ICE, CLOUD, and Land Elevation Satellite (ICESat-2) Project RAPID III

SPACECRAFT OBSERVATORY DO

ATTACHMENT A

STATEMENT OF WORK (SOW) ICESat-2-SCPM-CTR-0301

Revision B
Effective Date: April 7, 2011

National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

CM FOREWORD

This document is an Ice, Cloud, and Land Elevation (ICESat-2) Project signature-controlled document. Changes to this document require prior approval of the applicable Product Design Lead (PDL) or designee. Proposed changes shall be submitted in the ICESat-II Management Information System (MIS) via a Signature Controlled Request (SCoRe), along with supportive material justifying the proposed change.

In this document, a requirement is identified by "shall," a good practice by "should," permission by "may" or "can," expectation by "will," and descriptive material by "is."

Questions or comments concerning this document should be addressed to:

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***** Signatures are available on-line at: https://icesat-2mis.gsfc.nasa.gov *****

CHANGE RECORD PAGE

Document Version	Document Release Date	SCoRe Number	SCoRe Approval Date	Pages Affected	Description
Rev -	02/22/2011	TBD	02/22/2011	All	Initial release of document.
Rev A	03/31/2011	TBD	03/31/2011	Page 60	Removed section 4.1.2.3. Added decommissioning planning to section 4.3.7.4 Section 4.3.7.4 now covers everything from section 4.1.2.3
Rev B	04/07/2011	TBD	04/07/2011	Section 4.3.7.4	Modify section 4.3.7.4 to further clarify that any work after on-orbit acceptance will be a modification to the DO

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RAPID III
STATEMENT OF WORK

1.0 Introduction

This Statement of Work (SOW) defines the Contractor's efforts required for the Spacecraft implementation and Observatory integration for the Ice, Cloud, and Land Elevation Satellite-2 (ICESat-2) Mission under the Rapid Spacecraft Acquisition (RSA) "Rapid III" Contract. The purpose of this Delivery Order (DO) is to produce and deliver to the National Aeronautics and Space Administration (NASA) an ICESat-2 spacecraft with an option for the Mission Operations Center development and operation.

2.0 Scope

The Scope of Work encompasses all the required effort from receipt of the ICESat-2 Rapid III DO, through the launch, delivery, on-orbit checkout, acceptance of the spacecraft and continued on-orbit support.

3.0 Documents & Requirements

3.1 Applicable Documents

These documents apply directly to the performance required, and contain provisions that constitute requirements of this SOW on the Rapid III Contract ICESat-2 DO to the degree specified in Section 4.0.

Document Title	Doc #	Rev:
ICESat-2 MAR Applicable Documents	(See MAR)	(See MAR)
ICESat-2 Spacecraft-ATLAS Interface Description Document	ICESat-2-SYS-IFACE-0325	Rev A
ICESat-2 Spacecraft Requirements Document	ICESat-2-SYS-REQ-0002	TBD
ICESat-2 Launch Services Interface Description Document	ICESat-2-SYS-IFACE-0326	TBD
ICESat-2 Environmental Requirements Document	ICESat-2-SYS-SPEC-0222	TBD
ICESat-2 Spacecraft – Ground Interface Description Document	ICESat-2-SYS-IFACE-0324	Rev A
ICESat-2 Mission Operations Center Requirements Document	ICESat-2-MOC-REQ-0537	Rev -
ICESat-2 Mission Operations Center SOW	ICESat-2-MOC-CTR-0472	Rev -
ICESat-2 Mission Operations Center CDRL	ICESat-2-MOC-CTR-0473	Rev -
ICESat-2 Radiation Specification Document	ICESat-2-SMA-REQ-0037	Rev -
ICESat-2 Surveillance Plan	ICESat-2-SCSMA-PLAN-0193	Rev -
ICESat-2 Spacecraft – ATLAS Mechanical Interface Control Document	ICESat-2-MECH-IFACE-0478	Rev -
ICESat-2 Spacecraft – ATLAS Mechanical Interface Drawing	2153300	Rev -
ICESat-2 Spacecraft-ATLAS Electrical Interface Control Document	ICESat-2-ELEC-IFACE-0205	Rev -
ICESat-2 ATLAS Electrical Block Diagram	ICESat-2-ELEC-SPEC-0501	Rev A
ICESat-2 GOLD Rules Appendix	ICESat-2-SYS-RPT-0620	Rev -
Security of Information Technology	NPR 2810.1	A
NASA Space Flight Program and Project Management Requirements	NPR 7120.5	D
NASA Export Control Program	NPR 2190.1	A
NASA Procedural Requirements for Mishap and Close Call Reporting, Investigating, and Recordkeeping w/Change 5	NPR 8621.1	B
GSFC MANAGEMENT SYSTEM NONCONFORMANCE CONTROL	GPR 5340.2	I

REPORTING OF MISHAPS AND CLOSE CALLS	GPR 8621.1	B
ANOMALY NOTIFICATION SYSTEM FOR CODE 400 PROGRAMS AND PROJECTS	400-PG-8621.1	H
CONFIGURATION MANAGEMENT	GPR 1410.2	D
NASA Systems Engineering Processes and Requirements w/Change 1	NPR 7123.1	A
SYSTEMS ENGINEERING	GPR 7123.1	A
NASA Software Engineering Requirements	NPR 7150.2	A
Rules for the Design, Development, Verification and Operation of Flight Systems	GSFC-STD-1000	Rev E
ENGINEERING PEER REVIEWS	GPR 8700.6	B
Criteria for Flight and Flight Support System Lifecycle Reviews	GSFC-STD-1001	A
Configuration Control	400-PG-1410.2.1	C

3.2 Reference Documents

These documents contain information relating to the work required by this SOW on the ICESat-2 Rapid III Delivery Order.

Document Title	Doc #	Rev:
ICESat-2 MAR Reference Documents	(See MAR)	(See MAR)
ICESat-2 Ground System Requirements Document	ICESat-2-GSPM-REQ-0330	Rev -
ICESat-2 Geo-location Budgets	ICESat-2-SYS-REQ-0450	Rev -
ICESat-2 Engineering Peer Review Plan	ICESat-2-SYS-PLAN-0100	Rev -
ICESat-2 Mission Requirements Document	ICESat-2-SYS-REQ-0147	Rev C
ICESat-2 Mission Operations Concept Document	ICESat-2-SYS-PLAN-0006	Rev A
ICESat-2 Radiation Environment Description Document	ICESat-2-SYS-REQ-0277	Rev -

3.3 Requirements Precedence

In the event of a conflict in requirements between this SOW and other documentation, the order of precedence shall be: SOW, SRD, GRD, SC-Ground IDD, the ERD and the MAR, then any other referenced document. Applicable documents take precedence over Reference documents. The Contractor shall notify the Contracting Officer of any inconsistency in this DO, including all attachments and applicable documents. Upon notification of an inconsistency, the Contracting Officer will clarify which requirement takes precedence, and may modify the contract as deemed appropriate.

3.4 Terms and Definitions

In this SOW, a requirement is identified by "shall", a good practice by "should", permission by "may" or "can", expected outcome or action by "will" and descriptive material by "is" or "are" (or other verb form of "to be").

The term "TBS" (To Be Supplied) means that the Government will clarify or supply the missing information during the course of the DO. "TBR" (To Be Reviewed) means that the stated information will be reviewed for appropriateness by the Contractor and the Government and the value may be changed prior to final definition by the Government during the course of the DO. "TBD" (To Be Determined) indicates further research or analysis is needed to determine the information, during the course of the DO. "TBP" (To Be Proposed) means the Contractor proposes the information with the Offer submission for Government review and approval. All changes to resolve these "TBX" items will be done through a formal process of configuration change review, approval, and DO modification.

For the purposes of the ICESat-2 DO, the term "developer" as used in the ICESat-2 MAR shall be considered synonymous with "Contractor"

3.5 Non-Disclosure Agreements

The Contractor is responsible for executing any Non-Disclosure Agreements the Contractor deems necessary to enable information sharing among the ICESat-2 participating product and support Contractors and Subcontractors. Any other formal agreements between the Contractor and other ICESat-2 participating Contractors relevant to this as it pertains to this DO will be subject to Government review.

The Contractor is responsible for conducting Technical Assistance Agreements (TAAs) as required to implement the spacecraft and instrument integration and verification.

4.0 Work Performed by the Contractor

4.1 Standard Services

For this Delivery Order, the effort to produce a Rapid III Core Spacecraft with selected Rapid III Core Spacecraft Options and ICESat-2 mission-unique modifications required in the DO, results in a product called the ICESat-2 Spacecraft.

The effort to integrate ATLAS Instrument with the ICESat-2 spacecraft and qualify the combined payload instrument and ICESat-2 spacecraft in accordance with the DO, results in a system called the ICESat-2 Observatory.

4.1.1 ICESat-2 Spacecraft

The Contractor shall develop, implement, integrate, and test an ICESat-2 Spacecraft that is ready for ATLAS instrument integration, in accordance with all ICESat-2 mission requirements in the SRD and other documents specified in section 3.0 of this SOW.

4.1.2 ICESat-2 Spacecraft Option(s)

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4.1.3 ICESat-2 Mission Specific Modifications

In order to meet the ICESat-2 mission requirements as defined in the attached documents, the Contractor shall modify their Rapid III Core Spacecraft and Core Spacecraft Options as necessary.

4.1.4 Mission Observatory

The Contractor shall integrate the ATLAS instrument with the ICESat-2 spacecraft, qualify the resulting Observatory, ship the Observatory to the launch site, provide launch support and flight operations support, and satisfy all of the requirements of Section 4.3 and other documents specified in section 3.0 of this SOW applicable to the observatory.

4.2 Non-Standard Services

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4.2.1 Mission Specific Non-Standard Services

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4.2.1.1 Special Studies

ICESat-2 special studies will be issued by the Government and annually capped in maximum hours or funds for Contractor efforts in assessments, analysis, trades, and similar activities in areas that are not known at this point in the mission.

The Contractor shall perform special studies relating to the development, implementation, characterization, qualification, and operation of the Observatory, as authorized by the Government, and in accordance with the DO.

For proposal costing purposes, assume a total task support pool of 10,000 hours, extending over the development life cycle until Observatory I&T has begun. The Government is not obligated to fund any residual study hours beyond hours authorized in special study task orders.

4.2.1.2 Resident Office Services and Facilities

The Contractor shall provide office accommodations for three full time ICESat-2 Project Office representatives at the Spacecraft manufacturing facility. These accommodations are required to support the ICESat-2 Project Office throughout the performance of the DO. Accommodations for an additional 5 Project Office representatives at the spacecraft manufacturing facility shall be provided during spacecraft and observatory integration and test activities.

The Contractor shall provide office accommodations for five personnel from the ICESat-2 Instrument team during the period of Observatory integration and test, through shipment to the launch site. The accommodations shall be in the vicinity of the Instrument GSE to facilitate their day-to-day activities, and located outside the clean room.

The Contractor shall provide office accommodations for three Flight Operations Team (FOT) personnel during the period of spacecraft integration and test. The period of time for the FOT members shall coincide with the start of box-level integration of their assigned subsystem(s) and shall end at the completion of integration of that subsystem to the spacecraft. The Contractor shall provide office accommodations for one FOT member during the period of Observatory I&T.

Office accommodations shall include, but not be limited to, facilities to support in-plant representatives at the spacecraft development and build site, including securable office space, furniture, facsimile machine, office supplies, file and storage areas, speaker telephones, network access to the Contractor's electronic database, and access to a copier and a dedicated conference room, from DO award through Launch. The Contractor shall provide within these offices direct-dial long-distance telephone access, high-speed Internet access and access to an ISP (Internet Service Provider) outside the Contractor's facility to allow access to the GSFC and other networks.

4.2.1.3 On-orbit Task Support

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4.2.2 Non-Mission Specific Non-Standard Services

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4.2.3 Non-Mission Specific Hardware

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4.3 Standard Services Implementation

This section describes the effort required of the Contractor upon receipt of a DO.

The Contractor shall furnish all the necessary personnel, facilities (except facilities expressly stated in the Government Furnished Equipment list), equipment, services, and materials to design, analyze, fabricate, integrate, test, verify, and deliver the Spacecraft, integrate and test the Observatory, and support launch and acceptance activities, and sustaining engineering for the Observatory developed under this DO. This work shall be performed in accordance with the requirements of this document and all attachments.

4.3.1 Program Management

The Contractor shall provide a Program Management (PM) function that is responsible for control and coordination of all activities on the ICESat-2 DO. The PM function shall serve as the central point of contact with the Government for information for all activities under the DO.

The Contractor's program management shall report to a level of company management appropriate to ensure prompt resolution of all problems. The Contractor shall provide for, and facilitate the use of, this Program Management function to provide to NASA periodic reporting (within 10 business days of period closing), timely (within 48 hours) insight into issues, a program of formal and informal reviews, and on-going insight into the technical, quality, safety, security, and programmatic performance and status of all of the Contractor's responsibilities and activities performed under the DO. The Contractor shall prepare and deliver a comprehensive ICESat-2 Program Management Plan that shall be maintained over the life of the DO, as required by CDRL PM-2. The Contractor shall also perform all work necessary to successfully implement and complete the following program functions: Program Security, Property Management, Environmental Program Compliance, Export and International Traffic In Arms Regulation (ITAR) compliance, and OPSEC custodianship. The Contractor shall document security requirements and export control requirements in a Program Security Plan (CDRL PM-5) and in compliance with NPR 7120.5D and NPR 2190.1. The Contractor shall comply with NPR 8621.1, GPR 5340.2, GPR 8621.1, and 400-PG-8621.1.1E for mishaps, close calls and non-

conformances and shall make required notifications and route required documentation through the ICESat-2 Project Office at GSFC. The Contractor will be provided with the necessary current contact information.

4.3.1.1 Government Insight and Surveillance

The Contractor's PM function shall provide to the Government reporting and real-time insight into program status, as well as, technical and programmatic performance information on all of the Contractor's responsibilities and activities performed under the DO.

Insight is defined as the understanding necessary to knowledgeably concur with the Contractor's actions through watchful observation, inspection, or review of program events, documents, meetings, tests, audits, hardware, etc., without approval/disapproval authority.

The Contractor shall adhere to the surveillance plan for ICESat-2 as defined in the ICESat-2 Surveillance Plan (ICESAT-2-SCSMA-PLAN-0193). Should the Government identify non-compliance with requirements, a difference in interpretation of test results or in requirements, the Government will take action to ensure compliance.

The Contractor shall notify the Government Contracting Officer, the Government resident office or the appropriate Government operations organization or personnel of meetings, reviews, operations or tests in sufficient time to permit meaningful Government participation.

The Contractor shall grant access for NASA mission assurance and other representatives to conduct audits, assessments, surveys and GMIPs as outlined in the ICESat-2 Surveillance Plan, upon notice or as otherwise requested by the Government. The Contractor shall supply documents, records, equipment, and a work area within the Contractor's facilities.

The Contractor's Program Management function shall provide to the Government reporting and at least weekly insight into program status, as well as technical and programmatic performance of all of the Contractor's responsibilities performed. The Contractor shall prepare and lead weekly teleconferences with the Government to discuss status, risks, issues, schedule and other business related activities.

The Contractor shall prepare and submit monthly status reports in accordance with CDRL PM-1.

4.3.1.2 Control of Sensitive Information

The Contractor shall implement appropriate management systems that prevent the improper dissemination of sensitive information associated with the mission efforts.

4.3.1.3 Documentation

The Contractor shall develop, produce, deliver, and maintain all documentation required by the ICESat-2 Contract Data Requirements List (CDRL). CDRL items shall be delivered in accordance with ICESat-2 CDRL Tables.

All efforts, including the performance of tests and analyses not otherwise explicitly stated in other parts of the SOW, but determined jointly by the Contractor and the Government to be mission critical, shall be performed and documented by the Contractor. All documentation, data, and analyses generated for, or applicable to, the spacecraft design, fabrication and test, whether formal or informal, deliverable or non-deliverable shall be made available to the Government and Government support Contractor's with appropriate NDA's in place upon request. This information shall be provided electronically if possible through a Contractor provided web portal.

The Contractor shall provide a Specification Tree in accordance with CDRL SE-6.

The Contractor shall document and report lessons learned throughout the project life-cycle. Lessons learned shall be reported at each of the reviews defined in Section 4.3.1.4.2. The Contractor shall submit a Final Report and Lessons Learned in accordance with CDRL SE-8.

All documentation, data and analyses generated for, or applicable to, the DO effort, shall be made available to the Government upon request at the Contractor's facility or electronically.

4.3.1.4 Spacecraft Project Reviews

The Contractor shall conduct reviews and provide for timely reporting of project status to the Government. This shall include discussions on problem areas and timely transfer of technical information to the Government, including progress and status on achieving major project milestones and materials required by the Government for systems review and evaluation.

The Contractor shall conduct major reviews as outlined in the following sections. A Major Review is a meeting held at each major implementation milestone, where information is formally presented to a panel of Government experts and external independent reviewers. These experts and reviewers have the responsibility and authority to recommend next steps such as continue as planned, revise the plan, take corrective actions, provide more information, etc. All Spacecraft and Observatory Reviews in Section 4.3.1.4.2, and the Mission Reviews in Section 4.3.1.4.4 are Major Reviews. Major reviews can involve up to 40 Government representatives, and run up to four days. Formal action items are logged and tracked by the Project Office. Technical direction may be forthcoming from a Major Review.

The Contractor shall provide a review data package containing appropriate reference documentation for each review. The minutes and action items that result from these reviews

shall be documented by the Contractor and made available to the Government. If any deficiencies are found at the reviews, the Contractor shall be required to develop a corrective action plan. The Contractor may proceed prior to approval of the action plan at its own risk. The Contractor shall present at each review the status of all open action items up to that point in the implementation, with the corrective action or resolution for each item.

4.3.1.4.1 Monthly Program Status Reviews (MPSRs)

MPSRs shall be conducted in a monthly rotation of locations: at the Contractor's facility, GSFC, and via Video Conferencing.

At a minimum, the Contractor shall present the following information at each MPSR:

1. Status of work being performed including appropriate schedule progress and metrics;
2. Milestone Monitoring - The Contractor shall report on the progress made toward accomplishing each of the planned project milestones. Each report shall include a listing of major accomplishments and a discussion of any problems associated with each milestone as well as their resolution;
3. Changes to design parameters such as weight, power profile, communications, system performance, etc.;
4. Resource allocations and margins (e.g. telemetry, commands, power, weight, data storage, processor capability, etc.);
5. Status of technical issues;
6. Risks
7. Descriptions and status of technical problems and the resolutions;
8. Subcontract technical performance; and
9. Performance assurance status including non-conformance and failure report dispositions.

4.3.1.4.2 Spacecraft Systems Reviews

The Contractor shall provide technical and management support to certify the ICESat-2 Spacecraft or Observatory readiness at the following baseline set of spacecraft systems reviews. The Contractor shall support a dry run of the SRR, PDR, CDR and IIRR at the Contractor's facility. Each dry run shall be held no later than two weeks prior to the formal review. The Contractor shall meet the success criteria for the corresponding reviews as documented in the GSFC-STD-1001 Criteria for Flight Project Critical Milestone Reviews

Spacecraft Systems Reviews *	When	Length (Days)	Location	CDRL Deliverable
S/C Requirements Review (SRR)	Award + TBP mos	3	Contractor's Facility	CDRL 15A
S/C Preliminary Design Review (PDR)	Award + TBP mos	4	Contractor's Facility	CDRL 15B
S/C Critical Design Review (CDR)	Award +	4	Contractor's	CDRL 15C

	TBP mos		Facility	
Instrument Integration Readiness Review (IIRR)	TBP	2	Contractor's Facility	CDRL 15D
Observatory Pre-Environmental Review (PER)	Test – 1 mo	3	Contractor's Facility	CDRL 15E
Observatory Pre-Shipment Review (PSR)	Launch - 90 days	3	Contractor's Facility	CDRL 15F
Observatory Acceptance Review (OAR)	Launch + 2 mos	1	GSFC	CDRL 15G

The Contractor shall host and provide data for these reviews.

The Government will chair these reviews and provide Requests for Action (RFAs) to the Contractor for response. The PDR, CDR, PER and PSR will be additionally attended by a Government Integrated Independent Review Team (IIRT). The Contractor shall provide to the Government, for approval, formal responses to all RFAs.

At or before each review, the Contractor shall provide to the Government the CDRL submissions required relative to that review meeting as indicated in the ICESat-2 CDRL and MAR.

Each review shall be considered complete when: (1) the Government chairperson for the review provides notice that the criteria for successful completion have been satisfactorily met; (2) all RFAs deemed 'critical' by the chairperson have been closed to the Government's satisfaction and (3) all CDRLs required at or prior to that review have been delivered and found to be acceptable by the Government. Acceptance by the Government may require that all CDRL item modification recommendations resulting from Government "Review" or required for Government "Approval" have been incorporated by the Contractor. The criticality of RFA's will be determined and documented by the review chairperson when submitted to the Contractor.

4.3.1.4.3 Other Meetings/Reviews

In addition to these reviews the Contractor shall provide the following:

REVIEW	WHEN	WHERE	DAYS	CDRL
Spacecraft Kick-Off	Award + 1 week	Contractor's Facility	2	n/a
Weekly Status Telecon	Weekly	Telecon	0.2	n/a
Working Group Meetings	25 per year	Various/Telecon	2	n/a
Technical Interchange Meetings	12 per year	Various/Telecon	2	n/a
Peer Reviews	18 per year	Contractor	1	n/a

Observatory Test Readiness Reviews	1 week before test	Contractor	1	n/a

Spacecraft Kickoff

The Contractor shall host a Spacecraft Kick-Off meeting to present the plans, schedules, and activities required to meet the DO. The agenda and information to be presented shall be coordinated with the Government prior to the meeting, and will largely be based on the Contractor's offer, updated to reflect any changes since the offer submission, including any directed changes.

Weekly Status Teleconference Requirements

The Contractor shall support Weekly Status Teleconferences throughout the performance of the DO. If agreed to by the Government, a Weekly Status Teleconference will not be required during the week that an MPSR is held. The Contractor shall address the following topics as a minimum in the teleconferences:

1. Activities and plans, and the progress against those plans
2. Review of planned upcoming meetings and events
3. Any communications and correspondence related to the implementation, including Engineering Review Board activities.
4. Descriptions and status of technical problems and the resolutions.
5. Any anomalies and problem reports generated since the last teleconference
6. Issues and action items.

Working Group Meetings Requirements

The Government has identified several Working Groups to address specific ICESat-2 aspects. A Working Group is a cross-organizational team that meets periodically to address specific mission functions or implementation processes. Working Groups will meet at the lead organization's facility, typically for two days, several times a year, for each group's technical focus or topic. Actions and agreements will be tracked by the Working Group lead. Working Group meetings can be combined with other meetings for more effective use of time and travel, and may be via teleconference. No technical direction is given at a Working Group meeting. Each involved party will do all changes required to implement solutions resulting from Working Group meetings through a formal process of configuration change review, approval, and DO modification.

The Contractor shall host or attend the following working group meetings:

1. Space to Ground & Network Interface Working Group
2. Mission Operations Working Group
3. Systems Engineering Working Group (includes instrument interface)

4. Observatory I&T Working Group (instrument-spacecraft integration and test planning)
5. Mission Integration Working Group (MIWG) (annually, led by the launch vehicle Contractor)
6. Mission Data Systems Working Group
7. Operations Security (OPSEC) Working Group (bi-annual through IIRR).
8. Spacecraft Verification Working Group
9. On-Orbit Verification Working Group
10. Safety and Mission Assurance Working Group
11. Ground Operations Working Group at the Launch Site

Not all working groups meet regularly or over the implementation lifetime. Working groups shall be disbanded after the objectives of the group have been accomplished if agreed to by the Government. Additional working groups may be added during the performance of the DO. The leader of the particular working group will informally track actions and minutes from the working group meetings. The Contractor shall support the launch vehicle Contractor in closing MIWG and GOWG action items.

Technical Interchange Meetings Requirements

A Technical Interchange Meeting (TIM) is an informal meeting between the Contractor and approximately five to ten Government representatives to discuss a system process or feature. For example, to reach understanding of an operation or analysis, presentation of test results, discuss planned interface changes, plan for an upcoming test, etc. TIMs typically are held at a Contractor's facility and typically run two days, and occur monthly. Experts may be dialed-in via teleconference. TIMs involving the instrument, launch vehicle, or Ground Segment developers may be conducted at the spacecraft, or other developer's facilities. Parties involved in the TIM shall be notified at least a week in advance to allow travel to a Contractor facility. The TIM organizer tracks actions. No technical direction is given at a TIM. Each involved party will do all changes required to implement solutions resulting from TIMs through a formal process of configuration change review, approval, and DO modification.

The Contractor shall convene and support Technical Interchange Meetings (TIMs) with the several ICESat-2 Contractors (e.g. SIPS developer, MOC Contractor, Instrument provider, S/C discipline engineers, LV Contractor etc.), at the Contractor's facility, or the Instrument Provider facilities or other facilities, at the mutual consent of the participants. There will be one TIM on the average every month over the course of any year. The Contractor shall inform the Government at least one week in advance of each TIM. The Contractor shall identify and track all actions assigned at TIMs.

Peer Reviews Requirements

Peer Reviews provide focused, in-depth technical discussions that support the evolving design and development of a product subsystem including critical documentation or data packages. The peer review purpose is to add value and reduce risk through expert knowledge infusion,

confirmation of approach, and specific recommendations. A peer review provides a penetrating examination of design, analysis, manufacturing, integration, test and operational details, drawings, processes and data. Peer reviews shall be held for each critical subsystem in the months and weeks prior to a major review as a forum to generate and critique the review material, and also as-needed during the implementation whenever expert involvement is needed, for example, on part, material, test, or process issues. Peer reviews shall take place at the Contractor's facility and typically lasts one day. Peer reviewers shall include Contractor peer representatives as well as Government representatives from within the ICESat-2 Project and external to the Project. The peer review organizer tracks actions. Technical issues identified at a peer review shall be raised to Contract and Project Management to determine appropriate actions.

In addition, the Contractor shall convene peer reviews on mutual consent with the Government's request, to explore and resolve issues related to subsystem design, analysis, and performance. The Government will also request peer reviews on parts, materials, processes, and testing, as needed. The Contractor shall provide an Engineering Peer Review Plan per MAR DID 8-3 and shall be in accordance with the ICESat-2 Engineering Peer Review Plan.

The Contractor shall define and implement comprehensive subsystem/unit level design reviews and documentation in accordance with CDRL-SE-3.

4.3.1.4.4 Mission Reviews

In addition to the above reviews, the Contractor shall attend and provide support to various mission reviews. The Contractor shall provide review documentation in accordance with CDRL-SE-1. As a baseline, support of the following mission reviews shall be assumed:

Mission Reviews *	When	Length (Days)	Location	CDRL
Mission Operations Review (MOR)	L-22 months	2	Government Site	SE-1K
Flight Operations Review (FOR)	L-10 months	2	Government Site	SE-1M
Flight Readiness Review (FRR)	L- 2 weeks	1	Launch Site	SE-1Q
ATLAS Instrument PDR	L-53 months	4	Instrument Provider	n/a
Mission PDR	L-47 months	4	GSFC	SE-1H
Ground System PDR	L-48 months	3	GSFC	n/a
ATLAS Instrument CDR	L-42 months	3	Instrument Provider	n/a
Ground System CDR	L- 36 months	3	GSFC	n/a

Mission CDR	L-35 months	3	GSFC	SE-1J
ATLAS Instrument PER	L-23 months	3	3Instrument Provider	n/a
System Integration Review	L-15 months	3	GSFC	SE-1L
ATLAS Instrument PSR	L-18 months	3	Instrument Provider	n/a
Mission Readiness Review	L-1 month	4	GSFC	SE-1O
Safety & Mission Success Review	L-1 month	3	GSFC	SE-1P
Launch Readiness Review	L-1 week	1	TBR	SE-1R
Post Launch Assessment Review	L+2 months	3	GSFC	SE-1S
Critical Events Readiness Review	L+TBD	4	GSFC	SE-1T
Mission Operations Center PDR	L-49 months	2	MOC Provider	n/a
Mission Operations Center CDR	L-36 months	2	MOC Provider	n/a

The purpose of the MOR is for the Government project to provide to the Government Integrated Independent Review Team (IIRT) a comprehensive status of the project's mission operations planning, including a breakdown of requirements to the various elements and plans for verification and validation of those requirements.

The purpose of the FOR is for the Government project to present to the IIRT the state of readiness of the Flight Operations Ground Systems to support prelaunch, launch and flight operations.

The purpose of the FRR is for the Government project to provide to the launch management the state of readiness for all flight and ground systems to support launch and operations. The FRR is used to determine the final go/no-go decision for proceeding with the launch countdown.

Coordination of Mission Systems Design Reviews such as Mission PDR and Mission CDR with the related Spacecraft reviews shall be as indicated in the DO.

4.3.1.5 Engineering Change Proposals, Deviations and Waivers

In accordance with CDRL 14, Engineering Change Proposals (ECP), Deviations and Waivers, the Contractor's PM function shall be responsible for the timely reporting, submission and negotiation with the Government on all ECPs.

4.3.1.6 Electronic Distribution

The Contractor shall distribute CDRL deliverables and other ICESat-2 documentation to the ICESat-2 Project Office electronically. The Contractor shall provide a signed hard copy cover sheet for each CDRL item, invoice, modification, etc. for the DO file.

The Contractor shall establish a joint Contractor/Government working group to define acceptable requirements and methods for access via the internet, provisions for protected e-mail, transmission of all Contractor, Subcontractor, vendor proprietary data, ITAR/Export Controlled information, Government For Official Use Only information, and NASA unclassified sensitive information between program elements and facilities. All ITAR documentation shall be labeled and distributed using methods that meet ITAR regulations.

The Contractor shall provide a web-based, password-protected portal capability to facilitate the communication of information between the Contractor and the integrated ICESat-2 Project Team. Deliverables and informal documentation for review generated during the DO performance shall be placed on this website in addition to the formal delivery of these items as specified in the CDRL.

4.3.1.7 Schedule Management

The Contractor shall establish, implement, and maintain an integrated schedule in accordance with CDRL PM-3, Integrated Master Schedule. The Contractor shall prepare and submit monthly status reports in accordance with CDRL PM-1.

4.3.1.8 Risk Management

The Contractor shall establish and maintain a comprehensive risk management program in accordance with the ICESat-2 Spacecraft Mission Assurance Requirements (MAR) document. The Contractor shall generate a Risk Management Plan in accordance with ICESat-2 MAR DID 7-1. The Contractor shall generate a risk report (including mitigation activities) that is presented and reviewed at all Monthly Project Status Reviews (MPSRs). NASA shall have ongoing access (meetings and documentation) to risk identification and mitigation information at all levels of the Contractors and major Subcontractor's organizations performing ICESat-2 program work.

4.3.1.9 Configuration Management

The Contractor shall implement and execute a Configuration Management (CM) Program that complies with NASA requirements for control of hardware, software, and other program configured items. These requirements shall include compliance with GPR 1410.2, NPR 7123.1A and the ICESat-2 Configuration Control Procedure. The Contractor shall generate a Configuration Management plan in accordance with CDRL PM-6.

The Contractor shall notify the Government of Configuration Control Board (CCB) meetings and

allow Government participation at all CCB meetings. The Contractor shall maintain configuration of deliverable items throughout all phases of assembly, integration, and test. The Contractor shall perform and document configuration verification as assemblies are incorporated into higher-level assemblies and at major Project milestones (e.g., pre-environmental test, pre-ship, pre-launch, etc). The Contractor shall have a change classification and impact assessment process that results in Class 1 and Class 2 Configuration Change Requests (CCRs) being forwarded to NASA prior to being boarded. Change Classes are defined in 400-PG-1410.2.1. Class 1 changes impact functional, operational, or performance requirements, system safety, schedule, single point failures, external interfaces, and shall require government approval prior to implementation of the change. If the government determines that a change has been incorrectly categorized as Class 2 the Contractor shall resubmit the change as Class 1 for approval.

The Contractor shall submit for Government consideration a waiver or deviation for any flight item that is found to be non-compliant with the requirements of the DO SOW or Applicable Documents to the DO, and is not reworked to be compliant, or is not replaced with a compliant item.

The Contractor shall provide the Government electronic access to the Contractor's system for tracking non-compliances.

The Contractor shall prepare and provide the following configuration control documentation:

a. CCB status shall be reported at the MPSR
b. Engineering Drawings and Change Notices
c. The Configuration Item Identification List (CIIL) and the Computer Software Configuration Items (CSCIs) and Hardware Configuration Items (HWCIs)

4.3.1.10 Subcontractor Management

The Contractor shall ensure that technical, cost, and schedule oversight of Subcontractors is established and maintained. The Contractor shall ensure that all program, technical, insight, and ICESat-2 mission assurance requirements are flowed to subcontracts within 30 calendar days of ICESat-2 work being performed by the Subcontractor. Status of all subcontracts shall be reported at each MPSR. The Contractor shall establish appropriate incoming inspection, process, and acceptance testing of Subcontractor deliverables. The Contractor shall ensure that Subcontractors have established acceptable programs for parts and materials, quality assurance, and configuration management, as a minimum, which are periodically audited by the Contractor.

4.3.1.11 Conferencing

The Contractor shall have regular access to an on-site videoconference facility. The Contractor shall conduct videoconferences with the ICESat-2 Project Office as requested. The Contractor shall have access to Web conferencing.

4.3.1.12 Data Rights

Data rights shall be in accordance Clause I.89, I.90, and I.93. The Contractor shall make every effort to identify only that information which is proprietary, and shall be prepared to justify any such claim. Generic status charts, agendas, schedules, and the CDRL items are not expected to be proprietary.

4.3.1.13 Audits

The Contractor shall support Government audits of processes, products, rates, documentation and data, as defined in the ICESat-2 Surveillance Plan, in order to provide assurance to the Government that the program is being implemented according to all requirements and specifications. These audits will be invoked by the Government, performed by Government personnel and coordinated with the Contractor to ensure minimal delay and impact on the ICESat-2 implementation. The Government intends to execute at least one mission assurance compliance audit before ARO + 6 months.

4.3.2 Systems Engineering

The Contractor shall perform the necessary systems engineering required to ensure that the core spacecraft, options, and modifications meet all of the performance, interface, and implementation requirements of the ICESat-2 DO.

The systems engineering effort shall include the analyses and flow-down of technical requirements and allocation of system budgets for the ICESat-2 Spacecraft, as well as requirements for GSE and communications links. The effort shall also include definition and maintenance of all interface documents, verification of all defined and derived requirements, technical risk evaluations, system design tradeoff analyses, orbital performance analysis, flight software requirements analysis and lower level requirements (e.g. subsystem, components, assemblies, parts).

The systems engineering effort shall cover all stages of the ICESat-2 program including specification, design, development, fabrication, qualification and acceptance testing, verification and environmental verification and validation, shipping, launch preparation, launch, on-orbit verification, support to system operations and on-orbit anomaly resolution, and sustaining engineering.

The systems engineering effort shall include the analyses of technical requirements, allocation of derived system, spacecraft, and lower level requirements, establishing and maintaining requirements traceability between all levels of the system, definition and maintenance of all interfaces, cross-cutting integration and oversight/insight across all subsystems, support of the on-going risk management program, participate in technical aspects of the configuration management program, provide technical data management, trending of appropriate system, subsystem, and unit parameters, conducting the program of formal and informal reviews, the

program of technical interchange meetings (TIMs), development and maintenance of spacecraft, ground, and launch vehicle performance budgets, and verification and validation of all defined and derived requirements.

The Systems Engineering effort shall conduct a program to ensure environmental, survivability, and reliability requirements are established, appropriately allocated and analyzed, and subsequently demonstrates performance against requirements. Program Systems Engineering shall assume ultimate responsibility for satisfactory completion and closure of all unit level and above designs, design reviews, process anomalies, problem reports, and test anomalies for both hardware and software for flight, interface, GSE, and ground systems. Systems Engineering shall be responsible for definition, execution, and demonstration of spacecraft testing, and on-orbit verification and acceptance testing.

The Systems Engineering effort shall lead any risk reduction and mitigation activities. It shall ensure deployment designs are sufficiently analyzed and tested. It shall lead all required On-Orbit Debris Analysis. It shall establish and control critical clearances, both static and dynamic.

The systems engineering effort shall be coordinated with the ICESat-2 Project Office systems engineering effort, and shall be ongoing through development and on-orbit activation of the Observatory. The Systems Engineering effort shall be in accordance with NASA requirements, including NPR 7123.1A and GPR 7123.1.

The Contractor shall develop a System Engineering Management Plan (CDRL SE-4) and shall perform a fully integrated systems engineering effort in accordance with the Contractor's SEMP and applicable NASA requirements, including NPR 7123.1A and GPR 7120.5A. This support shall include the following activities:

1. Providing technical direction and oversight throughout all phases of the program.
2. Leading formal and informal reviews. This shall include responsibility for the preparation of responses to all action items assigned to the Contractor during the reviews, documentation of closure, and documentation of the minutes from each review.
3. Establishing a comprehensive program of Peer Reviews and supporting peer reviews. Ensuring all peer review actions are closed appropriately and the results of the peer reviews are documented.
4. Conducting Technical Interchange Meetings with the government, as necessary, and documenting the minutes and actions from these meetings.
5. Supporting all MPSRs
6. Performing and documenting all system studies, analysis, and trades and risk assessments necessary to develop the spacecraft design, launch vehicle interfaces, space-ground interfaces, and instrument interfaces. All analysis shall be document in formal controlled engineering reports.

4.3.2.1 Requirements Analyses and Allocations

The Contractor shall conduct complete analyses of the mission requirements that fully establish, define, maintain and control system budget allocations.

An appropriately updated index of analyses and allocations shall be maintained by the Contractor. The results of all analyses shall be made available by the Contractor for Government review at each subsequent monthly status review.

The Contractor shall establish and maintain a requirements traceability database which accurately and completely captures and maintains allocation and flow of requirements between requirements documents (including government specifications) and specifications, including interface control documents.

The Contractor shall utilize a requirements management tool that will interface with the ICESat-2 Project DOORS requirements management tool for the import/export of requirements and traceability linkages. The Contractor shall provide a Spacecraft Requirements Specification in accordance with CDRL SE-5.

4.3.2.2 Interface Definition, Verification and Control

The Contractor shall specify all interfaces not explicitly defined by the Government. These interfaces shall be defined, documented, verified and controlled for the duration of the DO, by the Contractor.

External interfaces, models, and analysis shall be documented in accordance with CDRL 6. Telemetry and command requirements shall be documented in accordance with CDRL 5.

4.3.2.2.1 Spacecraft/Payload-Instrument Interface

The Contractor shall document and maintain all design interface information between the spacecraft and the Government provided ATLAS Instrument. The Contractor shall prepare the Spacecraft - ATLAS Interface Control Documents (IICD), as defined in SE-9A, and shall be responsible for its maintenance and configuration management.

The Government and the Contractor will have signature approval on the IICD.

The Contractor shall perform systems engineering and analysis in support of designing, documenting, and implementing all interfaces between the Spacecraft subsystems and the Instrument, and Spacecraft GSE-to-Instrument GSE. This support shall include:

1. Addressing Instrument accommodations and status as part of each Spacecraft review.

2. Identifying cognizant engineer(s) responsible for the Spacecraft interface to the

Instrument.

3. Providing technical support for interface design, documentation, and verification.

4. Performing mechanical, thermal, power, contamination, radiation shielding, jitter, alignment, pointing, and other analyses as necessary to ensure Spacecraft to Instrument compatibility, in accordance with CDRL 6 and CDRL SC-4.

5. Attend the Instrument reviews during their implementation prior to Instrument deliveries.

7. Identifying cognizant engineer(s) responsible for the instrument mounted spacecraft components (e.g. gyros and star trackers)

The Contractor shall utilize the Government provided Spacecraft to ATLAS instrument drill template to support the integration to the instrument as documented in the SC-ATLAS IDD and corresponding ICD. The template shall be to form & fit, including connector locations for each connector of the ATLAS instrument.

The Contractor shall provide analytical models and shall perform all analyses and tests required to ensure proper electrical, mechanical, thermal, and operational compatibility between the ICESat-2 Spacecraft and the ATLAS instrument.

Reduced Thermal Math Models

Reduced Thermal Math Models (RTMMs) of the Instrument will be supplied by the Government for use in defining the Spacecraft-Instrument interfaces in accordance with the CDRL 6 in the format given in ICESat-2-THM-RPT-0212. This model will be in Thermal Desktop format. The Contractor shall combine the Instrument RTMMs with the analytical models of the Spacecraft to create a system level thermal model of the Observatory (CDRL SC-1). Reduced Thermal Math Models (RTMMs) of the Spacecraft will be supplied by the Contractor for use in modeling the Spacecraft-Instrument interfaces in accordance with the CDRL SC-3.

Finite Element Models

NASTRAN Finite Element Model (FEM) of the Instrument will be supplied by the Government for use in designing the Observatory. The Contractor shall combine the Instrument FEM with the Spacecraft FEM to form an integrated comprehensive Observatory FEM for launch and on-orbit configurations, and shall provide the Observatory FEM to the Government for coupled load analyses by the launch vehicle provider in accordance with the CDRL 6. The Contractor shall provide the model transformation to English units for the LV and transportation as necessary. After completion of the coupled loads analysis, the Government will provide the results of the coupled loads analysis to the Contractor. The Contractor shall provide to the Government the Instrument-related results from the coupled loads analysis. The Government will then provide appropriate information to the Instrument relating to launch loads.

4.3.2.2.2 Observatory/Ground Operations Interface

The Contractor shall participate in the preparation and maintenance of the Flight Operations Ground System Interface Control Document (OPS-ICD). The Contractor shall submit Flight Operations Ground System Interface documentation as defined in CDRL 7.

The Contractor shall develop, maintain, and provide the Spacecraft-MOC ICD (CDRL SE-9B) and the Spacecraft – RF ICD (CDRL SE-9C) also called the OPS-ICD.

The responsibility for writing, configuration management, and gaining approval of the OPS-ICD shall reside with the Government.

The Contractor shall develop, maintain and provide all technical and programmatic documentation required to ensure successful operation of the Observatory, including the requirements outlined in CDRL 13, Spacecraft Operations Description Manual and CDRL 12, Flight Operations Support Plan. The Government and the Contractor will have signature approval on the OPS-ICD.

4.3.2.2.3 Observatory/Launch Vehicle Interface

The Contractor shall participate in the preparation and maintenance of the Observatory-to-Launch Vehicle Interface Control Documents (LV-ICD). The Contractor shall submit Launch Vehicle documentation in accordance with CDRL 8. The Government and the Contractor will have signature approval on the LV-ICD.

The responsibility for writing, configuration management, and gaining approval of the LV-ICD shall reside with the Government.

A flight ready mechanical fit check and an electrical interface verification test of the Core Spacecraft (or Observatory) to the launch vehicle interface shall be performed by the Contractor prior to the final flight mate to the launch vehicle interfaces. The mechanical fit check and electrical interface verification test shall be performed at the Contractor's location prior to shipment to the launch site. The Government, or launch service provider, will supply a test payload attach fitting which simulates the launch vehicle side of the interface. The Contractor shall provide the analytical models and shall perform all analyses and tests required to ensure proper electrical, mechanical, thermal, and operational compatibility between the Observatory and the Government provided launch vehicle and launch vehicle environments. The Government, through the launch service provider, will provide for two (baseline) cycles of Coupled Loads Analysis. The Contractor shall develop, maintain and provide all technical and programmatic documentation required to ensure a successful launch activity, including documentation in accordance with CDRL 10, Observatory Launch Site Operations and Test Plan, and CDRL 11, Observatory Launch Site Operations and Test Procedures.

The Contractor shall provide Inputs to the Launch Vehicle Integrated Procedures (CDRL 8) in order to coordinate the launch operation between the launch vehicle organization, the ICESat-2 project, and the Mission Operations Center.

4.3.2.3 Design and Performance Verification Analyses

The Contractor shall perform and document all analyses of the data and information from the design, qualification testing, acceptance testing, compatibility testing and on-orbit testing of the Contractor's hardware and software that are required to ensure that the program shall meet its specifications and objectives.

These efforts shall include the following:

1. Preparing and maintaining the Performance Verification Plans (CDRL MAR DID 9-1 and 9-2) and gathering the data for the corresponding Performance Verification Matrix (PVM) (per the CDRL MAR DID 9-3 and MAR DID 9-4) for use at the unit, assembly, subsystem, module, and spacecraft levels of integration. The PVM shall be tied to the requirements database and shall be compatible with the Government DOORS tracking system.

2. Analyzing and making available for inspection the required lower level design specifications and as-built performance data in order to meet higher-level performance requirements. All such analyses shall be identifiable and accessible for Government review

3. Preparing and maintaining verification test procedures for use at the unit, assembly, subsystem, module, and spacecraft levels of integration

4. Data reduction, analysis, and documentation of test results at unit, assembly, subsystem, module, and spacecraft levels of integration

5. Data reduction, analysis, and documentation for ground system testing, compatibility testing, and on-orbit testing

6. Preparing documentation and providing necessary support for reviews

7. Supporting system-level technical interface meetings, including technical issue resolution, performance verification buy-offs, pending configuration change requests (CCRs), CDRL data submission review/approval status, test data review, anomaly resolution activities, and test support planning

8. Providing the Engineering Drawings and Change Notices.(CDRL PM-4)

The system engineering function shall ensure that no flight components, assemblies, or units are integrated onto the spacecraft until the qualification and acceptance package is complete and demonstrated to satisfy program functional and performance requirements, particularly with respect to environments, reliability, and application. The Contractor shall perform end-to-end

verification of sensor/control system/actuator polarity.

The Contractor shall perform environmental testing necessary to ensure the spacecraft functional and performance requirements are satisfied under all spacecraft environments, per the ICESat-2 ERD.

The Contractor shall verify that each spacecraft satisfies its requirements through a Performance Verification Matrix (PVM). Systems Engineering shall be responsible for ensuring that all required analyses are performed and all required data is collected during the identified tests or inspection points. Systems engineering shall ensure collection of all data/analysis/inspection required by the matrix and review it for closure as the required data is taken, or analysis completed, with government representatives. The Contractor's system engineering efforts shall perform the on-orbit verification and acceptance program for the spacecraft which shall ensure that the spacecraft satisfies all functional and performance requirements after achieving the required orbit.

The Contractor shall establish a system for trending performance data. The Contractor shall coordinate with the Government the selected list of parameters to be trended and maintain a Trend Analysis and Operations Log that is accessible to the government. The Contractor shall monitor selected parameters for trends starting at the beginning of bus or payload module assembly and continuing during the system integration and test phases through the on orbit acceptance test phase. The Contractor shall analyze the trended data for indications of anomalous conditions and for possible performance or reliability degradation. The Contractor shall provide Trending Reports and operating hours reports as part of the Trend Analysis and Operations Log and provide a summary report at monthly status reviews and system reviews. The Contractor shall summarize trending results at each spacecraft Pre-Ship and Post-Launch Acceptance Review.

4.3.2.4 Fault Management

The Contractor shall provide a subsystem-level independent Systems Engineering function for fault management. The Contractor shall produce a Fault Management plan and ensure that fault management requirements are integrated and flowed to all subsystems. The Government shall have access to this plan. The Contractor shall ensure that all fault management requirements are verified during integration and test activities.

4.3.3 Safety and Mission Assurance Management

The Contractors spacecraft design and associated services shall comply with the requirements of the ICESat-2 Mission Assurance Requirements (MAR).

4.3.4 Spacecraft Systems Implementation

The Contractor shall develop and implement a System Performance Verification Plan in accordance with MAR Sections 9.1 and 9.2 and associated CDRLs.

The Contractor shall develop and provide a System Performance Verification Matrix in accordance with MAR Sections and 9.3 and 9.4 and associated CDRLs.

4.3.4.1 ICESat-2 Spacecraft

The Contractor shall produce and verify the performance of a spacecraft that meets all of the requirements, specifications, and interfaces defined in the ICESat-2 DO and the ICESat-2 Spacecraft Requirements Document.

Prior to Instrument integration, the spacecraft structural, thermal and electrical design shall be qualified, per the ICESat-2 ERD, and verified by a combination of analyses and tests on engineering models, prototype or proto-flight hardware and software. The Contractor shall conduct a successful comprehensive performance test to demonstrate readiness for Observatory level integration prior to instrument integration.

4.3.4.1.1 IT Security

The Contractor shall comply with all applicable sections of NPR 2810.1, Security of Information Technology in development, integration, and testing of the Spacecraft.

4.3.4.1.2 Instrument Mounted Spacecraft Components

The Contractor shall provide spacecraft equipment that will be mounted on the instrument in order to meet Observatory performance requirements. The instrument mounted Spacecraft hardware shall be fully flight qualified prior to delivery. The Gyro and Star Trackers will be provided as instrument mounted Spacecraft hardware. The Contractor shall provide applicable procedures, simulators, templates and personnel to support the integration to the instrument as documented in the SC-ATLAS IDD and corresponding ICD. The templates shall be to form & fit, including connector locations, as well as a pair of mating connectors for each connector of each IMSC.

4.3.4.1.3 Circuit Protection and Resetting

The Contractor shall perform analysis to show circuit protection and resetting capabilities of the spacecraft power system and document results in a formal engineering report.

4.3.4.1.4 Power Interface Model

The spacecraft vendor shall generate a simplified model of the spacecraft power interface up to the instrument power interface connector (CDRL 6). This model will be used to simulate the spacecraft power interface to the instrument during instrument integration testing & during EMC tests. This model will be used to replace the LISN (Line Isolation Stabilization Network) in Mil-Std-461F testing. The model shall represent the impedance of the power & return wires as well as their impedance to spacecraft structure.

4.3.4.1.5 OPSSEC

The Contractor shall define and implement a Command Authentication strategy for the ICESat-2 mission. The Contractor shall produce all documentation required for the design, verification, management and flight of the system. The Contractor shall obtain any certifications necessary for the system. The Contractor shall review and provide inputs to the ICESat-2 Key Management Plan consistent with CDRL SE-10.

If necessary per the Contractor's implementation, the Contractor shall conduct all required testing required by the NSA, both for the initial certification and to address any issues that may arise following certification, including rework of any relevant hardware or software. The Contractor shall maintain a list of all classified documents generated or held under for this DO. Security violations shall be reported to NASA within 48 hours. Defense Security Service (DSS) or other government agency findings or direction applicable to Program activities shall be reported to NASA monthly.

Any deviations or waivers to the Government security requirements shall be approved by the Government.

A program security indoctrination meeting shall be conducted, with participation from government security representatives. A splinter meeting on the OPSSEC implementation and certification process shall be conducted. This meeting and its splinter shall be conducted under the aegis of the OPSSEC Working Group.

4.3.4.1.6 Ground Support Equipment

The Contractor shall provide all the Ground Support Equipment (GSE) to integrate, test, and verify the Spacecraft and Observatory except for Instrument provided GSE. The Government will deliver the Instrument to the Observatory integration and test site. The Government will also provide the Instrument ground support equipment (IGSE) and software (flight and embedded IGSE) necessary to support testing of the Instrument at the Observatory level.

The Contractor shall provide the accommodations for the Instrument electrical and mechanical GSE and Instrument stimuli and targets, as defined in the Instrument ICD. Instrument provided equipment to be used in thermal-vacuum testing will be certified by the instrument provider for

chamber use.

The Contractor shall provide an S-band antenna system, compatible with TDRSS and the GN, at the Contractor's I&T facility to support Spacecraft, Observatory, system, and operations tests.

4.3.4.1.7 Contamination Control

The Contractor shall assure appropriate contamination control is maintained throughout all phases of integration and test. The Contractor shall maintain and demonstrate the cleanliness levels specified in the SRD, ATLAS-Spacecraft IDD and ERD.

The Contractor shall provide a Contamination Control Plan coordinated with the Instrument contamination control requirements, in accordance with the ICESat-2 MAR DID 10-2.

After instrument integration, the Contractor shall include the instrument contamination engineer as a member of the Contamination Control team.

The Contractor shall perform tapelift particle count and NVR rinse residue gravimetric analysis of samples collected by the instrument team. The sample count will not exceed 10 tapelifts and 6 NVR rinse samples. Samples will be collected in response to anomalous environmental or handling conditions that necessitate re-verification of instrument cleanliness.

4.3.4.2 ICESat-2 Interface Simulators

4.3.4.2.1 Spacecraft Interface Simulator

The Contractor shall provide ICESat-2 Spacecraft Interface Simulators for use by mission elements for interface verification of the instrument. The Spacecraft Interface Simulators shall meet the requirements as specified in the ICESat-2 Spacecraft Requirements Document. The Contractor shall make the Spacecraft Interface Simulators available to the Instrument supplier as required in this DO to support the ATLAS Instrument development.

The Contractor shall provide two Spacecraft Interface Simulator (SIS) for use at the Instrument Provider's facility for interface verification during Instrument development. The SIS shall meet requirements as documented in the ICESat-2 Spacecraft Requirements Document. The simulator shall simulate bi-directional command and telemetry interfaces, including all serial, discrete, ground, return, and power interfaces. The connecting hardware shall be certified for use with flight hardware via flight-quality electrical interface to the instrument. The Simulator shall be certified for use in a flight hardware development facility. The Contractor shall deliver and setup the first SIS at the Instrument Provider's facility prior to Instrument CDR – 2 months timeframe. The Contractor shall provide one week of SIS operations support and training, as well as user's documentation. The Contractor shall provide ongoing maintenance and support for the SIS through instrument delivery. The second SIS shall be delivered to and setup at the Instrument Provider's facility in the Instrument CDR+6 months timeframe.

The Contractor shall provide the documentation to define the performance requirements, plan the I&T, report the acceptance testing results, user's guide, and training plan and materials, in accordance with CDRL SIM-1A, SIM-2A, SIM-3A, SIM-4A, and SIM-5.

In addition to the SIS, the Contractor shall conduct a one-time interface test with the S/C Engineering Model Power System and the S/C Engineering Model C&DH and Instrument EM subsystems. The test will take place at the Instrument facility in the Spacecraft CDR – 1 month timeframe. And will last approximately one week in duration. The Contractor shall, in working with the instrument provider, perform the planning test setup, execution, and test configuration breakdown.

4.3.4.2.2 Government Furnished Front-End Processor

The Government will provide a Front-End Processor to interface between the Spacecraft GSE and the Ground System, to support the spacecraft command and telemetry traffic with the MOC during I&T. The Front-End Processor will provide digital signaling at its interface to communicate with the spacecraft GSE, similar to the demodulated clock and data signals between the spacecraft and the GN.

4.3.4.2.3 Government Furnished Instrument-Spacecraft Simulator

The Government will provide an instrument simulator to be used to check out the interface with the S/C. In addition the Government will provide an instrument simulator to be used in the Observatory Operations Simulator (OOS). The fidelity of the instrument simulator shall be sufficient to validate all electrical, data, and command and telemetry interfaces between the instrument and the Spacecraft. The details of the Instrument-Spacecraft simulator and their interfaces shall be documented in the Spacecraft-ATLAS ICD.

4.3.4.2.4 Observatory Operations Simulator

The Contractor shall develop and deliver an Observatory Operations Simulator (OOS) to be used by the MOC in Ground System testing, Flight Operations Team (FOT) training, FOT procedure verification, and anomaly resolution. The Contractor shall integrate the GF instrument simulator and develop the MOC interface simulations required to verify the Observatory Simulator interfaces and its functionality prior to Simulator delivery. The Contractor shall provide the documentation to define the performance requirements, plan the I&T, report the acceptance testing results, user's guide, and training plan and materials, in accordance with the CDRL SIM-1B, SIM-2B, SIM-3B, SIM-5. The OOS shall be compliant with NPR 7150.2A for Class C software as further described in Section 4.3.6 below.

The Contractor shall provide an OOS that meets requirements documented in the ICESat-2 Spacecraft Requirements Document.

Following acceptance of the Observatory Operations Simulator by the Government, the Contractor shall integrate the GF Instrument simulator and, with the support of the Instrument Provider, verify the performance of the resulting Observatory Operations Simulator by running procedures and scripts mutually agreed with the FOT, MOC Contractor, and Instrument Provider.

The Contractor shall deliver the OOS to the MOC, assemble and check out its performance as needed, and verify the OOS performance against the pre-ship baseline.

The Contractor shall support interfacing the OOS with the MOC/Front-End Processor at the MOC, and maintain the OOS through Observatory acceptance. The Government will provide the maintenance for the instrument portion of the OOS.

4.3.4.3 ICESat-2 Spacecraft Integration and Test (I&T)

The ICESat-2 Spacecraft design shall be verified by a combination of demonstration, inspection, analyses and test utilizing, as needed, Contractor supplied engineering models, prototypes, proto-flight or heritage flight hardware and software.

Spacecraft component testing shall be tested as define in ICESat-2 ERD.

The Spacecraft power interface to the instrument shall be characterized as described in ERD.

Prior to instrument integration, the Contractor shall integrate and test all ICESat-2 Spacecraft to payload-instrument interface hardware and software. Since the gyro and star trackers will be mounted on the instrument, the Contractor shall provide a flight gyro and star tracker mass and volume simulator to the instrument to support structure testing and integration activities. The Contractor shall provide the flight gyro and star trackers to the instrument at a negotiated delivery date during the instrument integration phase for integration on to the instrument bench. The gyro and star tracker shall pass an acceptance test at the instrument integration facility prior to integration onto the instrument. The Contractor shall work with the instrument team for the installation of the gyro and star trackers on the instrument and for testing of the gyro and star trackers through the instrument test program.

The Contractor shall prepare a Spacecraft Integration and Test plan and procedures in accordance with the CDRL IT-1. The Government shall have access to review all spacecraft integration and test procedures at least 10 days prior to the execution of the test and to the last minute updates to the procedures.

The Contractor shall plan, manage and execute Spacecraft performance verification, system testing, and environmental testing in accordance with the Spacecraft Integration and Test Plan, and the ICESat-2 Environmental Requirements Document (ERD). The Contractor shall submit a System Environmental Verification Plan and Matrix in accordance with CDRL MAR DID 9-2 and 9-4. Hardware powered on for launch shall be powered on for testing. For any test that is

used to verify contractual requirements, the Contractor shall notify the Government at least 10 days in advance so that Government personnel may witness if it so chooses.

The Contractor's integration and test program shall include, as a minimum:

1. Electrical interface testing performed prior to integration of any assembly, component or subsystem into the next higher assembly. As a minimum, pin-out configuration, impedance, power and signal characteristics, grounds, and isolation of power and signal lines from ground shall be verified.

2. Performance testing shall be performed. Performance testing shall verify, to the maximum extent possible, full functionality of all components including redundant systems, as applicable unless negotiated with the Government. A Spacecraft CPT shall be run prior to the Observatory Integration to establish the baseline performance. Modifications to this flow shall be coordinated with, and approved by, the Government. A CPT shall be a detailed demonstration that the spacecraft hardware and software meet their performance requirements within allowable tolerances as specified in the ICESat-2 ERD. An LPT shall be a subset of the CPT and demonstrate the aliveness, addressability, and response of all units including primary and redundant sides of the spacecraft and shall be utilized in accordance with the ICESat-2 ERD. CPTs shall be performed in the test flow as defined in the ICESat-2 ERD.

3. The Contractor shall conduct Test Readiness Reviews prior to each test. The Government shall be invited to all Test Readiness Reviews.

4. The Contractor shall develop Spacecraft Integration and Test Reports and provide access to the Government for all reports. The Contractor shall provide post-test reviews with the Government to determine if the test was successful and the Contractor may move onto the next test in the sequence. Subsequent tests shall not be conducted until critical test points or pass/fail criteria have been verified.

5. RF compatibility testing shall be performed to demonstrate compatibility with the ground segment.

6. Results from the system level Thermal Balance testing shall be used to validate/correlate the spacecraft-bus/instrument integrated analytical thermal model. The thermal model shall replicate temperatures observed in test to within 2C on all powered components and on all surfaces critical to instrument alignment.

7. Proof pressure tests shall be conducted on the propulsion subsystem as defined in ICESat-2 ERD

The ICESat-2 Spacecraft shall be tested with calibrated and maintained GSE.

The Contractor shall archive, digitally store and provide access to all photographs and video

recordings made during integration. The Contractor shall provide the Government digital copies of all photographs and video recordings made during integration, testing, and closeouts, in accordance with the CDRL SE-7. The Contractor shall photograph and video all spacecraft and Observatory lift operations, installations of flight components, environmental test setups, and hazardous operations.

The Contractor shall follow ANSI/ESD S20.20-2007 for electrostatic discharge training and as an applicable document. All personnel working on flight hardware will be grounded prior to touching flight hardware or any system that is attached to flight hardware.

Real-time monitoring of command and telemetry shall be made available to Government analysts supporting the Spacecraft system level testing.

4.3.4.3.1 RF Telecommunications System Testing

Since workmanship and contamination can be critical factors, all passive stand-alone flight components shall be individually tested to the following test conditions:

1. Input power: the RF power applied to the input of the unit under test shall be 6 dB above the maximum operating level.
2. A pre-test soak in vacuum, followed by the multipaction test at the stated RF power for 8 hours minimum at 1E-5 Torr or lower pressure. The duration of the pre-test soak is determined by the result of a venting analysis, which shall be performed to ensure that the interior of the unit under test is at the desired pressure level for the test. This must include outgassing.
3. Temperature: ambient (room) temperature.
4. The unit under test shall be terminated with a matched load.
5. The multipaction test method and test set-up used shall be verified to have the sensitivity to detect multipaction. Verification of the test set-up's sensitivity can be accomplished by testing a device (component or unit) that is known to be susceptible to multipaction.

Passive components (such as filters, circulators, etc.) containing gap and resonant cavity that are used in stand-alone active components (such as transmitters and power amplifiers) shall be tested to the above conditions prior to installation in the stand-alone active components.

Multipaction analysis shall be incorporated in the design process to ensure sufficient margin in the developed hardware.

Exception to the above test requirements can be considered for passive components that do not contain resonant cavity. In such case, the following requirements shall be met:

a. An analysis is performed and the result demonstrates that there is at least 10 dB of margin above the maximum operating level;
b. There is a proven heritage of similar qualified designs;
c. The component has a geometry that allows accurate electric field calculations to be

performed with high confidence;

d. The multipaction-critical areas of the component have commonality with an existing design that has established the correlation between analysis and test

4.3.4.3.2 Solar Array Verification Requirements

Solar Array Component Qualification

The ICESat-2 flight solar cells shall be qualified by similarity or in accordance with AIAA S-111-2005, "Qualification and Quality Requirements for Solar Cells" with the following exceptions, AIAA S-111-2005 Section 7.2.3.3.2 LEO Coupon and any other sections relating to LEO qualification may be waivered.

To qualify by similarity or heritage, the similar cells shall meet the following criteria:

a. Identical in design, size, type, and construction to the heritage flight solar cells.
b. They shall have heritage to requirements that meet or exceed those of the ICESat-2 flight solar cells.
c. Flight solar array heritage with more than 1000 cells on a solar array successfully performing in *ICESat-2* orbit for a minimum of 2 years.

The ICESat-2 flight solar array components shall be qualified in accordance with the ICESat-2 ERD and mission life requirements.

Each unique ICESat-2 flight solar panel(s) shall be qualified in accordance with AIAA S-112-2005, "Qualification and Quality Requirements for Space Solar Panels" with the following exceptions, which may be waived:

a) AIAA S-112-2005 Section 7.1.3.4 Humidity Exposure for the AIAA S-112-2005 Section 7.1 Solar Panel Life-Cycle Coupon Test
b) AIAA S-112-2005 Section 7.1.3.5 Visual Inspection and Electrical Test After Humidity Exposure
c) AMO illumination during hot portion of cycling of AIAA S-112-2005 Section 7.1.3.8 Combined Effects Exposure
d) AIAA S-112-2005 Section 7.2 Panel-Level VCM/Acoustic Test
e) AIAA S-112-2005 Section 8.2 Angle of Incidence Characterization
f) AIAA S-112-2005 Section 8.3 Hemispherical Emissivity Characterization
g) AIAA S-112-2005 Section 8.7 Atomic Oxygen Test

The ICESat-2 flight solar panel qualification life-cycle coupon(s) shall include examples of all the ICESat-2 series flight solar panel components as required by AIAA S-112-2005.

Solar Array Panel Component Level Testing

The ICESat-2 flight solar panel(s) shall meet their required out gassing rate in a 1 x 10-5 Torr or less vacuum at 10C above their maximum on-orbit operating temperature.

The ICESat-2 flight solar panel(s) shall successfully complete a minimum of 12 thermal-vacuum cycles between their acceptance mission allowable temperature hot and cold temperature extremes.

Before and after ICESat-2 flight panel thermal-vacuum cycling, the ICESat-2 flight solar panel(s) acceptance testing shall include as a minimum the following tests:

a) Visual Inspection with stereoscopic visual inspection at 30X magnification for resolution of potential defects.
b) Continuity testing
c) By-pass diode functionality testing
d) ICESat-2 flight panel string output power and I-V performance characterization with Large Area Pulsed Solar Simulation (LAPSS) at air mass zero (AM0) at 23C ± 5 C with data corrected to 28 C
e) ICESat-2 flight panel string output power and I-V performance characterization with Large Area Pulsed Solar Simulation (LAPSS) at air mass zero (AM0) at the ICESat-2 flight panel maximum operating temperature ±5°C.
f) Blocking diode functionality testing
g) Insulation resistance testing between the ICESat-2 solar panel strings and their substrates
h) Grounding continuity testing
i) ICESat-2 series solar panel temperature sensor functionality test
j) Final visual inspection with stereoscopic visual inspection at 30X magnification for clarification
k) Acoustic testing as defined in the ICESat-2 ERD

A Hotbox test shall be performed at the Solar Array Vendor prior to shipment to the spacecraft contractor. A Hotbox test shall be performed at the Spacecraft contractor after delivery from the Solar Array Vendor.

Solar Array Spacecraft Level Testing

The ICESat-2 flight solar panel(s) shall successfully pass the ICESat-2 flight solar panel acceptance testing after spacecraft mechanical environmental testing prior to the start o Spacecraft to ATLAS (Observatory) Integration and Test.

The ICESat-2 flight solar array spacecraft level testing shall include as a minimum the following tests:

a. Solar array electrical verification
b. Solar array grounding test verification
c. Solar array magnetics testing (as part of spacecraft level magnetic testing)
d. Solar array mechanical deployments

Solar Array Observatory Level Testing

The ICESat-2 flight solar panel(s) shall successfully pass the ICESat-2 flight solar panel acceptance testing after Observatory mechanical environmental testing.

The ICESat-2 flight solar array Observatory level testing shall include as a minimum the following tests:

a. Solar array electrical verification
b. Solar array grounding test verification
c. Solar array magnetics testing
d. Spacecraft sine vibration with the ICESat-2 flight solar array in the launch configuration
e. Spacecraft acoustics testing with the ICESat-2 series flight solar array in the launch configuration
f. Spacecraft shock test with the ICESat-2 series flight solar array in the launch configuration
g. Solar array mechanical deployments
h. Final stereoscopic visual inspection after all mechanical environmental testing at 30X magnification for clarification (either before or after final re-stow)

The ICESat-2 flight solar array(s) final Observatory integration testing shall include as a minimum the following tests:

a. Visual inspection with stereoscopic visual inspection at 30X magnification for clarification.
b. Solar array electrical continuity to the spacecraft on a circuit by circuit basis.
c. Solar array spacecraft to ground verification
d. Solar array forward bias testing
e. Solar array final mechanical deployments and re-stow
f. Final visual inspection with stereoscopic visual inspection at 30X magnification for clarification (either before or after final re-stow).

4.3.4.3.3 Propulsion Testing

The Contractor shall conduct propulsion leak and pressure testing as follows:

- Manifold proof pressure test that accounts for latch valve back relief pressures.
- Subsystem proof test and leak test
- Component functional and leak tests
- Dry-Vibe workmanship test of subsystem if modular (not integrated w/ spacecraft)
- Component functional and leak tests
- Environmental tests (spacecraft level)
- Component functional and leak tests (before shipping to the launch site)
- Component functional and leak tests (after arriving at the launch site)

4.3.4.3.4 Laser Retroreflector Assembly (LRA) Verification

The Contractor will test the quality and performance of LRA, individual cubes by performing interferogram tests and far field pattern tests. In addition, the Contractor shall supply a report showing analytical and/or experimental data related to the performance of the array as a whole (i.e. variations in the LRA "phase center" and optical cross-section as a function of LRA azimuth and elevation angle within the active array FOV. (MAR DID 9-5)

4.3.4.3.5 Weight and Center of Gravity

The Contractor shall measure the weight and center of gravity of the integrated spacecraft. The Contractor shall provide a Mass Properties Report in accordance with CDRL SC-2.

4.3.4.3.6 Battery Tests

Test/Flight data shall be presented at the S/C PDR that validates the battery design to meet the mission lifetime requirements. The spacecraft contractor can present a battery mission life test/analysis utilizing existing battery lifetime tests or on orbit battery operations. If there is not sufficient heritage test data to validate the mission lifetime, an accelerated battery life test shall complete greater than or equal to the total number of mission charge/discharge cycles times 1.2 to the flight expected depth-of-discharge (DOD). The charge/discharge cycles shall be conducted within the qualified charge and temperature limits of the battery. This test shall be an accelerated life test utilizing similar battery design cells and completed prior the S/C CDR. Seven (7) battery cells from the flight battery lot shall be provided to GSFC for real time life testing and destructive physical analysis (DPA)

The Contractor shall generate a Battery Handling Plan per CDRL SC-5.

4.3.4.3.7 Verification of Mechanical Clearances

Verification of mechanical clearances and margins including potential reduced clearances after blanket expansion shall be performed on the final as-built hardware.

4.3.4.3.8 GPS Analysis and Testing

A multipath analysis shall be performed to show that errors caused by multipath signals from the spacecraft body, solar arrays, and any articulated antennas do not prevent the GPS receivers from meeting their performance requirements.

The GPS receivers shall be tested with real-world signals from the GPS constellation during comprehensive performance tests and mission simulations. Alternative test methods that provide end-to-end performance are acceptable.

A test shall be performed to demonstrate that the gyro & star-tracker time-tage relative to the GPS 1-Hz signal meet their performance requirements.

4.3.4.4 Observatory Integration and Test

The Contractor shall plan and conduct integration of the ICESat-2 Spacecraft and ATLAS instrument to form an Observatory. The Contractor shall plan, manage, and execute Observatory level interface verification, system test, environmental test, and support specific tests as defined in this DO. The Observatory shall be tested with calibrated and maintained GSE, and shall be compatibility tested with the ground control system. At no time shall any test, functional or environmental, expose the ATLAS instrument to environments, signals, or other conditions that exceed the limits specified in the Contractor's Spacecraft – ATLAS Interface Control Document (CDRL SE-9A).

The Contractor shall submit for Government approval a written justification for each analysis that the Contractor plans to perform in lieu of testing, MAR DID 9-1 and MAR DID 9-2.

The Contractor shall submit for Government approval a written justification for each environmental test or environmental exposure level that the Contractor does not plan to perform, MAR DID 9-1 and MAR DID 9-2

The Contractor shall prepare Observatory Integration and Test plans in accordance with the CDRL IT-3.

The Contractor shall provide the Government digital copies of all photographs and video recordings made during Observatory integration, testing, and closeouts, in accordance with the CDRL SE-7.

The Contractor shall provide support facilities for the Instrument Provider to use for flight delivery, unpacking, lifting and handling, and bench checkout activities. The Contractor shall provide basic cleaning supplies and standard calibrated instrumentation (e.g. digital volt/amp meters, oscilloscopes), as requested. The Instrument Provider will provide their own tools and test cables.

The Contractor shall generate a Laser Safety Plan in accordance with CDRL SMA-1. The Contractor provided facility shall be compliant with laser safety practices identified in the Laser Safety Plan. The Contractor shall provide the appropriate facilities for laser testing at the Observatory level. The ATLAS instrument laser will be fired during the following test events:

- ATLAS testing post-shipment to the Integration facility
- During EMI/EMC testing
- During TVAC testing
- During Observatory CPTs and LPTs at the Observatory integration facility and at the launch site

The Contractor shall notify the government any time power is to be applied to or removed from the instrument. The Contractor shall be responsible for monitoring and reporting the instrument health and safety at all times the instrument is powered after it is transferred to the Contractor. The Contractor shall maintain a safe environment for the instrument, personnel, and associated GSE from the time they are delivered to the spacecraft facility through Observatory delivery to the launch site payload processing facility.

The Contractor shall inform the Project Office of all regular and any significant ad-hoc I&T meetings, and coordinate phone access to allow the Government to participate via teleconference.

The Contractor shall provide facility support for the MOC Front-End Processor and the resident FOT members, during Observatory I&T. The Contractor shall provide telemetry connectivity to the MOC Front-End Processor for FOT members to monitor I&T activities throughout spacecraft I&T. The Contractor shall enable the FOT to monitor and participate in a non-interference basis in Spacecraft and Observatory testing of, for example, flight software, attitude control, command and data handling, etc.

The Contractor shall support Front-End Processor communication with the spacecraft and instrument telemetry at all times the spacecraft is powered.

4.3.4.4.1 Observatory Integration

The Contractor shall plan and conduct, with the input of the Government and instrument provider, integration of the Spacecraft and Instrument. The Contractor shall provide all required Spacecraft and Observatory mechanical and electrical GSE unless negotiated and put into the SC-ATLAS ICD and provided as GFE. The Contractor shall develop integrated Observatory test procedures in coordination with the Instrument provider. The Contractor shall develop the detailed test requirements in conjunction with the Instrument Provider as part of interface development and documentation. After Instrument integration, all tests shall be conducted through the Spacecraft and its associated GSE (i.e., Spacecraft GSE to Spacecraft to Instrument). Real-time monitoring of Instrument command and telemetry shall be made available to Instrument Provider analysts supporting the Observatory system level testing,. The Contractor shall provide all Instrument test data to the Instrument Provider analysts and Ground System engineers (including science data CDRL IT-2), in mutually agreed upon format and media after completion of testing. Except to support anomaly resolution, the Instrument Provider data acquisition/commanding GSE will not be connected to the Instrument after integration.

The Instrument Provider will be responsible for all physical contact with the Instrument up to the time the Contractor's lifting equipment touches the Instrument lift hardware. The Contractor shall be responsible for all physical contact with the Instrument from the time the Contractor's lifting equipment touches the Instrument lift hardware (i.e. "On-Hook"), and for the Instrument mechanical safe-keeping, until the Instrument is removed from the spacecraft and turned back over to the Instrument Provider or the Observatory launches. After installation,

instrument connections shall not be disturbed without the instrument team's concurrence.

4.3.4.4.2 Weight and Center of Gravity

The Contractor shall measure the weight and center of gravity of the integrated Observatory. The Contractor shall provide a Mass Properties Report in accordance with CDRL SC-2.

4.3.4.4.3 Verification of Mechanical Clearances

Verification of mechanical clearances and margins including potential reduced clearances after blanket expansion shall be performed on the final as-built Observatory.

4.3.4.4.4 Observatory Test

The Contractor shall plan, manage and execute Observatory interface and performance verification, system testing, and environmental testing in accordance with the Observatory Integration and Test Plan, and in accordance with the ICESat-2 Environmental Requirements Document (ERD). The Contractor shall follow the observatory test flow as defined in the ERD. Exceptions to this flow shall be coordinated with, and subject to approval by the Government. The Contractor shall submit a System Environmental Verification Plan and Matrix in accordance with CDRL MAR 9-2 and MAR 9-4. The Contractor shall provide all Ground Support Equipment for the Observatory tests unless negotiated with the instrument and provided as GFE. Hardware powered on for launch shall be powered on for testing in accordance with the ICESat-2 ERD.

The Contractor shall verify the Observatory requirements, as documented in the SRD, using one or more methods (analysis, inspection, demonstration, or test) as selected by the Contractor and defined in the Contractor's Observatory Integration and Test Plan in accordance with CDRL IT-3. All analysis shall be documented in formal controlled engineering reports.

In addition to test plan definition, the Contractor shall generate all test procedures, test reports, success criteria, test tools and resources to conduct the Observatory verification. The Contractor shall conduct any pre-test set-up as necessary and define the detailed schedule and dependencies for the execution of the identified tests. Observatory test requirements are detailed in the ERD. For any test that is used to verify contractual requirements, the Contractor shall notify the Government at least 10 days in advance so that Government personnel may witness if it so chooses.

The Contractor's integration and test program shall include:

1. Electrical interface testing shall be performed prior to integration of the ATLAS instrument. As a minimum, pin-out configuration, impedance, grounding, and power and signal characteristics shall be verified.

2. Performance testing shall be performed. Performance testing shall verify, to the maximum extent possible, full functionality of all components including redundant systems, as applicable unless negotiated with the Government. An Observatory CPT shall be run as the last activity prior to the PER to establish the baseline performance. A CPT shall be a detailed demonstration that the Observatory hardware and software meet their performance requirements within allowable tolerances as specified in the ICESat-2 ERD. An LPT shall be a subset of the CPT and demonstrate the aliveness, addressability, and response of all units including primary and redundant sides of the Observatory and shall be utilized in accordance with the ICESat-2 ERD. The pre-ship CPT shall be run following exposure to all environments, and its results compared with the pre-test baseline. The Contractor shall submit Observatory Integration and Test Plans in accordance with CDRL IT-3. The Contractor shall generate Observatory Integration and Test Procedures and provide the Government access to the procedures at least 10 days prior to the execution of the test.

3. The Contractor shall conduct Test Readiness Reviews prior to each test.

4. Functional testing shall be performed prior to and as soon as practicable following each environmental load testing. The Contractor shall submit Observatory Integration and Test Reports in accordance with MAR DID 9-5. The Contractor shall provide post-test reviews with the Government to determine if the test was successful and the Contractor may move onto the next test in the sequence. Subsequent tests shall not be conducted until critical test points or pass/fail criteria have been verified.

5. RF compatibility testing shall be performed to demonstrate compatibility with the ground segment.

6. Electromagnetic Interference and Compatibility Environmental testing, as defined in ICESat-2 ERD, shall be performed to demonstrate self-compatibility between the Spacecraft and instrument. Compatibility with the launch vehicle and launch site as defined by the applicable specifications for each shall also be demonstrated.

7. Thermal vacuum environmental testing, shall be performed in accordance with the ICESat-2 ERD to demonstrate that all Spacecraft and Instrument components function properly in their intended operational environment. Performance testing shall be performed during thermal-vacuum testing. Representative thermal balance and orbital power simulation tests shall be run in this environment as well.

8. A set of environmental tests, as specified in the ERD shall be performed to verify Observatory performance under the expected structural loads, vibro-acoustics limits, sine vibration limits, mechanical shock limits (including solar array release and launch ring separation), during all phases of the ICESat-2 mission.

9. Boresight alignment testing shall be performed pre and post each mechanical test (vibe and acoustic) and pre, during and post thermal vacuum testing. The Contractor shall

provide the required feed-thrus in the thermal vacuum chamber for the instrument fibers and will provide room in the thermal vacuum chamber for instrument alignment GSE to be suspended in front of the telescope and laser and provide a clear path to the GSE. It is anticipated that two feed-thrus will be required (one fiber-optical and one electrical). The instrument GSE shall be approximately 1m x 1/2m x ¼m. Boresight alignment testing shall be repeated again at the launch site. In addition, the Contractor shall provide room in the thermal vacuum chamber for instrument alignment GSE to be suspended in front of the ATLAS LRS and provide a clear path to the GSE. This GSE is approximately half the size of the previous mentioned GSE. It is expected that each boresight alignment test will require one day.

10. Leak checks shall be conducted on the propulsion subsystem as defined in ICESat-2 ERD.

11. Magnetic requirements shall be verified in accordance with ICESat-2 ERD

The Contractor shall perform all necessary tasks to verify Observatory function and performance with all interfaces, including the MOC/Front-End Processor, Ground Network and Space Network. The Contractor shall verify Observatory outputs, format and contents, directly with the interfaces or with Contractor-provided simulator(s) and GSE. The Contractor shall schedule and coordinate all resources required to execute the tests to complete the I&T Plan.

The Contractor shall archive, ancillary, and housekeeping data generated by the spacecraft and instrument from the beginning of Observatory integration and test through on-orbit acceptance, as well as selected science data generated by the instrument. The Contractor shall provide subsets of the archived data to the Government upon request for data analysis. The Contractor shall provide the data requested within 48 hours of the request. All archived data shall be handed over to the government upon acceptance of the observatory by the government, CDRL OPS-7

The Contractor shall generate and archive real-time and playback files of a typical day's data in accordance with CDRL IT-2, as requested by the Project Office, comprising instrument science data in the format as delivered to the Ground Network. The intent is for ground segment personnel to use the files to represent the downlink science digital data flow as it would be seen, recovered from the RF downlink at a ground station, with all the spacecraft science frame formatting including science-like data from the instrument (not spacecraft fill bits), in accordance with the Spacecraft – Ground IDD / ICD. The Government intends to use these files in Ground and Mission Readiness Testing to support functional and interface verification. The Contractor shall provide each real-time playback file on appropriate media within two days of the request.

The Contractor shall provide data to the MOC provided Front-end processor throughout I&T to provide a real-time eavesdropping capability.

The Contractor working with the instrument provider shall provide a "Quick Look" status as-needed during, and at the completion of each test activity. This status will provide a preliminary

assessment of the test data that indicates the test is progressing successfully, and whether the Contractor and instrument provider recommends the test continue, or that the test configuration can be broken and moved on to the next activity.

The Contractor shall provide an automated system that logs and tracks the generation, status, and closure of all anomalies that occur during Observatory integration and test, MAR DID 2-2 and DID 2-4. I&T anomalies shall include at a minimum any failures, problems, and concerns affecting I&T (e.g. unanticipated or unsatisfactory performance of the spacecraft, facilities, personnel, GSE, procedures, materials, etc.). The Contractor shall generate weekly reports showing the content and status of any and all anomalies. The reports shall include all instrument anomalies following the integration of the instrument to the spacecraft.

The Contractor shall provide all relevant test data and anomaly reports to the Instrument Provider as needed.

The Contractor shall incorporate all troubleshooting, recursion testing, and repair, etc. information from the Instrument Provider regarding instrument anomaly resolution in the process of closing anomaly reports.

4.3.4.5 ICESat-2 Spacecraft/Observatory Storage

The Contractor shall provide appropriate ground storage for the ICESat-2 Spacecraft, prior to delivery or instrument integration, or for the Observatory prior to shipment to the launch site, as defined in the SRD. This activity shall encompass storage, in-storage maintenance, and post-storage activities necessary to bring the ICESat-2 Spacecraft or Observatory to pre-storage state of readiness. This shall include, but not be limited to, the storage and maintenance of spare parts and GSE. The Contractor shall submit storage related documentation in accordance with CDRL 9.

4.3.4.6 Shipment of the ICESat-2 Spacecraft and Observatory and Ground Support Equipment

The Contractor shall be responsible for the shipment of the ICESat-2 Spacecraft and Observatory between the places of manufacture, integration and test, storage and launch operations. The Contractor shall provide all appropriate shipping containers and handling equipment, cables, documentation, and consumables. The Contractor shall provide for the shipment of necessary GSE required to support the ICESat-2 Spacecraft/Observatory during each phase of test, integration and launch preparation. Transportation and Handling plans shall be documented in accordance with CDRL 9.

The Government will be responsible for the planning, preparation, packing, and shipment of the Instrument GSE after launch.

The Contractor shall obtain any necessary shipping permits and hazardous material exemptions.

During all shipments the Contractor shall perform continuous monitoring of the shipping and handling environment for all controlled conditions (shock, temperature, air cleanliness, air or nitrogen purge, and humidity) while the Observatory is in the shipping container and ensure that the shipping method utilized is that validated within the environmental verification activity.

The Contractor shall, using a released procedure, reassemble, check out, and certify all Contractor GSE after each shipment, verifying that they are all operating within normal specification limits before their use with the Spacecraft/Observatory. All hardware shall comply with the seismic safety requirements of AFSPCMAN 91-710, Vol 3.

The Contractor shall perform all post-ship and prelaunch testing (e.g. Comprehensive Performance Tests) as documented in the Observatory Launch Site Operations and Test Plan (CDRL 10).

The Government will, using a released procedure, disassemble, reassemble, check out, and certify the Instrument GFE-GSE prior to utilization.

4.3.4.7 Mission Readiness Testing

The End-to-End Mission Readiness Testing (MRT) is performed to certify the ability of the Observatory and Ground System to operate as required to meet mission performance requirements, assessing their performance and their interfaces in various operational environments.

The Contractor shall support the ICESat-2 integrated test team to plan coordinate, and execute the MRTs. The Government will facilitate the test working group sessions in preparation for test execution. The Contractor shall provide detailed inputs to the test procedures based on the mutually defined test steps to accomplish the test objectives and shall coordinate with the Government for generation of test procedures for the MRT. The Contractor shall provide all necessary information, including the command and telemetry database, command procedures, and expected results from the spacecraft perspective. The Contractor shall support test execution with engineering support personnel in attendance at the MOC and at the Contractor facility. The Contractor will have approval of the spacecraft test procedures and will be capable of halting the test should the need arise. The Contractor shall perform any pre-test setup and check out as necessary to ensure readiness of the MRTs. The Contractor shall be responsible for reviewing and approving the procedures to be executed for the MRTs.

The six MRTs are defined in the following tables. The Contractor shall support all six test activities and pre-test checkouts to ensure readiness of the MRTs.

MRT 1		
Test Objectives	**Target Time Frame**	**Brief Description**
▪ RT Spacecraft HK telemetry all rates ▪ Basic SSR operations ▪ Basic diagnostic data ▪ RT Observatory HK TLM packets to the ISF	Completion of S/C I&T	Basic Spacecraft T&C Capabilities

MRT 1 is expected to run in one day, excluding any setup or other supporting test activities. The test configuration may include hard-wire or RF connection to the spacecraft.

MRT 2		
Test Objectives	**Target Time Frame**	**Brief Description**
▪ Capabilities in MRT 1 plus.. ▪ Memory dumps ▪ More complex stored command loads ▪ Spacecraft and instrument commands ▪ Observatory timeline/load input from ISF to MOC ▪ RT Observatory HK TLM packets to the ISF	12-10 months prior to launch	Basic Command and Memory Management functions for Spacecraft and Instrument

MRT 2 is expected to run in two days, excluding any setup or other supporting test activities. The test configuration may include hard-wire or RF connection to the spacecraft

MRT 3		
Test Objectives	**Target Time Frame**	**Brief Description**
▪ MRT 1 and 2 plus ▪ S and X-band telemetry flow ▪ Maneuver planning and execution ▪ Off Nadir Pointing Commanding ▪ Flight software and special SSR management commands ▪ Orbit Determination ▪ Interface to the FDF ▪ Interface and processing of the POD/PAD data from//to MOC and	10-8 mos. prior to launch	Nominal operations including calibration and TOO maneuvers and orbit tracking

SIPS ▪ Clock Management ▪ Level 0 Data production ▪ Science data processing at the SIPS and delivery to the archive. ▪ Memory/FSW load uplinks ▪ Tables and FSW patches ▪ May be performed in TVAC ▪ If so, will include procs which can only be run in TVAC		

MRT 3 is expected to run in two days, excluding any setup or other supporting test activities. The test configuration may include hard-wire, but will be primarily RF connection to the spacecraft. If the test is not conducted in TVAC, there will need to be an augmented MRT-3 that is executed from the MOC during TVAC for procedures and functions that cannot be tested at ambient.

MRT 4		
Test Objectives	**Target Time Frame**	**Brief Description**
▪ MRT 1 thru 3 plus ▪ L&EO Timeline segments (e.g. subsystem activation) ▪ Spacecraft unique operations (not simulated adequately) ▪ Subsystem failovers and contingencies (e.g. A-B-side CPU, Spacecraft and Instrument. ▪ More advanced/complex FSW patches/updates ▪ Mechanism movement (e.g. SADA, X-band antenna)	7 - 6 mos. prior to launch	MRT 4 will be a large step in complexity. It will involve the more advanced operations, Launch and Early Orbit activation timelines as well as contingency operations.

MRT 4 is expected to run in three days, excluding any setup or other supporting test activities. The test configuration may include hard-wire but will be primarily RF connection to the spacecraft

MRT 5		
Test Objectives	**Target Time Frame**	**Brief Description**
▪ Demonstrates full science operations ▪ FOT performs all routine and periodic operations including	6 – 4 mos. prior to launch	Full science operations, regression testing and additional contingencies. MRT 5

validation data collection, processing, and distribution ▪ Any remaining contingency operations ▪ Regression testing for: ▪ Ground system fixes/enhancements ▪ Revised/new PROCs ▪ FSW updates ▪ T&C database updates		concentrates on all activities supporting science data collection, processing and analysis. The resulting data is provided to the Science Team for analysis. It will also focus on regression testing and any remaining contingency operations

MRT 5 is expected to run in three days, excluding any setup or other supporting test activities. The test configuration may include hard-wire but will be primarily RF connection to the spacecraft. MRT 5 can be run during Observatory thermal-vacuum testing. MRT 5 is expected to be the last MRT prior to shipment

MRT 6 (Launch Site)		
Test Objectives	**Target Time Frame**	**Brief Description**
▪ Demonstrate launch site interfaces ▪ Demonstrate routine operations.	At the launch site	Verify that the launch site interfaces and routine operations at the launch site one last time prior to launch. This test will also retest and function deemed necessary from previous testing results.

MRT 6 is expected to run in two days, excluding any setup or other supporting test activities. The test configuration may include hard-wire but will primarily be RF connection to the spacecraft.

4.3.4.8 Several Day in the Life Testing

The Contractor shall conduct a Several Day in the Life test, which runs over one integral operating period to demonstrate long-term autonomous operations. The test will execute for approximately 72 hours not including the initial setup or other test supporting activities. The test will be planned and coordinated with the MOC and Flight Operations Team. The test will be targeted for the time frame approximately 6 months prior to launch.

4.3.4.9 Mission Operations Testing

Mission Operations Testing includes those exercises, simulations, and rehearsals used to prepare the operations staff for launch, checkout, science mission activities and contingency operations. Mission Simulations will be conducted from the MOC. These tests will utilize the spacecraft

wherever possible, but a sufficiently capable simulator will be used if needed. The government will use an incremental approach to mission simulations. These increments correspond to the complexity of the task being performed. Mission Simulations will commence approximately one year before launch. Three types of readiness simulations are defined, exercises, simulations, and rehearsals (rehearsals are defined in section 4.3.5 The spacecraft Contractor shall lead, coordinate, and conduct all tests that involve the Observatory. The Government Mission Operations Manager shall lead, coordinate, and conduct all tests that do not involve the Observatory.

4.3.4.9.1 Exercises

This testing is performed at the subsystem level. It involves relatively few engineering and MOC operations staff. These tests are used to show that a particular command, command procedure, or command sequence produces the desired result. These tests occur on a daily or weekly time scale. These tests may last from hours to days in duration. The Contractor shall provide timely review of all government developed command sequences and procedures. This will be a low level of effort for the Contractor involving logistical support for the setup and takedown of circuits and equipment. The Contractor shall answer specific questions regarding the planning, execution, and interpretation of the results of these tests.

4.3.4.9.2 Mission Simulations

This testing is performed at the system level and involves all space and ground elements except the launch site. The simulations involve a large number of engineering and operations staff. These simulations are based on the results of the exercises described above. Details of the simulations are mission time line dependent but will include all nominal and contingency activities. The Contractor shall provide input to the simulations plans and provide subsystem and system engineering support to accomplish the activities. It is expected that approximately seven Mission Simulations will be required for ICESat-2.

4.3.5 Launch Operations Support

The Contractor shall provide launch support of the completed Observatory. This shall include launch vehicle interface definition, design verification and management, Observatory launch preparation and launch support. The Government will make the final go/no-go decision for launch. The launch support activity shall include the following efforts:

1. Launch Site Safety - Prior to shipment of the Observatory and associated equipment to the launch site, the Contractor shall prepare and provide Observatory related safety documentation as required by the launch site safety and launch range organizations. The Contractor shall submit the Missile Safety Prelaunch Safety Package (MSPSP) in accordance with MAR. The Government will provide to the Contractor launch site related information for all Government Furnished Equipment, including the payload-instrument(s), for inclusion in the MSPSP.

2. Launch Operations Planning - This effort requires the development and maintenance of interfaces with all entities that play a role in Observatory launch. This involves coordinating, planning and performing all tasks, which are necessary to implement a successful launch. The Contractor shall provide technical and management support of meetings to define launch related interfaces.

3. Launch Simulations - This effort encompasses the conduct, analyses and evaluation of pre-launch training and simulations of the launch (through orbit insertion). This testing is performed with all individuals who will participate in the launch in their launch day positions. These events will require significant advanced planning, review and coordination. The Contractor shall provide launch support for launch simulations and rehearsals. The Contractor shall provide all personnel who will participate in the launch for these events. The Government will conduct, analyze, and evaluate pre-launch training and simulations of the launch (through orbit insertion). The Contractor shall support and participate in two launch and activation simulations and three launch rehearsals.

4. Pre-launch Integration and Test - The Contractor shall perform all tasks necessary to integrate, test and prepare the Observatory for launch at the launch site. Hazardous test procedures and other safety related deliverable documentation shall be provided to the launch range safety in accordance with the MAR. The Contractor shall provide management and engineering support for all Observatory activities associated with the launch vehicle and launch services. These activities include but are not limited to: systems integration, interface definitions, interface verification, Observatory to launch vehicle integration, ground processing facilities and GSE integration and readiness, and launch support effort. The Contractor shall assure that compatible interfaces between hardware and software are defined, coordinate launch vehicle interface requirements definitions, and support and conduct design and safety reviews, technical interchange meetings, and working group and ad-hoc meetings. The Contractor shall support all activities related to the development of interface documentation. The Contractor shall provide a Launch Site Support Plan in accordance with CDRL LV-1. The Contractor shall define spacecraft launch site processing requirements to successfully prepare the Observatory for launch. These requirements include, but are not limited to, any Mechanical Ground Support Equipment (MGSE) or Electrical Ground Support Equipment (EGSE) required from the Payload Processing Facility (PPF) Contractor as well as the need for s/c propellant loading facilities and services. Propellant will be provided as GFE. The Contractor shall provide the loading cart and perform the loading of the fuel. PPF environmental requirements shall be defined by the spacecraft Contractor that include, at a minimum, any purge, temperature and humidity control and contamination control requirements. The Contractor shall participate in the Ground Operations Working Group (GOWG) meetings. The Contractor shall provide data to the MOC provided Front-end processor throughout Launch Site Testing activities to provide a real-time eavesdropping capability. The Contractor shall support development of Observatory to launch vehicle integration test plans, procedures, and services; check out of interfaces with the launch vehicle and launch facilities; and support mission readiness tests involving the Observatory, launch vehicle, and ground system. The Contractor shall

demonstrate first motion of all deployable spacecraft assemblies.

The Contractor shall support, review and certify the results of Propellant Loading GSE "end of line fuel sampling" tests, prior to loading propellant to the Observatory. The Contractor shall sample the propellant at the end of the GSE just before the fill and drain valve of the spacecraft. These samples shall be tested for particle contamination and propellant verification. Loading shall continue once the test results have been certified.

5. Launch Operations - The Contractor shall provide all required integration, safety, and engineering support to process the Observatory through the ground processing facilities, launch site facility and on the launch vehicle. The Contractor shall support the actual launch and post-launch orbit insertion. The Contractor shall perform Observatory initialization, deployments and preparation for on-orbit performance verification testing. All activity will be under Government direction from launch through separation of the Observatory from the launch vehicle. The Contractor shall provide Launch Commit Criteria in accordance with CDRL LV-2.

4.3.5.1 Launch Analysis Support

The Contractor shall provide management and engineering support for all analytic efforts conducted by the Government-provided launch services Contractor necessary for the assessment of launch vehicle environments, interfaces, and ground processing on the Spacecraft design. This support includes development of detailed Observatory analytic models analysis of ground processing facility compatibility, compliance with interface safety requirements, and compatibility with launch vehicle flight environments and flight design, CDRL 6. The Government will be responsible for obtaining valid coupled loads analysis results from the launch organization. The Contractor shall compare the results of the coupled loads analysis cycle to the design loads used in Spacecraft structural analyses to confirm that the resulting loads are within the design requirements as specified in the launch vehicle ICD. In addition, the Contractor shall support all MIWGs and tests (e.g., fit checks, shock tests), as required, to ensure that Observatory requirements are satisfied.

4.3.6 Software

The software for the ICESAT II includes the following elements:

- Flight Software (FSW)
- Flight Software Development & Maintenance System (SDMS)
- Observatory Operations Simulator (OOS)

4.3.6.1 Software Definitions

The Contractor shall treat the software component of firmware, which consists of computer

programs and data loaded into a class of memory that cannot be dynamically modified by the computer during processing (including PROMs, programmable logic arrays, digital signal processors, Field Programmable Gate Arrays (FPGAs), etc.) as Flight software for the purposes of this SOW.

The Contractor shall design build, verify and deliver and maintain the FSW in compliance with NPR 7150.2A, ICESat-2 Spacecraft MAR, and GSFC-STD-1000.

4.3.6.1.1 Flight Software Element

Flight software (FSW) for the ICESAT II is embedded real-time software in microprocessor Random Access Memory (RAM) and Electrically Erasable Programmable Read-Only Memory (EEPROM. Some of the functions provided by the FSW are: Boot-up, real-time operating system (may be COTS), time management, telemetry monitoring, command storage and metering, internal communication bus control, failure detection and correction, and ground operations interface.

Likewise, for any autogenerated software from databases, models or other sources, these sources as well as the autogenerated code shall be considered Flight software for the purposes of this SOW.

4.3.6.1.2 Flight Software Development and Maintenance System (SDMS) Software Element

The Contractor shall provide the necessary ground based hardware, software, procedures, documentation and services to maintain the FSW after on-orbit acceptance. This hardware, software, procedures, and documentation shall be referred to as the Software Development and Maintenance System (SDMS). The SDMS shall contain the hardware platform(s) and software used in development of the FSW, including host development computer operating systems, high level language compilers and debuggers, autocode generator software systems, and test scenarios and procedures. It includes the software in the simulators that models: sensors, actuators, and attitude environment and dynamics. It also includes development support software such as document and code configuration management systems. The SDMS shall contain all tools and utilities required to format executable code for uplink to the spacecraft.

4.3.6.1.3 Observatory Operations Simulator (OOS) Software Element

Observatory Operations Simulator is used by the MOC in Ground System testing, Flight Operations Team (FOT) training, FOT procedure verification, and anomaly resolution. It includes host development computer operating systems, high level language compilers and debuggers, autocode generator software systems, machine language emulators, and test scenarios and procedures. It includes the software in the simulators that models: sensors, actuators, and attitude environment and dynamics. It also includes development support software such as document and code configuration management systems.

4.3.6.2 Software Management, Requirements, Development, Verification, and Testing

The Contractor shall document their systematic approach to all software development in the Software Management Plan (SMP), in accordance with CDRL SW-1. Planned deviations from CMM/CMMI standards shall be explained in the SMP and require approval of the Government.

NPR 7150.2A and this solicitation require that the FSW be Class B and that the SDMS and OOS be Class C.

For **Class B** software:
CMMI-DEV Maturity Level 2 Rating or higher for software, or CMMI-DEV Capability Level Rating or higher for software in the following process areas:

a. Requirements Management.
b. Configuration Management.
c. Process and Product Quality Assurance.
d. Measurement and Analysis.
e. Project Planning.
f. Project Monitoring and Control.
g. Supplier Agreement Management (if applicable).

4.3.6.2.1 Planning and Requirements Life Cycle Activities

The Contractor shall perform all analyses and software systems engineering required to allocate (from system and subsystem requirements) and identify, software and software interface requirements, and document these in accordance with CDRL SW-2 (Software Requirements Document including ICDs). All requirements shall be forward and backward traceable between system and software requirements and between software requirements, design, and test.

The Requirements phase shall be concluded when the Contractor has responded to all action items from the successful Software Requirements Review (SWRR) (CDRL SE-1).

4.3.6.2.2 Design Life Cycle Activities

The Contractor's software design shall be captured and maintained in the Software Design Document (SDD) in accordance with CDRL SW-3. This shall describe the architecture, structure, and organization of each software component (CSCI) and its sub-components (CSC). The SDD shall describe the interfaces, logic, data flow and unique data structures contained in each sub-component. Draft versions shall precede the final as-built version.
The Contractor's testing approach and methodology shall be documented in the Software Test Plan (in accordance with SW-4). All phases of the software testing, from informal routine and function tests through the Acceptance Tests shall be carried out conforming to the documented

plan. Detailed testing procedures are captured and maintained in the Software Test Procedures and Results (in accordance with CDRL SW-5). Electronic versions of test results shall be accessible.

Software design (preliminary and detailed) shall be subject to peer review by design walk-throughs. Inclusion of all software requirements shall be assured. Government representatives may attend these reviews at their discretion. Action items shall be tracked by the Contactor through completion.

The Preliminary Design phase shall be concluded when the Contractor has responded to all action items from the successful Software Preliminary Design Review (SWPDR) (CDRL SE-3). The Detailed Design phase shall be concluded when the Contractor has responded to all action items from the successful Software Critical Design Review (SWCDR) (CDRL SE-3).

4.3.6.2.3 Implementation through Delivery Life Cycle Activities

Each Computer Software Unit (CSU) shall be unit tested by its developer as part of implementation. A software test above the CSU level shall not be developed or performed by the same individual who developed the code under test.

The Contractor shall subject each CSU to code reading review by cognizant developers other than the CSU author and a Software QA representative. The code reading shall verify that each CSU is in compliance with the documented and approved programming practices, conventions, and standards, as well as assuring it meets both its intended requirements and design. Government representatives may attend these reviews at their discretion. Action items shall be tracked through completion by the Contractor.

The Contractor shall perform regression testing prior to version releases to ensure the integrity of existing software. With each delivery of verified and tested software, the Contractor shall concurrently deliver a Software Version Description Document (VDD) in accordance with the NPR 7150.2A.

As part of the delivered systems, the Contractor shall include a Software User and Maintenance Manual, in accordance with CDRL SW-6. This will provide the operators of the system a full understanding of how the software is used and how it is to be maintained.

The purpose of the Software Test Readiness Review (SWTRR) (SE-3) shall be to assess whether the Contractor has adequately prepared for formal software acceptance testing to include, at a minimum, the check-out of test procedures, test cases, and requirements traceability. With this phase of testing, the Contractor shall prepare for formal monitoring of software testing by QA, the Contractor's System staff, and Government personnel to include the NASA IV&V staff. Upon successful completion of this phase of testing, the Contractor shall close out all action items and prepare for formal delivery of the software.

The Acceptance phase shall be concluded when the Contractor has delivered the software and responded to all action items from the successful Software Acceptance Review (SWAR) (CDRL SE-3).

4.3.6.3 Software Management Requirements

4.3.6.3.1 Resource Estimation and Allocation

Resource planning for the software elements shall include the Contractor's participation in various technical working groups and interface meetings that relate to software, and support of NASA IV&V, as defined in section 4.3.6.3.3.1.

The Contractor shall be solely responsible for the management of any sub-contractors or team members. The Contractor shall be responsible for acquiring and including Software Measures (Metrics) from any sub-contractors or team members.

4.3.6.3.2 Government Insight

This section defines Government access to Software documentation, data, and analysis to allow appropriate insight of development effort, including the NASA IV&V interface.

All Contractor, sub-contractor, and team member reviews, audits, meetings and other activities pertinent to the execution of the contract shall be open to Government review/attendance. The Contractor shall provide the Government with reasonable and timely notification, to facilitate Government attendance in person, by telecon, or by videocon. Other Government ICESAT II contractors may also attend these reviews, audits, and meetings at the Government's discretion.

4.3.6.3.2.1 NASA IV&V Support

The Contractor shall ensure that all software documentation and code required for the NASA Software Independent Verification and Validation (IV&V) effort is made available to NASA IV&V personnel. Where electronic/web-based access to information is available to the ICESAT II Project, the Contractor shall also make access available to NASA IV&V. The Contractor shall allow NASA IV&V review and participation before final product delivery to the Government. The Contractor shall respond to formally delivered issues from IV&V that are delivered from the ICESAT II Project's IV&V Liaison.

4.3.6.4 Software Maintenance

The Contractor shall maintain the software (SW), along with the environments and emulators necessary to develop and verify the FSW, thru completion of the mission.

The Contractor shall retain SW documentation for the complete software lifecycle development until the end of the mission life. This documentation will be used for maintenance of the system and shall be accessible to the Government for review until the end of the mission life.
The Contractor shall provide a Software User and Maintenance Manual in accordance with CDRL SW-6.

The Contractor shall define, with Government concurrence, the portions of flight software that will be maintained by the FOT during on-orbit operations (e.g. table loads). The FOT will facilitate efficient and effective mission operations. The Contractor shall maintain those portions so designated.

The SDMS shall be delivered in place at the Contractor's facility and operated from there through spacecraft acceptance and thru the mission life. The Contractor shall work with the Government in the design development of the communications links between the SDMS and the Flight Operations Ground Systems.

4.3.7 Flight Operations Interfaces and Support

Under the baseline effort, the Government will provide the Flight Operations Ground Systems and personnel. Providing the Mission Operations Center and Flight Operations Team is Option 1 of this DO.

The Government furnished flight operations team will be responsible for developing and executing all on-orbit operations procedures for the ICESat-2 Observatory. The Contractor shall support the FOT's production of operational procedures and scripts by providing written operations procedures and I&T scripts for launch, early-orbit, activation, acceptance, and nominal operations; participating in TIMs and providing spacecraft expertise on flight operations. The Contractor shall provide the Operations Procedures and Scripts in accordance with CDRL OPS-6. The Contractor shall review, comment, and sign-off on all operational procedures and the operational command and telemetry database prior to launch.

The Contractor shall train the Flight Operations Team for on-orbit initialization, check out, performance verification, nominal operations, and anomaly resolution. The Contractor shall conduct the training of up to 20 members of the flight operations team, and qualify their ability to operate the Observatory, in accordance with CDRL OPS-1. The Contractor shall provide the documentation and data required to provide training and logistics support necessary for the training of flight operations personnel at the Contractor's facility. All training presentations shall be video recorded and provided to the Government.

The Contractor shall participate in GF MOC training in support of the Contractor's use of the MOC and MOC systems during launch and early operations.

The Contractor shall provide a Flight Activation Operations Plan as described in CDRL OPS-3.

The Contractor shall provide Observatory related parametric data sufficient to properly configure the mission operations element flight dynamics attitude and orbit services. Pre-launch values provided shall be integrated into the mission operations element by the Flight Operations Team and tested against flight dynamics data provided by the Contractor. Post-launch revised values for applicable parameters shall be provided by the Contractor during On-Orbit Performance Verification.

4.3.7.1 Flight Operations Ground System Interface Definition

The Contractor shall provide a spacecraft compatible with the ground systems as specified in the Spacecraft-Ground IRD.

The Contractor shall work closely with the Government mission engineers to perform communications, command, control and operational requirements trade analyses.

The Contractor shall provide all necessary interfaces between the GSE and the Government-provided network interface, for connectivity to the MOC. This shall include all necessary system documentation, interface control documents (CDRL SE-9C), databases (CDRL OPS-8) and test efforts.

The Contractor shall support MOC/Front-End Processor interface tests for early confirmation of the data flows, formats, and contents as specified in the Spacecraft-Ground IRD. To support these tests, the Contractor shall provide the command and telemetry handbook in accordance with CDRL 5 and the command and telemetry database compliant with the Handbook and in accordance with CDRL OPS-8. The Contractor will establish and maintain the ICESat-2 Project Database (PDB) in accordance with CDRL 5, which will combine the spacecraft and instrument command and telemetry databases, and other database information required to operate and maintain the observatory in a common format. A current copy of the Project Database and the Command and Telemetry Handbook shall reside at the test conductor console during all instrument I&T and observatory level testing.

4.3.7.2 Training and Support for Flight Operations Team

The Contractor shall provide support to the mission flight operations team for training and preparations for on-orbit operations and anomaly resolution.

The Contractor shall provide to the Government a Spacecraft Operations Description Manual (CDRL 13) to support the launch and early orbit operations and checkout. The manual shall be of sufficient detail to provide a basis for troubleshooting and isolating spacecraft anomalies by the flight operations team. The manual shall include written and diagrammatic descriptions of the flight hardware, flight component box interfaces and software functionality. Instrument sections will be provided by the Government.

4.3.7.3 On-Orbit Performance Verification

The Contractor shall perform an on-orbit performance verification program confirming that the Observatory performance is in accordance with the mission requirements, the ICESat-2 Spacecraft Performance Specification (CDRL 1) and interface specifications. The Contractor shall develop an On-Orbit Commissioning Plan (CDRL OPS-2).

At a minimum, this shall include:

1. Observatory On-Orbit Checkout:
The Contractor shall provide support to the Government in the preparation of on-orbit test and verification procedures. The Contractor shall verify the post-launch performance and state-of-health of the Observatory. To the extent possible, the proper function and performance of all systems shall be verified. The Government will provide payload-instrument performance evaluation support. The Contractor shall support Spacecraft check out and establishing state of health following launch and Observatory separation. The FOT will issue all Observatory commands, with the concurrence of the Contractor, in accordance with the Flight Activation Operations Plan, CDRL OPS-3. The Contractor shall monitor the Observatory telemetry, support on-orbit anomaly investigations, and acquire historical data for trend analysis. Checkout of the spacecraft will nominally complete less than 30 days after launch, unless delayed by unresolved spacecraft anomalies.

The Contractor shall provide system lead and subsystem engineering support at the mission operations center on an around-the-clock basis until all Spacecraft subsystems are activated and checked out, the Observatory is in the mission orbit with all Spacecraft subsystems performing nominally; and 16 hours x 7 days per week coverage through Instrument activation (approximately 30 days); and 8 hours x 5 days per week until Observatory acceptance by the Government (approximately 60 days). The Contactor shall submit daily status reports through system acceptance by the Government. The Government will provide Instrument check out and operations support during this time.

The Contractor, in conjunction with Instrument Provider support, shall support an on-orbit performance verification program to confirm that the Observatory performance is in accordance with the mission requirements, specifications, and interfaces. The ICESat-2 Instrument Operations Team will perform the necessary Instrument testing, in accordance with the following paragraphs.

The Contractor shall prepare a report that summarizes the on-orbit performance of the Observatory compared to its required performance for the mission after launch in accordance with CDRL OPS-7. All pertinent issues affecting mission success shall be addressed. The extent of performance explanation required depends on the seriousness of the impacts that any problems identified may have on mission success. The Contractor shall also provide an assessment of the flight operations team's readiness to assume operational control of the Observatory. This report summarizes the Observatory performance on-orbit after launch and

check out to determine initial mission success. Government acceptance of the Observatory will occur after the on-orbit check out based upon successful operation of the Observatory as mutually defined and agreed to in the Flight Activation Operations Plan.

The Contractor shall support database updates by making database corrections, validating them on the software development validation facility, and participating in the uplink transmission, up through Government spacecraft acceptance, CDRL OPS-8.

The Contractor shall develop an on-orbit Spacecraft engineering trending approach. The Contractor shall identify parameters to trend, including pseudo-parameters, and analyze the data with the intent to identify anomalous performance, out-of-family performance, degradation of components, characterize nominal aging effects, predict EOL, etc. Comparisons shall be made between on-orbit performance and Spacecraft-level pre-launch test data. This approach shall be documented in the Spacecraft and Operations Description Manual as described in the CDRL 13.

2. Observatory to Flight Operations Ground Systems Interface Verification:
This effort shall be performed by the Contractor after the Observatory on-orbit performance and state-of-health have been confirmed. The test shall verify proper operations of the Observatory to Flight Operations Ground System interfaces and to provide the necessary calibrations.

3. OAR and Presentation Package (Reference Section 4.3.1.4.2 and CDRL 15G):
The completed OAR Presentation review package shall summarize the on-orbit Observatory performance through checkout. The presentation results shall be used to determine initial mission success and final payment milestone completion status.

The Contractor shall resolve all out-of-specification on-orbit performance issues as assigned to the Contractor by the ICESat-2 Project Office. This support shall remain effective until the end of the check out period, or until Spacecraft acceptance by the Government, whichever occurs later. The Contractor shall provide any support required to resolve such pre-acceptance Spacecraft anomalies. This includes support of periodic conference calls on the status of anomalies under investigation.

In association with the OAR, the Contractor shall provide to the Government an acceptable End Item Data Package in compliance with ICESat-2 MAR Section 16 and MAR-DID 16-1 and CDRL OPS-7.

The Contractor shall provide an Operations Transition Plan in accordance with CDRL OPS-4.

4.3.7.4 Support to On-Orbit Operations

The Contractor shall provide support to resolve all on-orbit Observatory anomalies. Baseline support shall be through the period of on-orbit operations verification testing, instrument activation and calibration, handover to the flight operations team and on-orbit acceptance.

After on-orbit acceptance, the Government may modify the DO to address post-acceptance activities. The DO may also be modified to extend the mission life.

The Contractor shall provide a Sustaining Engineering Plan covering activities thru on-orbit acceptance in accordance with CDRL OPS-5.

4.3.8 Observatory Models

The Contractor shall provide twelve $1/25^{th}$ scale models of the completed Observatory. The delivery dates and scale will be mutually agreed between the Contractor and the Government.

4.4 ICESat-2 Options

4.4.1 Option 1 Mission Operations Center and Flight Operations Team

An option shall be priced for the Contractor to provide a non-GFE, Mission Operations Center and perform the mission from this facility with a Contractor provided Flight Operations Team. Under this option, the Contractor shall provide all personnel, services, materials, facilities, software and hardware required to develop, deliver, install, verify, operate and maintain the ICESat-2 Mission Operations Center for the life of the mission. In the event that Mission Operations services are not required for 3 years, the government has a right to negotiate an equitable adjustment. This option will be invoked within Award plus 8 months notice.

The Mission Operations Center is the primary link between the ground-receive sites and the science community as described in the Mission Operations Concept Document ICESat-2-SYS-PLAN-0006. This option has two major components: Mission Operations Center Development and Mission Operations.

Deliverables if this option is invoked will include:

- Mission Operations Center after Acceptance Review and 60 days on orbit
- Backup Mission Operations Center after Acceptance Review and 60 days on orbit
- S-Band Observatory HK Trending System for ISF at start of Observatory I&T – 3 months

4.4.1.1 Mission Operations Center Development

The Contractor shall provide a Mission Operations Center and backup Mission Operations Center that meets all requirements specified in the ICESat-2 Mission Operations Center Requirements Document, Mission Operations SOW and CDRL.

4.4.1.2 Flight Operations

The Flight Operations portion of this option shall provide the price of performing all routine and pre-planned activities required to successfully execute the ICESat-2 mission as defined in the Mission Operations SOW and CDRL. The pricing shall include per year cost of operating the MOC for up to three years of flight operations.

4.4.2 Option 2 Three-Month Launch Delays (may invoke up to 4 times)

The Contractor shall accommodate a 90 calendar day slip in the delivery schedule of the ATLAS Instrument as indicated in the GFE List or other programmatic considerations, with a corresponding 90 calendar day launch delay. This option will be invoked with at least 60 calendar days' notice prior to the Instrument delivery dates. The Government may exercise any 90-day launch delay in increments from two-weeks to three-months.

4.4.3 Option 3 Three-Month Launch Vehicle Selection Delays (may invoke up to 4 times)

The Contractor shall accommodate a 90-calendar day slip in the selection of the LV Contractor beyond the Spacecraft Preliminary Design Review. This option will be invoked with at least 60 calendar days' notice prior to the Preliminary Design Review initially and 30 days prior to the expiration of the option subsequently. The Government may exercise any 90-day launch vehicle selection delay in increments from one month to three-months.

4.4.4 Option 4 Extended Operations

When exercised by the Government, the Contractor shall provide the following services in one-year periods after the first 3 years of mission operations (i.e. years 4-8):

1. Management, systems engineering, and administrative support to engineering support activities
2. Maintain the FSW for the spacecraft.
3. Participate in a joint ICESat-2 Configuration Control Board with the Government. Assume one telecon meeting per month of one-half day duration starting at the end of the acceptance phase
4. Maintain the SDMS for mission operations, including all unique non-commercial hardware (e.g. C&DH avionics flight computers)
5. Maintain the spacecraft portions of the OOS at the MOC.

The first determination to exercise this option will be made 90 days before the end of the first three years on orbit. Determination for each of the subsequent options will be made 90 days before the end of the preceding operating year.

5.0 Government Furnished Equipment (GFE) List

See ICESat-2 RFO Attachment F

6.0 Mission Unique Deliverables List

See ICESat-2 RFO Attachment E

7.0 SOW Acronyms List:

A/R	As Required
ATLAS	Advanced Topographic Laser Altimeter System
CCB	Change Control Board
CCR	Change Control Request
CDR	Critical Design Review
CDRL	Contract Data Requirements List
CSCI	Computer Software Configuration Item
CSU	Computer Software Unit
DID	Data Item Description
DO	Delivery Order
ECP	Engineering Change Proposal
EMC	Electromagnetic Compatibility
EMI	Electro-Magnetic Interference
ERD	Environmental Requirements Document
ESD	Electrostatic Discharge
FOT	Flight Operations Team
FSW	Flight Software
GFE	Government Furnished Equipment
GMIP	Government Mandatory Inspection Point
GOWG	Ground Operations Working Group
GRD	Ground system Requirements Document
GSE	Ground Support Equipment
I&T	Integration and Test
ICD	Interface Control Document
ICESat-2	ICE, Cloud, and land Elevation Satellite - 2
IDIQ	Indefinite Delivery Indefinite Quantity
IDD	Interface Description Document
IICD	Instrument ICD
IIRR	Instrument Integration Readiness Review
IIS	Instrument – Spacecraft Interface Simulator
ISF	Instrument Support Facility
ITAR	International Traffic in Arms Regulation
IRD	Interface Requirements Document
LV	Launch Vehicle
LV-ICD	Launch Vehicle Interface Control Document
MAIP	Mission Assurance Implementation Plan
MAR	Mission Assurance Requirements
MIWG	Mission Integration Working Group
MOC	Mission Operations Center
MSPSP	Missile System Prelaunch Safety Package
MPSR	Monthly Project Status Review

NASA	National Aeronautics and Space Administration
NDA	Non-Disclosure Agreement
OAR	Observatory Acceptance Review
OOS	Observatory Operations Simulator
OPS-ICD	Flight Operations Ground System ICD
OPSSEC	Operational Security
PDR	Preliminary Design Review
PER	Pre-Environmental Review
PI	Principal Investigator
PM	Program Management
PSR	Pre-Ship Review
RF	Radio Frequency
RFP	Request for Proposal
RFO	Request for Offer (Request for Proposal for a Delivery Order)
S/C	Spacecraft
S&MA	Systems Safety and Mission Assurance
S/C	Spacecraft
SDMS	Software Development & Maintenance System
SIPS	Science Investigator led Processing System
SOW	Statement of Work
SPS	Systems Performance Specification
SRD	Spacecraft Requirements Document
SRR	(Spacecraft) Systems Requirements Review
TAA	Technical Assistance Agreement
TBD	To Be Determined
TBP	To Be Proposed
TBR	To Be Reviewed
TBS	To Be Supplied
TIM	Technical Interchange Meeting
TO	Task Order