Mechanical Integrated Services and Technologies (MIST) Representative Task Order (RTO) Summary
Middle Latitude Observer (MLO) Project

A set of representative task orders (RTOs) has been assembled to cover key elements of the major Statement Of Work (SOW) content. The mission described in the RTOs does not represent an actual NASA mission nor does it reflect a future proposed mission. The purpose of these task orders is to provide the Contractor a sampling of the type of tasks to expect under this Indefinite Delivery/Indefinite Quantity (IDIQ) contract. Contractors shall prepare a response to each RTO using the specified criteria in the proposal instructions.
The MLO Project is a new mission recently won by the NASA Goddard Space Flight Center (GSFC). MLO will be designed, integrated, and tested by a team comprised of GSFC Civil Servants and a Commercial Contractor that will provide engineering and technician services as described in the RTOs below.

MLO will include two primary but unrelated scientific objectives on a common spacecraft bus. The first is to characterize the topographical properties of Carolina Bays utilizing a synthetic aperture radar. Carolina Bays are the unusual elliptical depressions found almost exclusively on the Atlantic seaboard from New Jersey to Florida, but most prominent in North and South Carolina. The second is to measure the aerosols in the atmosphere in the middle latitudes and characterize their seasonal variations. The spectra of interest are the visible light spectrum through Long Wave Infrared (LWIR). This instrument will also be measuring the water utilization in agriculture through accurate ground surface temperature measurements.

The MLO observatory will consist of the spacecraft bus (and its related subsystems) as well as the two science instruments referenced above. The synthetic aperture radar instrument will be referred to in the RTOs as the Carolina Bay Observing Radar Experiment (CBORE) and the aerosol-measuring instrument will be referred to as the Earth Resource Imager (ERI).

The MIST RTOs are to be evaluated as a separate and unrelated problem. <u>No work, described under the statements of work in these RTOs, is to be performed by the Contractor.</u>
The Contractor shall prepare a response to each RTO summarized below:

RTO-1 **Earth Resource Imager Instrument Development**
Focus on thermal, contamination and thermal coatings, cryogenic, and optical elements of the instrument design.

RTO-2 Mechanical Engineering Design, Analysis, and Integration & Test

Focus on the mission-level mechanical engineering, structural analysis, solar array drive assembly, observatory integration and test, and materials and processes.

MLO Mission Characteristics

Responses to the RTOs should use the following MLO Characteristics as required.

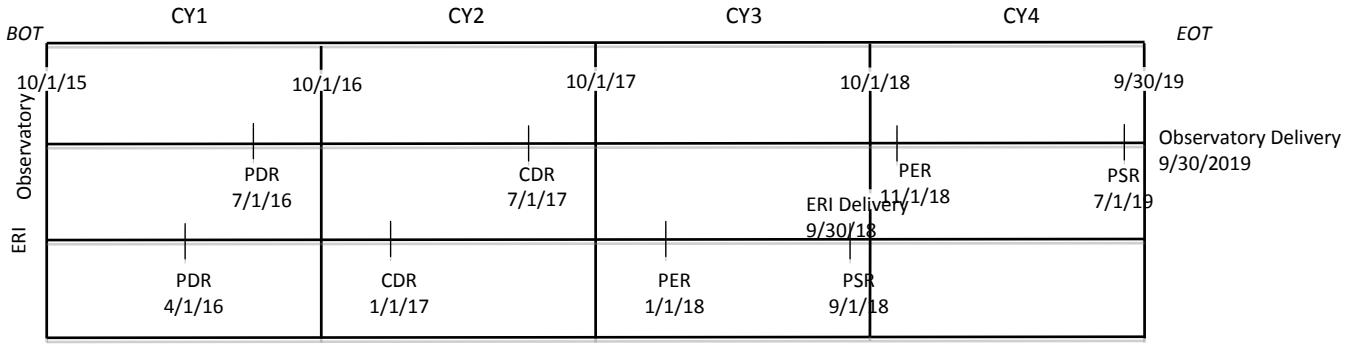
MLO Mission Characteristics

Mission Orbit	660 km, circular
Orbit Inclination	40°
Mission Lifetime	Minimum 2 years
Launch System	Falcon 1e
Attitude Control	3-axis stabilized, nadir-pointing with 30.0 arc-second, 3-sigma pointing, 10 arc-second knowledge 3-sigma
Dry Mass	650 kg
Risk Classification	C

MLO Project Schedule

The following schedule shall be used in RTO responses.

Task Period of Performance



Applicable Documents and Specifications

General:
NPR 7120.5E, NASA Program and Project Management Processes and Requirements
NPR 8705.4, Risk Classification for NASA Payloads
GPR 8070.4B, Administration and Application of Goddard Open-Learning Design
GSFC-STD-1000E, Goddard Space Flight Center (GOLD) Rules for the Design, Development, Verification, and Operation of Flight Systems
NASA/SP-2007-6105, NASA Systems Engineering Handbook

Launch Vehicles:
NASA-STD 8719.24, NASA Expendable Launch Vehicle Payload Safety Requirements"
NPR 8715.7, "Expendable Launch Vehicle Payload Safety Program
SpaceX Falcon 1 Users Guide (provided)
SpaceX Falcon 1 Data Sheet (provided)

Conformal Coating and Staking:
NASA-STD-8739.1A, Workmanship Standard for Polymeric Application on Electronic Assemblies

Soldering – Ground Systems:
IPC-J-STD-001E, Requirements for Soldered Electrical and Electronic Assemblies (except Chapter 10)
IPC-J-STD-001ES, Space Applications Electronic Hardware Addendum to IPC-J-STD-001E Requirements for Soldered Electrical and Electronic Subassemblies (except Chapter 10)

Electronic Assemblies – Ground Systems:
IPC-A-610E, Acceptability of Electronic Assemblies

Crimping, Wiring, and Harnessing:
NASA-STD-8739.4, Crimping, Interconnecting Cables, Harnesses, and Wiring

Fiber Optics:
NASA-STD-8739.5, Fiber Optic Terminations, Cable Assemblies, and Installation

Electro-Static Discharge (ESD) Control:
ANSI/ESD S20.20-2007, Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)

Printed Wiring Board (PWB) Design:
500-PG-8700.2.2C, Electronics Design and Development
500-PG-8700.2.4E, Mechanical Design and Development
500-PG-8700.2.5C, Engineering Drawing Requirements Manual
IPC-2221A, Generic Standard on Printed Board Design
IPC-2222A, Sectional Design Standard for Rigid Organic Printed Boards
IPC-2223C, Sectional Design Standard for Flexible Printed Boards

PWB Manufacture:
GSFC-EEE-INST-002, Instructions for EEE Parts Selection, Screening, Qualification, and Derating - Incorporated Addendum 1: April 2008
IPC A-600H, Acceptability of Printed Boards (Class 3)
IPC-6011, Generic Performance Specification for Printed Boards (Class 3)
IPC-6012C, Qualification and Performance Specification for Rigid Printed Boards (Class 3/A)
IPC-6013B, Qualification and Performance Specification for Flexible Printed Boards (Class 3)
IPC-6018B, Qualification and Performance Specification for High Frequency (Microwave) Printed Boards (Class 3A)

Materials Processing
NASA-STD-6016, Standard Materials and Processes Requirements for Spacecraft

Contamination
IEST-STD-CC1246D, Product Cleanliness Levels and Contamination Control Program

Mechanical Design
541-PG-8072.1.2B, GSFC Fastener Integrity Requirements
540-PG-8700.2.1A, Design of Dollies, Stands, and Spacecraft Shipping Containers
540-PG-8719.1.1A, Lift Sling Design

Environmental Testing
GSFC-STD-7000, General Environmental Verification Standard (GEVS)

Outgassing
ASTM E-595-07, Standard Test Method for Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment
Outgassing Data for Selecting Spacecraft Materials Online:
http://outgassing.nasa.gov

RTO-1

Task Title: Earth Resource Imager (ERI) Instrument Development

Task Start Date:
10/1/2015

Task End Date:
9/30/2019

Location: On-site at GSFC unless otherwise specified in a subtask.

Government Furnished Property For all RTO-1 Subtasks:

- All documents from the mission, spacecraft and instrument are available for use, as well as computer math models and mechanical drawings (also in electronic format).
- Ground support equipment for applicable testing.

Subask Start Date:	Subtask (a):	10/01/2015
	Subtask (b):	10/01/2015
	Subtask (c):	10/01/2015
	Subtask (d):	10/01/2017
	Subtask (e):	10/01/2015
Subtask End Date:	Subtask (a):	08/01/2019
	Subtask (b):	09/30/2019
	Subtask (c):	09/30/2018
	Subtask (d):	09/30/2018
	Subtask (e):	09/30/2018

Task Background:

Earth Resource Imager (ERI) is a “push broom” Earth imaging optical aerosol and surface temperature measurement instrument. ERI will measure aerosol composition of the atmosphere over highly populated and industrialized latitudes and their variations with season. This instrument will also be measuring the water utilization in agriculture through accurate ground surface temperature measurements.

The Earth Resource Imager will be used to image in five (5) visible bands and four (4) infrared bands. Data from the infrared and visible bands are to be collected simultaneously. The visible data will be used to measure aerosol emissions in the atmosphere and infrared data will be used to precisely measure the surface temperature to an accuracy of 0.25 K. Aerosol data will enable scientists to map the aerosol emission sources in real time. Surface temperature measurements

will enable scientists to approximate soil moisture content, which in turn will be used to estimate water usage by farmers.

The ERI system primary characteristics are:

- Power 100 W Orbit Average Power
- Mass Not to exceed 100 kg
- FOV 30 km visible, 50 km LWIR
- Resolution, Visible 60 m on the ground
- Resolution, IR 100 m on the ground
- Detector Format Linear array in multiple bands spread over visible to LWIR
- Visible Detectors Sensitive from 400 nm to 1 µm in visible band
- LWIR Detectors Sensitive from 8 µm to 12 µm in infrared band
- Detector Operating Temp Visible: 210 K +/- 0.1 K and LWIR: 45 K +/- 0.01 K
- Detector Format 25 µm pixels, 1024 linear array

Five (5) subtasks have been identified in the following areas: Thermal, Contamination and Thermal Coatings, Cryogenic, and Optical. Work will be performed on-site at GSFC unless otherwise specified within the subtask. Milestone reviews (PDR, CDR, etc.) reference the ERI schedule, unless otherwise specified in a subtask. Assess each item within a subtask separately and independently unless instructed otherwise in the subtask item.

Subtask (a): Thermal Control System Design, Analysis, and Development

The ERI Instrument is to have its own independent thermal control system for thermal management. The ERI instrument is to be thermally isolated from the spacecraft bus. The thermal control system design shall meet the optical and cryocooler requirements of 45 K operationally. The instrument shall meet stability and distortion requirements to operate properly. The Contractor shall provide engineering support for a thermal control system (TCS) for the ERI and perform detailed thermal analysis for all mission phases.

Thermal subsystem requirements:

- Detector operating temperatures:
  - 45 K +/- 0.01 K (LWIR)
  - 210 K +/- 0.1 K (VIS)

The ERI shall be fully qualified and designed to flight levels. The Instrument will be built and tested at GSFC. The Contractor shall provide a detailed Instrument Development Plan for the thermal control system. Also, the Contractor shall support procurement activities and the delivery of a fully qualified ERI to the Observatory.

Statement of Work For Subtask (a) Thermal Control System Design, Analysis and Development:

The Contractor shall perform this work on-site at GSFC.

1) Support the design efforts for a thermal control system that meets the optics, cryocooler, and detector temperature requirements. Provide status reports and support project meetings.
2) Perform the thermal design analyses, design studies and trade studies to support the design effort.
3) Develop geometric mathematical models and thermal models of ERI. The thermal analysis software utilized must be compatible with Systems Improved Numerical Differencing Analyzer (SINDA), Thermal Synthesizer Systems (TSS), Thermal Desktop, Finite Element Modeling and Post-processing (FEMAP/TCON), or Thermal Model Generator (TMG) software packages.
4) Support instrument PDR, CDR, PER and PSR
5) Perform the SINDA model correlation for flight predicts and for test predicts.
6) Provide model correlation results of pre-test and post-test temperature predictions.
7) Provide temperature gradients and temperature mapping for STOP analysis.
8) Include a detailed development plan for ERI Instrument thermal control system in all milestone review data packages.
9) Provide procurement support for all the thermal hardware components
10) Develop the Integration and Test plan for the thermal system for ERI Instrument
11) Develop thermal ICDs.
12) Develop the test plan and test procedure for the ERI Instrument thermal balance testing.
13) Support thermal vacuum and thermal balance testing for the ERI Instrument level test. (It should include 24-hour coverage).
14) Develop thermal test reports.

Additional Government Furnished Equipment For Subtask (a):

- Geometrical model for analysis of ERI instrument in Pro-Engineer format.

Milestones/Deliverables & Dates for Subtask (a):

Deliverable	Due Date
1) Monthly status reports	BOT + 1 months
2) PDR data package	PDR
3) CDR data package	CDR
4) PER data package	PER
5) PSR data package	PSR
6) Deliver Thermal ICD package	PDR + 3 months

7) Analytical reports of trade and design studies, and thermal design analysis	CDR + 3 months
8) Instrument I&T plan for thermal control system	CDR + 3 months
9) Thermal balance test plan	CDR – 3 months
10) Reduced ERI GMM and SINDA model to the Observatory thermal team that represents 100% of the Instrument. The temperatures need to be representative of the Instrument for all mission phases.	CDR – 2 months
11) Detailed ERI Instrument Geometric Math Models (GMM), internal and external (using software compatible with Thermal Desktop, TSS, FEMAP/TCON or TMG).	CDR – 3 months
12) Detailed ERI Systems Improved Numerical Differencing Analyzer (SINDA) model	CDR – 3 months
13) Test model temperature predictions report	PER + 1 month
14) Flight model temperature predictions report	PSR + 1 month

Subtask (b): Contamination Engineering and Thermal Coatings

The Instrument detectors and electronics will be built in-house at Goddard. The ERI instrument has a visible imager in the 400 nm – 1 µm range, and a Long Wave Infrared Imager in the 8 µm – 12 µm range and contains optical and detector elements sensitive to contamination. The contamination requirement for ERI surfaces is Level 100A per IEST-STD-CC1246.

The Contractor shall provide comprehensive Contamination Engineering and Thermal Coatings Engineering support for the ERI instrument for all mission phases, from concept development to delivery at the launch site.

The ERI radiator requires a thermal coating which shall meet the thermal and environmental requirements of the mission and instrument, and which shall support the 45 K temperature of the ERI cryocooler.

Using the latest state-of-the-art analytical models and techniques, the Contractor shall demonstrate the ability to perform molecular and particulate contamination analyses, and evaluate synergistic on-orbit environmental effects on contamination accumulations. Contractor shall also perform MOLEKIT and Image Analysis testing on provided samples.

Statement of Work For Subtask (b) Contamination Engineering and Thermal Coatings:

The Contractor shall provide comprehensive contamination engineering support for the ERI Instrument throughout all mission phases, on-site at GSFC. The Thermal Coatings Laboratory at GSFC shall be used for fabrication and application of thermal control coatings. The MOLEKIT, Solar Wind Facility, Building 7 Measurements Lab, BRDF, and Image Analysis labs at GSFC shall be used for testing and analysis.

1) Assess ERI contamination requirements and develop a contamination budget.
2) Develop a contamination engineering approach for all mission phases.
3) Develop contamination control, implementation, and verification plans.
4) Develop contamination requirements in support of thermal vacuum bakeouts.
5) Develop I&T contamination plans.
6) Perform necessary testing and measurements to ensure contamination requirements are met.
7) Develop cleaning, verification, and protection plans for the instrument.
8) Develop transport and launch site accommodation plans.
9) Evaluate which thermal coating is required for the radiator application.
10) Select and apply thermal coating to ETU and Flight radiators.
11) Touch up radiator thermal coating, if necessary.
12) Validate thermal coating adhesion, integrity, and thickness.
13) Perform measurements of thermal coating absorptance and emittance values.
14) Perform molecular mass transport analyses for the ERI instrument.
15) Perform particulate deposition analyses for the ERI instrument.
16) Evaluate synergistic on-orbit environmental effects on contamination accumulations.
17) Perform MOLEKIT analysis of ten (10) materials and thermal coating samples. Results reports shall be generated.
18) Perform Image Analysis testing of twenty (20) sample wafers. Results reports shall be generated.

Additional Government Furnished Equipment For Subtask (b):

- Geometrical model for analysis of the ERI instrument in Pro-Engineer format.
- One (1) ETU radiator panel.
- One (1) Flight radiator panel.
- Ten (10) samples for MOLEKIT analysis.
- Twenty (20) Image Analysis samples.

Milestones/Deliverables & Dates for Subtask (b):

Deliverable	Due Date
1) ERI Draft Contamination Control Plan	PDR - 2 months
2) ERI Contamination Control Plan	CDR - 3 months
3) ERI Launch Site Contamination Control Plan	CDR + 9 months Observatory PSR – 4 months
4) ERI I&T Contamination Control Plan	CDR + 3 months Observatory PER – 2 months
5) Monthly Written Status Reports	BOT through delivery to launch site
6) Mass Transport Analyses Reports	PDR – 1 month CDR – 1 month PER – 1 month
7) Particle Deposition Analyses Reports	PDR – 1 month CDR – 1 month PER – 1 month
8) MOLEKIT Analysis of Ten (10) Materials	PDR – 1 month
9) Image Analysis of Twenty (20) Wafers	During I&T
10) PDR Data Package	PDR
11) Pre-CDR Peer Review Package	CDR – 2 months
12) CDR Data Package	CDR
13) PER Data Package	PER
14) PSR Data Package	PSR
15) Final coating selection and application plan	CDR + 4 months
16) Coating Measurements Reports	ETU: CDR - 1 month Flight: PER – 1 month

Subtask (c): Cryogenic Systems Design, Instrumentation and GSE Hardware Support

The ERI Instrument includes an IR detector, which requires an active cryogenic system to achieve an operating temperature of 45 K. The ERI Instrument cryocooler is to interface with the thermal control system to provide the required heat rejection.

Analysis will be performed using software compatible with Systems Improved Numerical Differencing Analyzer (SINDA), Thermal Synthesizer Systems (TSS), Thermal Desktop or the Thermal Model Generator (TMG) software package.

The instrument requires twenty (20) sensors to provide thermometry that are spread from the spacecraft bus interface to the detector interface. The sensors shall be capable of providing

accurate temperatures during the cool down process, from 300 K down to the operating temperature of 45 K.

A Ground Support Equipment (GSE) cryogenic dewar with a cooled target for optical testing is required for the instrument. The GSE will consist of a 77 K optical target cooled with liquid nitrogen (LN2). The 77 K target will be at least 30 cm diameter. Design must include the required LN2 storage, piping manifold, the 77 K target, and the associated control system.

Statement of Work For Subtask (c) Cryogenic Systems Design, Instrumentation and GSE Hardware Support:

The Contractor team shall perform this work on-site at GSFC unless otherwise specified within the subtask.

1) Provide support to perform a preliminary design study for a cryogenic system that meets the thermal requirements listed in the RTO.
2) Produce a report detailing the design study.
3) Support preparation of a cryogenic thermal design and analysis of the detector interface. Provide support to develop analytical mathematical models, including geometric mathematical models.
4) Provide support to procure a space flight qualified cryocooler that meets the requirements of the RTO. This effort requires support for engineering requirements definition, statement of work preparation, and supplier surveillance. GSFC will perform all procurement functions not stated in this subtask.
5) Prepare the plan and procedures for the supplier to characterize the cryocooler in a thermal vacuum chamber. Support the cryocooler supplier in performance of this test. Perform pre-test cryocooler performance modeling, post-test modeling correlations, and generate a report on the at-vender test.

6) Provide support to design and analyze conductive pathways, select materials, and design structural components for the cryocooler that will accommodate the required heat transfer between the detector, cryocooler, and its support structure. Produce a report including the design and analysis results.
7) Provide support to determine strategies for cryogenic thermometry. Produce a specification for the twenty (20) sensors that will be in the instrument. Install the sensors into the instrument package.
8) Provide support to design the required cryogenic GSE dewar. Generate a report with analysis and drawings of the design.
9) Support integration of the cryocooler into the instrument and thermal system.

Milestones/Deliverables & Dates for Subtask (c):

Deliverable	Due Date
1) Preliminary design report	PDR – 30 days
2) Status report	Monthly after BOT + 3 months
3) Conductive pathways analysis report	CDR – 30 days
4) Cryocooler requirements definition report	PDR – 30 days
5) Supplier audit reports	Visit + 10 days
6) Cryocooler testing plan and procedure	CDR
7) Cryocooler test results report	CDR + 3 months
8) Specification for cryogenic thermometry of the instrument	PDR
9) Installation of the cryogenic thermometry	CDR + 6 months
10) GSE dewar design report	PDR
11) Final Report, including any drawings, analysis, parts, and materials provided at task completion	PSR

Subtask (d): Adiabatic Demagnetization Refrigerator (ADR) Support

NOTE: This subtask is not related to the ERI instrument.

A next generation IR detector, a superconducting transition edge sensor that requires an operational temperature of 70 mK, is under development at GSFC. To support the operation of these detectors, a two-stage Adiabatic Demagnetization Refrigerator (ADR) system has been selected to achieve and maintain the operational temperature. The 2nd stage ADR will be capable of rejection of a 0.25 µW detector load. The overall design of the system is performed by GSFC. The Contractor shall be responsible for support of the design and manufacturing of subcomponents.

A heat switch is required to operate the ADR. The heat switch shall operate at a 2 K operational temperature. Heat flow through the switch should be at least 10 mW/K when on and less than 5 µW/K when off. The heat switch must fit within a 50 mm x 50 mm x 200 mm envelope. Kevlar mechanical structures are required for supporting and thermally isolating the ADR and subcomponents. Wire leads are required to transmit current to the ADR. The leads shall be qualified for 2 amps and shall minimize heat leak into the system. The wire leads shall be capable of operation from 0.5 K - 10 K.

Statement of Work For Subtask (d) Adiabatic Demagnetization Refrigerator (ADR) Support:
The Contractor team shall perform this work on-site at GSFC.

1) Provide support to design a component that enables heat flow when necessary and isolation when required (heat switch or analogous technology). Produce a design study report.
2) Provide support for the design and selection of wire for the magnet leads for the ADR. Produce a design report and selection summary.
3) Provide support for design and analysis of thermally isolating structures for supporting components within an ADR. Produce a report on the design and analysis of the structures.
4) Provide support for winding the magnet wire for use in an ADR.
5) Provide support for growth of a chromium potassium alum salt pill for use in an ADR.
6) Provide support for prototyping small subcomponents using machining tools, such as a mill, lathe, and a drill press.

Milestones/Deliverables & Dates for Subtask (d):

Deliverable	Due Date
1) Heat switch design study report	BOT + 30 months
2) Design and selection report for wire leads	BOT + 33 months
3) Design and Analysis Report for thermally isolating structures	BOT + 36 months
4) Deliver an ADR magnet	BOT + 36 months
5) Deliver a Salt Pill	BOT + 36 months
6) Deliver prototype components	BOT + 36 months

Subtask (e): ERI Instrument Optical System Development

The optical system images the scene on the ground in the five (5) visible and four (4) LWIR bands onto their respective detectors, each of which is a linear array of 1024 pixels, which are 25 µm wide (total of 9 detector rows). The visible resolution is 60 m over the 30 km field of view, and the LWIR resolution is 100 m over the 50 km field of view. A key design objective is the minimization of mass and volume.

Statement of Work For Subtask (e) ERI Instrument Optical System Development:
The Contractor team shall support the GSFC civil servants in the design, fabrication, and verification of the optical system. The Contractor team shall perform this work on-site at GSFC.

1) Support the design and analysis for an optical subsystem that will meet the instrument imaging requirements over the lifetime of the mission.
2) Support presentation of the design at PDR.
3) Support presentation of the final design at CDR.

4) Support analysis of expected performance of the optical system in terms of imaging, stray light, and predicted effects of environmental disturbances.
5) Support the identification of cleanliness requirements to prevent degradation of optical surfaces and coatings.
6) Support the development of the optical error budget for the optical subsystem integration, alignment, and test.
7) Support the development of the optical test and integration plans and procedures.
8) Support the assembly, alignment, and test of the system, including analysis of the metrology results.
9) Support imaging tests of the optical system after instrument environmental tests.

Milestones/Deliverables & Dates for Subtask (e):

Deliverable	Due Date
1) Ray trace calculations of imaging performance over entire field of view in format compatible with Zemax	PDR – 2 weeks CDR – 3 weeks PER – 4 weeks
2) Stray light analyses in format compatible with FRED	PDR – 2 weeks CDR – 3 weeks PER – 4 weeks
3) Presentation materials in support of PDR	PDR – 2 weeks
4) Presentation materials in support of CDR	CDR – 3 weeks
5) Report of results of evaluation of cleanliness requirements	PDR CDR
6) Inputs to error budget development	CDR
7) Imaging test results report with analysis	PER
8) Post environmental imaging test results with analysis	PSR – 1 month

[End of RTO 1]

RTO-2

Task Title: Mechanical Engineering Design, Analysis and Integration & Test

Task Start Date:
10/1/2015

Task End Date:
9/30/2019

Location: On-site at GSFC unless otherwise specified in subtask.

Subtask Start Date:	Subtask (a):	10/1/2015
	Subtask (b):	10/1/2015
	Subtask (c):	10/1/2015
	Subtask (d):	10/1/2016
	Subtask (e):	10/1/2015
Subask End Date:	Subtask (a):	9/30/2019
	Subtask (b):	9/30/2019
	Subtask (c):	9/30/2018
	Subtask (d):	9/30/2019
	Subtask (e):	9/30/2019

Task Background:
The Middle Latitude Observer spacecraft bus shall be designed, analyzed, integrated, and tested in-house at GSFC. A significant amount of mechanical contract support shall be required to finish the development of the observatory's bus on time. This work shall include: mission-level mechanical engineering design, structural analysis support, mechanism design & analysis support, materials engineering support, and observatory integration and testing support.

Five (5) subtasks have been identified. Contractors shall work alongside civil servant engineers and attend regularly scheduled weekly meetings, occasional technical meetings, and reviews as needed. Contractors shall support major scheduled reviews, providing documentation ensuring that relevant mission requirements are being met. Work will be performed on-site at GSFC unless otherwise specified within the subtask. Milestone reviews (PDR, CDR, etc.) reference the Observatory schedule.

The following subtasks have been identified:

Subtask (a): MLO Mission-level Mechanical Engineering

Contractor support shall be used to develop mechanical systems requirements, generate an integrated mission CAD model and initiate preliminary packaging of the MLO, prepare interface control documents and drawings, provide a mission mass budget, provide CAD-based mass estimates, provide released fabrication, assembly and integration drawings, and support mission mechanical risk management. Ground support equipment design, such as lift slings, drill templates, integration fixtures, mechanical test fixtures, and transportation dollies are needed. The civil servant MLO Mission Mechanical Lead Engineer is the point of contact and technical monitor for the Contractor team and shall oversee all Contractor support.

Statement of Work For Subtask (a) MLO Mission-Level Mechanical Engineering:

1) Provide mechanical systems engineering and CAD support for the MLO spacecraft bus design effort. Develop mechanical systems requirements. Create and maintain the spacecraft bus CAD model.
2) Develop and maintain an integrated 3D CAD model of the MLO observatory (compatible with STEP file format). The model will be used to optimize instrument mounting locations on the spacecraft and shall have sufficient detail to ensure that all mechanical interface requirements are satisfied. ERI, CBORE, and other subsystem CAD models shall be supplied separately.
3) Prepare draft versions of interface control documents and mechanical interface control drawings. Drawings shall be compliant with all GSFC and ISO requirements. All mission hardware interfaces shall be addressed.
4) Calculate and report mission-level mass properties. Generate and maintain the mission-level mass properties table. Prepare final report.
5) Produce CAD fabrication drawings for the spacecraft bus. Drawings shall be checked and signed prior to release.
6) Provide design support and produce fabrication drawings for mechanical ground support equipment, such as lift slings, drill templates, integration fixtures, mechanical test fixtures, and transportation dollies for use during integration and testing.
7) Contractor shall attend weekly meetings scheduled by the Mechanical Lead Engineer and shall be prepared to discuss the status of the mechanical design.
8) Contractor shall support required peer reviews and mission-level PDR, CDR, PER, and PSR, as well as other reviews that occur during the task period of performance.
9) Generate and deliver a mechanical systems risk management plan and report.

Additional Government Furnished Equipment For Subtask (a):

- 3-D Pro Engineer CAD Model of ERI translated into STEPformat.
- 3-D Solid Works CAD Model of CBORE translated into STEP format.
- Computer workstations with GSFC-licensed IDEAS CAE software installed.

Milestones/Deliverables & Dates for Subtask (a):

Deliverable	Due Date
1) Spacecraft bus CAD model	Initial: BOT + 7 weeks Updates: 30 days prior to PDR, CDR, PER
2) Integrated MLO CAD model	Initial: PDR – 60 days Updates: 30 days prior to CDR, PER, and PSR
3) Mechanical interface control drawings and documents	Drawings: Initial: BOT + 8 weeks Updates: 60 days prior to PDR, CDR, PER, and PSR. Documents: Initial: BOT + 10 weeks Updates: 60 days prior to PDR, CDR, PER, and PSR.
4) Mass Properties Report	Tests + 30 days
5) Released flight hardware fabrication drawings	Drawings to be released periodically as needed
6) Released GSE fabrication drawings	Drawings to be released periodically as needed
7) Presentation data packages	30 days prior to PDR, CDR, PER, and PSR,
8) Mechanical systems risk management plan	30 days prior to each PDR and CDR.

Subtask (b): Structural Analysis Support

Contractor support shall be required to develop, maintain, and update the MLO mission finite element model (FEM) and perform finite element analysis (FEA) as well as other structural analyses. The civil servant MLO lead structural analyst shall oversee all Contractor support. All FEA shall be performed using MSC Nastran or a compatible solver. FEA pre- and post-processing solvers shall be MSC Nastran compatible. All FEMs shall pass standard validity checks detailed at http://femci.gsfc.nasa.gov/ValidityChecks/.

Statement of Work For Subtask (b) Structural Analysis Support:

1) The Contractor shall provide a Mission Level Analysis Plan that details all the required analyses for the spacecraft to verify that all design and verification requirements are met.
2) The Contractor shall develop and maintain a FEM of the spacecraft bus and shall integrate models for the instruments and other subsystems to create an observatory FEM. The FEM shall be used for all static and dynamic structural analyses. The FEM shall be constantly updated through the design process, and it must reflect the 3-D CAD model as it reaches maturity. Contractor is responsible for the management of the FEM numbering.

3) Contractor shall perform validity checks, prior to any FEM analysis, to ensure the mathematical accuracy of the model. http://femci.gsfc.nasa.gov/ValidityChecks/
4) Trade studies shall be performed and documented during the development of the mechanical design. Perform a trade study to determine the structurally optimal bus material and fabrication method.
5) Contractor shall develop finite element models of mechanical GSE hardware.
6) Contractor shall perform structural analysis on GSE designs.
7) Contractor shall attend weekly meetings scheduled by the Analysis Team Lead and shall be prepared to discuss status of the FEM and current analysis. The Contractor shall provide analysis status and/or results reports in support of weekly meetings.
8) Contractor shall support required peer reviews and mission-level PDR, CDR, PER, and PSR, as well as other reviews that occur during the task period of performance.
9) Contractor shall support the following tests: strength qualification, modal, sine vibration, and acoustics. Contractor shall perform all analysis required, and shall write the test plan and test report for each test.
10) Contractor shall correlate FEM utilizing the Modal test results.
11) Contractor shall perform the required analysis to create a Craig-Bamptom model of the observatory suitable for Coupled Loads Analysis (CLA) on the Falcon 1e launch vehicle.
12) Contractor shall perform CLA based on updated acceleration time history for each launch event, provided by the launch vehicle company to provide additional data recovery.
13) The Contractor shall write a Stress Report that summarizes all stress analysis, including all margins of safety, performed on the spacecraft members and sub-systems.
14) Contractor shall prepare a FEM Report that documents sub-systems, mass distribution, numbering of elements, type of elements, validity checks, materials, and normal modes.

Additional Government Furnished Equipment For Subtask (b):

- Finite Element Model of the ERI instrument.
- Finite Element Model of CBORE instrument.

Milestones/Deliverables & Dates for Subtask (b):

Deliverable	Due Date
1) Mission Level Analysis Plan	BOT + 3 weeks
2) Spacecraft bus FEM	BOT + 7 weeks
3) Spacecraft bus trade study	PDR – 3 months
4) Integrated MLO FEM	Initial: BOT + 10 weeks Updates: 60 days prior to PDR, CDR
5) FEM views, modal animations, and analysis results for PDR, CDR, and PER	3 weeks prior to PDR, CDR, and PER
6) Modal Test Plan	CDR + 3 months
7) Correlated MLO observatory FEM	Test + 2 months
8) Modal Test Report	FEM correlation + 1 month
9) Strength Qualification Test Plan	CDR + 4 months
10) Strength Qualification Test Report	Test + 1 month
11) Craig-Bampton model for CLA	CDR-level CLA: CDR – 5 months Verified loads cycle: FEM correlation + 2 months
12) CLA	C-B Model Delivery + 4 months
13) Stress Report	Initial: PDR – 1 month Update: CDR – 60 days Final: PER – 1 month
14) GSE finite element models	Initial: PDR – 3 months Final: PER – 1 month
15) GSE Stress Analysis Report	Initial: CDR – 60 days Final: PER – 1 month
16) FEM report	Initial: PDR – 1 month Updates: CDR – 60 days Final: PER – 1 month
17) Sine Vibe Test Plan	PER – 1 month
18) Sine Vibe Test Report	Test + 1 month
19) Acoustic Test Plan	PER – 1 month
20) Acoustic Test Report	Test + 1 month

Subtask (c): MLO Solar Array Drive Assembly

The Contractor shall develop a detailed design for the flight Solar Array Drive assembly (SADA) that meets or exceeds the requirements listed below. The Contractor shall support fabrication, assembly, test, and delivery of a flight qualified SADA. Drive control electronics design and

testing are not part of this task. No additional instruments or sensors are mounted on the solar array or boom. G-negation of the solar array assembly will be utilized for ground operation and testing. The solar array assembly is defined as the boom and the solar array panels outboard of the SADA.

Requirements For Subtask (c)

- Single drive axis mechanism.
- The Center of Mass of the Solar Array Assembly is 1.7 m outboard of the interface with the SADA.
- Assume fixed base with a Solar Array Assembly deployed frequency > 2.0 Hz.
- Solar Array Assembly Mass (80 kg).
- I_{xx} (drive axis) = 10 Kg-m^2 $I_{yy}=I_{zz}=250$ Kg-m^2 $I_{xy}=I_{yz}=I_{zx}= 0$
  Coordinate system origin at SADA-Solar Array Assembly interface
- SADA operational temperature range (measured at the housing and lubricated drive components): 273 K to 303 K.
- SADA survival temperature range (measured at the housing and lubricated drive components): 253 K to 323 K.

Statement of Work For Subtask (c) MLO Solar Array Drive Assembly (SADA):

1) Contractor shall support required peer reviews and mission-level PDR, CDR, PER, and PSR, as well as other reviews that occur during the task period of performance.
2) Develop a detailed design for the SADA that meets requirements. Produce CAD model and fabrication drawings. Provide supporting documentation.
3) Perform structural analysis on SADA design. Provide supporting documentation.
4) Develop environmental test plans and test reports for thermal and vibration testing (random and sine). Provide test support.
5) Support fabrication, procurement, assembly, and integration of the flight SADA in accordance with Quality Assurance (QA) protocols.
6) Demonstrate torque margin compliance with GEVS. Provide a torque margin compliance report.
7) Develop a life test plan for the SADA. Provide support for the life test of the SADA.

Milestones/Deliverables & Dates for Subtask (c):

Deliverable	Due Date
1) CAD model	Initial: PDR – 1 month Update: CDR – 1 month
2) Fabrication drawings	Drawings to be released periodically as needed
3) Structural analysis	Initial: PDR – 1 month Update: CDR – 1 month
4) Life Test Plan	CDR – 1 month
5) SADA Vibration Test Plan	CDR + 6 months
6) SADA Thermal Test Plan	CDR + 6 months
7) SADA Vibration Test Report	Test + 1 month
8) SADA Thermal Test Report	Test + 1 month
9) Torque Margin Compliance Report	Test + 1 month

Subtask (d): MLO Mission Integration and Testing of the Observatory

Contractor support shall be required for mechanical integration of the MLO observatory. Contractor shall be responsible for the full integration of the observatory, including the solar arrays, the high gain antenna, and the CBORE and ERI instruments. Work order authorization (WOA) and integration procedures shall be written. Support shall include engineers and technicians required to complete the full integration in preparation for observatory-level mechanical and thermal testing.

Contractor support shall be required for mechanical testing of the observatory. This shall include the test conductor who shall ensure that the observatory is prepared for testing, ready to be transported to GSFC test facilities, that all test plans and procedures are written and signed off, that the test is conducted properly, and that all success criteria are met. The conductor shall ensure that the hardware is safely returned to the integration facility. Testing shall include modal testing of the protoflight bus structure, all observatory mass properties testing, and protoflight qualification testing (mechanical and thermal). Testing of the instruments, deployables (solar arrays and high gain antenna), and other subsystems is not included in this subtask.
The ERI and CBORE instruments, the high gain antenna, and the solar array assembly are delivered as fully integrated subsystems prior to observatory integration.

Statement of Work For Subtask (d) MLO Mission Integration and Testing of the Observatory:

1) Contractor shall prepare the Mechanical Systems inputs in support of the overall mission-level I&T plan. The Mechanical Systems inputs shall include task details, schedule, and a mission-level I&T flow chart to be presented at CDR and updated for PER. This flow will be used during the I&T phase of the MLO project. The flow of mechanical activities will begin with assembly of the primary bus structure and end with the delivery of a fully

qualified observatory to the launch site. Contractor must work with the MLO mission mechanical lead engineer, the MLO lead structural analyst, MLO I&T Manager and other MLO mission personnel to support the develop of the I&T flow.

2) Contractor shall support the mechanical integration of the MLO bus, including the solar array assembly, the high gain antenna, and the CBORE and ERI instruments.
3) Contractor shall write work order authorizations (WOA).
4) Contractor shall write integration procedures.
5) Contractor shall write all mechanical and thermal test plans and procedures.
6) Contractor shall support modal testing of the protoflight bus structure.
7) Contractor shall support mass properties testing.
8) Contractor shall support the mechanical and thermal environmental tests, working with the facilities engineers and technicians. The Contractor shall ensure that the test is conducted properly and that all success criteria are met.
9) Contractor shall ensure that the hardware is safely transported between the various test facilities and the integration facility.

Milestones/Deliverables & Dates for Subtask (d):

Deliverable	Due Date
1) Mechanical Systems inputs to the Mission I&T plan	CDR – 30 days
2) Work Order Authorizations (WOAs)	As required
3) Integration procedures	I&T start – 30 days
4) Mechanical and thermal test plans	Test – 30 days
5) Mass properties reports	Test + 30 days
6) Mechanical and thermal environmental test reports	Test + 30 days

Subtask (e): MLO Mission Materials and Processes

Contractor support is required for Materials and Processes Assurance Engineering for the MLO mission. The Contractor shall provide support to product design teams and provide materials and processes related inputs tailored for the project's specific requirements. Contractor shall act as a liaison between the project and the GSFC Materials Engineering Branch Laboratories. The liason requires knowledge of capabilities and expertise and should remain cognizant of all project related activities occurring within the laboratories and ensure that results are reported promptly and accurately.

Reviews of on-site and off-site processing and quality facilities for producing flight hardware are required. Reports of findings for bringing facilities into compliance with project requirements shall be prepared.

Audits of on-site and off-site manufacturing facilities, in-process and end-item inspection for compliance with NASA and project requirements shall be reported.

Statement of Work For Subtask (e) MLO Mission Materials and Processes:

1) Provide a comprehensive Materials and Processes Selection, Control, and Implementation Plan (MPCP), addressing conformance to the requirements of NASA-STD-6016, with prescribed changes and a description of the method of implementation. The plan shall address the identification and documentation of materials and processes through Materials Identification and Usage Lists (MIULs). The plan shall also consider the procedures and required data documentation for proposed test programs to support materials screening and verification testing.
2) Provide materials assurance engineering support for the development and review of project documentation, with respect to the selection and application of materials and processes.
3) Review and recommend flight-usage for materials lists (MIULs) in accordance with project requirements.
4) Review and manage the use of non-compliant materials though Materials Usage Agreements (MUA).
5) Provide support for the evaluation of GSFC and off-site processing facilities for producing flight hardware. Prepare reports of findings for bringing facilities into compliance with project requirements.
6) Support the audit of NASA and off-site manufacturing of flight hardware, in-process, and end-item inspection for compliance with NASA and project requirements.
7) Materials assurance engineering shall support all required project and subsystem status reviews as well as support materials review board (MRB) meetings.
8) Provide engineering and technician support for laboratory operations associated with the testing and analysis of organic, ceramic, composite, and metallic materials.

Milestones/Deliverables & Dates for Subtask (e):

Deliverable	Due Date
1) MPCP	BOT + 60 days, for approval
2) MIUL	Preliminary: PDR- 30 days, for review As-Designed: CDR - 30 days, for approval As-Built: PER - 30 days, for approval
3) MUAs.	New MUAs: CDR - 30 days, for approval Revised MUAs: Identification + 30 days
4) Facility review reports	Visit + 10 days
5) Hardware inspection reports	Inspection + 10 days

[End of RTO-2]

Acronyms Definitions

ADR	Adiabatic Demagnetization Refrigerator
BRDF	Bidirectional Reflectance Distribution Function
b/w	Black and white
BOT	Beginning Of Task
CAD	Computer Aided Design
CBORE	Carolina Bay Observing Radar Experiment
CDR	Critical Design Review
CLA	Coupled Loads Analysis
cm	Centimeter
ERI	Earth Research Imager
FEA	Finite Element Analysis
FEM	Finite Element Modeling
FEMAP	Finite Element Modeling and Post Processing
FMEA	Failure Modes and Effects Analysis
FOV	Field of View
FRB	Failure Review Board
GDMS	Goddard Directives Management System
GEVS	General Environmental Verification Standard
GMM	Geometric Math Models
GOLD	Goddard Open Learning Design
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
HGAS	High Gain Antenna System
HTS	High Temperature Superconducting
I	Inertia
I&T	Integration and Testing
ICD	Interface Control Document
IDIQ	Indefinite Delivery/Indefinite Quantity
IR	Infrared
ISO	International Organization for Standardization
K	Kelvin
Kg	Kilogram
km	Kilometer
LN2	Liquid Nitrogen
LWIR	Long Wave Infrared
m	Meter
MIUL	Materials Identification and Usage List
mK	Mille-Kelvin
MLI	Multilayer Insulation

MLO	Middle Latitude Observer
μm	Micrometer (Micron)
mm	Millimeter
MOLEKIT	Molecular Kinetics Facility
MPCP	Materials and Processes Control Plan
MUA	Materials Usage Agreement
mW	Mill watt
NASA	National Aeronautics and Space Administration
nm	Nanometer
PDR	Preliminary Design Review
PER	Pre-Environmental Review
PSR	Pre-Ship Review
QA	Quality Assurance
RFA	Request For Action
RTO	Representative Task Order
SADA	Solar Array Drive Assembly
SINDA	Systems Improved Numerical Differencing Analyzer
STEP	Standard for the exchange of product model data
STOP	Structural Thermal Optical
TCON	Thermal Converter
TCS	Thermal Control Systems
TMG	Thermal Model Generator
TOMS	Task Order Management System
TSS	Thermal Synthesizer Systems
Vis	Visible
W	Watt