Marshall Space Flight Center
Engineering, Science & Technical Services

Task Order Plan (TOP)

Contract Number: *NNM05AB50C*
TO Title: *Analysis Support of Space Shuttle Propulsion System*
TO Number: *33-040101* **Revision:** *15*

Period of Performance: *10/02/2010* to *3/31/2011*

MSFC Initiator: *Greg Frady*

(b)(4) [redacted]

Emergency: *No*

Revision 15: The purpose of this revision is to extend this task into Contract Year 6 of the NNM05AB50C ESTS contract. This revision defines and estimates work for the period October 2, 2010 through March 31, 2011. Additionally, the Schedule, Performance Plan and Risk Assessment have been revised to reflect changes in task activities for the new period of performance. This revision also consolidates work previously performed under task order 33-040103 (SSME Structural Dynamic Analysis Support) into this task. Changes are as follows:

Subelement 00, SSME Structural Strength Analysis Support (WBS 522094.08.01.01.03.01)
This subelement is closed. Work performed on this subelement will be continued under Task Order 33-040101-SA.

Subelement SA, SSME Structural Strength Analysis Support (WBS 522094.08.01.01.03.01)
This new subelement continues work previously performed under Task Order 33-040101-00. Estimated (b)(4) [redacted] for a total cost estimate of (b)(4) [redacted]

Subelement SB, SSME Structural Dynamic Analysis Support (WBS 522094.08.01.01.03.01
This new subelement continues work previously performed under Task Order 33-040103-00. Estimated (b)(4) [redacted] for a total cost estimate of (b)(4) [redacted]

Subelement SC, Propulsion Systems Engineering and Integration (PSE&I) Support (WBS 197009.10.01.01)
This new subelement continues work previously performed under Task Order 33-040103-02. Estimated (b)(4) [redacted] for a total cost estimate of (b)(4) [redacted]

The total estimate for this Task Order is (b)(4) [redacted]

Subelement 01, Reusable Solid Rocket Motor (WBS 520871)
This subelement is closed. Work performed on this subelement will be continued under Task Order 33-040114-SA.

Subelement SA, Reusable Solid Rocket Motor (WBS 520871)
This new subelement continues work previously performed under Task Order 33-040114-01. Estimated (b)(4) [redacted] and one trip for a total cost estimate of (b)(4) [redacted]

Revision 14: The purpose of this revision is to increase the scope of this task to include additional analyses to be completed in the current Contract Year. Specific analysis tasks are as follows:

- Perform structural analysis of the Space Shuttle Main Engine (SSME) High Pressure Fuel Turbopump Turbine Inlet Housing. Perform parametric thermal/mechanical analyses to characterize Low Cycle Fatigue crack propagation.
- Perform turbomachinery hardware modeling to develop/utilize skills and investigative techniques to solve complex integrated problems.
- Update existing historical finite element models of SSME components. Migrate to the most recent software version, perform verification cases, and archive.

Additionally, the Schedule, Performance Plan and Risk Assessment have been revised to reflect changes in task activities. Changes to the financial estimate for this task are as follows:

Subelement 00 (WBS 522094.08.01.01.03.01)
Estimated (b)(4) for a total cost estimate of (b)(4) This is an increase of (b)(4) for this subelement from the previous revision.

Revision 13: The purpose of this revision is to extend this task into Contract Year 5 of the NNM05AB50C ESTS contract. This revision defines and estimates work for the period October 3, 2009 through October 14, 2010. Additionally, the Schedule, Performance Plan and Risk Assessment have been revised to reflect changes in task activities for the new period of performance. Changes are as follows:

Subelement 00 (WBS 522094.08.01.01.03.01)
Estimated (b)(4) and one trip for a total cost estimate of (b)(4)

Revision 12: The purpose of this revision is to adjust labor hours to reflect actual utilization and add expenses incurred with hiring new Task Order personnel. New personnel were hired one month earlier than originally planned and at a higher labor grade than initially estimated. This revision compensates for the original estimating assumptions and accounts for the associated recruiting and relocation expenses. The net change in the Task Order cost estimate for this revision is an increase of (b)(4) from the previous revision. Changes are as follows:

Subelement 00 (WBS 522094.08.01.01.03.01)
Deleted (b)(4) Added (b)(4) recruiting costs and (b)(4) relocation expenses. The total cost estimate for the Task Order is now (b)(4)

Revision 11: The purpose of this revision is to adjust the phasing of labor hours to reflect actual utilization. Unused labor hours were retained and moved forward in the task schedule in anticipation of work to be performed later in the fiscal year. In addition, verbiage was added to the “Task Order Description & Objectives” to permit relevant skill development and skill retention analyses to be performed under this task order. There is no net change in the financial estimate for this revision.

Revision 10: The purpose of this revision is to extend this task into Contract Year 4 of the NNM05AB50C ESTS contract. This revision defines and estimates work for the period September 27, 2008 through October 2, 2009. Additionally, the Schedule, Performance Plan and Risk Assessment have been revised to reflect changes in task activities for the new period of performance. Changes are as follows:

Subelement 00 (WBS 522094.08.01.01.03.01)
Estimated (b)(4) for a total cost estimate of (b)(4)

The purpose of this revision (09) is to more accurately reflect the effort required during this period of performance. Labor estimate on was reduced by (b)(4) with a corresponding reduction in cost of (b)(4) The Schedule, Performance Plan and Risk Assessment have not been revised since there are no expected changes in task activities for this period of performance. No additional budget is required.

The purpose of revision 08 is to extend this task into Contract Year 3 of the NNM05AB50C ESTS contract. This revision defines and estimates work for the period 29 September 2007 through 26 September 2008. Additionally, the Schedule, Performance Plan and Risk Assessment have been revised to reflect any changes in task activities for the new period of performance.

The purpose of this revision (07) is to remove labor resources that will not be used in this fiscal year due to changes in the scope of the task. (b)(4) (b)(4)

The purpose of this revision (06) is to implement customer-requested changes in the level of support provided by task personnel. Changes in task personnel required the deletion of (b)(4) (b)(4)

The purposes of this revision (05) are to:

(b)(4)

The purpose of this revision is to extend this task into Contract Year 2 of the NNM05AB50C ESTS contract. This revision defines and estimates work for the period 30 September 2006 through 28 September 2007. Additionally, the Schedule, Performance Plan and Risk Assessment have been revised to reflect changes in task activities for the new period of performance.

This Task Order (TO) replaces TO 23-040103 due to the NASA/MSFC reorganization and the subsequent realignment of the NNM05AB50C ESTS contract. This TO defines and estimates work for the period 1 April 2006 through 29 September 2006. Funding for this task is provided per MSFC PR 4200150904. Additionally, the Schedule, Performance Plan and Risk Assessment have been revised to reflect changes in task activities for the new period of performance.

1.0 Task Order Description & Objectives

Subelement -SA, SSME Structural Strength Analysis Support

The objective of this task order is to provide structural analysis support of the Space Shuttle propulsion system. Components of the Space Shuttle Main Engine (SSME) including systems interfacing with the SSME are included within the scope of this task order. The Marshall Space Flight Center (MSFC) Task Order initiator will coordinate specific ESTS Group assignments with the ESTS Group task order lead.

In addition, at the discretion of the SSME Project, task personnel may perform related analyses relevant to the development and retention of skills necessary to support the structural analysis of SSME components. These analyses may be parametric in nature or use generic models of liquid engine hardware to develop analytical capability applicable to the SSME.

Subelement -SB, SSME Structural Dynamic Analysis Support

The objective of this subelement is to provide structural dynamic analysis support and structural dynamic data review/analysis support for the Space Shuttle Main Engine (SSME). The primary goals of this subelement are to create and verify engine system models and use them for structural dynamic

loads analysis, as well as to provide review and analysis of SSME test data, to prepare structural dynamic loads data analysis documentation packages, and to aid in the development of a database for SSME test data. In addition, skill development and retention tasks will be performed as approved by the SSME Project. These goals are discussed in more detail below.

Item 1: Perform engine system, component and/or sub-component modal and response analyses for ground test and flight loads verification. This analysis will be conducted as required by configuration changes such as engine upgrades, and by anomalous structural dynamic behavior, such as out-of-family operational vibration, component fatigue failures, etc. This analysis includes developing loads for SSME components and/or sub-components using the R7 environments and assessing changes from the R5 environment loads.

Item 2: Develop a database of SSME Hotfire test data for use in post-test reviews, to track the amplitude of specific channel(s) over multiple tests, to track pump harmonics, and to tracking frequencies that may be unique to a specific engine's components. The database development will enable the government engineering community to more quickly identify out-of-family engine data using less manpower and have more insight into the operational characteristics of the SSME during anomaly investigations.

Item 3: Review, evaluate and document SSME vibration, strain gage, and acoustic data from ongoing hot fire tests. Evaluate impact of exceedances on component qualification status. Assess and recommend revisions to component vibroacoustic test criteria as necessary. Perform statistical analysis where insufficient test data is available. Review vibration, acoustics and shock test plans and procedures for accurate environments and test methods. Participate in design and test reviews for SSME design enhancements.

Item 4: Prepare structural dynamic loads data analysis documentation packages for SSME ongoing data reviews to support R7 load environments definition and component life assessment. Attend and participate in engine data reviews and technical meetings.

Item 5: At the discretion of the SSME Project, task personnel may perform related analyses relevant to the development and retention of skills necessary to support the dynamic analysis of SSME components. These analyses may be parametric in nature or use generic models of liquid engine hardware to develop analytical capability applicable to the SSME.

Subelement -SC, Shuttle Propulsion Systems Engineering and Integration (PSE&I) Support
The objective of this subelement is to provide structural dynamic analysis support for issues relating to Space Shuttle Propulsion Systems Engineering and Integration. The intent of this subelement is to have the support mechanism in place to enable immediate response to support resolution of unforeseen issues.

2.0 Technical Approach (Including required input, guidelines & assumptions)

Subelement -SA, SSME Structural Strength Analysis Support
The Marshall Space Flight Center (MSFC) Task Initiator will coordinate specific ESTS Group assignments with the ESTS Group Task Lead. Work assignments will include support of the SSME Engineering Change Review Board in the disposition of deviations, anomalies, and design changes, as well as pre-flight and post-flight support as required. Additional efforts will be supported as they are defined.

Subelement -SB, SSME Structural Dynamic Analysis Support
Component and Sub-System Models –

1) Engine component and sub-system MSC or NX NASTRAN finite element models will be created to support flight or hardware development issues. The models will be created using MSC/PATRAN based on CAD files and/or drawings provided by MSFC.

2) The models will be used to calculate natural modes and frequencies as well as perform parametric and response analyses as necessary. Depending on the situation, MSFC may need to provide the parameters and loads for these analyses, or the analyst performing the work may develop this input.
3) Support component and/or sub-system dynamic model validation testing, including modal survey and/or shaker-table testing used to characterize the frequencies and damping characteristics of component and/or sub-system dynamic models.

Hotfire Database –

1) Utilize conversion utilities to translate SSME hotfire test and flight raw dynamic data to native PC-Signal software format.
2) A database of engine firing data will be generated using PC-Signal tools.
3) Perform beta testing of PC-Signal database recall module to validate capabilities unique to the SSME data analysis task. Provide software developer description of enhancements and additional features for PC-Signal Software.

Vibroacoustic Environments Analysis –

Component qualification data for SSME hardware will be reviewed. This includes review of test plans to verify components are tested to proper levels and recommendations for overcoming test deficiencies. SSME engine hot fire acceleration and strain data will be reviewed and archived in a database so that it can be compared with previous test data. Differences in the data will be rationalized in light of SSME hardware changes.

1) Review, evaluate and document SSME accelerometer, strain gage, and acoustic data from ongoing hot fire tests, as well as component qualification data for SSME hardware. The hot fire test data will be compared with component qualification status and the impact of exceedances experienced during hot fire tests on component qualification status will be evaluated. This will include the reviewing of test plans to verify components are tested to proper levels and making recommendations for overcoming test deficiencies. The MSFC Group will also assess and recommend revisions to component vibroacoustic test criteria as necessary. Vibration, acoustics and shock test plans and procedures will be reviewed for accurate environments and test methods. Participate in design and test reviews for SSME design enhancements.
2) Prepare structural dynamic loads data analysis documentation packages for SSME ongoing data reviews to support R7 load environments definition, component life assessment, and support engine data reviews and technical meetings.

Required input for these items will include: SSME accelerometer, strain gage, and acoustic data from ongoing hot fire tests; component qualification data; and component vibroacoustic test criteria.

Subelement -SC, Shuttle Propulsion Systems Engineering and Integration (PSE&I) Support

When an issue or anomaly requiring structural dynamics support is identified, the typical approach would be to develop models to characterize and evaluate the anomaly. Mitigation techniques would be proposed and assessed. The investigative team and ER41 peer analysts would be kept informed of the progress in modeling, analysis, and development of interim results.

3.0 Discussion of Skills Required

Subelement -SA, SSME Structural Strength Analysis Support

This subelement will require personnel with extensive experience in structural analysis of space flight hardware. In particular, the personnel shall possess experience with advanced modeling techniques such as plasticity, contact analyses, and friction.

Subelement -SB, SSME Structural Dynamic Analysis Support
Both senior engineers and journeyman engineers with experience in structural and dynamic loads analysis, component qualification testing methods including environmental testing using sine, random and sine on random vibration test criteria are required for this task. In particular, the journeyman engineers must be familiar with standard methods of modal analysis, frequency response analysis and random vibration analysis for linear, damped structures, as well as vibration test data interpretation. The senior engineers must be proficient with advanced methods of dynamic loads analysis and environmental test data interpretation.

Subelement -SC, Shuttle Propulsion Systems Engineering and Integration (PSE&I) Support
A senior analyst with experience in structural and dynamic loads analysis, component qualification testing methods including environmental testing using sine, random and sine on random vibration test criteria is required for this task. In particular, the analyst must be familiar with standard methods of modal analysis, frequency response analysis and random vibration analysis for linear, damped structures, as well as vibration test data interpretation. The analyst must also be proficient with advanced methods of dynamic loads analysis and environmental test data interpretation.

4.0 Special Tools Required

Subelement -SA, SSME Structural Strength Analysis Support
MSC/PATRAN and ANSYS finite element software.

Subelement -SB, SSME Structural Dynamic Analysis Support
NX or MSC NASTRAN, MSC/PATRAN, MATLAB, and PC-Signal software.

Subelement -SC, Shuttle Propulsion Systems Engineering and Integration (PSE&I) Support
NX or MSC NASTRAN, MSC/PATRAN, MATLAB, and PC-Signal software.

5.0 Participating Subcontractors

None.

6.0 Milestones & Deliverables

a) Periodic Bi-weekly Notes
b) Monthly Activity Reports
c) Presentations as required
d) Analysis/Methodology Reports as required

Report deliverables shall be produced using Microsoft Office products. (Word, Excel, PowerPoint). All model definitions and results files will be delivered and archived on approved MSFC computer systems or on CDROM. Corresponding documentation will be delivered to MSFC personnel.

7.0 Special Considerations (Recruiting, Special Equipment / Material, Safety, etc.)

Finite element analyses shall be performed using ANSYS, NASTRAN or other approved finite element analysis codes.

Reports will reference the source of material property and analysis data necessary to meet the requirements of the ESTS Group's AS9100-compliant Performance Management System.

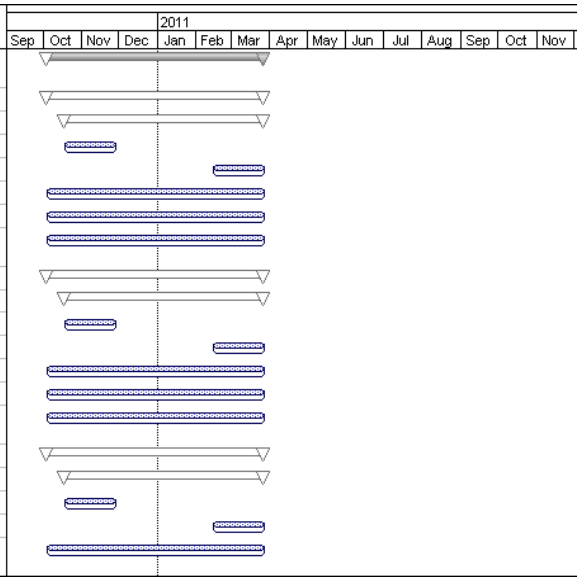
8.0 Work Shelf

The following activities could be accomplished as part of the Task Order performance by personnel that are temporarily available due to program or funding delays on other Tasks. Specific assignments will be coordinated with the Task Initiator to ensure appropriate skills and experience.

TO/Subelement	Description	Due Date	Skill

9.0 Schedule

Subtask #	SubElement	Task Work Element
33-040101		**Analysis Support of Space Shuttle Propulsion System**
33-040101	**SA**	**SSME Structural Strength Analysis Support**
33-040101	**SA**	**Shuttle Pre-Flight and Post-Flight Support**
33-040101	SA	STS-133
33-040101	SA	STS-134
33-040101	SA	Develop / Maintain Turbomachinery Analysis Skills and Methodology
33-040101	SA	Update Historical Finite Element Models
33-040101	SA	Support SSME Engineering Change Review Board: Deviations, Anomalies, Design Changes, Flight Dispositions.
33-040101	**SB**	**SSME Structural Dynamic Analysis Support**
33-040101	**SB**	**Shuttle Pre-Flight and Post-Flight Support**
33-040101	SB	STS-133
33-040101	SB	STS-134
33-040101	SB	Develop / Maintain Turbomachinery Analysis Skills and Methodology
33-040101	SB	Update Historical Finite Element Models
33-040101	SB	Support SSME Engineering Change Review Board: Deviations, Anomalies, Design Changes, Flight Dispositions.
33-040101	**SC**	**Shuttle Propulsion Systems Engineering and Integration (PSE&I) Support**
33-040101	**SC**	**Shuttle Pre-Flight and Post-Flight Support**
33-040101	SC	STS-133
33-040101	SC	STS-134
33-040101	SC	Support SSME Engineering Change Review Board: Deviations, Anomalies, Design Changes, Flight Dispositions.



ESTS Contract Task Order Request Performance Plan

Task Order Title: Structural and Dynamics Analysis Branch

Task Order Number: 33-040101 Revision: 15

Category	Weighting Technical %	End of Period Technical Score
Technical Objectives	65%	X 65% =
		Justification
The objective of this Subtask is to provide structural and dynamic analysis support of the space shuttle propulsion system. Components of the space shuttle main engine (SSME) including systems interfacing with the SSME are included within the scope of this subtask. Finite element techniques and traditional hand calculations will be applied to support structural analysis issues. The Marshall Space Flight Center (MSFC) task initiator shall coordinate work assignments.		
Schedule Objectives (Milestones)	**Weighting Schedule %** 10% *(min 10%)*	**Schedule Score** X 10% =
		Justification

ESTS Contract Task Order Request Performance Plan

Task Order Title: Structural and Dynamics Analysis Branch

Task Order Number: 33-040101 Revision: 15

Monthly Activity Reports will be provided to the MSFC Task Initiator with detailed descriptions of the work completed each month. Technical presentations and reports shall also be delivered as they are completed. All finite element model databases and results files will be delivered and archived on CD or on an approved MSFC computer system. Corresponding documentation will be delivered to MSFC personnel.		
Cost (actual vs. negotiated)	**Weighting Cost%** 25% *(min.25%)*	**Cost Score** X 25% = **Justification**
	Weighting Total % 100.00%	**Total Score**

ESTS Contract Task Order Request Performance Plan

Task Order Title: Structural and Dynamics Analysis Branch

Task Order Number: 33-040101 Revision: 15

Technical, Schedule, and Cost Grading Scale

Score	Description
9.0-10.0	Exceeded TO Performance Plan objectives resulting in major benefit(s)
8.0-8.9	Exceeded TO Performance Plan objectives resulting in modest benefit(s)
7.0-7.9	Met TO Performance Plan objectives
3.0-6.9	Did not meet all TO Performance Plan objectives resulting in minimal impact or requiring additional agency funds
0.0-2.9	Did not meet TO Performance Plan objectives resulting in substantial impact and/or requiring additional agency funds

ESTS Contract Task Order Request Performance Plan

Task Order Number: Structural and Dynamics Analysis Branch

Task Order Number: 33-040101 Revision: 15

Comments:

Marshall Space Flight Center
Engineering, Science & Technical Services

JACOBS
ESTS Group

Risk Assessment

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TO Number: *33-040101* **Revision:** *15*

Period of Performance: *10/02/2010* to *3/31/2011*

MSFC Initiator: *Greg Frady*

(b)(4)

Task Order Risk Assessment to Cost, Technical, and Schedule

List identified risk associated with Task Order performance as related to task cost, technical, and schedule. Classify the risk(s) according to probability of occurrence and impact as defined below and enter the risk into risk matrix.

Risk	Risk Type	Probability (1-4)	Impact (1-4)	Risk Description
Risk C1	Cost			No cost risks have been identified for this Task Order.
Risk C2	Cost			
Risk T1	Technical	1	1	Technical knowledge of personnel assigned not appropriate for work assigned.
Risk T2	Technical			
Risk S1	Schedule	1	2	If required input data is not available on schedule, it may cause delays in associated deliverables.
Risk S2	Schedule			

*Note: See page 2 for risk mitigation plan for those risks which are Primary Risk Drivers.

Task Order Risk Matrix

		1 Minimal Impact	2 Minor Impact	3 Medium Impact	4 Major Impact
Inevitable Occurrence (>95% Probability)	4	Y	Y	R	R
High Probability of Occurrence (>60% but <95% Probability)	3	G	Y	Y	R
Medium Probability of Occurrence (>25% but <60% Probability)	2	G	Y	Y	Y
Low Probability of Occurrence (<25% Probability)	1	G T1	G S1	Y	Y

Legend

- R — **Primary Risk Driver:** Requires Risk Mitigation Plan
- Y — **Caution:** Requires status updates and general plan for risk reduction as determined necessary by Team Lead and Initiator
- G — **Watch:** No Action required

Impact Level	Cost Impact Definition	Technical Impact Definition	Schedule Impact Definition
(1) Minimal Impact	No significant cost impact	No significant technical impact	No significant schedule impact
(2) Minor Impact	Potential to recover cost	Potential to gain required technology without impact	Minor delay in deliverables but no impact to customer
(3) Medium Impact	>0 but <10% subtask cost overrun	Some technical impact but potential to recover	Delay in subtask deliverables but work arounds available and acceptable to customer
(4) Major Impact	>10% subtask cost overrun	Unable to meet technical requirements to perform subtask	Delay in subtask deliverables with impact to customer

Risk Mitigation Plan

Complete the following chart for those risks identified on page 1 as “Primary Risk Drivers”. The following chart will serve as the Risk Mitigation Plan.

Risk No.: Risk Description:		
Mitigation Step No.	Planned Completion Date	Mitigation Step Description