Advanced Transportation System Studies

Technical Area 3

Alternate Propulsion Subsystem Concepts
NAS8-39210
DCN 1-1-PP-02147

Final Report
DRs – 4, 8, 9
Volume II – Final Report

April 2000

Prepared for
NASA Marshall Space Flight Center

The Boeing Company
Rocketdyne
6633 Canoga Avenue
Canoga Park, California 91303
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Introduction

This is Volume II of the Final Report covering the efforts under a NASA NRA – NAS8-39210, Advanced Transportation Systems Studies, Technical Area 3 (TA3), Alternate Propulsion Subsystem Concepts. There are three other Technical Areas contracted under the NRA. TA3 is managed through MSFC/PD with Gary Johnson as project manager. The contractor team is led by Rocketdyne with Thiokol, Workingsolutionz Software, Davis Aerospace, and the University of Alabama as team members.

The contract started on 6 April 1992 and continued through April 2000.

The objective of the contract was to provide definition of alternate propulsion systems for both earth-to-orbit (ETO) and in-space vehicles (upper stages and space transfer vehicles). For such propulsion systems, technical data to describe performance, weight, dimensions, etc. will be provided along with programmatic information such as cost, schedule, needed facilities, etc. Advanced technology and advanced development needs will be determined and provided.

A propulsion system database was also developed which is capable of including the systems examined under TA3 and any other existing or conceptual propulsion systems.

The contract results are reported in three parts:

Volume I – Executive Summary which overviews each of the contract tasks giving its objective, main results, and conclusions;

Volume II – Final Report which references the individually delivered detailed Task reports (the detailed results are in the separate Task Reports, not in Volume II) and fulfills the requirements of a place to Report DRS 8 (Computer Aided Design Graphics and Analysis Data Documentation and Transfer) and 9 (New Technology Report), neither of which had any activity to report;

Volume III – Program Cost Estimates which contains DRs 5 (Work Breakdown Structure (WBS) and WBS Dictionary) and 6 (Program Cost Estimates Document).
Technical Discussion

The Alternate Propulsion Subsystem Concepts contract had seven tasks defined that are reported under this contract deliverable. The tasks were: F-IA Restart Study, J-2S Restart Study, Propulsion Database Development, SSME Upper Stage Use, CERs for Liquid Propellant Rocket Engines, Advanced Low Cost Engines, and Tripropellant Comparison Study.

The two restart studies, F-IA and J-2S, generated program plans for restarting production of each engine. Special emphasis was placed on determining changes to individual parts due to obsolete materials, changes in OSHA and environmental concerns, new processes available, and any configuration changes to the engines.

The Propulsion Database Development task developed a database structure and format which is easy to use and modify while also being comprehensive in the level of detail available. The database structure included extensive engine information and allows for parametric data generation for conceptual engine concepts.

The SSME Upper Stage Use task examined the changes needed or desirable to use the SSME as an upper stage engine both in a second stage and in a translunar injection stage.

The CERs for Liquid Engines task developed qualitative parametric cost estimating relationships at the engine and major subassembly level for estimating development and production costs of chemical propulsion liquid rocket engines.

The Advanced Low Cost Engines task examined propulsion systems for SSTO applications including engine concept definition, mission analysis, trade studies, operating point selection, turbomachinery alternatives, life cycle cost, weight definition, and point design conceptual drawings and component design. The task concentrated on bipropellant engines, but also examined tripropellant engines.

The Tripropellant Comparison Study task provided an unambiguous comparison among various tripropellant implementation approaches and cycle choices, and then compared them to similarly designed bipropellant engines in the SSTO mission.

Figure 1 shows the schedule for the first year of the contract.
The detailed study results, with the data to support the conclusions from various analyses, are being reported as a series of separate Final Task Reports. This distribution scheme was influenced by three factors:

1. each individual task focused on a different and well defined subject,
2. a user interested in one subject is not necessarily interested in any of the other subjects,
3. after a core distribution of 18 copies only 14 copies are available for general distribution.

Consequently, distribution of the details as a single report would require that a user only interested in one subject use up one of the 14 available copies, while distribution of separate detailed task reports would potentially produce a wider distribution by allowing a user to only request the reports on the tasks of particular interest to that user.

Figure 2 shows the reviews which took place during the contract and the specific documentation available on either the reviews or the specific tasks. Also Volume I of this Final Report contains an Executive Summary of all five tasks with objectives, main results and conclusions, all under one cover. All the documentation is available from Gary Johnson (MSFC/PD).
## Figure 1. Contract Schedule

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ATP – Authority to Proceed
KO – Kick-Off Meeting
R# – Interim Review #
FR – Final Review
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**Figure 2. Reviews and Documentation**
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**Figure 2. Reviews and Documentation (Cont’d)**
Advanced Transportation System Studies

Technical Area 3

Alternate Propulsion Subsystem Concepts
NAS8-39210
DCN 1-1-PP-02147

Computer Aided Design Graphics and Analysis Data
Documentation and Transfer
DR-8

April 2000
There was no work conducted under this contract for which DR-8 applies.
Advanced Transportation System Studies

Technical Area 3

Alternate Propulsion Subsystem Concepts
NAS8-39210
DCN 1-1-PP-02147

New Technology Report
DR-9

April 2000
March 10, 1993

New Technology Officer, AT01
National Aeronautics & Space Admin.
George C. Marshall Space Flight Center
Huntsville, AL 35812

Subject: Contract No. NAS8-39210
Summary of Patent Activities - First Interim

Personnel of the Patent Department of the Rocketdyne Division have made periodic reviews of technical reports and similar documents prepared under the subject contract in order to determine the presence of inventions or innovations. Technical personnel have been contacted frequently, advised and reminded of their obligation to report items under the patent rights clause of this contract.

No reportable items have been found during the performance of this contract.

No subcontracts for research, development, experimental or engineering have been let under this contract.

The following responsible program administrators have been sent a copy of this report:

Contract Administrator: R. Glupngam
Program Manager: D. Goracke

If you have any questions or if we may be of further assistance, please contact this office at (818) 586-4616.

ROCKWELL INTERNATIONAL CORPORATION

Danielle Bartoli
Technology Utilization Administrator

Enclosure (2 copies of this letter report)
April 7, 1994

Technology Utilization Office, M/S ATO1
National Aeronautics & Space Admin.
George C. Marshall Space Flight Center
Huntsville, AL 35812

Subject: Contract No. NAS8-39210
   Patent Report - Second Interim

In compliance with the New Technology Clause in the subject contract, attached is MSFC Form 4204 constituting Contractor's subject patent report.

The following responsible program administrators have been sent a copy of this report:

   Contract Administrator: A. Burds, Jr.
   Program Manager: D. Goracke

If you have any questions or if we may be of further assistance, please contact this office at (818) 586-4616.

ROCKWELL INTERNATIONAL CORPORATION

Danielle Bartoli
Patent Analyst

Enclosure: MSFC Form 4204
**SECTION I** NEW TECHNOLOGY NFS 18-52-227-70

5. "REPORTABLE ITEMS": (If "none" so state)
   - **a. NAME OF INNOVATOR(S)**
   - **b. TITLE OF DISCLOSURE**
   - NONE

**SECTION IA - SUBCONTRACTS (Containing a "Patent Rights" clause)**

6. SUBCONTRACTS AWARDED BY CONTRACTOR/SUBCONTRACTOR. (If "none" so state)
   - **a. NAME OF SUBCONTRACTORS**
   - **b. ADDRESS (include Zip Code)**
   - **c. SUBCONTRACT NO.(S)**
   - **d. DESCRIPTION OF WORK TO BE PERFORMED UNDER SUBCONTRACT(S)**
   - NONE

**SECTION II** PATENT RIGHTS FAR 18-52.227-11

7. "SUBJECT INVENTIONS" (If "none" so state)
   - **a. NAME OF INNOVATOR(S)**
   - **b. TITLE OF DISCLOSURE**

**SECTION III - CERTIFICATION**

8. CERTIFICATION OF REPORT BY CONTRACTOR/SUBCONTRACTOR
   - **a. NAME OF AUTHORIZED CONTRACTOR/SUBCONTRACTOR OFFICIAL**
   - **b. TITLE**
   - **C. I CERTIFY THAT THE CONTRACTOR HAS THE REQUIRED PROCEDURES FOR PROMPT IDENTIFICATION AND TIMELY DISCLOSURE OF (PLEASE CHECK): □ (REPORTABLE ITEMS) □ (SUBJECT INVENTIONS), AND THAT SUCH PROCEDURES HAVE BEEN FOLLOWED, AND THAT THIS REPORT IS COMPLETE AND ACCURATE.**
   - **SIGNATURE OF AUTHORIZED CONTRACTOR/SUBCONTRACTOR OFFICIAL**
   - **DATE (YYMMDD)**

**NASA - MSFC TECHNOLOGY REPORT**

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April 11, 1995

Technology Utilization Office, M/S AT01
National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Huntsville, AL 35812

Subject: **PATENT REPORT - Third Interim**
Contract No. NAS8-39210
Period: 920406 to 950405

In compliance with the New Technology Clause in the subject contract, attached is MSFC Form 4204 constituting Contractor's subject patent report.

The following responsible program administrators have been sent a copy of this report:

Contract Administrator: A. Burds, Jr.
Program Manager: D. Goracke

If you have any questions or if we may be of further assistance, please contact this office at (818) 586-4616.

ROCKWELL INTERNATIONAL CORPORATION
Rocketdyne Division

Danielle Bartoli
T. U. Administrator

Enclosure: MSFC Form 4204
**SECTION I - NEW TECHNOLOGY NFS 18-52.227-70**

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**SECTION IA - SUBCONTRACTS (Containing a “Patent Rights” clause)**

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<th>e. SUBCONTRACT DATES (YMMDD)</th>
<th>f. ESTIMATED COMPLETION</th>
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**SECTION III - CERTIFICATION**

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<td>Patent Analyst</td>
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I CERTIFY THAT THE CONTRACTOR HAS THE REQUIRED PROCEDURES FOR PROMPT IDENTIFICATION AND TIMELY DISCLOSURE OF (PLEASE CHECK): ☑ (REPORTABLE ITEMS) ☐ (SUBJECT INVENTIONS), AND THAT SUCH PROCEDURES HAVE BEEN FOLLOWED, AND THAT THIS REPORT IS COMPLETE AND ACCURATE.

**Signed:**

[Signature]

**Date:** 950411

**MSFC FORM 4204 (FEBRUARY 1993)**
April 22, 1996

Technology Utilization Office, M/S AT01
National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Huntsville, AL 35812

Subject: PATENT REPORT - Fourth Interim
Contract No. NAS8-39210
Period: 92-04-06 to 95-04-05

In compliance with the New Technology Clause in the subject contract, attached is MSFC Form 4204 constituting Contractor's subject patent report.

The following responsible program administrators have been sent a copy of this report:

Contract Administrator: N. Savage
Program Manager: D. Goracke

If you have any questions or if we may be of further assistance, please contact this office at (818) 586-4616.

ROCKWELL INTERNATIONAL CORPORATION
Rocketdyne Division

Danielle Bartoli
Intellectual Property Analyst

Enclosure: MSFC Form 4204
**SECTION I - SUBJECT INVENTIONS**

- **a. NAME(S) OF INVENTOR(S)** (LAST, FIRST, MI)
- **b. TITLE OF INVENTIONS**
- **c. DISCLOSURE NO., PATENT APPLICATION SERIAL NO., OR PATENT NO.**
- **d. ELECTION TO FILE PATENT APPLICATIONS**
  - (1) UNITED STATES
  - (2) FOREIGN
  - (b) YES
  - (b) NO
- **e. CONFIRMINATORY INSTRUMENT OR ASSIGNMENT FORWARDED TO CONTRACTING OFFICER?**
  - (1) YES
  - (2) NO

- **f. EMPLOYER OF INVENTOR(S) NOT EMPLOYED BY CONTRACTOR/SUBCONTRACTOR**
  - (1)(a) NAME OF INVENTOR (LAST, FIRST, MI)
  - (1)(b) NAME OF INVENTOR (LAST, FIRST, MI)
  - (b) NAME OF EMPLOYER
  - (c) ADDRESS OF EMPLOYER (INCLUDE ZIP CODE)

**SECTION II - SUBCONTRACTS (Containing a “Patent Rights” clause)**

- **a. NAME OF SUBCONTRACTORS**
- **b. ADDRESS (INCLUDE ZIP CODE)**
- **c. SUBCONTRACT NO(S).**
- **d. DFAR "PATENT RIGHTS" CLAUSE (1)  CLAUSE (2) DATE NUMBER**
- **e. DESCRIPTION OF WORK TO BE PERFORMED UNDER SUBCONTRACT(S) (YMMDD)**
- **f. SUBCONTRACT DATES (YMMDD) (1) AWARD (2) ESTIMATED COMPLETION**

**SECTION III - CERTIFICATION**

- **a. NAME OF AUTHORIZED CONTRACTOR/SUBCONTRACTOR OFFICIAL (LAST, FIRST, MI)**
  - Bartoli, Danielle
- **b. TITLE**
  - Intellectual Property Analyst
- **c. I CERTIFY THAT THE REPORTING PARTY HAS PROCEDURES FOR PROMPT IDENTIFICATION AND TIMELY DISCLOSURE OF "SUBJECT INVENTIONS," THAT SUCH PROCEDURES HAVE BEEN FOLLOWED AND THAT ALL "SUBJECT INVENTIONS" HAVE BEEN REPORTED.**
- **d. SIGNATURE**
  - Danielle Bartoli
- **e. DATE SIGNED**
  - 96-04-22

(Previous editions are obsolete)
April 9, 1997

Technology Utilization Office, M/S AT01
National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Huntsville, AL 35812

Subject: PATENT REPORT - Fifth Interim
Contract No. NAS8-39210
Period: 92-04-06 to 97-04-05

In compliance with the New Technology Clause in the subject contract, attached is MSFC Form 4204 constituting Contractor's subject patent report.

The following responsible program administrators have been sent a copy of this report:

  Contract Administrator:  N. Savage
  Program Manager:  D. Goracke

If you have any questions or if we may be of further assistance, please contact this office at (818) 586-4616.

BOEING NORTH AMERICAN, INC.

Danielle Bartoli
Intellectual Property Analyst

Enclosure:  MSFC Form 4204
NASA - MSFC TECHNOLOGY REPORT

1a. NAME OF CONTRACTOR/SUBCONTRACTOR
   Boeing North American, Inc.
2a. CONTRACT NUMBER
   NAS8-39210
3a. TYPE OF REPORT (a ONE)
   □ a. INTERIM   □ b. FINAL

b. ADDRESS (INCLUDE ZIP CODE)
   P. O. Box 7922
   Canoga Park, CA 91309-7922
d. AWARD DATE (YYMMDD)
   92-04-06

SECTION I - NEW TECHNOLOGY NFS 18-52.227-70

5. "REPORTABLE ITEMS" (IF "NONE," SO STATE)
a. NAME(S) OF INVENTOR(S)
   (LAST, FIRST, MI)
   NONE
b. TITLE OF DISCLOSURE
   NONE

SECTION II - PATENT RIGHTS FAR 18-52.227-11

7. "SUBJECT INVENTIONS" (IF "NONE," SO STATE)
a. NAME(S) OF INVENTOR(S)
   (LAST, FIRST, MI)
   NONE
b. TITLE OF DISCLOSURE
   NONE

SECTION IA - SUBCONTRACTS (Containing a "Patent Rights" clause)

6. SUBCONTRACTS AWARDED BY CONTRACTOR/SUBCONTRACTOR (IF "NONE," SO STATE)
a. NAME OF SUBCONTRACTORS
b. ADDRESS (INCLUDE ZIP CODE)
c. SUBCONTRACT NOS.
d. DESCRIPTION OF WORK TO BE PERFORMED UNDER SUBCONTRACT(S)
e. SUBCONTRACT DATES (YYMMDD)
   (1) AWARD
   (2) ESTIMATED COMPLETION
   NONE

SECTION III - CERTIFICATION

8. CERTIFICATION OF REPORT BY CONTRACTOR/SUBCONTRACTOR
a. NAME OF AUTHORIZED CONTRACTOR/SUBCONTRACTOR OFFICIAL (LAST, FIRST, MI)
   Bartoli, Danielle
b. TITLE
   Intellectual Property Analyst

C. I CERTIFY THAT THE CONTRACTOR HAS THE REQUIRED PROCEDURES FOR PROMPT IDENTIFICATION AND TIMELY DISCLOSURE OF (PLEASE CHECK): □ (REPORTABLE ITEMS) □ (SUBJECT INVENTIONS), AND THAT SUCH PROCEDURES HAVE BEEN FOLLOWED, AND THAT THIS REPORT IS COMPLETE AND ACCURATE.

Daniel Bartoli

SIGNATURE OF AUTHORIZED CONTRACTOR/SUBCONTRACTOR OFFICIAL

DATE (YYMMDD)
   97-04-09

MSFC FORM 4204 (FEBRUARY 1993)
April 7, 1998
98RC1677

Technology Utilization Office, M/S AT01
National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Huntsville, AL 35812

Subject: PATENT REPORT - Sixth Interim
Contract No. NAS8-39210
Period: 92-04-06 to 98-04-05
ADVANCED TRANSPORTATION SYSTEMS

In compliance with the New Technology Clause in the subject contract, attached is MSFC Form 4204 constituting Contractor's subject patent report.

The following responsible program administrators have been sent a copy of this report:

Contract Administrator: Nancy Savage
Program Manager: Daniel Levack

If you have any questions or if we may be of further assistance, please contact this office at (818) 586-1367.

BOEING NORTH AMERICAN, INC.

Danielle Bartoli
Patent Analyst Senior

Enclosure: MSFC Form 4204
### SECTION I - NEW TECHNOLOGY NFS 18-52.227-70

<table>
<thead>
<tr>
<th>a. NAME(S) OF INVENTOR(S) (LAST, FIRST, MI)</th>
<th>b. TITLE OF DISCLOSURE</th>
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### SECTION II - PATENT RIGHTS FAR 18-52.227-11

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### SECTION IIA - SUBCONTRACTS (Containing a "Patent Rights" clause)

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### SECTION III - CERTIFICATION

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<th>b. TITLE</th>
<th>c. I CERTIFY THAT THE CONTRACTOR HAS THE REQUIRED PROCEDURES FOR PROMPT IDENTIFICATION AND TIMELY DISCLOSURE OF (PLEASE CHECK): ☒ REPORTABLE ITEMS ☐ SUBJECT INVENTIONS, AND THAT SUCH PROCEDURES HAVE BEEN FOLLOWED, AND THAT THIS REPORT IS COMPLETE AND ACCURATE.</th>
<th>SIGNATURE OF AUTHORIZED CONTRACTOR/SUBCONTRACTOR OFFICIAL</th>
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<td>Patent Analyst Senior</td>
<td></td>
<td>Danielle Bartoli</td>
<td>98-04-07</td>
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July 28, 1998
98RC4194

Technology Utilization Office, M/S AT01
National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Huntsville, AL 35812

Subject: PATENT REPORT - Final
Contract No. NAS8-39210
Period: 92-04-06 to 98-07-28
ADVANCED TRANSPORTATION SYSTEMS

In compliance with the New Technology Clause in the subject contract, attached is MSFC Form 4204 constituting Contractor's subject patent report.

The following responsible program administrators have been sent a copy of this report:

Contract Administrator: Nancy Savage (818) 586-1756
Program Manager: Dan Levack (818) 586-0420

If you have any questions or if we may be of further assistance, please contact this office at (818) 586-1367.

BOEING NORTH AMERICAN, INC.
Rocketdyne Propulsion & Power

Danielle Bartoli
Patent Analyst Senior

Enclosure: MSFC Form 4204
**NASA - MSFC TECHNOLOGY REPORT**

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**SECTION I - ☑ NEW TECHNOLOGY NFS 18-52.227-70**

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**SECTION IA - SUBCONTRACTS (Containing a "Patent Rights" clause)**

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**SECTION III - CERTIFICATION**

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<td>Patent Analyst Senior</td>
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The Alternate Propulsion Subsystem Concepts contract had seven tasks defined for this report. The tasks were: F-1A Restart Study, J-2S Restart Study, Propulsion Database Development, SSME Upper Stage Use, CERs for Liquid Propellant Rocket Engines, Advanced Low Cost Engines, and Tripeopellant Comparison Study.

The detailed study results, with the data to support the conclusions from various analyses, are being reported as a series of five separate Final Task Reports. Consequently, this volume only reports the required programmatic information concerning Computer Aided Design Documentation, and New Technology Reports.

A detailed Executive Summary, covering all the tasks, is also available as Volume I of this report.