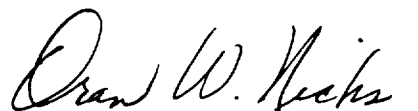


WIND TUNNEL TESTING AND RESEARCH
NASA JOHNSON SPACE CENTER CONTRACT NO. NAS 9-18261

January 25, 1990 - March 12, 1993



Oran W. Nicks
Research Engineer

November 15, 1993

(NASA-CR-188273) WIND TUNNEL
TESTING AND RESEARCH Final Report,
25 Jan. 1990 - 12 Mar. 1993 (Texas
A&M Univ.) 21 p

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"Wind Tunnel Testing and Research"

NASA Johnson Space Center Contract No. NAS 9-18261

Introduction

In accord with the contract requirements, this is the final report for the subject contract effort. Included are summary data covering the tasks, a brief synopsis of results and a summary report on the labor, facility, and materials.

Each task was formalized and agreed to after a proposal task description was submitted by the contractor to the Contracting Office Technical representative at JSC. Task descriptions as officially approved are included as Attachment No. 1 to this report. Each task description contains the nature of the task and estimates of man-hours, facility hours, facility modifications, and material costs. As each test was being performed, technical data and experimental results were provided directly to NASA representatives. At the completion of each task, test reports in the contractor standard format were provided giving the test results and analyses. Under separate cover, an accounting of the actual materials, man-hours, computer facility hours expended along with a billing for each task effort was submitted to NASA from the Texas Engineering Experiment Station Business Office. For reference, copies of the title pages of the technical reports are included as Attachment No. 2.

Brief Synopsis of Results

Task Order No. 1 (2-2-90): Task 1 was a test of a Space Shuttle model with various base enhancements intended to help reduce the drag of the Shuttle in the landing configuration. Forty hours of testing provided force and moment data which were reduced to coefficient form for use in engineering analyses. Wake survey data were also obtained to determine velocity components and flow angles.

Task Order No. 2 (6-28-90): Further tests were conducted using a Shuttle model to explore base drag improvement techniques. In addition to providing test results, engineering analyses were performed showing the effects of base drag enhancement devices.

Task Order No. 3 (2-3-92): This task involved the testing of parafoils having different airfoil shapes and line lengths. Six component forces and moments, control line loads, and pressure measurements were made. In addition, flow field studies were conducted. Performance data on the parafoils were reduced to coefficient form. High speed photographs were provided to enable the consideration of dynamic motions under various conditions.

Task Order No. 4 (8-12-92) Task 4 involved a study of ground effects on a Shuttle model. The purpose of the test was to obtain force and moment data useful for determining the change in performance, stability and control near the ground on landing. In addition to obtaining the wind tunnel test data, engineering analyses were performed and documented by an Honors student.

Task Order No. 5 (2-3-93): Three dimensional velocity profiles in the wake aft of the Space Shuttle were determined to study the effects of wake velocities on the Orbiter drag chute. These data were primarily useful in supporting a computer simulation of the opening and stable position of the Orbiter drag chute. Data were provided in tabular and graphical form. Video tapes were provided to show the dynamic behavior of drag chutes.

Summary of Labor and Facility Hours, Material and Costs

Attachment No. 3 includes a summary table showing all the labor and facility hours and costs for each task.

ATTACHMENT NO. 1

TASK DESCRIPTIONS

TASK ORDER

CONTRACT NUMBER NAS 9 - 18261

ORDER NUMBER 2

DATE 6-28-90

Requirements for wind tunnel testing by NASA-JSC at the Texas A&M University Low Speed Wind Tunnel.

DESCRIPTION OF WORK:

Base drag reduction of space shuttle orbiter.

The tests will be conducted using a 4.05% scale model furnished by NASA - JSC. In addition to the vortex generators, three different geometries of V-channels, splitter plates and base plates with cavities will be built and attached to the base region of the orbiter model for a possible base drag reduction. The wind tunnel will provide the appropriate strut mounts, hardware and data acquisition equipment necessary for the test.

FACILITY HOURS REQUIRED:

64 hours (basic rate \$240/hr.) \$ 15,360.00

DIRECT LABOR HOURS:

Principal Investigator	115 hrs. @ \$41.0/hr.	\$ 4,715.00
Graduate Student	8 months @ \$900.0/m	\$ 7,200.00
Fringe Benefits:	P.I. 26% of \$ 4,715.00	\$ 1,226.00
	Student 15% of \$ 7,200.00	\$ 1,080.00

FACILITY MODIFICATIONS:

Supplies and materials for drag reducing devices \$ 1,000.00

Machining and Modifications \$ 2,000.00

TRAVEL:

2 trips to JSC @ \$ 100.00/trip \$ 200.00

PUBLICATION COST:

Bound test reports \$ 500.00

INDIRECT COST:

43% of total direct costs less facility hours cost \$ 7,706.00

TASK ORDER TOTAL COST:

Total task price \$ 40,987.00

PERFORMANCE SCHEDULE:

Program is scheduled to begin in August 1990. After completion of the drag reducing devices, the low speed wind tunnel tests will be conducted for flow visualization purposes in October 1990 and the test photographs will be analyzed for possible further modifications. High speed tests will be conducted following the low speed tests. Preliminary task report will be available in late December. The final report will be available in May 1991.

DATA REQUIREMENTS:

1. Force and Moments measurements reduced to coefficient form with standard wind tunnel equations.
2. Base pressure distribution for each base modification reduced to coefficient form.
3. Flow visualization photographs.

All data will presented in digital format. Graphical modification will be performed as required during the test time.


Technical Manager

Gail L. Boyes 713/1183-2905

Contracting Officer

NOTE: Any Task Order which has not been signed by the Contracting Officer is an illegal task order. The Contractor is encouraged to report and send any illegal task order to the Contracting Officer. If instead the Contractor chooses to perform on the basis of an illegal task order, he does so at his own risk.

TASK Order
CONTRACT NUMBER NAS9-18261
ORDER NUMBER 3
DATE 2-3-92

Requirements for wind tunnel testing by NASA-JSC at the Texas A&M University Low Speed Wind Tunnel.

DESCRIPTION OF WORK:

Sub-scale parafoil wind tunnel testing to determine six-component aerodynamics, control line loads, flowfield studies, and pressure measurements internal and on the surface of the parafoil. The testing will be conducted in two phases. The first phase will be used to check the mounting and hardware with one parafoil. Phase II will use the same setup and study two different parafoils with different airfoil shapes and line lengths. High speed photography will be used during Phase II and will be provided by NASA-JSC. The wind tunnel will provide the required mounting hardware and data acquisition equipment necessary for the test.

FACILITY HOURS REQUIRED:

24 hours (basic rate \$270/Hr.) for set-up, testing and dismantlement of the test model and mounting hardware.	\$6,480.00
40 hours (Internal balance test \$310/Hr)	12,400.00

DIRECT LABOR HOURS:

30 hours - Engineering Technician - Mounting fabrication	750.00
40 hours - Co-op and Part-time student - Mounting Design	240.00
Total Direct Labor Cost	990.00

FACILITY MODIFICATIONS:

Materials	400.00
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TRAVEL:

None

TASK ORDER TOTAL COST:

Total task hours/price	134 hours/\$20,270.00
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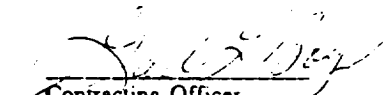
PERFORMANCE SCHEDULE:

Mounting and hardware modification to be completed by March 9, 1992.
Phase I scheduled: March 9-11, 1992 and Phase II April 6-10, 1992.
Task report June 10, 1992.

DATA REQUIREMENTS:


Force and moment measurements reduced to coefficient form with standard wind tunnel equations. Surface pressure measurements reduced to coefficient form. Control line loads measured and presented in pounds. All data will be presented in digital format as indicated in the task description by the NASA-JSC Technical Manager/support staff. Graphical presentation will be performed as required during the test time as requested by the Technical Manager/support staff.


Technical Manager


Contracting Officer

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APPROVED:


Carol J. Cantrell
Assistant Deputy Chancellor
Texas Engineering Experiment Station

APR 24 1992

TASK Order
CONTRACT NUMBER NAS9-18261
ORDER NUMBER 3A
DATE 4-1-92

Requirements for wind tunnel testing by NASA-JSC at the Texas A&M University Low Speed Wind Tunnel. This is an amendment to Task Order 3 for additional costs incurred above the original estimate.

DESCRIPTION OF WORK:

Same as Task Order 3.

FACILITY HOURS REQUIRED:

Same as Task Order 3.

DIRECT LABOR HOURS:

15 hours - Engineering Technician - Mounting fabrication 375.00

Total Additional Direct Labor Cost 375.00

FACILITY MODIFICATIONS:

Materials 760.00

TRAVEL:

None

TASK ORDER TOTAL COST:

Total task hours/price 15 hours/\$1,135.00

NOTE: These charges are over and above those included in Task Order 3 (\$20,270.00)


PERFORMANCE SCHEDULE:

Same as Task Order 3.

DATA REQUIREMENTS:



Same as Task Order 3.


Technical Manager


Contracting Officer

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APPROVED:

Carol J. Cantrell
Assistant Deputy Chancellor
Texas Engineering Experiment Station

POSTED
MAY 27 1992
Contracts & Grants

TASK Order
 CONTRACT NUMBER NAS9-18261
 ORDER NUMBER 4
 DATE August 12, 1992

Requirements for wind tunnel testing by NASA-JSC at the Texas A&M University Low Speed Wind Tunnel.

DESCRIPTION OF WORK:

Ground effect studies on the Shuttle using the variable height strut set-up. The project will be conducted in two phases. During the first phase, wind tunnel tests will be performed to acquire the necessary data to compare with flight data. During the second phase, the data will reduced, analyzed, and documented in a comprehensive report.

FACILITY HOURS REQUIRED:

40 hours (basic rate \$270/Hr.) for set-up, testing, and dismantlement of the test model and mounting hardware. \$10,800.00

DIRECT LABOR HOURS:

300 hours - Student worker	1818.00	
300 hours - Co-op/part time student - design/support	1818.00	
Fringe Benefits (15% of \$3636.00)	545.00	
Indirect Cost (45% of \$4181.00)	1882.00	
Total Direct Labor Cost		6,063.00

FACILITY MODIFICATIONS:

Equipment and Materials 1,000.00

TRAVEL:

None.

TASK ORDER TOTAL COST:

Total Task Hours/Price 640 hours/\$17,863.00

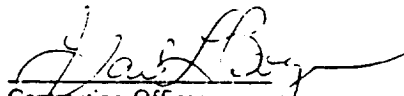
PERFORMANCE SCHEDULE:

Phase I - Model preparation and testing September 1, 1992 - December 31, 1992
 Phase II - Data reduction, analysis, comparison, and report - January 1, 1993 - May 31, 1993
 Task Report - May 31, 1993

DATA REQUIREMENTS:


Force and moment measurements reduced to coefficient form with standard wind tunnel equations.


 Technical Manager


 Contracting Officer

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APPROVED:


 Carol J. Cantrell
 Assistant Deputy Chancellor
 Texas Engineering Experiment Station

TASK Order
CONTRACT NUMBER NAS9-18261
ORDER NUMBER 5
DATE February 3, 1993

Requirements for wind tunnel testing by NASA-JSC at the Texas A&M University Low Speed Wind Tunnel.

DESCRIPTION OF WORK:

Define the average 3-dimensional velocity profile of the Space Shuttle Orbiter wake aft of the existing drag chute location in nominal landing conditions. This wake velocity data will be used to compute wake factors in a computer simulation of the Orbiter drag chute, complementing the wake velocity data already obtained in a previous test. The data will be used to assess the viability of moving the drag chute to larger trailing distances.

FACILITY HOURS REQUIRED:

63 hours (basic rate \$270/Hr.) for set-up, testing, and dismantlement of the test model and mounting hardware. \$17,010.00

DIRECT LABOR HOURS:

60 hours - Co-op and Part-time Student worker @ \$6.25/Hr. 375.00
40 hours - Technician @ \$11.30/Hr. 452.00
10 hours - Engineering @ \$22.21/Hr. 222.00
Insurance (40 Hrs @ 1.02/Hr & 10 Hrs @ 1.61/Hr) 57.00
Fringe Benefits (15% of \$375.00 & 23% of \$674) 211.00
Indirect Cost (43% of \$1317.00) 566.00

Total Direct Labor Cost 1,883.00

FACILITY MODIFICATIONS:

Mechanical Engineering Shop Costs-Orbiter elevon brackets 5,000.00
Assorted materials for Orbiter modification 100.00

Total Facility Modifications 5,100.00

TRAVEL:

None

TASK ORDER TOTAL COST:

Total Task Hours/Price 173hours/\$23,993.00

PERFORMANCE SCHEDULE:

Phase I - Model preparation February 2, 1993 - February 26, 1993.
Phase II - Installation, testing, and removal of model March 1 - 10, 1993.

DATA REQUIREMENTS:

Raw and reduced flow field velocity components will be presented to the principal investigator in tabular and graphical form after the test is completed. A test report outlining the test procedures, model installation, model configuration, data recording and reduction systems, and data presentation will be sent to the principal investigator within 60 days of test completion.


Technical Manager


Contracting Officer

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TEXAS ENGINEERING EXPERIMENT STATION
Project Establishment Notice

Date: March 9, 1993

Number: 32525-27900 AE

Project Action: Additional Time & Funds

Proposal: 89-604

Award: Contract Number NAS9-18261, Task Order No. 5

Type: Cost Reimbursable

Title: *Wind Tunnel Testing and Research*

Sponsor: NASA-Johnson Space Center

Type: Federal

Principal Investigator: O. W. Nicks

Division: Aerospace Engineering

Period of Performance: January 12, 1990 - March 12, 1993

Amount of this action:	\$ 23,993	Total Project:	\$113,998
Previous Tasks: Order #1	9,750	To be obligated	<u>9,939</u>
Order #2	40,987	Total Award	\$123,937
Order #3	20,270		
Order #3A	1,135		
Order #4	<u>17,863</u>		
Total Task Orders:	\$113,998		

Indirect Cost Rate: 43% MTDC

Indirect Cost Distribution: 7.5% to PI / 33.75% to Aerospace

Payroll Accounting Analysis: Monthly - 50120027900 Biweekly - 50120027900

Cost Sharing: None

Information: May release information and acknowledge sponsor.

Subcontracts: None

Property: Title vests with TEES.

Property Reports: None referenced per contract.

Sponsor Approval Required for Non-Budgeted Equipment: Yes No

Equipment Budgeted: Yes No

Travel: Must have prior approval of sponsor.

Sponsor Contractual Contact: Richard Lee (713) 483-8513

Sponsor Technical Contact: David Kanipe

TEES Contact: Project Accounting Administrator, Jill Card 845-3395
Contracts & Grants Administrator, Nancy Belding 845-1264

Regulations: NASA Contract and Research Task Order Terms.

Budget: May adjust budget categories without prior sponsor approval except for travel.

Technical Reports: Task description prior to each task (3 copies). Task report ten (10) days after completion of each task (3 copies). Final report due 10 days after contract completion

(March 22, 1993)

Approved By:

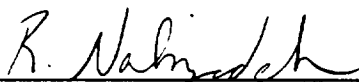

Carol J. Cantrell, Assistant Agency Director of Finance and Administration

ATTACHMENT NO. 2


TITLE PAGES OF TECHNICAL REPORTS

AEROSPACE ENGINEERING DIVISION
TEXAS ENGINEERING EXPERIMENT STATION
TEXAS A&M UNIVERSITY SYSTEM

Wind Tunnel Test for Base Enhancement
of the NASA 16-0 Space Shuttle Model - Phase II
Test Number 9004



Rodney Nabizadeh
Cooperative Education Student



Jorge L. Martinez
Engineering Research Associate

College Station, Texas

March 1991

NASA Contractor Report 185671
0000

Subsonic Drag Reduction of the Space Shuttle

Anwar Ahmed
Mohammad Javed Khan
Edmundo Varela-Rodriguez

CONTRACT NAS 9-18261
May 1992

NASA-JOHNSON SPACE CENTER

PARAFOIL TEST

TEST NUMBER 9207 & 9213

b y

Robert C. Reed

a n d

Scott Hafermalz

TEES REPORT NO. TR-9213

April 1992

NASA-Johnson Space Center
Study of the Space Shuttle Orbiter in Ground Effect

TEST NUMBER 9238

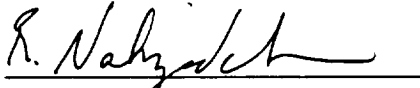
BY


Jennifer L. Devolites

TEES REPORT NO. TR-9238

AEROSPACE ENGINEERING DIVISION
TEXAS ENGINEERING EXPERIMENT STATION
TEXAS A&M UNIVERSITY SYSTEM

Wake Survey Study of the NASA 16-0 Space Shuttle Model in Ground Effects
Configurations
Test Number 9305


Rodney Nabizadeh
Engineering Research Assistant


Jorge L. Martinez
Engineering Research Associate

College Station, Texas

May 1993

ATTACHMENT NO. 3

SUMMARY TABLE

FINAL REPORT PERFORMANCE SCHEDULE SUMMARY

		Date Issued	Test Date	Task Report Date
TASK 1	Estimated	2/2/90	2/5-9/90	Apr-90
	Performance		2/5-9/90	Mar-91
TASK 2	Estimated	6/28/90	Aug-90	May-91
	Performance		12/17-21/90 & 8/7-8/91	May-92
TASK 3 & 3A	Estimated	2/3/92	3/9-11/92 & 4/6-10/92	Jun-92
	Performance		3/4-6/92 & 4/6- 10/92	Apr-92
TASK 4	Estimated	8/12/92	Dec-92	May-93
	Performance		11/16-25/92	Feb-93
TASK 5	Estimated	2/3/93	3/1-10/93	May-93
	Performance		3/1-12/93	May-93