

FINAL REPORT

NASA GRANT NGR 47-004-129

Composite Materials Research and Education

(The NASA-Virginia Tech Composites Program)

(NASA-CR-162719) COMPOSITE MATERIALS N80-16101  
RESEARCH AND EDUCATION PROGRAM: THE  
NASA-VIRGINIA TECH COMPOSITES PROGRAM Final  
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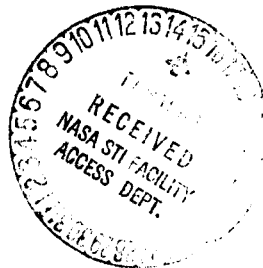
Period of Performance  
January 1, 1974 - December 31, 1979

Submitted by

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Principal Investigator  
Professor of Engineering Science and Mechanics  
Virginia Polytechnic Institute and State University

February, 1980



## FOREWARD

This report summarizes the accomplishments of the subject grant during the period January 1, 1974 through December 31, 1979. The program established under the grant is continuing under NASA Cooperative Agreement NCCI-15. Dr. John G. Davis, Jr. has served as the NASA Technical Monitor.

## SUMMARY

A cooperative program in research and education in the field of composite materials between NASA-Langley Research Center and Virginia Polytechnic Institute and State University was established in January 1974. The stated purpose of the program was to conduct research in the field of composites, to train engineers in composites, and to provide for interaction between NASA engineers and Virginia Tech faculty and students. Summary accomplishments are as follows:

- Significant research progress has been made in a number of areas including: edge effects; test methods; nonlinear behavior; thermal and moisture effects; damage development; failure analysis; structural analysis.
- Twenty graduate students and eight faculty members have conducted research in composites with support from the Program.
- Ten students have completed graduate degrees under sponsorship of the Program.
- Virginia Tech faculty and students have interacted with ten NASA engineers.
- Nineteen technical papers have been published or are in press.
- Seventeen technical reports have been completed or are in press.
- Nineteen presentations have been made at national or international meetings.

- Graduates of the Program are in great demand by employers in the field of composite materials. Four graduates have been hired by NASA.

### Research

The research accomplishments are fully documented in the papers, and technical reports listed in Tables 1-2. Major areas of study include:

- Investigation of edge effects in finite width laminated composites subjected to mechanical, thermal and hygroscopic loading with temperature dependent material properties, Analysis of the influence of edge effects on the initiation of failure, and experimental investigation of initiation and accumulation of edge damage associated with static, fatigue, thermal and moisture loading.
- Numerical and experimental investigations of test specimens for shear and compression testing of composite materials at room and elevated temperatures.
- Development of optical techniques for precise measurement of coefficients of thermal expansion of composites. Investigation of CTE for graphite-epoxy and graphite-polyimide using same.
- Development of models for the nonlinear behavior of composites including material nonlinearity and damage accumulation. Experimental verification of same under biaxial loading.

- The compressive failure of graphite/epoxy plates with circular holes. Buckling of composite cylinders under combined compression and torsion.
- Determination of the nonlinear mechanical properties of borsic/aluminum, graphite/polyimide and boron/aluminum. Some measurements made at cyrogenic and elevated temperatures as well as room temperature. Influence of temper condition on boron/aluminum investigated.
- Numerical and experimental investigation of the strength characteristics of spliced sandwich panels.
- Experimental and analytical investigation of curved graphite/epoxy panels subjected to internal pressure.

#### Faculty and NASA Engineers

Since the inception of the Program in 1974, seven Engineering Science and Mechanics and one Aerospace and Ocean Engineering faculty have advised twenty graduate students. They have worked with five NASA engineers from the Materials Division and five engineers from the Structures and Dynamics Division. The faculty and engineers are listed below.

#### NASA Engineers

##### Materials Division

Mr. Donald J. Baker  
 Dr. John G. Davis, Jr.  
 Mr. Jerry W. Deaton  
 Dr. Wolf Elber  
 Dr. Darrel Tenney

##### Structures and Dynamics Division

Dr. Paul A. Cooper  
 Dr. Martin M. Mikulas, Jr.  
 Mr. Robert R. McWithey  
 Dr. J. Wayne Sawyer  
 Dr. James H. Starnes, Jr.

## Virginia Tech Faculty

### Engineering Science & Mechanics

Prof. Edmund G. Henneke II  
Prof. Carl T. Herakovich  
Prof. Michael W. Hyer  
Prof. Eric R. Johnson  
Prof. Manohar P. Kamat  
Prof. Daniel Post  
Prof. Wayne W. Stinchcomb

### Aerospace & Ocean Engineering

Prof. Terrence A. Weisshaar

## Students

All graduate students who have participated in the grant are listed in Table 4. This table gives complete information on each student including dates of participation, degree, initial employer, Langley residence, research topic and advisors. Ten students have completed advanced degrees, nine Masters students and one Ph.D. Students currently participating in the Program include three Ph.D. candidates and five Masters candidates. With the exception of one student who entered the Navy, all students who completed their work in the Program took an initial position working in composites or continued their graduate studies. Four students have been employed by NASA Langley. The other graduates have accepted positions with major aerospace firms.

Interest in the Program continues to grow. The number of students requesting information and the number actually submitting applications increases each year. One hundred and sixty applications have been received through January, 1980 with thirty-five being received during the past year. Over 1500 requests for information have been received

from prospective students. The caliber of students desiring a position in the Program has remained at a high level.

#### Interaction

The Program has resulted in interaction between ten NASA engineers, eight Virginia Tech faculty and twenty graduate students. In addition, six undergraduates have spent a summer working at Langley under sponsorship of the Program. As of January 1, 1980, a total of 111 man-months (9.25 man-years) in residence at Langley have been completed by students and an additional 9 man-months in residence by Tech faculty. This day-to-day interaction has resulted in close coordination on technical matters, and common understanding of each others immediate needs, long range goals, methods of operation, capabilities and limitations. In addition to the residence period, faculty and students have made numerous one-day trips to Langley. Details of these one-day visits are given in Table 5.

TABLE 1 - Publications

1. Wilson, III, G. H., and Herakovich, C. T., "Application of a Dedicated Micro-processor for Automatic Data Acquisition of Load, Strain and Acoustic Emission Data," Experimental Mechanics, Vol. 16, No. 3, March 1976.
2. Herakovich, C. T., "On Thermal Edge Effects in Composite Laminates," International Journal of Mechanical Sciences, Vol. 18, No. 3, 1976.
3. Herakovich, C. T., Davis, Jr., J. G., and Viswanathan, C. N., "Tensile and Compressive Behavior of Borsic/Aluminum," Composite Materials: Testing and Design (Fourth Conference) ASTM STP 617, Am. Soc. for Testing and Materials, 1977, pp. 344-357.
4. Herakovich, C. T., Kennedy, J. M. and Tenney, D. R., "Effect of Cyclic Loading and Temper Condition on the Tensile Behavior of Boron-Aluminum," Environmental Effects in Engineering Materials, Virginia Polytechnic Institute and State University, Blacksburg, VA., Oct. 1977.
5. Herakovich, C. T. and Wong, D. M., "Influence of Residual Stresses on the Tensile Strength of Composite-Metal Sandwich Laminates," Experimental Mechanics, Vol. 17, No. 11, Nov., 1977.
6. Hsu, P. W. and Herakovich, C. T., "Edge Effects in Angle-ply Composite Laminates," J. Comp. Materials, Vol. 11 (Oct. 1977) p. 422-428.
7. Farley, G. L. and Herakovich, C. T., "Influence of Two-Dimensional Hygrothermal Gradients on Interlaminar Stresses Near Free Edges," Environmental Effects on Advanced Composite Materials, ASTM STP 658. Am. Soc. for Testing and Materials, 1978.
8. Kennedy, J. M., Tenney, D. R., Herakovich, C. T., "Tensile and Compressive Stress-Strain Behavior of Heat Treated Boron-Aluminum," Proceedings, 2nd Int. Conference on Composite Materials, Toronto, Canada, April, 1978.
9. Kriz, R. D. and Stinchcomb, W. W., "Elastic Moduli of Transversely Isotropic Graphite Fibers and Their Composites," Experimental Mechanics, Vol. 19, No. 2, February 1979.
10. Weisshaar, T. A. and Garcia, R., "Analysis of Graphite/Polyimide Rail Shear Specimens Subjected to Mechanical and Thermal Loading," NASA CR 3106, March, 1979.
11. Garcia, R., Weisshaar, T. A. and McWithey, R. R., "An Experimental and Analytical Investigation of the Rail Shear-Test Method as Applied to Composite Materials," SESA Paper No. R79-105, May, 1979.



Publications (continued)

12. Shuart, M. J. and Herakovich, C. T., "An Evaluation of the Sandwich Beam in Four-Point Bending as a Compressive Test Method for Composites," NASA TM 78783, September 1978.
13. Herakovich, C. T. and O'Brien, D. A., "Failure Analysis of an Idealized Composite Damage Zone," MFPG Symposium on Advanced Composites: Design and Applications, National Bureau of Standards, Gaithersburg, Md., May 23-25, 1979.
14. Herakovich, C. T., Bergner, H. W. and Bowles, D. E., "A Comparative Study of Composite Shear Specimens using the Finite Element Method," ASTM Symposium on Test Methods and Design Allowables for Fibrous Composites, Dearborn, Michigan, October 2-3, 1979.
15. Herakovich, C. T. and Johnson, E. R., "Buckling of Composite Cylinders Under Combined Compression and Torsion - Theoretical/Experimental Correlation," ASTM Symposium on Test Methods and Design Allowables for Fibrous Composites, Dearborn, Michigan, October 2-3, 1979.
16. Herakovich, C. T., Nagarkar, A. and O'Brien, D. A., "Failure Analysis of Composite Laminates with Free Edges," Modern Developments in Composite Materials and Structures, ASME Winter Annual Meeting, December 2-7, 1979, New York.
17. Herakovich, C. T., Davis, J. G., Jr. and Mills, J. S., "Thermal Microcracking in Celion 6000/PMR-15 Graphite/Polyimide", Proc. Conference on Thermal Stresses in Materials and Structures in Severe Thermal Environments, Virginia Polytechnic Institute and State University, Blacksburg, VA., March, 1980.
18. Knauss, J. F. and Henneke, E. G., II, "The Compressive Failure of Graphite/Epoxy Plates with Circular Holes," Accepted for publication, Third International Conference on Composite Materials, Paris, August, 1980.
19. Herakovich, C. T. and Nagarkar, A., "On Failure Modes in Finite Width Angle-Ply Laminates", Third International Conference on Composite Materials, Paris, August, 1980.

TABLE 2 - Interim Reports

Report No.	Title and Author(s)
1.	"Tensile and Compressive Behavior of Borsic/Aluminum Composite Laminates", C. N. Viswanathan, J. G. Davis, Jr., and C. T. Herakovich, VPI-E-75-12, June, 1975.
2.	"Optimum Design of Composite Laminates with Thermal Effects", L. R. Markham and C. T. Herakovich, VPI-E-76-11, June, 1976.
3.	"Tensile and Compressive Test Results for Metal Matrix Composites", M. J. Shuart and C. T. Herakovich, VPI-E-77-6, February, 1977.
4.	"Topological Design Variable Technique", G. L. Farley, VPI-E-77-8, February, 1977.
5.	"Three-Dimensional Hidden Line Plotting Algorithm with Contour Capability", G. L. Farley, VPI-E-77-9, February, 1977.
6.	"Analysis of Shear Test Methods for Composite Laminates", H. W. Bergner, Jr., J. G. Davis, Jr., and C. T. Herakovich, VPI-E-77-14, April, 1977.
7.	"Effect of Material Properties on Interlaminar Stresses in an Angle-ply Composite Laminate", R. D. Kriz, VPI-E-77-16, May, 1977.
8.	"Influence of Temper Condition on the Nonlinear Stress-Strain Behavior of Boron-Aluminum", J. M. Kennedy, C. T. Herakovich and D. R. Tenney, VPI-E-77-18, June, 1977.
9.	"Two-Dimensional Hygrothermal Diffusion Into a Finite Width Composite Laminate", G. L. Farley and C. T. Herakovich, VPI-E-77-20, June, 1977.
10.	"Influence of Two-Dimensional Hygrothermal Gradients on Interlaminar Stresses Near Free Edges", G. L. Farley and C. T. Herakovich, VPI-E-77-26, September, 1977.
11.	"The Compressive Failure of Graphite/Epoxy Plates with Circular Holes", J. F. Knauss, J. H. Starnes, Jr. and E. G. Henneke, II, VPI-E-78-5, February, 1978.
12.	"Finite Element Stress Analysis of Idealized Composite Damage Zones", D. A. O'Brien and C. T. Herakovich, VPI-E-78-6, February, 1978.

Interim Reports (continued)

- | Report No. | Title and Author(s)  |
|------------|--|
| 13.        | "On Poisson's Ratio for Metal Matrix Composite Laminates", C. T. Herakovich and M. J. Shuart, VPI-E-78-26, September, 1978.  |
| 14.        | "Analysis of Graphite/Polyimide Rail Shear Specimens Subjected to Mechanical and Thermal Loading", T. A. Weisshaar and R. Garcia, VPI-E-78-27, October, 1978.                                |
| 15.        | "An Evaluation of the Sandwich Beam in Four-Point Bending as a Compressive Test Method for Composites", M. J. Shuart and C. T. Herakovich, NASA TM 78783, September, 1978.                   |
| 16.        | "Effects of Moisture Residual Thermal Curing Stresses and Mechanical Load on the Damage Development in Quasi-isotropic Laminates", R. Kriz and W. W. Stinchcomb, VPI-E-80-5, February, 1980. |
| 17.        | "Thermal Microcracking in Celion 6000/PMR-15 Graphite/Polyimide", J. S. Mills, C. T. Herakovich and J. G. Davis, Jr., VPI-E-79-35, March, 1980.  |

TABLE 3 - Presentations

Presenter denoted by \*.

1. Herakovich\*, C. T., "Failure of Composites Subjected to Generalized Plane Strain," 11th Annual Meeting, Society of Engineering Science, Inc., November, 1974, Durham, North Carolina. (Invited)
2. Wilson, G. H., III and Herakovich\*, C. T., "Application of a Dedicated Micro-processor for Automatic Data Acquisition of Load, Strain and Acoustic Emission Data," SESA Spring Meeting, Chicago, May, 1975.
3. Herakovich\*, C. T. and Wong, D. M., "Strength Comparisons for Composites and Composite-Metal Sandwich Laminates," SESA Spring Meeting, Washington, May, 1976.
4. Herakovich\*, C. T., Davis, J. G., Jr., and Viswanathan, C. N., "Tensile and Compressive Behavior of Borsic/Aluminum," ASTM (Fourth Conference) on Composite Materials: Testing and Design, Valley Forge, Pennsylvania, May, 1976.
5. Herakovich\*, C. T., "On Failure of Composite Materials," Spring Seminar Series, University of Delaware, April, 1975. (Invited)
6. Farley, G. L. and Herakovich\* C. T., "Influence and 2-D Hygrothermal Gradients on Interlaminar Stresses Near Free Edges," ASTM Symposium on Environmental Effects on Advanced Composite Materials, Dayton, Ohio, September, 1977.
7. Herakovich\*, C. T., Kennedy, J. M., and Tenney, D. R., "Effect of Cyclic Loading and Temper Condition on the Tensile Behavior of Boron-Aluminum," Environmental Effects in Engineering Materials, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, October, 1977.
8. Herakovich\*, C. T., and Davis, J. G., Jr., "The NASA-VPI&SU Composites Program," Composite Materials Testing and Design (Fifth Conference) New Orleans, March, 1978. (Invited)
9. Kennedy, J. M., Tenney, D. R., and Herakovich\*, C. T., "The Nonlinear Stress-Strain Behavior of Boron-Aluminum Laminates during Cyclic Loading," Proceedings, 2nd Int. Conference on Composite Materials, Toronto, Canada, April, 1978.
10. Herakovich\*, C. T., "The NASA-VPI&SU Composites Program," 2nd Int. Conference on Composite Materials, Toronto, Canada, April, 1978. (Invited)

Presentations (continued)

11. Kriz\*, R. D. and Stinchcomb, W. W., "Elastic Moduli of Transversely Isotropic Graphite Fibers and Their Composites," SESA Meeting, Wichita, Kansas, May, 1978.
12. Herakovich\*, C. T., "On Edge Effects in Composite Laminates," University of Illinois, February, 1978.
13. Herakovich\*, C. T., "On Edge Effects in Composite Laminates," University of Minnesota, February, 1978.
14. Garcia\*, R. and Weisshaar, T. A., "An Experimental and Analytical Investigation of the Rail Shear-Test Method as Applied to Composite Materials," 1979 SESA Spring Meeting, San Francisco, Ca., May 20-25, 1979.
15. Herakovich\*, C. T., and O'Brien, D. A., "Failure Analysis of an Idealized Composite Damage Zone," MFPG Symposium on Advanced Composites: Design and Applications, National Bureau of Standards, Gaithersburg, Md., May 23-25, 1979.
16. Herakovich\*, C. T., Bergner, H. W., and Bowles, D. E., "A Comparative Study of Composite Shear Specimens Using the Finite Element Method," ASTM Symposium on Test Methods and Design Allowables for Fibrous Composites, Dearborn, Michigan, October 2-3, 1979.
17. Herakovich, C. T., and Johnson\*, E. R., "Buckling of Composite Cylinders Under Combined Compression and Torsion - Theoretical/ Experimental Correlation," ASTM Symposium on Test Methods and Design Allowables for Fibrous Composites, Dearborn, Michigan, October 2-3, 1979.
18. Herakovich\*, C. T., Nagarkar, A., and O'Brien, D. A., "Failure Analysis of Composite Laminates with Free Edges," ASME Winter Annual Meeting, New York, December 2-7, 1979.
19. Herakovich, C. T., Davis, J. G., Jr. and Mills, J. S., "Thermal Microcracking in Celion 6000/PMR-15 Graphite Polyimide", Int. Conf. Thermal Stresses in Material and Structures in Severe Thermal Environments, VPI&SU, Blacksburg, Va., March, 1980.

TABLE 4 - Graduate Student Participation in the NASA-VPI&amp;SU Composites Program

STUDENT/INITIAL EMPLOYER	ENTERED PROGRAM	DEGREE COMPLETED	LANGLEY RESIDENCE	RESEARCH TOPIC	LANGLEY SUPERVISOR	VPI&SU ADVISOR
C. N. Viswanathan/ Graduate Student Columbia University	Jan. 1974	M.S. June 1975	6/17/74-12/31/74	Tensile & Compressive Behavior of Borsic/Aluminum Composite Laminates	John G. Davis/ Carl T. Herakovich	
John M. Kennedy/ NASA-Langley	June 1975	M.S. June 1977	3/15/76-10/15/76	Influence of Temper Condition on the Nonlinear Stress-Strain Behavior of Boron-Aluminum	Darrel R. Tenney/ Carl T. Herakovich	
Larry R. Markham/ Lockheed California	June 1975	M.S. June 1976	6/9/75-9/14/75	Optimum Design of Composite Laminates with Thermal Effects	John G. Davis/ Carl T. Herakovich	
Henry W. Bergner Boeing Com. Air. Co.	June 1975	M.S. June 1977	6/9/75-9/12/75 9/13/76-3/15/77	Analysis of Shear Test Methods for Composite Laminates	John G. Davis/ Carl T. Herakovich	
Gary L. Farley U.S. Army Mobility R&D Lab.-Langley	Sept. 1975	Ph.D. Candidate	6/15/76-9/3/76 6/11/77-4/4/78	Nonlinear Finite Element Analysis of Edge Initiated Laminate Failure	Donald J. Baker/ Carl T. Herakovich	
Mark J. Shuart NASA-Langley	June 1976	M.S. Aug. 1978	6/9/75-9/12/75 6/15/76-7/3/76	An Evaluation of the Sandwich Beam as a Compressive Test Method for Composites	John G. Davis/ Carl T. Herakovich	
David A. O'Brien U. S. Navy	Sept. 1976	M.S. Dec. 1977	6/9/75-9/12/75	Finite Element Stress Analysis of Idealized Composite Damage Zones	Jerry W. Deaton/ Carl T. Herakovich	
James F. Knauss Vought Corp.	Aug. 1976	M.S. Dec. 1977	6/15/77-12/15/77	The Compressive Failure of Graphite/Epoxy Plates with Circular Holes	James H. Starnes, Jr./ Edward G. Henneke	
Ramon Garcia NASA-Langley	Sept. 1976	M.S. June 1978	6/15/77-3/25/78	Rail Shear Testing of Composite Materials: Analysis and Experiment	Robert R. McWhitney/ Terence A. Weisshaar	
Ronald D. Kriz Nat. Bureau Std.	Sept. 1976	Ph.D. Dec. 1979	6/20/77-9/8/78 4/1/79-9/1/79	Effects of Moisture Residual Thermal Curing Stresses and Mechanical Load on the Damage Development in Quasi-Isotropic Laminates	Darrel R. Tenney/ Wayne W. Stinchcomb	
Mark A. Palie	Jan. 1977		6/1/77-8/30/77	Resigned from Program 3/78		

TABLE 4 (continued)

STUDENT/INITIAL EMPLOYER	ENTERED PROGRAM	DEGREE COMPLETED	LANGLEY RESIDENCE	RESEARCH TOPIC	LANGLEY VPI&SU SUPERVISOR ADVISOR
J. Steven Mills McDonnell Douglas Astro. West	Sept. 1977	M.S. Dec. 1979	6/15/78-4/14/79	Transverse Microcracking in Celion 6000 Graphite/PMR-15 Polyimide Composite	John G. Davis/ Carl T. Herakovich
Richard L. Boitnott	Jan. 1978	Ph.D. Candidate	6/11/79-9/10/79	Edge Effects in Curved Composite Panels Subject to Internal Pressure	James H. Starnes Jr./ Eric R. Johnson
Marek J. Pindera	Jan. 1978	Ph.D. Candidate	6/15/78-9/1/78 10/15/79-	Nonlinear Behavior of Composite Materials	John G. Davis/ Carl T. Herakovich
David E. Bowles	June 1978	M.S. Candidate	9/15/79-	Dimensional Stability of Composite Structures	Darrel R. Tenney/ Carl T. Herakovich & Daniel Post
Thomas A. Zeiler	July 1978	M.S. Candidate	7/3/78-9/1/78 7/1/79-	Bonded Lap Joint Analysis and Testing of Sandwich Panels	J. Wayne Sawyer/ Terence A. Weisshaar
Kimberly N. Yates	Sept. 1979	M.S. Candidate		Dimensional Stability of Composite Structures	Darrel R. Tenney/ Michael W. Hyer & Daniel Post
Michael P. Nemeth	Sept. 1979	Ph.D. Candidate		Finite Element Analysis of Composites	John G. Davis/ Carl T. Herakovich & M. P. Kamat
David A. Erb	July, 1979	M.S. Candidate	6/25/79-8/31/79		Paul A. Cooper/ Terence A. Weisshaar
Ernest Brooks	Jan. 1980	M.S. Candidate		Optical Strain Measurement Techniques for Composites	Darrel R. Tenney/ D. Post & C. T. Herakovich

TABLE 5 - Langley Visits

<u>Date</u>	<u>Travelers</u>	<u>NASA Contacts</u>
5/29/74	Herakovich, Viswanathan	Davis
6/17/74	Herakovich	Davis
7/23/74	Herakovich	Davis
9/12/74	Herakovich	Davis
11/7/74	Herakovich, Kennedy, Davis	Davis
12/19/74	Herakovich	Davis
9/10/75	Herakovich	Davis
11/18/75	Herakovich, Kennedy	Davis, Tenney
3/24/76	Herakovich	Davis, Tenney
6/17/76	Herakovich	Davis, Tenney
7/22/76	Knauss, Herakovich, Weisshaar	Davis, Mikulas
9/13/76	Henneke, Herakovich, Stinchcomb, Weisshaar	Davis, Duberg, Tenney, et al
10/21/76	Garcia, Herakovich, Weisshaar	Cooper, Davis
11/4/76	Henneke, Herakovich, Knauss, Shuart	Davis, Starnes
11/29-30/76	Garcia	Cooper
12/20/76	Herakovich, Kennedy, Kriz, Shuart, Stinchcomb	Davis, Elber, Tenney
1/11-14/77	Kennedy	Tenney
2/4/77	Farley, Herakovich, Garcia, O'Brien, Palie	Davis, Deaton, Hoffman, McWithey, Tenney
2/25/77	Herakovich, Kamat, Palie, Shuart	Davis, Elber
4/4/77	Garcia, Knauss	McWithey, Starnes



Table 5 - (continued)

<u>Date</u>	<u>Travelers</u>	<u>NASA Contacts</u>
6/3/77	Frederick, Herakovich, Stinchcomb	Davis, Elber, Tenney
7/8/77	Henneke, Herakovich	Davis, Elber, Starnes, Tenney
7/18-22/77	Stinchcomb	Tenney
8/16/77	Herakovich	Davis, Tenney, Elber
8/17/77	Henneke	Starnes
9/19/77	Henneke, Herakovich, Stinchcomb	Davis, Elber, Starnes, Tenney
11/18/77	Weisshaar	Cooper, McWithey
11/21/77	Herakovich, Mills, O'Brien, Palie, Stinchcomb	Davis, Deaton, Elber, Tenney
1/11/78	Herakovich, Johnson, Boitnott, Pindera	Shuart, Starnes, Kennedy
2/15/78	Herakovich, Johnson, Weisshaar	Davis, Shuart, Tenney, Kennedy, Hoffman, Deaton, Starnes, Cooper, Dixon
5/15/78	Herakovich, Johnson, Stinchcomb	Baker, Davis, Kennedy, Shuart, Starnes, Tenney
6/2/78	Herakovich, Weisshaar, Garcia, Mills, Zeiler	Cooper, Davis, Dixon, Shuart
7/23-28/78	Stinchcomb	Tenney
7/30-8/4/78	Weisshaar	Cooper, Garcia, Sawyer, McWithey
8/28-31/78	Weisshaar	Cooper, Garcia, Sawyer, McWithey
9/26/78	Boitnott, Bowles, Herakovich, Johnson, Kriz	Dexter, Farley, Starnes, Shuart, Tenney
10/31/78	Bowles, Herakovich, Kriz, Weisshaar, Zeiler	Cooper, Davis, Sawyer, Tenney
1/5/79	Boitnott, Herakovich, Johnson, Kriz, Stinchcomb	Davis, Starnes

Table 5 - (continued)

<u>Date</u>	<u>Travelers</u>	<u>NASA Contacts</u>
2/27/79	Weisshaar, Bowles, Kriz, Zeiler	Sawyer, Tenney
3/12/79	Herakovich	Davis, Kennedy, Tenney
3/16/79	Herakovich, Post, Bowles	Cooper, Kennedy, Mikulas, Tenney
4/24/79	Herakovich, Weisshaar, Boitnott, Pindera, Zeiler	Cooper, Davis, Starnes, Tenney, Whitcomb
6/18/79- 6/22/79	Johnson	Housner, Starnes, Boitnott
6/21/79	Herakovich, Bowles, Pindera, Rooney	Davis, Tenney, Kennedy
6/24/79- 6/28/79	Weisshaar	Cooper, Sawyer, Garcia
7/29/79- 8/3/79	Stinchcomb	Kriz, Tenney
7/31/79 8/3/79	Weisshaar	Erb, Zeiler
8/7/79	Herakovich, Johnson, Bowles, Kriz, Pindera	Davis, Kennedy, Starnes, Tenney
8/27/79- 8/28/79	Weisshaar	Cooper, Sawyer
9/17/79	Herakovich, Hyer, Johnson Boitnott, Yates	Baker, Cooper, Davis, Starnes, Tenney
11/20/79	Herakovich, Johnson, Post, Boitnott	Davis, Starnes, Tenney
12/17/79	Herakovich, Plunkett, Stinchcomb, Boitnott, Kriz	Anderson, Card, Crews, Davis, Mikulas, Pinson, Starnes, Tenney
2/5/80	Herakovich, Hyer, Johnson, Brooks, Yates	Davis, Mikulas, Tenney