

### 3. SPACECRAFT INTERFACE IN APOLLO, INCLUDING APOLLO EXPERIMENTAL PALLET

RAYMOND CLEMENCE  
*Planning and Management Office*

GILL: Our third speaker will be Mr. Raymond Clemence, who is here instead of Mr. Jack Small, who was not able to make it today. Mr. Raymond Clemence represents the Experiments Office at the Manned Spacecraft Center, the Block II, Pallet, and so forth, and he will be discussing these problems of the real world in the experimental picture.

CLEMENCE: As Dr. Gill mentioned, Mr. John Small is unable to be here because of illness. I hope he and you will forgive me for seeing some irony in the fact that he was prevented from speaking to the American Institute of Biological Sciences by a virus.

I would like to talk this afternoon about the capability of the Apollo spacecraft to carry experiments, and the steps you, as prospective experimenters, might take to assure the successful flight of your experiments.

Let me begin by describing the spacecraft's capabilities.

Figure 1 shows the Apollo Block II command module and the sections of the command module available for experiment stowage. The total weight allotment for the experiments is 80 pounds. The allowable weights shown next to the various compartments are upper weight limits for those specific compartments. It is not possible to utilize the full weight capability of each compartment, since some of these compartment maximum weights exceed the total spacecraft allowable weight of 80 pounds.

Some other standard provisions for Block I and II experiments are as follows:

- (1) Space for equipment storage
- (2) Electrical power system (ac and dc)
- (3) Electrical power and data handling/telemetry outlets
- (4) Coolant circuit system (coldplates)
- (5) CSM umbilical provision
- (6) 80 pounds, gross weight allocation
- (7) Data transmission system (real time and playback)

We have already talked about space allocation. There is also spacecraft power available for experiments, and I will discuss this a little more in detail shortly. Spacecraft systems are also able to provide support in areas of data handling and telemetry, thermal control. Provisions for utilizing the command and service module umbilical are also provided, and data transmission capability, both real time and playback, are also provided.

A more detailed description of the available electrical power follows:

Maximum energy: 10 kwh of dc

Source: Electrical power system serviced by nonessential buses A and B

AC power: 3 phase; 115  $\pm$  2-V steady-state voltage

DC power: 27.5  $\pm$  2.5-V steady-state voltage

**Power profile:** To be outlined for each spacecraft when specific mission requirements are defined. Operation of scientific equipment shall not cause main bus voltage to drop below 25 volts, dc

**Other power:** When scientific equipment requires special voltage levels, batteries, inverters, and converters will be provided as scientific equipment

A maximum energy of 10 kilowatt-hours of dc is available from the spacecraft electrical power buses A and B. Three-phase, 115-volt ac and 27.5-volt dc power is provided. The specific power profile for each spacecraft is developed just as soon as specific mission requirements are defined. Some power constraints are that operation of the spacecraft or the experiments must not cause main bus voltage to drop below 25 volts dc, and if experiment requirements of electrical power have characteristics different from those described, the additional power or the equipment to modify available spacecraft power must be provided as part of the experiment.

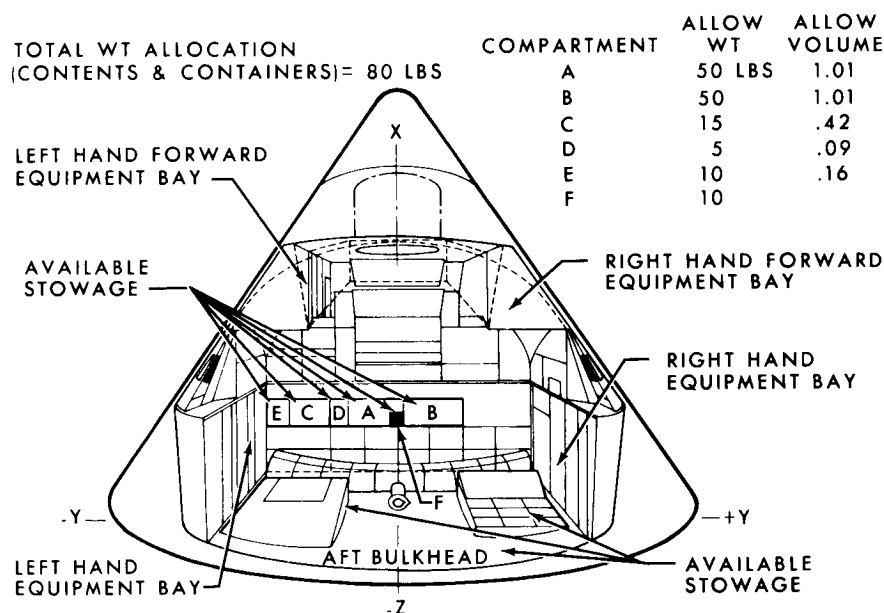


Figure 1. —Available stowage (Block II).

One of the jobs in the environmental control system (ECS) is cooling of spacecraft subsystems. Cooling by the ECS is also available, as shown in table I.

The base temperature range for all locations shown on this slide is 68° F minimum to 118° F maximum, with an average of about 92° F.

The cold-plate capacity for all locations is 1 watt/in.<sup>2</sup> average, and 2 watts/in.<sup>2</sup> local.

One interesting feature of the Block II spacecraft will be the experiments airlock shown in figure 2.

The purpose of the airlock is to allow exposure of certain experiments to the space environment without exposure of the entire cabin and crew. The airlock is shown in the deployed configuration in figure 2. Spacecraft hatches are shown in the stowed position.

Table I. —Cooling Provisions

| Location               | Volume,<br>ft <sup>3</sup> | Type of<br>cooling | Coldplate<br>area     | Source                     | Capacity                                                         | Base<br>temperature                              |
|------------------------|----------------------------|--------------------|-----------------------|----------------------------|------------------------------------------------------------------|--------------------------------------------------|
| Block I:               |                            |                    |                       |                            |                                                                  |                                                  |
| Volume B<br>lower bay  | 0.641                      | coldplate          | 171 in. <sup>2</sup>  | CSM ECS<br>coolant<br>loop | 1 watt/in. <sup>2</sup> average<br>2 watt/in. <sup>2</sup> local | 118° F maximum<br>68° F minimum<br>92° F average |
| Volume C<br>lower bay  | 0.618                      | coldplate          | 147 in. <sup>2</sup>  | CSM ECS<br>coolant<br>loop | 1 watt/in. <sup>2</sup> average<br>2 watt/in. <sup>2</sup> local | 118° F maximum<br>68° F minimum<br>92° F average |
| Block II:              |                            |                    |                       |                            |                                                                  |                                                  |
| Volume A*<br>lower bay | 1.01                       | coldplate          |                       | CSM ECS<br>coolant<br>loop | 1 watt/in. <sup>2</sup> average<br>2 watt/in. <sup>2</sup> local | 118° F maximum<br>68° F minimum<br>92° F average |
| Volume B*<br>lower bay | 1.01                       | coldplate          |                       | CSM ECS<br>coolant<br>loop | 1 watt/in. <sup>2</sup> average<br>2 watt/in. <sup>2</sup> local | 118° F maximum<br>68° F minimum<br>92° F average |
| Volume D<br>lower bay  | 0.09                       | coldplate          | 56.8 in. <sup>2</sup> | CSM ECS<br>coolant<br>loop | 1 watt/in. <sup>2</sup> average<br>2 watt/in. <sup>2</sup> local | 118° F maximum<br>68° F minimum<br>92° F average |

\*Note: Volumes A and B in Block II are coldplated for initial lunar landing mission.

Thus far we have looked at the capability of the Apollo Block II command module to accommodate experiments. Now let us consider some truly exciting capabilities and possibilities which the Block II service module affords.

Figure 3 shows the Block II command module attached to the service module, and the experiments pallet. The experiments pallet fits into Sector 1 of the Block II service module. This concept, the use of the pallet in the service module, permits a variety of experiments to be accommodated without changes to the spacecraft configuration and without the necessity for a development program for the integration of specific experiments with spacecraft subsystems. It is anticipated that this technique will enable an ambitious space experiments program to be accomplished at relatively modest program cost.

The capabilities of the pallet in comparison to the capabilities of earlier manned spacecraft to carry experiments is enormous. A single pallet can accommodate as much as 3600 pounds of experiments. This 1.8 tons of experiments is almost twice as much as the estimated weight of experiments to be carried by the entire Gemini program. It has 3600 watt-hours of electric power for exclusive use of experiments, and a volume of about 170 cubic feet. Coincidentally, this volume is identical to the volume of a nine-passenger Volkswagen bus.

About 60 percent of the total volume is for experiments. A typical pallet load of experiments is shown in figure 4. This is just intended for purposes of illustration, those particular experiments shown.

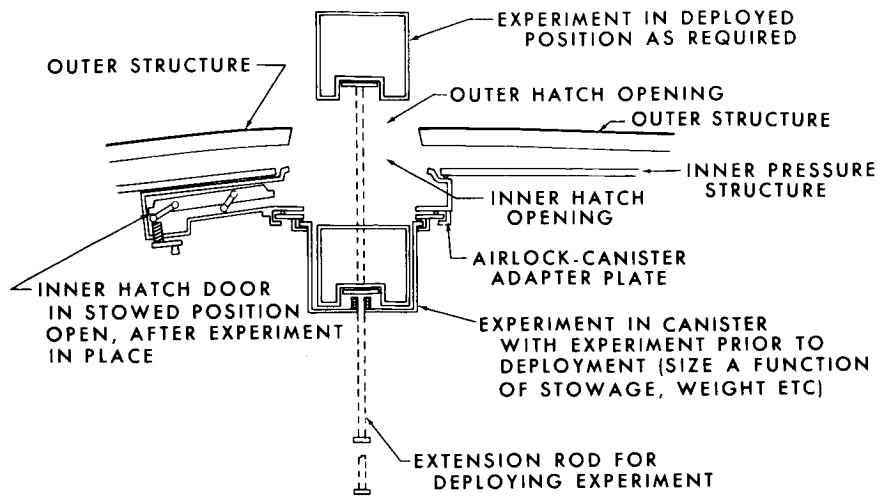
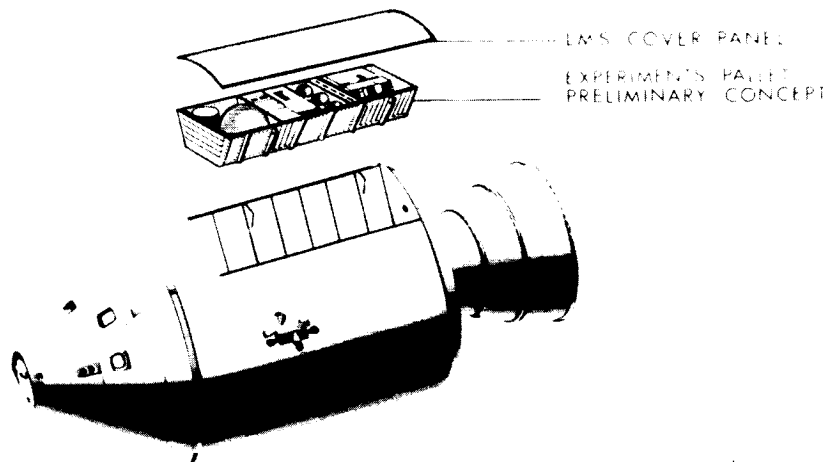


Figure 2.—Experiments airlock.



## EXPERIMENTS PALLET DATA

|                                  |               |
|----------------------------------|---------------|
| VOLUME FOR EXPERIMENTS           | 170 CU. FT.   |
| WEIGHT FOR EXPERIMENTS           | 36,000 LBS.   |
| ELECTRICAL POWER FOR EXPERIMENTS | 3000 WATT-HR. |
| ALLOWABLE GROSS WEIGHT           | 50,000 LBS.   |

Figure 3.—Block II CSM showing experiments pallet.

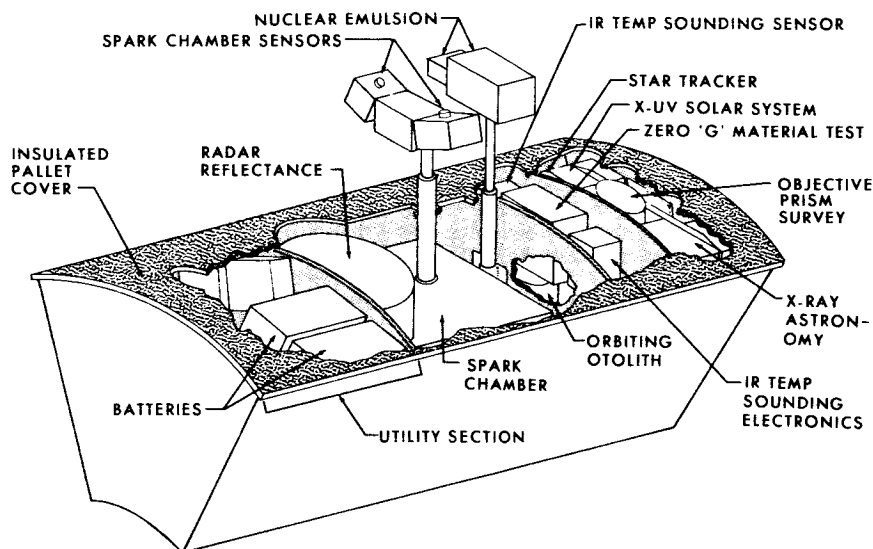


Figure 4. —Typical pallet load of experiments.

I should emphasize that the pallet carries its own utilities, and electrical power system, thermal control system, and data system, which are integral to the pallet. Stabilization and control are provided by the spacecraft, which can maintain an attitude of about plus or minus one-half a degree, and an attitude rate which will not exceed 2.4 arc-minutes per second.

I hope I have given you an accurate picture of the capabilities of the Block II Apollo spacecraft to carry out experiments. Further, I hope I have conveyed the notion that there is a lot of capability.

Now I would like to consider how you as prospective experimenters might exploit this capacity. I will not repeat what Mr. George has already covered with you; that is, the procedure established by NASA for submitting an experiment and having it considered for flight aboard a manned spacecraft. He has already discussed the operation of the Manned Space Flight Experiments Board (MSFEB), but I might bring to your attention the document you have received, NPC500-9, Apollo Experiments Guide, which is an excellent source of information to you prospective experimenters on the steps to be taken in having an experiment considered for manned space flight.

I would like to talk in a little bit more detail about what is done at the Manned Spacecraft Center after we have received an order from the Director of the Apollo program to implement an experiment on a particular flight.

Figure 5 shows the steps or milestones which an experiment goes through after the receipt of this implement order at the Manned Spacecraft Center.

The first, and one of the most important events after receipt of the implementing order, is the completion of a statement of work. A statement of work is just what its title suggests, a clear and explicit description of the work to be performed in implementation of a particular experiment. It generally consists of a performance specification that tells what the experiment will do. The NASA quality and reliability requirements are also spelled out. A delivery schedule, documentation requirements, and the NASA requirements for data reduction and publication of scientific information are other standard features of the statement of work.



- Title
- Objective
- Description
- Prelaunch techniques
- Operations requirements
  - Crew-oriented requirements
  - Flight operational requirements
- Data requirements
- Proposed suit modifications
- Crew training plan
- Detailed data processing plan
  - Photographic criteria
  - Data-processing requirements
- Control
- Preflight, flight, and postflight plans
  - Preflight, flight, and postflight plans
  - In-flight requirements
  - Postflight debriefing plan
- In-flight consultation plan
- Status report
- Postlaunch report
- Experiment supplement to the postlaunch report

This will be the authoritative reference on a particular experiment. It will be used by the spacecraft contractor, by the Manned Spacecraft Center, and by other elements of the NASA, such as the launch operations personnel at the Kennedy Space Flight Center.

The plan serves to notify the many organizational elements—and there are many involved in a manned space flight—of support that they may be required to give to an experiment. A good example of this is the S-4, 0 G, and radiation on blood during the Gemini 3; the requirement that blood samples be taken from the crew and from a preexamined subject; storage of these blood samples prior to flight; simultaneous conduct of the experiment on the ground, simultaneously with the experiment conducted in flight. These are the kinds of things that the definitive experiment plan should point out, and notify all of those elements, as I have stated, involved in a manned space flight of support which they may be required to give to an experiment.

Let us return for just a moment to figure 5 and talk about delivery of hardware. The numbers of units required and their types, that is, mockups, prototypes, qualification test units, flight hardware, spares, are specified in the contract. The units shown in figure 5 represent normal requirements. They may vary as a result of the number of missions to be flown by a given experiment, its complexity, and a number of other factors.

Two important points to note are that successful completion of qualification testing is prerequisite to flight, and delivery of flight hardware should occur at the beginning of the checkout and test of the spacecraft. This can be as much as 9 months prior to flight.

If I may, I would like to recap what I have covered thus far. We have looked at the capabilities of the Apollo Block II spacecraft to fly experiments, and we have reviewed the steps the prospective experimenter must take in order to fly his particular experiment. More specifically, we have seen how we in the Experiments Program Office of the Manned Spacecraft Center work with the experimenter in trying to assure the successful implementation of his experiment.

Before closing, I offer the following special considerations for manned space flight experiments.

Crew safety

Spacecraft/experiment compatibility

Technical

Schedule

Quality control

Reliability

Mission

Crew training

First, of course, is crew safety. I think you as bioscientists are keenly aware of this requirement. In fact, much of your effort is devoted to just that objective.

Experiment spacecraft compatibility is also important, in each area shown, technically. For example, the experiment must be designed to survive the rigorous boost environment, as well as designed to function in orbit. I think Dr. Montgomery's and Dr. Gualtierotti's experiments are good examples. This morning the message came through loud and clear of some of the requirements placed on their experiments by the fact that they fly aboard a spacecraft which has to be launched and has to withstand the rigorously severe boost environment.

The experiment must be developed in sufficient time to support spacecraft schedules. The levels of quality and reliability must be commensurate with flight objectives. Finally, they must both be compatible with the design mission, and with a multitude of contingency or off-design missions. This sometimes is a major effort to build the experiment to survive the off-design missions. The design mission in some cases is relatively straightforward, and it is the contingency or off-design missions which consume a good deal of your effort.

Finally, if we are to make the maximum use of the man as a scientist observer, as an intelligent and discriminating operator, we must give adequate attention to crew training. Familiarization of the crew with the experiment objectives, the operation of the experiment equipment, and the part to be played by the crew in performing the experiment are all vital to making the crew what I call experiment oriented. Optimization of the man-machine, or in our vocabulary, man-experiment system, should be a prime objective.

I would like to say that I have just barely touched on the problem of data reduction, analysis, and dissemination of results. This is certainly not because this effort is unimportant or relatively straightforward. Quite the contrary. It results from the fact that this presentation sought to emphasize the spacecraft capabilities and steps leading up to successful flight. I personally feel that our increased payload capabilities present some rather interesting problems to the agency and to you as experimenters in the area of data reduction, analysis, and dissemination, if for no other reason than the sheer bulk of data generated by these large payloads.

In closing, I would like to say that we at the Manned Spacecraft Center feel that the Block II Apollo spacecraft offers attractive possibilities for carrying on experiments, and we do welcome your efforts toward putting the spacecraft capabilities to good use.

## DISCUSSION

BRODERSON: Mr. George, what do you mean by the topic, extravehicular engineering?

GEORGE: That includes an area which results in one of the astronauts actually leaving the space vehicle itself to conduct certain experiments outside of the vehicle. I can give you an example of that. For example, the erection of the large communications antenna outside of the space vehicle itself, the man actually leaves through an airlock, goes into outer space, assembles the antenna, which has already been constructed, of course, and is inside the space vehicle. He actually assembles it outside, and then returns into the space vehicle. This would be an example of an extravehicular activity.

PINCE: Mr. Clemence, are those illustrations available anywhere, so that those of us who do not write as quickly as you talk can have the benefit of what you have just said?

CLEMENCE: I apologize for my quick talking. My wife warned me about that, but I did not heed her advice, it seems. Yes; I think we could make those available. They are not available any place else, but for the glass originals that I have with me. But I can, if you will give me your name and mailing address, get a packet of glossy prints to you, and I would be more than happy to mail you copies.

STAUB: On the temperature control system, could you give us the range of calories exchanged, and what method of cooling or heating is used?

CLEMENCE: In the command module itself?

STAUB: Right.

CLEMENCE: The spacecraft contractor has prepared a detailed performance and interface specification which specifies the operations which they will guarantee to the experiment. They are just as I indicated to you. The temperature range for the various locations shown in figure 1 are taken directly from that performance and interface specification. That range I have given was about 68° F, I believe, to about 118, was the range, and the average temperature was about 92° F. The heat rejection in those compartments, or the rate of cooling, was 1-watt-per-square-inch average, and 2-watt-per-square-inch local.

STAUB: So within the given module or compartment using electrical devices, further local cooling would be possible?

CLEMENCE: That is correct. What I said about electrical power is also true of cooling requirements. If the experiment requires capability beyond that provided by the spacecraft, you are perfectly free to provide that capability as part of the experiment, but it will penalize you with regard to your weight available. In the pallet, it is a little different situation. The cooling system in the pallet design itself is evolving, and we do not have firm capabilities to give you at this time for the pallet.

MARTON: I do not mean to take you to task for this, but Mr. Taylor brought up the point, too, and that is this pallet concept. I find that particularly dangerous, since what we are doing is

taking a pallet and putting it external to the pressure area, and once the vehicle is space-borne, the man has no access to it. How do we who are interested in manned space flight, and yourself, justify the inclusion of three men into what essentially is a package that they cannot modify or touch?

CLEMENCE: I would not, first of all, presume to defend the pallet concept for NASA, but I will give you my individual opinion. First of all, I do not believe that access to the pallet is completely out of the question.

MARTON: He would have to go extravehicular in order to get at it.

CLEMENCE: That is true.

SACKEY: Is it not possible that there are many experiments that could fit in the pallet in which there would be absolutely no reason for the astronaut to have any access to the pallet? I wanted to blow up a little controversy here.

CLEMENCE: There are a number of experiments that can be put in the pallet that the astronaut would not have to physically get in there and manipulate. I think, however, he does serve a very useful function, in that displays and controls can be provided in the command module which would monitor the observation of experiments which are in the pallet.

SACKEY: My own view is an expression of delight really over the fact that we might eventually have enough space on some of these vehicles to plan some rather detailed experiments, broader experiments.

CLEMENCE: I think I heard somebody say, when I talked and gave a little homely analogy about what sort of volume that is, like a nine-passenger Volkswagen bus, that we can now put up a nine-passenger Volkswagen bus. But it does. And it is encouraging, and frankly it is very exciting that we do have this kind of capability.

GUALTIEROTTI: One point to me is very critical, because of the experiments ahead. What about a data-processing system for this kind of large load of experiments? We are hard put to instrument our rather minute necessities in the mission. There are so many different experiments with so many different specifications as far as the system is concerned; how can that be managed? I would like to hear some thoughts on this.

CLEMENCE: The data handling of the amount of data generated by this kind of payload weight?

GUALTIEROTTI: Yes. There might be a number of different specifications where the different information has to be stored and printed. For instance, frequency response of the data-processing system, duration of the actual acquisition time. It may be continuous. That means on different channels. Now, a payload like that would mean an enormous amount of channels for the different specifications.

CLEMENCE: I think that the data problem is perhaps somewhat analogous to the thermal problem or the electrical power problem, in that you do have significant growth in the capabilities that these subsystems require, and they are being considered in the design of this pallet. There also is the capability of utilization of data storage and data transmission capability of the spacecraft itself. So I think the people who are responsible for the design of the pallet are considering these things, and are trying to provide and have a definite feeling that they must provide a data system that is compatible with that great volume of weight that you can have.

GUALTIEROTTI: That is a kind of reasoning that is very nice, but we had, for instance, a problem with our experiment, and we had to content ourselves with some halfway solution, instead of the best one, because we had to share channels, and therefore the frequency response was

not exactly the same. There comes a certain point at which you make sort of a halfway provision like that. and your chances decrease.

CLEMENCE: I think one of the reasons for the evolution of the pallet concept is just the problem you ran into with your experiment, in that you had to rely on spacecraft subsystems for data reduction, for thermal control, and they had to provide all of the support of the experiment; whereas the pallet has its own utilities, its own electrical power, its own thermal control system, its own data system. It will free you from restraints that the spacecraft itself has placed on you previously.

GILL: I think Dr. Gualtierotti is worried about the fact that we might attempt to do too many different things at the same time, too many different kinds of experiments. I think we do not contemplate this. We intend to specialize as soon as we can. In other words, we might conceive of using the pallets, say, for life science experiments, or we might conceive of using it for astronomy experiments, or for things that went together.

GUALTIEROTTI: That is OK, but take the life science experiments, take any kind of recording of electrical activity in the system, you go from dc potential which has been found to have to be on the order of 5000 per second. That is an enormous range. If you have a number of experiments that are in that kind of payload, and you make one pallet, say, only for biological experiments, you might be in a more difficult situation. It might be easier to have, for instance, our experiment, and the data-handling system, together with the noise band, not to include biology, because we find out that the two same things were more compatible. That is quite a problem.

GILL: Well, compatibility is certainly a very great problem.

CLEMENCE: Dr. Gill, if I may, I would like to say that the pallet also enables you, because of its great payload capability, it is conceivable that you could design a data system as part of your experiment package, and supplement the existing capability, if your experiment package has rather unique data-handling or telemetry requirements.

GUALTIEROTTI: Yes; but there is still a limited type of telemetry.

CLEMENCE: That is true.

GILL: You are just getting into the problems. There is no question about it.

PITTS: Is there anywhere collected into a single document a list, preferably with abstracts, of the experiments that have been flown and are approved to be flown in a manned spacecraft? The point is that in the listing, I see several titles which suggest things which I might want to propose, you see, and I do not want to put a lot of effort into rediscovering the wheel.

CLEMENCE: Representing the Manned Spacecraft Center, we do have some involvement in this, but what I am going to do is try to pass the buck to somebody from headquarters involved in the experiments program, and perhaps they could better answer that question than I could.

GERATHEWOHL: I hope that I can cover this later.

DE VINN: I wonder if you could give us some idea of the demands we could place on the astronaut, and how much time would be available for training, how long a task might be performed in flight, and how complex a task might the astronaut do?

CLEMENCE: That is one I would like to pass on also to Dr. Gerathewohl. The requirements for utilization of the astronaut's time, to my knowledge, are nowhere generally described. There is no publication, and for a number of reasons. I think they are good ones. The mission-duration changes, and the required use of their time in performing operations that are

directly connected to the flight itself, directly connected with checking or testing on-board subsystems, or performing a maneuver like rendezvous, which is essential to the overall mission objective of landing three men on the Moon, but could not be properly classed as a scientific experiment. So I cannot really give you the general answer about what demands you can place on the astronaut's time and how complex a task you can ask him to do, but I will give you a general comment, which is probably not what you want. I think as the emphasis is shifting from the development of manned space vehicles and their hardware in just proving that they will work, and that man can survive for 14 days, the emphasis will shift from that to utilizing this platform. I think some of the previous speakers touched on the fact that that emphasis will shift. As we more and more develop confidence in the spacecraft and its ability to support the crew, I think you will see a shift in emphasis in the crew's utilization more and more toward using them for experiments.

So all I can say is that I think the demands on the crew have utilized their time quite fully, and crammed the mission full of everything we could up to now, but I think you are going to see more of that, and I think you are going to see more of an emphasis on using spacecraft as an experiment platform. I think that the possibilities of your placing demands on the crew is why we are flying a manned spacecraft, and not an unmanned. I think we want to use them to the very maximum, but I cannot give you a specific answer.

THUROW: Back to this temperature control thing, I think some of this supplementary cooling could be dispensed with if we knew the exact duration of the extremes of temperature in the different locations of the spacecraft. In some instances you could substitute insulation where the particular organism would not be bothered by extremes of certain duration. This information has not always been made available.

CLEMENCE: I think if we would be to the point where we have a specific experiment and had been given an order to implement, we would sit the principal investigator down with the spacecraft contractor, and they would be able to provide you with a great deal of detailed information about temperature, vibration, environment, in a specific spacecraft location. But all they have agreed to provide right at the moment is a performance and interface specification which tells the general performance of the overall spacecraft. But when we reach the point of having a specific experiment, and having an order to implement, we would be able to provide that kind of detailed information.

GUALTIEROTTI: Is there any chance in this particular mission, or a future mission, as the flight develops as an experimental tool that some of the most difficult phases of flight can be reduced, like, for instance, acceleration vibration? Is any thought being given to having a vehicle which is smoother in flight, because whenever we look at a biological study, this high-acceleration vibration range especially is a very demanding initial factor, and may alter severely the success of the experiment, or the entire findings of the experiment?

CLEMENCE: Well, I think the approach here would be just as I mentioned for the data system. Rather than go into the development of a new vehicle, the increased payload capability would allow you to isolate your package, to give it the degree of isolation or the degree of isolation from vibration environment, or from noise or from special temperature environment in particular parts of the spacecraft. These increased payload capabilities will allow you to do that as an integral part of your experiment, to isolate it from the harsh launch environment, for instance, with a fairly brute-force-type vibration isolation system. Increased payload allows you to do this.

CRANDALL: Can you tell us what the guaranteed maximum G-levels will be in both the pallet and also in the AAP configuration?

CLEMENCE: I cannot guarantee the maximums in the pallet at this time, and I cannot recall from memory what they are for the command module, but I do have a performance and interface specification with me, and I will be more than happy to look at that. It does contain the vibration profile for the launch phase.

CRANDALL: I am not speaking of launch phase. I mean the actual orbital operation itself.

CLEMENCE: The maximum accelerations—

CRANDALL:  $10^{-2}$  or  $10^{-3}$ ?

CLEMENCE: No; I could not specify those for you. They would be much higher than that, particularly if you had firing with your service module engine or your reaction control jets controlling the attitude of the spacecraft, I think, would give you accelerations that would exceed that, but I do not know. I think it would properly be in the interface specification just what impulse the reaction control motors give and during the normal operational mode what accelerations you would likely have.

WILLERS: Consistent with the requirements for crew safety, to what extent could not only the time of the astronauts be used, but the astronauts themselves be used as biological experimental material? I was thinking would it be possible, for example, with proper training, to draw blood specimens during flight for processing, rather than postflight blood specimens?

CLEMENCE: The use of the astronauts themselves is, of course, already happening. The Manned Spacecraft Center has quite an extensive medical program utilizing the astronauts. I am sure they have every intention to continue. The one thing that presents a bit of a problem is, of course, the fact that they have been required to have the full pressure suit on during flight. If some of the things you are considering are possible with the suit being worn by the astronaut, I am sure that those experiments would be considered by the NASA.

MARTON: Do I understand in the case of the pallet, this is nonrecoverable?

CLEMENCE: The total pallet? That is correct. It is nonrecoverable. The service module detaches from the command module just prior to reentry, but it may be possible through extravehicular activity, or even some sort of mechanical mechanism for withdrawing tapes or certain data, film packages, or whatever, from the pallet, and stowing them in the command module, and then returning to Earth with them.

WALLMAN: This is to Mr. George. He mentioned in the experimental program here of jumping from rats on up to chimps, and nothing was mentioned in between. There are some good baseline data on macaques, and I just wondered if this was considered. Certainly with a 48-pound return, you are not dealing with a mature chimp, and there are certainly some advantages to using a mature primate. Was that just used in a loose sense, that chimps included all primates?

GILL: Dr. Gerathewohl, would you answer that?

GERATHEWOHL: I may be able to give you the answer right now, although I will speak about this tomorrow morning. The two species that were used were rats and chimps, and only representative of what could be done.

WALLMAN: That is what I thought it was—representative.

GERATHEWOHL: They are representative. They are not experiments that have been accepted as just experiments for rats, but will cover the whole range of experimental animals.

DRYSDALE: The question is about what kind of skills are available? Are they life scientists trained in astronautics, or will they be astronauts tried on biological problems?

GILL: Dr. Gerathewohl, would you attempt to answer that?

GERATHEWOHL: The question was what kind of people will be available to do experiments in the AAP. Are these astronauts which have been trained a little bit on the sideline to know how to prepare a petri dish and to do some biology, or are these biologists who are being trained as astronauts?

This, again, is one of the subjects I am planning to cover tomorrow morning. You are stealing all of my thunder. But we have at the present time astronauts who are the technology types, the flying personnel types who are being trained to do the experiment just by performing some manual labor, so to speak. At the same time, you may have heard that the National Academy of Sciences and NASA have been selecting the first astronaut-scientists already, who are trained scientists, who are now being trained as astronauts. These are the first six scientists who are being called astronaut-scientists or scientist-astronauts, on whichever part you want to put the main emphasis. But these are actually scientists, people who know how to do experiments in the special discipline. It is very unfortunate, though, that none of the biologists who had volunteered for this program were selected. They did not classify according to the standards that are still being applied for astronauts. So at the present time we do not have the biologist in the astronaut-scientist training program. This has to be remedied. I think I can say with some assurance: when we need the biologists in orbit for the experimental work there, we will have biologists all right.

DRYSDALE: I have another question about the atmosphere available for bioscience experiments. Is it going to be the same atmosphere as is available for the astronaut, or is it going to be a normal atmosphere like we run our experiments in on Earth?

GILL: Well, I will attempt that. I may be talking out of turn. But in view of the amount of payload that is available, I suppose that you could construct your own atmosphere if you had to. If you wanted a special atmosphere for your experiment, you could construct it.

DRYSDALE: Well, in most of the biological experiments, we are going to compare the effect of weightlessness, and so forth, and we have to turn the factors so that the variable will be only weightlessness and not other different atmospheres that might be the results of different experiments. The astronaut will be living in an atmosphere with a different pressure and different composition than the experiment, where the experiment is performed, so how will we get access from one atmosphere to the other?

GILL: Well, that would be a problem, but I suppose there will be a solution, at least a first-order solution.

GUALTIEROTTI: I have a very naive question. What is the basic philosophy for the pallet business? Would it not be nice to have a second subcapsule for the same thing, which is fully instrumented initially just exactly like the capsule of the astronauts, and have a nice environment there very similar to a laboratory? With the same payload and the same complication, I think two satellites would be just as good.

GEORGE: I might say that NASA has given some considerable consideration to the point that you raise here. In fact, there has been a proposal that was made regarding the development of what we refer to as an experiment module. That is pretty much what you are describing here. However, the present philosophy of the Apollo Applications Program is that we will try to stay as close as possible to the basic Apollo hardware, and not go into any major modifications during at least the early phases of the AAP. Now, the experiment module, or

canister, as it was referred to occasionally, would represent a fairly major deviation in terms of hardware, so that is probably going to be one of the restraining factors. However, your idea, I think, is a very good one, and is certainly going to be considered by NASA. Possibly Mr. Taylor has something else to add to that.

GILL: Perhaps you would restate the question. Will you repeat the question, and Mr. Taylor will answer it in his way.

GUALTIEROTTI: My question is given the amount of money and effort to build a separate pallet, and the amount of weight and space we have there, costing a lot of money because it has to have its own refrigerating system, its own atmosphere support. My question was what was the reason not to study to start with a second module system. Instead of having all these different pieces, each one of which has to take care of itself, build a satellite-like structure, why not build a second module with a space already serviced with air, power, temperature control, and everything?

TAYLOR: Well, we have done quite a bit of study on this, as a matter of fact, and have traded off various new configurations, as Mr. George suggested, of alternate spacecraft modules against what we already are building and spending a considerable amount of money to build and fly.

GUALTIEROTTI: Well, there is one more point that I would like to find out, if there would not be more advantage if the two modules were intercommunicating, so that if anything goes wrong, the astronaut can go in the second one and take care of whatever is not working properly. It would be an enormous advantage.

TAYLOR: Well, I think you should keep in perspective that the pallet is not the only capability for handling experiments in the Apollo Applications Program. As a matter of fact, in my discussion earlier, I discussed the use of the LEM system as a module as you are talking about. Now, it is not an optimum module, either, but it does sort of double or triple the pressurized volume available for shirtsleeves operation by the astronauts about 250 cubic feet. It is interconnected directly with the command module, and it does have life-support, power, and electrical communications subsystems to support experiments that do require the direct monitoring by the astronaut actually operating it. As a matter of fact, the bioscience mission which I described involves the astronaut directly in operations with the specimens or the animals which are carried on that particular mission. So we have traded off and done a number of engineering and programmatic analyses of developing new alternate spacecraft modules to substitute for the LEM. They have lots of attractiveness. However, in the kinds of studies which I indicated earlier, I showed you the one bioscience mission where we actually analyzed some 20 missions, and we have not had identified for us in our studies any experiments which require any more pressurized volume to perform the experiments than the LEM has. As you say, NASA is spending a lot of money, and spending it to man-rate and qualify spacecraft modules that are reliable and safe. We feel that before developing new and additional modules for other purposes, we should see what the capability is of the ones we are developing. So far, it appears that the use of the LEM system with the command and service modules is a very flexible orbiting-laboratory configuration. Possibly it is not optimal. Neither would a larger module with like a 45-day or 90-day lifetime limitation be optimal. I do not know whether that helps any.

SACKEY: When you speak of a pressurized volume, is this still 100 percent oxygen, or will you start thinking again of ambient atmosphere some time?

TAYLOR: The Apollo spacecraft as it is now being built in on a 5-psi, 100-percent oxygen atmosphere, or nominally 100 percent. There are traces. For the longer duration missions that we are considering, we are doing design studies on changing this environment system to a two-gas system. It will not be at one atmosphere, because this involves considerable structural problems, or structural redesign and weight, but it does appear that a 5-psi, or possibly a 7-psi, two-gas system is compatible with a relatively minimum change and a relatively early availability, so this is what is now being defined in our design study.

The early flights that I described that use the Apollo hardware precisely as it is being built for the lunar mission will be in 100 percent oxygen, 5-psi atmosphere. The later ones—1970, 1971, and beyond—may have a two-gas atmosphere, either oxygen and nitrogen, or possibly oxygen and helium. Oxygen and nitrogen look better to us.

OLCOTT: Will there be no more than 80 pounds of capability for return?

TAYLOR: No; that is the current specification on the Apollo lunar spacecraft, and it is based on not only the command module reentering capability, and the parachute hung weight. There is a lot of margin there. It is also based on the LEM's capability to launch from the lunar surface that amount of lunar samples. The design of the command module is geared also to this. So the basic specification now is 80 pounds. Our design goal in the preliminary design of the follow-on spacecraft is something like 250 pounds, and this looks like it is reasonable to expect. As a matter of fact, as far as weight is concerned, you can get considerably more than that; maybe up to 700 or 800 pounds. Then there is the problem of center-of-gravity location, and that sort of thing, to keep the L-over-D aspect proper.

SACKEY: That is for the command module?

TAYLOR: That is return to Earth in the command module.

HENRY: What is the current thinking so far as on-board controls are concerned? I am thinking specifically that we have heard quite a bit about synergistic action between essentially 0 G and radiation, and this, that, and the other. Is there any thought being given to the possibility of getting 1 G up there, so you could run controls at the same time?

TAYLOR: Yes. You mean variable G specifically.

HENRY: Well, specifically I mean 1 G versus some lower number.

TAYLOR: Let me break that down into variable gravity for man versus variable G for small biological samples.

HENRY: I was thinking for small biological samples.

TAYLOR: All right, fine. In the feasibility studies we have done, as a matter of fact, in that flight for which I showed you the engineering drawing, there was included a small sample centrifuge in the LEM laboratory space for just the purpose you describe. There was also included, if you recall, and I pointed it out, a concept of a one-man centrifuge for variable G dependent on the radial arm and the rpm associated with it. There are other concepts for getting artificial gravity in the spacecraft for the crew, namely, the separation of two portions of the spacecraft, or the spacecraft and the launch vehicle, and setting up a large rotation there. As far as we know, there are no adverse effects of 0 G on the crew, so we are not planning an artificial gravity capability as an inherent part of the spacecraft for the crew. We feel that we should do some sort of contingency planning in the event that you need some conditioning artificial gravity, but it seems to us that in putting experiments or putting spacecraft into space, the purpose is to determine the effect of the space environment, and so therefore unless forced to we would not provide artificial G for the crew. But for samples,

laboratory samples, it certainly is possible. It does take weight and it takes power, but we seem to have weight and power capabilities within limits.

HENRY: Would it be possible to get copies of these illustrations?

TAYLOR: I talked to Dr. Gerathewohl.

GERATHEWOHL: We have not decided yet whether we are going to transcribe the whole meeting and publish it, or bring it out so you can have it, but if there is a demand for it, and since we have everything on record anyway, we will do this. I think from the many responses we have had so far, this will be the way we will do it. So you all, or at least the participants, will get the summary of this meeting in published form, including the illustrations.

TIBBETS: Will we be able to use fluorescent lighting in these systems?

TAYLOR: I do not know of any prohibition on it. It depends on the illumination levels, and whether there are any specific requirements of your experiment that require more volume than we have got, but there is certainly power and the volume available to do it.

TIBBETS: There is concern for the noise that fluorescent lighting puts out.

TAYLOR: Are you talking about continuous, or just for short intervals?

TIBBETS: No; continuous lighting.

TAYLOR: Well, we have specified certain light levels in the volume for the purpose of conducting the experiment, and at the moment I am not familiar with the illumination levels and whether fluorescent or incandescent is preferred. I would have to check on that. Except for the EMI problem, if you want a continuous fluorescent lighting, then you may have an electromagnetic interference (EMI) problem, or I am sure you would. The question is can we suppress it or live with it or isolate it, and I just do not know. I think if it is a requirement that you have to have fluorescent and incandescent or other types of illumination are not satisfactory, then it is an engineering problem for us to work out how it can be done. But I cannot give you the answer right now as to whether we can or not.

REPRESENTATIVE OF NORTH AMERICAN: I am wondering if you have given any consideration to the issue of placing an on-board radiation source in any of the configurations? I am involved in the first biosatellite experiment where we have the capability of doing a radiation-weightlessness interaction experiment, and this might be very valuable. This could be a generalized condition, and a number of people could avail themselves of it.

TAYLOR: Well, you are from North American, and I am sure your people know there are some radiation sources already on board of some of the missions. For example, the propellant-level-measuring device used in the propellant tanks is a cobalt 60 device. In the lunar mission, the lunar surface experiments package which is now under definition will involve an RTG employing an alpha-emitting isotope. There is no inherent reason why a specific reference source, as you, I think, are referring to, could not be involved, but it takes a systems look at the interaction between this source, whatever dose level or energy level you want to operate it at, what its effects will be on the rest of the spacecraft or on other experiments. There is no prohibition to it. There is already artificial radiation, manmade radiation sources on board. So if a specific experiment requires it, it could be provided, but it would take a fairly careful look at its effects on the other activities planned. If you want a strong gamma source, for example, to test the effects of living cells, then because of the fact that you have the crew on there, there have to be fairly careful design provisions. But I will not say it cannot be done.