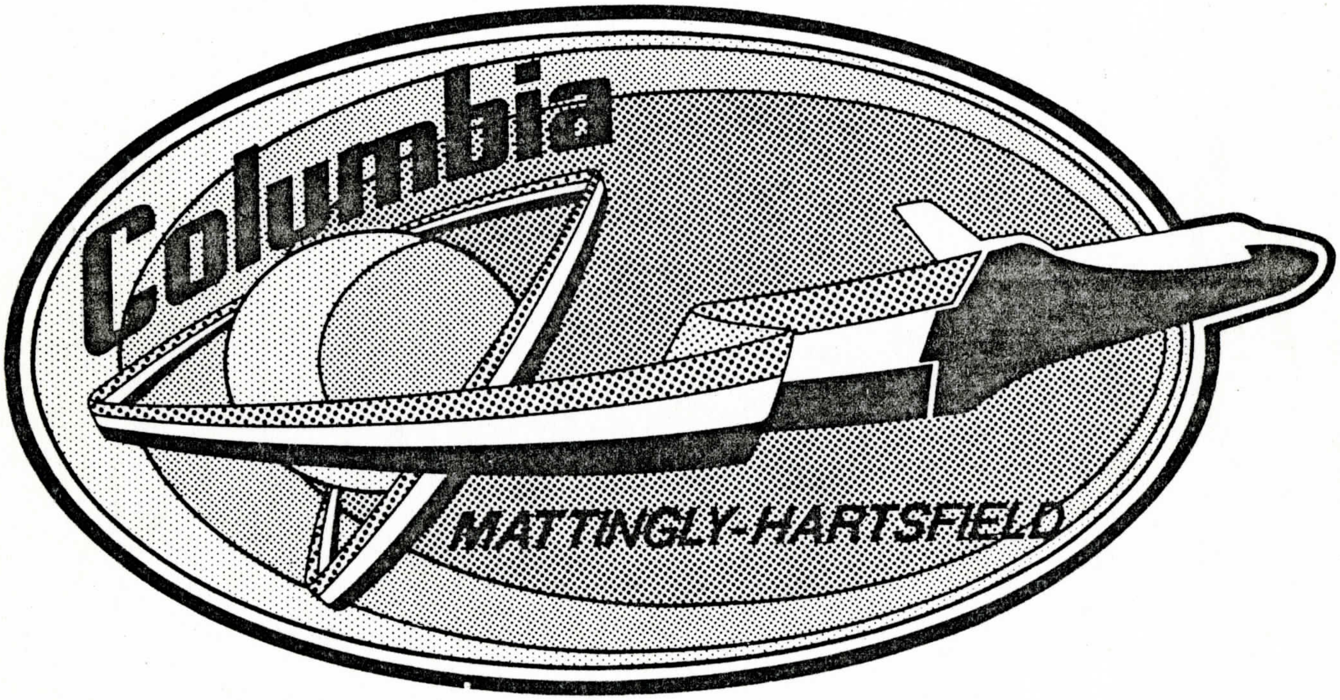
STS-4
Crew Report



Bill—
Thanks for your help - We couldn't have done some of this w/o your insight + persistence.

T.K. Hank

U.S. Government

MEMORANDUM

Lyndon B. Johnson Space Center NASA

REFER TO: CB	DATE August 30, 1982	INITIATOR CB/TKMattingly:nh:8/23/82:4513	ENCL 4
TO: CB/Chief, Astronaut Office		CC	
FROM: CB/STS-4 Crew		SIGNATURE T. K. Mattingly Henry W. Hartsfield, Jr.	
SUBJ: STS-4 Crew Report			

One week aboard Columbia convinced the STS-4 crew that in many ways the Shuttle really is the DC-3 of the space age. This analogy is most appropriate when considering their respective roles in revolutionizing society's concepts of how to apply advanced technology to solve contemporary problems. Two major differences, however, stand out and are responsible for much of this report. These are first, that like modern aircraft the Shuttle will be an evolutionary design and second, the Shuttle is a true spaceship and therefore, must integrate many features of both ships and aircraft.

Contemporary airframes serve for decades in their original shape, yet increase their efficiency and effectiveness enormously through avionics and propulsion improvements. We believe this same trend will be demonstrated over the life of the Shuttle and, therefore, have tried to indicate areas where evolutionary growth may be appropriate.

Ships are designed to be relatively self sufficient for extended periods of time. Aircraft, on the other hand, are typically extensions of a larger base. A seagoing ship must provide not only working spaces for her crew, but must also provide a long term self contained habitable environment. Aircraft leave as much of the crew services on the ground as possible in order to improve performance. The spaceship must provide a compromise between traditional aircraft and ship strategies. Weight and volume considerations are as critical to a spaceship as they are to any aircraft, however, the crew's health and efficiency are equally significant in executing both seaship and spaceship missions. The one area in which the spaceship is more critical than either its aircraft or ship predecessors is that of time management. Orbital time is expensive and must be used as efficiently as possible. Many of the STS-4 crew observations, therefore, pertain to improving habitability and crew efficiency.

STS-4 represented the final dedicated flight test mission prior to embarking on the operational employment of the Shuttle. Typical flight test programs for aircraft include a formal segment dedicated to the conduct of an operational suitability evaluation. The STS-4 crew attempted to evaluate operational characteristics to the maximum extent possible within the constraints of the formal engineering test objectives. The scope and number of observations included in this report reflects this approach and is, therefore, larger than would normally be expected from a mission as nominal as STS-4.

Report Format

Four appendices present the observations recorded during the period surrounding the STS-4 mission. The style and content has been shaped assuming that the Flight Operations Directorate will be the recipient. In order to provide some organization to these observations, they have been arranged in appendicies as follows:

- o Crew Training
- o Flight Data File and Mission Planning/Execution
- o Vehicle Systems (hardware and software)
- o Operational Observations

Wherever possible, these appendices attempt to avoid restating those events and anomalies which are known to appear in other organization mission summaries. Therefore, this report does not contain a mission chronology and may not even address the most significant happenings.

Major Crew Impressions

A "magic machine" is the only way to describe the Shuttle from a crewman's viewpoint. In spite of daily involvement in the Shuttle development from award of the ATP through the OFT program, the crew was still impressed with the tremendous capability that has been built into this element of the STS. Only three events involving the vehicle design marred an otherwise flawless performance. The following comments reflect only the flight crew's perception of these events and how they may affect our operations.

o Ascent performance is the key to the long term success of the STS. STS-4 carried a relatively light cargo, flew a $28\frac{1}{2}^{o}$ inclination and shaped its ascent profile to accommodate demonstrated SSME and SRB performances. Nevertheless, a reconstruction of the STS-4 ascent phase indicates a great deal of uncertainty remains in describing the contribution of each element in this complex scenario. It appears that STS-4 had less margin than anticipated. The implications of this finding, if it proves correct, will significantly influence the ascent/abort strategies as well as how ambitious we can be in putting payloads into orbit. The possibility that STS-4 carried a significant amount of water into orbit in the tile system may have implications for orbit timelines and TPS integrity as well as ascent performance.

o The port PLBD apparently hung up on the door seal during a thermal gradient door closure test. The engineering community is working this event and should have it understood prior to the next mission. From preliminary reports it appears that the aft bulkhead/PLBD interface does not have as much tolerance to mechanical mismatch as the rest of this system. Distortions, such as encountered during this test, might seriously jeopardize entry and the success of an EVA to correct this condition is highly questionable. It seems essential that conditions such as encountered during STS-4 must be prevented, not fixed.

o Landing and stopping the Orbiter on a runway is a precise task requiring careful control and accurate information. By design the STS-4 landing task provided large margins for execution error and data uncertainties. In spite of extensive crew training for the scheduled submaximum braking test, the crew did not achieve the target level of deceleration and was unable to hold a constant value. Landing weights will most certainly increase with the TAL abort weight requiring a perfect maximum performance stop in order to use the available runways. The achievable envelope of Orbiter braking performance must be demonstrated in order to allow practical mission planning.

Payload Integration

o Supporting payloads provided by other than NASA is a new opportunity. The procedures employed by all parties worked well and made incorporation of the CFES and DOD payloads into this mission a pleasant experience. The dedication and competence of these non-NASA participants was of the same high caliber as we have come to expect from NASA itself.

Key Long Term Operational Considerations

Three key observations appear to warrant special attention as we move into the operational era with the Shuttle.

o Personal morale and dedication have been the real reason this and previous manned space programs have been so spectacularly successful. The strict attention to detail that has brought us this far will be just as necessary in 1990 as it is today. Flight crews have never and will never have any problem with personal motivation, however, the pace of the future requires that particular attention be given to finding challenging career patterns for all of those who support crew and vehicle preparations. This, in itself, can be a challenge within the constraint of government employment. There is no evidence today that NASA personnel have lost any of their traditional dedication or skill. Nevertheless, sustaining the current pace without burning out our work force deserves attention at all management levels.

o Training flight crews will always be a long and demanding process. Until the vehicle operations and scope of our procedures can be simplified, the only hope for reducing this training task is improved efficiency in the training process itself. Both of these elements must be addressed as vigorously as resources will permit. In the long run it will be cheaper to launch well prepared crews in half the time than to hold down the flight rate or risk damaging an Orbiter.

o Habitability covers more than just the care and feeding of flight crews. It must also address the efficiency of their efforts on-orbit. Since the adequate support of humans is a minimum requirement, the major gain in crew productivity must be derived from cutting the overhead which is associated with it.

APPENDIX A

FLIGHT CREW TRAINING

Crew Background

Crew training began informally in 1972/73 when both the CDR and PLT were assigned to work on STS development. Formal training began with their assignment as the B/U crew for STS-2. In the time prior to commencing formal training, this crew flew every engineering simulation and participated in the STS detailed development. Assignment as the STS-2 B/U crew provided six months of intensive training focused almost exclusively on mastering the basics of ascent, entry, and systems management. Following STS-2 this crew became the B/U for STS-3. During this period, attention was focused on the STS-3 mission profile and its rather complex payload. The STS-4 dedicated time was approximately three months which were split rather evenly between learning the STS-4 mission and exercising basic skill proficiency training. This schedule resulted in a work pace of ~100 hrs/wk for STS-2 and ~ 80 hrs/wk for STS-4. It is interesting to note that the formally logged training time reflects ~ 25 hrs/wk for STS-2 yet often exceeded 30 hrs/wk on STS-4.

STS-4 Schedule

STS-4 training was scheduled for six days/week until the final two weeks when it was reduced to five days. Most STA training was accomplished on weekends in order to allow the most effective interaction between the crew and others at JSC. Integrated simulations were limited to six weeks due to MCC upgrading activity. The relatively short integrated sim period caused the crew and flight directors to scrub the number of simulations to a minimum in order to allow what the crew believed was the absolute minimum of stand-alone proficiency training in the SMS. The number of integrated simulations supported by the STS-4 crew was substantially less than the flight control team felt they needed to maintain their own skills. Therefore, other crews were used on sims which were primarily aimed at systems training. This split seemed to work adequately. In spite of all efforts to simplify the STS-4 training flow, several areas such as contingency EVA were not even given a refresher.

The STA is a most critical piece of training equipment and must continue to be flown on a weekly basis during the final months of flight preparation. The travel time to El Paso and the rigidity of the range schedules means that a single flight requires a full day of the pilot's schedule. The only way this time commitment could be absorbed was to fly on weekends. Even though this is a higher cost than flying during the week, it's the only way to work it all in until the SMS can be made available on weekends. The bottom line is, training for a mission requires six days a week.

The total number of training hours was very impressive. The STS-4 crew had over 700 SMS hours and averaged over 900 STA approaches.

Training Perspective

Following the STS-2 mission the STS-4 crew prepared a note which described their experiences as the STS-2 backup crew. These observations were intended to apply to a new crew's introduction to the STS and are still considered valid. In fact, several of these observations justify restatement in light of the STS-3/4 experiences.

o Formal documentation of the procedures rationale needs to be expanded. As the flight rate picks up, each crewmember will not have the opportunity to be individually coached on the when, why and how of these rather extensive and mature FDF elements.

o The formal training process stresses systems management rather than flying the vehicle. As the newer pilots move into the flight schedule, more formal attention needs to be focused on the pilot technique and skill areas. The older pilots have amassed a huge storehouse of valuable do's and don'ts through their participation in Orbiter development and the OFT/ALT preparations. Somehow, these lessons need to be captured and passed on before they are relearned in an embarassing way.

o What the student is expected to know or do must be the goal of any training program. Nevertheless, such a statement cannot be clearly identified for STS crews. As a result, a considerable amount of the CDR's time was occupied in defining training goals and mapping out a plan of attack. Certainly the mission CDR should have a voice in this process, but it should not be his task to develop a plan at the same time he is trying to execute it. This condition was unavoidable in the early STS development, but the time has come to develop a core training program. These program goals should be phrased in terms of skill and proficiency levels rather than numbers of hours or lessons.

o The biggest training problem is the sheer volume of material to be mastered and retained. Most of the training time is devoted to off-nominal procedures for a variety of reasons. The STS-4 crew estimates that 75% of their time was devoted to training for things they did not do and probably 50% of the planned CAP was never practiced. This statement is not a criticism but merely an observation. Early in the STS-4 period the crew addressed the question of should they really be practicing the multiple failure scenarios? The premise being that the vehicle design is such that the first failure of a component is almost always transparent and in many cases, the second-like failure is also benign. The problems which are most difficult to handle are those which involve electrical power or data/instrumentation paths in concert with a component failure. If one can assume launching with a full up vehicle, then there is some justification for reducing the training on multiple failures. However, if the launch criteria permits a less than full up vehicle, then the flight crew's first in-flight anomaly will probably be of the multiple failure variety. Recognizing that an on time launch was a primary objective of STS-4, the crew elected to continue emphasizing multiple failures. This situation need not always appear to be insurmountable if we can rationally do two things. First, we need to clearly identify what capabilities we expect a crew to be proficient with. Second, the impact of a launch delay due to component replacement should be compared with the impact of training every crew to cope with multiple failures. There is bound to be some economical compromise. The number of procedures contained in the FDF is large because many have been optimized for each flight phase. Just having a documented procedure does not generally provide a real time capability. It takes crew training time to both master and maintain an adequate level of proficiency. It is the STS-4 crew opinion that most of these mission phase dependent procedures could be consolidated into single procedures which are safe but non-optimal. This could substantially reduce the training time while increasing confidence in the crew's ability to properly execute what is remaining. Until the number of FDF procedures is reduced, crew training time cannot be substantially reduced.

o The large number of hardware and software work around procedures incurs a substantial training committment. While each of these techniques appear reasonable by themselves, the aggregate is impressive. Correcting these vehicle design characteristics is necessary in order to substantially reduce the training time.

o During STS-4 training, each open question was documented using a computer print out. These questions and their answers are available in a notebook. If subsequent crews follow this practice, it should be possible to compare these questions after a few flights. Common questions might indicate deficiencies in the knowledge part of the training documentation.

Specific Training Observations

o The integrated sim scripts emphasize the MCC team training and the air/ground interactions. The amount of training that is scheduled for stand-alone quickly exceeds the time available. It appears that many of the stand-alone objectives could be included in the integrated plan with proper coordination between the crew, sim sup and the training team lead.

o The long sim was one of the most productive parts of STS-4 training, even after doing one on STS-3. This should always be accomplished because it provides the best simulation of actual orbit workloads.

o There is a crying need for a GN&C part task trainer to avoid the inefficient use of the SMS in this mode.

o IFM training is well done, but requires a refresher exercise near to launch. Crews should have an opportunity to look under the floorboards and behind panels in a real Orbiter as a formal part of training. The video tapes look like a step in the right direction, however, some of the current scenes should be replaced with video of an actual component changeout as the opportunity arises.

o Familiarity with the terminal count procedures was provided by crew participation in an abbreviated CDDT. This experience was both adequate and invaluable. Each crew should have an opportunity to go through the ingress/cabin closeout procedures and the terminal count timeline. From the crew's point of view, this experience does not require a full system CDDT, however, they need to see the displays and hear the normal calls in the proper sequence even if this is done at a faster than normal pace. It is extremely important to have some experience with the launch director and his team prior to launch day. From the crew's viewpoint, participation in CDDT is the most efficient way to become familiar with both the launch team and the prelaunch protocol. It should be continued as long as possible, perhaps in conjunction with the pad egress training. If CDDT is ever eliminated, then something must be developed to provide this training.

o There are several failures which can occur during the terminal count and require crew/LCC voice communications. Neither integrated nor stand-alone crew training exercise failures which involve LCC/crew coordination because MCC is not in control at this point. Nevertheless, the crew response and habit patterns must be crisp and correct. Appropriate crew responses can only be achieved through practice in the time critical prelaunch phases just as is done after liftoff. Critical malfunctions prior to launch in both stand-alone and integrated simulations should be added to the training program.

o The STS-4 crew noted significant reach and visibility differences between the SMS and Columbia. These geometry deltas are apparently very subtle, yet critical and may never be completely rectified in the SMS. Launch procedures are generally time critical and are exercised often in the SMS. During integrated simulations, both the flight and ground teams develop an assessment of which procedures can be accomplished, when and how long it should take. Flight day decisions are based on these experiences and, therefore, they must be accurate. Use CDDT to allow the STS-5 crew to verify their personal reach and visibility envelopes. In parallel, a special effort should be initiated to precisely configure the operational seat/panel geometry in the SMS to replicate OV 099.

o The SMS fixed base does not allow positioning the CDR and PLT seats to the launch position. A great deal of our integrated ascent/abort simulations were conducted in the SMS FB. Without the ability to properly position the seats, inappropriate habits can be developed. Schedule constraints have, so far, prevented our efforts to conduct all launch training in the SMS moving base. When ops seats are incorporated in the SMS FB we should insure that they are capable of being used in the launch configuration.

o Stand-alone training for ascent requires that the SMS be provided with an ARD type capability. Today, this training is accomplished by using the full MCC team. In the future, the MCC teams will not have the time to individually train each flight crew to the desired level of proficiency.

o The SMS should be capable of driving all window scenes simultaneously to allow better orbit timeline training.

o The SMS FB should have a high fidelity mid-deck to enhance orbit training with full stowage.

o Full stowage of the SMS for integrated timeline sims is essential to avoid embarrassment on-orbit. Today, much of this equipment must be borrowed from other facilities. The logistics of this activity are so cumbersome as to restrict its application to the "long sim." At the earliest time, we should acquire a dedicated set of SMS stowage hardware and use it routinely.

o Post OMS #1, the SSME slew to the stow position is very dynamic and induces a significant series of RCS firings. The SMS should model the dynamics of SSME stow, not just shake the motion base cabin.

o The SMS needs a capability to uplink a state vector and refinement in stand-alone training. Training which involves nav errors or IMU recovery must be done during integrated sessions in order to have this capability today.

o The number of SMS reset points is inadequate for efficient training. In order to practice entries on other than the preflight planned rev requires starting at a canned point, stepping ahead to the deorbit burn and then flying the entry. This same procedure must be used in order to practice approaches to the alternate landing sites. Further aggravating the situation is the difficulty in saving and using safe stores. Safe stores cut on one base cannot be used on the other base, they can be overwritten and each new training load wipes them out. One of the more critical timelines is the period surrounding OMS #1, yet the only practical way to do this today is to fly an entire ascent. Selection of reset points should consider stand-alone training requirements as well as those needed for integrated sims.

o The STA is an invaluable training device, yet its efficiency could be dramatically enhanced if it had the capability to record video of each approach and play it back between approaches.

o The STA should be provided with a density model such that sea level performance can be simulated at NOR.

o STA practice to unsupported runways should be encouraged throughout the formal mission training period to aid the pilots in developing techniques for use in TAL aborts. Since these techniques may be quite different from these normally used, they should not be the last ones practiced.

o The use of the KC-135 as a landing trainer should be continued. Its primary virtue is that it is the only opportunity the pilot has to actually land an aircraft of a size and geometry similar to the Orbiter. The difference in mental approach between a simulated landing in the STA and an actual landing with a real aircraft on a runway is significant. As a bonus, the KC-135 requires a considerable amount of pilot concentration during landing just as the Orbiter does albeit for different reasons.

APPENDIX B

FLIGHT DATA FILE (FDF) AND MISSION PLANNING/EXECUTION

How operations are conducted and the material used to support these philosophies are really one topic. In fact, it is very difficult to separate vehicle design and training but has been attempted in this report as an aid to organization.

STS-4 Major Changes

STS-4 was the first mission to make a conscious effort to use the Astronaut Office organization as the interface between the FDF community and the flight crew. As far as the STS-4 crew could tell, this procedure worked very well.

At the beginning of the STS-4 preparation period, three major FDF changes were agreed to as objectives by CB, CF and CH. These were the use of cue cards rather than the pocket checklist (PCL) during entry (MM304/305) and the streamlining of the post insertion, deorbit prep checklists (PDP).

1. Cue Cards

The initial attempt to use cue cards rather than the entry PCL in MM304/305 was accomplished quickly. Since we had previously agreed that the ascent cue cards should cover any ascent evolution including RTLS and TAL, it became apparent that entry ought to be a subset of the ascent procedures. The new objective became one of developing a single set of cue cards which covered all MM102, 103, 601, 602, 603, 304, and 305 systems anomalies. This task did not turn out to be as straight forward as expected because of the optimization which had been built into each existing set of procedures. Many of the changes, which on the surface appeared to relate solely to format, turned out to actually change the technical content. A related problem was the amount of data which was appropriate. For example, if an IMU fan fails, is a written procedure required to tell the crew to switch to an alternate fan? The flight crew felt this was unnecessary, however, the systems people countered with the opinion that obvious as this action appeared, it was necessary to document it somewhere. The real problem turned out to be that the onboard FDF is the only source for those procedures.

The process of developing new cue cards, verifying their technical content and producing a training product took much longer than any one would have expected. The training products were further delayed because of the need to prepare the flight units. This resulted in the crew seeing flight-like units for the first time within the last two weeks of training.

The following recommendations are suggested for consideration on future flights.

o Develop a detailed procedures document that describes what, when and why for ascent and entry systems anomaly responses. The cue cards should then contain only those steps which are not obvious to a trained crew.

o Critically examine the need for unique ascent and entry responses to a common symptom. It is the STS-4 crew opinion that a common response which is safe is preferable to two optimal responses. Reducing the number of procedures in ascent and entry will not only shorten training time, but will also improve the probability of an accurate response when required.

o Avoid nice to do improvements within three months of a mission. This does not mean stop improvements, but rather recommends separating the flight production and development functions. A group of knowledgeable people ought to be able to work out improvements and hand over a verified set to the crew in training.

o The three existing PCL's should be combined into one.

2. PDP

Post Insertion

The STS-4 crew developed a post insertion procedure which utilized picture panels to establish the on-orbit switch configuration. This technique has the virtue of allowing the crewmember to approach any panel in any orientation and still achieve the proper configuration as well as being much faster and less error prone than the individual switch callouts used previously. The only problem we encountered was that the panel drawings were not ordered in the FDF in the same sequence in which we configured the cabin. The entire post insertion routine was typically executed in two hours in the SMS, but required approximately three hours in flight. Most of the extra time was invested in doffing the EES and transferring articles from the pockets of one to the other.

To expedite the initial unstowage, a list of early use items was carried on the crew kneeboard. These items were those required prior to the first meal period. The intent was to get far enough ahead of the timeline to allow full orbit stowage reconfiguration prior to entering the CAP at an MET of four hours. This latter activity was not completed until the first night's sleep period because of minor timeline interruptions and the zero g environment.

The following further improvements are recommended.

o Publish the picture switch lists in the order they will be used.

o Schedule a period to deploy the spacecraft stowage to the orbit configuration in the time saved by not having to doff the EES.

Deorbit

The deorbit prep activities were substantially streamlined for STS-4. This was accomplished in order to both shorten the time from wakeup on FD8 to the deorbit burn and to provide time for a thoughtful crew briefing prior to the burn and entry. The new procedures took approximately two hours in simulation, two and a half hours on-orbit and were scheduled for four hours. The reason it took longer inflight was because it took longer than anticipated to don the EES. These procedures worked flawlessly and provided enough time to accommodate some unanticipated events. This is exactly how entry day should always be. Any extra time might be spent getting one last treadmill exercise.

3. OPS Checklist (Ascent, entry/orbit)

- STS-4 attempted to remove all mission dependent data from the ascent and entry checklists. Even though changes in mission software may require some detail changes, the concept of using timeline and targeting cue cards seemed to accomplish this goal without increasing the crew workload. In fact, the timeline cue cards which provided a summary timeline from liftoff through the PI PDP and again during the D/O PDP were a significant aid to the STS-4 crew.

- The current ascent checklist flows smoothly and is a slow enough pace to allow doing things deliberately while the crew transitions to the orbit environment.

- The ascent checklist calls out transfer to internal power as part of the terminal count, yet this has been gradually occurring over enough time that it is totally transparent to the crew. On the other hand, the SSME slew to the start position can be felt, occurs at a specific time and is not mentioned in the procedures. The terminal count is a period where it is important for the crew to recognize what is nominal and what is abnormal. Checklist and training should emphasize only those things which are visible to the crew or require crew response to avoid real time confusion. The power transfer call in the ascent checklist should be deleted and the engine slew cues added to the SMS motion base.

- The orbit ops checklist now contains the procedures for the FCS checkout. It was moved from entry day to accommodate any discovered anomalies and to relax the entry prep timeline as much as possible. Since we can handle, during entry, any of the problems which might be identified by the FCS checkout, it raises the question of how important this procedure is. At some point in the ops era, it may make sense to delete this as a routine evolution and retain it as a diagnostic tool to be used when required. If this procedure is executed it should always be done with the PLT and CDR steps in parallel rather than sequentially.

4. Other FDF Articles

- The Malfunction Procedures, Reference Checklist, and the OMS/RCS slide rule appear to be good candidates for eventual inclusion on mass memory.

- The Reference Checklist contains an alphabetical stowage list. Unfortunately, not all equipment can be found via its common name. For example, the STS-4 crew wanted to find the spare urine filter inflight, but could not go into this list and find it. As these problems surface the nomenclature should be updated.

During training and inflight, the yellow plastic caps were used to indicate switches that were not functioning normally. In training, the crew found that the best way to remind themselves of anomalous switch functions was to apply switch caps and tape to non-functional switch positions. The SMS had some yellow electrical tape as well as the yellow plastic switch caps. The loss of some data or power busses can lead to one or more switch positions being non-functional. Rather than change every possible procedure to reflect these non-functional positions, the STS-4 crew found it was easier to mark the panels as reminders.

It is recommended that some yellow tape be added to the FDF kit to allow use of both tape and switch caps as panel reminders.

The afternoon of FD7 was scheduled for pre-entry stowage. A copy of the stowage list had been annotated to indicate what was to be left out until entry morning. The process of stowage was to have one crewmember open each locker and call out what needed to stowed. The other crewmember retrieved the necessary equipment and passed it to the stowing crewmember. This worked very well and allowed a very efficient operation. Two hours were used in this activity. The rest of the time was used in taking pictures that had fallen by the wayside. Stowage was simplified by starting a "return to Houston" bag on FD1. This was the large jettison bag flown for the first time on STS-4. The intent was to put all annotated FDF articles, film, VTR and tape cassetes into one bag for easy location post landing. Unbeknownst to the flight crew, the post landing procedures required that this bag be inventoried and only those items designated were immediately returned to Houston.

The post flight procedures should be changed to insure everything in the "return to Houston" bag is indeed returned, whether it is on the manifest or not.

5. CAP and Orbit Timelines

The following observations are offered for consideration during development of future orbit timelines.

The pace of FD1 had been intentionally relaxed to allow for the anticipated zero g crew learning curve. The day was scheduled to end at nine hours MET, yet the activities were not completed until several hours later. Since the crew had been on schedule at the end of OMS #4, they were surprised at the rate at which they fell behind the timeline. Post flight analysis of this day shows that activation of the Getaway Special, scheduled for ten minutes (a two minute job) took approximately one hour because of a malfunction. Support of the DOD payload, 82-1, took an additional unscheduled hour and the COAS CAL took 20 minutes as opposed to the scheduled five. These delays, when added to the deferred spacecraft stowage, account for most of the time discrepancies and illustrates the sensitivity of timelines to unanticipated events. The crew elected to delay the sleep period and insure that FD2 would start properly. In retrospect, this seems like an appropriate decision, however, had the first day been a longer one, it might not have worked as well.

The crew's zero g learning curve appeared very steep during FD2. By the end of FD2, crew efficiency had approached their steady state proficiency. It should be noted that this is in no way related to motion sickness.

During STS-4 the flight crew felt that they were working as hard as they ever have throughout the mission from the end of OMS #2 to the afternoon of FD7. The onboard perception was that of scrambling every minute to stay caught up. This apparently did not come across to the MCC team since they were surprised by this crew comment during debriefing.

Sixteen hours of reacting to timelined activity is very fatiguing. Breaks for meals and exercise are very necessary and should be honored as often as possible. If one activity is running over its allotted time, it should not be terminated prematurely, but when it is complete the time off should be reinstated.

The PLT got his first exercise period on the treadmill on FD3. The CDR got his first on FD4. Both exercised each subsequent day through FD7. About one hour per crewman is required to accomplish 20 minutes of exercise. This is certainly time well spent.

Changes to the mission thermal attitude sequences resulted in massive rescheduling of flight activities beginning with FD4.

The changes were sent up via TPR msg just before wakeup on FD4. Typically, the CAP allocated 15 minutes each morning for TPR review. Simulations had shown that this time is about right for a nominal day's update. Flight experience validates this assumption. However, with a massive update this is not adequate with our current CAP format. On FD4, the crew never had time to develop a mental overview of what was going to happen that day. Consequently, this was probably the hardest day of the flight. The crew was no longer in a position to exercise any contribution to the day's activity because they were just hanging on, reading each new activity as they got to it. This condition was remedied on subsequent days by a major ground effort. The subsequent days were completely replanned rather than trying to modify the existing CAP. These brand new CAP's were sent up in two forms each day. A summary of the day's activity was prepared in chronological order to show the crew what would be done that day. Then a detailed execution message was sent. This worked very well in spite of the fact that FD5, 6, and 7 were totally new, as long as the summary was received first. The crew mounted the summary on the forward glare shield and used it to plan and execute the day. The details were clipped using the now useless CAP, as a clipboard. Other supporting messages on systems status were clipped together and velcroed to the side of the PLT's ejection seat. This file was used in a fashion analogous to a NOTAM file. This mission used greater than 200 ft. of TPR paper.

Before flight, both the flight crews and MCC team must agree on how and when mission replanning will be accomplished. The STS-4 crew had discussed this extensively with the planning shift Flight Director and the exchange of ideas made it possible to just barely cope with the revised CAP. One of the difficulties for both flight and ground teams was the relatively rigid format of the CAP. If the CAP is going to contain all the actions in detail, then the CAP Must be executed as planned in order to avoid making costly mistakes. Flipping back and forth within the CAP is inherently inaccurate and time consuming. It defies ingenuity to keep track of what has been done or what is coming next. The other extreme approach is to package the details in a CAP supplement and use the CAP only as a master schedule. This makes execution of the CAP less efficient on a nominal day, but allows a great deal more flexibility.

In any situation which requires operating off a TPR msg, the crew will need something to lay it on so that they can write notes and check off completed steps. A clipboard might be useful.

The flight crew spends a great deal of their training time mastering the anticipated flight timeline. This is appropriate for their role as supervisors and executors of the CAP. They cannot execute these responsibilities if they do not know what is coming next or where they are headed. Therefore, the following suggestions are offered:

o Decide preflight what, when, and how replanning of the CAP will be accomplished. Different missions may require different strategies.

o When massive CAP changes cannot be avoided, a new day's summary must be generated and shipped first. Details should be avoided, but can be sent up later.

o Avoid forcing the crew to operate in the response mode. If it becomes necessary for short periods, then a master plan should be discussed as soon as possible. It is the only way to avoid costly mistakes.

o Provisions for handling and writing on the TPR messages should be provided.

o When major TPR changes are required, a commensurate period must be scheduled in the new CAP to allow the crew to digest the content.

o During the STS-4 long sim, the MCC team discovered that if they listened to the playback of the crew intercom, they could discern what the crew was thinking about the next day. This allowed them to avoid telling the crew things the crew already knew and allowed them to address crew questions. This procedure was formalized for the STS-4 mission. The plan was for the crew to record, on the ICOM, a summary of the day's activity, express questions and opinions about the next day's plans and feedback their impressions of what the MCC had told them during the day. This worked with varying degrees of success during the mission. The primary problem was missing the summary section of the tape dump because of an inadequate set of markers for the crew to identify this time to the MCC. The MCC had wanted this summary before or during the pre-sleep period. The crew, however, never got to it until comm had been secured for the evening.

This concept should be considered for subsequent missions after developing an unambiguous set of air to ground cues to indicate the required MET's.

Flight crews are frequently approached on the side about doing a little extra to collect some additional data. This seems innocuous enough and the flight crew is always willing to do a little extra to help. This process, however, runs the very real danger of allowing the mission priorities to be subtly reshaped without everyone being aware of it. Except for things the flight crew pursues in their "free time" (as opposed to meal and sleep periods) these activities should all be formalized at least to the extent of appearing on an official shopping list. The use of an official shopping list was successfully used on STS-4 and substantially improved the quality and quantity of returned data.

Wake up on FD8 was delayed over an hour because the landing rev had been moved from the first to the second opportunity. This was appreciated by the crew, however, one of the major problems tackled in the development of the CAP had been how to move the sleep periods forward during the mission. A greater than six hour sleep adjustment was cut to approximately four hours by shortening FD1 and FD8 activities. Nevertheless, it might have been more effective to have not moved the sleep periods at the beginning of the mission quite so much, rather than pull them forward on the high workload days and then give some of it back at the end.

Circadian rhythms can be changed, but this must be done with a great deal of thought and planning. While sleep periods can be scheduled at any time, many crewmembers will find it difficult to turn in early. The end result is a lack of productive sleep.

The amount of sleep period adjustment required on-orbit should be minimized by tailoring the launch and deorbit day activities as much as possible.

The relaxed pace at the end of FD7 provided the first real opportunity for the flight crew to observe and ask questions about the earth passing by outside. During this period, it was noted that massive lightning discharges were taking place over desert areas. It was also noted that those same areas had experienced a very noticable build-up of aerosol, assumed to be dust, during the mission. Apparently related, but not continuous discharges were observed to spread over a distance estimated to extend as much as several hundred miles. These observations seemed to correlate with an earlier observation that the colors and intensity of the atmosphere at sunrise and sunset varied with both latitude and longitude.

Flying curious, intelligent and trained observers in space will most likely lead to many new endeavors if time can be provided for them to use their natural skills in an unprogrammed way. Many of the current astronaut population have advanced degrees in various fields where their backgrounds may find application.

Each crewmember should be scheduled for TBD hours of individual pursuits on each mission.

APPENDIX C

VEHICLE SYSTEMS OBSERVATIONS

Vehicle systems have apparently achieved a remarkable level of maturity during the initial four flights. Most of the STS-4 observations can be catagorized as constituting an operational suitability evaluation rather than as a functional assessment. Even though any change to the hardware or software requires an investment of resources, it is the opinion of the STS-4 crew that the potential cost savings to be realized through reduction in crew training requirements or increased orbital crew efficiency warrants a thoughtful review.

Observed Basic Orbiter Systems Characteristics

Nuisance Alarms

- Three nuisance alarm types occurred during dynamic flight.

  - The dp/dt alarm occurred as anticipated, however, unlike in the SMS, the CDR was unable to see the dp/dt gage. The limits on this alarm should be adjusted to avoid nuisance alarms during ascent.

  - In spite of adjusting the Evap Out Temp alarm to its upper limit, it was triggered near SRB staging.

    This nuisance alarm has occurred in three of our four launches. This has two potential crew traps. First, a valid alarm may go unrecognized and second, the fact that the sensor is saturated complicates any ensuing corrective action during powered flight. The crew response time to activation of the evaporator can alter the incidence of this occurrence. This is an unfortunate aspect of our current design since this function was intended to be udner GPC control, yet because of a potential single point failure, we are procedurally doing this at SRB staging.

    The Evap Out Temp transducer limits should be expanded to avoid these nuisance alarms and to aid in subsequent corrective actions following a real malfunction.

    If the sensor range cannot be extended, then another way to avoid this nuisance alarm should be developed.

    Ascent is sufficiently dynamic that normal functions like enabling the evaporator should be automated. The CDR should devote his undivided attention to monitoring the ascent trajectory. The system should allow the evap and NH_3 to be launched in the GPC position.

  - Two nuisance master alarms were encountered during entry. The first came when the SSME TVC was repressurized just prior to EI and the second occurred at the MM304 transition when the elevons were commanded to move to the entry position.

    The problem in this case is that there is no filter or time delay in the primary (h/w) C&W for low hydraulic pressure. The backup C&W (s/w) avoids this with a filter. A time delay to the h/w C&W for hydraulic pressure should be added.

Vehicle Torques

o Unexplained torques were noted on the vehicle during the COAS cal and during a gravity gradient test period. These torques were large enough that the CDR had to use an excessive number of vernier RCS pulses to keep the COAS cal star in a useful location. These torques also caused the gravity gradient attitude to diverge dramatically in roll within one hour. The source of these torques was not identified in flight and were either absent or greatly diminished by FD2 since gravity gradient held for the entire schedules period. It has been postulated that this torque was created by H_2O in the TPS being vaporized. A similar, although less obvious, condition may have occurred during the STS-2 gravity gradient exercise. Prior to launch, STS-4 experienced a very heavy rain and H_2O entrainment was considered likely. Depending on the quantity of H_2O trapped, it is possible that some of the STS-4 ascent performance loss might be attributed to this. If this condition occurred on STS-4, it seems plausible that it also occurred on previous flights to a lesser degree.

The source of these unanticipated torques needs to be identified. If H_2O trapped in the tiles remains a likely candidate, it may be possible to measure the mass with a series of RCS burns spread over the mission. If H_2O in the tile is indeed a repeatable phenomenon, then a method to prevent or limit the amount of H_2O seems appropriate. The effects of hydration on silica structural integrity should also be verified.

PLBD

o FD4 included a thermal gradient PLBD closure test. The port door appeared to close normally, however, when the aft bulkhead latches were commanded closed, the door deflected substantially at the aft bulkhead and the latches jammed after only partial travel. The aft PLB CCTV's were used to send pictures to MCC for evaluation. The PLB lighting was degraded and the latch mechanisms are all dark, offering very poor contrast. The crew had considerable difficulty identifying major components and in positioning the CCTV.

It is imperative that we determine the cause of this door interference and insure that adequate operational tolerances are provided. We should develop a simple technique to allow the flight crew to insure a safe latching if possible if all conceivable tolerances cannot be demonstrated to be adequate.

Increased crew training in the area of PLBD mechanisms, as viewed through the CCTV, should be considered until the acceptable PLBD operating envelope is defined.

EMU COMM

o When the EMU comm was activated, the PLT on the flight deck could hear the EVA crewmember normally, but the EVA crewmember had so much noise that it was hard to read the cockpit. This noise did not prevent voice, but was bad enough to make EVA questionable. During the EMU activities, the noise suddenly went away and provided good comm even though the crew was unaware of the cause. Lab tests have suggested an intermittent ground between the EMU and airlock support structure as the probable cause.

Entry Dynamics

o During entry, both crewmembers were surprised by a vibration which was described as feeling like atmospheric turbulence in a high speed, high wing loading aircraft. These sensations began around M22 and varied in intensity throughout entry until the transonic buffet became the dominant vibration. This had not been previously reported and raised some question about the wisdom of executing the PTI protocol. Just prior to the M18 PTI, these vibrations reached a peak and then started to diminish enough that the PTI was executed without concern.

Post flight data evaluation from surface accelerometers suggests that these vibrations were probably the result of the yaw RCS exciting the vertical fin. The structural model infers that the accelerations of the cockpit resulting from the fin motion should have been on the order of $\pm$ .02g. It is a little surprising that such a low level would have been so obvious. If the vibrations STS-4 experienced were solely the result of structural bending, then it seems prudent to evaluate the inherent structural damping to insure that adequate margins exist at higher $\bar{q}$, especially in the presence of FCS/sensor anomalies.

Brake Performance

o Prior to flight, the brake and wheel/tire performance received a lot of attention. The braking DTO called for application of brakes at a ground speed of 140 Kts and a constant deceleration level of 8 - 10 fps^2. The crew was advised that this level would not result in activation of the antiskid system until the velocity was relatively low when the decel levels would naturally be reduced. During SMS training, the STS-4 crew found it very difficult to achieve a constant decel rate. However, with a lot of practice the CDR learned how to hold roughly 10 ± 1 fps^2. During the actual landing the CDR was unsuccessful in raising the decel level to his target of 10 fps^2. The maximum value was 9 fps^2 and this was only for a brief interval. The CDR was also frustrated by his inability to hold the decel levels anywhere near constant. Both crewmembers had the distinct impression that the antiskid cycled several times at the beginning of brake application.

Post flight discussions and data analysis seem to indicate that the antiskid system did not activate and that the brake pressure fluctuations followed the brake pedal commands normally. One problem with this evaluation is the fact that the brake pedal position is sampled much less frequently than the rest of the data so that exact cause and effect relationships are difficult to quantify. The fact that the flight day decel levels fluctuated as badly as they do in simulations raises a question about the brake pedal pressure gradient and magnitude. It is not obvious to the crew whether these force levels are too high, too low or if there is some other reason for the non-uniformity of the brake commands. It is the opinion of the CDR that the manual task of precisely controlling Orbiter decel rates is an unreasonable one. If precise levels are required to insure stopping or to preserve the brake life, then an auto decel system should be developed. This system is currently available in some commercial transports. In an ideal design, the pilot should be able to select the desired decel level and then command execution with a single switch. Differential braking should still be accommodated and the decel level should be capable of adjustment during auto braking. The cost of replacing the brakes following heavy weight landings can become significant over the life of the STS. Most probably, the vehicle landing and abort weights will rise as we develop the launch systems and techniques. This will severely complicate an already marginal situation. Early in the Orbiter development cycle, the design included a drag chute which was eliminated because of its complexity, weight and a belief that the Orbiter aerodynamic drag was sufficient to stop comfortably on a 10,000 ft. R/W. Since then, our operational capabilities have increased to the point where alternative deceleration techniques warrant further consideration. Since the Orbiter already has a substantial thrust structure, it may not require a great deal of additional weight to provide a tail hook which could be used for nominal landings and at planned abort sites. The brakes should be retained as emergency devices to cover contingency landings or hook failures. This would essentially remove brake refurbishment costs from the operational employment of the STS.

Basic Orbiter Systems Improvements

Ascent Displays

o About one minute into ascent, the crew noticed that the trajectory appeared to be depressed on the BFS traj #1 display. The ADI attitude error needles also indicated a slightly low attitude (nose towards the earth). Once the displays moded to OPS 103, the crew confirmed that the trajectory was still slightly depressed and the propellant remaining calculation indicated approximately 1% less than normal. The MCC confirmed the crew's assessment of low performance and indicated that the abort boundary calls would be slightly later than normal. The traj was still slightly low at a velocity of 16,000 fps, but the propellant was normal.

The STS-4 crew used the BFS ascent trajectory displays because they provide more useful information than the PASS display. The only data used on the PASS display was the calculation of propellant remaining and the display of TMECO. TMECO was compared with the same value on the BFS to assure the crew that the BFS data was valid. Based on extensive training, the crew had developed a good feel for how much performance could be degraded while still making a viable MECO target. This allowed the crew to get a head start on planning their post-MECO activity. There is not too much time between MECO and OMS #1 to make a decision about which targets should be loaded, etc. Even when the MCC calls these target selections, the STS-4 crew found they did a better job if they could anticipate what would probably be required. Today, the BFS ascent traj #2 display is the only way the crew has to monitor nominal trajectories or TAL aborts.

The use of the BFS traj displays creates another problem since the BFS is also the only source of systems data in OPS 1. To provide both systems and trajectory data from the BFS during ascent, required that one CRT (#1) be assigned to the BFS with the BFS CRT SELECT switch and the second CRT (#3) be assigned permanently through the keyboard. This introduces other complications if a GPC or CRT fails.

The BFS does not display the propellant remaining in OPS 103 so this data has to be obtained from the PASS traj display. In order to interpret this data the CDR must refer to a nominal profile which is on a cue card mounted by the ADI. This is a time consuming cross check and requires a profile which is derived from the flight I-loads as opposed to generic data.

Proper use of both the trajectory profiles and the propellant values can only be accomplished today by practicing with the flight I-loads. The software should eventually be upgraded to include a propellant remaining versus velocity profile. This should be displayed along with the current calculation or perhaps only the delta needs to be displayed.

Abort Data

- o During preparation for STS-4, a scheme was developed to allow the crew to determine when an RTLS powered pitch around should be initiated. Unfortunately, this scheme required a SPEC 0 memory read after abort initiation which is tedious and error prone. This strategy, however, eliminated the ambiguity over whether the guidance was converged and when/if manual intervention was required. (The use of a memory read during an abort is totally unacceptable). If a piece of data is required in an abort, it should be automatically displayed.

  Several pieces of critical abort data are currently not displayed to the flight crew even though the information is resident within the GPC. The crew should know the time of SSME failure, the status of the guidance converged flag and the mass target for RTLS powered pitch around.

ET SEP

- o A primary concern in the execution of RTLS aborts is the need to separate the ET with < 2% propellant remaining. In fact, the entire RTLS strategy has to be built around a very critical fuel dissipation phase. This is the only area of the RTLS powered flight guidance scheme to uncover problems to date. There is some evidence that safe aerodynamic tank/Orbiter separation can be attained with substantially larger propellant loadings. The full envelope of safe aerodynamic ET separations should be defined and the RTLS guidance revised to capitalize on it.

OMS Burn Logic

- o One of the most time consuming crew preflight activities is attempting to learn the OMS/RCS burn logic in ascent. Today, we have a relatively large number of unique emergency procedures and very little real time insight into what is actually happening during each. The STS-4 crew is not sure if all of these procedures can always be executed due to changing reach and visibility envelopes during ascent.

Training time must be reduced in the Ops era and this area represents a potentially large reduction if the hardware and software could be made compatible with operational procedures. Certainly the OMS #1 (MM104) burn logic should be made consistent with all other OMS burns.

OMS Gaging

o The OMS gaging system is complex and has not been reliable to date yet crew knowledge of the amount of propellant remaining is essential.

Accurate propellant gaging in zero g has always been difficult. In Apollo, the crews relied on accumulated burn time for the SPS rather than the gaging. The OMS gaging has proven unreliable to date and even when it works properly is only accurate after a burn has started. Because of the tank construction, there is an ungagable region which must be estimated in any case. This estimate is done in the hardware and assumes that only one OME is drawing propellant. This assumption is not valid during many burns, especially ascent abort propellant dumps. Since the GPC calculates the amount of OMS propellant used by the RCS on-orbit rather accurately, why not develop a software calculation of OMS propellant quantity to be based on counting the number and mass flow of all users and subtracting this from the initial tank load.

Structural Limits

o Columbia has a thermally induced 2g limit beginning near the TAEM interface and extending through rollout. Columbia also has a 6 fps $\dot{h}$ limit for touchdown, a nose lowering limit and a R/W smoothness limit all constrained by the forward fuselage structure. While none of these limits were exceeded on STS-4, they were uppermost in the crew's mind during portions of vehicle recovery. During the entry α sweeps the vehicle cg experienced a delta n_z of approximately one and yet neither crewmember was aware of this change.

There are a number of reasons why pilots should not be required to remain within these limits with an operational vehicle. The task of maneuvering around the HAC to set up the landing energy is sufficiently demanding that the pilot should not be required to cross check his g level as an additional constraint. The difference between a normal HAC n_z profile and an excessive one is too small to rely on physiologic cues as a warning. The pilot must fly whatever trajectory is required to assure a proper landing set up.

The landing $\dot{h}$ limits are normally not a problem, however, any slow landing, a balloon or steep approach can easily result in touchdowns at or above the 6 fps limit. The difficulty in achieving smooth landings is caused by the aircraft geometry and can only be controlled by a proper set up. Once a set up has been missed, the pilot has no choice but to do the best he can with the conditions he faces. Any upsets to the trajectory caused by turbulence, wind shear or last minute energy corrections can create a condition which requires the pilot to use his controls in such a way as to significantly increase the probability of a touchdown $\dot{h}$ in excess of 6 fps. Sitting as high above the R/W as the Orbiter pilot does, severely complicates this task.

Controlling the nose derotation is another region where the pilot has very little latitude. Today's techniques work well as long as everything proceeds nominally. If the pilot lands slow for any reason, he will have the nose too high and at too low an airspeed to allow for anything less than perfect post touchdown technique. This is very difficult to achieve or simulate. In this case, the problem is again related to Orbiter geometry; short nose gear (negative α during nose gear touchdown) and the desire to avoid large up elevon deflections with the nose on the R/W (negative α plus elevon downloads on main gear).

The final problem is beyond pilot technique unless landing speeds can be reduced. These inherent limitations apply equally to pilots and autoland, therefore, the following recommendations are offered for consideration.

- o Apply structural beefup as necessary to provide a 2 1/2g airplane mode n_z limit for all nominal end of mission conditions.

- o Improve structural margins to assure that landing $\dot{h}$'s up to 6 fps at all landing weights can be tolerated without concern.

- o For long term operations the nose strut should be extended to avoid negative α problems or active canards should be considered. Active canards, although expensive to retrofit have sufficient virtues to justify serious consideration. Active canards would provide a vehicle center of rotation near the cg, thus making the Orbiter fly and land in a conventional manner. Active canards would also allow the elevons to be lowered as landing flaps. Back of the envelope calculations indicate that a 240,000 pound Orbiter could be landed close to 150 Kts with the elevons deflected to $\sim 10^{\circ}$ down. It is conceivable that an active canard could even unload or control the nose derotation below zero angle of attack and avoid the need for nose gear extension.

<u>Habitability</u>

The general subject of habitability is extremely important to long term operations because of its implications for crew health, morale, and efficiency. Individual topics are discussed although the general subject must be treated as a system in order to reach an effective operational solution.

- o <u>The Closed Ecological System</u>. The spacecraft becomes a closed ecological system in orbit and must be treated as such since the components interact. The subjects of interest are the WCS, food preparation, personal hygiene, and trash management. Any change in one can affect the others so the system must be treated as an entity.

1. <u>WCS</u>. A detailed debriefing of the WCS problems and comments has been given to the subsystem engineers, hence, only a brief summary will be given here.

   a. The preflight training was excellent and gave the crewmen confidence that body positioning was correct and cemented their knowledge of the WCS operations. This training is strongly recommended for new crewmembers.

   b. The human interface with the WCS for fecal collection is not natural. In fact, the OFT design hindered rather than aided proper body positioning.

c. There is not an adequate restraint system for urine or fecal collection.

d. The slinger speed began to vary and noticeably slowed after day 4 of the flight. Fan/separator motor speed also varied during the last days of the flight.

e. The urine cup design allows urine to collect under the lip of the cup and in the funnel itself. There is always a cleanup problem with this design. Urine surface tension allows it to run around the funnel and plastic cover. Perhaps unique male and female urine adapters are needed.

f. The urine cup spring retainer system came completely apart during an attempt to position the cup on the track for urine collection; during fecal collection the adjustment limits for this purpose are inadequate. Something akin to a gooseneck-type adjustment came to mind as a possibility.

g. Air flow is inadequate for urine collection of the "last drop." Perhaps a high flow flush mode could be implemented.

Some of these problems require remedies which must be engineered on the ground. Those problems which have to do with zero-g operation are probably easiest to solve by providing a set of candidate devices for inflight development. A DTO should be defined to cover this orbit activity to insure adequate flight plan integration.

2. Personal Hygiene. The following observations are made based on flight experience and projections for larger crew operations.

a. There can be little privacy and certainly no room for modesty when it comes to personal hygiene. Bathing requires access to the H_2O dispenser which is located in the mid deck which is a focal point of crew activity. Perhaps a curtain could be used.

b. Each crewmember was allotted two washcloths and one towel per day. One cloth is wet at the H_2O dispenser and soaped for bathing. The second cloth is used for rinsing. There is no way to rinse the cloth so it becomes soapy. When the galley flies (not on all flights) there are provisions to wring a cloth and re-wet it for rinsing. When shaving, one of the cloths must be used to wipe the razor and to remove shaving cream from the face. You can readily see that the daily washcloth allowance is rapidly depleted. Add to this a spill and subsequent hygiene during the day and the towel supply problem is evident. A permanent towel washer/squeezer like the one used successfully in Skylab should be implemented with an increase in towels manifested until the washer/squeezer is available.

c. Bathing H_2O must be obtained from the same station as drinking H_2O, a potential health hazard. With larger crews, the need to allow concurrent food preparation and hygiene becomes obvious. Isolated hygiene and food H_2O supplies should be developed for the operational Shuttle.

d. The wet wipes provided were all used by early in day 8. They were useful for WCS clean up which was not the intended usage but was more convenient. The quantity of wet wipes should be substantially increased.

e. The DOP kit design leaves a bit to be desired. All items are installed in the kit under an elastic loop with such tension that removing them sometimes causes the kit to release from its velcro stowage location. Except for the soap dish, when an item is removed, there is no velcro with which to restrain it and trying to insert it back under the elastic loop is difficult. For example, removing the shaving cream from under the loop requires quite a tug building pressure on the tube so that when the cap is removed, shaving cream squirts out. Also, the razor blades were stored under the same loop and became free when the cream was removed. One quickly runs out of hands with a tube of shaving cream and its cap in one hand and a hand full of cream to rub on the face in the other. Velcro restraints for all items in the kit should be provided.

3. <u>Food Preparation</u>. The Ops food preparation and eating worked very well.

a. A mishap occurred once during rehydration of a package when the H_2O injector needle punctured the side of the septum. Alignment is critical.

b. The Ops food seemed to require slightly more H_2O than called for to obtain proper consistency.

c. The squeeze cutoff on the plastic straw was required for some beverages and not for others. Some tended to dribble out without the cutoff.

d. Food with high surface tension (mushroom soup) could not be accelerated permanently into the container bottom by swinging it around. The fluid would crawl into the plastic cover making a rather messy opening.

e. In addition to the Ops food packages, we still have some food in "wet packs." STS-4 found that these wet packs could be cut on three sides with the side folded back to expose the food. The meat could then be eaten with a knife and fork in a conventional manner. The one problem encountered was that the juices would tend to run onto the locker surface by surface tension. Either a paper towel to catch the run off or some form of holder/tray would handle this.

4. <u>Trash Management</u>. This may be a serious problem in the Ops era.

a. Trash generation by the Ops food is a potentially severe problem. On STS-4, four wet trash bags were filled. Almost all food trash (but <u>not</u> all) was put into these bags. The Ops food packages do not compact well and the trash volume is about equal to the pre-use stowage volume. Double or triple the number of crewmembers and the problem is self-evident.

b. Dry trash was bagged and stored in the LiOH storage locker. This space may not always be available and it was not designed for that purpose.

c. Wet trash can easily become a haven for bugs and must be properly stowed. A large, easily accessed stowage area must be supplied to accommodate all the trash generated by larger crews. A trash compactor would help considerably in managing the quantity of trash that will be generated in future flights.

The closed ecological system must be critically evaluated. If one crewmember should become ill due to a breakdown in the system, illness could rapidly spread to others.

After subtracting the time for meals, exercise, and hygiene it appeared that the STS-4 crew worked no more than 10 productive hours out of the scheduled 16. The difference between what was scheduled and what was delivered came out of the sleep and meal periods.

At the demonstrated work level even two shifts won't produce around the clock operations and there is some evidence that some of these overhead tasks may take longer with more people on board. Since on-orbit crew time is very expensive and extending the individual work day seems impractical, it seems attractive to look at ways to make these overhead tasks more efficient. For instance, going to the bathroom shouldn't take any longer on-orbit than it does on the earth.

A major improvement in the efficiency of required habitability tasks should prove cost effective.

Cabin Noise

- The STS-4 crew was surprised at the cabin noise levels. Preflight data indicated that the SMS was noisier than the spacecraft. The sound pressure meter was used to survey the cabin and indicated that the noise levels were the same as previously reported. Side by side conversation was satisfactory. Talking to a crewmember on the other side of the mid-deck required raising one's voice to a fatiguing level and shouting was required just to get a crewmember's attention when talking between the flight and mid-decks. This acoustic environment did not interfere with sleep, however.

  Based on the measured sound pressure levels, the spacecraft on STS-4 was not unusually noisy and yet electronic communications were generally required. This condition is conducive to fatigue and inhibits good crew coordination. In the long term, these factors may become significant.

  A quieter cabin should be developed for the Ops era.

- Freezer/Refrigerator. A small freezer/refrigerator was evaluated on STS-4 and proved to work flawlessly. Although the volume was small, three drink containers or cereal packages could be cooled at once. This dramatically increased the palatability of certain foods and made the beverages more pleasant to drink. Such a device with larger capacity would greatly enhance the habitability in the Ops era. The current VPC should be flown until a larger device can be obtained.

o <u>FD/MD Isolation</u>. For external night photography, the flight deck must be darkened or reflections from the windows will mar the pictures. It was noticed that light coming from the mid-deck interfered with this type of photography. Some means of isolating the mid-deck and flight deck should be developed.

o <u>Time Display</u>. There is no time display on the mid-deck and one is sorely needed. Many operations are carried out on the mid-deck and the crewman must rely on a wristwatch for time. This is not always convenient, for example, during exercise. The mid-deck should include a MET timer.

o An inspection of the cabin fan duct outlet was performed. There was no free water. The windows facing overhead and into the PLB developed condensation covering the middle 75 per cent whenever the window covers were installed. The condensation cleared quickly on the overhead windows after the shades were removed, however, the aft windows never cleared completely while in the tail sun attitude. The carry on ducts for the PLB windows seemed to work properly in that air flow over the window could be felt. Nevertheless, they had no effect on the condensation. One day was run with the duct in the port window and none in the starboard window. The condensation in each window was identical. No condensation appeared on the side hatch window even though it was covered almost continuously.

o <u>Lighting</u>. The lighting in the mid-deck is generally adequate for all activities performed except 16mm photography. Adequate lighting must be provided on both flight decks if decent 16mm photography is to be obtained.

Lighting on the flight deck over C-3, CDR and PLT seats is inadequate. The floods do not shine in the right place. The crewmember's head and hand shadow a pad when trying to write. When it is dark outside, the lighting is poor. The integral lighting produces an excessive amount of heat and no use was found for the panel integral lighting. Integral lighting for the CRT keyboard was essential for use during a darkened cockpit operation such as COAS work.

Lighting for the MS launch and entry positions was not evaluated in flight but based on the SMS it appears inadequate.

Adequate illumination to allow the flight crew to read and write is mandatory. In rectifying this deficiency consideration should be given to making the remaining light controls accessible from the crew seats during launch and entry.

o <u>Lockers</u>. The lockers are designed to be held closed by magnetic latches, however, the doors and latches are useful to hold onto for translation and restraint. If they are not latched, they can't be used for that purpose.

The doors served as very useful storage areas for small items as well as food trays.

Some of the locker doors were very difficult to latch because the thumb latch on one door interfered with the adjacent latch. The threads on some of the latches became cross threaded and impossible to tighten. At best, the male part had to be jiggled with one hand while the female part was threaded on.

Some type of net restraint, preferably sectioned, is needed in drawers with small loose items. If this is not done in two drawer lockers when the inner drawer is pulled out, items from the lower drawer will float up and jam the upper drawer preventing it from being closed.

The ball locks on the sleep restraint pip pins did not firmly mate with all the locker latches causing difficulty in setting up the sleep station.

Utility Outlets

o STS-4 used all of the mid-deck utility outlets for both AC and DC power. Cables had to be routed from the flight deck to the mid-deck to support several operations.

As the Orbiter becomes operational it will not be unusual to find increasing requirements to supply AC and/or DC power to carry on mid-deck equipment. The use of batteries should be avoided because of their stowage volume and weight. It is entirely conceivable that a desire to access the Orbiter data buss structure from the mid-deck will also materialize.

o Restraints. A system of restraints should be developed for flight use that retains as much flexibility and versatility as possible. A restraint is useful for getting items in and out of the lockers. One can restrain himself adequately by wedginghis toes under the bottom row of lockers, however, this was not helpful for access of the top locker row. The toe restraint was also good for food prep and eating with the trays installed on the middle locker doors.

A foot loop of tape around the cabin temperature controller access door was tried. When both feet were inserted and pointed slightly outward, adequate and very comfortable restraint was obtained.

The handholds on the CFES components were very useful. Consideration should be given to some sort of removable handles for the locker doors to aid translation and locker access.

Suction-cup shoes were evaluated and worked fairly well although they had two undesirable characteristics. They did not always release easily, and more annoying, they sometimes released prematurely without warning.

A restraint is very useful for taking photographs from the overhead and aft windows. This area should be studied.

The whole area of restraints should be done in flight in the proper environment, not in 1g. Restraint "cut-and-paste" kits should be prepared and flown to arrive at the most useful and versatile schemes with dedicated crew time scheduled for evaluation and development.

o Sleep. Sleep requirements and ability to sleep vary with the individual. The mid-deck area is noisier (∿ 69 db) than the flight deck (∿ 65 db), fans being the big noisemakers. The PLT slept on the mid-deck on a sleep restraint stretched across the MF43 lockers and the CDR slept floating behind the seats on the flight deck. The only time the CDR was awakened because of bumping into things was during PTC. He used the sleeping bag only for thermal control. Neither experienced any difficulty sleeping. The WCS is noisy and its use would probably awaken the average sleeper although it did not awaken the PLT. The mid-deck was darkened for sleep. Light shafting in from the flight deck awoke the PLT once. The flight deck shades were usually installed for sleep by the CDR dependent on vehicle attitude.

For shift operations, consideration must be given to isolating the sleep area from both noise and light. It should be remembered that today the mid-deck serves as the kitchen, bathroom, experiment area, message center and gym. With larger crews it is probable that individual isolation or at least some form of restraint may be required to make the space usage more efficient. Some method of isolating the sleep area must be found before multi-shift ops can become practical.

o SMU. The speaker-mike unit was used very successfully on FD2. The ability to operate without wearing a headset, yet allowing constant air-ground communications is very desirable. This became a routine configuration for meal and sleep periods. Today's configuration is cumbersome to use because of the precautions which must be taken to avoid setting up a totally disruptive squeal.

Even the best personal electronic communications device will become a bother when worn continuously. The STS-4 crew found that removing the LWHS during meals and certain other operations was not only more comfortable, but was, on occasion, necessary. The only configuration which worked satisfactorily was to use the SMU in PTT On A/G only. Even then, when the crew transmitted, they had to insure that the second SMU was off to avoid a devastating squeal. This meant turning off all WCCU's and the flight deck SMU during meals. Both SMU's were used during sleep periods to provide redundancy. This only worked because no spacecraft transmissions were anticipated.

The operational Orbiter should allow the SMU's to be used simultaneously as an intercom between the flight and mid-decks as well as for A/G. It would appear that a feedback supression circuit could be developed to work analagously to a noise cancelling mike.

o Headsets and WCCU. The WCCU was an essential device for smooth operations. It was found that some locations in the spacecraft caused static in the intercom loop, but it was still preferable to the HIU with its inherent constraints to mobility.

The PLT's WCCU appeared to fail about halfway through the mission. The spare unit was used with no further problems.

Post flight examination indicated that the antenna may have broken. This was the same problem experienced on STS-3 and numerous times in training. The semi-rigid antenna is located at a very awkward position and is often snagged/bent by leg activity and on equipment during translation. The SMS has been supplied with a chest mount and softwire antenna which ought to avoid these problems in training. If it works in training, it ought to work in flight also.

The earpiece/mike boom design is poor. The ear hook unit that holds the mike comes off easily with small head movements. Replacing the ear unit causes loud intercom noise to others on the loop and is very annoying. If one wears glasses continuously, the earpiece clip alleviates this problem.

Perhaps the mike boom can be attached directly to the molded ear insert. In any event, the present scheme is unacceptable for long term operations. It appears that the current unit exhibits three related problems. The ear clip isn't sufficiently rigid to allow restraining the mass when the head is moved. It also is very sensitive to the inherent rigidity of the electronic cable. Many crewmembers wear glasses only temporarily and the LWHS design should neither depend on wearing glasses nor should it interfere with easy donn/doff of glasses.

The most significant of these problems appears to be the lack of flexibility of the electronic cable. Every effort should be made to remove the EMI shield and use more pliable cable covers. These small forces become significant in zero g.

Several candidate mountings and cables have been evaluated on the ground and look promising. They should be evaluated for suitability inflight.

o <u>VW Pouch</u>. Three VW pouches were evaluated inflight, one across the airlock hatch, and one on the back of each ejection seat. These were the most useful temporary stowage devices on-board and not enough good things can be said about them. They were used to stow each day's film supply, camera lenses and filter, spare WCCU batteries, drink containers, etc. They were extremely useful for small component management on the flight deck. Such stowage devices should be made a permanent part of the ship set.

One small flaw in the design was noted. There needs to be a stiffener behind each pocket opening so that the elastic does not draw in the back and allow the pocket to open. The concept has been proven; it only remains to refine the design.

<u>Crew Equipment</u>

o <u>Watches</u>. A good watch would aid orbit operations. A digital watch was used by each crewmember.

Individual crew requirements should be defined and evaluated in the SMS. The technology in this field is changing so rapidly that the practice of allowing each crewmember to select his own flight watch should be continued.

o <u>Kneeboard</u>. A standard pilot kneeboard was evaluated and found to be superior to the notebooks. They did not get in the way and were very useful for taking notes during A/G passes. The particular kneeboard used, however, was not considered optimum. The large head for a light was more a hindrance than useful and the light was not even functional. A less bulky kneeboard should be evaluated on future flights.

o <u>Clothing</u>. Each crewmember evaluated a standard flying suit as well as the Shuttle two-piece IVA clothing. One crewman preferred the flying suit while the second gave the IVA clothing the edge on convenience.

1. <u>Flying suit</u>. Both crewmen agreed the flying suit needed a different pocket design to be most useful for space operations. A thigh pocket similar to that on the IVA pants was suggested. One crewmember stated the coverall was inconvenient for WCS operations and did not lend itself to the layer concept for temperature control, i.e. there was no shirt to remove if one became warm. Both agreed the suit was very comfortable to wear. One distinct advantage, however, is the demonstrated fact that the flight suit works equally well during 1g training as it does in flight.

2. <u>IVA clothing</u>. One crewman did not like the two-piece concept for training since the weight of items in the pockets tended to pull the pants down. This was, of course, not a problem on-orbit. Coveralls did not generate this problem. The IVA shirt pocket design was not good for stowage of pencils since the point tended to stick into the knit fabric instead of going easily into the pocket. A pocket liner or a pencil pocket would help. One crewman complained of the tightness of the waist elastic. This is not needed for orbit operations and perhaps a non-elastic, but adjustable, waist band could alleviate this problem. Both agreed that the lower pockets on the pants were too baggy and a normal pocket would be better for tissues, etc. Both also agreed that the pants were too baggy.

o <u>Entertainment</u>. Some sort of music playback is needed for entertainment. The recorder carried on STS-4 was of poor quality. The requirement that only GFE tapes could be used and all music had to be re-recorded on them is particularly annoying and unreasonable. Commercially available tapes should be authorized for flight. A good recorder/sound system should be a permanent installation for the Orbiter for the Ops era.

o <u>World Map</u>. The roller world map was used throughout the flight. It was the only display that allowed looking ahead to which ground stations would be crossed and over what part of the world the spacecraft would fly. This information is essential for planning.

The map is cumbersome to use at best. First, the AOS/LOS program must be exited in the HP-41 and the MET program called, this taking several minutes. The longitude of the ascending mode and minutes past the ascending mode are then calculated in the MET program. The event timer is set to the time past the ascending mode and counting up. The roller map is then adjusted to put the ascending mode at the right place. The AOS/LOS program must then be recalled to get the AOS/LOS displays (several minutes). This process must be repeated every couple of orbits to keep the map current.

A substantial portion of the STS-4 mission activity was tied to the spacecraft's position over the earth and its relative attitude. The crew should be able to quickly determine their position and attitude with respect to the earth in order to efficiently execute the flight plan and provide the essential flexibility necessary for them to capitalize on their unique vantage point while accommodating the high relative speed of advance. This capability will always be paramount in achieving productive use of men in space.

Until TDRSS becomes routine, the crew will require a big picture of the communications capability which is also ground track dependent. Today, the best way to do this is with the world map.

Today's SM OPS display shows a pictorial antenna pattern which has little utility. If this OPS display were replaced by an electronic world map, it would be the most useful display in the spacecraft.

Since knowledge of earth relative position and attitude is essential for good flight planning, a display should be immediately developed which provides the current position, future ground track, major earth features, relative spacecraft attitude and day/night terminators.

o <u>HP-41</u>. Four HP-41 computers and a card reader were carried onboard. Three had CAP alert programs and the other carried an AOS/LOS program as well as a stopwatch and countdown alarm function. The large number of CAP alerts utilized in the planned mission required breaking them down into three load segments. One segment was preloaded into each of the CAP alert units to avoid having to use the card reader or real time loads. Both the card reader and printed alert lists were available in case one of the calculators had to be replaced.

Each day's activities were stored with an MET timetag. An alarm sounded as each event came due. The purpose was to relieve the crew of clock-watching and allow them to concentrate on any particular task without fear of missing a time critical event. This worked very well in training, but did not work well in flight for two reasons. First, the alarm tone was too faint to be heard from more than several feet away in Columbia. Second, the timer module stopped on numerous occasions. The concept of using audible and visual aids as a means of improving crew efficiency on-orbit was demonstrated during training. Once the crew incorporated these tools into their procedures, it became very difficult to do without them on-orbit. It is unlikely that the HP tone volume will be increased. However, an external tone booster should be very simple to build. Just as a point of interest, the crew did try using an HIU to put this tone on the SMS ICOM. The SMS would not pick up the HP frequencies even though it did work on the CFES. This was not evaluated in flight.

How to assure ourselves that the alert program time function can be relied upon is equally as important as and potentially more difficult to solve than the tone volume issue.

The nature of the HP timer problem has not been identified as yet. The crew believes the orbit problem was the same as encountered several times during SMS training. Prior to flight, this behavior had been attributed to specific timer modules since this problem could not be repeated in the office. In flight, all three alert program calculators stopped at least once although the AOS/LOS unit ran the entire mission. In retrospect, the crew has never seen the AOS/LOS program halt, only the alert program. Therefore, procedural error or EMI are the current candidates.

Even without these two problems the HP utility would still have been compromised because of the **massive** CAP changes which were invoked. These could have been entered manually had the time been provided, however, a much more versatile solution would be to uplink this from the ground. Eventually, a basic Orbiter capability should be the ability to update both summary and detail CAP's automatically on-orbit. In fact, it should even allow execution directly from the CRT using it as a master checklist. The cost savings which may be realized by replacing printed pages with magnetic tape just might pay for itself as well as enhance the Ops era capabilities.

This is a fundamental crew tool which should be permanently implemented in the Orbiter DPS. As an interim measure increased volume on the tone and a fix for the program halts is required.

Operational Flexibility

o We should strive to achieve flexibility in the operations era for such things as velcro installation and launch stowage. Velcro hook and pile should be carried in adequate quantities on each flight to allow installation where needed. Post flight safety inspections should be the only requirement and eliminate costly mapping and removal of unmapped velcro.

  Problems were encountered close to flight date getting last minute required items onboard the spacecraft. There will probably always be last minute stowage items and crews in training should not have to devote precious time to such worries.

  While stowage must be controlled, the present systems seems unwieldly. STS-4 was told there was no more stowage room even though much of the locker space was occupied by foam cushions. When this condition was challenged the crew was reminded of the high cost of producing new stowage drawings. Now that all locker stowage is managed locally at JSC, it would apppear that a streamlined system could be devised that would provide both flexibility and control at a reasonable cost. Why not reserve one locker specifically for late changes?

Mission Documentation

o Mission documentation is often taken for granted, however, it can be a major output of any flight. This documentation takes several forms, still and movie pictures, VTR tapes, voice tapes, written notes and voice transcriptions. The use of each also varies considerably from that required to fulfill mission objectives to post flight PAO pictures. Each use must be identified preflight and the appropriate method of documentation selected. Any on-orbit documentation takes a surprising amount of time and should be streamlined as much as possible. The post flight period is also quite active and does not allow much time to search for data. If the data is hard to acquire, it generally is ignored.

- <u>Microcassette</u>. The STS-4 crew made extensive use of the microcassette recorder for general thoughts and observations. This approach has the virtue that it is relatively easy to get hold of these cassettes as memory joggers post flight. The ICOM and A/G channels can be provided, however, each segment has to be asked for individually by MET and may take several days to retrieve. STS-4 intended to use this ICOM data source only for launch and entry to minimize the data retrieval problems. Launch and entry happen fast enough and contain so many events that one's memory can easily be fooled. During ascent, the CDR gave a running commentary of what was happening, what the crew was doing and the current velocity or event. This made the reconstruction relatively simple and reminded the crew of numerous details they had forgotten. During entry the commentary was significantly less and has made the reconstruction of events much more difficult and unreliable. This is one area where practice in the simulator would have helped.

- <u>Photos</u>. Photo documentation presents a unique problem depending on the type of photo and camera used. The 35mm now has a data back that prints hours, minutes and seconds on each frame if desired. This is a big help, but would be much more useful if days, hours and minutes were recorded. The option to print seconds should be retained for some engineering data.

  1. <u>70mm</u>. The 70mm system is used primarily for out the window scenes and currently has no data back. These scenes are generally taken when the opportunity presents itself and for some purpose. Today, the crew must rely upon their memory of the what and why, and make a voice or written note. Memory seldom is accurate a week after flight and unorganized notes are almost impossible to correlate. Adding to the problem is the coarseness of the 70mm film magazine counter. A day/hour/minute data back is available and should be used for all out the window pictures. Some commercial still cameras now feature a limited voice recording capability. This ought to be investigated for Shuttle applications.

  2. <u>VTR</u>. The VTR system is a powerful tool for engineering data, training material and general public relations. The cabin cameras have a tremendous depth of field and low light level capability. One advantage is that cameras can be set up to document a long sequence of events such as deployment of an upper stage. The camera can be placed out of the way and the VTR left running. The shortcomings of the current system are:

     a. The VTR should not be continuously run longer than some TBD time because of potential thermal problems. If this is a valid contraint, an audible alert should be triggered either by a timer or a temperature sensor.

b. There is no alert when the VTR runs out of tape.

c. The camera is very bulky and therefore hard to manage for some shots.

d. The VTR cannot dump its audio channel to the ground in real time.

e. The tape counter on the VTR is all but unusable because of its location.

f. A fast scan feature would be a very useful addition to aid in air to ground editing and playback.

3. 16mm. The 16mm camera system is antiquated. It should be replaced with a system which includes an automatic lens, through the lens viewing and enough film to allow at least a 24 fps film rate. In addition, the mid-deck illumination needs to be increased so that the lens does not have to be used at its largest f-stop. Incorporation of the above will insure movie vs. sequence photos, proper focus, scene content and exposure. The current system has been pushed to its limits and requires an inordinate amount of crew time and training.

4. Future Systems. Speech recognition devices are currently available today. Future spacecraft documentation systems should consider this as a way to not only direct voice comments to a dedicated recorder, but could also provide a way of cataloging comments by topic to speed up the post flight and in flight review.

APPENDIX D

OPERATIONAL OBSERVATIONS

This section is intended primarily for the members of the Astronaut Office. In addition to objective observations, a number of these comments include opinion, judgement and the operational philosophy of the STS-4 crew.

Pre Launch

o The Health Stabilization Program, as implemented for STS-4, had a minimum of annoyances. In fact the semi-isolation contributed to the relaxed pace of the final week.

o The KSC protocol is excellent in content and execution. The only area recommended for review is the now "traditional" PR. Having the press waiting at the airport for the arriving crew is a risky practice. The STS-4 crew diverted into the SLF due to weather and left the press standing in the rain at COF. That is bad PR, but PR committments ought not be a factor in deciding the best place to land. The "Last Supper" aura of the launch day breakfast ought to go because it runs counter to the operational impression we are trying to convey. Granted some PR is appropriate, maybe a mini press conference could take the place of these other events.

o Weather can be a factor in determining when the crew leaves for KSC and the route selection. The STS-4 crew had to divert into Tyndall AFB enroute. Honoring the spirit of the health stabilization program made this unanticipated turnaround awkward. Consideration should be given to having a primary contact go along when weather is a factor.

o Since the L-2 T-38 local aerobatic flight was missed, it was rescheduled immediately following the L-1 STA and was conducted from the SLF. This worked very well and should be considered as part of the routine.

o The vehicle systems briefs were streamlined by having the charts sent to JSC at the beginning of the week. This allowed the crew to do their homework and eliminate discussion of things everyone was already familiar with. This procedure saves time for everyone and is recommended for continuation.

o The discomfort experienced from being strapped in on the pad is minimal for the first hour and a half, then increases noticeably during long hold periods. Partially unstrapping allows enough movement to significantly relieve pressure points and allows much greater stay time. Long duration comfort of the Ops seats in the vertical position should be evaluated and if necessary, some thought might go into developing techniques for partially unstrapping and unaided resecuring of the restraints.

o The ET nose can be seen from the cockpit if the seats are at the top of their vertical travel.

- We had a late morning launch which put a lot of sun in the windows. It was noticably warm with the sun shining directly in, but not uncomfortable with the suit flow. The sun reflecting off the pilot's suit made it difficult for the CDR to read CRT #2 on the pad because of reflections, however, this problem disappeared shortly after launch. The lighting controls cannot be reached when strapped into the launch position so it is important to consider adequate lighting before the ASP departs. This may be significant for late afternoon launches where the transition to darkness may occur prior to the completion of OMS #1.

Ascent through OMS #1

- The ascent felt very much like the Saturn except that the vibration and g levels were reduced. Previous crew descriptions were quite accurate. The Shuttle second stage qualitatively felt smoother than either the S-II or S-IV. There was no buzz or indication of POGO. The major motion sensations associated with ascent events were the prelaunch SSME slew, liftoff, SRB tailoff and pre-MECO throttling. The air noise became obvious below 35,000 ft. Vibration frequency and magnitude seemed to reach their peak near 35,000 ft. The vibrations diminished noticably around M=2 (∿ 70,000 ft) and became very low by M=2.7.

  The only real indication of SRB separation was the flash from the sep motors. The acceleration change at SRB separation could be read on the AMI, but was not physically noticed. After staging, the two window mounted DAC's could clearly be heard. At approximately 2g, body movement was noticably affected. By 3g it was very restricted. Much to our surprise, breathing became conscious at 3g. At 3g, prior to MECO, the SSME shutdown PBI's were very hard to see and reach.

- One of the DTO's called for a visual assessment of any debris which would be seen around the vehicle during ascent. Specific questions concerning size, shape, color, velocity and source were added to a post insertion debriefing guide. The STS-4 crew tried to comment as often as possible during boost using the ICOM tape recorder to document these observations in real time.

  The first observation was made after completion of the roll program. There were a lot of small particles going by which the CDR describes as looking like flying in a light snow shower. This was most apparent looking out the CDR's side and quarter windows. This apparent assymetry may be real or due to the sun angle.

  This same "snow shower" was observed several more times during ascent. The apparent density, velocity, and appearance of these sparkling particles appeared to remain constant throughout ascent. In fact, this same phenomenon was observed after ET sep and again following OMS #1.

  These particles were noted throughout the flight. Their appearance remained uniform although the concentration seemed to diminish as the mission progressed. Towards the end of the mission, there were very few particles, although they seemed to be more prevalent following a jet firing.

- At ET sep, the glow from the downfiring jets could be seen. This was not the case on-orbit and may be due to the low altitude.

- The auto-TAL software appears to work very well and ought to deliver the Orbiter to a landing posture with a high degree of confidence. At the end of TAEM, however, the CDR is solely responsible for landing a heavy weight vehicle on a short R/W with no aids other than his judgement and experience. The amount of effort the program expends in order to assure that the Orbiter can be stopped on a 15,000' fully supported R/W seems inconsistent with our approach to a TAL landing. Both ROTA and DAKAR are only slightly longer than 10,000 ft and today neither are equipped to aid the pilot in executing a landing. As a minimum, PAPI's should be installed at any TAL landing site until HUD performance has been shown to be inadequate. Some form of aim point may always be required.

<u>On-Orbit</u>

- MCC noted that one of the RCS DAP PBI's on C-3 had not made all of its contacts. Post flight inspection showed that if the PBI was lightly depressed enough contacts would be made to cause the function to respond, but not all contacts would be closed. The STS-4 crew noted that PBI's on C-3 were awkward to push in zero g unless the crewmember was restrained or used some means to help apply force to the PBI. In zero g the body's inertia may not always be enough to apply the necessary force to these PBI's. For OPS transitions where the DAP PBI's had to be held down, the crew found it necessary to use their spare fingers to grab the panel overlay in order to apply continuous pressure to the PBI.

- The EMU prep activities were exercised in the airlock by a single crewman. All procedures worked well. The LTA could not be attached to the HUT without the use of the donning aids. With the donning aids, the task was easy. The second EMU was pressurized and left mounted on the airlock wall to allow evaluation of mobility with two pressurized crewmembers in the airlock. Only the manned EMU used the portable work restraint. The ability to turn around and over, as well as reach hatch mechanisms was found to require preplanning but was feasible.

- It was noted prelaunch that the air flow on the PLT's vent was much higher than that delivered by the CDR vent. Sometime on-orbit it was noticed that this flow pattern had been reversed.

- The RMS control precision and harmony was excellent. The CDR, with very little preflight practice, was able to quickly execute a grapple task. The RMS rate hold capability was demonstrated by pointing the end effector CCTV cross hairs at a cloud and allowing rate hold to maintain this pointing even though the spacecraft was in an inertial attitude hold. The auto function was very smooth and corrections were easy to make although seldom required.

- The RMS unloaded tests appeared to validate the preflight predictions of arm response to PRCS firings. The amount of flexure and frequency is such that they must receive special care when manipulating large or massive payloads. The arm flexure was hard to see when just watching it against the earth background. It looked like it was steady against the moving earth features and then would slowly move in apparent jumps. When viewed through the CCTV or against parts of the Orbiter, the natural periodic motion was quite apparent.

o Star tracker operations normally were very rapid. On only one occasion did the star tracker seem to take an unusually long time to acquire a lock on. The only obvious difference in this case was the presence of a brightly illuminated horizon in the general direction that the -y tracker was pointed. The star was eventually acquired although it took several minutes.

o The PRSD stratification test required two 180^{o} pitch rotations. These were executed using the pitch axis in accel with roll and yaw in DRC. It was noted that after returning the RHC to detent in the accel mode that the vehicle rates, as displayed on the ADI, continued to accelerate for a short period.

o When the FLT CONT PWR was turned off following OMS #1, the DAP downmoded from auto to manual and fired some jets. This was the only occurrence on STS-4.

o The WCCU batteries were replaced as part of the presleep activities each day rather than according the the CAP schedule. The batteries held up with this duty cycle.

o The PLT noted icicles on the center SSME engine bell. They disappeared sometime before the end of FD2.

o The PLB liner appeared to be intact except for a small opening approximately 6 inches long under the P/L pallet.

o Both inboard and outboard elevons could be seen and they appeared to slowly drift throughout the mission. No correlation between circ pump operation and drift was noted.

o The theodolite was very easy to use and its readings appeared to be very repeatable. The PLBD centerline targets are very difficult to find aft of about the mid PLB. Use of approximate angles, determined preflight, and the handheld flashlight made this a viable task.

o During the RCS plume survey, the crew had an opportunity to pay close attention to RCS thruster characteristics. In general, the forward primary jets shake the vehicle quite impressively. The signature is one of two large amplitude shocks for each firing. The first shock occurs when a firing is initiated and the second, when it is terminated. Both are felt even on an impulse burn. The aft primary RCS exhibit the same characteristics, but the cabin level shock is substantially less than with the forward jets. There are no sounds during the burn between start and stop. The plumes from both the primary and vernier thrusters can be seen plainly at night or against a dark background.

The STS-4 crew noticed that the up firing aft jet plume appeared to have a second emanation when firing was terminated. This was not noted for any other jets.

- The PLB CCTV was used to view the earth at night in moonlight. The camera easily picked up stars, clouds and lightning as well as vernier thrusters. PLB details could easily be seen in moonlight. The top of the atmosphere (∿ 90 km) was easily distinguishable as distinct from the earth's horizon.

- Both crewmembers could easily feel vernier RCS firings by FD5. These were perceived as a low amplitude, soft wiggle. They were more perceived than felt.

- Items are routinely lost on-orbit, i.e. if unrestrained, they float away. Typically, they could be found on the DEU screens on the flight deck and behind the DFI package on the mid-deck.

- The micro-cassette recorders were used to record thoughts and data for use in preparation of the post flight debrief. The crew used these extensively in training, but found there was not as much time to use them on-orbit as had been anticipated. However, their use provided much more data than would have been obtained otherwise. They worked perfectly and did not even require a battery changeout during the mission.

- The top of the glareshield makes an excellent stowage location for small articles. Temperatures did not become high enough to cause any concern.

- The humidity in the spacecraft remained at a comfortable level throughout the flight. The temperature of the spacecraft varied with the attitude, being warmer in PTC than in tail-to-sun. The temperature was slow to respond to changes in the controller setting. The mid-deck remained warmer than the flight deck. During a DTO that called for the flood and integral lighting to be on, it was noted that they radiated considerable heat. Both crewmen perspired profusely during the test while on the flight deck. The cockpit was slow to cool at the completion of the test.

- What an observer can and cannot see from orbit has received a lot of discussion. All crews have reported that they saw a great deal more than what shows up in their pictures. STS-4 was no exception. Examples of things noted with the naked eye from 160mm altitude are: ship wakes, major freeway systems, the VAB from over Key West, R/Ws, population centers, and aircraft contrails were seen as shadows on cloud tops.

  Looking through the 10x binoculars or through the 250mm lens on the 70mm camera, ships of destroyer size could be seen but not identified according to type.

  Ten power binoculars are the maximum magnification that are practical for hand held use. Gyro stabilized binoculars should allow at least 20x. One additional feature that should be included in any optical mangification system is a way to easily switch between high magnification and no magnification. This is necessary to allow orientation and target acquisition.

- How tired should the crew allow themselves to become? The STS-4 crew tried to remain relatively alert as long as a de-orbit opportunity existed. Once the nominal access to recovery sites passed, the crew allowed themselves to become more fatigued to the point where anything other than emergency deorbit with its attendent adrenalin would not have been prudent. This subject is worth thinking about preflight.

Payload Support

- The CFES equipment and procedures worked well. Preflight, the crew was concerned that they might not be able to hear the CFES alert tone if they were on the flight deck. A test was conducted on FD1 which confirmed that an audio boost would be required. The mid-deck ATU was used in VOX with an HIU which was taped adjacent to the CFES speaker. This worked well.

  The CFES was designed to a specification alert tone frequency and volume. The Space Program has encountered this problem before and apparently there is a need for a spacecraft unique audio alert criterion.

  The volume on the CFES tone should be increased for future flights. NASA should develop an adequate audio alert tone specification or if one exists, insure it is made available to all Shuttle customers.

- FD3 was expected to be the most demanding day of the mission because it involved two very long RMS/IECM time dependent sequences. The PLT had practiced these sequences extensively preflight and determined that there were virtually no margins in the timeline. To add to the difficulty, these two sequences were constrained by a scheduled burn at the end of the last one and a minimum time for the IECM to be parked on the REM in between. The entire flight planning community had tried unsuccessfully to relax this timeline or its constraints for months prior to the mission.

  An RMS anomaly, discovered during the initial checkout, set the day's timeline back one hour. This would have destroyed the rest of the day's timeline if the IECM representative had not immediately volunteered to cut the IECM/REM time to 30 minutes between sequences. The PLT then ran the entire set of sequences and picked up three RMS shopping list activities while meeting the burn constraints at the end of the day. The first IECM sequence took six seconds longer than the two and a half hours scheduled. The primary reasons the PLT was able to accomplish this feat were that he had trained extensively preflight then worked at an unforgiving pace in real time, experienced no further anomalies, and finally, the MCC team exercised exceptional comm discipline and anticipated every required input. The only unfortunate aspect of this day was that after it was over, the IECM representatives discovered that the IECM internal sequencer had not responded properly and was not in the proper configuration for the final two hours of the plume surveys.

  The reason this day's schedule was so messy can be directly related to the IECM thermal constraints. Apparently, these were not hard constraints since they were substantially relaxed in real time. The loss of data occurred because of the total absence of any ground or on-board monitor capability of the IECM. Its malfunction was diagnosed parametrically during the evening and operation restored later in the mission. The fact that the crew worked very hard for several hours on a non-functional objective is unfortunate to say the least. Now the survey must, presumably, be reflown and that time which could have been used to do other activities, was essentially wasted.

The IECM was not designed for the use we put it to. Rather, it was adapted. Nevertheless, this experience raises a question about what role the operators should play in experiment design. All of the design shortcomings, which made the IECM operations awkward and unrewarding could easily have been circumvented had they been addressed early in the design cycle. The operators should be involved in the design review process. This ought to be mandatory for NASA payloads and optional for commercial ones.

o The NOSL experiment required a disproportionate amount of crew orbit time because of the nature of the experiment and the hardware design. The purpose of the experiment was to photograph lightning discharges in both the daytime and at night. The equipment was very awkward to use from the spacecraft cabin due to the number of components and their size. The night time photography was further compromised by the requirement to darken the cabin in order to avoid window reflections and the fact that the optic train, including a difraction grating, attenuated light to the extent that lightning discharges could not be seen through the lens.

Lightning is not scheduled so it was decided to let the crew use their judgement in selecting photo opportunities. During the mission MCC "suggested" specific target areas which required a lot of crew time to support. A one minute photo sequence usually required five to ten minutes of crew time and at night affects both crewmembers because of the need to turn out the lights. After all of this was done, the crew believed that their own targets were more active than those they were sent after.

The best way to operate this type of experiment is with one of the PLB CCTV systems since these cameras clearly "see" lightning, can be pointed and tracked over a wider field of view and do not require the cabin to be darkened.

The following observations should be considered for future experiments.

o Experiments to be flown in the Orbiter cabin should be coordinated with operations personnel early in the conceptual design phase to preclude the problems encountered with NOSL.

o Experiments which are better managed on-orbit should be.

o Experiments which require substantial crew time must be recognized and planned accordingly.

Deorbit, Entry and Landing

o The last crew activity on FD7 was a detailed review of deorbit burn procedures and entry/landing techniques. This review was conducted at the flight deck forward station and used the cue cards, checklists, etc. in their entry day location. This was not only a good mental exercise, it also verified that all entry data was indeed in place.

- The transdap pulse **size** is relatively small and requires a lot of RHC activity to counteract the evaporator and APU exhaust venting.

- Once in MM304, two aft RCS yaw thrusters are fired as a minimum. They were as noticable as the forward thrusters. The crew couldn't tell if this impression is due to their increased personal sensitivity or some other phenomenon. The aft thruster plumes were observed causing a glow around the vehicle nose prior to sunrise and after EI.

- The entry control system seemed very tight. The number of RCS firings, as indicated by the RCS activity lights, appeared to be less than what is normal in the SMS.

- The ionization glow was basically reddish orange compared to the white sheath noted during Apollo lunar entries. The crew did not observe the area of recombination. All evidence of this sheath disappeared at sunrise.

- Just after the first roll command (~ 300,000 ft altitude) both crewmembers commented on what they perceived as turbulence. The amplitude of this sensation came and went throughout the entry. Preliminary post flight analysis indicated that this may have been a vertical fin bending mode.

- The combination of 40^0 α and an 80^0 bank angle produces some unique visual sensations when looking down at the cloud tops going by sideways.

- At ~ M17 the CDR felt it appropriate to adjust his seat up to maintain the proper instrument panel and window picture.

- Shortly after PTI-0 (structural) was selected at M=2.1, the CDR felt the vehicle "shake". Preliminary data indicated this may have been caused by a low frequency roll oscillation seen on previous flights.

- The transonic buffet is very noticable and peaked at M=.9 followed by a very rapid damping.

- CSS was used for S/B control from M=.9 through rollout. The auto system commanded S/B retraction at approximately 4000' altitude. Approximately 50% S/B were retained until 2500' with an A/S of 287. CSS was used from M=.9 (pitch and yaw/roll) to ~ 45^0 of HAC turn remaining. Auto was then selected with a mode to Autoland at 9600' AGL. CSS was reselected at 2500' and maintained through rollout.

- The landing was near nominal from preflare through rollout. Preflare was initiated on a radar altimeter cue with the ADI pitch rate used as an aid. The nominal preflare initiation altitude is too high for the CDR to execute it repeatably using out the window perspective only. This does not mean it cannot be done safely - just not repeatably. The landing gear was deployed at approximately 400 AGL and could be felt, but not heard. A very shallow final approach was flown to minimize pitch corrections near the runway. During the entire final approach the PLT called altitude and airspeed. This is not an ideal data transfer mechanism, but is required until the HUD becomes available. The CDR relied more on the PLT's altitude calls than he did on his perception of altitude during the final flare. At touchdown, the CDR felt he was actually higher than what the PLT was calling out. The final flare was controlled by flying pitch attitude changes, in a semi-open loop fashion, to control the PLT's altitude callouts. The CDR had intended to make some grease pencil marks on his window to aid in this task, but a survey of the windows prior to entry indicated that there were enough natural smudges to function as attitude references.

Touchdown occurred near 200 KEAS. The nose was left at the landing attitude until the PLT callout of 180 KEAS when a 1^{o}/sec pitch down was initiated. The RHC was returned to detent as the nose approached the horizon and not touched again until the nosewheel was on the runway when full nose down was commanded to off load the main gear. The nosewheel touchdown was much softer than had been anticipated. Full S/B was selected after main gear touchdown. No conscious directional controls were applied during rollout. Braking was initiated at 140 KTS ground speed. The target value of 10 fps^2 deceleration was not achieved. The peak value noted was 9 fps^2. The crew believed that the antiskid was cycling during the initial braking. The CDR was frustrated by this inability to obtain either the target or a smooth level of deceleration. Braking was relaxed as the Orbiter slowed to less than 60 KTS with lots of R/W remaining. The 4000' remaining marker was slightly ahead of the Orbiter at wheel stop.

The Orbiter is a difficult aircraft to land. Successful landings require very high concentration levels and a conscious effort to minimize anything but very minor pitch corrections below approximately 100 ft AGL. The pitch control loop is very crisp and acts more like an attitude hold rather than a rate command system. A natural characteristic of the Orbiter geometry is that due to the relatively large elevon area, the apparent center of rotation is forward of the cockpit rather than close to the CG as in most aircraft. As a result, when the pilot puts in a pitch command, there is a delay in flight path response at the cockpit of one-half to one second. This means that the pilot cannot tightly close the loop on ḣ but rather must estimate how much pitch change is required at his current airspeed to effect the desired change in ḣ. As in most airplanes, when a pitch up command is made, the loss of lift due to elevator movement causes the CG to initially go down until the lift increase due to the higher angle of attack becomes effective. The Orbiter's geometry strongly amplifies this reverse response suggesting that pitch inputs close to touchdown may not achieve the hoped for results. These characteristics are very undesirable, but can be accommodated as long as trajectories which avoid abrupt control inputs are used. The pilot's task then is to insure that his final approach is shallow and stable. These characteristics are sufficiently subtle to make the danger of landing short very real until the HUD becomes operational. Maximum brake performance has not been demonstrated yet, so the pilot cannot afford to plan on landing long just to insure he does not land short.

The STS-4 experiences prompt the following recommendations.

- o Do not plan a R/W landing until the HUD has been shown to eliminate the possibility of reasonable pilot technique producing a short landing.

- o Demonstrate max braking performance before it is required in order to remove undue conservatism from the landing rollout calculations.

- o Develop external trajectory cues to aid the pilot in smoothly executing the preflare to inner glideslope transition.

- o Eliminate the 6 fps landing sink restriction as soon as possible.

o Prior to STS-1 we were concerned about entry nav sensors polluting the PASS state vector to an unflyable degree. To protect against this potential, we elected to inhibit nav sensor updates into the BFS. This seemed like a prudent technique for the first flight. We now have four flights and untold hours of testing and simulations behind us with no evidence of this occurring. Nevertheless, we continue to inhibit the TACAN and ADTA's in the entry BFS nav. On STS-4 the MCC requested a state transfer to improve the BFS nav estimate at a time when there were other things for the crew to do. We encountered this often in simulations also.

It appears that we may be increasing the crew workload on most entry's solely to protect against a problem we have been unable to create. If this is correct, the concept of a BFS virgin nav state should be reexamined.

Flight Crew Physiology

o Crew physiological adaptation to and from the zero g environment has received a lot of attention since the beginning of spaceflight. It appears that there is a great deal of individual variation in this adaptive process which makes it difficult to discern generic symptoms. The following observations are offered solely to describe two sets of experiences.

The STS-4 CDR had one previous flight of approximately ten days duration during Apollo. This experience allowed some comparative observations although the ten year interval between flights limits the precision significantly. This was the PLT's first space flight.

Preflight, both the CDR and PLT were evaluated on the rotating chair using a standard protocol. The CDR was surprised to find that his tolerance to the rotating chair was minimal. On his first ride, the protocol had to be terminated early due to nausea. Since the CDR had no problem during Apollo and had never had any difficulty in aerobatics or on the KC-135, this test was repeated but produced similar results. The PLT on the other hand had no problems whatsoever with the chair protocol.

During the week before launch both crewmembers flew several local sorties in the T-38 emphasizing maximum roll and turning performance maneuvers. The last flight was at L-1 following the STA mission at KSC.

Immediately after insertion, while the crew were still strapped into their seats, the only evidence of zero g was the behavior of objects floating around the cabin. Some time later, both crewmembers noted that the other crewmember had "fat" faces. The CDR noted that he needed his reading glasses to comfortably use the FDF in any lighting condition. This was in contrast to his experience in training where he seldom needed to use his glasses except with poor lighting or poor zerox copies. The pilot had not noted any change, however, after being asked, he thought his corrective lenses did not seem as strong on-orbit as on the ground but the difference was not enough to cause any difficulty.

Both crewmembers began orbit Ops by moving very slowly, minimizing translations and rotations, turning the body rather than the head and attempting to maintain a good visual frame of reference. The PLT stayed on suit cooling until time to doff the EES while the CDR was off cooling for approximately 30 minutes during aft flight deck reconfiguration. Neither became warm and the suits were relatively dry when doffed. Within 30 minutes the CDR decided that moving slow was an unnecessary precaution. This experience was identical to his Apollo experience. The PLT moved slowly per plan and seemed to be enjoying zero g for several hours before he commented on having a headache and a "knot" in his stomach.

These symptoms came and went throughout the remainder of FD1 and into FD2. Toward the middle of FD2, the PLT experienced two sudden waves of nausea. The first one passed quickly and the second resulted in one short episode of explosive vomiting. As soon as this episode was over, all symptoms disappeared permanently. The effect of these symptoms on the PLT's performance was minimal. The primary result was that he did not enjoy the first 24 hours as much as the rest of the flight.

As the mission progressed, both crewmembers noted an increased sensitivity to low level accelerations. By the end of the mission, each vernier thruster firing could be sensed whereas they were transparent on the early days.

Appetite was generally diminished, however, it is not obvious if this should be attributed to the environment or to the pace of crew activity. The appeal of the food itself lessened during the end of the mission and by the evening meal on FD7 the crew had to search the pantry and meal packages looking for something they wanted. It appeared that although each food retained a distinctive flavor it all took on an aura of sameness. Perhaps one way to describe this would be as if the food had all picked up a common unappetizing taste/smell.

During entry, both crewmembers experienced a strong sensation of pitching up shortly after sunrise, possibly associated with a small bank adjustment. The vehicle drag acceleration at this point was quite low. The CDR experienced a subsequent tumbling sensation when turning his head while flying around the heading alignment circle just prior to landing.

Time compression has been previously reported during entry and this mission was no exception. Unlike the CDR's previous experience with dense timelines where it is not uncommon to feel that the clock is running fast, he described this sensation as one where the clock is normal but it is taking longer than usual to execute mental activity.

During the entry α sweeps the vehicle n_z varied between 1.8g and 0.5g yet neither crewmember was aware of these changes. This is in stark contrast with other comments about their increased sensitivity to low level accelerations.

Post landing, both crewmembers felt extremely heavy. The CDR was not sure he was going to be able to get out of the seat without assistance. He discovered that he had adequate strength to do anything he wanted but it required an attempt to overdo major motions. He described it as being analogous to a closed servo loop with inappropriate gains on the output. In contrast to this experience, he never had any trouble working on the treadmill with the ∿ 160 pound bungee forces. In reflection, one difference seems to be that the treadmill activity can be characterized as applying reactive loads, whereas the initial 1g activities involved the body sending out a command open loop and waiting for a response. Another obvious difference is that the post landing activity came some time after the application of entry g. The CDR believes that the post landing "heaviness" was much more pronounced following the Orbiter landing than he remembers from Apollo, although the STS mission was of shorter duration. The only differences noted during entry were the g-time profiles and the relative body g vector orientation.

Typical coordination problems were experienced post landing with a very rapid relearning curve. The crew walked around and did mild exercise in the mid-deck for about 20 minutes before exiting the Orbiter. The initial efforts to climb down the ladder and walk around the Orbiter took substantial concentration. Several hours after landing the crew still had to think about walking, but could do it satisfactorily. By the time the crew arrived at Ellington they were able to negotiate normally.

During the flight from EDW to EFD the crew noticed that their appetites had returned and the CDR no longer needed his glasses.

The crew had not had a great deal of sleep during the mission, however, they were not aware of any prolonged fatigue. Upon return to Houston they were both exhausted. After several days, the physical fatigue had passed, but the mental fatigue seemed to linger for several weeks. This emotional let down after the mission has been experienced on previous flights and seems rather normal considering the pace of the preceding year. It is real and should be considered in planning post flight activity.

o Throughout the flight, the crew had been forcing fluids to insure that they avoided dehydration. This resulted in far more urinations than would be considered normal. The crew had been briefed that on entry morning they should augment the forced fluids with four drinks and salt tablets. This last quart was to be consumed within two hours of deorbit. The donning of the EES three hours prior to deorbit complicated this task. On FD8 the crew prepared the four entry drinks and stowed them and the salt tablets in R-5. The PLT and CDR drank two inside D/O - one hour and drank another post burn. The PLT drank his last just prior to EI while the CDR saved his fourth for post landing.

The requirements for forcing fluids on-orbit and on entry morning should be reviewed with the aim of curtailing as much as seems prudent.

- The IECM contamination survey required a top sun condition. The CDR watched the RMS response out his overhead window for approximately a minute. Later in the afternoon, his eyes were very tired and he had trouble keeping them open. This condition eased by the end of the day and was not noted after that. Even short periods of looking near the sun must be procedurally avoided.

- Exercise is extremely important to the crew for several reasons. Just as in 1g exercise improves one's outlook and reduces tension during a tedious day's work. Exercise helps to maintain muscle tone which is important to post landing readaptation to 1g. The CDR found that exercise cleared his stuffy sinuses and that they did not get blocked as often as on his Apollo flight. Measurements taken pre and post exercise showed a reduction in head circumference and increase in leg circumference.

  Because of setup and tear down time and personal hygience required post exercise, 50 minutes to one hour should be allowed per crewman for 20 minutes of exercise. Exercise periods should be preserved with a high priority in the daily flight plan.

  The location of the treadmill allowed use of the airlock and DFI as hand holds and support. Some form of hand support should be available during exercise. The high loads applied by the bungee/harness unit are large enough to cause an injury if someone slips without any hand grips. The protocol used on STS-4 was left up to each crewmember. The PLT exercised rather vigorously while the CDR used a heart rate profile with five minutes at each level 90,110 and 150. The electronic monitor should always be available to avoid boredom and allow exercise quantization. The treadmill made quite a racket and shook the deck panels. The crew avoided exercise during activities like CFES which work better during low acceleration periods.

  The treadmill is an excellent exercise device and should be made a permanent part of Orbiter stowage.