retained for the development of candidate concepts which were evaluated in the Interim Evaluation.

EVALUATION AND SELECTION OF CANDIDATE CONCEPTS

A total of 105 candidate concepts were developed from the concept elements which survived the Initial Evaluation. The Study Team, with the support of the Advisory Panel and with the concurrence of the NASA/COR, selected 29 of these for further study and analysis.

The Study Team based its selection of the evaluation of each candidate concept with respect to 11 subjective and 7 objective criteria. The "worth" of each concept was established by statistically combining the subjective opinions of qualified members of the Advisory Panel, and objective engineering data researched and calculated by the Study Team. This statistical process involved the establishment of the relative weight of each of the evaluation criteria. The definitions of the evaluation criteria, the methods for the establishment of the relative weight of these criteria, the resulting relative weight, as well as the procedures for the establishment of concept "worth's", are presented in detail in Section I of the Interim Study Report (SRP-14S-003). The unreduced data from which the "worth's" were computed appears in the Appendix to that report.

Each candidate concept developed from the surviving concept elements, the "worth" of each concept with respect to each criterion, the total "worth" of each concept and the rationale for the selection of the recommended concepts, appear in Part B, Section II of the Interim Study Report (SRP-14S-003).

DEVELOPMENT OF PARAMETRIC DATA

Pertinent parameters relating the personal hygiene functions to the mission profile were categorized as independent or dependent variables. In order to provide an organized method for the identification of sensitive independent variables, a matrix of the 29 selected concepts versus the dependent variables was prepared.

Theoretical analyses, literature research, and engineering analysis and judgement were then used to establish a mathematical expression for the relationship between each concept's independent and sensitive dependent variables. These relationships, including their derivation, rationale, and graphic representations, are displayed for each selected concept in the Personal Hygiene Manual for Designers (SMA-14S-001).

ASSESSMENT OF SELECTED CONCEPTS

Each of the selected concepts was assessed by the Study Team with respect to eight subjective and six objective criteria on an absolute basis. The merits and deficiencies of each were explored and evaluated. The Study Team, supported by the evaluations previously generated by means of data supplied by the Advisory Panel, enumerated each selected concept's advantages and disadvantages. These are displayed in the Personal Hygiene Manual for Designers (SMA-14S-001).