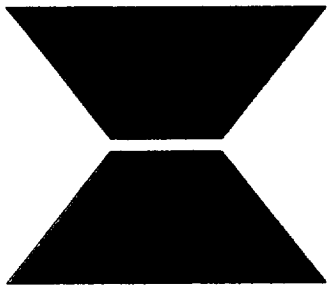


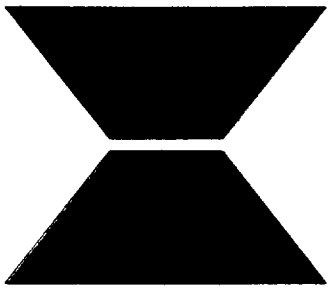
C. J. ASSOCIATES, INC

FINAL REPORT

NASA CONTRACT NUMBER
NAS8 40195
C.J. ASSOCIATES,INC. REPORT NUMBER
CJ-A10

RESEARCH STUDY ENTITLED

"TITAN IV TPS REPLACEMENT IMPLEMENTATION STUDY"



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"TITAN IV TPS REPLACEMENT IMPLEMENTATION STUDY"

FINAL REPORT
January 18, 1995 - September 17, 1996

TITAN IV TPS REPLACEMENT IMPLEMENTATION STUDY

CONTRACT NO.
NAS8-40195
C. J. ASSOCIATES, INC.
REPORT NO. CJ-A10

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CONTENT

I. ABSTRACT

This document is the Final Report of a contract (NAS8-40195) to investigate, study, analyze and propose solutions regarding qualification, sensitivity testing and implementation into production relative to an environmentally friendly thermal protection system, Marshall Convergent Coating Number 1 (MCC-1), for the Air Force Titan IV Program. MCC-1 is a coating developed jointly by NASA and United Space Boosters, Inc., (USBI) the Contractor for the Space Shuttle Solid Rocket Boosters (SRB).

Testing and production implementation of MCC-1 for Titan IV Payload Fairing (PLF) application was to be achieved as a combined effort by United Space Boosters, Inc. (USBI) and McDonnell Douglas Aerospace (MDA) as subcontractors to Lockheed Martin Aerospace (LMA) the prime Air Force Contractor for Titan IV launch system. MDA built a new facility at Pueblo, CO specifically for MCC-1 application to Titan IV PLF's.

The scope-of-work for this contract (NAS8-40195) was accomplished through documentation reviews, participation in telecons, technical interchange meetings, and program reviews, and by making MCC-1 application site visits to the Marshall Space Flight Center Productivity Enhancement Complex, the USBI operated Space Shuttle Solid Rocket Booster Assembly and Refurbishment Facility at Kennedy Space Center, and to the new McDonnell Douglas Aerospace operated Titan IV MCC-1 Application Facility at Pueblo, CO.

This contract ended on September 17, 1996, where as, initial operating capability (IOC) for the Titan IV MCC-1 Pueblo, CO facility is March 10, 1997. If the contractors, LMA, MDA and USBI complete the material and process testing, and implementation into the Pueblo, CO facility as planned, then the overall application of MCC-1 to the Titan IV PLF's will be as successful as it has been for the Space Shuttle SRB's.

II. EXECUTIVE SUMMARY

The thrust of this contract was to conduct an investigation, study, analyze, and propose solutions regarding the qualification, sensitivity testing, and implementation into production of an environmentally friendly thermal protection system (TPS) for the Titan IV rocket system Payload Fairing (PLF), thereby replacing previously used materials (silicone based) which had environmental regulatory problems. The regulatory problems were primarily ozone depleting chemical (ODC) and Volatile Organic Compound (VOC) based.

In 1993 the Air Force committed to a TPS replacement effort that included MSA-3 initially and later included MCC-1.

In 1994 the Air Force made a decision to qualify a TPS material (Marshall Convergent Coating one (MCC-1) for Titan IV use that the National Aeronautics and Space Administration (NASA) had already developed at Marshall Space Flight Center (MSFC) for Space Shuttle Solid Rocket Booster (SRB) applications. During the NASA Qualification testing of the MCC-1 for the Space Shuttle SRB's it was learned that the MCC-1 Topcoat (Urethabond) did not meet the Air Force requirements for the Titan IV PLF. In a fairly comprehensive Topcoat Screening Program, the Air Force selected Dupont Corlar 76P as their first choice Topcoat for MCC-1 for use on the Titan IV PLF. A Titan IV MCC-1 Qualification Test plan was subsequently written and conducted by United Space Boosters, Inc. (USBI), the NASA contractor for Space Shuttle SRB's, under subcontract to the Air Force Prime Contractor, utilizing the different (Corlar) topcoat material.

In addition, the Air Force decided that they would consolidate all TPS application activity for the Titan IV PLF at one site, which would require a new facility to be built at the existing McDonnell Douglas Facility at Pueblo, CO., and would have the NASA contractor (USBI) procure and install the MCC-1 application process equipment into the new Pueblo, CO TPS facility, since they were the NASA contractors responsible for the MCC-1 development, and installation and operation of equipment for MCC-1 application on Space Shuttle SRB's at Kennedy Space Center (KSC), Florida. The Air Force prime contractor, Lockheed Martin of Denver, CO, subcontracted with McDonnell Douglas of Pueblo, CO to oversee the construction of the MCC-1 application facility at Pueblo and to run the facility after activation by USBI.

This investigation and study was accomplished through documentation reviews; participation in telecons, technical interchange meetings, and program reviews; and by making MCC-1 application site visits to the Marshall Space Flight Center Productivity Enhancement Complex, the USBI operated Space Shuttle Solid Rocket Booster Assembly and Refurbishment Facility at Kennedy Space Center, to the new McDonnell Douglas Aerospace (MDA) operated Titan IV MCC-1 Application Facility at Pueblo, CO, and to MDA Huntington Beach, CA.

The Titan IV specific MCC-1 Qualification Test Program was initiated in May, 1996 and the MCC-1 application process will be successfully implemented, if all criteria is met, (see Appendix I) into the new Titan IV MCC-1 Application Facility at Pueblo, CO if all testing/implementation plans are completed as planned.

A Timeline of major events for the whole program is listed in Appendix III and IV. Contractual relationships are shown in Appendix V and VI.

Since this contract ended on September 17, 1996, and where as, initial operating capability (IOC) of the Titan IV Pueblo, CO facility is March 10, 1997 it is only possibly to predict, based on planning reviewed, that the implementation of MCC-1 on Titan IV PLF's in the new Pueblo, CO facility will be successful if the Qualification Test plan, sensitivity testing and implementation plans are completed. Success can be predicted with a high degree of confidence since MCC-1 has already been successfully implemented on the Space Shuttle SRB's and the Titan IV effort mimics the Space Shuttle SRB Program to a large degree.

III. REPORT

A. BACKGROUND/GENERAL

In 1991 the Environmental Protection Agency (EPA) passed legislation that threatened the primary thermal protection system (TPS) for both the Space Shuttle Solid Rocket Booster (SRB) and the Titan IV Payload Fairing (PLF). The EPA threat was primarily to the solvents utilized to apply the TPS materials to both the Space Shuttle SRB and Titan IV PLF hardware. The SRB TPS was Marshall Sprayable Ablator-Version Two (MSA-2) and was applied by spray application using $1^1 1^1 1^1$-Trichloroethane and methylene chloride as a mixed spray solvent. The Titan IV PLF TPS was Silicone-based STM-K-799 and was applied by spray application using Freon TF (chlorofluorocarbon) as the spray solvent. All of these solvents are ozone depleting chemicals (ODC) or are on the EPA hit list and have been targeted from use by both the National Aeronautics and Space Administration (NASA) and the U.S. Air Force (AF).

Both TPS materials, MSA-2 and STM-K-799, protect the structures of the Space Shuttle SRB's and Titan IV PLF's, respectively, from aerothermal and radiant heating during ascent. The Space Shuttle SRB structural materials are also protected during hardware recovery decent heating.

In 1992 NASA and United Space Boosters, Inc. (USBI) personnel in the Marshall Space Flight Center (MSFC) Productivity Enhancement Complex (PEC) identified a candidate for TPS replacement on the Space Shuttle SRB's, Marshall Sprayable Ablator - version three (MSA-3). Later (1993) USBI developed Marshall Convergent Coating - version one (MCC-1), which was initially called USI, as a second replacement candidate for the SRB's.

In early 1993 a NASA/USBI Total Quality Management (TQM) team was formed to downselect to one material for the MSA-2 replacement for SRB. The MCC-1 (called USI at the time) was selected as the most viable in terms of cost, process, and performance. The convergent spray technology process is shown in Figure I.

As early as 1992 the AF made contact with NASA, inquiring how NASA was going to meet the EPA restrictions on ODC's in TPS materials for the Space Shuttle. Later (1993) Titan IV engineering personnel visited MSFC to obtain documentation and samples of the two candidates (MSA-3 and MCC-1) that NASA and USBI were considering in their down select process.

In 1994 the AF, after numerous meetings with NASA/USBI, and through their own downselect process that mimicked the NASA/USBI downselect process, they made a decision to qualify MCC-1 for Titan IV PLF use. That decision considered commonality with the Space Shuttle SRB TPS replacement program, taking advantage of the SRB Testing where technical requirements were similar and imposing Titan Specific Tests where requirements were different. A Titan IV MCC-1 Qualification Test Plan was written by USBI that incorporated both SRB Common and Titan IV Specific Testing.

During the NASA Qualification testing of the MCC-1 for the Space Shuttle SRB's it was learned that the MCC-1 Topcoat (Urethabond) did not meet the Air Force requirements for the Titan IV PLF. The biggest concern was water absorption by the Urethabond and subsequent lack of topcoat performance in aerothermal testing in the MSFC Improved Hot Gas Facility. In a fairly comprehensive Topcoat screening program, the Air Force selected Dupont Corlar 76P as their first choice for the MCC-1 Topcoat for use on the Titan IV PLF. A Titan IV MCC-1 Qualification Test Plan was subsequently written and conducted by USBI, the NASA contractor for Space Shuttle SRB, contracted through the MSFC NASA SRB Project Office, utilizing the different (Corlar) Topcoat material (see Appendix V and VI for the complex contractual relationships).

Because of the perturbation caused by the different Topcoat and because the Air Force (AF) delayed the Authority to Proceed in the contracts, the initial AF implementation schedule of 12/13/95 for the MCC-1 process (see Appendix II) was slipped to 3/10/97 (initial operating capability).

MCC-1 (Convergent Spray Technology)

On Demand

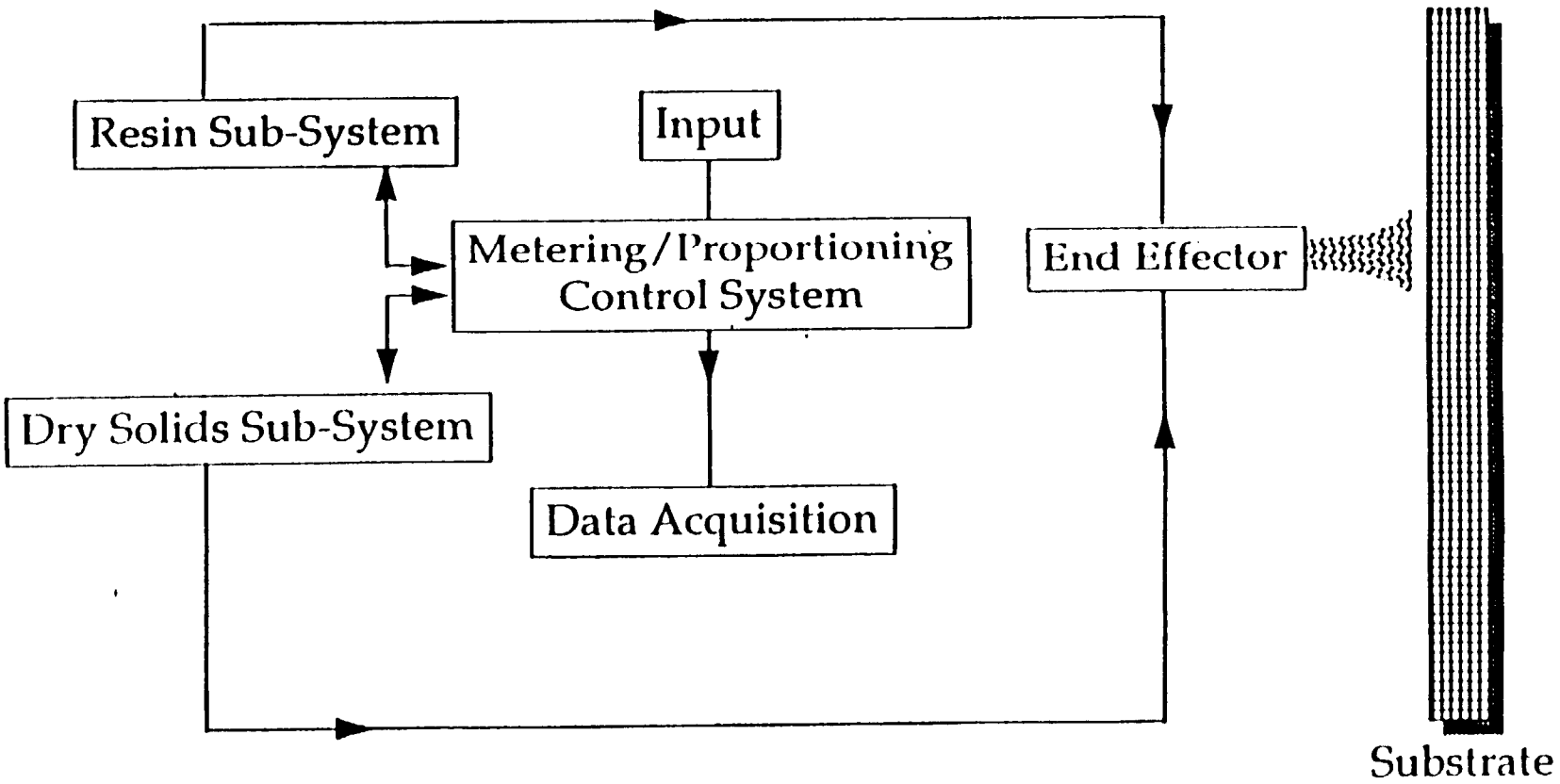


FIGURE 1

At the same time that the AF downselected to MCC-1 for the Titan IV PLF TPS, they also made a decision to consolidate all Titan IV PLF TPS application processing operations at one site, which would require a new facility to be built at the existing McDonnell Douglas Aerospace (MDA) Facility at Pueblo, CO, and would have the NASA contractor (USBI) procure and install the MCC-1 application Process Equipment into the new Pueblo, CO TPS facility, since they were the NASA contractor responsible for the MCC-1 development and installation and operation of equipment for MCC-1 application on the Space Shuttle SRB's at Kennedy Space Center, FL.

During the course of this contract, many documents were reviewed (see section III B.) with specific emphasis on the Titan IV Qualification Test Program and the MCC-1 process implementation into the new Pueblo, CO facility. A number of trips were required to attend program reviews, facility reviews and walkdown process inspections. The sites were at the Space Shuttle Solid Rocket Booster MCC-1 application facility at Kennedy Space Center (KSC), at the new Pueblo, CO Titan IV MCC-1 application facility, at MDA Huntington Beach, CA, and at USBI Huntsville, AL. The reason for going to both implementation sites was because of the commonality and the fact that the Space Shuttle SRB facility activation at KSC preceded the Pueblo, CO Titan IV Payload Fairing facility by more than a year. The success of the KSC facility was a predictor of the success of the Pueblo, CO facility.

In addition, many telecons, engineering work sessions, and status meetings were attended in order to track the status of the overall Titan IV MCC-1 Qualification and implementation activities.

A MCC-1 Process Implementation Checklist for the T-IV Pueblo, CO Facility, that captured the process requirements and sensitivities identified during the Qualification and Sensitivity Testing for both the Space Shuttle SRB and Titan IV PLF MCC-1 programs, was made during the study and is shown in Appendix I.

B. DOCUMENTS REVIEWED

All documents reviewed in the performance of the contractual scope-of-work are listed by Contract Status Report Periods. Where there are duplications of some documents from one Report Period to another, shows that more than one draft, revision, or issue of that specific document was reviewed. Most of the documents reviewed will be retained in the company files for a period of two years after completion of the contract.

REPORT PERIOD - JANUARY 18 TO MARCH 17, 1995:

1. CMT-056-95MP, "Characterization and Sensitivity Test Plan for Titan IV Payload Fairing".

2. DWG.10753-0064, "MCC-1 Insulation, Sprayable, dated: January 19, 1995".

3. 10PRC-0637, "Procedure for Insulation Application, MCC-1".

4. NUSTO 93-025, Rev. 22 Nov. 1993, "Thermal Protection System Replacement Study for T-IV: TPS Requirements for Core, PLF and SRM's".

5. "Summary of Recent Characterization Tests of as Sprayed MCC-1 TPS (OGT-MGT) Test Panels".

6. JCC-035-93MP, Rev. "C", "Procedure for Application of TPS Topcoat (Sealcoat) (Urethabond 3015 Mod. #3/#4), Rev. August 1994".

7. "Test Matrix to Establish Minimum Urethabond Paint Application Amount", dated Jan. 23, 1995.

8. 61PLN-0001, "MCC-1 Qualification Test Plan for Titan IV", draft. Dec. 22, 1994.

9. "Test Plan to Evaluate Potential Effect of Moisture on MCC-1".

10. "Contamination Pyroshock Test Plan for Preliminary TPS Evaluation", January 24, 1995.

11. "Pyrotechnic Shock Qualification of MCC-1", USBI-AR-94-0192, December 1994.

12. "Standard Operating Procedure for MCC-1 Spraying", PE104-02 Basic.

13. "Procedure for Spray Application of TPS Topcoat (Urethabond 3015 Mod. #3/#4)", CMT-046-94MP, Rev. A.

14. "Cork, Granular, 40/80 Superclean", DWG. NO. 10753-0060.

15. "Glass Eccospheres IG-101", DWG. NO. 10753-0024.

16. "Paint, Polyurethane Kit. Urethabond 3015 Mod. #4", DWG. NO. 10753-0062.

17. "Ancamine K54 Hardener", DWG. NO. 10753-0061.

18. "Scotch-weld Epoxy Adhesive", DWG. NO. 10753-0007.

19. Second Preliminary Draft "Alternate TPS Sealcoat Qualification Test Plan", dated Feb. 14, 1995.

20. "Qualification Test Plan for Trich-free Hypalon over MCC-1", DCN-009-95MP, Feb. 1995.

21. "MCC-1 Phase 2 Sensitivity Test Plan", HRL-002-95, (draft).

22. "MCC-1 Radiant Heater Test Program Summary" and Supplement.

23. "Paint, Chlorosulfonated Polyethylene", DWG. NO. 10753-0013.

24. "Similarity Testing with Special Hypalon Topcoat to Replace Current Hypalon TPS Topcoat", REC-005-94MP.

25. Each weekly "MCC-1 Team Update".

26. "USBI weekly MCC-1 Reports".

REPORT PERIOD - MARCH 18 TO MAY 17, 1995:

1. "Solid Rocket Booster Thermal Protection System Certification Plan", SE-019-149-2H.

2. Revised and signed copy of "MCC-1 Phase 2 Sensitivity Test Plan", HRL-002-95.

3. "10753-0013 (paint chlorosulfonated) Application of Insulated Structures", STP 603, Rev. Q-1.

4. "Test Plan for Alternate Hypalon Qualification", HYP-159-90, Basic, Sept. 1990.

5. Summary of MCC-1 Test Panel Results and Sprays Conducted at Florida Operations During March 1995.

6. Topcoat Alternatives Team - Test Plan Outline and Setup Schedule, dated April 5, 1995.

7. "Terrestrial Environment (Climatic) Criteria Guidelines for Use in Aerospace Vehicle Development", NASA Technical Memorandum 4511, 1993 Revision.

8. "Titan IV Topcoat Alternatives Screening Plan", Preliminary review draft.

9. "Test Plan for Exposure of TPS Material Systems to Simulated Rain Conditions", LJT-11-95 MP, preliminary.

REPORT PERIOD - MAY 18 TO JULY 17, 1995.

1. 10PRC-0624A, "Process Control Specimen Preparation and Test Methods", Revised to incorporate MCC-1.

2. 10PRC-0637, "Procedure for Insulation Application, MCC-1", Released Version.

3. Final draft "Test Plan for Screening Candidate Topcoats for Use on MCC-1 Thermal Insulation - Titan IV Payload Fairing Program", May 1995.

4. Preliminary "Test Plan for Exposure of TPS Material Systems to Simulated Rain Conditions".

5. Preliminary TPS (MCC-1) Facility drawings of the McDonnell Douglas Aerospace (MDA) Facility at Pueblo, CO and notes from the June 12, 1995 telecon, in which the drawings were initially reviewed.

6. "Combined Environments Qualification of MCC-1, USBI-AR-95-0206"
Volume 1 - Test and Analysis Report
Volume 2 - Appendix 1, Quality Assurance Package
Volume 3 - Appendix 2, Tabulated Data Package

REPORT PERIOD - JULY 18 TO SEPTEMBER 17, 1995:

1. July 5, 1995 emittance/absorptance test data on candidate MCC-1 topcoats from the Titan IV Alternate Topcoat Screening Test program (faxed from Bob Ramsauer on July 5, 1995).

2. Final (signed copy) of "Test Plan for Exposure of TPS Material Systems to Simulated Rain Conditions", LJT-11-95MP.

3. Revised draft of drawings for the "MDA Pueblo, CO MCC-1 Application Facility" for a 100% Design Review.

4. "Screening Tests for a Topcoat for Use on MCC-1 Thermal Insulation-Titan IV Payload Fairing Program", August 1995, First Draft.

5. August, 1995 revision, "MCC-1 Qualification Test Plan for Titan IV, 61PLN-0001", Revised to incorporate use of a topcoat other than Urethabond.

6. August 23, 1995, "Titan IV Alternative Topcoat Test Program-Review of Results".

7. Dupont CORLAR 76P, Specification.

REPORT PERIOD - SEPTEMBER 18 TO NOVEMBER 17, 1995:

1. Reviewed the bi-weekly "MCC-1 TEAM UPDATE", a newsletter jointly published by NASA and USBI (edited by C.N. Lester/EH35), for pertinent Titan IV PLF information.

2. Reviewed USBI "Window", a newsletter for USBI employees.

3. Reviewed a 10/18/95 revision of the "MCC-1 Qualification Test Plan for Titan IV, 61PLN-0001".

4. Reviewed the Titan IV TPSR Open Action Items status for numbers 224, 230, 231, 232, 233, 234, 235, 236, 237, 238, 239 and 240.

5. Reviewed the Titan IV TPSR Closed Action Items, Numbers 1 thru 241 except for those indicated in item 4 above.

6. Reviewed the first draft "McDonnell Douglas Titan IV Thermal Protection System Building Specification Verification Document", MDC 95H1067, October 22, 1995.

REPORT PERIOD - NOVEMBER 18, 1995 TO JANUARY 17, 1996:

1. Reviewed "MCC-1 Team Updates".

2. Reviewed the Final Report - "Screening Tests for a Topcoat For Use on MCC-1 Thermal Insulation, Titan IV Payload Fairing Program, MDC 95H0182", dated October 1995.

3. Reviewed Revision 1, November 3, 1995, "McDonnell Douglas Titan IV Thermal Protection System Building Specification Verification Document, MDC 95H1067".

4. Reviewed a draft "TITAN IV PAYLOAD FAIRING CLEANING PROCEDURE PRIOR TO COATING WITH DEFT 44-GN-7 QUALIFICATION TEST PLAN", Memorandum A3-242-CED/PJP-95-35, dated 21 November 1995. The procedure was obtained at the November Program Review.

5. Reviewed the "T-IV TPSR Program Review Minutes", of November 28-29, 1995.

REPORT PERIOD - JANUARY 18 TO MARCH 17, 1996:

1. Reviewed "MCC-1 Team Updates" for this period.

2. Reviewed E-mail message from USBI to NASA concerning Titan IV Payload Fairing Qualification Vibration Loads.

3. Reviewed the "TPS Open Action Item Status" sheets from T-IV TPS Replacement Telecon hand-out.

4. Reviewed "McDonnell Douglas Titan IV Thermal Protection System Building Specification Verification Document Volume I - Specification Derivation, MDC95H1067, Rev. 2, Dated December 19, 1995.

5. Reviewed "Thermal Sensitivity Testing of MCC-1, RWL-006-96-E", distributed by USBI.

REPORT PERIOD - MARCH 18 TO MAY 17, 1996:

1. Reviewed minutes from various Titan IV TPS replacement telecons.

2. Reviewed bi-weekly "MCC-1 Team Updates".

3. Reviewed updates of "Titan IV TPS Open Action Items Status" sheets.

4. Reviewed initial draft of "Titan Program Corlar Sensitivity Study Parameters Matrix".

5. Reviewed New Action Items from "Titan IV TPS Facility IPT meeting notes". dated March 25, 1996.

6. Reviewed notes from "Thermal Telecon of March 27, 1996", distributed by John Kirby.

7. Reviewed proposed baseline settings for Corlar 1LB76P for a 2-3 week study of the different types of Corlar used by MDA and USBI.

8. Reviewed Chemical Make-up Matrix for the different types of Corlar 76P, such as, LF-63276P, 1LB76P, 2MB76P, and 3DB76P.

9. Reviewed "Table III, Test Matrix Summary for MCC-1" from 61PLN-0001, which highlights the number of Qualification Test panels required for MCC-1 for the Titan IV TPS Replacement Program.

10. Reviewed an agenda recommended for the proposed April 30th TIM and Titan IV TPS Replacement Program Review at Huntington Beach. CA.

11. Reviewed composite schedules from the Titan IV TPS PROGRAM REVIEW April 30 - May 2, 1996 at McDonnell Douglas Aerospace (MDA), Huntington Beach, CA.

12. Reviewed Titan IV TPS Replacement, USBI Overview, April 30, 1996 PROGRAM REVIEW at Huntington Beach, CA.

13. Reviewed Titan IV TPS, Materials and Processes Development IPT status, April 30, 1996 PROGRAM REVIEW at Huntington Beach, CA.

14. Reviewed Titan IV PLF SURFACE PREPARATION METHOD presented at the April 30, 1996 PROGRAM REVIEW at Huntington Beach, CA.

15. Reviewed Titan IV PLF ENGINEERING IPT STATUS presented at the April 30, 1996 PROGRAM REVIEW at Huntington Beach, CA.

16. Reviewed Titan IV BUILDING IPT STATUS presented at the April 30, 1996 PROGRAM REVIEW at Huntington Beach, CA, including construction schedule.

17. Reviewed the Titan IV PLF TPS TOOLING AND FAIRING HANDLING EQUIPMENT (FHE) STATUS presented at the April 30, 1996 PROGRAM REVIEW.

18. Reviewed the Titan IV PLF TPS PATHFINDER IPT STATUS presented at the April 30, 1996 PROGRAM REVIEW at Huntington Beach, CA.

REPORT PERIOD - MAY 18 TO JULY 17, 1996

1. Reviewed the minutes from the Titan IV TPS Engineering Integrated Product Team (IPT) telecon of 5/15/96.

2. Reviewed the Titan TPSR Minutes for the 5/16/96 Telecon.

3. Reviewed the Monday, May 20, 1996 Telecon notes on the Titan IV Pueblo, CO MCC-1 Application Facility construction.

4. Reviewed the minutes from the Titan IV TPS Engineering IPT telecon of 5/22/96.

5. Reviewed the minutes from the Titan IV TPS Engineering IPT telecon of 5/29/96.

6. Reviewed the minutes from the Titan IV TPSR telecon of 5/30/96.

7. Reviewed the Titan IV TPS integrated program plan and schedule, dated June 4, 1996.

8. Reviewed the minutes of the June 12, 1996 Titan IV TPS Engineering IPT Telecon.

9. Reviewed the minutes of the June 13, 1996 Titan IV TPSR Telecon.

10. Reviewed the minutes of the June 24th and 27th TPS Building IPT Telecon.

11. Reviewed the Pueblo, CO MCC-1 application building check-out plan. The plan presents the method to check-out the building requirements, which are derived by McDonnell Douglas as part of the TPS replacement program as documented in a requirements derivation document.

12. Reviewed the 2nd Titan IV TPS Facility Review handout that covered the schedule, concrete floor design, building requirements, security requirements, verification process steps, and verification details.

13. Reviewed the MCC-1 Team Update(s).

14. Reviewed the Titan IV TPS Open Action Items Status.

REPORT PERIOD - JULY 18 TO SEPTEMBER 17, 1996:

1. Reviewed topics listing for the July 17, 1996 Titan IV TPS Engineering IPT telecon.

2. Reviewed the John Kirby (MDA, Pueblo) file notes for the July 15, 1996 Titan IV TPS Facility IPT telecon.

3. Reviewed McDonnell Douglas update notes on the Pueblo, CO MCC-1 Building Walkdown inspection.

4. Reviewed TPS (MCC-1) Open Action items status sheet as of 7/18/96.

5. Reviewed the July 17, 1996 Titan IV TPS Engineering IPT Telecon minutes.

6. Reviewed the July 18, 1996 Titan IV TPS Replacement Telecon minutes, along with new action items, as a result of the telecon.

7. Reviewed an agenda for the Test Readiness Review held on August 6 in Huntsville, AL.

8. Reviewed the MCC-1 Team Updates.

9. Titan IV TPS Replacement, Open Action items #264, 270, 292 and 293.

10. Reviewed notes from the July 17, 1996 TPS Engineering IPT Telecon.

C. TRIPS MADE

Each trip made in the performance of the contractual scope-of-work is listed according to the Contract Status Report Period in which it was made.

REPORT PERIOD - JANUARY 18 TO MARCH 17, 1995:

No trips were made during this bi-monthly reporting period.

REPORT PERIOD - MARCH 18 TO MAY 17, 1995:

One trip was made, from April 3 to April 6, 1995, to the Kennedy Space Center (KSC), Space Shuttle, Solid Rocket Booster (SRB) Assembly and Refurbishment Facility(ARF). The purpose of the trip was to see the MCC-1 Spray System hardware configurations and to observe the system in operation. That first hand knowledge of the KSC ARF MCC-1 spray system was considered important to the performance of the contract since the proposed Titan IV MCC-1 spray system for the Pueblo, CO facility would be almost identical except for the size and configuration of the spray envelope. In addition, that knowledge could be utilized as a prompt for expecting the required documentation pertinent to the Pueblo, CO Titan IV facility.

REPORT PERIOD - MAY 18 TO JULY 17, 1995:

No trips were made during this bi-monthly reporting period.

REPORT PERIOD - JULY 18 TO SEPTEMBER 17, 1995:

On August 22, 1995, in conjunction with a Titan MCC-1 TIM, a trip to Deft Coatings, Irvine, CA, was made to discuss the use of Deft primer (44GN7) and Topcoat 03-W-127A as the base between aluminum substrate and the Thermal Protection System (TPS). During the meeting the primer/topcoat application process was discussed extensively, as-well-as the chemistry involved in applying the coatings. Also, establishment of a material specification was discussed and a plant tour was made. Based on what was discussed and observed at the Deft Coatings facility, no problems were foreseen with the utilization of the 44GN7 primer and 03-W-127A topcoat with the MCC-1 for T-IV applications.

On August 23-24, 1995 a MCC-1 TPS TIM was attended at McDonnell Douglas Aerospace (MDA), Huntington Beach, CA to review screening/test data (results) to identify an alternative topcoat to the Urethabond used in the Space Shuttle Solid Rocket Booster (SRB) MCC-1 TPS Qualification Test Plan. The Titan IV contractors felt that an alternative was needed because the Urethabond creeped (flowed) in MSFC Improved Hot Gas Facility (IHGF) tests after moisturization to levels 10% and higher.

During the TIM MDA presented test results on four of seventeen coatings that remained viable after initial screening tests. Those were Acrymax, Corlar 76P, Sherwin Williams and Urethabond. Of the initial seventeen coatings in the screening candidate list, ten were rejected during application process testing and three were rejected due to failures in thermal testing. The four remaining coatings were submitted to testing discriminators to include six day water absorption, accelerated aging, solar absorptance, weight gain, number of coats required, time between coats, thermal/contamination, and degree of flow under high shear conditions. Acrymax did not perform as well on six day water absorption, accelerated aging, and degree of flow under high shear conditions. Sherwin Williams was not selected only because of the extended time (18-24 hrs.) period between coats, however, it was proposed as back-up to the coating selected. As a consequence of these results, it was recommended by MDA that Dupont Corlar be utilized as the Titan IV PLF Topcoat, and was unanimously agreed to by all TIM attendees (35 people representing LMA, MDA, Aerospace, USBI, NASA, LSIC and C. J. Assoc.) The Corlar performed well on all screening tests; is procured from a large manufacturer (Dupont) with good technical support: provides a potential weight savings compared to the K799 (silicone-based) TPS presently used; and meets all Safety and Environmental requirements.

As a result of the recommendation to use Corlar as the Titan IV MCC-1 Topcoat a number of actions were initiated. The actions were:

1. USBI/MDA had to work with Dupont (manufacturer of Corlar) to establish a material specification that is controllable for the anticipated life of the Titan program.

2. USBI had to establish a new topcoat (Corlar) test plan to determine all material and control parameters after receipt at the user site.

3. USBI had to develop a plan to determine how to apply Corlar with a robot for the Titan PLF. The plan had to be based upon developing a system with acceptance criterion of no pinholes in the final product and with proper coverage over critical areas such as the PLF separation rails which have a backface temperature maximum of 160^0F. In addition, USBI had to determine the best delivery system (airless, high volume-low pressure, etc.) to utilize for robotics applications.

4. USBI/MDA/LMA thermal personnel had to investigate why the aluminum backface temperature of the Corlar coated samples was higher than the backface temperature of a similar sample with a Urethabond coating, and determine what thermal sizing issues exist at current temperatures and for optimized temperatures.

5. USBI had to review and up-date the "Titan IV MCC-1 Qualification Test Plan" relative to the TIM recommendations to use Corlar as the MCC-1 topcoat. All Titan MCC-1 Team members had to review the plan where up-dated to ensure that all issues are adequately addressed.

6. USBI had to establish a thermal sensitivity test plan for use of Corlar topcoat in-lieu-of Urethabond for the Titan IV program.

REPORT PERIOD - SEPTEMBER 18 TO NOVEMBER 17, 1995:

No trips were made during this bi-monthly reporting period.

REPORT PERIOD - NOVEMBER 18, 1995 TO JANUARY 17, 1996:

No trips were made during this performance period. However, a two day Titan IV MCC-1 Program Review was attended that was split between sites at USBI, Huntsville, AL and Marshall Space Flight Center. Information relative to the Program Review is covered in other sections of this report.

REPORT PERIOD - JANUARY 18 TO MARCH 17, 1996:

Charles Jackson of C. J. Associates traveled to the USBI SRB processing facility at Kennedy Space Flight Center, Cape Canaveral, FL from 1/27/96 to 2/1/96 to observe the application of MCC-1 to the 1st Space Shuttle SRB flight hardware. The MCC-1 was successfully applied to the left Aft Skirt of the SRB that was slated to fly as STS-80 in November, 1996, but later was moved to STS-79 to fly in Sept.,1996. The process was observed through the post-spray curing, bake cycle. The success of this application to Flight hardware is considered a monumental milestone in the qualification of MCC-1 for both Space Shuttle SRB and Titan IV PLF projects due to the similarities of the application process equipment. It was apparent that the previous spraying of Verification hardware with MCC-1 was a significant learning process for the USBI/KSC team. If the verification process can be repeated with the McDonnell Douglas Titan IV PLF team, that too will be successful, and will complement the Air Force Titan IV MCC-1 application schedule.

REPORT PERIOD - MARCH 18 TO MAY 17, 1996:

1. Although not considered a trip, a Technical Interchange Meeting (TIM) was attended at USBI, Huntsville, AL on April 2, 1996. Topics of interchange are discussed in other sections of this report.

2. A trip was made on April 29 - May 3, 1996 to Huntington Beach, CA at McDonnell Douglas Aerospace to attend a full Titan IV TPS replacement program review. Topics reviewed during the three day meeting are discussed in other sections of this report.

REPORT PERIOD - MAY 18 TO JULY 17, 1996

A trip was made from 6/3/96 - 6/6/96 to Pueblo, CO to attend a Construction Status Review of the Titan IV MCC-1 Application Facility.

Other items/topics were covered during the meeting, which was attended by 19 people representing NASA, AF, USBI, LMA, MDA, Aerospace, and the construction contractor. Those topics were:

1. Robot status
2. Tooling status
3. Requirements Verification
4. A walking tour of the new MCC-1 Application building.
5. A detailed review of the Titan IV TPS Integrated Plan.

Details relative to the various items/topics are discussed in other sections of this report.

REPORT PERIOD - JULY 17 TO SEPTEMBER 18, 1996:

No trips were taken during this report period.

D. FINDINGS/OBSERVATIONS

All findings and observations compiled in the performance of the contractual scope-of-work are listed by contract status report period.

REPORT PERIOD - JANUARY 18 TO MARCH 17, 1995:

1. It was observed during telecons that there was a lack of adequate communication between the many MCC-1 development team members (approx. 40). The team membership consisted of representatives from various organizations within United Space Boosters, Inc. (USBI), Martin Marietta Technologies, Inc. (MMTI), Aerospace Corp., Lockheed Space and Missile Co. (LSIC), McDonnell Douglas (MDA), USAF, and NASA from locations in Alabama, Florida, Colorado and California. Because of the communication problem several issues had gone unresolved for extended periods.

2. The overall project schedule may be impacted by poor performance of the presently baselined Urethabond topcoat and a delay of authority to proceed much beyond the mid-April time frame.

REPORT PERIOD - MARCH 18 TO MAY 17, 1995:

1. In response to "E" mail correspondence between Hank Miller (NASA), Keith Bates (USBI), and Mike Prince (NASA) relative to moisture pick-up concerns with Urethabond topcoat, the following thoughts were compiled.

a. The phenomenon of water-based paints absorbing moisture is not uncommon due to the following reasons.

(1) Many water-based paints have some ingredients that are hydrophilic, such as, titanium dioxide that is often selected as a pigment because it imparts desirable optical (emissivity) properties.

(2) Agents are added to provide elasticity/plasticity properties that are necessarily water miscible and hydrophilic, attracting some water molecules even when the paint has been cured. Urethabond has 8.5% (resin weight) of plasticizer (N. Methyl Pyrrolidone).

(3) The very mechanism of curing/drying of the water-based paint leaves a paint layer that is permeable by water molecules. The small paths left by the water leaving the paint during curing/drying also allows water molecules to re-enter under the right conditions.

b. Maximum moisture gain for beach exposed Urethabond topcoated MCC-1 was approximately 10%. Moisture levels as high as 15% have been achieved only artificially in humidity chambers at higher temperatures (100^0F) where liquid water condensed on the test specimen. Cyclical humidity chamber exposure, more closely representative of day/night temperature and relative humidity excursions produce moisture levels generally less than 5%. Panels exposed at KSC to rain conditions, gained to <15% moisture levels. Prior to rain, in fog conditions, panels reached 10-11% level (liquid water is required to reach 15% moisture level).

c. Dry panels of Urethabond/MCC-1 performed well in the IHGF at 5 BTU/ft^2-sec. for 100 seconds. Panels with nominal 10% moisture had some paint flow in the IHGF at 5 BTU/ft^2-sec. for 100 seconds. Panels with nominal 15% moisture had even more paint flow in the IHGF at 5 BTU/ft^2-sec. for 100 seconds.

d. The Titan IV thermal environment is significantly milder than that seen in the IHGF (5 BTU/ft^2-sec.). The Titan IV sees only 3.5 BTU/ft^2-sec. for about 25 seconds, therefore the IHGF test was an over test of the Urethabond paint. If test panels with 15% moisture could have been run at the Titan IV thermal environment the Urethabond would most likely not flow at all.

e. No other water-based topcoat materials had been tested and determined acceptable at this time in the project.

f. Urethabond test panels previously tested for moisture pick-up were cured for two days at 120^{0}F which may have been insufficient for complete crosslinking. Additional tests are required.

g. Based on tests on Urethabond,

(1) It meets the Titan IV requirements on Absorptivity and Emmisivity (Alpha/Epsilon).

(2) It meets contamination requirements after heating environment exposure.

(3) It meets Air Force low VOC requirements.

(4) It is close to Titan IV weight requirements with 300^{0}F backface temperature requirement.

Conclusion:

a. Topcoat flow in the IHGF at 10% and 15% moisture level was thought to be due to the following reasons.

(1) Freshly applied topcoat was probably not completely crosslinked. The six month, SRB MCC-1 Qualification Testing, beach exposure panels that were topcoated with Urethabond Mod #4, visually appeared whiter and in better condition than the Hypalon and Flood topcoated MCC-1 exposed during the same timeframe at KSC.

(2) 10%-15% moisture levels will seldom, if ever be seen in the real launch timelines/conditions. If that concern remains, a launch pad witness panel could be utilized to determine the real moisture level on the vehicle and could be used as a launch constraint during inclement weather.

(3) The IHGF test conditions are much more severe than what will ever be seen during the Titan ascent.

(4) Additional tests were needed to resolve questions associating moisture pick-up with freshly applied (not fully crosslinked) topcoat.

REPORT PERIOD - MAY 18 TO JULY 17, 1995:

1. Observed the application of MCC-1 to a full scale Space Shuttle Solid Rocket Booster (SRB) Frustum at the Marshall Space Flight Center (MSFC) Productivity Enhancement Complex (PEC). The application of the MCC-1 to the full scale hardware was significant for several reasons as follows,

a. The application, which lasted 92 minutes, demonstrated that the application process equipment was capable of duration runs capable of coating hardware the size of Titan IV Payload Fairing (PLF) tri-sectors.

b. The application also demonstrated that the process equipment was capable of spraying MCC-1 material over long durations with only slight changes in density and strength. Witness panel tests showed densities from 30.1 to 32.2 lb/ft^3 (Av. 31.1) for a standard deviation of 0.54. FTS testing on the witness panels showed strengths from 265 to 382 psi/FWT (Av. 332 psi) for a standard deviation of 33.7 psi. Porta-pull tests on the frustum yielded values of 272 to 327 psi, comparing favorably with the FWT test results on the witness panels; with a standard deviation of 18.5 psi.

Considering the uniformity of strength, density, thickness and smooth surface texture of the MCC-1, the spraying of the frustum was an undisputed success and a major milestone in the MCC-1 development program.

2. Observed that the condition of "0.21 inches per hour precipitation for a 24 hour duration" cited as average condition for Cape Canaveral, Florida in paragraph 1.0 (scope and background) of "Test Plan for Exposure of TPS Material Systems to Simulated Rain Conditions", was in fact maximum conditions (99 percentile) as stated in NASA Technical Memorandum 4511, "Terrestrial Environment (climatic) Criteria Guidelines for Use in Aerospace Vehicle Development, 1993 Revision."

3. Observed that the Authority to Proceed (ATP), for USBI to implement the MCC-1 process at Pueblo, CO and initiate the Titan IV Qualification Testing, was not given at that point in the program as previously projected.

4. The Titan IV technical community decided to delete the requirement for a conductive coating over the TPS topcoat as presently used.

5. In a search for acceptable alternate topcoat materials, the Titan IV technical community abandoned UV cured material and plasma sprayed candidates as not being practical for application to the Titan IV PLF TPS.

6. Observed that the Air Force set June 27, 1995 as the time a search, for an alternate to the MCC-1 TPS for the Titan IV, would have to begin should one be required. No known action was taken by the June 27 date.

7. During review of the preliminary drawings of the TPS (MCC-1) facility, to be installed at the MDA Pueblo, CO facility, it was observed that the west elevation exterior door scheme was different on sheets A-2 and A-3 of the drawing package.

8. Found that operational personnel at the KSC SRB Assembly/Refurbishment Facility (ARF) have successfully sprayed MCC-1 on a full scale SRB Forward Skirt in the newly upgraded TPS application cell.

REPORT PERIOD - JULY 18 TO SEPTEMBER 17, 1995:

1. NASA plans to initiate a project to find and develop a cheaper resin for use in the MCC-1 Thermal Protection System to be utilized on both SRB and Titan IV.

2. USBI has qualified Urethabond, Mod. #4 for use as a topcoat for MCC-1 for Space Shuttle Solid Rocket Boosters (SRB) application. However, USBI Management indicated that the first time MCC-1 is flown on the SRB's it would be with regular Hypalon as the topcoat. USBI management also indicated that if the Titan IV Program came up with a viable topcoat during their "Titan IV Topcoat Alternatives Testing" (TTAT) that USBI would be amenable to considering it for SRB application also.

3. IHGF tests were run on topcoat candidates surviving a preliminary T-IV screening program. Panels for the three candidates, Urethabond, Corlar, and Sherwin Williams water-based were tested both dry and moisturized per T-IV recommended cycle of 99% RH at 95^0F. Moisturized (32%) Urethabond flowed during the IHGF test and was marginal for T-IV use. Moisturized (8-9%) Corlar and Sherwin Williams passed the tests with minor spalling on the surface peaks of the Sherwin Williams topcoat.

4. During the TIM at MDA, Huntington Beach, CA it was observed, based on data submitted, that the Dupont Corlar 76P was significantly better in performance in those screening parameters tested than Urethabond. The next best coating was the water-based Sherwin Williams, which was proposed by MDA as back-up to Corlar.

REPORT PERIOD - SEPTEMBER 18 TO NOVEMBER 17, 1995:

1. At the very end of the previous reporting period the long awaited Titan IV MCC-1 implementation Authority to Proceed (ATP) was given by the Air Force to Lockheed Martin and subsequently by Lockheed Martin to McDonnell Douglas Aerospace (MDA) on a tentative basis. The ATP allowed MDA to continue some work items, such as a review of the Pueblo, CO implementation facility drawings. ATP for USBI was delayed at that particular time because the USBI proposal had expired.

2. On the 6th of October the long awaited official Authority to Proceed (ATP) was given by Lockheed Martin to McDonnell Douglas Aerospace (MDA). On the 10th of October USBI received ATP and a contract for almost $4 million dollars from Lockheed Martin. The ATP/Contract authorized USBI to procure, install, and start-up the MCC-1 system in the Thermal Protection System (TPS) building in Pueblo, CO, being built under the purview of MDA, the Pueblo Titan IV Payload Fairing Facility Operator. Start-up includes check out, verification, and procedurization of an automated robotic application system using USBI's patented Convergent Spray Technology coating process. The process will be used to apply the environmentally friendly MCC-1 (TPS) developed jointly by NASA/USBI for use on the Space Shuttle Solid Rocket Boosters (SRB's).

3. On September 22, 1995 it was learned that the McDonnell Douglas facilities interface was to direct the architect to release the drawings and project manual for the McDonnell Douglas Aerospace, Pueblo, CO facility to the general contractors for bid. Comments from previous drawing reviews were attached. It was felt that none of the open issues would affect cost substantially and if other changes were found that affected cost, the architect would be asked to submit a supplement to the RFP. The reason for expediting this matter was a concern about getting good cost and schedule information as soon as possible on the proposed building, since those data drove many tasks.

4. An overall project schedule encompassing the material(s) development and qualification testing for MCC-1/Topcoat, Pueblo, CO facility construction, and implementation of the MCC-1/Topcoat process into the facility was non-existent. A detailed TPS facility construction schedule was, however, being developed. The preliminary schedule called for bids to be in by October 27 and opened on October 31. A contractor was to be picked November 7, 1995, however, selection was not made on that date. A concern was raised about the ability to pour concrete during the upcoming winter months. The initial schedule for material(s) development and qualification testing was perturbated by the selection of Corlar topcoat for the Titan IV in-lieu-of the Urethabond topcoat qualified for Space Shuttle SRB use. Some concerns also remained relative to procurement lead times for large equipment items such as the MCC-1 application robot, which was the item with the longest lead time. USBI reported that 80% of all equipment had been ordered as of 10/19/95.

5. Near the end of the previous period, USBI received twenty gallons of Dupont Corlar 76P Topcoat. A plan was established for application development of the Corlar to MCC-1. The plan called for the spraying of the Corlar over 1/4" thick panels of MCC-1, to begin the week of October 11, 1995 in the NASA-MSFC Productivity Enhancement Complex utilizing Binks High Volume, Low Pressure (HVLP) spray equipment. Sixteen 10" x 10" panels of Corlar topcoated MCC-1 were produced according to the plan. Key parameters of the investigation included gun tip size, gun pressure, pot pressure, and topcoat thickness per gun pass. The plan called for successive coats of topcoat to be applied until no pinholes were visible, then apply one additional coat. The panels were then evaluated for moisture resistance, composite density and flatwise strength. The latest information was that the spraying of the sixteen panels had been completed. Of these, only six were deemed to be successful, with between 8 and 10 coats of paint being required for adequate coverage. Additionally, the paint coverage density was almost twice (0.95 grams/in^2 vs. 0.5 grams/in^2) that which was achieved during the topcoat screening evaluation. Based on these less-than-favorable results. HVLP did not appear to be a probable application technique at the time. A standard air spray gun, as well as an airless gun if necessary would later be tested as back-up methods.

6. It was reported that some of the twenty gallons of Corlar topcoat material would be used for a Space Shuttle Solid Rocket Booster (SRB) alternate topcoat screening process. If successful, it could potentially lead to commonality of Titan IV PLF and Space Shuttle SRB topcoat for MCC-1.

7. The SRB MCC-1 Production implementation schedule called for the first flight structures, a left Aft Skirt to be sprayed on December 11, 1995, with launch on STS-80 slated for November , 1996. It was planned to fully implement MCC-1 on STS-81 (Aft Skirts, Forward Assembly Structures (Fwd. Skirt, Frustum, and Nose Cap), and System Tunnel Covers) which is scheduled for December, 1996. The STS-80 left Aft Skirt was actually sprayed with MCC-1 on January 30, 1996.

On September 29, 1995 a SRB Aft Skirt was successfully sprayed with MCC-1. The hardware was later stripped after flatwise tension and Porta-pull tension tests were performed on both hardware and witness panels. The structure was sprayed selectively with 1/2" and 1/4" MCC-1 on various areas of the skirt structure. All tests passed the SRB requirements (verification).

While this information was not directly related to the application of MCC-1 to the Titan IV Payload Fairing (PLF), it was considered significant, in that, it would be the ultimate demonstration of the MCC-1 material application system equipment, that would almost duplicate the Pueblo, CO Titan IV MCC-1 application system, prior to actual use on the Titan IV PLF hardware.

8. In review of the "McDonnell Douglas Thermal Protection System Building Specification Verification Document, MDC 95H1067", dated 10/22/95, a number of discrepancies were found that were inconsistent with data generated as a result of MCC-1 process sensitivity studies (see Appendix 1). Data in the MDC 95H1067 document was primarily inconsistent with data from line items 13, 15, 16, 21, 22, 27, 29, 30 and 31 of Appendix 1 (attached).

In addition, the MDC 95H1067 document indicated that verification of the facility specifications would be a Quality Assurance function.

REPORT PERIOD - NOVEMBER 18, 1995 TO JANUARY 17, 1996:

1. The Federal Government operations shut down on November 14, 1995 due to the lack of an acceptable continuing U.S. budget resolution. Government personnel returned to work on November 20, 1995. During that time all NASA personnel and on-center contractors at Marshall Space Flight Center ceased on-center activities. Scheduled MCC-1 activities that were postponed included 1/16" Titan IV MCC-1 sensitivity sprays, Corlar topcoat application testing, and the Titan IV Program Review scheduled initially for November 16-17, 1995.

2. In the November 9, 1995 "Titan IV MCC-1 Telecon" the Air Force and McDonnell Douglas Aerospace personnel asked for a bond strength number for MCC-1 at 300^{0}F under flight loads. The equivalent Space Shuttle Solid Rocket Requirement is "that the MCC-1 remain bonded to the flight hardware at 300^{0}F under flight loads". USBI agreed to try and develop that number.

3. USBI developed a process to successfully spray 1/16" MCC-1 at 30-36 lbs/ft^2 density range for Titan IV application. Additional testing was required in determining:

(a) composite density (with topcoat)

(b) composite thermal conductivity and specific heat with Corlar applied.

(c) thermal performance in the Marshall Space Flight Center Improved Hot Gas Facility (IHGF).

4. USBI developed a hot water flushing process for cleaning of the MCC-1 Spray gun. It was estimated that the need for approximately 2500 pounds of methylene chloride per year was eliminated. Additionally the procurement/disposal costs and the possible carcinogen risk associated with methylene chloride use was eliminated.

5. A Titan IV MCC-1 Program Review was held November 28-29 in Huntsville, AL. Attendees included representatives of the Air Force, Lockheed Martin, McDonnell Douglas, Aerospace Corporation, USBI, and NASA. The first day of the review was held at USBI, where schedules, MCC-1 and Topcoat Qualification Plans, building construction (Pueblo) status, and process implementation activities for the Pueblo, CO facility were presented and discussed. The second day of the Review included a tour of the Marshall Space Flight Center (MSFC) Productivity Enhancement Complex (PEC) where a spray process for MCC-1 was demonstrated. Also inspected were the Space Shuttle Solid Rocket Booster Titan IV topcoat (Corlar) test specimens. Following the PEC tour, Titan IV personnel toured the MSFC Improved Hot Gas Facility where thermal testing is accomplished on thermal protective systems and materials.

6. The integrated schedule which was presented by McDonnell Douglas during the November 28-29 Program Review showed a Titan IV MCC-1 initial operating capability (IOC) of March 10, 1997 for the Pueblo, CO facility. Other major milestones, complementing the IOC include the beginning of process equipment installation at Pueblo, CO on June 21, 1996, with completion of process equipment and robotic installation on January 14, 1997. The integrated schedule was very success oriented. The USBI Testing, equipment procurements/installation, and the MDA engineering effort constitutes a critical schedule path for the overall program.

7. The Titan IV MCC-1 Program contracting relationships presented a schedule and management challenge. The contracting relationships were multifarious in the following manner.

The Air Force had contracted with Lockheed Martin for the overall establishment of a Titan IV MCC-1 application facility at Pueblo, CO. Lockheed Martin Aerospace had subcontracted with McDonnell Douglas Aerospace to build and operate the facility at Pueblo, CO. In addition, McDonnell Douglas Aerospace would assist with the Qualification of the MCC-1/Topcoat composite. Lockheed Martin Aerospace had also subcontracted with United Space Boosters, Inc. (USBI) to procure, install, and initiate implementation of the Titan IV MCC-1 Spray process equipment in the Pueblo, CO facility. In addition, USBI would continue Qualification/Process Sensitivity testing of the MCC-1, relative to Titan IV requirements, under contract to NASA with funding provided by the Air Force.

8. The Titan IV thermal protection system (TPS) facility construction schedule presented a challenge relative to pouring concrete during the winter and early spring months of 1996 in Pueblo, CO.
Concrete cannot be poured during freezing weather without some means of protection from the temperature dropping below 40^0F. Structural concrete normally is kept above 40^0F for 48 hours for proper cure.

9. It was noted during the Titan IV Program Review that nothing similar to an operational readiness inspection (ORI) had been scheduled for the Pueblo, CO Titan IV MCC-1 facility prior to the IOC date of March 10, 1997. The facility construction planning called for some verification activity, however, it fell far short of a full blown ORI with team members representing Facilities, Safety, Production, and Processing.

10. On December 18, 1995, the Marshall Space Flight Center activities were shut down due to furloughed NASA/Contractor employees, as a result of a Congressional/Presidential budget impasse. Many MCC-1 development and qualification activities were curtailed for the second time during this report period. The government (NASA) and Contractor (USBI) employees were all back to work on January 8, 1996.

11. It was noted that approximately one-half of the 1/16" MCC-1 Sensitivity test sprays were completed for the Titan IV prior to the December 18, 1995 government (NASA) shutdown.

REPORT PERIOD - JANUARY 18 TO MARCH 17, 1996:

1. Found that new Titan Vibration loads would be ready by the end of January, 1996. It was anticipated that testing would begin around the second week in April, 1996.

2. It was reported on 1/18/96 that a Pueblo, CO TPS facility lease agreement had been worked, with McDonnell Douglas Aerospace as the lessee. The Pueblo, CO T-IV Thermal Protection System (TPS) facility was being built by the Pueblo Development Foundation, Inc (PDF) and leased to McDonnell Douglas Aerospace (MDA) under contract to the Lockheed Martin Aerospace Corporation (LMA) in order to apply MCC-1, the new, environmentally friendly TPS that was developed by USBI under funding from both NASA and Air Force.

3. It was reported on 1/18/96 that the Pueblo, CO TPS facility structural steel design and procurement was the long tent pole of the construction schedule. The drawings for the steel were expected to be completed the week of 1/22-26/96, but were actually completed 2/19/96.

4. On 1/18/96 it was reported by USBI that Corlar Topcoat development project was on schedule, but no spray equipment for application of the Corlar had been base-lined as of that date.

5. It was announced on January 18, 1996 that a meeting was to be held at the McDonnell Douglas facility at Pueblo, CO to review the overall facility status and hold discussions with the contractor, and also have a ground breaking ceremony for the Titan IV Payload Fairing (PLF) processing facility, adjacent to the existing McDonnell Douglas facility. This new facility would house the MCC-1 production equipment for the Titan IV PLF. The meeting was held on January 30th as planned. The facility ground breaking ceremony was held on January 31st as planned. On February 8th, 1996 it was anticipated that the contractor would start moving dirt and driving foundation caissons. This work was completed around February 22nd. Shop drawings for the steel structure, which was a critical path, were out about the 19th of February. The contractor stated that he believed he could beat the schedule. McDonnell Douglas Aerospace personnel felt that the Pueblo, CO facility project was in good shape at that point.

6. USBI was continuing to investigate various application methods (HVLP, Wagner power painter, and airless spray) for the Corlar topcoat material that would be applied over MCC-1 as a moisture barrier and solar selective coating. On February 7th, 1996 a decision was made to drop airless spray development activity as a viable method for application of Corlar topcoat to MCC-1. It was determined that airless spray did not provide any advantages over High Volume, Low Pressure (HVLP) spray.

7. A contract for testing of the Corlar topcoat samples for specific heat and thermal conductivity was awarded by USBI procurement. The test specimens had been prepared for some time. This test data was needed for inclusion into the Qualification Test plan for Titan IV MCC-1.

8. Test panels (1/4" and 1/2" MCC-1) were sprayed to qualify BTA application over Porta-pull locations in MCC-1, without removing the MCC-1 down to the substrate following the Porta-Pull test. BTA is a Marshall Space Flight Center/United Space Boosters, Inc. developed repair and closeout material for Thermal Protection System (TPS). The previous repair procedure for Porta-Pull test areas required that all of the remaining TPS be removed, so that the underlying painted substrate was exposed, prior to repair with BTA. The proposed repair method would allow BTA to be applied directly over the remaining MCC-1. BTA over MCC-1 panels would be tested in Marshall Space Flight Center's Improved Hot Gas Facility in order to access the thermal performance of this new repair configuration. It would be applicable to the Space Shuttle, Solid Rocket Booster (SRB) and potentially Titan IV Payload Fairing hardware, after additional testing.

9. On 1/30/96 MCC-1 was successfully applied to the 1st Space Shuttle SRB flight hardware. It was applied to the left hand Aft Skirt that would fly on STS-80, slated for November 1996. The density of the MCC-1 was 34.6 lb/ft^3, with a range of 33.2-35.3. The average flatwise tensile strength was 364 PSI, with a range of 322-422. Twelve Porta-Pull adhesion tests were performed on the Aft Skirt. Eleven of the tests were terminated when load reached 200 PSI, per established guidelines, and one test pulled at 188 PSI. The failure mode for the flatwise tensile and Porta-Pull tests was 100% cohesive within the MCC-1. The MCC-1 thickness after light sanding was in the 244-302 mils range for the low heat area and 548-605 mils for the high heat area. The application was observed by Charles Jackson of C.J. Associates and was considered a significant milestone in the Qualification of MCC-1 for both the Space Shuttle SRB and Titan IV PLF projects because of application equipment similarities.

10. On February 8th USBI reported that they were looking at five concepts of creating a separation plane in the MCC-1 layer for the PLF separation rails. It was suggested by Lockheed Martin Aerospace and Air Force personnel that other concepts be investigated. A splinter telecon to discuss other concepts was held February 12th. Success criteria for separation was that there be no resistance to separation at the separation plane of the separation rail and also no significant contaminating particles generated as a result of the separation process.

11. Thermal Sensitivity Testing of MCC-1 was successfully completed in November, 1995 and the final report, "Thermal Sensitivity Testing of MCC-1, RWL-006-96-E", was issued during this report period. The report consists of three volumes, the latter two having two books each. The objectives of the thermal testing were to evaluate the impacts of off-nominal MCC-1 processing on the MCC-1 recession rate and substrate temperature rise.

A total of 54 MCC-1 panels were tested by USBI to investigate 24 material/process variations in 13 different parameters of the MCC-1 formulation and application process. The panels were unpainted (not topcoated) and exposed to a constant heat rate of 10 BTU/ft^2-sec for a test duration sufficient to achieve measurable recession. Recession data were obtained on all the material/process variations and the control specimen. The test results showed that all of the MCC-1 sensitivity data fell on or below the 1/4 inch MCC-1 Baseline Characterization design recession curve documented in USBI-AR-94-0180. The MCC-1 spray parameters were held within the limits that were tested, and the baseline design recession curve was used to compute the MCC-1 thickness requirements on the Space Shuttle Solid Rocket Booster and was pertinent data for the Titan IV Payload Fairings, since the thermal environments for those are even less severe, and sizing is driven primarily by insulative properties.

12. The first Titan IV MCC-1 Qualification Test sprays were performed in the MSFC-PEC. As of Feb. 28th, four spray runs were completed, involving 29 two foot by two foot panels. No anomalies were reported. All sprays were Quality witnessed.

13. All 1/16" MCC-1 spray runs for Titan IV repeatability tests were completed. The testing was to ensure that the average density was in the 30-36 lb/ft^3 range. The densities actually averaged 33.2-34.4 lb/ft^3, which was within the established limits.

14. Titan IV prequalification testing was performed on 1/16" MCC-1, where flatwise tensile tests were performed at 300^0F. The data was acceptable with an average FWT of 99 PSI. The typical failure mode was 86% cohesive failure within the MCC-1. These tests resolved a USBI action relative to the MCC-1 strength when the substrate temperature reaches 300^0F.

REPORT PERIOD - MARCH 18 TO MAY 17, 1996:

1. The earth and concrete foundation work for the Titan IV MCC-1 application facility at Pueblo, CO was completed, basically, on schedule.

2. Pouring of the concrete floor for the Pueblo, CO MCC-1 facility was delayed, until the steel structure was up, due to concerns relative to the affect of unreliable weather on the concrete cure.

3. All of the structural steel for the Pueblo, CO facility had arrived, about a week ahead of schedule, by 3/25/96. That did not include metal sheeting for the roof and sides of the building. By 4/4/96 the steel was going up. On that date the south 1/2 of the building structural steel was up, the foundation for the paint booth was in work and the overall construction schedule was 2-3 days ahead.

4. The Pueblo, CO Titan IV TPS application facility construction was approximately one week ahead of schedule as of May 2, 1996. The steel structure was erected, steel paneling on the exterior of the building was completed on May 5 and roof panels were started May 7. The large exterior entrance doors were hung on April 28, 1996. The overhead cranes had also been installed. All mechanical equipment for the basic building was on-site, including the paint (TPS) booth. The steel structure for the booth was complete.

It was expected that the Pueblo facility would be completed on schedule. The next review was scheduled for June 4, 1996.

5. Action was taken to make application for a MCC-1 spray booth permit for the Pueblo, CO facility.

6. During this period USBI continued refining and experimenting with concepts (design options) of spraying MCC-1 over the Titan IV Payload Fairings (PLF) separation rails and achieving the desired gap in the MCC-1. Success criteria was, (a) that there be no resistance to separation, (b) that contamination be an acceptable level as defined by Titan IV requirements, and, (c) that minimum thermal requirements for the rails by met.

7. At a TIM on April 2nd in Huntsville, AL, the differences in the various types of Corlar (LF-63276P, 1LB76P, 2MB76P, and 3DB76P) were discussed. The spray test parameters to resolve the coating disparities between MDA at Huntington Beach, CA and USBI at Huntsville, AL were discussed and agreed to by the collective materials and processes representatives at the TIM. The problem was that USBI had LF63276P Corlar and MDA had 1LB76P. USBI could not repeat what MDA had done (number of coats and weight per inch square) during the topcoat screening study.

8. During the 2nd day of the TIM (April 3rd) the group of materials and processes representatives finalized a Design of Experiment (DOE) for determining optimum Corlar coats/thickness for application to Titan IV MCC-1. In addition, they observed the application of MCC-1 to one concept of a Titan IV PLF separation rail closeout simulator.

9. During the 3rd day of the TIM (April 4th) the group of materials and processes representatives reviewed drawings of the Payload Fairing (PLF), made a tour of the MSFC IHGF, and separation rail simulator that MCC-1 was applied to the day before. It was generally agreed that the separation rail closeout concept showed some promise.

10. Twelve Titan IV Corlar over MCC-1 Pre-Qual test panels were prepared in order to evaluate the effect of varying Corlar penetration on the thermal performance of MCC-1. Three bare panels were produced, as were three which had three sprayed coats of Corlar, followed by three panels which had six to seven sprayed coats of Corlar (the latter case considered full coverage), and finally by three panels which had one coat of hot (110^0F) Corlar rolled on. The panels were tested in the MSFC Improved Hot Gas Facility (IHGF).

11. The latest Corlar (1LB76P) topcoated MCC-1 tested at the MSFC Productivity Enhancement Complex (PEC) showed promise. Areal density, measured as weight per unit area, is an important issue for Titan IV. Two application techniques were demonstrated. The first technique involved spraying even coats of Corlar, to a per coat wet thickness of about 15 mils, with four hours of drying time between coats. The second technique applied a first coat of 10-30 mils, with a one hour drying time, wet thickness. Drying times increased to 1 1/2, two, and three hours, after the third, fourth and subsequent coats, respectively. It was noted from this preliminary data that the sanded panels typically had a lower areal density than the unsanded panels at the same conditions. The Corlar topcoated 60 mil MCC-1 samples had a lower areal density than the 370 mil MCC-1 samples, regardless of whether they were sanded. Based on the limited data available, there was no definite trend to show that one of the two application techniques produces a lower areal density. Total wet paint thicknesses varied from 45-75 mils and 79-120 mils for the 60 and 370 mils MCC-1, respectively.

12. USBI, LMA and MDA representatives would travel to Minnesota during May, 1996 to verify functionality of the robot, to be installed in the Pueblo, CO Titan IV facility, prior to shipment from the manufacturing facility. The robot was believed to be one month ahead of schedule.

13. The Posi-Turner had been ordered for the Pueblo, CO facility and was due August 1, 1996.

14. Noted that the Composite Program Schedule presented at the April 30-May 2 Review was inconsistent with some on-going USBI contract activities.

15. Noted that MDA was proposing that MCC-1 and topcoat be applied to the Titan IV PLF's in the horizontal position.

16. It was noted that for Qual. Testing, system weight would not be a requirement.

17. During the combined M&P/Thermal group sessions at the April 30-May 2, 1996 Titan IV Program Review the following was jointly agreed to, concerning qualification panels,

a. MCC-1 will be sanded to remove loose overspray and to remove the highest peaks, since the operation is a minor labor impact. Sanding saves topcoat, especially in thicker MCC-1. No sanding allowance will be added for thermal sizing.

b. Qualification panels would be topcoated by a spray application process, because it provides a fairly repeatable weight gain.

c. Use Corlar baseline target parameters of,
   (1) Nominal thickness (pinhole free).
   (2) Temperature of application - $75^0F \pm 5^0F$.
   (3) Apply at Relative Humidity (RH) greater than 50%.
   (4) Use baseline cure delay between coats.
   (5) Remove system weight wording from the Qualification Test Plan, because the system weight has nothing to do with materials and processes qualification. If the system is overweight, a number of options exists to lower the weight, all of which have schedule and cost impacts.

18. It was noted that a number of areas require gap width control of MCC-1, including the separation rail (already under investigation). Investigation of all gap areas should be accomplished prior to Pathfinder, to be sprayed in early 1997.

19. Based on the composite Program Schedule and information presented at the Titan IV TPS Replacement Program Review, all aspects of the program are on schedule or slightly ahead of schedule (Re: Facility construction, Robot procurement, and TPS Tooling).

20. It was noted that the PLF nose cap is part of Pathfinder, however, it is not clear that a nose cap will be available for MCC-1 application check-out prior to the Pathfinder scheduled spray.

21. It was noted that not all areas of the PLF can be sprayed with MCC-1 (boattail areas, etc.).

REPORT PERIOD - MAY 18 TO JULY 17, 1996

1. As of May 22, 1996 spraying of the MCC-1 Qualification Panels for Titan IV was underway, following the baselining of the Corlar spray process. A total of thirty-four 370 mil thick MCC-1 panels had been sprayed, by that date, with Quality Engineering witnessing the operations. All Qualification panel spraying of Corlar was due to be completed within a four week period.

2. Off-line programming had verified that the robot for the Pueblo, CO MCC-1 Application Facility could reach all portions of the Payload Fairing separation rail.

3. It had been determined that the processing time for the MCC-1 application on the biconic section of one Payload Fairing trisector was approximately one hour and thirty-five minutes, not counting the time to spray the separation rail, which will be sprayed first.

4. The robot was not due to arrive at the Pueblo, CO Titan IV MCC-1 Application Facility until August 6, with the first trial sprays anticipated two to three weeks after installation.

5. In preparation for development of the tooling design for the Payload Fairing Nose Dome, a damaged, test Nose Dome would be sent to USBI after refurbishment at Huntington Beach. The Dome would also be used for MCC-1 Pathfinder sprays.

6. As of May 20, 1996 the exterior walls and roof of the Pueblo, CO Titan IV MCC-1 Application Facility were complete. The air compressors were installed also. Overall, it was estimated that the construction of the facility was one and one half weeks ahead of schedule on that date.

7. It was agreed that gap sizing, between MCC-1 interfaces (on separation rail, nose dome, etc.) would be addressed during sensitivity testing.

8. Park Industries, the manufacturer of the Posi-Turner that will be used in conjunction with the overhead cranes, and Wazee Crane, the crane manufacturer will ensure that controller frequencies will not interfere with each other in the Pueblo, CO MCC-1 Titan IV facility.

9. It was noted that USBI personnel in the Marshall Space Flight Center Productivity Enhancement Complex report a Corlar 1LB76P viscosity drop when it is filtered prior to spraying.

10. As of 6/4/96 the construction status of the Pueblo, CO MCC-1 Application Facility was as follows:

a. The exterior walls and doors of the building were basically complete.

b. All lighting in the building, with the exception of the paint booth was installed and operating.

c. The control room floor was poured.

d. The paint booth floor was poured.

e. The paint booth construction was estimated at 80% complete. Some wall panels, lighting, ducting, etc. was yet to be installed.

f. Bathroom, storage room, control booth, and process equipment room studs were in place, and drywall materials were on-site.

g. The primary building floor was being prepared for pouring of concrete. The floor was to be poured in three large sections; each being stressed with tensional cables to prevent contraction cracking during cure.

h. The exterior grounds on the south side of the building was being prepared for pouring of the concrete skirt.

i. It was estimated that construction of the facility was one to one and a half weeks ahead of schedule.

j. It was agreed that coating of the control and equipment room floors would not interfere with USBI process equipment delivery.

11. Around the first of June the status of Titan IV MCC-1 Qualification Testing was as follows:

a. Quality acceptance data for the 0.370" panels looked good with the bulk of the data in.

b. Topcoating of the 0.370" panels with Corlar paint was scheduled to begin on June 6.

c. The data for the 0.185" panels looked good. Topcoating was scheduled for June 12-14.

d. Development sprays for the 0.083" (1/16") panels was going good with spraying of Quality panels scheduled for June 11, and Topcoating on June 21.

12. It was noted during the Pueblo, CO Facility Review that the integrated program plan and schedule still had several disconnects, primarily between the end of facility construction and when USBI will start installation of process equipment; and between USBI and MDA MCC-1 processing personnel relative to MCC-1 Process Training, prior to Pathfinder activity.

13. By June 13 the status of the Pueblo, CO Titan IV MCC-1 Facility construction was as follows:

a. All exterior walls and roof of the building were complete, including all tar on the roof.

b. All floors were poured and post tensioning was in progress.

c. The contractor was finishing the outside grading in anticipation of pouring the concrete the following week.

d. All paint booth panels were in place and lighting was being installed in the booth.

e. The contractor was finishing the dry wall work in the control, bath, and process equipment rooms.

f. It was reported that the paint booth and cranes would be checked-out on June 23rd during a work-down inspection.

g. Plumbing was over two-thirds complete.

h. Roughing-in of the electrical work was done.

i. It appears that the Pueblo, CO facility would be completed by July 15, ahead of schedule.

14. It was noted, during the facility review in Pueblo, CO on June 4th, that a critical item in the implementation schedule was the conceptual verification and design of the "gap tools" for various areas on the Titan IV PLF. The schedule called for the design of the tools to be complete by July 31, which means that the conceptual verification to be performed by USBI would have to be accomplished prior to the final tool design. Initial attention was focused on the separation rail gap which was successfully sprayed with MCC-1 by USBI at MSFC using a prototype tool. However, several other areas on the PLF require gap control for which no prototype tools have been designed. MDA was to deliver a list of the various gaps to USBI and arrangements were to be made to provide USBI with components, such as a dome cap, ordnance covers, etc., that they need to verify the various gap sprays prior to Pathfinder. USBI indicated that they would need a dome cap for a period of 90 days, which was being shipped from Vandenberg AF Base.

15. Topcoating of the .370 Qualification Test panels was completed the week of June 13.

16. MDA turned in a proposal to USBI to do the contamination testing on the Corlar topcoated MCC-1 as part of the overall Qualification Tests. Negotiations were scheduled to begin the week of June 17.

17. A contamination testing agreement was reached, as follows:
    a. A ball drop test would be used after verification of the shock environment validation.
    b. Front face temperature would be measured by thermocouple for all tests except for the protuberance test.
    c. Front face temperature for the protuberance test would be measured by Calorimeter.
    d. Acceptance criteria is 0.01% obscuration.
    e. No STM K799 testing would be done.

18. As of June 12, 1996 the final version (Revision) of the Titan IV Qualification Test Plan was still not released due to the need to incorporate information on a contamination test matrix, text regarding the 75 PSI FWT acceptance criteria, and a few other minor changes. The contamination Qual. Test Matrix was released as Table I of the minutes of the June 12th TPS Engineering IPT Telecon.

19. On 6/24/96 the Pueblo, CO facility contractor (Whitlock) agreed to provide a summary sheet of tests that would be accomplished on overhead cranes and the paint booth. They also agreed to establish a date for testing so LMA and MDA could witness the testing. The date was set at July 8th.

20. On 6/24/96 the concrete skirt in front of Pueblo, CO MCC-1 facility had been poured.

21. The material delivery room, paint booth and other rooms in the Pueblo, CO building lean-to were epoxy coated on Monday July 1st.

22. On 6/24/96 Steve Cosby (USBI) indicated that MCC-1 process equipment would arrive at the Pueblo facility on July 8-9 and would be moved into the building thru the west door. It was confirmed in the June 24th telecon that the facility would be ready to allow Steve and USBI to begin installation of the equipment at that time.

23. On June 26, 1996 the spraying of the 1/16" MCC-1 Qualification Panels was successfully completed. Thirty-four panels in all were sprayed with MCC-1. The density range was 30.9 to 34.0 lb/ft^3, meeting the specified range of 30-36 lb/ft^3.

24. By June 26 Corlar topcoat had been successfully applied over the 2nd of two sets of 370 mil MCC-1 Qualification Panels. The weight gain data after five days of cure ranged from 1.01 - 1.26 grams/in^2, which is within the 1.0 - 1.4 grams/in^2 range expected. The wet film thickness ranged from 90 to 110 mils. The variations in weight gain and wet film thickness appear to be influenced by a combination of the degree of sanding of the MCC-1 surface and the spray-to-spray variation of MCC-1.

25. On June 27, 1996 the construction of the Pueblo, CO Titan IV MCC-1 Application Facility was nearly complete. Items remaining included painting the dry walls in the control room, MCC-1 process equipment room, and adjacent areas; installing glass over the paint booth lights, epoxy coating the concrete floors, installing the glass in the control room observation windows, and asphalting the area around the building outside the concrete apron. Walk-down and check-out inspection were scheduled to begin July 8th, with facility completion July 15th, ahead of schedule.

26. On June 27, 1996 the PLF trisector tool design was sent out for bids. Bids were to be received by MDA by August 20th.

27. The preliminary estimated thicknesses of MCC-1 for the Pathfinder PLF spraying was released by MDA in the minutes of the June 19, 1996 TPS Engineering IPT telecon. The estimates are listed in Table I of the minutes.

REPORT PERIOD - JULY 18 TO SEPTEMBER 17, 1996:

1. As of July 15, 1996 the Pueblo, CO Titan IV TPS Facility was "officially" complete as signified by the sign off of all four building inspectors and receipt of the "certificate of occupancy" from the City of Pueblo, CO, ahead of schedule as predicted in January 1996.

2. As of July 15, 1996 Steve Cosby (USBI) and his crew were already installing the MCC-1 material delivery equipment in the Material Processing room of the Pueblo, CO Titan IV TPS Facility.

3. As of July 15, 1996 the checkout testing of the Wazee cranes in the Pueblo, CO Titan IV TPS Facility was essentially complete. There were a few problems recorded on a punch list that Wazee worked and the cranes were bought off on July 18, 1996.

4. As of July 15, 1996 problems were encountered in the paint booth checkout in the Pueblo, CO Titan IV TPS Facility. The boiler required to control the relative humidity in the booth did not function as planned. The booth was tested without the boiler and it performed as expected, in the required temperature control range. After the boiler and its controls are working, the booth should meet all requirements, except for the door (see next item).

5. During the walkdown inspection of the Pueblo, CO MCC-1 facility, a problem was noted with closing the paint booth door. It was estimated, at that time, that it would take approximately 2 weeks to correct the problem.

6. As of July 15, 1996 the air conditioners for the Pueblo, CO MCC-1 Building were not working. All three systems (2 each for the high bay and low bay areas and one dedicated to the control room) needed to be wired correctly.

7. On 7/18/96 it was noted that the next Titan IV TPS Replacement Program Review was scheduled for mid to late September, 1996 in Pueblo, CO to allow all participants to view the new MCC-1 Application Facility. It was also noted that the Review would be a pivotal point for detail planning of the Titan IV Pathfinder spraying with MCC-1, to show that the TPS application process does not harm the Payload Fairing and change the MCC-1 properties to the point where there would be problems with meeting requirements.

8. On 7/18/96, USBI was making good progress with the installation of the MCC-1 process equipment into the new Pueblo, CO facility. Approximately 80% of the electrical conduit had been installed at that point.

9. As of 7/18/96, final acceptance testing of the paint booth was expected on July 24th.

10. As of 7/18/96, delivery of the PLF handling fixture was scheduled for August 27th.

11. As of 7/18/96, MDA had received 80% of the USBI MCC-1 specifications and processes and the conversion to the MDA format was underway. No schedule problems were expected.

12. As of 7/18/96, the robot delivery for the Pueblo, CO MCC-1 Application Facility was expected to be 2 weeks late.

13. As of 7/18/96, it was reported that the Titan IV MCC-1 Qualification Test Plan was in the final release cycle at USBI and would be delivered within the following two weeks.

14. As of 7/18/96, it was reported that IHGF Testing of MCC-1 Qualification Test panels would begin on August 6, after the Test Readiness Review.

15. As of August 1, 1996 the Pueblo, CO Titan IV Facility was basically complete. A few items, considered minor, with no short term impact to MCC-1 implementation, remains to be done. They include:

a. Boiler had problems with ignition.
b. General clean-up of the building exterior grounds.
c. Landscaping the surrounding grounds.
d. The east gate does not roll easily and needs repair.
e. Some bubbles in the floor coating needs repair.
f. The MCC-1 process room needs a hot water supply.

16. As of August 1, 1996 the Tooling required for MCC-1 implementation was on schedule. The linear bearing tool was scheduled to arrive August 27th, 1996. Tooling to hold the PLF dome cap was estimated at 40% complete.

17. As of August 1, 1996 all USBI Specifications (M & P Specs.) had been given to MDA except a Corlar 76P material specification.

18. As of August 1, 1996 the robot for the Pueblo, CO MCC-1 facility was on schedule to be delivered August 20th. Buy-off was scheduled for August 12-13, 1996 at the Vendor.

19. The Titan IV MCC-1 Qualification Test Plan was basically complete. All comments had been incorporated, however all buy-off signatures had not been obtained.

20. As of August 1, 1996 the Qualification Test Panels had been sprayed, topcoated and acceptance testing completed.

21. As of August 1, 1996 a Test Readiness Review was scheduled for August 6 at USBI, Huntsville, after which authority to proceed (ATP) would be given for fabrication and testing of Contamination Qualification Test Panels.

22. As of August 5th a hot water supply had been provided to the Process Equipment Room of the Pueblo, CO Titan IV MCC-1 Facility. In addition, an electrical box had been run to the Material Storage Room and the glass for the paint booth lights had been installed.

E. RECOMMENDATIONS/COMMENTS

All recommendations and comments made in the performance of the contract are listed by Contract Status Report Periods.

REPORT PERIOD - JANUARY 18 TO MARCH 17, 1995:

1. CMT-056-95MP (document reviewed)
   a. Para. 2.3: Add topcoat procedure JCC-035-93MP or 10PRC-0638 "Procedure for Application of TPS Topcoat".
   b. Para. 4.1.1: Add a sentence "d" to read "weigh each panel, prior to MCC-1 application, to the nearest gram and record on the "Substrate Preparation Log" (Appendix A) for future use.
   c. Para. 5: The Phase 2 sensitivity study variables should include the viscosity and temperature of the topcoat material and the temperature of the MCC-1 substrate during the topcoat application, all of which have an impact on the wicking of the topcoat into the porous MCC-1, thusly affecting the overall TPS System density.
   d. Substrate Preparation Log (Appendix A, page 16), put a line item for recording the prepared panel weight.

2. DWG. 10753-0064 (document reviewed)
   a. Para. 1.1: Calls for MCC-1 application to epoxy painted substrates. Para. 5.2 of 10PRC-0637 allows application to small bare areas. Change Para. 1.1 to allow small bare areas.
   b. Para. 3.2.2: Does not specify if density is based on coated or uncoated MCC-1. Specify which one.

3. 10PRC-0637 (document reviewed)
   a. Para. 3.6: Cleaning and flush solvent specifications should be listed.
   b. Para. 3.7, 3.8, 3.9, and 8.1: List vendors, type and model of dry powder feeders, fluid meter pumps, robot, and eddy current thickness testers, respectively.
   c. Para. 4.1: List the certification requirement and procedure number.
   d. Para. 4.5: States that "flight hardware should not be handled with bare hands". Provide info. on how to handle, such as, with gloves. Include info. on gloves, etc.
   e. Para. 5.5: Calls for ultraviolet inspection. List method or procedure to be used.
   f. Para. 5.5: States "re-inspect if more than 8 hours have lapsed since ultraviolet light inspection". Change to read "since previous cleaning per Para. 5.4.
   g. Para. 6.4: States "topcoat per 10PRC-0638". Actually two procedures exists for topcoat application, JCC-035-93MP and 10PRC-0637. Only one is required.
   h. Para. 3.7, 3.8, 3.9, 4.5 and 8.1: Equipment and materials should be listed under Para. 3.0.

4. JCC-035-93MP (document reviewed)
   a. Para. 3.1: Include temperature and viscosity control of mixed Urethabond.
   b. Para. 3.2: Include substrate temperature control.

5. Test Matrix to Establish Minimum Urethabond Paint Application Amount:
   a. Control the temperature and viscosity of the mixed Urethabond during the application process.
   b. Control the temperature of the MCC-1 substrate while applying the Urethabond topcoat.
   Rational: The temperature and viscosity parameters determine the degree that Urethabond wicks into the MCC-1, thusly affecting the final density of the overall TPS system and diffusivity. Uncontrolled parameters will yield a wider variation for both.

6. 61PLN-0001 (document reviewed)

   a. Para. 4.1, 4.2, and 4.3.2: Add additional instructions and testing to qualify topcoated MCC-1 at a maximum absorbed moisture content of TBD, determining the affect on backface temperature and recession rate.

   b. Para. 4.2.2.1: Add - "After the test panel surfaces have been prepared for TPS application, each panel will be weighed and documented to the nearest gram on data sheets shown in Appendix D (sheet D-1) as required, for future assessment use".

   c. Para. 4.3.1: Add additional instructions and testing to qualify MCC-1 at a maximum absorbed moisture content of TBD, determining the physical and mechanical properties at that level.

   d. Appendix D-1, Substrate Preparation Log: Add line item to record panel weight.

   e. Appendix D-9, Topcoat Data Sheet: Adjacent to "Spray Cell Data", add a line item to record the substrate temperature. Note: substrate temperature is one parameter that affects topcoat wicking.

   f. Appendix N, Titan IV Requirements for Qualification, Characterization, and Sensitivity Studies - Thermal Matrix, item 4a, 4b, and 7: Add under Titan IV Requirements column - "--- under worse case T-IV aero/shear and moisture absorption environment".

   g. Appendix N, Titan IV Requirements for Qualification, Characterization, and Sensitivity Studies - Physical and Mechanical Properties Requirements matrix, item 27 & 30: Change Titan IV Requirement column to reflect the worst case launch environment conditions for absorbed moisture.

   h. Appendix N, Titan IV Requirements for Qualification, Characterization, and Sensitivity Studies - USBI Sensitivity Study Matrix: Immediately after item 44--add a new item to establish the viscosity/temperature of the MCC-1 substrate during the application of the Urethabond to the MCC-1, to better control the wicking of the Urethabond into the MCC-1.

7. "Test Plan to Evaluate Potential Effect of Moisture on MCC-1".

   a. Add a paragraph to specify time allowed from time of removal of test specimen from the sealed bags to initiation of actual tests.

   b. Para. 2.2: Change sentence to read "Once the desired moisture level has been obtained, the sample will be sealed in a plastic bag (4 mil thick min. polyethylene) to maintain the desired moisture content".

8. CMT-046-94MP, Rev. A. (document reviewed)

a. Para. 3.0: Add a subparagraph for the control of the MCC-1 temperature prior to and during the application of the topcoat.

b. Para. 4.1: Add steps to verify the viscosity and temperature of the activated topcoat meet requirements determined previously in sensitivity testing.

Note: Both "a" and "b" above will affect the degree of wicking of the topcoat into the porous MCC-1, to some extent. The booth and substrate temperature should be kept to the lowest point practical and raised to a higher cure temperature only after application of the first coat of topcoat.

c. Topcoat Data Sheet: Modify to enable recording of the following.

1. Viscosity and temperature of topcoat just prior to application of the first coat.
2. Cell temperature during application of the first coat of topcoat.
3. Substrate temperature just prior to application of the first coat of topcoat.
4. Adjusted cell temperature after first coat of topcoat.

9. "Cork Granular, 40/80 Super Clean", DWG. NO. 10753-0060 (document reviewed)

a. Para. 1.2: Change from "This material is 40/80 sieve size, ---" to "This material is 40/80 U.S. Standard sieve size, ---".

Note: The sieve size could be misconstrued as Tyler Standard sieve size 40/80, which is not the same size openings.

10. "USBI Weekly MCC-1 Report Dated: 2/20/95" (document reviewed) Reported a 19-28% (FTS) strength reduction with topcoated MCC-1 compared to bare MCC-1.

a. Recommended that the strength reduction phenomenon be evaluated by USBI to determine,

1. What causes the phenomenon?
2. How many test specimens the data represents?
3. How soon after topcoating the specimens were tested? How cured?
4. What the failure mode was?

b. Recommended that additional tests be run for clarification,

1. At different topcoat cure times.
2. At different MCC-1 thicknesses.
3. Possibly at different topcoat thicknesses.

11. "Alternate TPS Sealcoat Qualification Test Plan, Second draft (Preliminary), dated Feb. 14, 1995. (document reviewed)

a. Para. 2.4: Add reference document CMT-046-94MP, Rev. A, "Procedure for Spray Application of Topcoat (Urethabond 3015 Mod #3#4)" to accommodate the Titan IV thermal protection system development.

b. Para. 3.0 and Table I/II: Rewrite to include Titan IV qualification testing and criteria. Titan candidate sealcoat should be applied to test panels by spray.

c. Para. 3.1.1: Rewrite to include Titan IV interactive materials.

d. Para. 3.1.3 through 3.1.7: Rewrite to include Titan IV.

e. Para. 3.2.1 through 3.2.3 and Table III: Rewrite to include Titan IV.

f. Para. 3.3: Rewrite to include Titan IV.

g. Para. 3.4, subparagraphs and Table IV, V, and VI: Rewrite to include Titan IV.

12. General Comment (this period)

More frequent technical interchange meetings (TIM's) should be held during the development, sensitivity and qualification testing stages of the program. That will improve communication and provide a forum for resolution of outstanding issues and concerns that is more dynamic than telecons.

REPORT PERIOD - MARCH 18 TO MAY 17, 1995:

1. General Comment (this period)

a. Urethabond may be the best water-based topcoat available and should not be thrown out without an acceptable alternative. Testing should be accomplished to understand why environmentally cycled Urethabond topcoat becomes hard/brittle and picks up less moisture than freshly applied Urethabond. Less moisture absorption may be a function of better crosslinking of the polymer during the cycling or better crosslinking purely as a function of elapsed time.

2. Recommended that Trich-Free Hypalon be tested, for moisture pick-up, in the same manner that Urethabond was tested. Also recommended that the Hypalon containing 1,1,1,Trichloroethane be tested in the same manner, as baseline performance material, since a SRB flight data base exist for that material.

3. Suggested that the breakaway function of the robotic end effector device developed for the SRB MCC-1 spray cell at KSC is a desirable feature for the Titan IV robotic spray system to be installed at Pueblo, Colorado.

REPORT PERIOD - MAY 18 TO JULY 17, 1995:

1. Recommended that the "test delay time" in paragraphs 5.3.2 and 5.3.3 of 10PRC-0624A, "Process Control Specimen Preparation and Test Methods" and the "test delay time" in paragraph 6.1, process parameter #11 of 10PRC-0637, "Procedure for Insulation Application, MCC-1", be changed to be consistent. 10PRC-0624A presently states 4-15 hours delay from application to testing, while 10PRC-0637 states 5-15 hours.

2. Agreed to simulated exposure parameters of 0.21 inches per hour rainfall for a 24 hour duration, followed by 2.0 inches per hour rainfall for one hour for test panels of MCC-1 which have been topcoated with Urethabond and Hypalon and subjected to outdoor exposure for the last six months at KSC and freshly painted panels. The test panels were run in the IHGF to establish whether the topcoat was affected by the six month beach exposure and simulated rain exposure, relative to topcoat flow.

3. Recommended that the Titan IV AF representative be informed of the NASA TM 4511 moisturized, Urethabond coated MCC-1 exposure panels passing the IHGF tests (no creep). Specimens, cut from panels that were exposed to the environment on the beach at KSC for six months, were moisturized, as were newly painted and cured Urethabond panels, to a cycle derived from NASA TM 4511 cycle (previously outlined in section I.A of this report) considered average maximum (99% data) environmental conditions at KSC launch site and is derived from actual environmental data at KSC).

Previously moisturized panels tested in the IHGF at 5 Btu/ft^2-sec. failed due to creep (topcoat flow). However, those panels had only been coated a short time before the IHGF testing and had only been cured for 2 days at 120^{0}F. They were also moisturized in the horizontal position, which is not representative of launch vehicle surfaces on the launch pads at KSC and/or Vandenberg. It is theorized that the short cure was insufficient for proper crosslinking of the Urethabond and the horizontal position during moisturization (increasing the amount of moisture absorbed due to puddling on the surface) were the causes of the creep noted during IHGF testing. The successful (no creep) IHGF testing of the beach panels and the newly painted panels moisturized to the new NASA TM 4511 criteria substantiates that theory.

REPORT PERIOD - JULY 18 TO SEPTEMBER 17, 1995:

1. Recommended that NASA approach the Titan IV, Air Force management, in a timely manner, for potential shared funding of the NASA effort being initiated to find and develop a cheaper resin for use in the MCC-1 thermal protection system to be utilized on both Space Shuttle Solid Rocket Boosters and Titan IV Payload Fairings. It was suggested that after the Air Force gives the ATP for the presently defined activities would probably be the best time to discuss the issue.

2. Recommended that USBI personnel review and modify the "Titan IV Qualification Test Plan" relative to potential selection of a topcoat other than Urethabond, Mod. #4, by Titan IV contractors. The 12/22/94 version of 61PLN-0001 is a delta from the SRB TPS Qualification Test Plan, 10PLN-0131, and covers only the Titan IV unique qualifications requirements. Recommended that Tables I (Common SRB and Titan IV Tests) and II (Titan IV Specific Tests) of 61PLN-0001 be used as a guide to rewrite and expand the Qualification Test Plan requirements.

3. Recommended that the west elevation door scheme of the MDA (Pueblo, CO) MCC-1 facility drawing be made consistent between sheets A-2 and A-3 of the facility drawing package.

4. Since the MDA recommendation (and acceptance by TIM attendees) to use Corlar in-lieu-of Urethabond as the topcoat for MCC-1 on the Titan IV program creates a departure from commonality between the Space Shuttle SRB and Titan IV programs; and since Corlar performance during screening parameter testing was superior to Urethabond. especially in moisture sensitivity and IHGF tests, it was suggested that NASA and USBI thoroughly explore the technical and economic advantages of utilizing Corlar for the SRB program as well. The long term impacts of commonality between programs could be significant.

5. In review of the "MCC-1 Qualification Test Plan for Titan IV", for a September 7, 1995 review, the following changes were recommended.

a. Under para. 4.0 in Table of Contents: Change 4.3.3.2 to read: "Propellant compatibility with Corlar Topcoated MCC-1".

b. Under para. 4.0 in Table of Contents: Change 4.3.3.3 to read: "Cryogenic Flash Vapor Cooling with Corlar Topcoated MCC-1".

c. Para. 1.1, page 7: Change Urethabond 3015 Mod. #4 to Corlar 76P.

d. Para. 1.2, b: Change from "Topcoat application technique" to "Topcoat and application technique".

e. Para. 1.2, fourth paragraph, second sentence: Change to read: "In item "b" above, the Air Force has selected a different topcoat than the SRB program and material properties may be different associated with the TPS due to the topcoat application technique, and that the data obtained by the SRB TPS qualification effort (in accordance with 10PLN-0131) is not applicable to the Titan IV PLF".

f. Para. 2.4: Specification 10753-0062 "Urethabond 3015 Mod #4 Topcoat Drawing" no longer applies and should be replaced with a similar spec. for Corlar 76P. Also, specification CMT-046-94MP, Rev. B no longer applies for Urethabond.

g. Para. 4.1.1, C: Change "Urethabond 3015 Mod #4" to Corlar 76P. The asterisk note for this item now applies with the selection of Corlar topcoat.

h. Para. 4.2.2.3: Refers to topcoat application specification CMT-046-94MP, Rev. B, which is for Urethabond Mod #4. This specification should be replaced with a similar specification for Corlar 76P.

i. Table II Test Matrix Summary for MCC, page 19: Modify to incorporate the use of Corlar 76P topcoat.

j. Para. 4.3.3.1: Modify this paragraph to reflect the Air Force decision to use Corlar 76P as the T-IV PLF Topcoat and the USBI effort to develop an application process/procedure for Corlar.

k. Para. 4.3.3.3: Change title to read: "--cooling with Corlar 76P Topcoated MCC-1".

l. Para. 4.3.3.3, last sentence: Change to say that USBI will perform the tests.

m. Page 74, Topcoated Data Sheet (D-9): Modify, as required, for use with Corlar 76P application parameters.

n. Page 107, Matrix item 49: Add T-IV PLF rail backside temperature requirement of 160^0F.

o. Appendix N, CMT-056-95MP, Table 1: Modify Table 1 to incorporate the use of Corlar 76P Topcoat in-lieu-of Urethabond 3015 Mod #4.

p. Appendix N, CMT-056-95MP: Starting on page "i" of the document the designation changes from CMT-056-95MP to CMT-056094MP. Change to reflect correct designation.

q. Appendix N, CMT-056-94MP, para. 4.3.3: Change Urethabond Mod. #4 to Corlar 76P.

r. Appendix N, CMT-056-94MP, Table 2, page 11: Change matrix to reflect the correct number of coats of Corlar topcoat for no pinholes.

s. Appendix N, CMT-056-94MP, para. 7.0: Change schedule dates.

REPORT PERIOD - SEPTEMBER 18 TO NOVEMBER 17, 1995:

1. Recommended that a comprehensive schedule of the Pueblo, CO facility activity, the Corlar Topcoat development activity, the Titan IV MCC-1 Qualification Testing, and the implementation of the MCC-1 process into the Pueblo, CO facility be developed and maintained by USBI in concert with the Air Force T-IV contractor(s) inputs as soon as possible.

2. Recommended that USBI provide McDonnell Douglas Aerospace (MDA) with a copy of the MCC-1 Processing Specification 10PRC0637, dated February 20, 1995, so that the data in "McDonnell Douglas Thermal Protection System Building Specification Verification Document, MDC95H1067" can be changed to reflect the correct processing parameters developed in comprehensive processing. Sensitivity studies by NASA/USBI at the MSFC Productivity Enhancement Complex.

3. Recommended that the verification of the MDA, Pueblo MCC-1 Facility be accomplished by a team composed of Quality Assurance, Safety, MDA Maintenance/Facility, USBI MCC-1 Process, and MDA TPS personnel representatives.

4. "MCC-1 Qualification Test Plan for Titan IV, 61PLN-0001", 10-18-95 Revision.

Para. 1.2: The next to last sentence states "For items "b" and "c" above the Air Force has agreed that the data generated for bare MCC-1 and one close out material, K5NA, as part of the SRB qualification efforts (in accordance with 10PLN-0131) are applicable to the Titan IV PLF".

This sentence should state, "Items "b" and "c" above notwithstanding, the Air Force..."

Page 10, Para. 1.3.i: States "the density of bare MCC-1 shall be 30-36 pcf (Witness Panel Average)".

It is our understanding that the Titan IV community does not want to sand the MCC-1 surface prior to topcoat application. It should be noted that the 30-36 pcf specification for SRB is based on sanded MCC-1 and that the corresponding unsanded density is typically lower.

Page 12, Para. 2.4: States "CMT-056-94MP (Characterization and Sensitivity Test Plan for Titan IV Payload Fairing").

The Plan is also shown in paragraphs 1.1.d and 1.4 as CMT-056-95MP. The correct number should be used in all areas.

Page 19, Table Ia. (MCC-1 Key Process Parameters for Application): Some of the process parameters listed in this table are not consistent with those established in sensitivity studies and listed in 10PRC-0637, (MCC-1 Processing Specification).

REPORT PERIOD - NOVEMBER 18, 1995 TO JANUARY 17, 1996:

1. Recommended that the use of a "demand" type water heater be used for the hot water flush process developed for the MCC-1 spray gun. A "demand" type water heater would eliminate the requirement for long duration purging of the hot water line to obtain the desired temperature range. A "demand" type water heater provides water, at temperature, almost immediately.

2. Commented that an ORI was needed on the Pueblo, CO Titan IV MCC-1 facility prior to the IOC date of March 10, 1997.

REPORT PERIOD - JANUARY 18 TO MARCH 17, 1996:

1. Comments to review of "McDonnell Douglas Titan IV Thermal Protection System Building Specification Verification Document Volume I - Specification Derivation, MDC 95H1067, Rev. 2".

Para. 3.1.3: Paved surface dimensions 130' by 130' in front of the building are not consistent with those (140' by 140') shown on the page 21 sketch (Figure 6).

Para. 3.4.6.2.2: The "Impact upon Facility Specification" statement should read -- - "The temperature in the paint booth shall be maintained at 70^0F plus or minus 5^0F year round with humidity at 80% RH maximum and shop cleanliness except during periods when the paint booth is operated at elevated temperature to apply and cure materials." Refer to Paragraphs 3.1.18 and 3.1.19.

REPORT PERIOD - MARCH 18 TO MAY 17, 1996:

1. Commented during the 3-21-96 T-IV TPS Replacement Telecon, in response to a discussion relative to sanding of MCC-1 surfaces,
"The sanding operation performed by USBI on MCC-1, prior to topcoat application, is really no more than knocking the loose, fuzzy, overspray off and the tops of the highest peaks. When spraying large surface areas, such as the Space Shuttle Solid Rocket Booster Aft Skirt with MCC-1, there is more exposure to overspray due to the long length of the spray run, thus more overspray build-up, than that observed on 2' x 2' panels, sprayed for development or qualification testing, which is relatively short duration spray runs."

2. Commented during the April 2nd TIM at USBI, Huntsville, AL, that "dry" spraying Corlar was not a wise thing to do because the premature loss of water could inhibit the crosslinking of the polymer.

3. Provided the contract (NASA - 40195) COTR with a proposed cost estimated for supplementing the contract by increasing the average number of hours worked per week and extending the contract completion date to coincide with the scheduled Initial Operating Capability (IOC) of March 10, 1997 for the new Pueblo, CO Titan IV MCC-1 Application Facility.

4. Recommended closer schedule coordination between USBI, MDA and LMA to aid in the definition of a more meaningful composite Titan IV TPS Replacement Schedule.

5. Recommended that USBI run tests to simulate spraying MCC-1 on large horizontal PLF; this configuration will not allow gravity to impact on overspray reduction on the large surface area as it would in a vertical position. Excessive amounts of overspray accumulation could result in lower MCC-1 adhesion to the substrate and /or rougher and potentially lighter MCC-1.

6. Recommended that USBI run tests to correlate moisture absorption to number of coats of Corlar topcoat, regardless of what appears to be numbers of pinholes thru the Corlar. What appears to be pinholes may not actually be a pathway into the MCC-1.

7. Recommended that USBI confirm that all MCC-1 gaps (location and width) have been identified and are modeled and sprayed prior to Pathfinder.

8. Recommended that USBI confirm that a PLF nosecap will be available for test MCC-1 sprays prior to Pathfinder.

9. Recommended handpack of K5NA TPS to those areas on the PLF that cannot effectively be sprayed with MCC-1.

REPORT PERIOD - MAY 18 TO JULY 17, 1996:

1. Recommended that a sample of Corlar 1LB76P, that has been filtered, be tested to determine if the filter is physically removing some ingredient or is causing a breakdown of the colloidal suspension, thus resulting in a viscosity change (drop).

REPORT PERIOD - JULY 18 TO SEPTEMBER 17, 1996:

None this period.

G. CONCLUSION

Since this contract ended on September 17, 1996, and, where as, initial operating capability (IOC) of the Titan IV Pueblo, CO facility is March 10, 1997, it is only possible to predict, based on documentation and planning reviewed, that the implementation of MCC-1 on Titan IV Payload Fairing (PLF) in the new Pueblo, CO facility will be successful if the Qualification Test Plan, sensitivity testing and implementation plans are completed. Success of the program can be predicted with a high degree of confidence since MCC-1 has already been successfully implemented on the Space Shuttle Solid Rocket Boosters (SRB) at the Kennedy Space Center by USBI and the Titan IV effort mimics the Space Shuttle SRB program to a large degree.

The MCC-1 process equipment installed in the Pueblo, CO Titan IV facility is a near duplicate to the process equipment installed in USBI's KSC facility.

The Titan IV MCC-1 Qualification Test Plan is very similar to the Space Shuttle SRB MCC-1 Qualification Test Plan, that was successfully completed, except for test requirements that are specific to the Titan IV PLF's. In fact, the Titan IV Plan is a delta to the Space Shuttle SRB Plan. That is why success of the Titan IV PLF MCC-1 implementation program can be predicted with a high degree of confidence. In addition, the same USBI personnel involved in the implementation of MCC-1 on the Space Shuttle SRB's are involved in the Titan IV PLF MCC-1 implementation activity.

During the course of this contract, which initially was to run from 1/18/95 to 1/17/96, but was extended in 5/18/95 (at no additional cost) to 9/17/96, numerous documents were reviewed; five trips were made; numerous findings/observations were documented; and numerous recommendations were made, both written and orally, many with significant impact on the outcome of the Titan IV MCC-1 implementation project. The Titan IV MCC-1 Qualification Test Plan was reviewed each time that it was revised, which was at least four times prior to finalization. In addition, many telecons and status meetings were attended at Marshall Space Flight Center on an as scheduled basis.

From all of the above activity it can only be concluded that the terms of the contract have been met with few exceptions. What needs to be done as a follow on activity is listed below.

a. Review of the final data dump from the MCC-1 and Corlar Topcoat Sensitivity Testing, especially, for the 1/16" thick MCC-1 which is Titan IV specific.

b. Observe/review the Pathfinder (Full Scale Flight hardware) demonstration of the full MCC-1 and Corlar topcoat process, including using the tooling developed to produce the desired gap for the separation rail, dome cap, etc., the access and movement tooling for the Titan IV Payload Fairings, and the material performance tests for the Pathfinder.

c. Final on-site implementation support during the Pathfinder phase of the project at Pueblo, CO.

d. Review of the finalized process documentation based on successful MCC-1 application to the Pathfinder.

e. Final assurance that all specified acceptance criteria was met for Qualification Testing and implementation of the process into the new Pueblo, CO facility.

IV. COST DATA

A. GENERAL DISCUSSION/TABULATION

This contract started out as a 12 month contract. However, after the Titan IV MCC-1 implementation schedule started slipping, this contract was extended, at no cost, for an additional 8 months, from 1/17/96 to 9/17/96. The impact (shift) on the cost data can be seen on the following (Sheet 1) chart and the charts on Engineering, Secretarial, Travel and Overhead Cost Data (following) at the point after the 2nd contract period.

The Titan IV MCC-1 implementation schedule continued to slip due to the Air Force not providing the Authority to Proceed (ATP) to their prime contractor, Lockheed Martin (Denver, CO), and subsequently, McDonnell Douglas Aerospace (Huntington Beach, CA and Pueblo, CO) and United States Booster, Inc. (Huntsville, AL). The ATP was finally given and initial operating capability (IOC) for MCC-1 application to the Titan IV Payload Fairings (PLF's) at a new facility at Pueblo, CO was established as March 10, 1997, well after the termination date of this contract (9/17/96). At this time, the Titan IV MCC-1 Qualification and implementation should have been 100% complete based on the earlier schedule. However, based on the IOC of 3/10/97 the Titan IV TPS Replacement Project is estimated to be approximately 85% complete. Based on that estimate, this contact scope-of-work could only be completed to the same level by the end of contract (9/17/97). If the Titan IV MCC-1 implementation schedule IOC and this contact completion date had not gotten out-of-sync, then the cumulative costs (see charts) versus percentage of physical completion would have been, basically, on budget and on schedule.

B. CHARTS

CHART 1 - ENGINEERING COST DATA

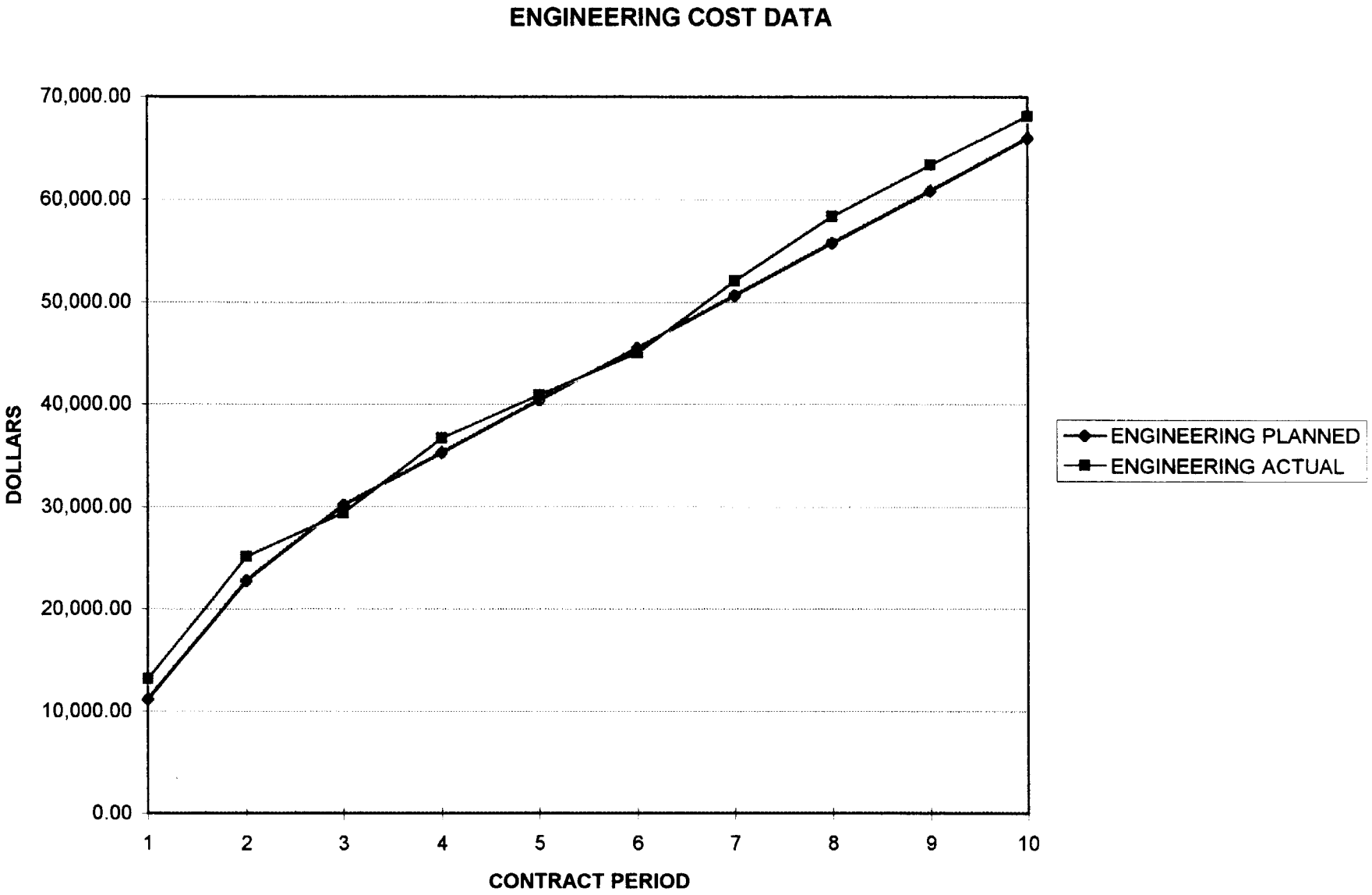
CHART 2 - SECRETARIAL COST DATA

CHART 3 - TRAVEL COST DATA

CHART 4 - OVERHEAD COST DATA

COST DATA

	ENGINEERING		SECRETARIAL		TRAVEL		OVERHEAD	
	PLANNED	ACTUAL	PLANNED	ACTUAL	PLANNED	ACTUAL	PLANNED	ACTUAL
1st Period	11,132.00	13,040.00	640.00	300.00	2,000.00	0	413.00	400.00
2nd Period	22,748.00	25,014.00	800.00	600.00	2,000.00	1,061.00	785.00	800.00
3rd Period	30,136.00	29,282.00	1,050.00	700.00	2,000.00	1,061.00	993.00	1,008.00
4th Period	35,258.00	36,578.00	1,500.00	800.00	2,795.00	3,661.00	1,186.00	1,188.00
5th Period	40,380.00	40,802.00	1,950.00	900.00	3,662.00	3,661.00	1,379.00	1,379.00
6th Period	45,502.00	44,886.00	2,400.00	1,000.00	4,527.00	3,661.00	1,572.00	1,572.00
7th Period	50,624.00	51,944.00	2,850.00	1,100.00	5,396.00	4,588.00	1,765.00	1,765.00
8th Period	55,746.00	58,210.00	3,300.00	1,200.00	6,263.00	6,611.00	1,958.00	1,958.00
9th Period	60,868.00	63,283.00	3,750.00	1,300.00	7,130.00	6,993.00	2,151.00	2,151.00
10th Perio	66,000.00	68,000.00	4,200.00	1,600.00	8,000.00	6,993.00	2,346.00	2,346.00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CONTRACT PERIOD
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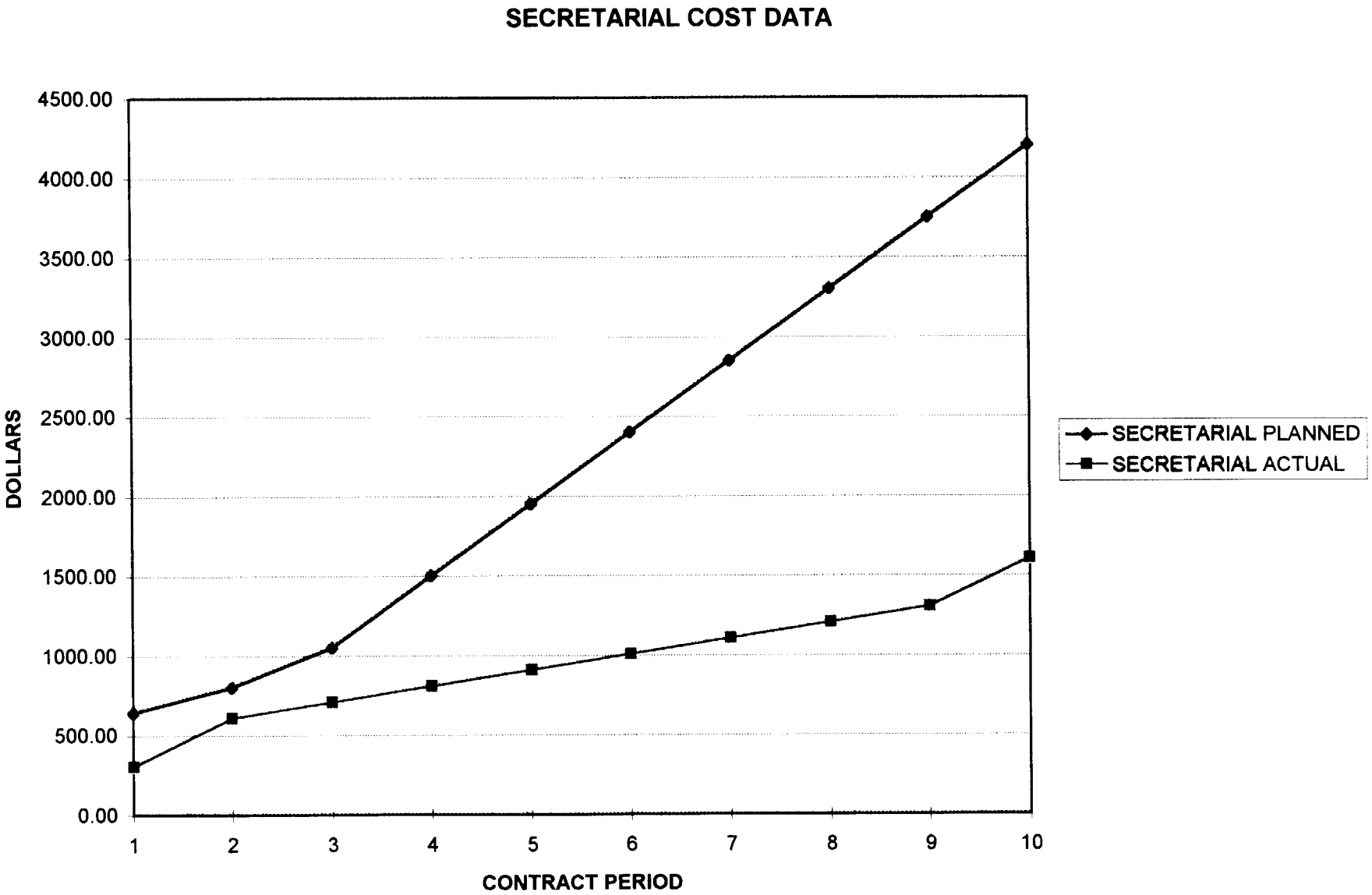
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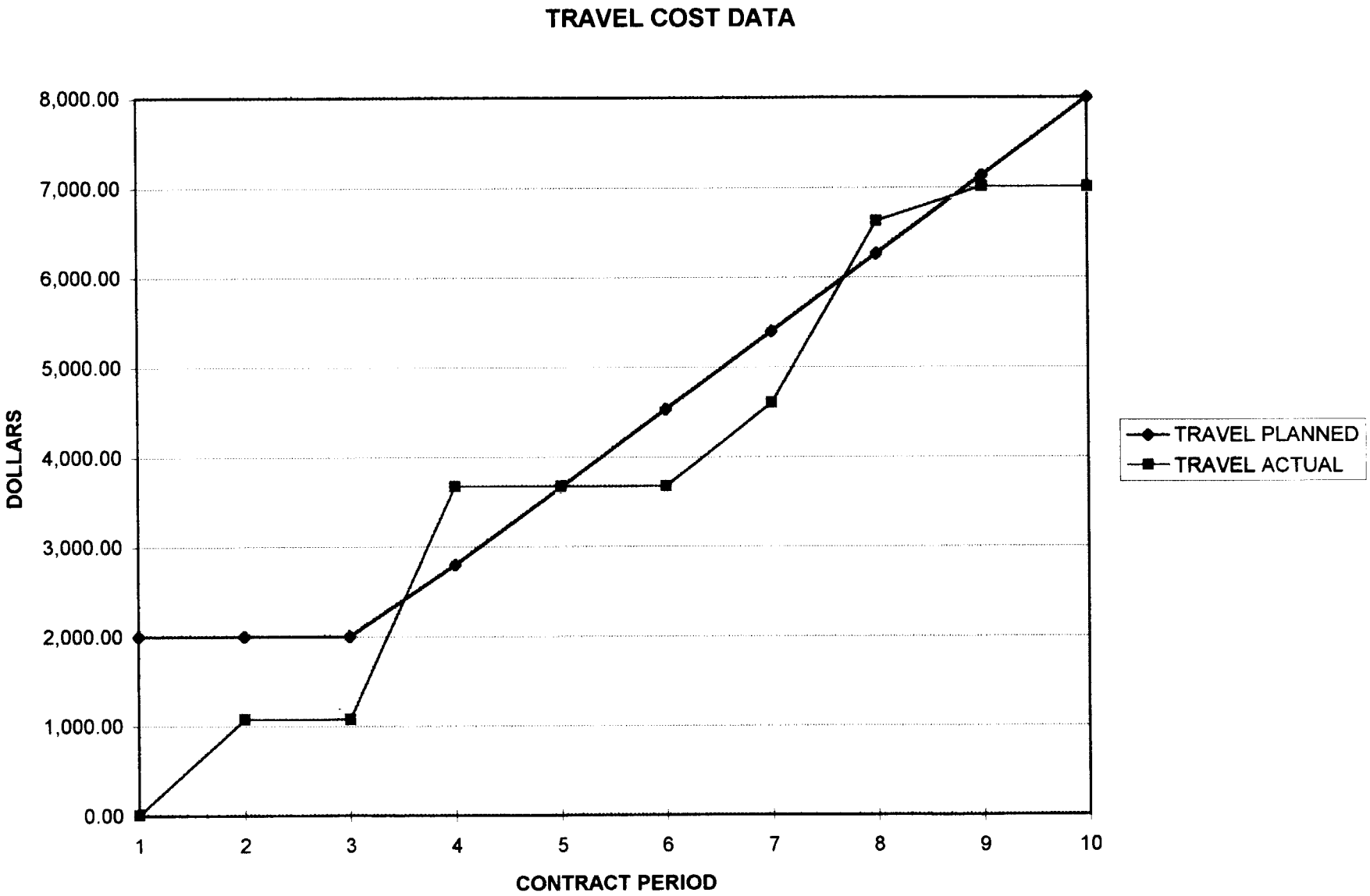
SECRETARIAL PLANNED
SECRETARIAL ACTUAL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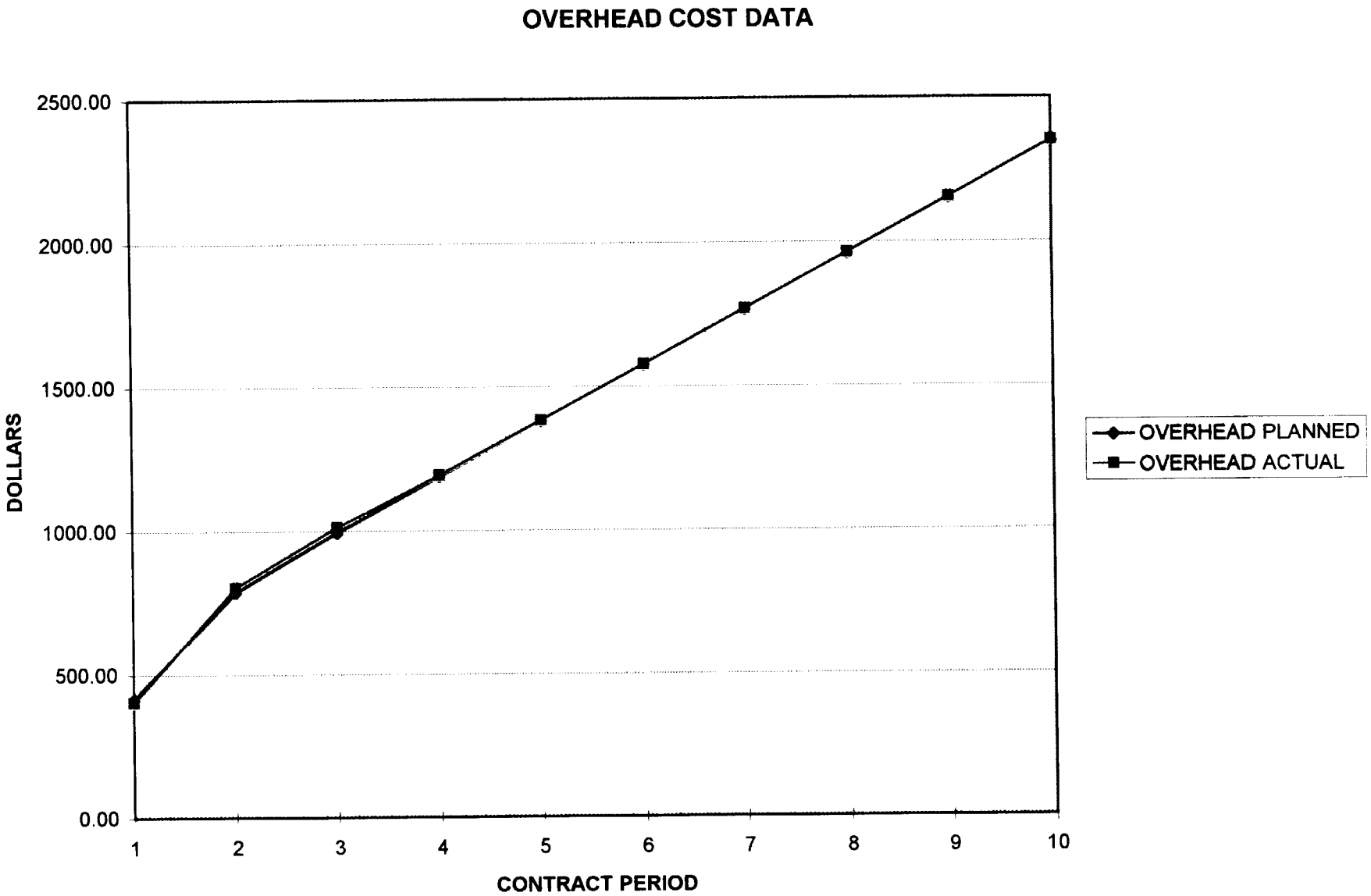
TRAVEL ACTUAL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CONTRACT PERIOD
OVERHEAD PLANNED
OVERHEAD ACTUAL

V. APPENDICES

I. MCC-1 PROCESS IMPLEMENTATION CHECKLIST FOR T-IV PUEBLO, CO FACILITY

II. TITAN TPS REPLACEMENT PROGRAM (as initially scheduled by the AF)

III. TITAN IV - TPS REPLACEMENT PROGRAM (as revised)

IV. TITAN IV TPS REPLACEMENT PROGRAM - TOPCOAT, TIMELINE OF EVENTS

V. COMPLEX CONTRACTUAL RELATIONSHIPS, CHARACTERIZES NON-RECURRING EFFORT

VI. SIMPLE CONTRACTUAL RELATIONSHIP CHARACTERIZES RECURRING EFFORT

APPENDIX 1

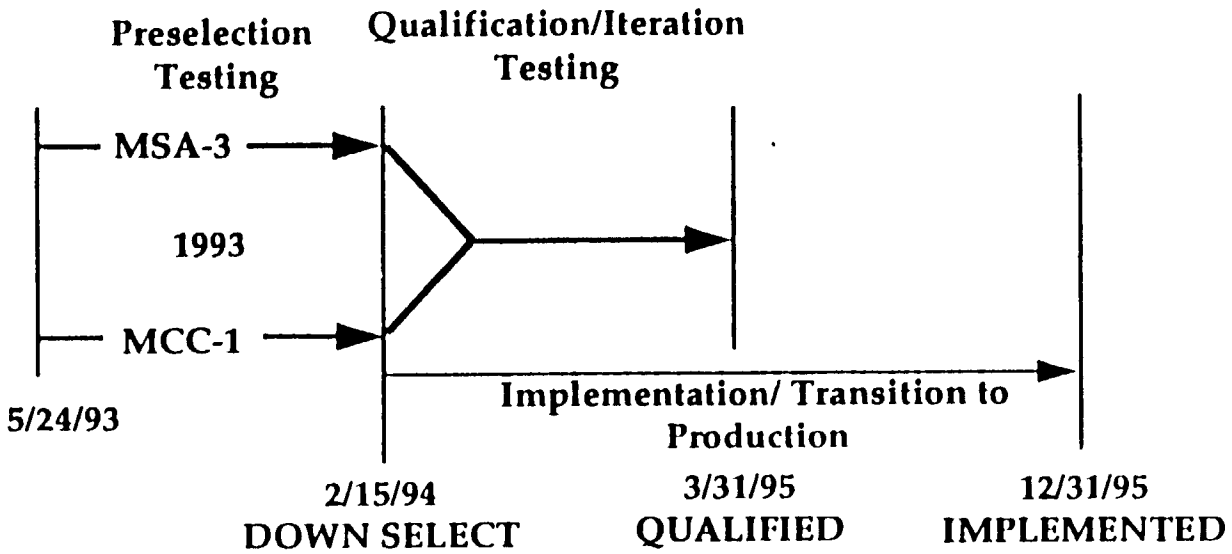
MCC-1 PROCESS IMPLEMENTATION CHECKLIST FOR T-IV PUEBLO. CO. FACILITY

NO	PARAMETER/VARIABLE	ACCEPTABLE RANGE	ACCEPTABLE	UNACCEPTABLE
1	Density.MCC-1. bare after cure	30-36 lbs/ft^3		
2	Density.MCC-1.topcoated			
3	Tensile Adhesion. FWT. Ambient Temp.	75 PSI Min. Req'd. 350-550 PSI normal range for 1/8" MCC-1		
4	Resin flow rate	228-244 g./minute		
5	Catalyst flow rate	228-244 g./minute		
6	Glass eccosphere flow rate	2242-2958g./hour		
7	Cork flow rate	2769-3281g./hour		
8	Gun Stand-off distance	7.0"-8.7"		
9	Eductor air pressure	29-35 PSI		
10	Atomizing air pressure	34-48 PSI		
11	EC2216 A/B Mixer air pressure	82 PSI minimum		
12	Cyclonic mixer air pressure	3-9 PSI		
13	Spray booth temperature	73°-93°F (87° max. if equip. cap. is ± 5°F of set point)		
14	EC2216 A/B temperature at gun	103° - 127°F		
15	Atomizing air temperature	70° - 90°F		
16	Eductor air temperature	70° - 90°F		
17	Overlap increments	0.4" - 1.3". Nominal 1"		
18	Number of coats for thickness	1/8" in one coat 1/4" in two coats		
19	Delay between coats	Up to 21 hour delay allowed (10 minutes min.)		
20	Linear application speed	35-45 FPM. 40 FPM Nominal		
21	Spray booth RH	20% - 55% RH		
22	Solids feed line height	Up to 15 feet is acceptable		
23	Vertical Spray pattern	Vertical spray is acceptable		
24	Solids convergence captype	Teflon is acceptable		

25	Delay time to topcoat	5-39 days in less than 50% RH is acceptable		
26	Brush down time for loose particle removal	Brush down after oven cure.		
27	Precure temperature	68° - 92°F		
28	Precure time	4 hours minimum		
29	Cure ramp rate	1° - 5°F per minute		
30	Cure temperature	112° - 200°F		
31	Cure time	9 hours minimum		
32	Post cure cool down	Not required		
33	K-54 Concentration	0.8-1.2 wt% of EC-2216A		
34	Cork particle size distribution	Up to 10% of -40 mesh Up to 12% of +80 mesh		
35	Cork moisture	Up to 4.3 wt.%		
36	Glass eccosphere bulk density	0.16-0.22 g/cc		
37	Environmental and health hazards	Meet EPA/OSHA/State and local requirements		
38	Gun break-away device	Activated by min. contact force to prevent flight hardware damage		
39	Operator safety	Isolation during spray ops. and/or personal protective equip.		
40	Pollution Prevention Compliance	Meet EPA/OSHA/State and local regulations		
41	Spraybooth/environmental controls	Sized for T-IV PLF, fixture and application robot with end effectors, and to maintain the req'd temp./RH range		
42	Robot	Sized and positioned to accommodate the T-IV PLF spray envelop, repeatedly.		
43	Heat assisted cure	An enclosure sized to accept the T-IV PLF including holding fixture, and maintain cure temp. range.		
44	Spray equipment	MCC-1 constituent storage, feed, convergent mix, and control system equipment comparable to that installed in the SRB-ARF at KSC.		

Titan TPS Replacement Program

- **Timeline**



Titan IV — TPS Replacement Program

Timeline of Events — MCC-1

1Q 1991	EPA Legislation threatens primary SRB TPS, MSA-2
2Q 1992	MSA-2 Replacement Candidates Identified — MSA-3, MCC-1
1Q 1993	Joint NASA/USBI TQM Team formed to Downselect Replacement SRB TPS Material
2Q 1993	Titan IV Considers Commonality with SRB TPS Replacement Program
2Q 1993	Selection Criteria and Qualification Requirements Identified by TQM Team
2Q 1993	Thermal Characterization and Physical Property Testing Demonstrate Viability of Both Candidates, MSA-3 and MCC-1
4Q 1993	MCC-1 Spray System Installed at Marshall Space Flight Center
1Q 1994	MCC-1 Downselected as SRB Replacement TPS Material
3Q 1994	MCC-1 Downselected as Titan IV Replacement TPS Material
3Q 1994	MCC-1 System Upgrade Completed, Baseline Process Parameters and Repeatability Verified
4Q 1994	MCC-1 Qualification Program and Phase I Sensitivity Studies Initiated

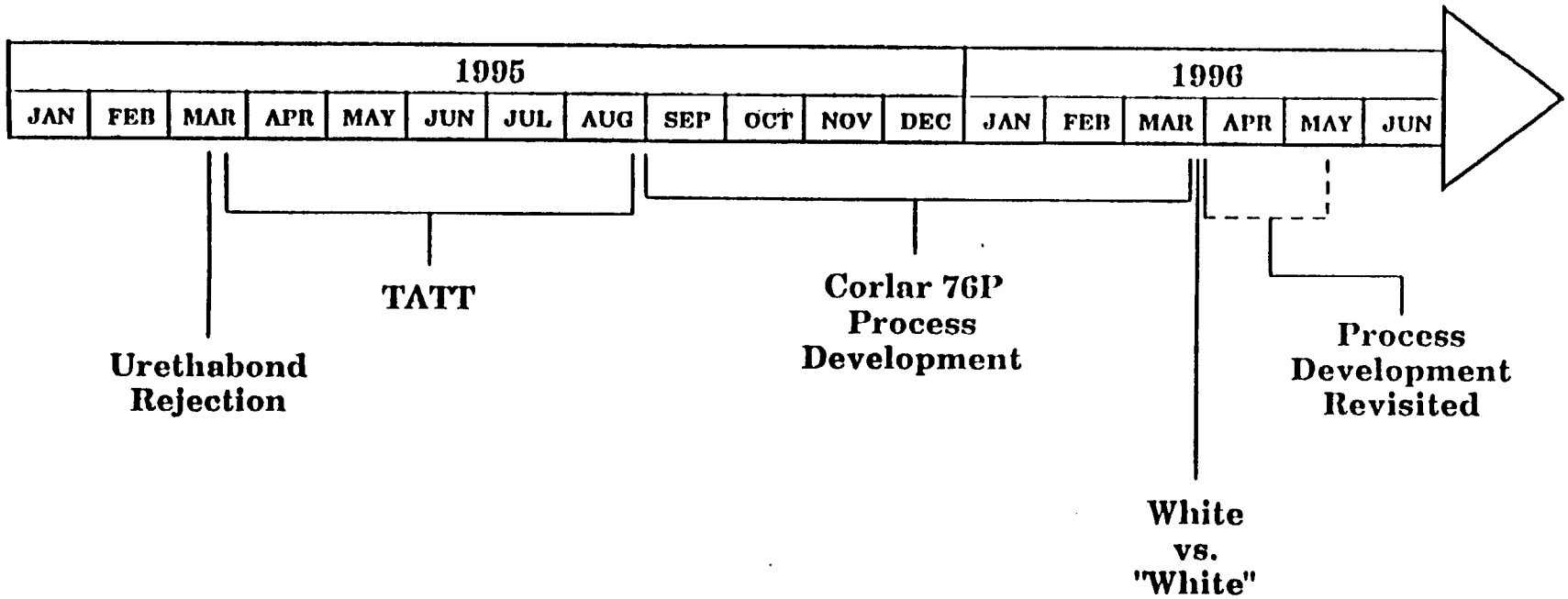
Titan IV — TPS Replacement Program

Timeline of Events — MCC-1 (Continued)

4Q 1994	Titan IV MCC-1 Qualification Plan Initiated
1Q 1995	MCC-1 Implementation Initiated at Kennedy Space Center
3Q 1995	MCC-1 Validation on SRB Flight Hardware
3Q 1995	MCC-1 Sealcoat Selected by Titan Community
4Q 1995	MCC-1 Engineering Approved by MSFC
4Q 1995	MCC-1 Verification on SRB Flight Hardware
4Q 1995	Titan IV MCC-1 Qualification Plan Completed
1Q 1996	Titan IV MCC-1 Qualification Scheduled
3Q 1996	Titan IV MCC-1 System/Robotics InstallationBegins
4Q 1996	Titan IV MCC-1 Qualification Scheduled for Completion
4Q 1996	Titan IV Implementation Scheduled, Pueblo, Colorado
1Q 1997	MCC-1 Implementation Complete for Titan IV
1Q 1997	MCC-1 Applied to Titan IV PLF

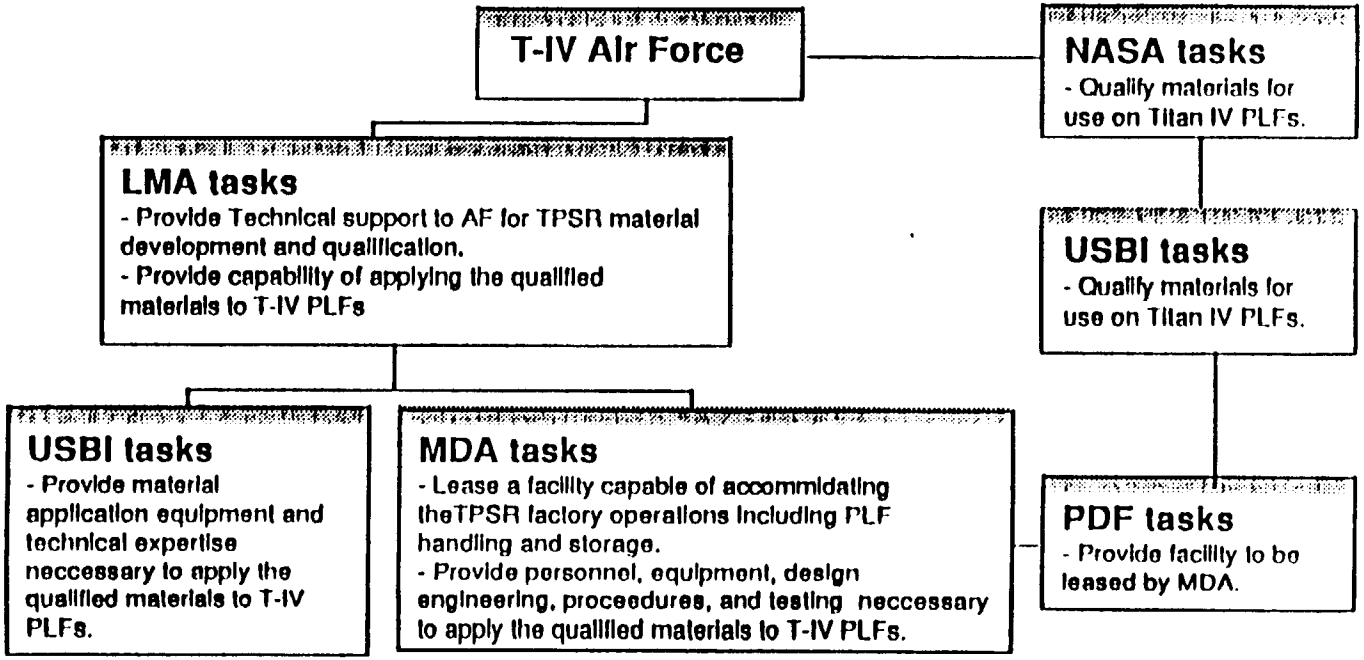
Titan IV TPS Replacement Program - Topcoat

Timeline of Events

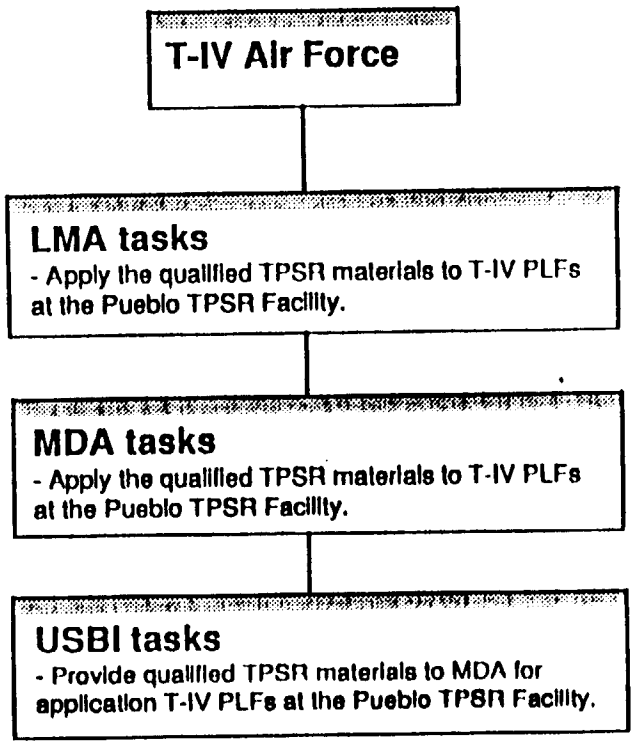


Complex Contractual Relationships Characterize Non Recurring Effort

Complex contractual relationships characterize the non-recurring effort



Simple Contractual Relationship Characterizes Recurring Effort



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This Final Report documents the overall progress of the study. It is a general discussion of the documents reviewed, recommendations, trips taken, findings/observations, and proposed corrective actions. In addition, cost data for the contract is addressed. The normal abstract and executive summary provided with most Final Reports is also provided as a part of this report. A conclusion section is provided that addresses the relative completeness of the Titan IV TPSR Project and this contract.

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