

SSC Project Recommendation for FY 2022

Predictive Maintenance of Ship Structural Details

1.0 OBJECTIVE.

- 1.1 The objective of this project is to develop a predictive maintenance for ship structural details.

2.0 BACKGROUND.

- 2.1 Ship structural maintenance had been studied extensively in 1990s when a life extension of oil tankers was called. The development of Very Large Crude Carriers (VLCC) and the use of high tensile steel (HTS) at that time caused significant fatigue cracks in oil tankers.

Preventive maintenance, corrective maintenance, risk based maintenance, and their combinations are the common maintenance practice in shipping industries. Predictive maintenance is used in shipping industry with the name “condition assessment” (TSCF, 1989).

At the core of a condition assessment is a multi-step spectral fatigue analysis procedure developed by the first principle. Given the uncertainties developed in each step, significant uncertainties are accumulated in spectral fatigue analyses which result in a large bias between the predicted and real fatigue lives (Xu, 2001). As a result, in-service conditions and remaining fatigue lives of ship structural details cannot be assessed with reasonable accuracies.

- 2.2 Given the fact that we cannot predict the in-service conditions and remaining fatigue lives accurately, an integrated Inspection, Monitoring, Maintenance, and Repair (IMMR) system was developed for ship structural details in 1996 to reengineer the ship structural maintenance system (Xu, 1997).

The integrated IMMR includes 1) a first principle based IMMR planning, e.g., probability based or risk based IMMR planning, and 2) a knowledge based IMMR planning.

The knowledge based IMMR system is to complement the first principle based IMMR planning. It used a combination of model-based diagnosis, heuristic classification, and case-based reasoning: model-based diagnosis to identify the details of a large class of possible problems, heuristic classification to identify the presence a set of idiosyncratic problems, and case-based reasoning to compare observation with previously identified cases.

Twenty more years later, this knowledge based IMMR system has become a data driven predictive maintenance, an emerging maintenance program in manufacturing, defense, and oil industries.

- 2.3 The predictive maintenance is to first predict when equipment, machine, or system failure could occur (based on certain factors), followed by preventing the failure through corrective maintenance. In theory, the predictive maintenance is the minimum cost maintenance because tasks are performed only when warranted.

Predictive maintenance cannot exist without condition monitoring and assessment, which is defined as the continuous monitoring and assessment of equipment, machine or system during process to ensure the optimal use of equipment, machine or system.

At the core of the predictive maintenance is Artificial intelligence (AI), a development of expert or knowledge systems in 1990s. AI is developed on the basis of data driven modeling. Many of these artificial intelligence based systems are powered by machine learning (statistical regression analysis, pattern classification), some of them are powered by deep learning (neural networks) and some of them are powered by very boring rules (rule based expert system).

2.4 This project is a pathfinding study of an AI based real time ship maintenance system (Xu, 2021). An AI based real time ship maintenance system is to integrate predictive maintenance, structural health monitoring system, and digital twin on the basis of the data driven methodology.

3.0 REQUIREMENTS.

3.1 Scope.

3.1.1 The Contractor shall perform a literature review on the ship structural maintenance, predictive maintenance, and machine learning. [SEP]

3.1.2 The Contractor shall identify and develop a methodology for utilizing in-service cracking data with spectral fatigue analysis data to drive a data driven fatigue damage evaluation model. This methodology shall be demonstrated by a typical ship structural detail fatigue damage evaluation.

3.1.3 The Contractor shall develop a predictive maintenance model for a typical ship structural detail, and demonstrate the model can be extended in the structural health monitoring system and digital twin.

3.2 Tasks.

3.2.1 The Contractor shall review the ship structural maintenance, and predictive maintenance in manufacturing, defense, and oil industries.

3.2.2 The Contractor shall review the fatigue cracking database and spectral fatigue analysis database provided by project sponsors. The Contractor shall develop a ship structural detail classification system based on the review of the database.

3.2.3 The Contractor shall develop methodologies to derive data driven fatigue evaluation models for ship structural details.

3.2.4 The Contractor shall demonstrate a data driven fatigue evaluation model for a typical ship structural detail.

3.2.5 The Contractor shall develop a predictive maintenance model for a typical ship structural detail.

3.2.6 The Contractor shall prepare a report.

3.3 Project Timeline.

	Month																	
Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
3.2.1	■	■																
3.2.2		■	■	■														
3.2.3				■	■	■	■											
3.2.4							■	■	■	■								
3.2.5										■	■	■	■					
3.2.6														■	■	■	■	
Reporting			■			■			■			■			■	■	■	■

4.0 GOVERNMENT FURNISHED INFORMATION.

4.1 Standards for the Preparation and Publication of SSC Technical Reports.

5.0 DELIVERY REQUIREMENTS.

5.1 The Contractor shall provide quarterly progress reports to the Project Technical Committee, the Ship Structure Committee Executive Director, and the Contract Specialist.

5.2 The Contractor shall provide a print ready master final report and an electronic copy, including the above deliverables, formatted as per the SSC Report Style Manual.

6.0 PERIOD OF PERFORMANCE.

6.1 Project Initiation Date: date of award.

6.2 Project Completion Date: 18 months from the date of award.

7.0 GOVERNMENT ESTIMATE. These contractor direct costs are based on previous project participation expenses.

7.1 Project Duration: 18 months.

7.2 Total Estimate: \$100,000

7.3 The Independent Government Cost Estimate is attached as enclosure (I).

8.0 REFERENCES.

8.1 Tanker Structure Cooperate Forum (1989) “Guidance Manual for the Inspection and Condition Assessment of Tanker Structures”.

8.2 T. Xu, et al (1997) “Reengineering the Ship Structural Maintenance System”, Dept. of Civil and Environmental Engineering, University of California at Berkeley, Berkeley, CA 94720.

8.3 T. Xu, (1997) “Fatigue of Ship Structural Details – Technical Development and Problems”, Journal of Ship Research.

8.4 T. Xu, et al (1999) “Uncertainties in the Fatigue Lives of Tubular Joints”, Proceedings of Offshore Technology Conference, Houston, TX.

8.5 T. Xu, (2014) “From Oil Platforms to High-Tech Cleanrooms – Reliability Applications in Facility Design”, Proceedings of the 33rd International Conference on Ocean, Offshore, and Arctic Engineering (OMAE).

8.6 T. Xu, (2021) “A Proposal for the development of an AI based real time ship maintenance system”, Tao Xu & Associates.

9.0 SUGGESTED CONTRACTING STRATEGY.

See attached terms and conditions.

10.0 COST ESTIMATE.

Direct Labor

Labor Category	Hours	Labor Rate	Price
Principal	320	\$300	\$96000
Other Direct Costs			
Travel			\$4000
Total Price			\$100,000

Note:

Labor rates are fully loaded including salary plus an allocation of costs for overhead, G&A, profit/fee, and any escalation for option years.

**STANDARD TERMS AND CONDITIONS
TAO XU & ASSOCIATES**

Tao Xu & Associates will perform the services specified in the Scope of Services contained in this proposal in accordance with the following terms and conditions.

A. COMPENSATION

Client will compensate Tao Xu & Associates on a fixed price basis as specified in the proposal letter.

1. Fixed Price

- a. Services Specified: Tao Xu & Associates will deliver the services specified in the Scope of Services on a fixed price basis. If the fixed price is specified to include only professional services, expenses will be billed in accordance with paragraph A.1 (c) above.
- b. Additional Services: Services outside the Scope of Services outlined in the proposal shall be considered Additional Services. Unless otherwise agreed, Client shall pay for such Additional Services on a time-and-materials basis at Tao Xu & Associates' standard hourly rate.

2. Payments

Invoices for time-and-materials agreements are rendered based on professional staff services and associated expenses furnished by Tao Xu & Associates. Invoices for fixed price agreements are rendered monthly based on a percent-of-completion basis unless a schedule of payment is otherwise agreed upon. Invoices are payable on receipt.

Client shall remit payment to Tao Xu & Associates by wire transfer to Chase Bank, Gilroy Office, 1177 First Street, Gilroy, CA 95020. ABA Routing No.: 322271627, for credit of Tao Xu & Associates, Account No.: 861-042825-8 by order of (Client name), with the message "Tao Xu & Associates Invoice #XXX," or such other account as Tao Xu & Associates may designate in writing.

B. OWNERSHIP OF DOCUMENTS

Drawings and other documents prepared by Tao Xu & Associates under the Agreement, which are delivered to Client shall be the property of Client. Tao Xu & Associates may retain copies for information and reference. The drawings and specifications shall not be used by Client on other projects nor shall Client make changes in drawings and specifications prepared by Tao Xu & Associates without Tao Xu & Associates' prior written authorization.

C. TAXES

All sales, use, value-added and non-United States withholding taxes, custom duties, tariffs, fees for permits and similar charges applicable to services provided and tangible or intangible items delivered to Client under this Agreement, shall be paid by Client.

D. LIMITATION OF WARRANTY, LIABILITY AND INSURANCE

Services provided by Tao Xu & Associates under this Agreement are based upon information, drawings, plans and designs provided by Client and other third parties. Accordingly, Tao Xu & Associates provides no warranties expressed or implied.

Tao Xu & Associates carries Professional Practice Liability Insurance, Worker's Compensation and Employers Liability Insurance, Comprehensive General Liability Insurance and Automobile Liability Insurance. Certificates of Insurance will be furnished upon request. Tao Xu & Associates shall indemnify Client for direct damages resulting from negligent acts or negligent omissions by Tao Xu & Associates in performance of its work thereunder.

Tao Xu & Associates shall not be liable for any special, incidental, or consequential damages. In no event shall Tao Xu & Associates liability for damages for any reason, in contract, tort (including negligence), warranty or otherwise, exceed the greater of \$25,000 or the contract value of the services provided by Tao Xu & Associates under this Agreement.

E. UNFORESEEN CIRCUMSTANCES

Tao Xu & Associates shall not be in default of its obligations to the extent that its performance be delayed or prevented by causes beyond its control, including but not limited to acts of God, delays in delivery by vendors, strikes or other labor disturbances.

F. EXPORT RESTRICTIONS

Without limitation, Client agrees to commit no act which, directly or indirectly, would violate any United States law, regulation or treaty, or any other international treaty or agreement, relating to the export or re-export of any of the software, documentation or technical data to which the United States adheres or with which the United States complies.

G. CONFIDENTIALITY

Tao Xu & Associates agree, for a period of three (3) years from the date of disclosure of information identified as propriety or confidential by Client, that Tao Xu & Associates will treat the information in strictest confidence and will not disclose it to third parties unless the information:

1. Was part of the public domain when received or becomes a part of the public domain through no action or lack of action by Tao Xu & Associates.
2. Prior to disclosure, was already in the Tao Xu & Associates' possession and not subject to an obligation of confidence imposed in another relationship.
3. Subsequent to disclosure is obtained from a third party who is lawfully in possession of the information and not subject to a contractual relationship to Client with respect to the information

H. TERMINATION

In the event of default by either party, either party may terminate this Agreement in whole or in part at any time by written notice to the other. Such notice is effective upon receipt. In the event of such termination, Tao Xu & Associates shall be compensated in accordance with this Agreement for the services rendered and expenses incurred or committed to prior to the effective date of notice of termination.

I. GENERAL

1. This Agreement, including any appendices attached hereto, constitutes the entire agreement between the parties with respect to the subject matter. This Agreement may be modified only by written agreement of Client and Tao Xu & Associates and is binding upon their respective successors and assigns.
2. Interpretation, construction and enforcement of this Agreement shall be pursuant to the laws as, statutes and regulations of the United States of America and the State of California, and Client hereby agrees to the jurisdiction of the courts therein.

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3. The rights and obligations of Paragraphs B and D shall survive the completion of termination of this Agreement.