NASA Technical Memorandum 4685

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P. D. Savage and W. E. Hinds, *Ames Research Center, Moffett Field, California*
R. Jaquez, J. Evans, and L. Dubrovin, *Lockheed Engineering and Sciences Company, Moffett Field, California*

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P. D. SAVAGE, W. E. HINDS, R. JAQUEZ,* J. EVANS,* AND L. DUBROVIN*

Ames Research Center

Summary

The Spacelab Life Sciences-2 (SLS-2) mission provided scientists with the unique opportunity of obtaining inflight rodent tissue and blood samples during a 14-day mission flown in October 1993. To successfully obtain these samples, Ames Research Center's Space Life Sciences Payloads Office developed an innovative, modular approach to packaging the instruments used to obtain and preserve the samples associated with the hematology experiments on SLS-2.

The design approach organized the multitude of instruments into 12 different kits used to accomplish a particular experiment on any given day during the mission. The 12 basic kits included blood processing, isotope and erythropoietin injection, body mass measurement, and microscope slides. Each kit contained all of the syringes, vials, microscope slides, etc., necessary for processing and storing blood and tissue samples for one rat on a particular day. On flight day 6 of the SLS-2 mission, for example, a total of five rats had blood samples taken, radioisotope labels injected, and body mass measured. To fulfill these experiment functional objectives, the astronaut crewmember removed from the onboard stowage a total of five each of the blood processing, radioisotope injection, microscope slide, and mass measurement kits and set them up in the general purpose work station (GPWS). The GPWS is a laminar flow work bench where all of the experimental procedures are carried out. For ease of stowage and transportation the kits were enclosed in larger Zero™ boxes.

In support of the SLS-2 mission, a total of 1,245 components, packaged into 128 kits and stowed in 17 Zero boxes were required to complete the scientific objectives of the hematology experiments. In training for the mission, astronaut crew members spent many hours using these kits and found the overall design to be extremely easy to use and laid out in a logical, simple configuration which minimized chances for error during the complex, tedious procedures inflight. This paper summarizes inflight performance of the kits on SLS-2.

Introduction

The SLS-2 mission was the second in a series of dedicated life sciences Spacelab missions, and as such was furthering the important research initiated on SLS-1 in June 1991. The payload comprised fourteen different experiments, six using animals (rats) as subjects and eight using the crew as subjects.

The six animal experiments on SLS-2 were grouped into four scientific disciplines—hematology (two experiments), bone, muscle (two experiments), and vestibular. Each of the six experiments were assigned a certain number of the total of 48 rats flown onboard, constituting their respective flight groups. The two hematology experiments shared a total of 15 animals, which were subdivided into three groups of 5, simply denoted as A, B, and C.

Experiment Kit Development

Experiment Objectives

The basic objectives of the two hematology experiments on SLS-2 were to:

• Measure circulating red blood cell levels in response to spaceflight.

• Measure erythropoietin (EPO) levels and the response of rat bone marrow cells to EPO in an in vitro culture system.

• Determine if the rat responds normally to EPO injected inflight.

• Determine if plasma levels of hematopoietic growth stimulating factors change during exposure to microgravity.

• Determine if red blood cell mass and plasma volume changes are different after a 14-day exposure to microgravity compared to the 9-day exposure of SLS 1.

• Determine if there is a change in erythropoiesis due to microgravity.

• Determine if there is a change in red blood cell shape during exposure to microgravity.

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*Lockheed Engineering and Sciences Company, Moffett Field, California.

Experiment Sample Requirements

In order to satisfy the hematology experiment objectives, inflight sample and data collection included the following parameters:

• Blood sample pre- and post-radioisotope injection (groups A, B, and C).

• Mass determination twice during mission (groups A, B, and C).

• Marrow, spleen, whole body blood sample (animals assigned to vestibular—total of 5)

• Hematocrit (groups A, B, and C)

• Red blood cell mass (groups A, B, and C)

• Plasma volume (groups A, B, and C)

• Reticulocyte and peripheral blood slides (groups A, B, and C)

• Blood sample for complete blood count (group A)

In addition, injections of the radioisotopes ^{125}I albumin (to measure plasma volume) and ^{59}Fe ferrous citrate (to indirectly measure red blood cell production) and the hormone erythropoietin (to enable the measurement of the response of bone marrow to EPO in microgravity) were required.

Experiment Kit Design Requirements

The design requirements associated with the SLS-2 hematology experiment kits were relatively simple. The main design issue faced was the packaging of the large number of small components required for collecting the numerous inflight samples. Key design requirements were as follows:

• Size and weight: a specific size and weight requirement for each kit was not imposed; however, it was recognized that because of the large number of components that were to be kitted for use on multiple flight days, small, easily handled enclosures would be required to fit within standard Spacelab stowage lockers. In addition, the kits would be used in the volume of the GPWS cabinet, lending further rationale for minimizing overall size of the kits.

• Human factors: to minimize confusion and error in collecting and storing samples inflight, a modularized approach to arranging and kitting kit components was required. Each set of components required for one rat on a given flight day would be kitted together according to the specific objective for that day (i.e., blood sample processing, microscope slide preparation, etc.). This first level of kitting would then be grouped into a second enclosure for ease in transportation between the stowage location and the GPWS cabinet.

• Materials selection: off-the-shelf components were used wherever practical. Components were compatible with standard techniques for sterilization.

• Astronaut crew safety: since a number of the experiment kit components could have either sharp points or edges, or could shatter and create dangerous fragments, adequate protection was required to contain possible fragments or minimize crew exposure to the sharp point/edge. In addition, since several of the chemicals contained in the kits could be hazardous to the crew, adequate containment was also required to minimize the potential for accidental crew exposure in flight.

• Reliability: an adequate number of spare components was required onboard because of the fragile nature of some items or because their small size increased the chance for loss of an item in flight.

Design Process

The design of the hematology kits evolved through a development process common to spaceflight hardware developed by the SLS Payloads Office at Ames Research Center. The initial stages of requirement definition and design concept development culminated in a Preliminary Design Review (PDR), where key personnel within the Payloads Office and hematology experiment teams were given the first opportunity to review the design approach for the hematology kits. During this phase remaining issues regarding design requirements were resolved and approval was given to continue the design development to the next phase, where prototype kits were developed and a final design concept presented for review. Key design issues resolved during the PDR were the complexity of the kit design and the number of individual kits required, adequacy of chemical and glass containment, and determination of the types of components requiring spares and the number of spares to be flown.

The next phase of the design effort culminated in the Critical Design Review (CDR) for the hematology kits. Key design issues addressed at the CDR included finalizing the specific off-the-shelf components to be used in the kits, finalizing an approach to containment of glass components, defining the labeling scheme for each component and the overall kit assemblies, finalizing design features of the second level of kit enclosure, and establishing the shelf-life of chemicals contained in the kits.

Upon completion of the CDR for the hematology kits, the design configuration was baselined and fabrication of the kit enclosures begun. In addition, procurement of all experiment kit components was initiated, including sufficient quantities for flight kits, spares, and training kits.

Design Approach

Given the fairly broad envelope of defined design requirements, considerable flexibility was afforded the design engineers in developing the experiment kits. The kit designs were initially organized around the daily functional objectives associated with the inflight experiment procedures. For example, all components associated with the blood sampling procedure of flight day 6 were grouped together to form one kit. Similarly, all components associated with preparing microscope slides on flight day 6 were grouped together as a separate kit. The following is a summary of the hematology experiment functional objectives for each applicable flight day.

- Flight day 6 (group A—5 rats)
  - – Blood processing
  - – Microscope slide preparation
  - – Radioisotope injection (plus dose)
  - – Mass measurement (15 rats)
- Flight day 7 (group A—5 rats)
  - – Blood processing
  - – Microscope slide preparation
- Flight day 9 (groups B and C—10 rats)
  - – Blood processing
  - – Microscope slide preparation
  - – Radioisotope injection (plus dose)
  - – Erythropoietin injection (plus dose; 5 rats)
  - – Saline injection (plus dose; 5 rats)
- Flight day 10 (groups B and C—10 rats)
  - – Blood processing
  - – Microscope slide preparation
  - – Mass measurement (15 rats)
- Flight day 13 (vestibular experiment group—5 rats)
  - – Whole body blood collection
  - – Serum collection
- Flight day 14 (group A—5 rats)
  - – Blood processing
  - – Microscope slide preparation

To streamline crew operations as much as possible, it was further decided that the kitting of components associated with blood processing, microscope slide preparation, isotope injection, and whole body blood collection should not only be by functional objective, but also by individual rat. Based upon this kit design approach, a total of 12 unique kits was required for SLS-2. These were designated alphabetically as follows:

- Kit A – Blood processing kit
- Kit B – Radioisotope injection kit
- Kit C – Microscope slide kit
- Kit D – Rodent restraint kit
- Kit E – Epo/saline injection kit
- Kit F – Radioisotope dose kit; also erythropoietin dose kit and saline dose kit
- Kit G – Whole body blood collection kit
- Kit P – Pumpette kit (collecting whole body blood during FD13 dissection)
- Kit S – Serum collection fit
- Kit J – Fetal calf serum (for preparing marrow samples during FD13 dissection)
- Kit K – Mass measurement kit
- Kit L – Hematocrit centrifuge kit

The first level of enclosure for kit components used a commercially available plastic case for storing video game cassettes, measuring 5 in. wide × 6 in. high × 1 in. deep (see figs. 1–9 for kits A–G, J, and K). To satisfy material offgassing requirements, an aluminum tape was applied to all exposed surfaces of the case. Kit components were attached using velcro. Since kits were arranged by functional objective and several assembled for each rat associated with a functional objective, a relatively large number of kits, 128, resulted.

A second, larger enclosure was then developed to facilitate transport of the kits between the stowage location and the GPWS cabinet. This second enclosure was a commercially available Zero box sized to maximize storage of the greatest number of individual kits while remaining small enough for a crewmember to easily handle it repeatedly over the course of the mission. Each box measured 9.5 in. wide × 7 in. high × 6 in. deep and could contain up to eight of the individual kits (fig. 10).

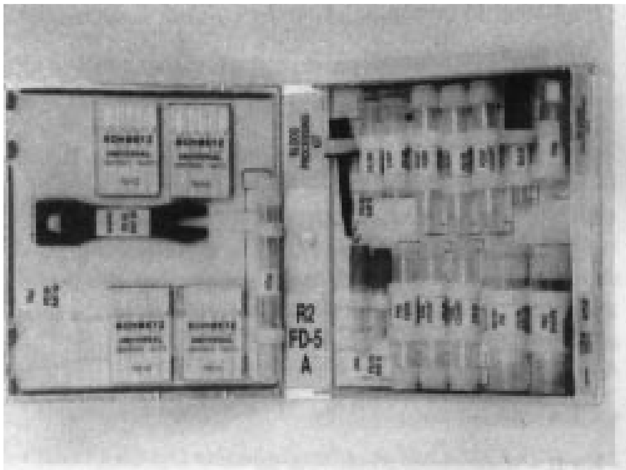

Figure 1. Blood processing kit, kit A.

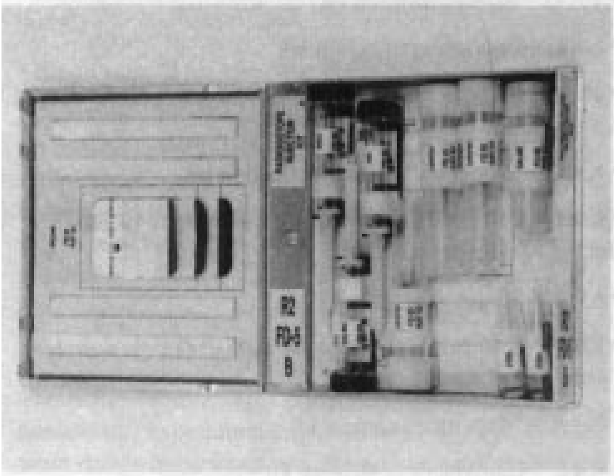

Figure 2. Radioisotope injection kit, kit B.

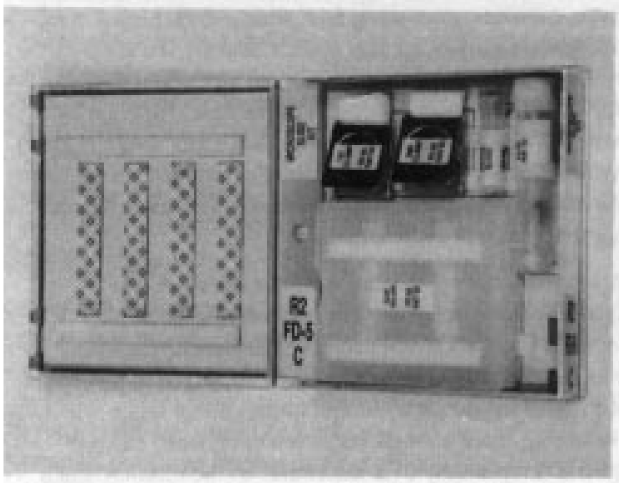

Figure 3. Microscope slide kit, kit C.

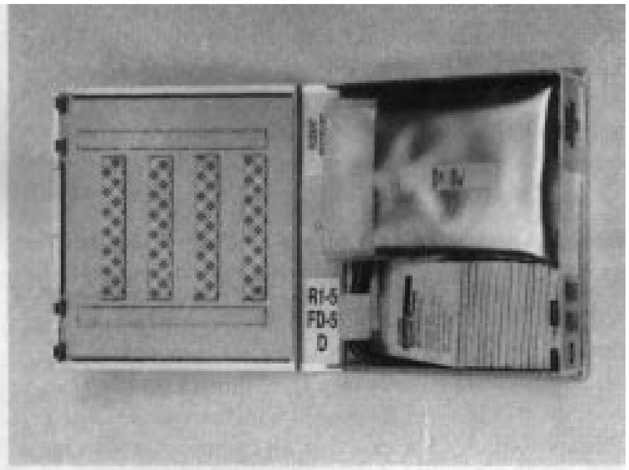

Figure 4. Rodent restraint kit, kit D.

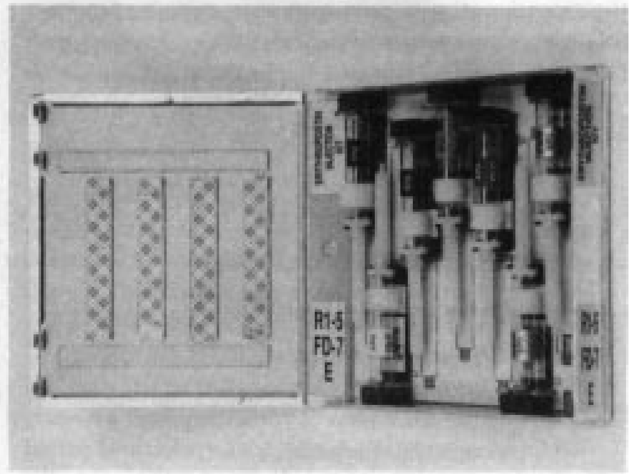

Figure 5. Erythropoietin injection kit, kit E.

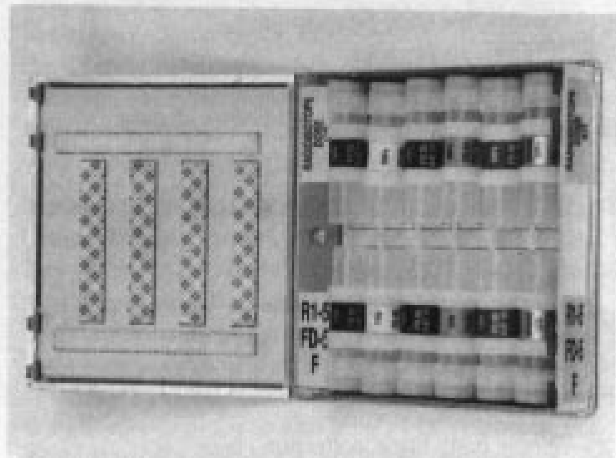

Figure 6. Radioisotope dose kit, kit F.

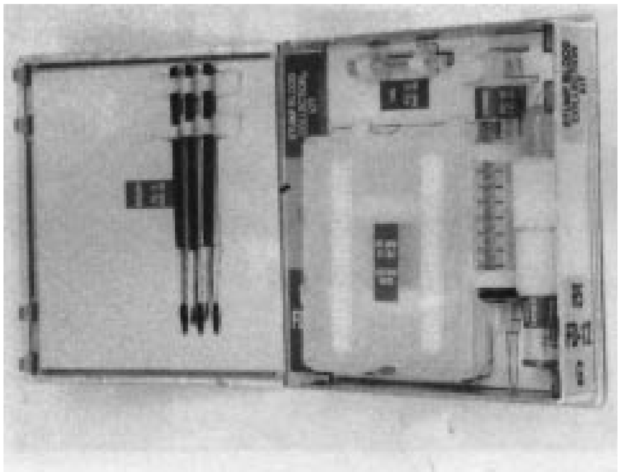

Figure 7. Whole body blood collection kit, kit G.

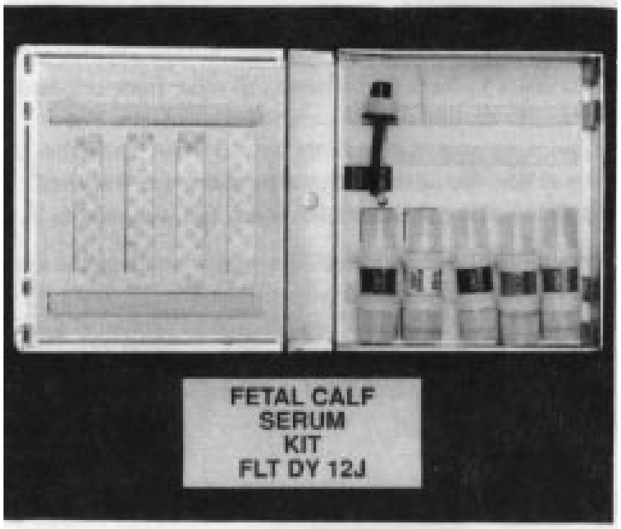

Figure 8. Fetal calf serum kit, kit J.

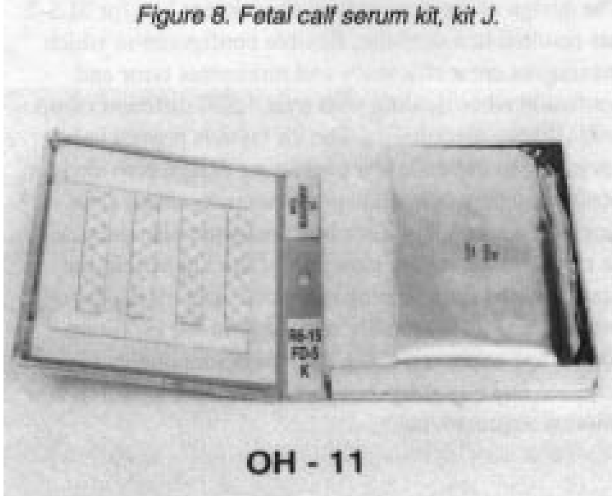

Figure 9. Mass measurement kit, kit K.

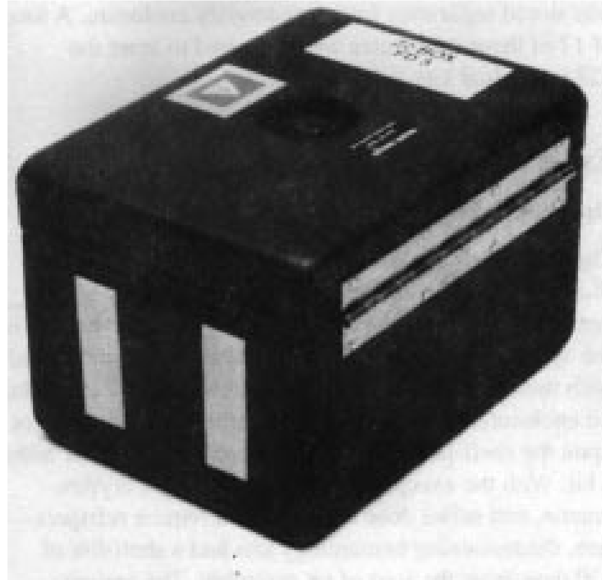

Figure 10(a). Secondary enclosure for hematology experiment kits, top view.

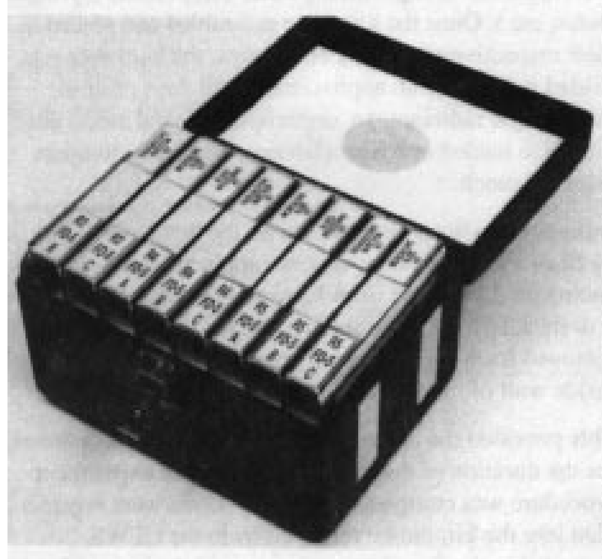

Figure 10(b). Secondary enclosure for hematology experiment kits, inside view.

This allowed for the storage of the necessary kits for two to three rats in one Zero box, depending upon the functional objectives to be carried out on a given flight day. For example, to complete the functional objectives for flight day 6, a blood processing kit, microscope slide kit, and radioisotope injection kit were required for each of five rats. These 15 kits were stored in two of the Zero box enclosures. Exceptions to this approach were the fetal calf serum kit, which required freezing, and the rodent mass measurement kit. In these cases the individual kit was stored separately from a secondary enclosure. A total of 17 of these enclosures were required to store the 128 individual kits.

Experiment Kit Operations

Operations Overview

The operations associated with the hematology kits for SLS-2 began with the final filling and assembly of the components into the kits and readying them for storage in the Spacelab. The preparation of the kits preflight started with the sterilization of the components and the individual kit enclosures. The timing of this activity was dependent upon the shelf-life of the most time-critical element within a kit. With the exception of the radioisotope, erythropoietin, and saline dose kits which all require refrigeration, the remaining hematology kits had a shelf-life of 120 days from the start of kit assembly. The various chemicals were added to their respective vials by members of the experiment teams and then placed into the individual kits along with the other components (syringes, slides, etc.). Once the kits were assembled and placed in their respective secondary enclosures, the hardware was loaded into Spacelab approximately 90 days prior to launch. The radioisotope, erythropoietin, and saline dose kits were loaded into Spacelab approximately 36 hours prior to launch.

Inflight operations associated with the hematology kits on SLS-2 involved removing the applicable secondary enclosure (Zero box) from Spacelab stowage and taking it to the GPWS. The necessary kits for a given rat were removed from the enclosure, opened, and attached to the inside wall of the GPWS cabinet with velcro (fig. 11).

Figure 11. Hematology experiment operations in the GPWS.

This provided the crewmember access to the kit contents for the duration of the procedure. Once the experiment procedure was completed, all components were reassembled into the kit, the kit removed from the GPWS, restowed in the Zero box enclosure and the box restowed in Spacelab lockers.

Inflight Performance on SLS-2

The SLS-2 hematology kits functioned extremely well in flight, with only two minor problems arising. On flight day 6, a crewmember noted a problem getting a saline cartridge into the injector due to warpage of the injector. This would prohibit flushing of any radioisotope from the tail vein catheter post-injection, if a work-around could not be developed. The issue was resolved by the crew member using one of the human hematology experiment saline doses to flush the catheter. All other injectors used later in the mission did not exhibit this problem. The second issue occurred on flight day 10 when it was discovered that one of the microscope slides was fractured. The slide had not shattered, however, and was used as is.

Overall, the SLS-2 crewmembers who were using the kits were extremely complimentary of their design. Several times during communication with ground personnel they commented on how easy the kits were to use and how easily they were deployed and restowed when operations were completed.

Conclusion

The design of the hematology experiment kits for SLS-2 has resulted in a modular, flexible configuration which maximizes crew efficiency and minimizes error and confusion when dealing with over 1,200 different components during the mission. The kit layouts proved to be very easy to use and their packaging design provided for positive, secure containment of the many small components. The secondary Zero box enclosure also provided an effective means for transport of the kits within the Spacelab and for grouping individual kits by flight day usage. The kits are readily adaptable to use on future flights by simply replacing the inner components as required and changing the labeling scheme to match new mission requirements.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY ***(Leave blank)***

2. REPORT DATE
May 1995

3. REPORT TYPE AND DATES COVERED
Technical Memorandum

4. TITLE AND SUBTITLE
Experiment Kits for Processing Biological Samples Inflight on SLS-2

5. FUNDING NUMBERS
106-30-02

6. AUTHOR(S)
P. D. Savage, W. E. Hinds, R. Jaquez,* J. Evans,* and L. Dubrovin*

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Ames Research Center
Moffett Field, CA 94035-1000

8. PERFORMING ORGANIZATION REPORT NUMBER
A-950016

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Washington, DC 20546-0001

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
NASA TM-4685

11. SUPPLEMENTARY NOTES
Point of Contact: P. D. Savage, Ames Research Center, MS 240A-3, Moffett Field, CA 94035-1000
(415) 604-5940
*Lockheed Engineering and Sciences Company, Moffett Field, CA 94035-1000

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Unclassified — Unlimited
Subject Category 55

12b. DISTRIBUTION CODE

13. ABSTRACT ***(Maximum 200 words)***

This paper describes development of an innovative, modular approach to packaging the instruments used to obtain and preserve the inflight rodent tissue and blood samples associated with hematology experiments on the Spacelab Life Sciences-2 (SLS-2) mission. The design approach organized the multitude of instruments into twelve 5- by 6- by 1-in. kits which were each used for a particular experiment. Each kit contained the syringes, vials, microscope slides, etc., necessary for processing and storing blood and tissue samples for one rat on a particular day. A total of 1245 components, packaged into 128 kits and stowed in 17 Zero™ boxes, were required. Crewmembers found the design easy to use and laid out in a logical, simple configuration which minimized chances for error during the complex procedures in flight. This paper also summarizes inflight performance of the kits on SLS-2.

14. SUBJECT TERMS
Life sciences, Spacelab, Animal habitat

15. NUMBER OF PAGES
9

16. PRICE CODE
A02

17. SECURITY CLASSIFICATION OF REPORT
Unclassified

18. SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

19. SECURITY CLASSIFICATION OF ABSTRACT

20. LIMITATION OF ABSTRACT