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LARGE RADIOISOTOPE
HEAT SOURCE CAPSULE (LRHSC)
TENTH QUARTERLY PROGRESS REPORT
OCTOBER-DECEMBER 1969

AEC Research and Development Report

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Atomics International
North American Rockwell

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HEAT SOURCE CAPSULE (LRHSC)
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FOREWORD

This is the tenth quarterly progress report, describing the technical status of the Large Radioisotope Heat Source Capsule (LRHSC) Program. It covers the work accomplished by Atomics International during the period from October 1, 1969 through December 31, 1969 under contract AT(29-2)-2338 for the U. S. Atomic Energy Commission

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I. INTRODUCTION

The Large Radioisotope Heat Source Capsule (LRHSC) Program was established to develop the technology of an isotope fuel capsule capable of operation in a space environment at a surface temperature of about 2000° F for five (5) years or more. The program has included the design, fabrication, test and evaluation of a tantalum alloy capsule whose design takes into account the operating requirements of a typical heat source. During the first quarter of GFY 1970, the tantalum alloy capsule technology developed under the LRHSC Program was selected for use in the Transit Program. At that time the LRHSC Program was reconfigured into two (2) series of tasks. The first series of tasks is a continuation of the high temperature isotope fuel capsule technology program. The second series of tasks provide direct support to the development of the isotope fuel capsule for the Transit RTG. Section II of this report contains a description of and a progress report on each of the tasks in the high temperature capsule technology program. Section III contains the same information for the tasks in the Transit Support Program.

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II. HIGH TEMPERATURE CAPSULE TECHNOLOGY PROGRAM

The objective of this program continues to be the development of the technology for an isotope fuel capsule capable of operation in a space environment at a surface temperature of 2000° F or more for five (5) years or more. The work includes process, fabrication and test activities. The process and fabrication has included the work required to define an acceptable manufacturing specification for the reference design capsule and to manufacture the test items required for the program. The test program involves various coupons and capsules with evaluation of chemical compatibility, thermal cycling and adherence of coatings, capsule creep, capsule impact and capsule survival in potential abort environments. The data generated in this program will be used to validate design approaches and define design margins that would exist for high temperature capsules intended for flight systems.

The high temperature capsule technology program is being accomplished under the following tasks:

- A1 - Technology Program Management
- A2 - Analytical Evaluations
- A3 - Hardware Design, Fabrication and Assembly
- A4 - Capsule Creep Testing
- A5 - Capsule Impact Testing
- A6 - Material Compatibility Testing

The objectives and progress during the quarter for each of the above tasks follow.

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TASK NO. A1 - TECHNOLOGY PROGRAM MANAGEMENT

Task Objectives

The objectives of this task are to provide management, direction and planning for all aspects of the High Temperature Capsule Technology Program. This includes technical direction, reporting, detailed plans and procedures.

Summary of Status

The technology program milestones are shown in Table A1-1. The program is on schedule with regard to all milestones.

TABLE A1-1

TECHNOLOGY PROGRAM MILESTONES	
	Dates
1. Complete Reference Capsule Impact Test Series	Completed
2. Release Reference Capsule Impact Test Topical (Topical Report No. 8)	Jan. 1970
3. Complete Compatibility Testing (out to 1,000 hours and up to 2500° F)	March 1970
4. Release Preliminary Creep Test Topical (Topical Report No. 9)	June 1970
5. Release Compatibility Test Topical (Topical Report No. 10)	June 1970

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TASK NO. A2 - ANALYTICAL EVALUATIONS

Task Objectives

The analytical task contains two (2) specific areas of analysis. These are impact correlations and creep correlations. During GFY 1970 the impact program on the LRHSC design will be completed and all impact results will be analyzed and correlated. The creep analysis effort will use the accumulated experimental data and attempt to correlate this data against the assumed mathematical creep model. Only a first cut at correlation at accumulated data is to be made.

Summary of Task Status

Analysis of the impact and creep data will occur in the January-March 1970 time period.

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TASK NO. A3 - HARDWARE DESIGN, FABRICATION, AND ASSEMBLY

Task Objectives

This task contains all efforts related to hardware design, fabrication, and assembly in support of other program tasks. The principal effort will be the fabrication and assembly of five (5) capsules for the thermal and impact test tasks. One capsule will be fabricated which contains an internal heater to simulate capsule operation when fueled. All supporting test fixtures for the coupon test task will be built under this task.

Summary of Task Status

Fabrication and assembly of two (2) impact capsules designated A-10 and A-11 was completed during the reporting period. Also, work is progressing on the fabrication of the internally heated capsule.

The coupon and coupon holder drawings for the GFY 1970 compatibility program were completed. Coupon stack CS-24-1 was fabricated, assembled and delivered to test.

Accomplishments During the Quarter

LRHS Impact Capsules

Fabrication and assembly of impact capsules A-10 and A-11 was accomplished. The inner liner subassemblies were welded with the standard LRHSC annular loading of fuel simulant (W-Mo powder). The structural shells were welded and then coated with Al_2O_3 . These "A" configuration capsules were delivered for test under Task A5.

Internally Heated Capsule

Work is progressing on the fabrication of the internally heated LRHSC capsule. This effort is being coordinated with the fabrication and testing of the Transit internally heated capsule.

Coupon Stacks and Holders

The coupon and coupon holder drawings for the GFY 1970 compatibility program were completed. Coupon stack CS-24-1 was fabricated, assembled, and delivered to test.

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TASK NO. A4 - CAPSULE CREEP TESTING

Task Objectives

The LRHSC Program fuel capsule design utilizes a first generation tantalum alloy (Ta-10W) for primary containment of the fuel, a second generation tantalum alloy (T-111) for secondary containment, and Pt-10%Rh for oxidation protection of the reactive refractory metal containers. The objective of this task is to provide and test a design approach that accounts for creep deformation at elevated temperatures for this capsule design.

To achieve this end a test series has been designed to evaluate heat-to-heat variations on the creep of the T-111 structural shell, determine the effects of variable stress on creep of the shell, relate uniaxial and biaxial stress states to creep of T-111 and finally to determine the interacting effects of capsule components on the creep of the structural member.

Creep testing activities during GFY 1970 will be related to completing on-going tests, post test evaluations and documentation of results. No new tests will be initiated during GFY 1970. Post test analysis and documentation will be completed on capsules tested in GFY 1969 and those completed in GFY 1970. A topical report summarizing this work will be released during the year.

Summary of Task Status

Creep testing of Capsules B-3a and B-6a continued during the reporting period. These capsules are long term tests of the T-111 structure shell. Capsule A-2a was removed from test for location of a suspected helium leak.

Accomplishments During the Quarter

Creep Capsule B-3a

Capsule B-3a is a long term creep test of the T-111 structure shell and has accumulated 5976 hours at 16,500 psi hoop stress. The capsule was scheduled to reach 0.1% diametral strain in 2800 hours while under a constant stress of 16,500 psi. Thereafter, it was to be increased at a rate to produce a total of 1% strain in the following 6000 hours. The apparent diametral strain is now 0.423 with the ramp portion continuing. The behavior of this capsule is shown in Figure A4-1.

Creep Capsule B-6a

Capsule B-6a is also a long term test of the T-111 structure shell and has accumulated 5343 hours at 16,500 psi hoop stress. The creep schedule for this test is the same as B-3a except the stress rate will continue until the capsule has achieved 5% total strain. B-6a has an apparent diametral strain of 0.390%. The behavior of this capsule is shown in Figure A4-2.

Creep Capsule A-2a

The test chamber for A-2a was disassembled to determine the cause of the furnace malfunction which had caused a shutdown of the test. It was found to be due to vapor deposition of some material, assumed to be tantalum, on the insulators causing a short. The furnace was repaired and replaced and the chamber evacuated. The capsule was brought back up to temperature and pressure.

On september 26, 1969 a failure occurred causing this test to terminate. All indications point toward a helium leak at 4225 psi pressure and 2000° F test temperature. The test history for this capsule and final test conditions are shown in Figure A4-3.

Figure A4-1. Creep Capsule B3a Test Behavior

Figure A4-2. Creep Capsule B6a Test Behavior

Figure A4-3. Creep Capsule A-2a Test Behavior

TASK NO. A5 - IMPACT TESTING

Task Objectives

The objective of this task is to determine, by testing, the capability of the reference capsule design to survive impact. The developmental impact tests will also allow insight into the actual capsule deformation phenomena, determine the capsule failure modes and ascertain the relative influence of various capsule impact parameters on capsule failure. During GFY 1970 a total of 4 capsules will be impacted on a granite target at various velocities, impact angles, and temperatures. Post-test analysis and documentation will be completed on all GFY 1969 and GFY 1970 capsules and a topical report summarizing this work will be released during the year.

Summary of Task Status

Two (2) LRHS capsules were impacted during the quarter. Both capsules were 0.082-inch wall configuration "A" capsules. Impact Capsule A-10 was impacted at 1200° F and 450 ft/sec, while Impact Capsule A-11 was impacted at 1200° F and 400 ft/sec. The test program has now been completed. Completion of the topical report which is in preparation will close this task.

Accomplishments During the Quarter

The impact capsules, A-10 and A-11 were impacted in December. A-10, Figure A5-1, was impacted end on at 450 ft/sec. The capsule incurred sheer failure encompassing approximately 280° of the impact surface. There was, however, total fuel containment.

Capsule A-11, Figure A5-2, was impacted end on at 400 ft/sec. This capsule also was breeched at the impact end. The crack is similar to the one in Capsule A-10 except it encompasses only 100° of the impact surface. Figure A5-3 shows the impact surface of these two capsules.

A topical report summarizing the total LRHSC Impact Program is in preparation and will be issued in January.

Figure A5-1. Impact Capsule A-10

Figure A5-2. Impact Capsule A-11

A-11

A-10

Figure A5-3. Impact Surface Showing
Cracks in A-10 on the right and A-11
on the Left.

TASK NO. A6 - MATERIAL COMPATIBILITY

Task Objectives

The LRHSC design requires that many dissimilar materials including noble metals, refractory metals and various ceramics be placed in close proximity or in contact with one another. The operating conditions for the capsule (2000° F for 5 years) are in a temperature range where the rates of solid state diffusion and vapor transport may be increased to levels which would cause significant degradation of the mechanical properties of capsule materials. To insure structural integrity of present and future capsules the compatibility task will determine the reactions that occur between the various materials proposed for capsule construction and evaluate what deleterious effect these reactions will produce during the lifetime of a capsule.

During GFY 1970, three (3) types of compatibility tests will be conducted. These are structural and liner materials, emittance coating and holdddown materials, and reentry materials. Testing will be conducted at 2000° F, 2250° F, and 2500° F for times of 10, 100, and 1,000 hours.

Summary of Task Status

The materials and holders required for the coupon compatibility tests were received during the quarter. The compatibility test rig was moved into the new LRHSC test area; and, the first coupon stack CS-24-1 was fabricated, assembled, and tested for 100 hours at 2250° F.

Accomplishments During the Quarter

The first coupon stack CS-24-1, Figure A6-1, was assembled and tested for 100 hours in the high vacuum compatibility test rig. The stack contained the interfaces illustrated in Figure A6-2. The stack is being prepared for metallographic examination.

Figure A6-1. Coupons and Holder for CS-24-1

CS-24-1

100 Hrs.

2250° F

Figure A6-2. Coupon Stack Assembly

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TASK NO. B1 - TRANSIT CAPSULE PROGRAM MANAGEMENT

Task Objectives

The objectives of this task are to provide management, direction and planning for all aspects of the Transit capsule support effort. This includes technical direction, reporting, detailed plans and procedures. Particular emphasis will be directed to maintaining a close liaison with TRW and MRC.

Summary of Status

During the quarter a task was added to this program to supply the capsule piece parts required for the Transit Program. Activities under this effort will be reported as Task B10 - Fabrication of Transit Capsule Piece Parts.

The milestones for the Transit Support Program are shown in Table B1-1. The program is on schedule with regard to all milestones.

TABLE B1-1

PROPOSED TRANSIT SUPPORT MILESTONES

	Dates
1. Complete Transit-Sized Capsule Impact Tests	Completed
2. Complete Thermal Verification Testing	Feb. 1970
3. Complete Transit Capsule Impact Test Program	April 1970
4. Complete Transit Capsule Fire Test Program	April 1970
5. Complete Transit Capsule Overpressure Test Program	April 1970
6. Complete Transit Capsule Fragmentation Test Program	April 1970
7. Complete Transit Post-Impact Oxidation Testing	June 1970

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TASK NO. B2 - TRANSIT CAPSULE PROCESS DEVELOPMENT AND QUALIFICATION

Task Objectives

Using the experience of the LRHSC Technology Program and the results of Task B9, this task will provide the detailed development and qualification of the fabrication processes for the refractory and noble metal components in the specific Transit capsule configuration. The task involves the forming and finish manufacturing of all capsule piece parts but does not include development of weld parameters or assembly techniques. Manufacturing process descriptions, and quality assurance plans will be generated for each component. The plans and specifications will be adequate for control of production of qualified hardware. Throughout the development task close control on the cost, quantity, process, traceability, and documentation will be maintained.

Summary of Task Status

This task was completed during the month of December and the piece part production capsule effort has been initiated under Task B10. In addition to qualification of the fabrication processes, the delivery of the initial five (5) sets of Transit hardware was completed under this task. The shipment of five (5) capsules was completed December 19, 1969.

Accomplishments During the Quarter

The fabrication process development and qualification started with the tooling and preliminary fabrication processes from Task B9 (originally Task 8). A number of piece parts were taken through each of the required fabrication sequences (liner body, liner cap, structure body, structure cap, clad body, clad cap, retainer ring and liner shims). The parts were examined visually and metallurgically at each stage of the forming processes and were dimensionally inspected at each stage of forming and machining. Changes were introduced at each stage in the fabrication process to improve material characteristics, dimensional conformance, and/or dimensional stability. These changes were recorded and were a part of the input to the final manufacturing process descriptions which were written. These process descriptions were used as the specifications from which the Manufacturing Department prepared their

detailed Manufacturing Station Procedures for Task B10. The Manufacturing Process Specifications and the Station Procedure are both available. Descriptions of the revised manufacturing tooling were also an output of this task.

In addition to manufacturing processes, quality assurance processes were developed under this task. The Quality Assurance Acceptance Procedures were generated for each fabrication step and form the ground work for the Quality Assurance Plan being used in Task B10.

In addition to fabrication process development and qualification, Transit piece part shipments to Monsanto under Task B2 were made as follows:

<u>Quantity</u>	<u>Description</u>	<u>Date</u>
5	Fuel Liner Caps	Nov. 14
3	Fuel Liner Bodies	Nov. 26
5	Strength Member Caps	Nov. 26
3	Strength Member Bodies	Dec. 4
2	Fuel Liner Bodies	Dec. 5
2	Strength Member Bodies	Dec. 9
5	Fuel Locator Rings	Dec. 9
5	Capsule Clad Body	Dec. 19
5	Capsule Clad Cap	Dec. 19

TASK NO. B3 - TRANSIT CAPSULE IMPACT TESTS

Task Objectives

This task will provide the impact test data and complete post-test evaluation of twelve (12) full-scale Transit capsules. Test parameters will vary angle, velocity, temperature, and fuel simulant, and will be specified by TRW.

Summary of Task Status

Test parameters for the twelve (12) impact capsules are to be provided by TRW by January 1, 1970. AI will provide detailed test plans by February 15, 1970. The breakdown of tests to be performed at AI and Sandia will be determined after review of the detailed test requirements. The impact tests will be conducted in March. Test reports are to be completed in April.

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TASK NO. B4 - TRANSIT CAPSULE FIRE TESTS

Task Objectives

This task will determine the response of the capsule to a solid propellant fire simulating a potential launch pad abort condition. Two (2) capsules will be exposed to the fire resulting from a burning block of propellant. Capsules will be instrumented to obtain the transient temperature response. The test configuration may be with or without reentry shield, or with or without oxidation clad, depending on results of overpressure and fragmentation tests. A comparison of fuel retention as well as complete post-test chemical and metallurgical examinations will be conducted.

Summary of Task Status

Test requirements for the two (2) fire test capsules are to be provided by TRW by January 5, 1970. AI will provide a test plan by February 30, 1970, assemble and instrument the capsules in March, conduct the tests in April and provide the post-test analysis and test reports in May and June.

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TASK NO. B5 - TRANSIT CAPSULE EXPLOSIVE OVERPRESSURE TEST

Task Objectives

This task will evaluate the capability of the heat source to withstand the shock wave which may result from a launch pad abort. Two (2) capsules will be used for this test, one of which may subsequently be used for sequential testing in Tasks B4 and B8.

Summary of Task Status

Test requirements are to be provided by TRW by January 1, 1970. AI will conduct the overpressure test in April. Reporting will be completed in May.

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TASK NO. B6 - TRANSIT CAPSULE POST-IMPACT OXIDATION RESISTANCE

Task Objectives

This task will provide data with regard to the oxidation parameters of actual capsules. It will make use of two (2) impacted capsules from Task B3 and may include verification coupon testing as well as exposure of an internally heated capsule. Tests will vary the temperature and exposure due to cladding breach. Full or partial burial may be examined.

Summary of Task Status

Test requirements for the Transit capsule are to be provided by TRW by February 1, 1970. Capsules will be put on test in April and run through June. Post-test analysis and reporting will be accomplished in June.

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TASK NO. B7 - TRANSIT CAPSULE THERMAL VERIFICATION

Task Objectives

This task will provide the data necessary to verify and upgrade the thermal models which are being used to predict steady-state operating, re-entry, and post-impact temperatures. A heat source will be assembled using an internal electrical heater and temperature instrumentation at each stage of assembly. The stabilized shell temperature as well as the temperature drops across the various gaps shall be determined. The piece-parts are to be GFE to this task.

Summary of Task Status

Test parameters were received from TRW during the month of November, 1969. The test plans and drawings have been released and the test procedures are in process.

Accomplishments During the Quarter

Work is progressing on the fabrication of the Transit internally heated capsule. Figures B7-1 and B7-2 show the internally heated capsule design. All materials have been ordered and the task is on schedule for assembly/test of the capsule starting in late January.

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Figure B7-1.
Thermal Verification Capsule

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Figure B7-2.
Thermal Verification Capsule

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TASK NO. B8 - TRANSIT CAPSULE FRAGMENTATION TESTS

Task Objectives

This task will test and evaluate the damage to the heat source resulting from fragments or shrapnel produced by a launch pad abort. The test will be performed under controlled conditions by using a sled facility and impacting the heat source into fragments representative of the shrapnel produced in an abort mold.

Summary of Task Status

Test requirements are to be provided by TRW by January 15, 1970. The tests will be accomplished at Sandia in April. AI will prepare the test plans, coordinate the tests and do the post-test analysis and reporting.

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TASK NO. B9 - TRANSIT-SIZED CAPSULE FABRICATION AND TESTING

Task Objectives

The objectives of this task are to provide limited process development, examination, fabrication and testing of a Transit-sized, vented capsule. The capsule will have a 0.020-inch Ta-10W liner, a 0.090-inch T-111 structural member, and a Pt-10Rh oxidation clad.

Fabrication process development will be done on ten (10) sets of blanks with the objective of obtaining at least enough piece parts to assemble four (4) vented capsules. Extra piece-parts will be shipped to MRC. A preliminary manufacturing specification will be prepared.

The four (4) assembled capsules will be impact tested by Sandia.

Summary of Task Status

The initial development effort to produce Ta-10W liners and caps, T-111 structure shells and caps, and Pt-10Rh barrier shells and caps for the Transit-sized impact capsules was completed during the quarter.

Assembly tooling was fabricated and preliminary weld parameters for the impact capsules were generated.

Impact capsules AIT8-1 through AIT8-4 were assembled, tested at the Sandia Laboratory Rocket Sled Test Facility, and returned to Atomics International where complete post-test analyses were performed.

Impact capsule AIT8-1 was destroyed during testing when the catcher door on the sled failed to close resulting in the capsule being run over by the sled. AIT8-5 was assembled to replace AIT8-1 and was tested successfully. A complete post-test analysis was performed on this capsule at Atomics International.

Accomplishments During the Quarter

Piece-Part Fabrication Development

The initial development effort to produce Pt-10Rh liners and caps was completed. Four Pt-10Rh liners and caps were formed, machined and assigned to impact capsules AIT8-1 through AIT8-4. Two (2) Pt-20Rh liners

- DRAWN THROUGH 6 DIES
- 7.25 in. DIAMETER – 0.030 in. THK BLANK
- FINAL WALL – 0.020 in.

- SINGLE STAGE COINING
- 4.0 in. DIAMETER – 0.035 in. THK BLANK
- FINAL WALL – 0.020 in.

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Figure B9-1. Oxidation Barrier Assembly Fabrication
(Pt - 10 Rh)

- DEEP DRAWN THROUGH 6 DIES
- 6.50 in. DIAMETER – 0.060 in. THK BLANK
- FINAL WALL – 0.020 in.

- SINGLE STAGE COINING
- 3.50 in. DIAMETER – 0.035 in. THK BLANK
- FINAL WALL – 0.030 in.

MICROSPHERE FUELING PORT

9-023-120-7

Figure B9-2. Fuel Liner Fabrication

were fabricated and shipped to Mound for gaging. The fabrication of the Pt-10Rh liners is summarized in Figure B9-1.

The initial development effort to produce fuel liners and fuel liner caps was completed. Four liners and caps were formed, machined and assigned to impact capsules AIT8-1 through AIT8-4. The fuel liner fabrication is summarized in Figure B9-2.

The initial development effort to produce structural shells and caps has been completed. Four structural shells and caps were formed, machined and assigned to impact capsules AIT8-1 through AIT8-4. The structure fabrication is summarized in Figure B9-3.

Development of preliminary weld parameters for the four impact capsules was completed and capsules AIT8-1 through AIT8-5 were assembled and delivered to Sandia Laboratory for testing. Impact capsule AIT8-1 and AIT8-5 contained W/Mo fuel simulant to represent the microsphere fuel form. Impact capsules AIT8-2, AIT8-3 and AIT8-4 contained Thoria/Moly fuel pucks to simulate the solid solution cermet fuel form. Figures B9-4 through B9-7 show the assembly sequence of these impact capsules.

SSC Simulant Grinding and Coating

SSC Fuel simulant (Thoria/Moly) was received from GE for the Task 8 impact capsules. The simulant was received as moly-coated discs. Discs were then ground for fit into the hemispherical ends of the capsule and re-coated with moly. The required discs for AIT8-2, AIT8-3 and AIT8-4 were ground to shape and plasma sprayed with moly, with an average coating thickness of 0.003-inch. Figure B7-8 shows an as-received disc and two (2) discs which have been ground and recoated. Figure B9-9 shows a completed loading of the SSC fuel simulant. The discs for AIT8-4 were outgassed at 2300° F prior to capsule assembly. The other two fuel loadings were not outgassed at temperature.

Task 8 Impact Tests

Five (5) Task 8 Transit capsules were delivered to Sandia for impact testing at their Rocket Sled Test Facility. Table B9-1 summarizes this test program. The first capsule to be impacted was the microsphere capsule,

- DEEP DRAWN THROUGH 6 DIES
- 6.50 in. DIAMETER – 0.170 in. THK BLANK
- FINAL WALL – 0.090 in.

- SINGLE STAGE COINING
- TAPERED BLANK – 3.6 in. DIAMETER
- FINAL WALL – 0.090 in.

9-023-120-8

Figure B9-3. Structure Fabrication

PRD/CAP SCHEMATIC

WELD FIXTURE

E. B. WELDED PRD/CAP

9-023-120-10

Figure B9-4. Liner/PRD Assembly

SSC FUELING CONFIGURATION

MICROSPHERE FUELING CONFIGURATION

SSC LINER ASSEMBLY

FUEL PORT CLOSURE

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Figure B9-5. Liner Assembly

**LINER ASSEMBLY IN
STRUCTURAL SHELL**

STRUCTURAL CAP IN PLACE

E B WELDED ASSEMBLY

9-023 120 12

Figure B9-6. AIT8-1 - Structural Assembly

STRUCTURAL ASSEMBLY IN CLAD

CLAD CAP IN PLACE

E. B. WELDED CLAD ASSEMBLY

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Figure B9-7. S/N 001 - Pt Clad Assembly

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Figure B9-8. SSC Simulant Configurations

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Figure B9-9.
Coated SSC Simulant

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Figure B9-10. Transit Capsule Impact Setup at Sandia

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TABLE B9-1

Impact Capsules	Type	Capsule Weight (lb)	Graphite Weight	Temperature °F at Impact	Velocity	Angle of Impact	Impact Energy (ft/lb)	Summary
AIT8-1	Microsphere	8.6	-	2100	355	45 °	16,825	Capsule intact following impact, but destroyed when run over by rocket sled.
AIT8-2	SSC	8.99	-	2100	385	45 °	20,650	Complete success. No leaks in Pt-10Rh or T-111. Total fuel containment.
AIT8-3	SSC	9.2	3.34	2190	388	45 °	29,175	Fuel totally contained. Ductile radial fracture of ~ 1-1/2-inch length.
AIT8-4	SSC	9.31	3.60	2100	327	45 °	20,750*	Fuel totally contained. Small crack in impact surface.
AIR8-5	Microsphere	8.45	3.33	2100	335	45 °	20,500	Total fuel containment. No leaks or cracks in strength member. Three small cracks in Pt-20Rh.

* Based on a post arc-jet, capsule and graphite weight of 12.52 pounds

designated AIT8-1. The capsule was mounted stationary on the sled tract at a 45° angle to the impact surface as shown in Figure B9-10. It was heated to 2100° F and impacted by the rocket sled at 355 ft/sec. The capsule was damaged considerably when the capsule catch box failed to contain it. The movies of the test and subsequent examination of the capsule indicate the capsule and clad were intact and the fuel simulant was contained prior to being run over by the rocket sled.

The second capsule AIT8-2, contained a solid solution cermet (SSC) fuel simulant which consisted of Thoria-232 in a molybdenum matrix, coated with molybdenum. This bare capsule was mounted stationary on the sled track and at a 45° angle to the impact surface. It was heated to 2200° F and impacted by the rocket sled at 385 ft/sec. AIT8-2, shown in Figure B9-11, was contained by the capsule catch box. A survey by Health Physics personnel at the facility indicated there had not been any release of fuel simulant. Visual examination of the capsule revealed the platinum barrier to be intact.

The capsule was smeared upon receipt at AI and there was no evidence of contamination. Gamma radiographs were taken at three angles and are shown in Figures B9-12, -13, and -14. An examination of the gamma radiographs indicate that there was not a breach in the T-111 or the Pt-10Rh. There was, however, indication of cracks in the liner. Fuel puck alignment and cracking was similar to AIT8-3, although the hump in the capsule due to displaced fuel pucks is forward of and encompasses about six (6) pucks rather than one or two as in the case of AIT8-3.

A helium leak test of the Pt-10Rh showed the cladding to be leak tight. The capsule was photographed, weighed and dimensionally checked. Removal of the Pt-10Rh cladding was accomplished with the exception of the pressure bonded areas of impact. A visual examination of the T-111 showed no evidence of cracks or even check marks. There is no discoloration, in fact, the surface color and texture as shown in Figure B9-15 are as fabricated.

A helium leak test of the T-111 shell showed no evidence of leaks. The T-111 shell was then removed exposing the Ta-10W liner. Figures B9-16, B9-17, and B9-18 show the liner exposed following the removal of the T-111 shell. Note the strain marks in the uncracked surfaces of the liner indicating

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Figure B9-11. Capsule AIT8-2

Figure B9-12. Gamma Radiograph of AIT8-2 — Side View

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Figure B9-13. Gamma Radiograph of AIT8-2 - 45°

Figure B9-14. Gamma Radiograph of AIT8-2 - Top View

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Figure B9-15. AIT8-2 With Pt-Rh Removed

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Figure B9-16. T-111 Half Shell Removed
From AIT8-2 Liner

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Figure B9-17. Side View of AIT8-2 Showing Liner

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Figure B9-18. End View of AIT8-2 With T-111
Half Shell Removed

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Figure B9-19. Capsule AIT8-2,
Fuel Exposed Except at Im-
pact End

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Figure B9-20. AIT8-2, Fuel Exposed

that the liner was ductile to some degree at impact. The strength member also exhibits all the indications of high ductility at impact yet it has a crack in the base caused from being too tightly squeezed in a mill vise during post-test analysis.

The liner pieces were removed to expose the fuel simulant as shown in Figures B9-19 and B9-20. The capsule was inverted and tapped lightly on the base without any significant amount of simulant spilling out.

The PRD was partially exposed by prying and brushing the fuel chucks away. Figure B9-21 shows the PRD partially exposed. Figures B9-22 and B9-23 show the PRD after more fuel had been removed.

An attempt was made to free the fuel simulant from the capsule by ultrasonic means without success. The fuel was coaxed out of the strength member. Figure B9-24 shows the two halves of the strength member and the broken fuel simulant.

The PRD, although damaged by the impact, was not sheared by the fuel discs. Figure B9-25 shows the PRD prior to being removed for shipment to TRW. The PRD to liner weld was visually inspected after being removed and is totally intact.

There is a discoloration on both the T-111 shell and the liner in the vicinity of the PRD. This can be attributed to a contaminant being expelled from the fuel through the PRD prior to and after impact.

The fuel was packaged into six relatively equal bags for shipment to LASL. Figure B9-26 is a photograph of the fuel after being packaged.

Conclusions on AIT8-2 were as follows:

- 1) The capsule survived impact with both the T-111 and the Pt-Rh intact.
- 2) The phenomena of displaced fuel pucks causing a hump in the back wall is present but less severe than with AIT8-3 due to involvement of more pucks.

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Figure B9-21. AIT8-2, PRD Partially Exposed

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Figure B9-22. AIT8-2, PRD Partially Exposed

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Figure B9-23. AIT8-2, PRD Partially Exposed

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Figure B9-24. AIT8-2, Fuel Removed From T-111 Shell

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Figure B9-26. Fuel From AIT8-2 in Packages

7734-40186
Figure B9-25. AIT8-2, PRD Exposed

AIT8-3, the third capsule, also contained an SSC fuel simulant. This capsule was supported in an ATJ graphite heat shield. The capsule was tested under the same conditions as AIT8-2 except the velocity was 388 ft/sec. AIT8-3, shown in Figures B9-27, -28, and -29, was contained by the catch box and a survey by Health Physics personnel indicated that there had not been an R. A. release. A visual examination of the capsule indicated a radial fracture of the platinum barrier opposite the impact side and approximately at the midplane.

AIT8-3 was smeared by Health Physics upon its return to AI with no detectable contamination on the platinum cladding. The capsule was photographed and gamma radiographed as shown in Figure B9-30 and Figure B9-31. The T-111 is obviously fractured and the photographs show that the fuel pucks are displaced into the area of the break. There is also extensive cracking of the fuel pucks.

Figure B9-27. AIT8-3 — Side View

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Figure B9-28. AIT8-3 - Bottom View

Figure B9-29. AIT8-3 - Top View

Figure B9-30. Gamma Radiograph of AIT8-3 - Side View

Figure B9-31. Gamma Radiograph of AIT8-3 - Top View

The capsule was transferred to the hot shop and was again smeared. Again there was no contamination on the surface of the Pt-10Rh. Direct monitoring over the crack with an alpha detecting instrument indicated a reading of 200 dpm.

The Pt-10Rh cladding was removed, Figure B9-32, except for that portion which is pressure bonded to the impact surface. An examination of the crack in the Pt-10Rh indicates a ductile, tensile failure. White crystalline particles were in the area of the crack on the inside of the Pt-10Rh. There was also a dark colored structure in the same area. X-ray diffraction analysis of these particles determined the white particles to be MoO_3 and the dark particles to be ThO_2 .

Visual examination of the T-111, Figure B9-33, showed a circumferential crack approximately 1/16 inch in width and with an arc length of approximately 60°. Discoloration of the T-111 in the area of the crack indicates oxidation of that material. The T-111 is intact in all other areas. Figures B9-34 and B9-35 show the capsule prior to removing the T-111 shell. A smear of the crack at the outside of the T-111 indicated 40 to 60 dpm. Direct monitoring over the crack showed a reading of 2200 dpm.

Figures B9-36 and B9-37 show the T-111 quarter section removed from the liner material. The liner is badly embrittled although the strain marks in the uncracked section indicate high deformation and ductility during impact. There are also indications that the T-111 was embrittled following impact; however, the cross section of the T-111 crack shows a ductile tensile failure.

The liner pieces were then removed from the quarter section exposing the fuel simulant. Figure B9-38 shows this condition. The crack in the T-111 follows exactly the line of the displaced fuel puck which sits directly under it.

The other quarter section of T-111 was removed from the upper portion of the capsule. The two quarter sections are shown in Figure B9-39. The crystalline structure in and near the crack in the pieces of T-111 were X-ray diffraction analyzed. The white crystalline structure was MoO_3 and the dark structure was ThO_2 . The upper half of the capsule with the fuel simulant exposed is shown in Figures B9-40, B9-41, and B9-42.

Figure B9-32. Pt-10Rh Clad
Removal From AIT8-3

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Figure B9-33. Top View of Crack in T-111 on AIT8-3

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7734-40130A

Figure B9-34. Capsule AIT8-3, Pt-10Rh Removed

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Figure B9-35. Capsule AIT8-3, Pt-10Rh Removed

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Figure B9-36. Capsule AIT8-3,
T-111 Quarter Sectioned

7734-40143A

7734-40144A

Figure B9-37. Capsule AIT8-3, T-111 Quarter Sectioned

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Figure B9-38. Capsule AIT8-3, Quarter Section Fuel Exposed

Figure B9-39. T-111 Quarter Sections From AIT8-3

7734-40139A

Figure B9-40. Capsule AIT8-3, Fuel Exposed

7734-40140A

Figure B9-41. Capsule AIT8-3, Fuel Exposed

The PRD was exposed by brushing the fuel chunks away from it. Figure B9-43 shows the PRD to be sheared in two places. The apparent cause is the shearing action set up when the fuel discs were impacted. The PRD to liner weld showed a brittle failure over about 40% of the circumference, although there was a significant amount of ductile strain during impact as evidenced by the elongation of the previously round PRD base. Figure B9-44 shows the PRD after removal. The PRD was returned to TRW for analysis.

The capsule was then inverted to allow the loose fuel simulant chunks to be pured out. About 30 to 40% of the fuel remained compacted in the bottom unimpacted end of the T-111 shell, as shown in Figure B9-45. Of the fuel which poured out, the order of magnitude of fine powder vs. chunks appears to be about 1%. The SSC fuel simulant and the bottom half of the T-111 shell was hand carried to LASL for analysis.

Chemical and metallographic samples were selected from corresponding areas of AIT8-2 and AIT8-3. The chemistry samples were taken from the ends and center of both the T-111 shell and the tantalum liner.

The results of the carbon and nitrogen analysis of the liners are presented in Table B9-2 and for the T-111 shells in Table B9-3. The data show no significant change in the carbon and nitrogen content of either the T-111 or the liners.

Chemical analyses for oxygen and hydrogen content in AIT8-2 and -3 were also completed. Those results are given in Table B9-4. The method used to extract the O_2 and H_2 was vacuum fusion. This method involves introducing the tantalum alloy into a 1900 to 2000° C platinum bath contained in a graphite crucible in a vacuum. The oxygen reacts with the graphite to produce CO. The CO is converted into CO_2 by passing it through CuO. At this stage any H_2 is converted to H_2O . It is then passed through $Mg(ClO_4)_2$ to remove the H_2O . The CO_2 is trapped by passing it through liquid N_2 . The CO_2 is converted to a gas by bringing it to room temperature and the volume of gas is measured. These volumes are expressed in PPM concentration.

The chemistry department has indicated that the reason the results vary is that the material is inhomogeneous. The trend, however, is sufficient to indicate the probable source of the contamination as the SSC fuel simulant.

Figure B9-42.
Capsule AIT8-3, Fuel Exposed

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Figure B9-43.
Capsule AIT8-3, PRD

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Figure B9-44. PRD From AIT8-3

Figure B9-45.
Fuel Compacted in
AIT8-3

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TABLE B9-2
CHEMICAL ANALYSIS OF LINERS

	Content (ppm)	
	C	N
AIT8-2-C4		74
Impact End	41	50
AIT8-2-C5		19
Center	7	5
AIT8-2-C6		27
End Opposite	36	25
AIT8-3-C9		16
Impact End	75	48
AIT8-3-C7		19
Center	37	27
(Next to crack)		
AIT8-3-C8		116
End Opposite	82	110

TABLE B9-3
CHEMICAL ANALYSIS OF T-111

	Content (ppm)	
	C	N
AIT8-2-C10		38
Impact End	37	35
AIT8-2-C11		26
Center	9	28
AIT8-2-C12		28
End Opposite	34	42
AIT8-3-C1		25
Impact End	13	29
AIT8-3-C2		37
Center	18	49
(Next to crack)		
AIT8-3-C3		46
End Opposite	16	36

TABLE B9-4
RESULTS OF OXYGEN AND HYDROGEN ANALYSES

	Impact End		Center		Opposite End	
	O ₂ ppm	H ₂ ppm	O ₂ ppm	H ₂ ppm	O ₂ ppm	H ₂ ppm
AIT8-2	1600	45	2300	180	1000	25
Liner	900	45	3500	30	1080	15
AIT8-3	4900	70	10,040	55	1900	65
Liner	3600	60	11,000	45	3200	75
			8,900	80		
AIT8-2	275	125	650	70	625	50
T-111	40	65	700	15	100	85
	37	40			115	50
AIT8-3	12	70	1000	65	70	75
T-111	60	65	750	100	60	60

8587-6-3

100X

Figure B9-46. Photomicrograph at Inside T-111
Surface of AIT8-3

8587-6-4

100X

Figure B9-47. Photomicrograph at Outside T-111
Surface of AIT8-3

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Metallographic samples were taken from the T-111 shells, of AIT8-2 and AIT8-3, along the side opposite the impact surface and intersecting the crack in AIT8-3. The samples were submitted to the met lab for preparation, photomicrographs and hardness traverses. It appears from the metallography that a reaction has taken place at the inside surface of the cylindrical section, up to 0.012 inch deep, and at the outside surface, up to 0.005 inch deep. At the ends, including the weld region, the reaction appears to be continuous. Figure B9-46 is a photomicrograph taken at the inside surface of the cylindrical section. Figure B9-47 is of the outside surface of the cylindrical section and Figure B9-48 is typical of the structure found near the nose of AIT8-3.

Hardness measurements of AIT8-2 and AIT8-3 indicate an increase in hardness up to 30% at the inside surface and up to 15% at the outside surface. The average hardness, excluding the outer and inner 15 mils of wall thickness, is approximately 20% higher than normal.

The contaminants responsible for embrittling the liner and structure come from the fuel simulant. They are primarily oxygen and hydrogen. The T-111 obviously is not brittle at impact as can be seen by a high degree of deformation without failure and the ductile, tensile nature of the failure of AIT8-3 shown in Figure B9-49. The liner does appear to have some ductility at impact but most certainly is brittle at room temperature.

The fuel simulant was outgassed at ambient temperature in a vacuum of 1×10^{-5} mm hg for 25 hours prior to being sealed into the liners of AIT8-2 and AIT8-3. Apparently contaminants contained within these fuel pucks were not fully released during this outgassing cycle. The contaminants were released during the heating cycle for impact, causing the liner to be considerably less ductile, even at the high temperature of impact, and brittle at room temperature. It is even possible that upon impact the broken fuel released even more contamination. The liner was also breeched at impact exposing the strength member to these contaminants.

To alleviate the problem of gaseous constituents being sealed into the liner, the fabrication and assembly procedure was revised to include the following:

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100X

Figure B9-48. Photomicrograph Near the
Nose of AIT8-3

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25X

Figure B9-49. Photomicrograph of the Fracture in AIT8-3

- 1) After machining and moly coating, the fuel discs are outgassed in a vacuum furnace. The temperature is at least 2300° F for 1 hour or until the outgassing ceases (as determined by vacuum).
- 2) The fuel discs are then handled in an inert atmosphere while loading into the liner and up to the time of welding.
- 3) The moly-tungsten powder is outgassed under the same conditions as the SSC simulant.
- 4) The fuel loading takes place in an inert atmosphere which remains until the liner is final welded.

Conclusions on AIT8-3 are as follows:

- 1) The SSC fuel simulant was contained in the capsule; however, a ductile circumferential crack of the Pt-10Rh and the T-111 occurred due to localized tensile stresses induced in the walls by one or two displaced fuel simulant discs.
- 2) Displacement of the discs was probably due to a combination of pinching of the disc bottoms due to compaction of the fuel simulant on the impact side and of a direct lateral force resulting from slap-down of the capsule on its side during impact.
- 3) The embrittlement of the capsule components, including the PRD weld, was increased by oxidation which occurred after the capsule was breached and during the cool-down phase from the 2200° F impact temperature.
- 4) The PRD was probably broken due to the shearing action between the fuel pucks.
- 5) An insignificant amount of fuel simulant fines was lost during disassembly; therefore, the analysis by LASL should be representative of the condition of the fuel simulant after impact.

The outgassing conditions were met in the fabrication and assembly of AIT8-4, an SSC capsule, and AIT8-5, a microsphere capsule.

AIT8-4, the SSC capsule with the reference Transit heat shield, was submitted to a thermal soak and a simulated Orbital Decay Reentry Test prior to being impacted. The impact test was performed in the usual manner.

The Thermal Soak Test consisted of heating AIT8-4 to 1350° F in a vacuum of less than 1×10^{-5} mm Hg for 24 hours. After the thermal soak was accomplished, X-rays of the capsule were taken at 45, 90, 135 and 180° to the intended stagnation line. The X-ray at 90° is shown in Figure B9-50, the stagnation line being opposite the thermocouple wires.

The Orbital Decay Reentry Test of AIT8-4 was performed at Sandia's Plasma Arc Jet Facility. The thermal data pertaining to the reentry test is presently being evaluated by Sandia and TRW and has not yet been released. However, some physical data is available. The graphite reentry outer shield body ablated more at the stagnation line than had been expected. The graphite shell burned through approximately 40 seconds from the end of the reentry test, exposing the capsule to a more severe environment than would ordinarily be expected. Figures B9-51 and B9-52 show the post orbital decay reentry appearance of the heat shield. The shiny surface seen through the hole in the heat shield is the pyrolytic graphite inner shield sleeve.

The heat shield was weighed and physically measured to determine the amount of ablation incurred. It was X-rayed for comparison with pre-test X-rays. In order to perform the post reentry test inspection, the capsule was removed from the heat shield. The disassembly is documented by photographs shown in Figure B9-53. The capsule appeared to be in pre-test condition except for the platinum-rhodium thermocouple insulation being fused to the capsule body. The capsule was reassembled into the heat shield and in doing so the proper orientation of each part to the stagnation line was maintained.

The impact test of AIT8-4 took place on Friday, December 19, 1969. The target impact velocity and temperature were 331 ft/sec and 2100° F respectively. The actual impact velocity and temperature were 327 ft/sec and 2070° F.

Figure B9-50. AIT8-4 Pre-Test X-Ray

Figure B9-51. AIT8-4 Post-Arcjet Configuration

Figure B9-52. AIT8-4 Post Arcjet Configuration

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Intermediate Disassembly Stage Showing Pyrolytic Graphite (bottom center) and Outer Shield Body and End Plugs

Figure B9-53. AIT8-4 Completely Disassembled After Reentry Test Shows Thermocouples Fused to the Capsule

An inspection of the capsule following the impact test resulted in the discovery of two cracks in the Pt-20Rh oxidation barrier. One of the cracks was on the impact end, Figure B9-54, and appeared to be a puncture rather than a crack. The other has the definite characteristics of a brittle fracture. It occurred in the thermocouples groove, which during the arc jet test, filled with melted thermocouple insulation. This is shown in Figure B9-55. The sides opposite and 90° to the impact surface are shown in Figures B9-56 and B9-57. The tape impressions and other marks seen on the capsule in the previous four figures were a result of its coming in contact with protective materials in the catch box designed to reduce secondary impacts.

The capsule was examined by the Sandia Health Physics staff immediately after the impact test. Direct monitoring and smearing of the capsule showed no evidence of fuel loss and there was no detectable level of contamination in or around the two cracks in the Pt-20Rh. The capsule was photographed by Sandia, packaged and returned to AI for a full post-test examination.

Upon receipt at AI the capsule was surveyed by the Health Physics representative and was found to have no detectable level of contamination on, in or around the cracks in the Pt-20Rh. The capsule was weighed, photographed and X-rayed followed by removal of the Pt-20Rh cladding from the side opposite the impact side of the capsule. Figure B9-58 shows the capsule with the cladding removed. The cladding could not be removed from the impact surface of the capsule or from around the crack as shown in Figure B9-59. The location of the crack in the impact end was circled and is also shown in Figure B9-60. A leak test of the capsule showed a potential leak at this location.

The capsule disassembly was continued by cutting through the structural shell and the liner to expose the SSC fuel simulant, as shown in Figure B9-61. The exposed liner and fuel were shinny, having the same texture and color of pre-assembled material.

The PRD was exposed by brushing the fuel from around it. As shown in Figure B9-62, the PRD is slightly bent and pinched near the tip but completely intact. The PRD and PRD weld are crack free.

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Figure B9-54. AIT8-4 Post Impact Configuration

7734-40204

Figure B9-55. AIT8-4 Post Impact Configuration

Figure B9-56. AIT8-4 Post Impact Configuration

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Figure B9-57. AIT8-4 Post Impact Configuration

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Figure B9-58. AIT8-4 With Clad Removed

Figure B9-59. AIT8-4 With Clad Removed

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Figure B9-60. AIT8-4 With Clad Removed

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Figure B9- 61. AIT8-4 Halves

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Figure B9- 62. AIT8-4 PRD

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Figure B9-63. AIT8-4 With Exposed Crack

The shiny highly compacted fuel seen above the PRD when removed revealed a small crack beneath it. The crack extends through the liner, T-111 and cladding. The crack is approximately 0.4-inches long and 0.025-inches wide. Figure B9-63 shows the crack after the fuel had been removed. The crack is a ductile shear, on a plane 45° to the impact surface. Upon examining the fuel, a very hard, highly compacted chunk of simulant was found which fit into the depression over the crack.

Conclusions on AIT8-4 are as follows:

- 1) There was no loss of fuel simulant during or after impact of the capsule.
- 2) The SSC simulant was sufficiently outgassed to prevent significant contamination of the liner.
- 3) The PRD is probably in operating condition.

Figure B9-64. AIT8-5 As Fabricated

Figure B9-65. AIT8-5 Installed Over Sled Track

- 4) The major fuel compaction, due to the change in volume at impact, occurred in a localized area in the impact end. The impinging forces between the impacting capsule and the granite block caused thinning in the capsule wall making it susceptible to puncture or shear. The crack in the capsule was probably a result of the interaction of fuel discs compacting at impact and/or the heat shield breaking apart leaving an uneven or irregular layer of graphite between the capsule and the granite block.
- 5) The liner, except for the crack in the impact end, and the liner weld are totally intact.

Chemical and metallographic analysis is in progress. The chemistry samples will be taken from the impact end, center of the capsule and the end opposite impact. Chemistry will be quantitative for O_2 and H_2 .

The microsphere capsule, AIT8-5, Figure B9-64, was impacted on November 26. This capsule was tested as a replacement for AIT8-1, the capsule which was destroyed when run over by the rocket sled.

Unlike AIT8-1, AIT8-5 was incased in an ATJ graphite reentry shell for the impact test because this configuration is considered to be a more severe test. The capsule was installed over the sled track as shown in Figure B9-65. The target impact velocity was set at 340 ft/sec. The actual velocity at impact was 335 ft/sec and the temperature at impact was 2100° F.

Examination of the capsule immediately following impact showed the capsule to be intact and with no visual defects in the capsule shell. However, after cooling to ambient temperature and after being cleaned to remove random smears of graphite, cracks in the Pt-20Rh could be seen in two areas. The capsule was photographed by Sandia, packaged and returned to Atomics International for full post-test analysis.

The post-test analysis of capsule AIT8-5 proceeded as follows:

- 1) The capsule was photographed to show "as impacted appearance." Figure B9-66 contains three views of AIT8-5.
- 2) The cracks in the Pt-20Rh were photographed as shown in Figure B9-67.

Figure B9-66. Capsule AIT8-5 Following Impact

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a. Crack on Side of AIT8-5

b. Crack on Impact Surface

Figure B9-67. Cracks in Pt-20Rh

Figure B9-68. AIT8-5 With Pt-20Rh Removed

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- 3) The capsule was weighed, gamma radiographed, measured dimensionally and then leak tested. The leak test showed the Pt-20Rh to leak in three places.
- 4) The Pt-20Rh was removed and the capsule was again leak tested to determine the integrity of the strength member. The T-111 capsule was helium leak tight. Figure B9-68 shows the capsule prior to being leak tested.
- 5) The surface of the T-111 was discolored slightly in the areas near the Pt-20Rh cracks but there was no evidence of any other irregularities.
- 6) A half section of the T-111 was removed exposing the liner. The inner surface of the T-111 and the outer surface of the liner were bright and shiny as shown in Figure B9-69. There was no evidence of contamination of either components.
- 7) The liner has three cracks equally spaced around the same circumference in the hemispherical end of the liner at the end opposite impact. Figure B9-70 shows one such crack and part of another. The cracks are ductile, tensile failures in a thinned region of about 0.25-inches wide. It was discovered subsequently that the liner used in this capsule was one of the first produced under Task 8 and did not have a final coining operation on the hemispherical end of the liner shell. Dimensional data on such liners indicate that extreme wall thinning occurs in the area where the cracks were observed. Local areas as thin as 0.005-inches have been detected. Coining of the end has solved this problem on subsequent liners.
- 8) The top half of the liner was removed, as shown in Figure B9-71, exposing the compacted fuel simulant. The powder completely filled the reduced internal volume of the capsule.
- 9) The fuel simulant was removed to expose the PRD. The PRD is bent at an angle of about 60° from vertical. The outer cylinder of the PRD neck failed at approximately 1/4 inch above the base and around 3/4 of its circumference. The PRD to liner weld was intact.

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Figure B9-69. AIT8-5 With Liner Exposed

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Figure B9-70. AIT8-5 Liner

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Figure B9-71. AIT8-5 With Fuel Simulant Exposed

- 10) Samples for chemical analysis were cut from the capsule liner and structural shell, at the impact end, center and end opposite the impact end. These samples were submitted with the AIT8-4 chemical samples.

The metallographic analysis, thus far, has revealed the structure in the T-111 to be typical of previously drawn and recrystallized material. Figure B9-72 is a cross section of the impact end. Figure B9-73 is typical of the side wall and Figure B9-74 is typical of the end opposite the impact end (end cap). The flow lines extending parallel to the surface are evidence of prior cold strain in the material. They are a result of the fabrication process and should not be interpreted as a product of impact. The apparent visual difference in the concentration of these flow lines is due to the drawing process for the structural shell versus the coining process for the end cap.

OD 8598-4-2 100X
Outside Wall

8598-4-1 ID 100X
Inside Wall

Figure B9-72. Microstructure at Impact End
of AIT8-5 Structural Shell

Etchant: 1 part H_2O_2
2 parts H_2O
4 parts HF
4 parts HNO_3

OD 8598-6-2

Outside Wall

100 X

ID 8598-6-1

Inside Wall

100 X

Figure B9-73. Microstructure of Side Wall of AIT8-5

Etchant: 1 part H_2O_2
 2 parts H_2O
 4 parts HF
 4 parts HNO_3

OD 8598-9-2

Outside Wall

100 X

ID 8598-9-1

Inside Wall

100 X

Figure B9-74. Microstructure of AIT8-5 at the End
Opposite the Impact End

Etchant: 1 part H_2O_2
2 parts H_2O
4 parts HF
4 parts HNO_3

The material hardness of the T-111 is equally distributed across the wall. However, the hardness becomes progressively harder near the impact end of the capsule.

Conclusions from AIT8-5 are as follows:

- 1) The fuel simulant was completely contained and the T-111 shell was helium leak tight.
- 2) Although the Pt-20Rh cladding contained some small localized cracks, its gross integrity was maintained.
- 3) There is no evidence of significant contamination in the liner or the structural shell.
- 4) The tensile failure in the liner, at the end opposite impact, was due to a thin wall, a condition which does not exist in current liners.
- 5) The compacted tungsten moly powder prevents movement of the PRD neck, causing a failure if the impact deformation results in a significant relative change in orientation of the gas in the liner cap.

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TASK NO. B10 - FABRICATION OF TRANSIT CAPSULE PIECE PARTS

Task Objectives

The objective of this task is to fabricate Transit capsule piece parts in accordance with TRW Systems drawings and on the schedule indicated in Figure B10-1.

Summary of Task Status

The fabrication activities for all piece part elements with the exception of the liner shims and fuel port closure discs are well underway. Material is in-house for the microsphere fuel port discs but work is being held up on the fabrication in deference to the higher priority SSC piece parts. Liner shim material has as yet not been received. Approximately 48 sets of parts are in various stages of fabrication with 22 sets of tantalum piece parts delivered. Ten sets of platinum rhodium have been delivered also. The lag in delivery of Pt-Rh parts was due to material unavailability.

Accomplishments During the Quarter

This task was initiated during this quarter. All of the processing station procedures (16) have been released and are in use. Inspection and NDT (non-destructive testing) data have been collected on all parts delivered to date and are being transmitted to MRC. A summary of the piece parts produced during the quarter and the materials status at the end of the quarter are as follows:

1. Piece Part Production (See Figure B10-1)

	<u>Item</u>	<u>Shipped</u>
C405495	Body Strength Member	10
C405496	Cap Strength Member	22
C405498	Body Liner	22
C405500	Cap Liner	22
C405593	Cap Capsule Clad	10
C405492	Body Capsule Clad	10
C405501	Fuel Vent Closure Disc	0
C405538	Fuel Spacer	10
C405506	Liner Shims	0

2. Material Performance

a. Pt-20Rh

Shipments of production die blank material have exhibited hardness values and grain size in excess of the specification requirements. As a result three of these typical die blanks were selected and drawn through the complete process. With the exception of a slight surface graininess, the parts were excellent. As a consequence the basic material procurement specs were revised to allow for DPH readings up to 132 and ASTM grain size down to 5.

b. Ta-10W

Material is acceptable and does not cause any drawing difficulty. Dimension of as-formed and annealed parts are excellent.

c. T-111

The production heats of this material differed so markedly from the Task 8 material in dimensional stability and surface imperfection of the drawn parts that the drawing process had to be revised. Revisions to the die and punch configurations were made, an intermediate anneal was introduced following the 5th draw, an additional coining operation was introduced in the forming and draw 6 was simply repeated as an additional ironing step. The piece parts produced from this modified process are dimensionally good and metallurgically sound.

3. Die Blank Status

		<u>Blanks Received</u>	<u>Parts in Process</u>	<u>Blanks Remaining</u>
T-111	4. 0-Inch Dia.	62	48	14
	6. 5-Inch Dia.	57	48	9
Ta-10W	4-1/4-Inch Dia.	87	24	63
	6-1/2-Inch Dia.	90	35	55
	1-1/2-Inch Dia.	89	20	69
Pt-20Rh	4. 0-Inch Dia.	65	24	41
	7. 0-Inch Dia.	57	24	33
Ta-10W	Liner Shims			
	0. 005	0	0	0
	0. 010	0	0	0
	0. 015	0	0	0
	0. 020	0	0	0

TRANSIT CAPSULE - PIECE PART PRODUCTION SCHEDULE