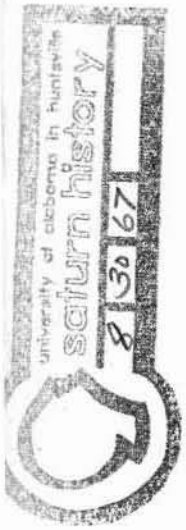

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DOUGLAS PAPER NO. 4396

THE ROLE OF THE S-IVB IN THE APOLLO AND POST APOLLO PROGRAMS

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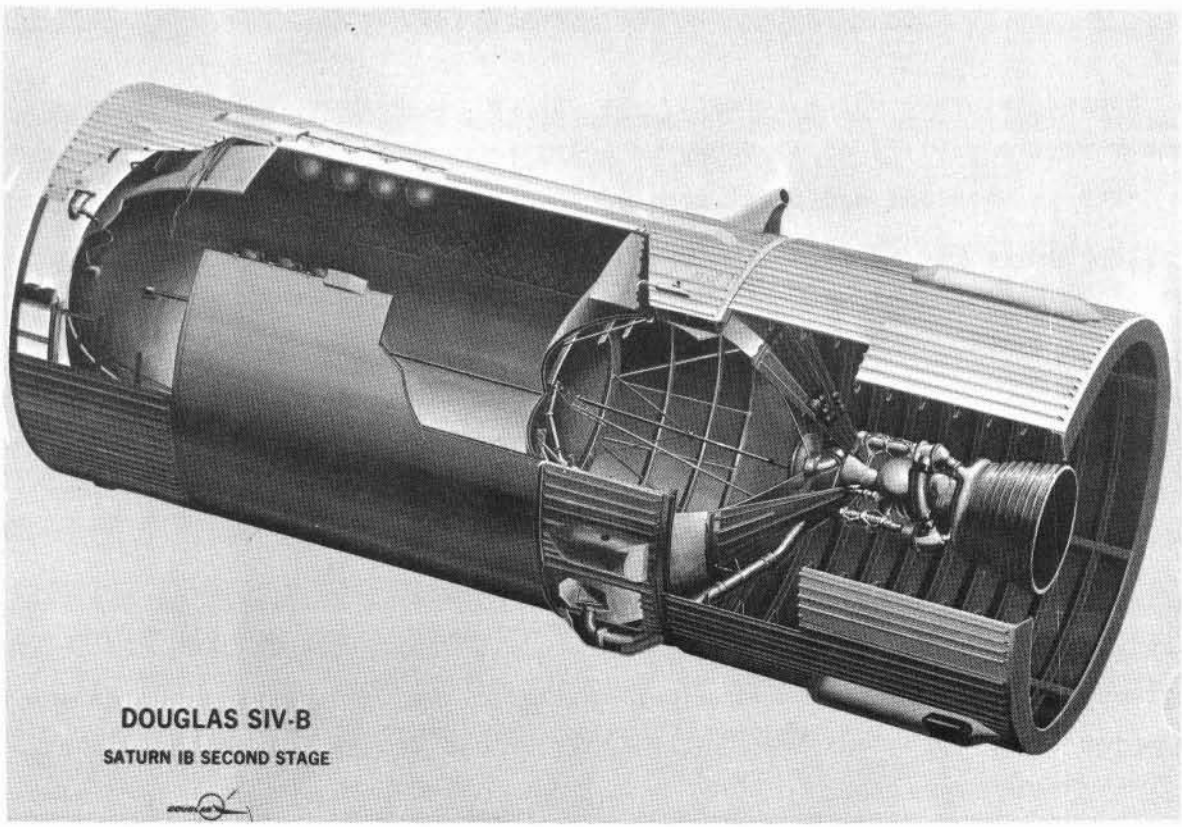
PRESENTED TO:
16TH ANNUAL CONFERENCE OF THE HERMANN OBERTH SOCIETY
BERLIN, GERMANY
AUGUST 30, 1967

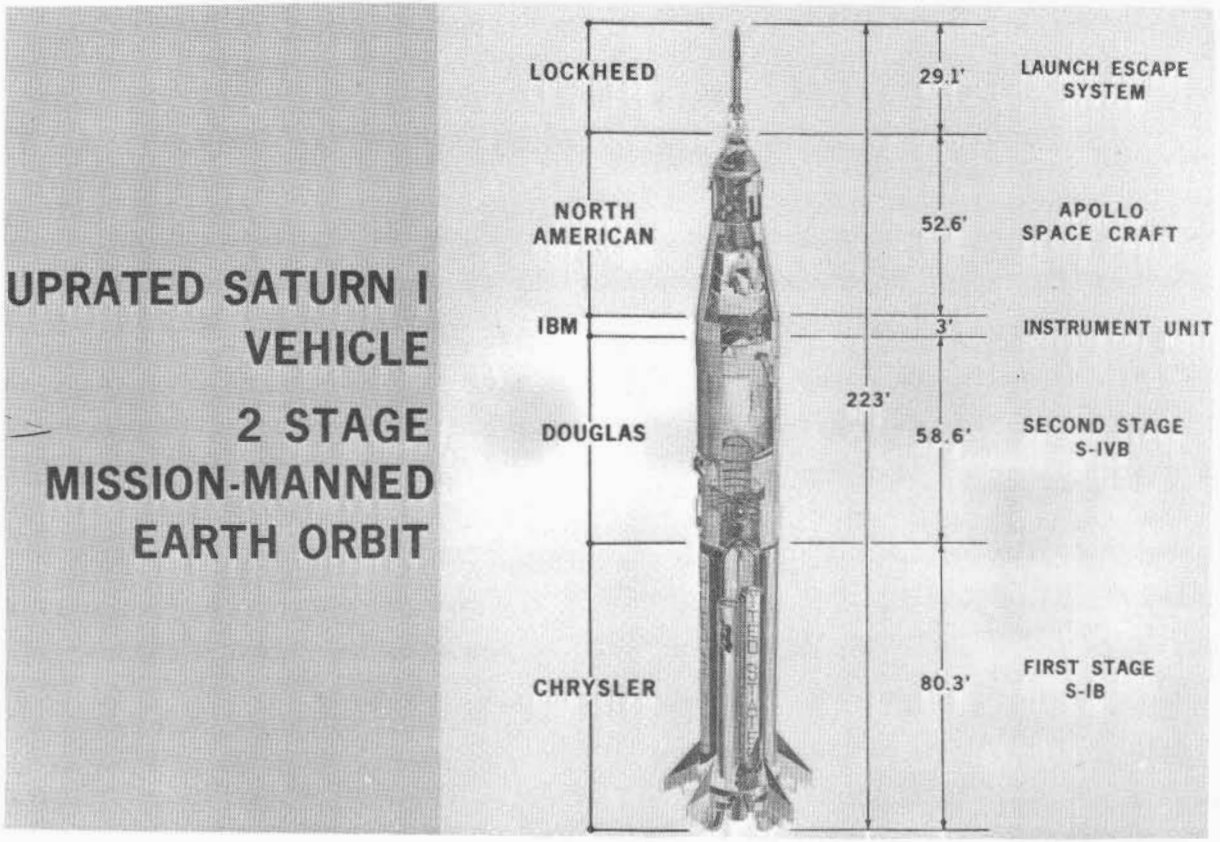
DOUGLAS MISSILE & SPACE SYSTEMS DIVISION
SPACE SYSTEMS CENTER — HUNTINGTON BEACH, CALIFORNIA

THE ROLE OF THE S-IVB IN THE APOLLO AND POST APOLLO PROGRAMS

Two years ago at the annual meeting of the Hermann Oberth Society I had the privilege to report on the development of one of the large launch vehicles in the Saturn Program, the S-IV. I mentioned that the next generation, the S-IVB, was well along in the development and today I am proud to be able to state that this vehicle seems to continue the success we had with the S-IV. Three S-IVB's have been launched in the meantime and all three fully fulfilled their mission.

To refresh your memory permit me to show you where the S-IVB belongs in the Saturn/Apollo Program. The development of the Saturn rockets is being carried out under the supervision of the National Aeronautics and Space Administration (NASA), Marshall Space Flight Center, Huntsville, Alabama.

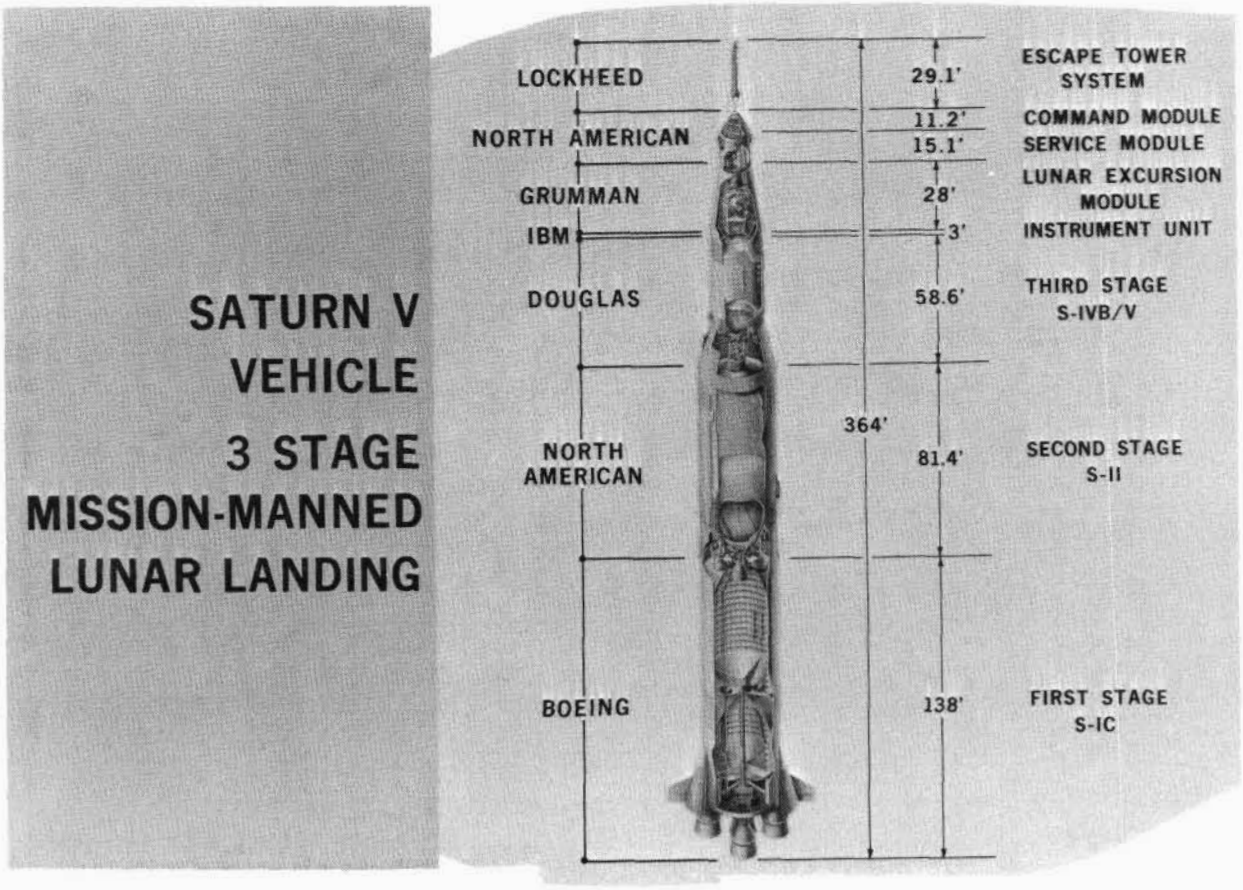




The uprated Saturn I which formerly was called the Saturn IB is a two stage booster with a payload of 17,000kg in a 195 kilometer earth orbit. It uses the S-IVB as a second and final stage. Twelve of these vehicles are in production at this time. Three of them have already flown as I stated before. Several have been delivered to NASA and are awaiting launch, and the rest are in final assembly. There are plans to provide for more vehicles of this type.

The Saturn V is a three stage "moon booster," consisting of the S-IC, the S-II and the S-IVB. Several of these S-IVB's have already been delivered and more are under construction. Preparations for nine additional stages are being made.

Landing man on the moon will be in the focus of public interest for the rest of this decade until we have reached this goal. But everyone involved in this program is already asking "What after Apollo?" NASA has established as one of the major "post" programs the Apollo Applications Program. The basic content

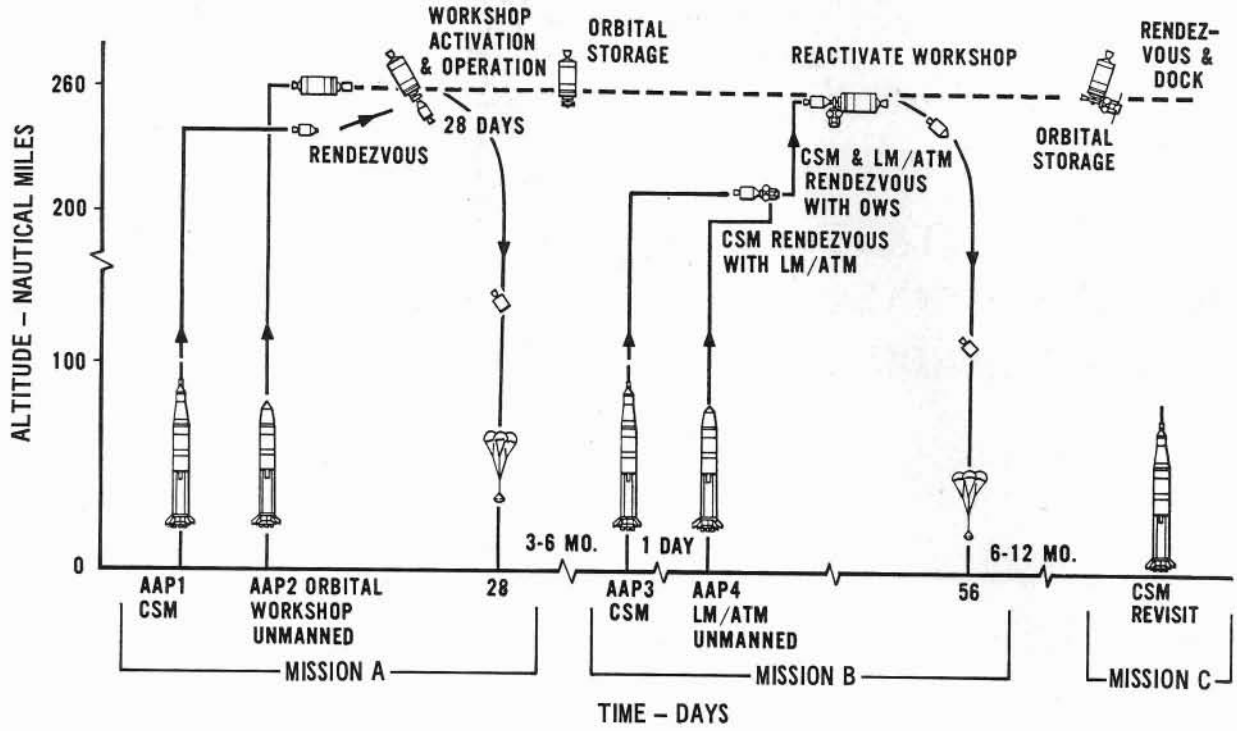


of this program is the scientific exploration of space in its broadest sense but based on hardware which was developed for the Apollo Program.

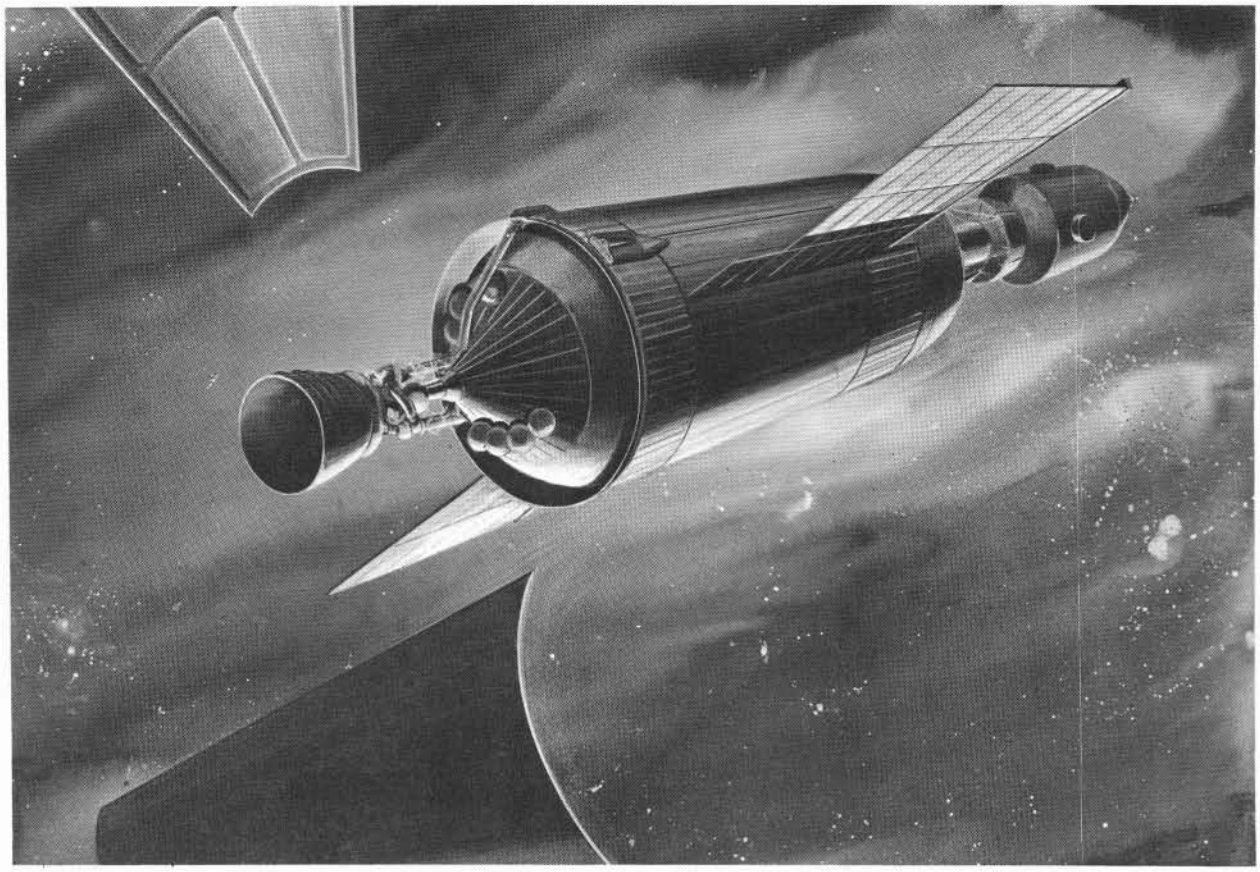
I personally believe that this program will finally surpass all other programs with respect to the interest and participation of the general public and especially the scientists of the whole world.

What is the present Apollo Applications Program? It is of course relatively difficult to precisely describe an emerging program when the existing prime program is as dominating as the Apollo Program. But the Apollo Applications Program has already established a list of numerous desirable experiments, large and small, and has defined its first mission, a very ambitious one as such. Let me show you some of the planning for this first mission since the S-IVB stage plays a major role in its accomplishment.

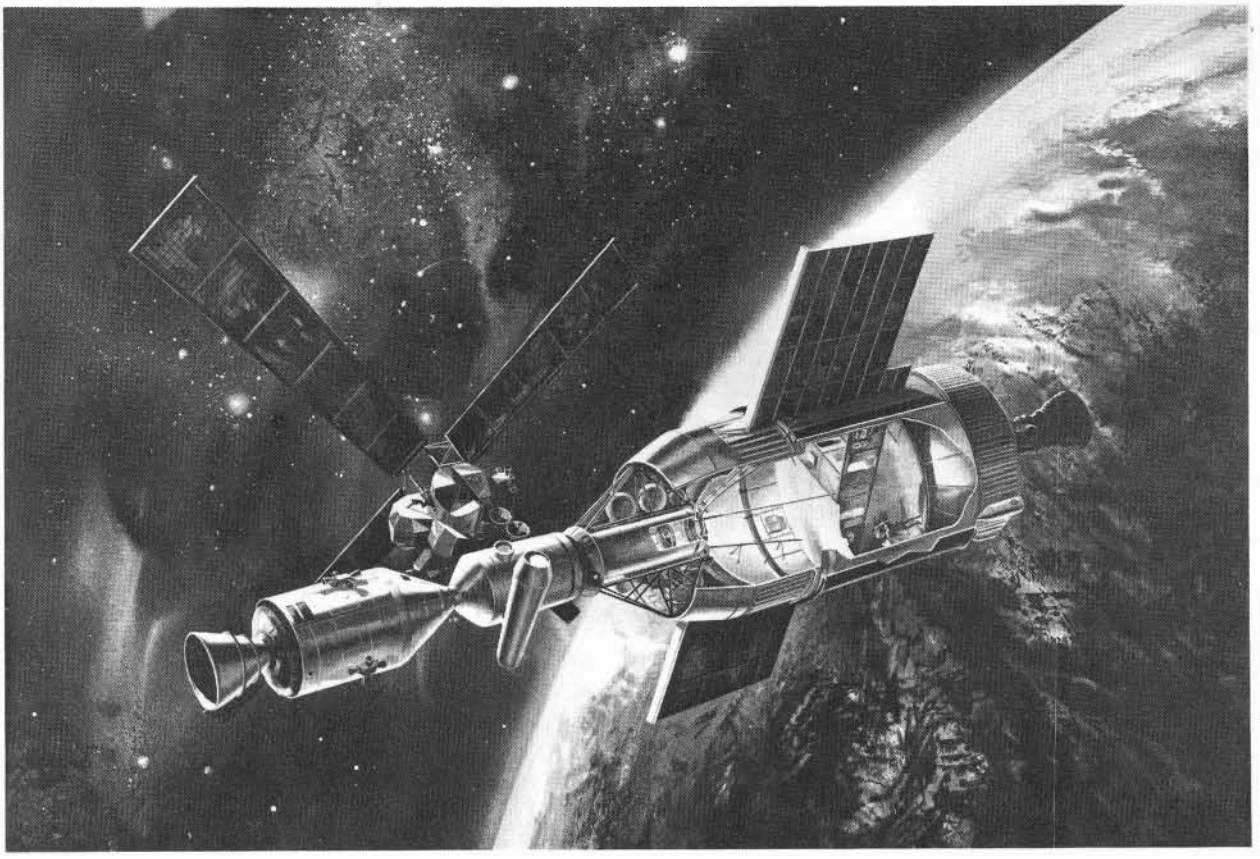
APOLLO APPLICATIONS PROGRAM
MISSION PROFILE



Four uprated Saturn I vehicles had been planned. As I explained earlier the uprated Saturn I has two stages and can carry a variety of payloads. In our case the payload of Vehicle No. 1 consists of a Command and Service Module (CSM) as used in the Apollo Program. This vehicle will be launched into a circular earth orbit of approximately 140 miles and an inclination of 29 degrees. The launch operation is identical to the standard Saturn procedure. The launch escape system will be discarded shortly after first stage cutoff. The S-IVB then will insert the system into orbit after which the crew detaches the CSM. A day later Vehicle No. 2 will be launched. It is an unmanned uprated Saturn I which carries as a payload an airlock and multiple docking adapter (MDA). It provides a special S-IVB stage which can be converted into a workshop after second stage cutoff. There is also a nose cone shroud which will be discarded after leaving the sensible atmosphere. The vehicle will be inserted into a 260N mile orbit in which the braking force of the atmospheric resistance has a relatively low value and will give it a life time of at least a year.



After reaching its prescribed orbit there will be certain automatic operations which will change the S-IVB from a liquid oxygen and hydrogen container into an oxygen gas container. I will explain this later on. In the meantime, the first spacecraft, ascends to the second vehicle orbit with the help of the CSM propulsion system and docks to the MDA. The astronauts enter the workshop through the MDA and airlock, complete the conversion of the S-IVB into a laboratory and conduct experiments for about 26 days. At the end of this period they return to the CSM, undock, and return to earth in the normal procedure. Workshop, airlock, MDA remain in orbit for three to six months before the next mission is started.



At the present time, discussions are being held to decide if there should be an inspection and resupply of the workshop between the two missions.

Vehicle No. 3 is a manned "Uprated Saturn I" consisting of a second CSM payload which will detach from the second stage and rendezvous with the workshop. This will then rendezvous with Vehicle No. 4 which is an unmanned Lunar Module (LM) and Apollo Telescope Module (ATM). The Vehicle No. 3 CSM will attach itself to the LM/ATM and carry them to the workshop where they join with the MDA. The astonauts again will enter through the airlock into the workshop and continue their scientific experiments, at the same time manning and operating the ATM. After an operation of approximately 56 days the crew will then return to earth using standard procedures. The whole workshop cluster will remain in space for an indefinite time.

At first glance this plan looks extremely complex for a first mission but one should consider that we have proven the feasibility of rendezvous in the Gemini flights and we are confident that we will not encounter many obstacles. We are aware that a large amount of new knowledge will be gathered during the lifetime of this program which will enable us to make better use of space flight in orbit and beyond to the planets.

S-IVB ORBITAL WORKSHOP PROJECT CONFIGURATION

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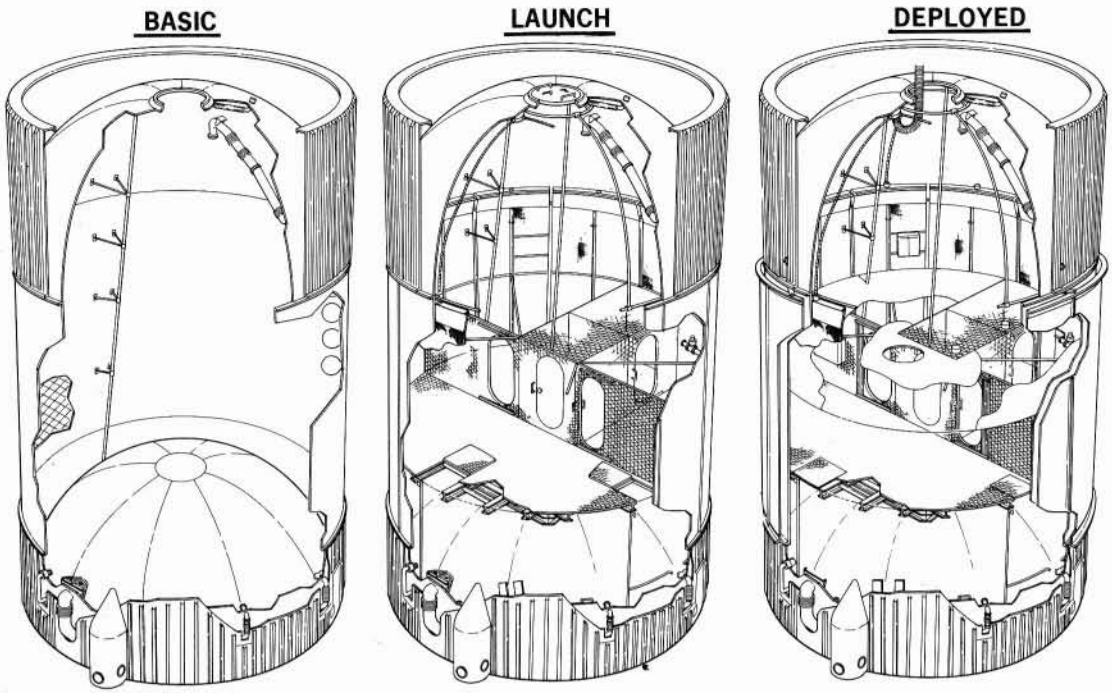
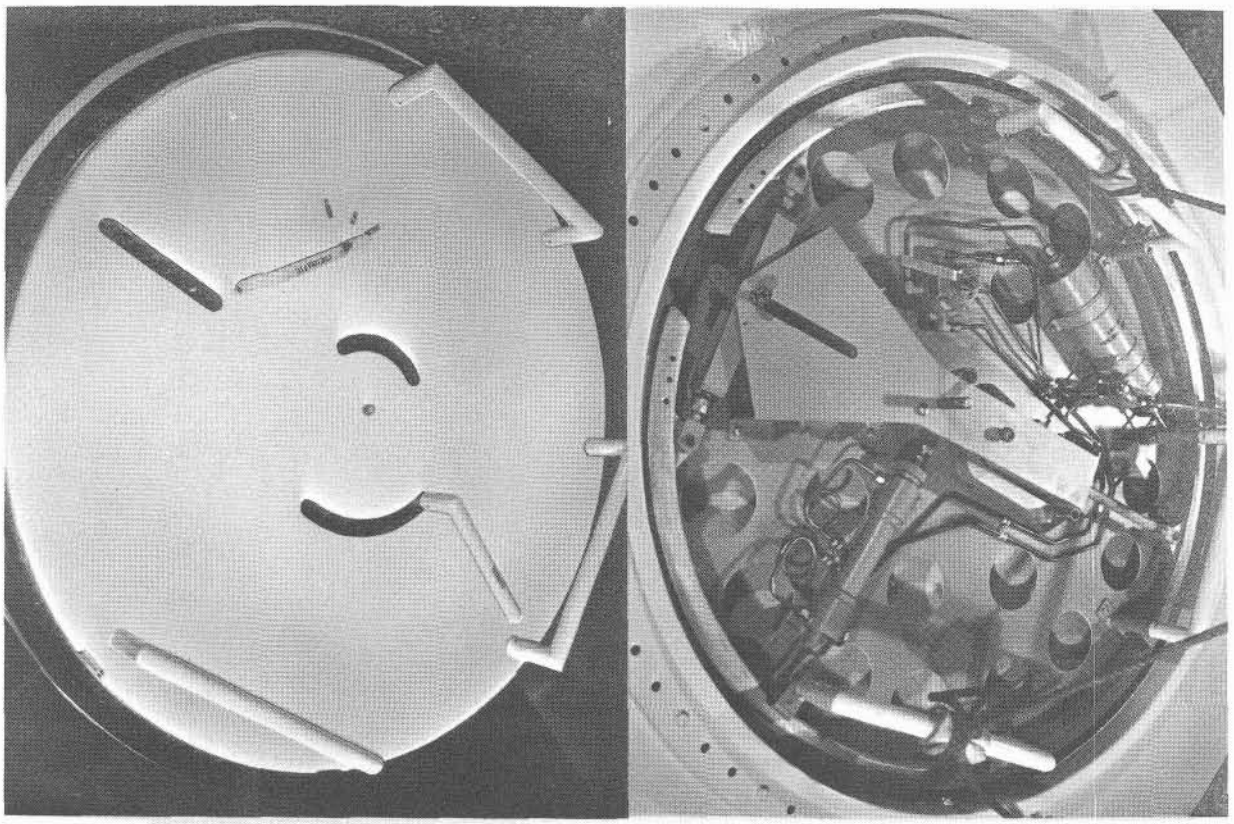


When the suggestion was first made to keep on using a depleted fuel container in space for other missions, reception was not too enthusiastic. These first proposals go back several years to the time when neither the S-IV or S-IVB had ever flown. The many unknowns scared most people who were then looking into the possibility of converting such a large vehicle into a workable laboratory. We have since accumulated much knowledge about the behavior of such systems in orbit, controlled and uncontrolled.

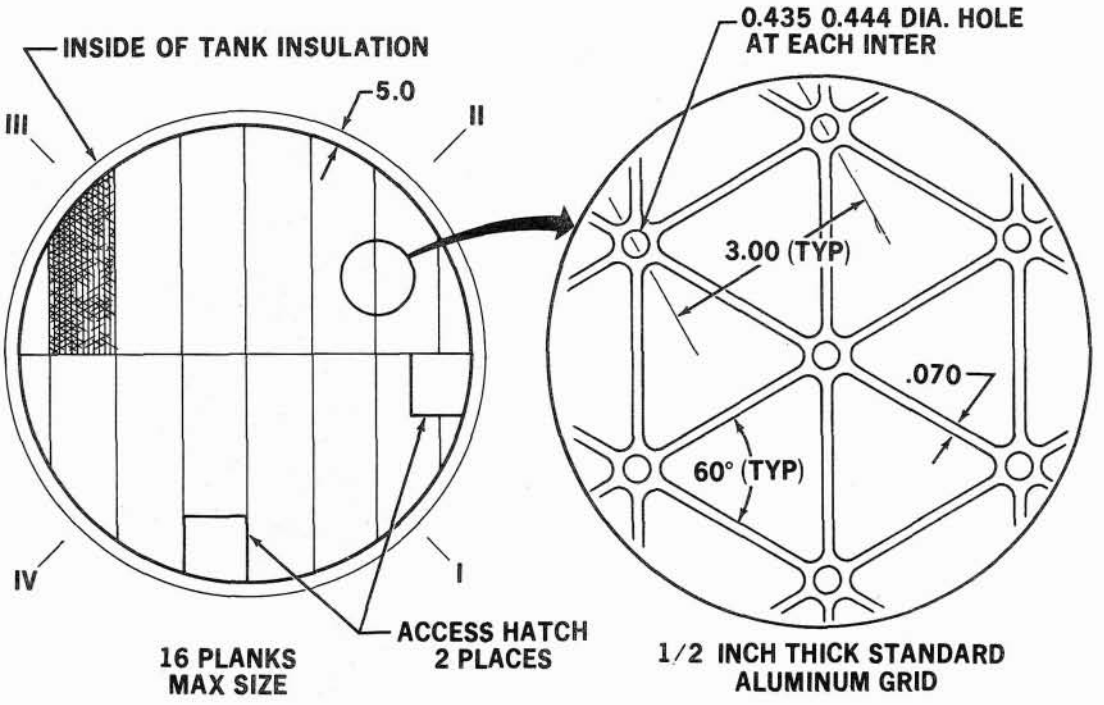
Now, let me give you some of these details. First of all assume the S-IVB stage has completed its delivery operation. It will be necessary to prepare it for ingress of the astronauts. This means that we will have to depressurize our pneumatic systems, the cold and ambient helium spheres which assist our propulsion system, the pressure systems in the auxiliary propulsion system and naturally to empty the liquid oxygen and hydrogen containers of residual



propellants. We will attempt to defuel through the engine since this can be accomplished in a relatively short time. We also have to disconnect the electrical power system. We call this activity "passivation". In order to enable the astronauts to enter the liquid hydrogen container we have provided certain minor modifications to our basic stage. We have, for instance, changed the man hole in diameter to a larger size, and designed a man hole cover or entry hatch which can be easily and quickly opened by the astronauts and stored inside the container. We have also provided in the grid pattern of the tank wall, attach points which enable us to install a variety of items. These attach points enable us to install the skeleton of the crew quarters and a laboratory arrangement within the stage. These walls and floors naturally have to be designed in a way that they do not affect the flow of the liquid hydrogen to the engine system. This means all walls, doors, etc., are designed as open grid work. The astronauts will either unfurl, or carry in, solid covers for these walls. Some of the experiments, the normal demands of human beings for privacy during rest periods, and the special requirements of food preparation and personal hygiene, demand closed quarters. Considering that the activity in these laboratories have to be conducted under zero-g conditions,

S-IVB ORBITAL WORKSHOP PROJECT
FLOOR SURFACE ASSEMBLY

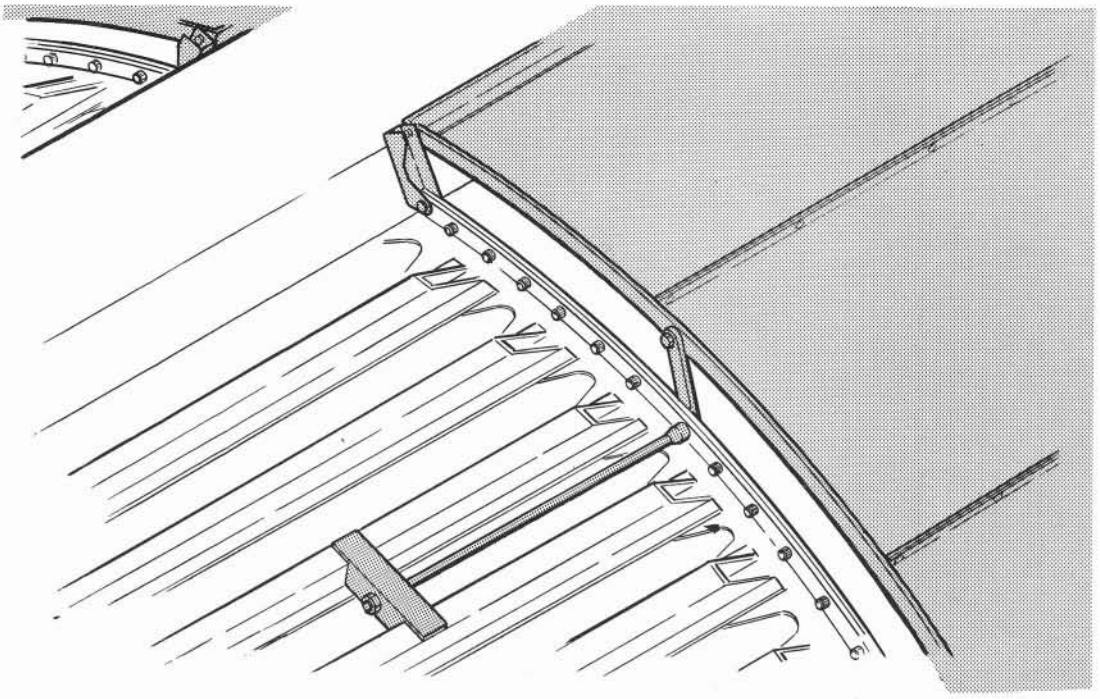
O/W-89 -X
5-6-67



mobility aids for the astronauts have to be provided. There will be furnished a fireman's pole leading from the entry hatch down to the laboratory area and there will also be hand rails around the circumference of the container to enable the astronauts to attach electrical lighting fixtures and ventilators. These ventilators have particular importance since it is necessary to keep the operating temperature within tolerable boundaries. The atmosphere in the container has to be constantly circulated and mixed since one side of the stage will be exposed to the radiation of the sun when the other side is exposed to the temperature of space. This temperature control of the workshop system is one of the most important systems to be developed.

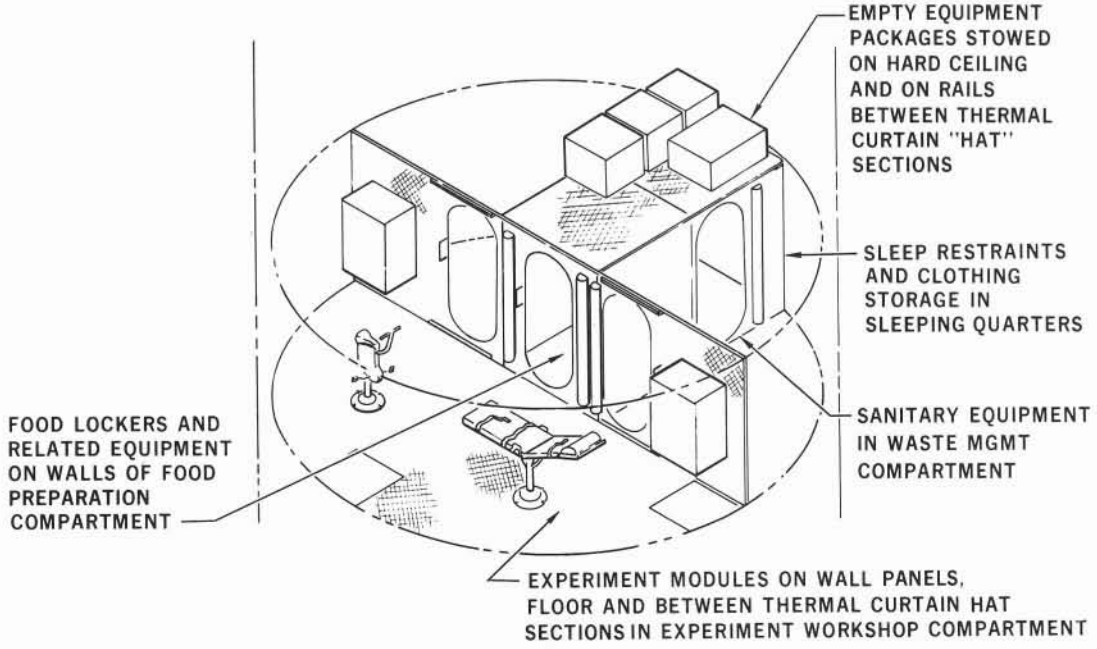
Another installation which is equally important is the protection against possible meteoroid penetration. Our present experience indicates that over the period of one year we might have three penetrations by meteoroids through the tank wall. Since this constitutes not only a possible danger of decompression but also a fire hazard, steps had to be taken to avoid any such penetration. The chosen solution was a meteoroid bumper to be arranged within a distance of 12 centimeters from the container wall. Such an aluminum shield will disintegrate incoming meteoroids so that the mass of the fractured particles is not sufficiently high to penetrate the tank wall.

METEOROID BUMPER



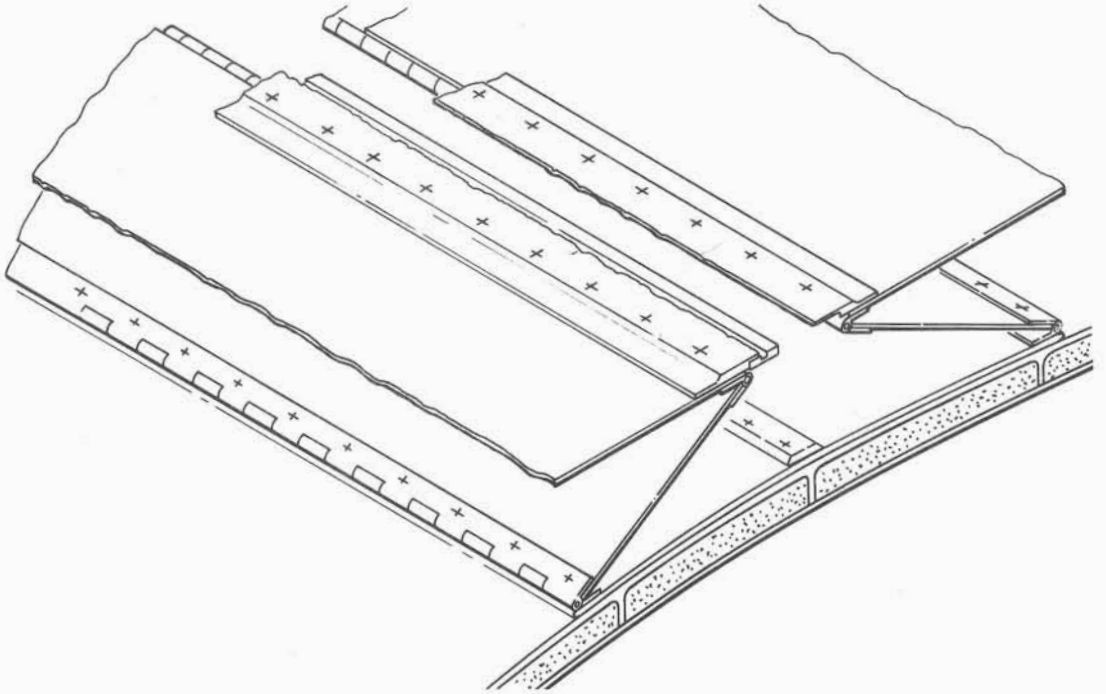
S-IVB ORBITAL WORKSHOP PROJECT
EQUIPMENT/ EXPERIMENT MOUNTING

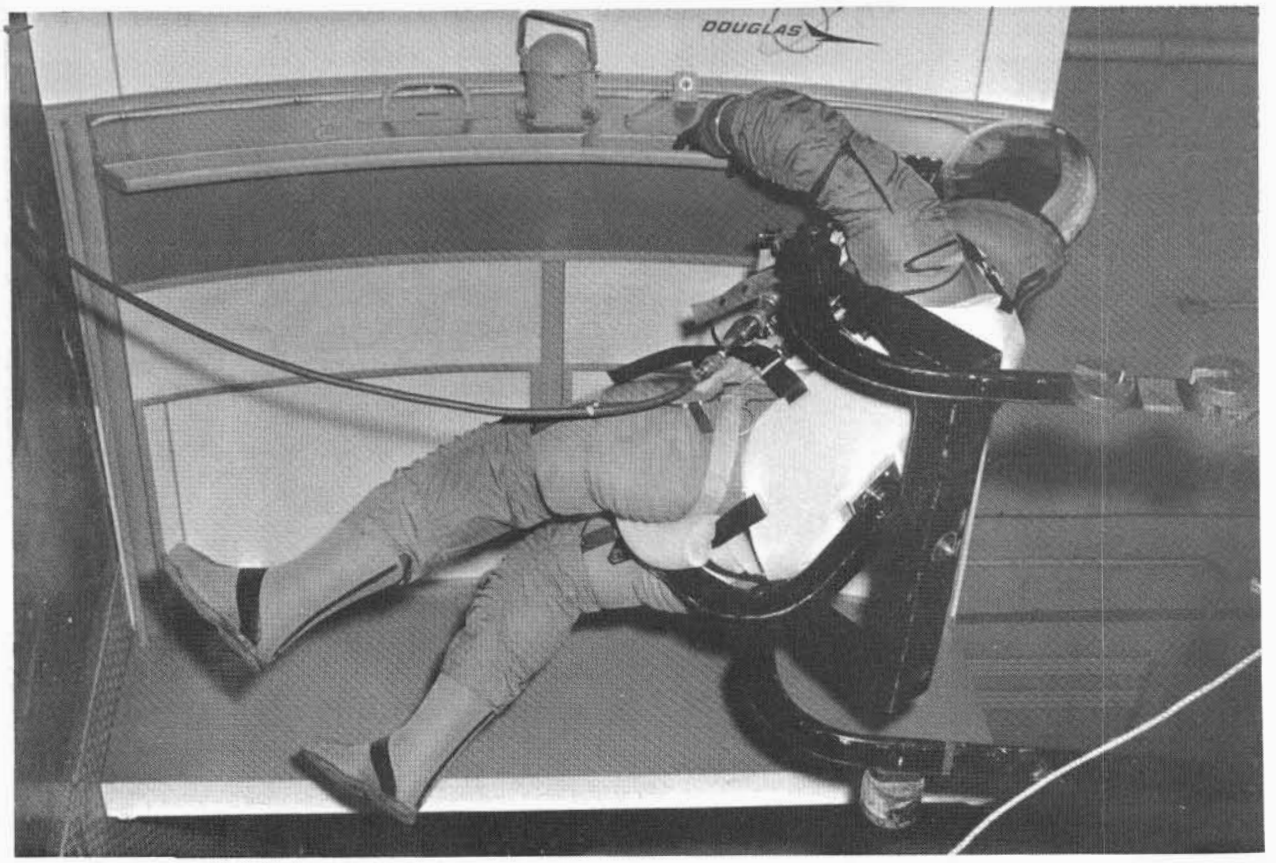
O/W-119 -X
5-6-67



S-IVB ORBITAL WORKSHOP PROJECT
METEOROID BUMPER-PARTIALLY DEPLOYED

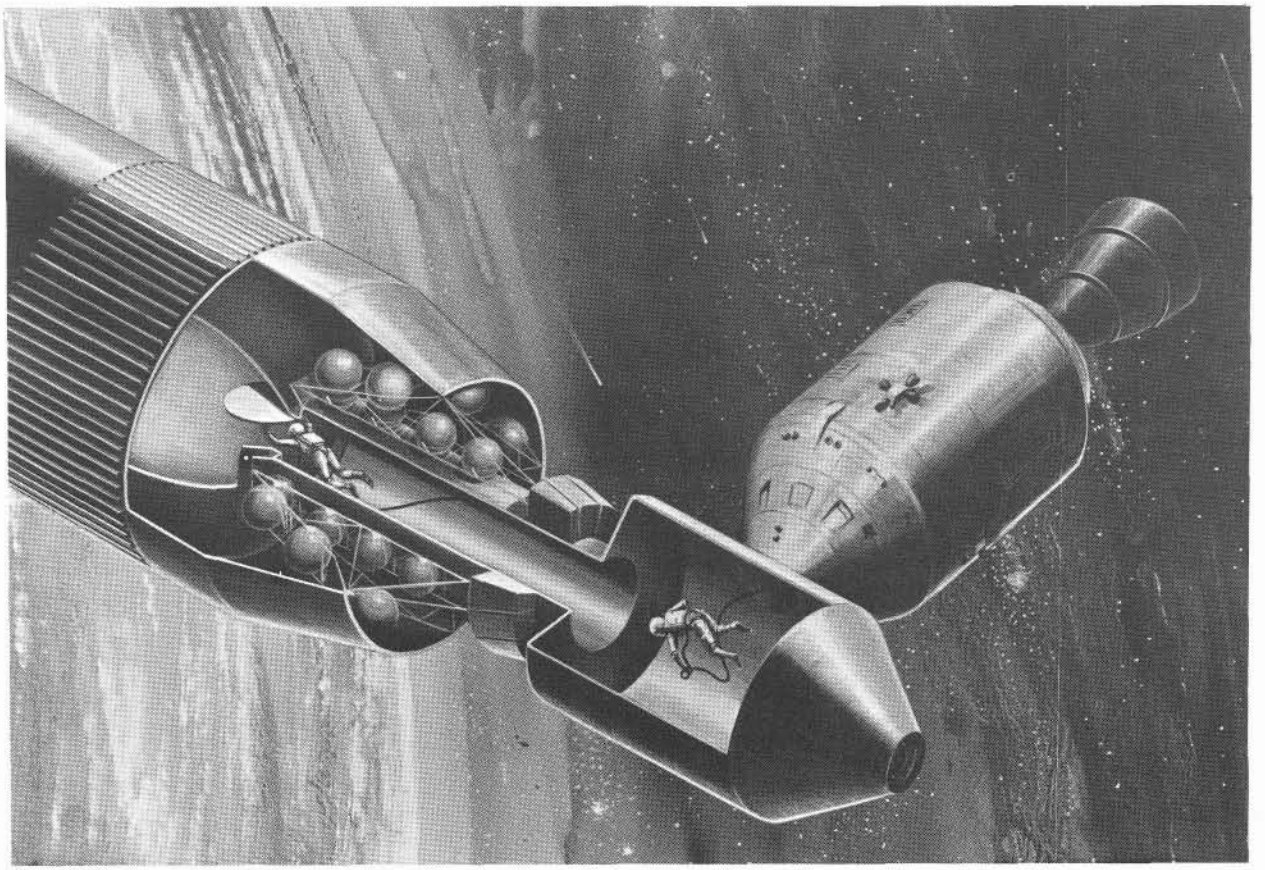
O/W-118
5-6-67



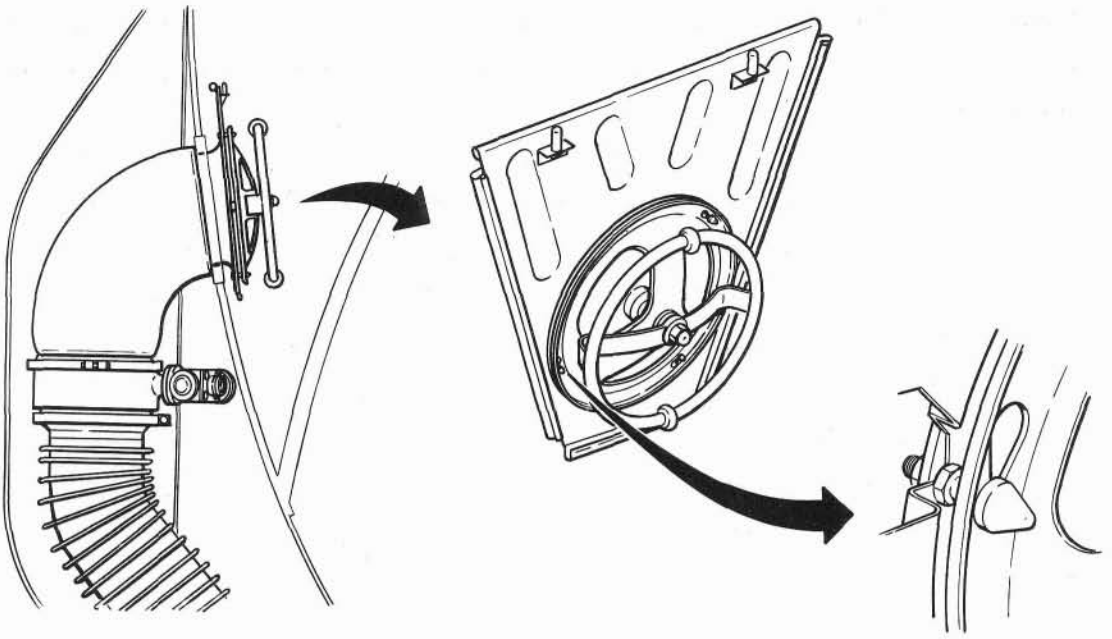


As you know, there had been an accident at the beginning of this year in the Apollo Program because of the presence of oxygen. We therefore, try to avoid flammable materials in the Orbital Workshop. The internal insulation of the hydrogen container, though flammable, could not be changed, therefore a new method was developed to prevent the development and spreading of fire. Over the existing insulation a thin aluminum foil is bonded to avoid fire generation and propagation. This foil is equipped with little holes so that any entrapped hydrogen gas can evolve during passivation.

Another challenge for the designer is the fact that all operations are conducted under zero-g conditions. We have to develop a "feel" for this new environment. Neutral-buoyancy-facilities are being used as design and development tools. Also special suspension systems have been designed to simulate zero-g conditions, but underwater operations seem to be still the best simulation.



LH_2 FEED DUCT PLUG



At the present time we intend to enter the tank while it is in unpressurized condition, but the astronaut will still be in his pressure suit. He will enter the tank, make certain electrical and mechanical connections, and inspect and seal the existing outlets. Maximum simplicity is therefore a must for these activities and constitute quite a challenge to the designer. Take for instance the main tank outlet which has a diameter of 25.24 cm with particularly close tolerances. There is a closed valve sealing the line but we have to assume that there might be some leakage after the operation of the propulsion system has ceased. A tight seal will be needed considering an operating period of one year for the workshop.

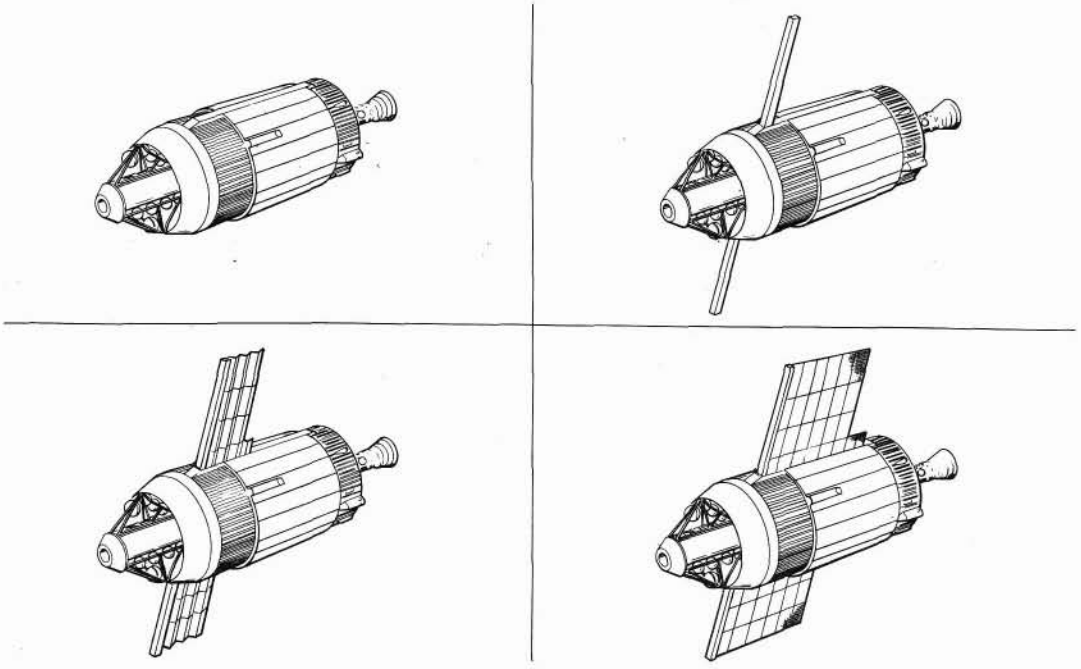
As we have seen this first primitive space station consists basically of the OWS, the Airlock, and the MDA. It is supposed to be in active operation for 28 and 56 days during the first year in orbit. The power requirements for these periods are naturally much higher than in the Mercury and Gemini spacecrafts. We therefore will use solar energy for the power system. As you know the efficiency of solar cells is very much dependent on the orientation toward the sun, so an attitude control will be needed. We will use the solar energy to recharge the batteries which are located in the Airlock. One of the presently planned configurations is shown in this picture. Several experiments

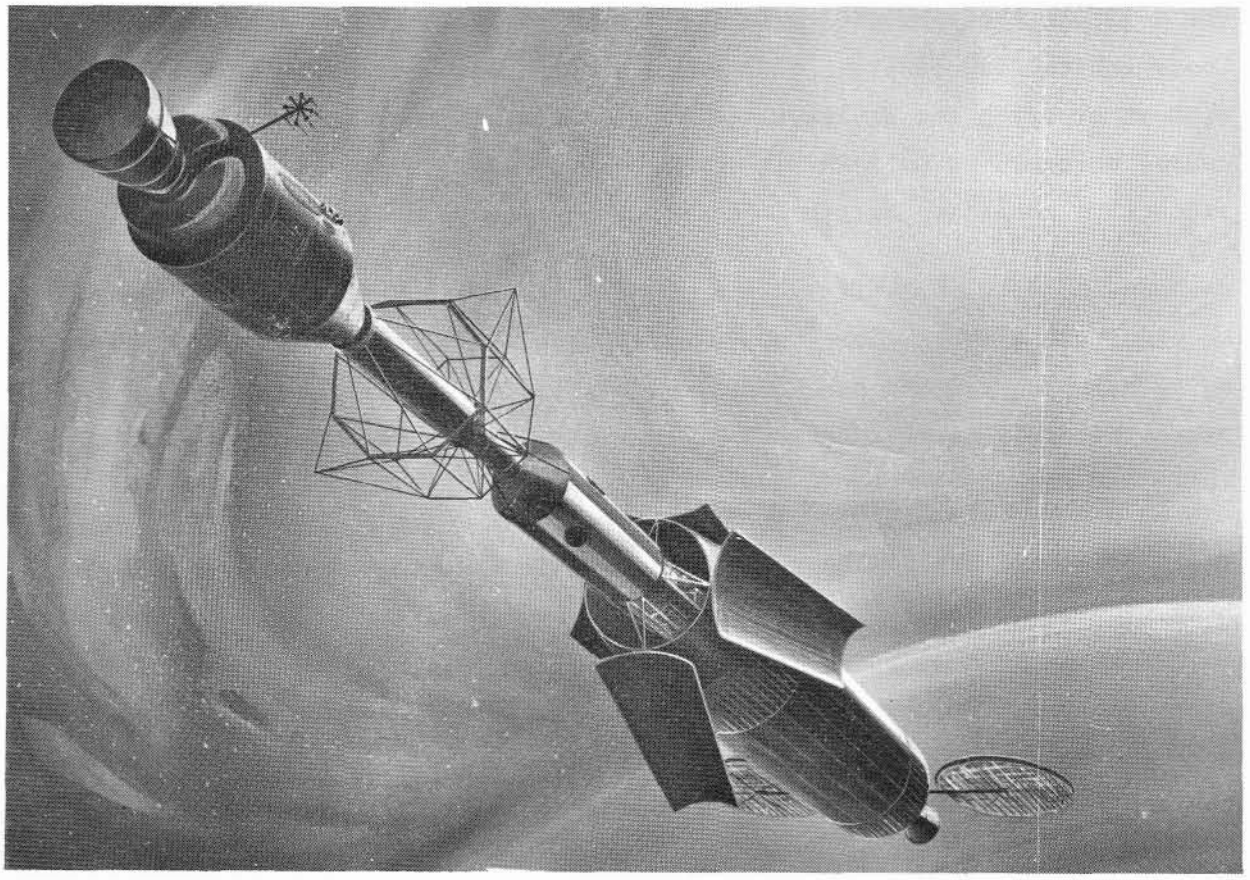
will have their own orientation requirements in addition to those of the solar panels. Two systems are being considered, a passive system based on the gravity gradients, which would orient the axis of the Cluster toward earth and an active system, using some type of mass expulsion like small rockets, gas jets, or something similar.

I hope that these few details give you an impression of the development of the orbital workshop in which we are engaged. The scientific and technical experiments which will be conducted by the three astronauts are largely connected with the investigation of human behavior in this particular environment. Some are intended to establish requirements for the accommodation of scientific space workers and still others will give us answers as to how to maintain such a system in space. I will refrain from going through the details of these experiments, since it would take too much time, and naturally the established list will see many changes before we have our laboratory in operation.

I have spent most of my time acquainting you with the use of the S-IVB as an orbital workshop, since this is presently in the focus of our attention. But let me shortly mention a few other possible uses of the S-IVB which are similarly exciting.

SOLAR PANEL DEPLOYMENT SEQUENCE





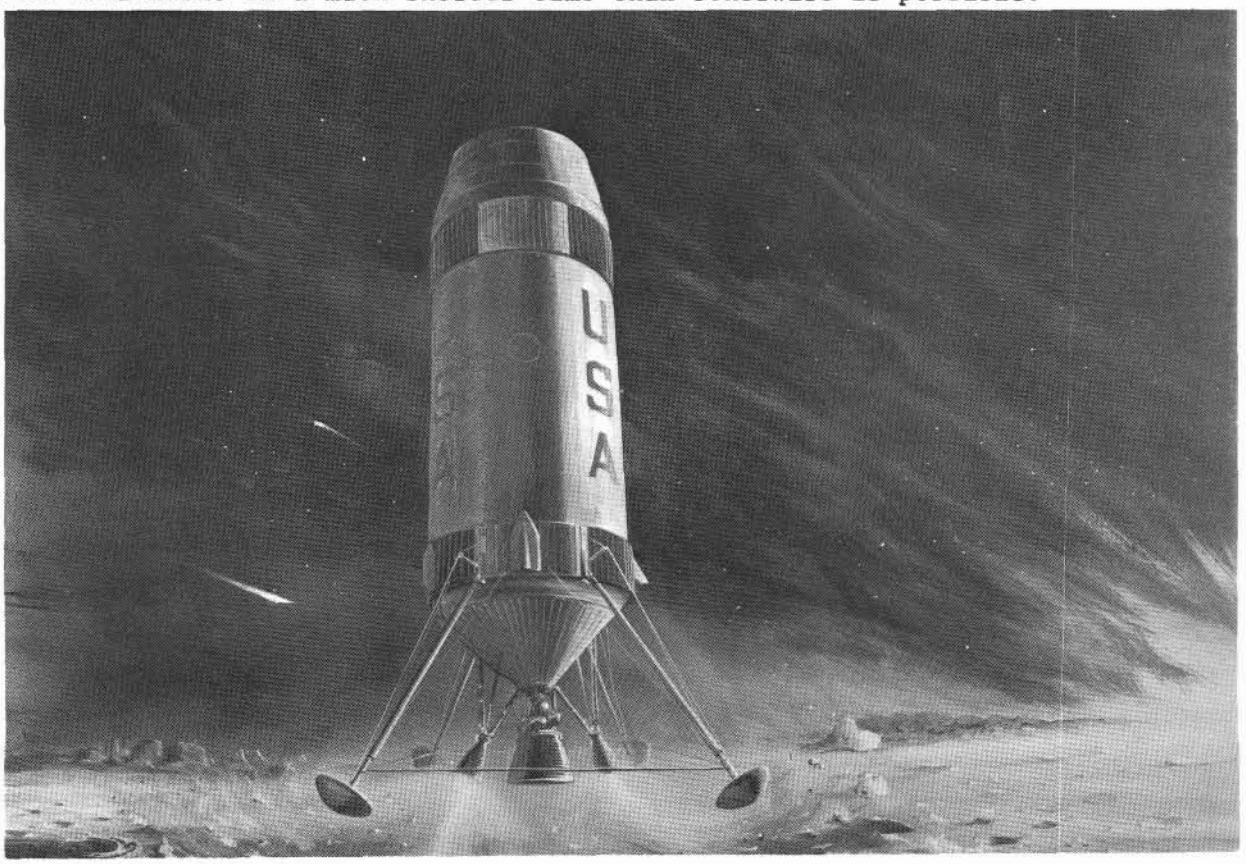
There is for instance the use of the S-IVB for synchronous missions. You know that in a synchronous orbit the vehicle takes a permanent "local" position above the earth. Many missions can make use of such a system. Since the Saturn V is capable of placing a payload of from 29,000 to 35,000 kg into such an orbit, we can place an orbital workshop into a synchronous orbit which would enable scientists to perform long term continuous observation of the earth. We have made studies to determine the necessary alterations to the S-IVB and we know that it can be accomplished relatively easily. Another program which is being studied is the so called advanced orbital workshop. Its configuration will enable us to spin the cluster around its mass-center and so create accelerations in the laboratory area of the orbital workshop.

With this system we could explore phenomena in a one-sixth-g environment over longer periods of time than has been possible so far. The next step in using

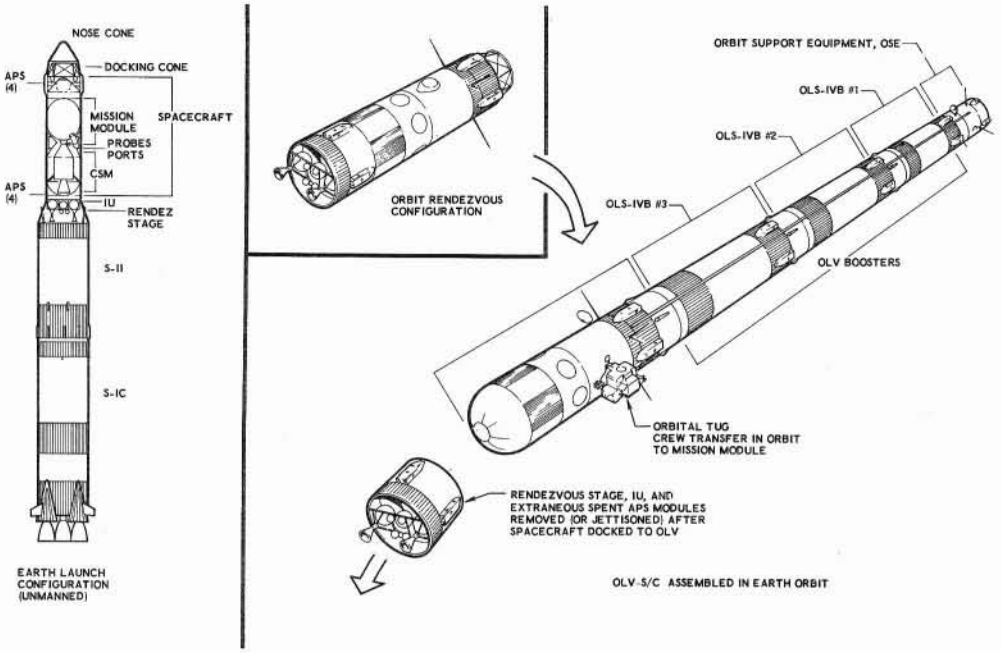
the S-IVB in the form of the orbital workshop could be the establishment of a lunar orbital laboratory. This would enable us to study the moon in detail without exposing the explorers to the hazards of lunar environment and of course we could as well land a stage on the lunar surface and use it as a protective shelter. All these missions obviously involve multiple launchings.

One more study we are presently engaged in is the potential use of the S-IVB in planetary fly-by. Here we are using as a final assembly a train of three S-IVB's, which you can see here in this artist's conception. With such a system we could conduct a Venus or Mars fly-by with performance as shown in this last figure.

In conclusion I would like to emphasize again that these possible missions I have mentioned are developed from a basic design of the S-IVB with the intent to reduce as much as possible new development costs by using existing and well proven hardware. The orbital workshop is a typical example of introducing such economic thinking into a seemingly uneconomical venture. We believe that the ambitious goals our planners are setting themselves can be achieved without always starting from scratch and have proven very recently that good results are obtainable in a much shorter time than otherwise is possible.



DACO MARS FLYBY SPACECRAFT CONFIGURATION



ORBITAL LAUNCH VEHICLE