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TRAINING FOR LIFE SCIENCE EXPERIMENTS IN SPACE AT THE NASA AMES RESEARCH CENTER

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SUMMARY

As this country prepares for exploration to other planets, the need to understand the affects of long duration exposure to microgravity is evident. The National Aeronautics and Space Administration (NASA) Ames Research Center's Space Life Sciences Payloads Office is responsible for a number of non-human life sciences payloads on NASA's Space Shuttle's Spacelab. Included in this responsibility is the training of those individuals who will be conducting the experiments during flight, the astronauts.

Preparing a crew to conduct such experiments requires training protocols that build on simple tasks. Once a defined degree of performance proficiency is met for each task, these tasks are combined to increase the complexity of the activities. As tasks are combined into in-flight operations, they are subjected to time constraints and the crew enhances their skills through repetition. The science objectives must be completely understood by the crew and are critical to the overall training program. Completion of the in-flight activities is proof of success. Because the crew is exposed to the background of early research and plans for post-flight analyses, they have a vested interest in the flight activities. The salient features of this training approach is that it allows for flexibility in implementation, consideration of individual differences, and a greater ability to retain experiment information. This training approach offers another effective alternative training tool to existing methodologies.

INTRODUCTION

The Space Life Sciences Payloads Office at NASA's Ames Research Center (ARC), is responsible for the development and operations of non-human Life Sciences research performed aboard the Space Shuttle. Experiment proposals are submitted to NASA by Investigators from the research community. Selected experiments are then developed by NASA for performance aboard the Space Shuttle. Once experiments are identified and manifested for a mission, the next important step is the training of flight crew to perform the experiments to be flown.

The objective of this paper is to describe the training approach used by the Ames Research Center Space Life Sciences Payloads Office to prepare payload crew for non-human life sciences experiments. Using a systems approach, the project office optimizes personnel and crew time within the constraints of mission schedules, equipment availability, and funding. What follows is a detailed description of the process used to train the crew, the documentation requirements, certification and final validation of operation. This approach to crew training has been successful in training crews on Spacelab-3 and most recently on STS-40, the Spacelab Life Sciences-1 (SLS-1) Mission.

CREW TRAINING FLOW

In order to prepare crew members for successful performance of the in-flight science objectives and tasks for each payload, critical tasks must be separated and identified in such a manner as to distinguish the discrete skills and knowledge required to perform. Training activities are aligned with the experiment objectives. To facilitate training, an experiment is divided into experiment sessions, which are related to the experiment objectives identified in the experiment requirements documents. Each session is then divided into distinct training modules. Modules are further divided into procedures and then into the smallest operational elements, procedural steps (fig. 1).

Training activities for all crews assigned on Space Shuttle missions are developed such that the various procedural elements flow with the training components, specifically Mission Dependent Training. Crew training for space life sciences payloads is managed as part of the overall Mission Dependent Training.

Mission Dependent Training on Life Sciences Payloads is divided into timed phases: Orientation, Task, Phase, Project Integrated, Mission Integrated, and Proficiency Training. Every component of each experiment and associated hardware is subject to the same basic training template (see fig. 2). This approach provides an ideal working model as each successive training session builds knowledge gained from the previous training session until proficiency on the integrated payload procedures is achieved. What follows is a description of each component of the training process, and how it is integrated into the in-flight operations.

Orientation Training

As part of Orientation training, the crew gets briefed on all aspects of the in-flight activities, as well as pre- and post-flight ground activities. This is an opportunity for the crew to gain a full understanding of the overall objectives to be accomplished as part of the mission. The in-flight activities are justified to the crew, which gives them an opportunity to relate to the various aspects of our activities, and help them fully understand the ramifications of the successful performance of the hardware. The training may take place at Ames or in the Principal Investigator's (PIs) laboratory. In the case of SLS-1, the crew's orientation at Ames Research Center consisted of a briefing of our experiments and orientation to our complement of rack mounted hardware (i.e., Research Animal Holding Facility, General Purpose Work Station and Small Mass Measurement Instrument), other associated hardware, and the middeck stowed Animal Enclosure Modules. They also received experiment orientation at PIs' labs for the Jellyfish Experiment and the Cardiovascular animals. For SLS-1, approximately 47 training hours were accomplished for each crew member during this interval of training.

Task Training

During task training, the payload crew becomes proficient in all aspects of the experiment objectives through intensive and in-depth lectures on Experiment Unique Hardware (EUH), stowed items, discussion of procedures, and thorough hands-on training with specimen and available experiment hardware. Task training is often accomplished together with orientation training. Sometimes a training session is offered at two different times so that every crew member can be exposed to the same material. In this way, we are able to cross-train each payload crew member.

Phase Training

This portion of training is designed to allow the crew the opportunity to complete enough repetitions of the experiment so the crew member is able to complete the experiment procedures at a defined level of time proficiency. Training utilizes the experiment operating procedures, payload specific hardware, and stowage items. This training opportunity also provides the crew with a level of proficiency which would guarantee a meaningful participation in the Experiment Verification Test, scheduled during the next phase of training.

For SLS-1, the crew logged approximately 37 hours during this portion of the training.

Project Integrated Training

The objective of crew training during an Experiment Verification Test is to conduct project integrated training of the payload crew members. Crew members must perform all ARC in-flight activities while assisting in validation of the SLS-1 timeline. The crew must be trained ahead of time in the tasks necessary to support these various experiments. Although the crew is familiar with the payload, this test is usually the first time they combine the tasks into operational procedures using flight hardware and stowage items.

For the SLS-1 Mission the crew participation covered approximately 40 hours of the total 72 hour execute shift. Crew participation was scheduled such that the crew witnessed and participated in the major in-flight activities and received systems and malfunction training during hours outside of the EVT timelined events. The verification test allows for evaluation of the 1-G timeline and also allows validation of the in-flight procedures as written for the hardware configurations and science requirements known at the time.

Mission Integrated Training/Simulations

Mission Integrated Training/Simulations is two fold; it allows the crew to develop their proficiency to a level of performance where they can successfully perform all the payload activities within the mission timeline and also allows the Payload Operations Control Center (POCC) cadre and PED support the opportunity to rehearse in-flight ground protocols. It is similar to project integrated training, but includes timeline performance of all mission experiments and other activities necessary to carry out the mission. This training occurs within a fully integrated spacelab mockup.

Locations for stowage hardware are finalized, locker foam is included, and the stowage hardware is integrated into the respective locations with the mockup. Procedure validation, designation of velcro mapping, and timelining are important elements of this phase of training. Flight documentation in various stages of development is normally used by the crew to support these simulations. In addition, the crew uses Spacelab and Orbiter equipment, consumes food to be supplied during flight, and dresses as they would during the actual flight.

During this phase, it is recommended that additional proficiency training be conducted on critical operations, this includes nominal as well as malfunction training.

The SLS-1 payload had the unique opportunity of participating in ten simulations with the POCC cadre. In addition 5 Joint Integrated Training/Simulations were scheduled with POCC Cadre at MSFC, mission control personnel at JSC, and the crew traveling between the spacelab mockup, the middeck mockup and the shuttle simulators. Each of these training opportunities simulates different start and stop times on the overall mission timeline.

DOCUMENTATION REQUIREMENTS

Working on a shuttle experiment involves a large number of people, working at different locations on a variety of activities. Crew training activities involve crew members, generally in Houston; mission management personnel, either at Johnson Space Center or Marshall Spaceflight Center; principal investigators, located throughout the United States, and project personnel and hardware, located at ARC. Publication and timely distribution of documentation are the most effective methods for coordinating information with personnel in multiple locations who engage in widely differing activities. Training documentation required for all ARC Space Life Sciences Payloads includes:

Crew Training Plan

This document describes in detail the content of the ARC training and how it will be conducted for a particular mission. It defines the number of hours required to achieve proficiency and subsequent flight performance. It describes the training approach and objectives. In addition, the project crew training plans will include appendices which address the following:

Experiment Summaries
Payload Training Requirements
(by level: Orientation/Task, Phase, Project Integrated, Mission Integrated, etc.)
Documentation Requirements Schedule
Flight Crew Training Schedule

The Crew Training Plan should be issued at the launch minus 24 to 18 month timeframe.

Milestones for Scheduling

When planning crew training, there are a number of milestones that must be accomplished before the training session can begin. Some are generic requirements and others are specific to the individual experiment or payload. These should be included in each project's sub-tier schedule for crew training. The following lists those generic milestones that are ordinarily included in a crew training sub-tier schedule:

Workbook/Familiarization Manuals Completed and/or Procedure update completed (include draft, review and signature cycle)
Room Logistics (Schedule conference rooms, labs or high bay)
Visitor Requirements
Public Information Office (PIO)/photo involvement
Training Agenda
Input from PI (for Orientation/Task Training)
To Crew
Final to Project Office
Hardware Readiness (Individual hardware items that are needed for training)
Readiness Reviews (1-2 weeks prior)
Training Session Dry Run (1 week prior)
Actual Training Sessions
Crew Debriefing after each training session
Project Debriefing

Familiarization Manual

This document provides background material that is useful for crew orientation. The manual summarizes the goals of the mission and describes each of the payload experiments and all associated hardware. Each manual is controlled under configuration management. This manual is usually distributed one month before the payload orientation session.

The basic format for a familiarization manual is as follows:

- Cover Page
- Table of Contents
- Background to particular mission
- Experiment Descriptions
- Experiment Hardware Descriptions – including labelled drawings and or photographs

Crew Training Workbook

A Crew Training Workbook is developed for each experiment or test to be flown. The workbook gives much more detail about each experiment than does the Familiarization Manual and is used by the crew as an orientation of the in-flight procedures, as a reference during hands-on training and as a post-training refresher. Each workbook is assigned a control number, and subsequent revisions are made by the Crew Training Office. Workbooks are distributed 2-4 weeks prior to experiment task training.

The basic format for the workbook is as follows:

- Cover Page
- Forward Page – which includes the instructor's (principal investigator), address, phone and general introduction statements
- Table of Contents
- Acronyms and Abbreviations
- Applicable Documents
- Lesson Introduction – covers the reason for the experiment, background, past research, rationale, methodology, expected results, references, and summary of Experiment-Unique Equipment.
- Learning Material – the bulk of the workbook, includes in-flight procedures
- Appendices – may include applicable PI publications

Depending on the complexity of the experiments or the payload, it may be necessary to combine the Familiarization Manual with the Crew Training Workbook. In such cases, it will be called a Workbook/Familiarization Manual.

Procedures

There are two categories of procedures: (1) Ground Experiment Operating procedures which detail experiment tasks, and (2) Experiment Operating procedures which are performed in flight.

Ground Experiment Operating procedures are detailed experiment specific laboratory procedures which are learned during task training. They may be more detailed or may be the same as experiment operating procedures. They may include specific specimen handling practices, surgical operations, materials processing and operation of experiment unique flight hardware. They are defined by the PI and other members of the experiment team and are part of the experiment workbook. They will be provided to the crew with workbooks.

Experiment operating procedures are discipline (experiment) oriented; they are performed in-flight. They may be the same as a ground operating procedure or they may involve several integrated experiment procedures which utilize an animal. They may also involve common hardware.

Payload Flight Data File

A portion of the Payload Flight Data File (PFDF) is an outgrowth of the nominal in-flight procedures used in the training workbooks and is revised during and after each training session. It develops with the crew's experience on the various experiments, hardware items, etc. The crew procedures are updated after each training session so that prior to Project Integrated training, the experiment procedures are converted to the PFDF format (the project's preliminary version). With each revision, the procedures are reduced from a detailed to a checklist format and requires input from the crew as they become more proficient in the experiments. The other portion of the PFDF consists of malfunction procedures. These procedures are also revised after being validated, whether through hardware verification or crew training. The nominal in-flight procedures, together with malfunction procedures, constitute a small portion of the PFDF. The PFDF consists of all documentation flown during a flight. This includes orbiter and payload nominal and malfunction procedures, reference documents and flight rules.

The by-products of Mission Dependant Training are documented in the following Payload Flight Data File documents:

Experiment Procedure Reference Book
Experiment Procedures Checklist
Stowage Book
Experiment Malfunction Procedures
Spacelab Photo/TV Checklist
Payload Systems Handbook
Payload Crew Activity Plan
Spacelab Activate/Deactivate Checklist

The final PFDF is a mission-produced document composed of project submittals.

CREW EVALUATION AND CERTIFICATION PROCESS

The evaluation and certification of crew members in the performance of experiment operations progresses through each training level in a building block fashion. The goal of training is to teach. The intent of crew evaluation is to identify areas where the training should be revised, improved or repeated. Each crew member has an important responsibility in this process. Evaluation and certification of crew proficiency in performing payload operations starts with the PI at the first level of training, moves on to the project level during phase and/or project integrated training and is finally completed by the mission manager after Joint Integrated Training Simulations (JITS).

Crew Evaluation

The following are suggested criteria to be used when evaluating crew proficiency:

1. Completion of all training documentation.

2. Completion of number of required training hours.

3. Demonstration of payload operations during task, phase, and project integrated training.

4. Demonstration that payload operations conform to predetermined timeframe.

5. Demonstration of understanding that experiment measurements and samples are in normal range.

6. Results of nominal, off-nominal, long duration, and joint integrated training simulations.

The PI is responsible for completion of a training report (see Appendix A) for each crew member following the completion of orientation/task training. Each crew member is also responsible for identifying additional training desired by completing questions 5 and 6 of the ARC Project Crew Evaluation form (see Appendix B).

IN-FLIGHT ACTIVITIES

After the crew supports the above training schedule, the fruits of their labor are witnessed as they conduct the in-flight activities on POCC console monitors and NASA Select television (figs. 3-9). The activities are generally performed as rehearsed during training, keeping the science constraints, flight rules, and hardware limitations in mind, adapting their skills and knowledge of the experiments to the zero-g environment. The actual results of the experiments is the validation of successful training.

CONCLUSION

While the project goals in support of a mission are generally assumed to be the delivery of hardware and its subsequent integration, an integral portion of flight development includes ensuring the prime operators of the experiments are fully versed in all its operations.

Effective crew training is crucial to the successful completion of in-space life sciences experiments. Ames Research Center has developed and utilized a training process that assures proper exposure of crew members to all aspects of experiment protocols and prepares them for proper implementation of these experiment protocols in space (ref. fig. 2).

The ability of the crew to perform the in-flight procedures, to respond to hardware anomalies, as trained, and to speak knowledgeably of the experiments at briefings can be considered the validation of a successful training program.

ACKNOWLEDGMENTS

The authors would like to thank Dr. M. Rhea Seddon, Dr. James P. Bagian, Dr. F. Andrew Gaffney, Dr. Millie Hughes-Fulford and Dr. Tamara Jernigan, the crew of STS-40 (Spacelab Life Sciences-1) for their support in the development of the Ames Research Center Payload Crew Training methodology described in this paper.

APPENDIX A

ARC PROJECT TRAINING REPORT

EXPERIMENT NAME/NO.: ______________________ DATE: __________

TYPE OF TRAINING: ____

TIME UTILIZED TO COMPLETE SESSION: ______________________

1. I certify that ______________________________ has successfully completed the above training session.

2. PI Comments:

   a. Accomplishments during training:

   b. Tasks requiring additional practice/training:

   c. Recommendations for future training sessions.

______________________ ______________

Principal Investigator Date

APPENDIX B

ARC PROJECT CREW EVALUATION

EXPERIMENT NAME/NO.: ______________________ DATE: __________

TYPE OF TRAINING: ______________________

LOCATION OF TRAINING: ______________________

1. Was training documentation provided in sufficient time to allow for adequate preparation for training?

_______ Yes

_______ No; explain

2. Were training resources such as training documentation, procedures, hardware, and facilities adequate?

_______ Yes

_______ No; explain

3. Was time used efficiently during training?

_______ Yes

_______ No, explain

4. Was the time allocated for training:

_______ Too long; explain

_______ Correct

_______ To short; explain

ARC PROJECT CREW EVALUATION

5. Do you feel the training activities have prepared you to perform the required tasks?

_______ Yes

_______ No; explain

6. Identify any additions, deletions or modifications to training and/or training resources (hardware, procedures, facilities, etc.).

7. Other comments?

____
Crew Signature (optional)

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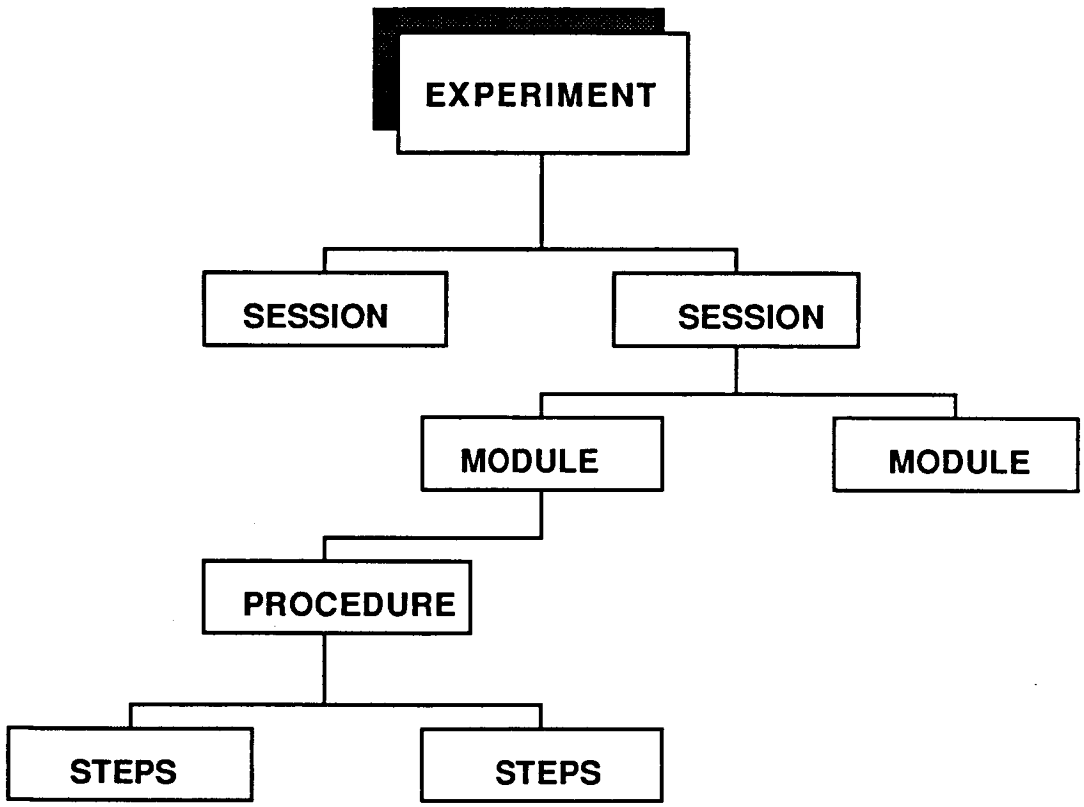

Figure 1. Experiment procedural elements.

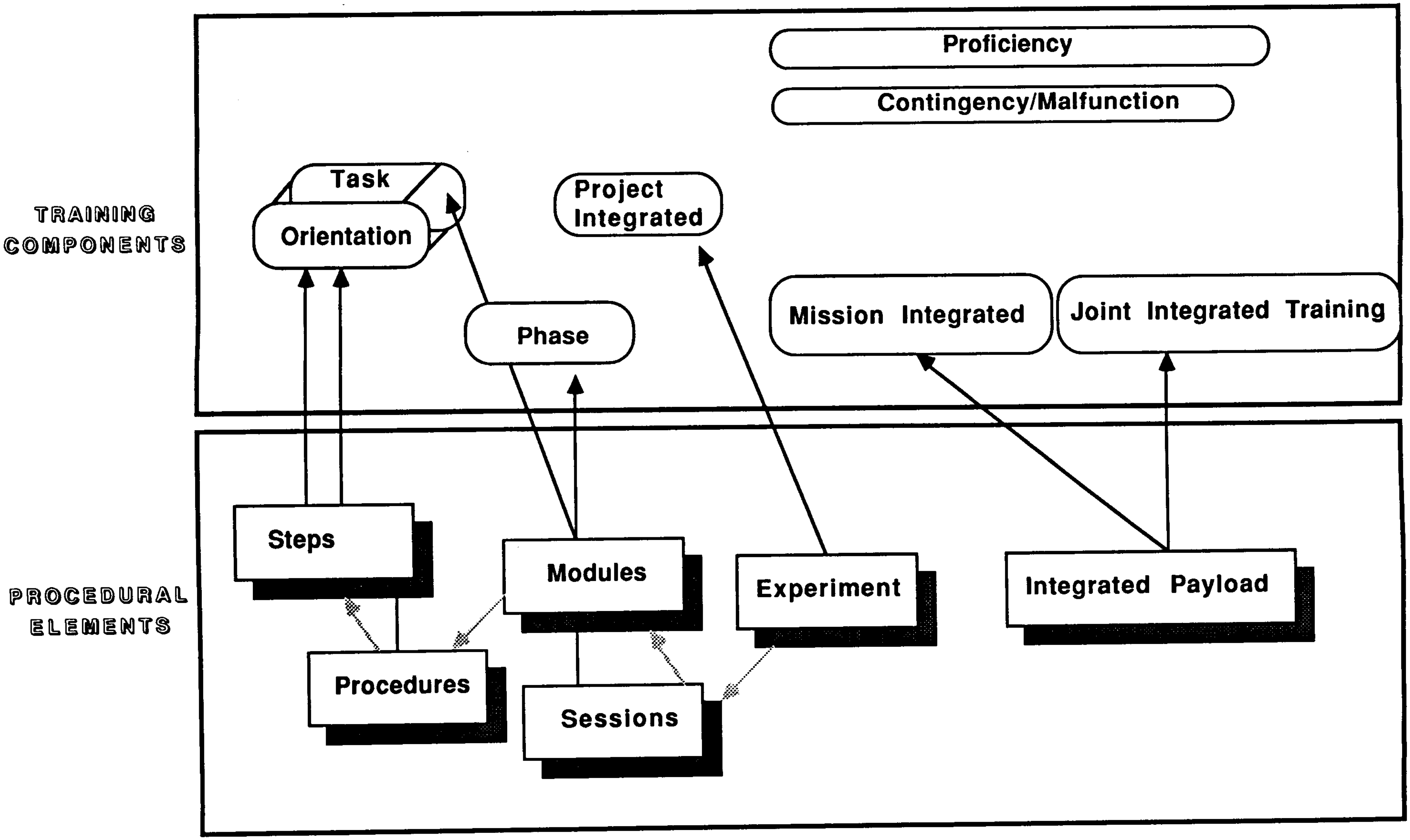

Figure 2. Crew training flow.

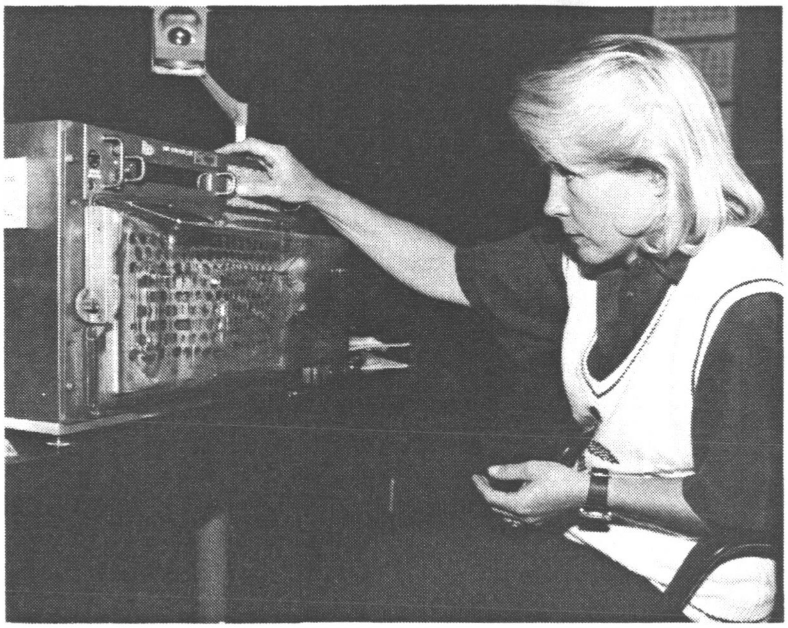

Figure 3. Mission Specialist Rhea Seddon during orientation training of small mass measurement instrument.

Figure 4. Payload Specialist Millie Hughes-Fulford during laboratory orientation training.

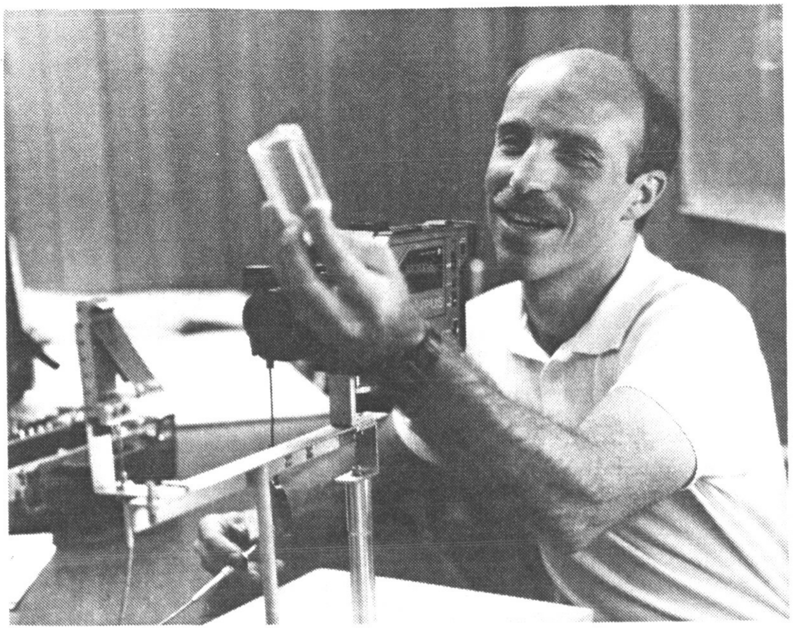

Figure 5. Mission Specialist Jim Bagian examining jellyfish specimen during jellyfish task training.

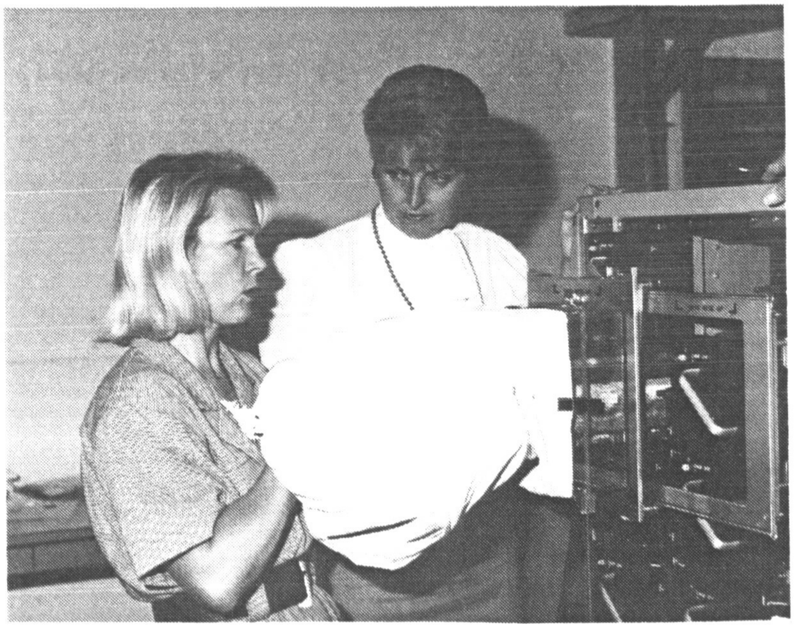

Figure 6. Mission Specialist Rhea Seddon and Payload Specialist Millie Hughes-Fulford during cage transfer phase training.

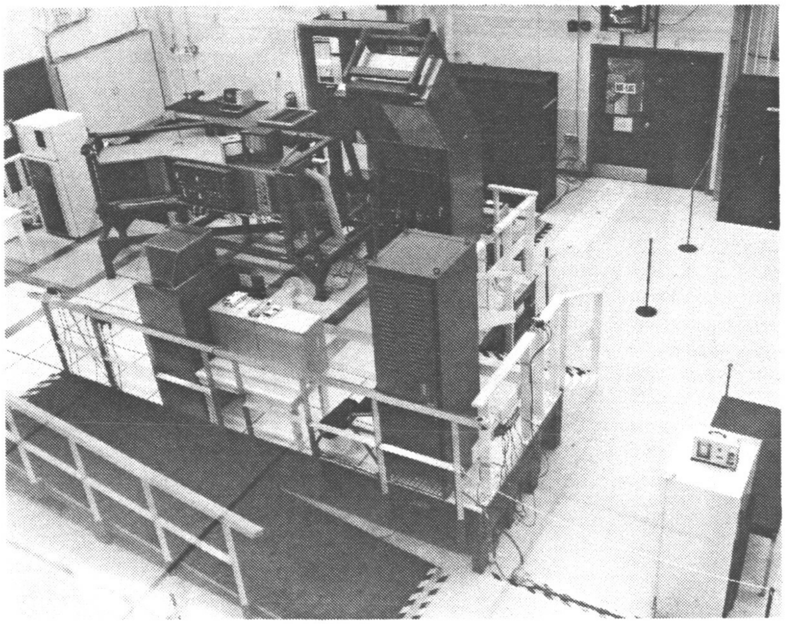

Figure 7. Project hardware configuration during payload experiment verification test.

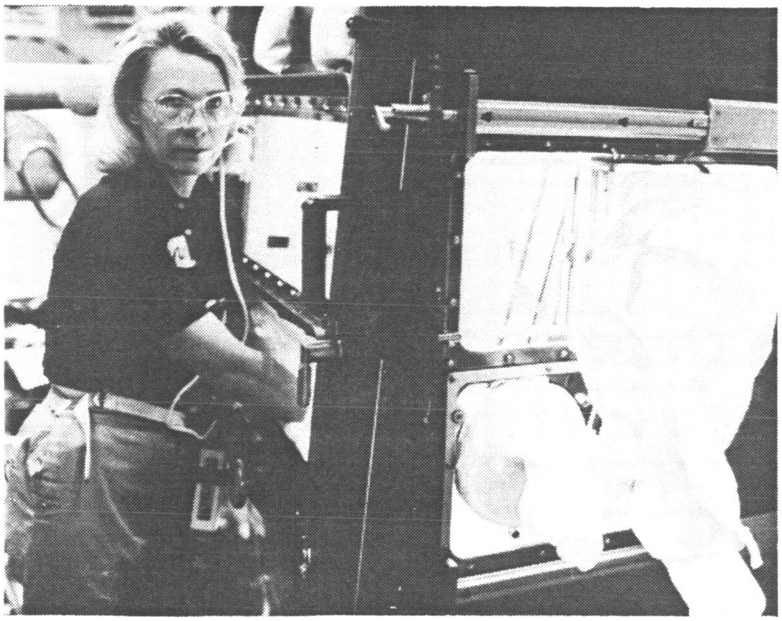

Figure 8. Ms. Rhea Seddon at general purpose workstation during EVT.

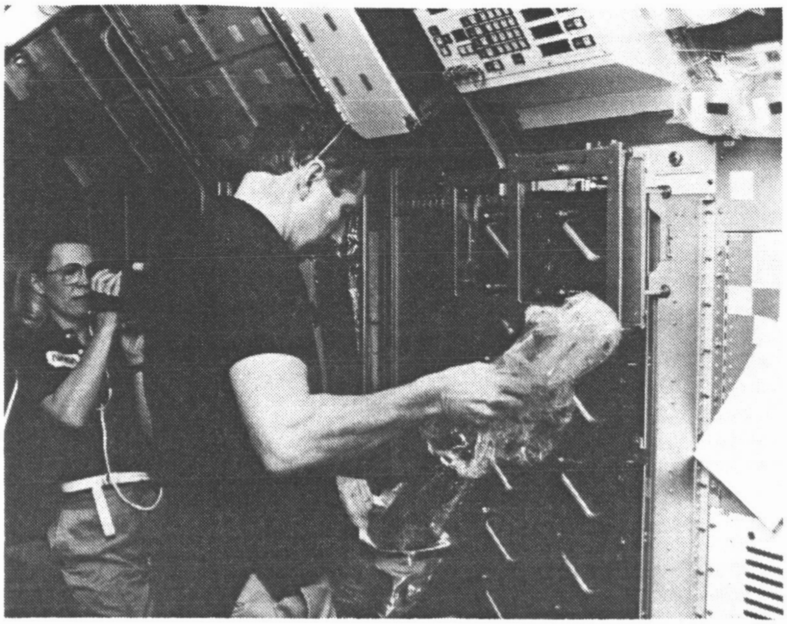

Figure 9. Payload Specialist Drew Gaffney and Mission Specialist Rhea Seddon doing cage transfer procedure during mission integrated simulation.

BIOGRAPHY

Annette T. Rodrigues started her Federal career with the Naval Radiological Defense Laboratory in 1968. Over the years she has acquired a vast array of experience in such areas as Government Procurement, Human Resources, Personnel Development, Spaceflight (experiment) Crew training and various Project Management functions. Her project experience at Ames Research Center has included work on the Biosatellite III and Spacelab Life Sciences Missions (SL-3, SLS-1, SL-J & SLS-2).

Currently Ms. Rodrigues is the staff assistant to the Center Deputy Director. In this capacity she serves as advisor and special assistant to the Deputy Director of the Center. As the Deputy Director's representative, she is responsible for the continuous review and analysis of institutional activities and policies. As the prime interface with the Deputy Director, she provides administrative advice and direction to his staff offices, including the offices of the Chief Counsel, Safety, Reliability, and Quality Assurance, Equal Opportunity and External Affairs.

Ms. Rodrigues received her BS degree in Business Administration from San Jose State University (1976) and an MS degree in Systems Sciences from University of Southern California (1987).

Christopher Maese graduated from the University of Santa Clara in 1980 with a B.S. in Biology, then earned an M.A. in Biology, specializing in physiology, from San Jose State University. Since 1988, he has worked in the Space Life Science Programs Office at Ames Research Center.