CR 73424
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TITLE: DEVELOPMENT OF PAYLOAD SUBSYSTEM - PRIMATE MISSION - BIOSATELLITE PROGRAM

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ABSTRACT:

The Primate, Biosatellite, Experiment, Payload Subsystem consists of government furnished equipment interface conversion and primate support equipment (PSE) supply by GE. Design development discussions are limited to the PSE as listed.

1. Pellet Feeder Assemt
2. Water Dispenser Asse
3. Feces Collector Asse
4. Trace Gas Contaminant Control Assembly
5. Camera Assembly
6. Lighting Assembly
7. Camera/Lighting Controller
8. Primate Life Support Controller
9. Couch Assembly

PSE design concepts were studied, reviewed in detail with the customer, detailed component requirements formulated and component designs completed.

This paper is based on National Aeronautics and Space Administration CR73424 prepared for Ames Research Center under contract NAS2-1900.

A. INTRODUCTION

1. PROBLEM - As part of GE-RESD's contract on NASA-ARC's Biosatellite Program, the life support unit was faced with a challenge. The challenge was to develop flight hardware which would provide the life support functions necessary to sustain a very inquisitive and manually dexterous (in retrospect) Macaca nemestrina monkey during a 30 day earth orbital space flight. Basically, the functions required to be supplied by the experiment payload subsystem are listed in the following.

1.1 Provide sustenance - food and water

1.2 Provide selected waste management - feces, ammonia, carbon monoxide and other trace gases.

1.3 Provide day and night cycle lighting (circadian rhythm reference)

1.4 Take single frame and motion pictures of the primate during both day and night periods and all mission phases.

1.5 Provide structural support for the restrained primate, blood pressure experiment equipment and physiological sensor signal conditioners through all mission phases.

1.6 Provide control for the regulation of the previous functions in accordance with preprogrammed experiment events.

Another problem which appeared throughout the subsystem development was the unanticipated extent of the monkey's inquisitiveness, manual dexterity, tenacity and ingenuity when left alone with complicated equipment for long periods of time. It was the result of this tampering which constituted the unique challenge in the development of the subsystem equipment.

Some of the feats which these monkeys accomplished would have made Houdini proud.

2. <u>POTENTIAL SOLUTIONS</u> - Many of the functional requirements could have been satisfied through the use of various equipments which performed the same function. However, since the development schedule was short, consideration of off-the-shelf hardware, where possible, limited the possibilities considerably. Even so, many trade-offs were required. Examples of two of the more basic ones are discussed in the following.

2.1 Provide Sustenance - Here the choice was between liquid and solid food. Water could either be mixed with the food, stored or obtained from the power system,fuel cell,by-product water.

2.2 Provide Lighting - Basically the choice was between fluorescent or incandescent sources. More subtly, trade-offs among multiple lamps, panel lights, direct lighting, spot lighting, voltage variation, special purpose lamps and/or lamp switching had to be made to result in a proper lighting arrangement.

B. DISCUSSION

1. SUBSYSTEM DEFINITION

The previously discussed and many other trade-offs were made and some will be discussed in following sections. The trade-offs and subsequent design and development resulted in the Biosatellite Primate Experiment Payload Subsystem consisting of the following primate support equipment (PSE) which was supplied by GE RESD.

1.1 Pellet Feeder Assembly
1.2 Water Dispenser Assembly
1.3 Feces Collector Assembly
1.4 Trace Gas Contaminant Control Assembly
1.5 Camera Assembly
1.6 Lighting Assembly
1.7 Camera/Lighting Controller
1.8 Primate Life Support Controller
1.9 Couch Assembly

The subsystem is a collection of assemblies unified in operation by the monkey and in function by the life support controller. See figure 1.

2. EQUIPMENT DETAILS

The following paragraphs describe in more detail the features of the subsystem equipment and in some areas the degree of primate induced configuration and function definition.

2.1 FOOD DISPENSER (PELLET FEEDER) ASSEMBLY -

As previously mentioned, solid vs liquid food trade-offs were made. Various factors including equipment availability led to the selection of a solid food pellet dispenser. The pellets were attached to a non-toxic adhesive tape much like the old candy buttons on waxed paper. To provide redundancy and minimize

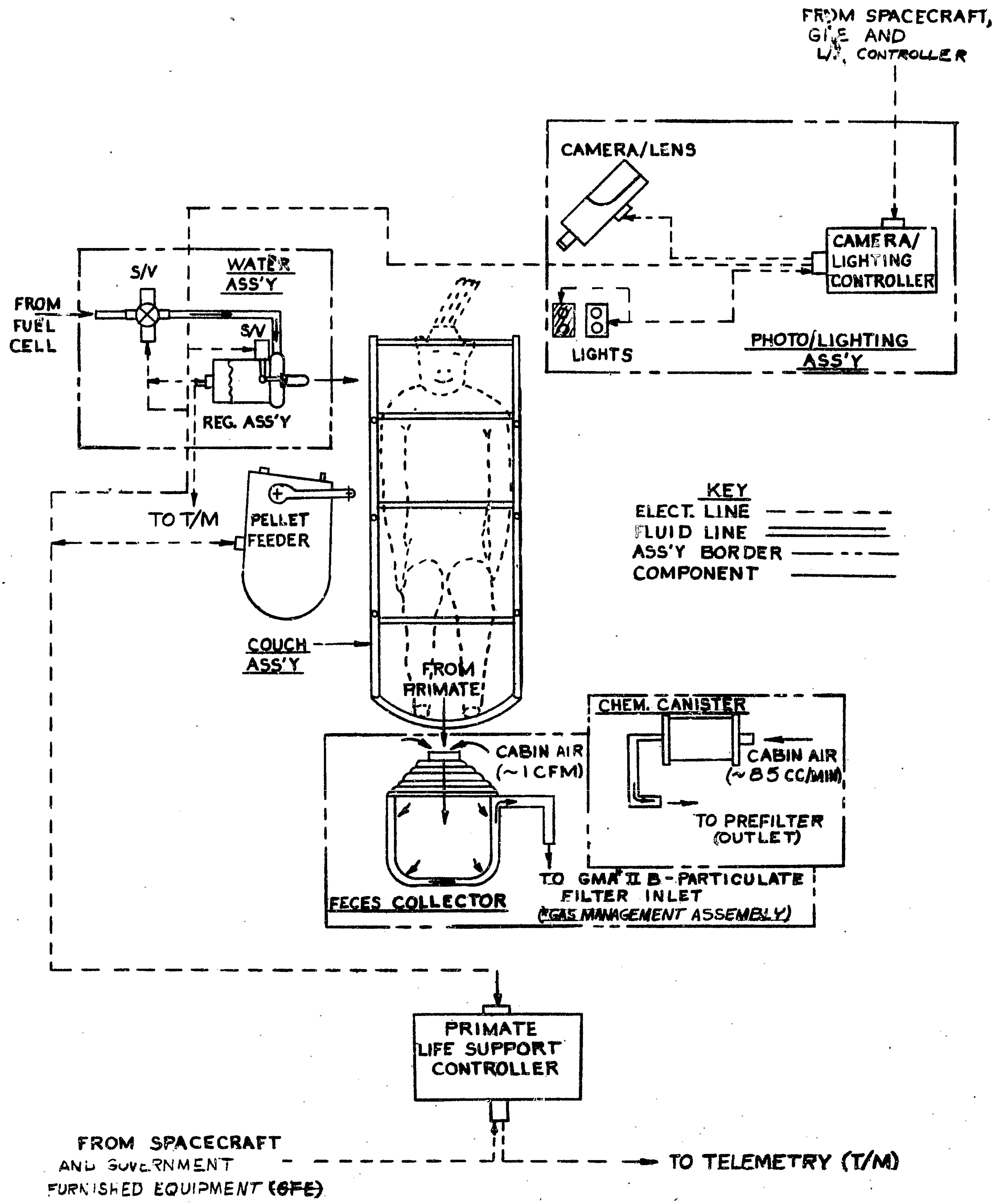


FIGURE 1:

30 DAY PAYLOAD SUBSYSTEM

PRIMATE SUPPORT EQUIPMENT (PSE)

packaging volume, eight pellet reel assemblies were provided. (See Figure 2) The machine was basically a mechanical design. Although arm, lock and unlock functions were solenoid initiated; pellet counting was switch indicated, and monkey cueing was via incandescent lamps, all other functions were mechanically accomplished through the use of primate power. An electrical signal armed the feeder and the cue light lit. The monkey responded to the light by pushing the handle. The handle shaft drove a geneva and tape sprocket. These in turn indexed to the next reel and pulled the pellet and tape from the supply reel. The tape passed on to a take-up reel while the pellet was stripped off and projected through the pellet slot. As the pellet moved into the slot, it raised a gate and tripped a switch which was counted and registered in the life support controller for later monitor from the ground via telemetry. The monkey managed to impart his influence on the design of the pellet dispenser through two primary factors. First his physiological limitations imposed a limit on the amount of force required to operate the machine. Secondly he caused through his persistent tampering what came to be known as the 2-for-1 problem. After many higher primates, the author included, deemed the design complete, it was turned over to the monkey. He very quickly learned that by judiciously working the handle after receiving one pellet he could get a second before the mechanism disarmed. These and several other problems led to the redesign of the machine.

A relatively equal blend of mechanical and electrical design disciplines were used to solve the feeder problems. The solenoids were removed and their functions were performed by a single motor and mechanism. The motor also provided the force required to dispense the pellet, and the monkey's involvement was reduced to tripping a switch with the feeder handle actuation. All other features, including the mechanical and electrical interfaces to the system were identical. As a fringe benefit, the feeder could be ground initiated to dispense a pellet independent of the monkey. This feature was

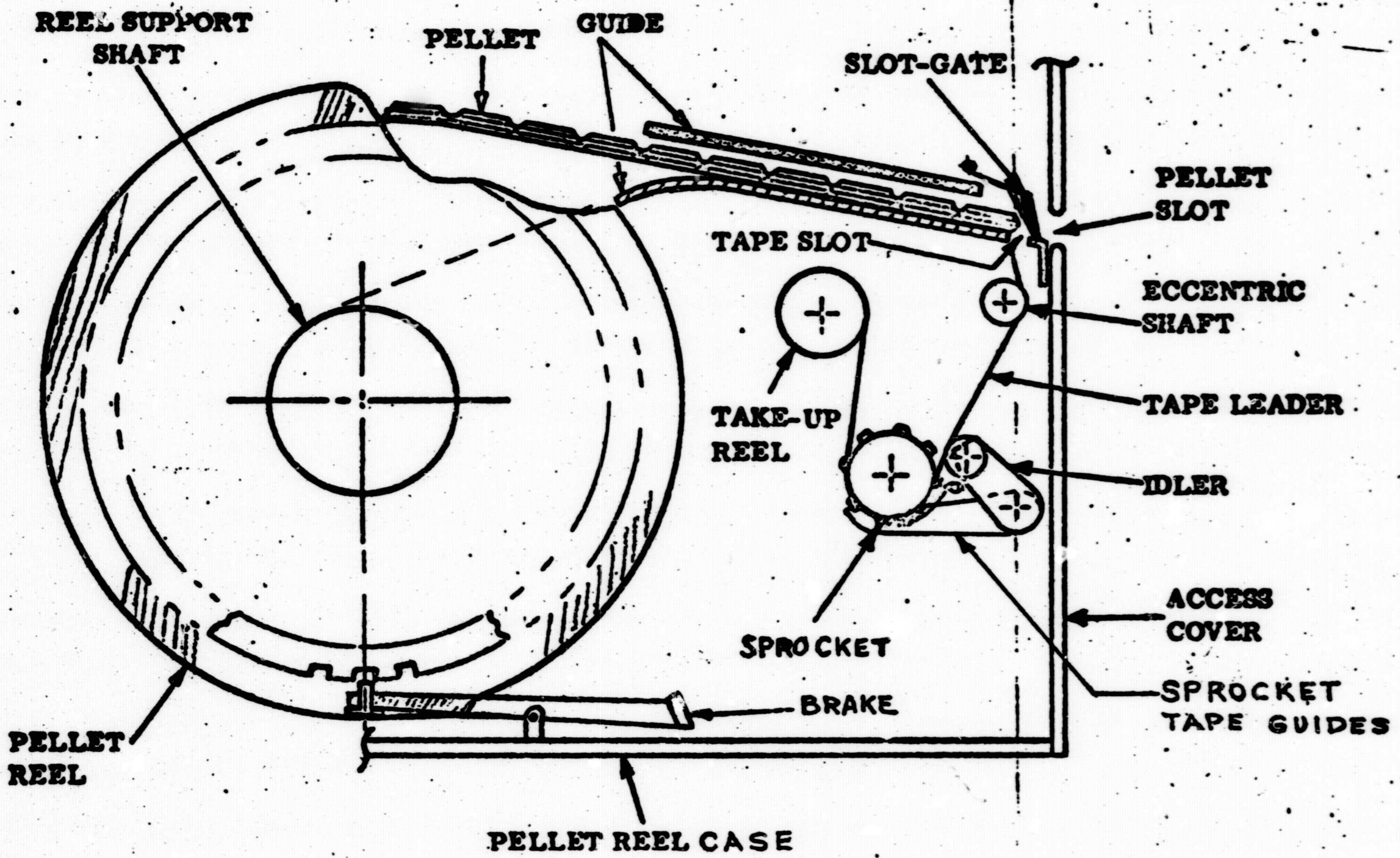


FIGURE 2: CROSS SECTION VIEW

PELLET FEEDER

//// TEFLON COATED

useful several times during the actual flight of Biosatellite III.

2.2 WATER DISPENSER ASSEMBLY - Treated fuel cell by-product water was selected as a drinking water supply to minimize system weight and storage volume requirements.

The primate's influence on the design is indicated in figure 1. The initial design had one solenoid to shut-off the supply. The primates learned that the noise of the supply solenoid signified water flow into the water dispenser. They became very proficient at cueing to the solenoid click, obtaining more water than was intended and thereby destroying the water measurement accuracy. As a result, a nipple solenoid and related electronics were added to close the nipple solenoid before opening the supply solenoid and keep the nipple closed until the supply solenoid had reclosed. The monkey then obtained water by sucking on the nipple which actuated the pressure demand regulator allowing water to flow and causing the flexible bellofram to collapse.

A travelling contact, and associated fixed contacts and electronics, in conjunction with the life support controller and GFE programmer initiated the fill cycle. The water dispenser was monitored by the life support controller which registered the water quantity for later presentation to the ground via telemetry.

2.3 FECES COLLECTOR AND COUCH ASSEMBLY-
Of all the subsystem equipment, the feces collector and couch assemblies were most sensitive to the range of Macaca nemestrina physiological features. Since the couch had to support the restrained monkey, monkey body dimension ranges, including urine and feces envelope interfaces, were required. A limited quantity of this type of monkey was available and of these only a few were at the proper age and weight required.

However, a body measurement matrix was defined and a National Aeronautics Space Admin., Ames Research Center and GE-RESD team obtained the necessary information.

In addition to the restrained primate and as shown in figure 3, the couch supported the Univ. of Southern California blood pressure experiment heparin supply, pumps, transducers, and signal conditioners. It also provided support for the Univ. of Calif. at Los Angeles physiological sensor signal conditioner. And last but not least the couch supported the feces collector. The collector provided the container for the heparin bags and support for the urine catheter line in addition to its primary function of feces collection.

The feces collector performed its function well when presented with formed stools through the use of a 1 CFM air flow provided by the spacecraft's gas management assembly (GMA). (See Figure 1.) The air flow provided the force to move the feces into the can, prevent odor leakage (suction side of fan), and dried the feces for storage and analysis upon recovery. The air was passed through a selective gas/liquid separator membrane and a bacteria filter.

2.4 TRACE GAS CONTAMINANT CONTROL CANISTER - Similar to the feces collector the trace gas contaminant control canister was located on the suction side of the GMA. Flow was set at approximately 100 cc/min to keep the ammonia (NH3) and carbon monixide (CO) levels within specification limits. Amberlyst was used for NH3 absorption and hopcalite was used to oxidize CO to CO2. The CO2 was then passed to the GMA for absorption in the LIOH. (See figures 1 and 4.)

2.5 LIGHTING AND CAMERA ASSEMBLIES AND CAMERA/LIGHTING CONTROLLER - (See Figure 1.)

Incandescent lamps were selected over fluorescent lamps primarily because of the concern early in the program over noise effects on the primate head sensors. (The lights were in the vicinity of the primate's head.) The light assembly had to

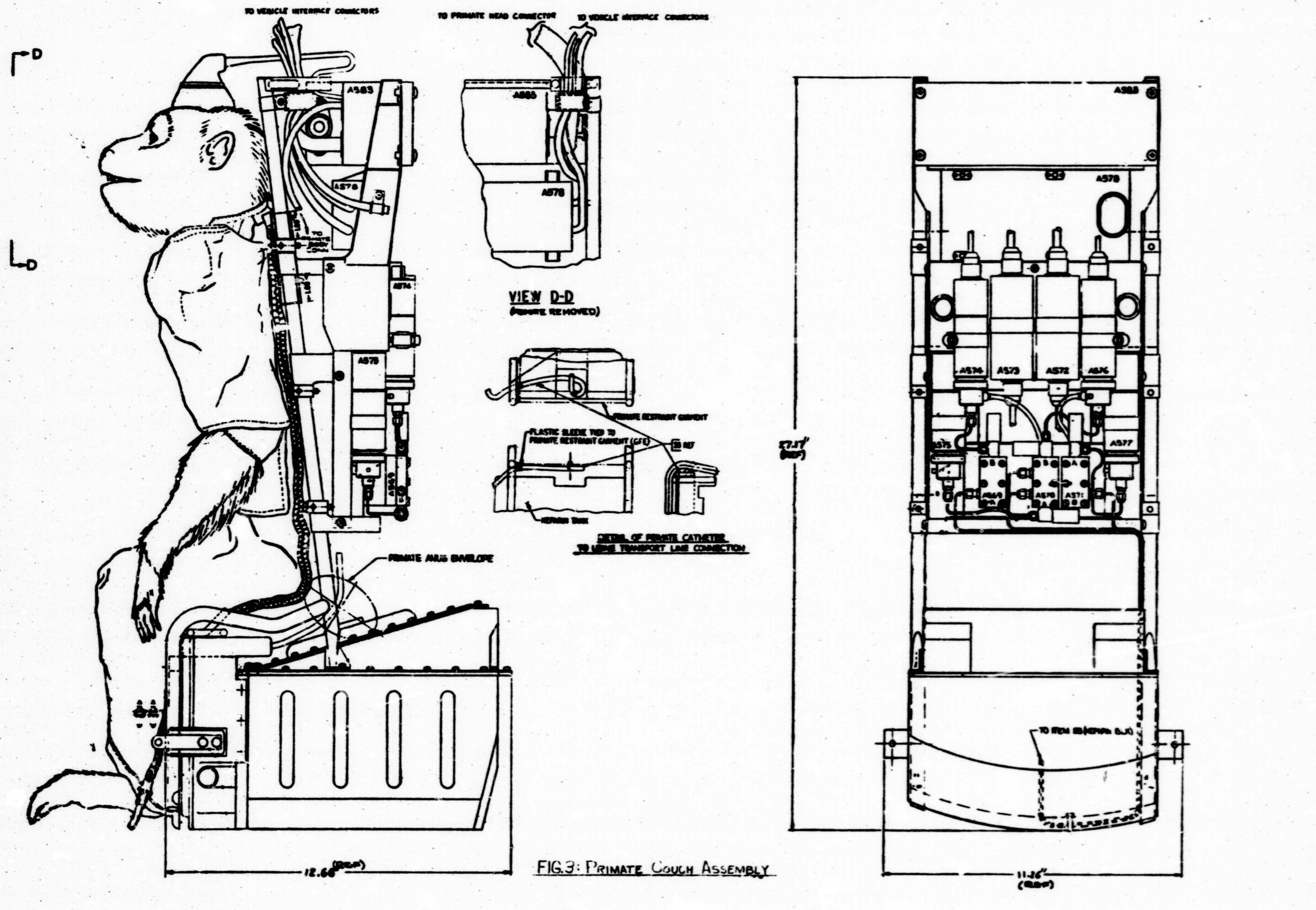
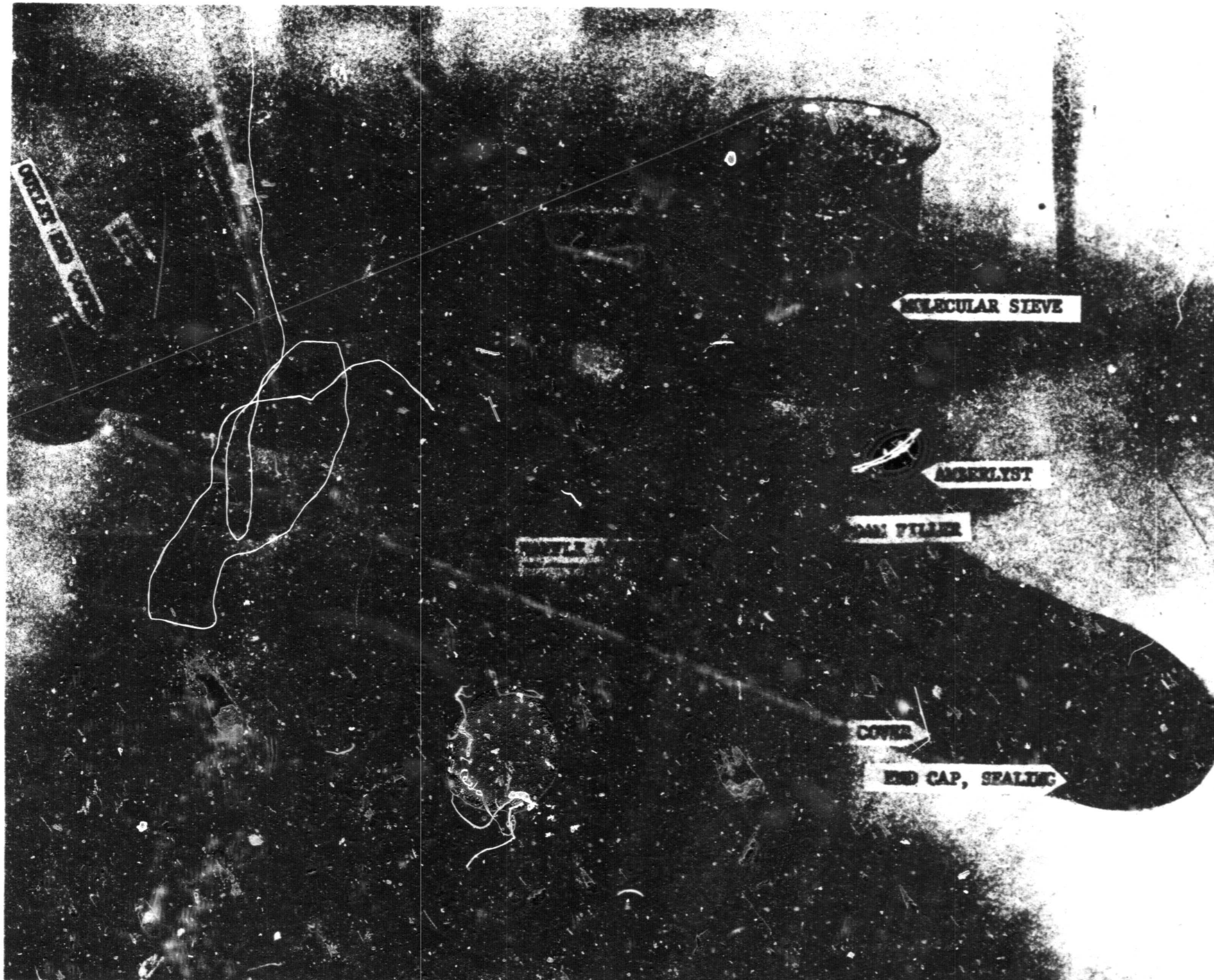


FIG.3: PRIMATE COUCH ASSEMBLY


MOLECULAR SIEVE
COVER
END CAP, SEALING

perform two functions, first, provide a day and night circadian rhythm reference for the monkey and, second, provide enough light for day and night photos.

The primate's influence on this design was found in the color of the light. It was determined that a 30 to 1 day to night light intensity (foot candles) change was required to insure a proper day to night reference for the monkey. A rather clever solution to this requirement was provided by taking advantage of the difference between the monkey's eye and the film's response to light wave lengths. Since the monkey was less sensitive than the film was to the red light region, a red filter was added to the night light. This provided greater than 30 to 1 (theoretically greater than 100 to 1) day to night light illumination ratio while providing enough light for high resolution photos at both day and night light levels and at one camera lens setting.

Two light housings were used, one for day and one for night lighting. Each light housing contained two bulbs, a primary bulb and a redundant bulb. Only one bulb was lit at any given time. Fiber optic bundles were routed from the light assembly to a NASA/ARC furnished calander clock. This clock provided the day, hour, minute and second record on the film.

A flight qualified pulse camera was used to take 16mm single frame or movies (4 frames per second) during all mission phases as preprogrammed or ground commanded. Thin base, high speed, black and white film was used.

Both the light and camera sequences were controlled by the camera/lighting controller in conjunction with the life support controller and government furnished programmer.

2.6 LIFE SUPPORT CONTROLLER - As identified in the preceeding sections, the life support controller unifies the functions of the subsystem. The significant feature in its development was the compilation of many individual component controller and monitor functions into one component with the resulting size, weight, complexity, interfacing and cost reductions.

C. CONCLUSION

It was recognized from past experience that design of equipment which had a substantial man/machine interface was more difficult than non-man-related equipment. This is due to the large variations in physiology from one person to another and the range of subjective reaction to the same stimulus, that is, the psychological variation of individuals. You are faced with an even greater challenge when these facts are coupled with the need to design for a monkey: 1. who is expending every ounce of his ingenuity in tampering with the equipment without concern for the various possible results on his own safety and/or well being and, 2. who is unable to provide routine support tasks or trouble shooting and repair.

Such was the challenge which was faced and successfully met through the coordinated and dedicated efforts of the NASA-ARC, Experimenters (UCLA, USC, Univ. of Calif. at Berkley, Jet Propulsion Laboratory, Texas Women's Univ., Harbor General Hospital) and GE-RESD team.

D. EPILOG

The experiment payload subsystem operated through the system performance tests and flight mission profile without failure or serious incident. In fact many of the assemblies exceeded their requirements by continuing to perform to specification following re-entry and water impact environments.

Specialthanks is given to Mr. Charles Wilson, Biosatellite Project Manager, NASA-ARC, for the consideration he has given to this paper.