ENCLOSURE 2
SES II-SAMPLE PROBLEM
V-1

RFP # NNG15498942R

Enclosure 2
SES-II Sample Problem

"GCC-F Mission Lifecycle Support"

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1 INTRODUCTION

1.1 Sample Problem Overview

The SES-II Sample Problem is defined to provide the offeror an opportunity to illustrate a wide range of experience, skills, and efficient management and development processes. Additionally, bidders can demonstrate an understanding of the complexities of working the many aspects of a mission's lifecycle within the National Aeronautics and Space Administration (NASA)/Goddard Space Flight Center (GSFC)/Software Engineering Division (SED) environment and the changes in mission support requirements and schedules that often occur. The Sample Problem spans many of the mission support activities routinely provided by the SED for a typical mission.

This Sample Problem depicts a fictitious cubesat mission. The mission was developed to address needs of the SES-II procurement activity and is not related to any existing or planned NASA mission.

This sample problem describes one type of mission that could be potentially supported through the SES-II contract. SED also supports much larger missions that may require SES-II support. The offeror shall highlight differences in their approach to this sample problem with what could be envisioned for one of the larger missions with the following general characteristics:

- 4 year development cycle plus 5 years on-orbit support
- Low earth orbit, earth science mission
- 5 science payloads, one is from GSFC, 2 are international
- Spacecraft integration and test at GSFC

1.2 Sample Problem Scope

For this Sample Problem, flight software, mission operations center software, and a limited science data handling system are to be developed under tasks to the SES-II contractor. The SES-II contractor is also responsible for the mission operations center system-level software integration and testing, including basic configuration of the mission operations software in the planned operations facility. Facilities costs and equipment purchases do not need to be addressed. Only local travel is anticipated.

Sample Task Orders are specific to WBS elements 4.1, 4.2, 4.3, and 4.6 outlined in the Statement of Work. Ties to other WBS elements or GSFC organizations may exist as points for coordination or indirect support.

1.3 Mission Description

GSFC CubeSat Constellation (GCC) is a series of fictitious multi-satellite earth science missions to be launched beginning in 2018. Each constellation of satellites consists of an initial set of up to six 6-U cubesats in near proximity to each other. Additional small satellites can be added over time for either replenishment or to increase the science collection ability of the overall GCC.

GCC missions are planned to take ocean surface measurements (GCC-O), atmospheric and pollution measurements (GCC-A), and farming chemical, moisture, and vegetation measurements (GCC-F).

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GCC-F is the first of the GCC series to be launched. This sample problem deals only with GCC-F, except to note that other GCCs could follow.

The GCC-F mission has been assigned to GSFC for overall management, development and operations. A key objective of the mission is to demonstrate GSFC's ability to fly clusters of small satellites with a total budget below the budget associated with past missions of the space science Small Explorer (SMEX) Program while still meeting valuable scientific objectives.

The mission is to be developed over a 24-month period (mission start date through launch) followed by a 9-month operations phase. Launch is planned for January 15, 2018, to allow for collection of data through an entire growing season.

The GCC series of missions build on work done at NASA's Goddard Space Flight Center in the development of cubesat missions; specifically in the areas of the generic cubesat structure, bus and processor, telemetry and command xmit/receive systems, and in the development of very small payloads of significant scientific merit. In some cases, the Goddard cubesats are assembled per GSFC specifications through University programs and fitted with University-developed payloads.

GCC-F is designed specifically to provide detailed fine-resolution data for large industrial farming operations, with some research planned to determine the value to smaller farming plots and other applications. NASA is collaborating with the nearby Agricultural Research Center and the University of Maryland on the GCC-F mission. The University effort is partially funded by a grant from the National Science Foundation. There is no international participation in any of the GCC missions. Because of rules established by the other partners, GCC-F is limited to gathering data only over U.S. territory.

The four spacecraft will be placed in a 350 km circular orbit at a 50 degree inclination to maximize observations over the middle-latitudes. A ride-share agreement will be established to support the planned launch date.

Data: Overall data requirements per satellite are considered on the low end for typical GSFC missions:

- 2 kbits/second real-time housekeeping telemetry
- 512 kbits/second file downlink rate
- 300 Mbits science data recorded for daily downlink
- 50 Mbits engineering data recorded for daily downlink
- Consultative Committee for Space Data Systems (CCSDS) protocols and formats for real-time telemetry and command
- CCSDS File Delivery Protocol (CFDP) file transfers for all recorded data downlink and for command load uplink
- All space-ground communications will be via S-band ground antenna stations located in the United States. UHF communications will not be permitted. Tracking and Data Relay Satellite System (TDRSS) is not an option. Downlink is available at seven different University antenna sites. Both uplink and downlink is available only from NASA Wallops, Virginia facility.
- 1 Kbps command uplink, 500 commands per day average (90% contained in stored time-tagged command loads, 10% real-time uplink to the spacecraft primarily to coordinate the contact)
- The on-board processor allows for flight software upgrades using the standard command uplink channel and CFDP file transfer protocol.

Satellite Bus: GSFC is responsible for the in-house design and development of the satellite bus. Code 587 has been responsible for much of the early cubesat and spacecube design work at GSFC and will work with other Applied Engineering and Technology Directorate (AETD) organizations in the GCC-F flight hardware development – outside of the SES-II contract. Two of the satellites will be provided to the University of Maryland as parts-kits for assembly and integration with instruments designed and built at the University of Maryland. Three satellites will be fully integrated at GSFC; one of which will be utilized for test and simulation activities. Global Positioning Satellite (GPS) receivers on-board are planned for position, time, and frequency reference. The initial satellite bus-to-Ground Systems and Instruments-to-Satellite Bus Interface Control Documents (ICDs) will be provided to the SES-II contractor.

Instruments: Each cubesat carries either one or two remote sensing instruments. They are referred to by their satellite ID (F1, F2, F3 . . .) and their instrument ID (A or B). Each instrument requires daily command loads to configure filters and on/off times.

Instrument F1-A. Surface soil moisture
Instrument F2-A. Soil Nitrogen sensor
Instrument F2-B. Soil nutrient sensor
Instrument F3-A. Soil temperature
Instrument F3-B. Subsurface soil moisture
Instrument F4-A. Vegetation color

A small cloud sensor may be added to each satellite so that on-board software can filter out cloud-impacted data sets. Some researchers have suggested that the cloud coverage data itself may also provide useful science data.

Operations Concept: The high-level operations concept was developed during Phase A, although several study areas were defined and additional concepts for further efficiencies are to be considered. The operations team (not an SES-II task) has asked that the ground system tools be able to automatically accept data streams from the receive-only stations. Command support will be based on satellite contacts when visible from the Wallops ground station. At most, two contacts in a day will be used for commanding the GCC-F; some days will not have any contact opportunities due to coverage geometry. All weekend operations are to be automated, with the software automatically notifying the operations team of potential anomalies. The SES-II team will provide ground software expertise to the mission operations team throughout the mission and will be on-call in case of ground system problems.

Command loads will generally consist of mode changes and on/off commands for data collection. On/off times will be based on the satellite ephemeris delivered by the flight dynamics facility and result in the instruments being on only while over the continental United States.

All satellites in GCC-F will share the same command frequency, with satellite ID in the uplink packets identifying which satellite is to process the command message. Each GCC-F satellite has its own telemetry frequency.

For this Sample Problem, it can be assumed that all satellites in the GCC are in the same antenna view for command uplink and telemetry downlink.

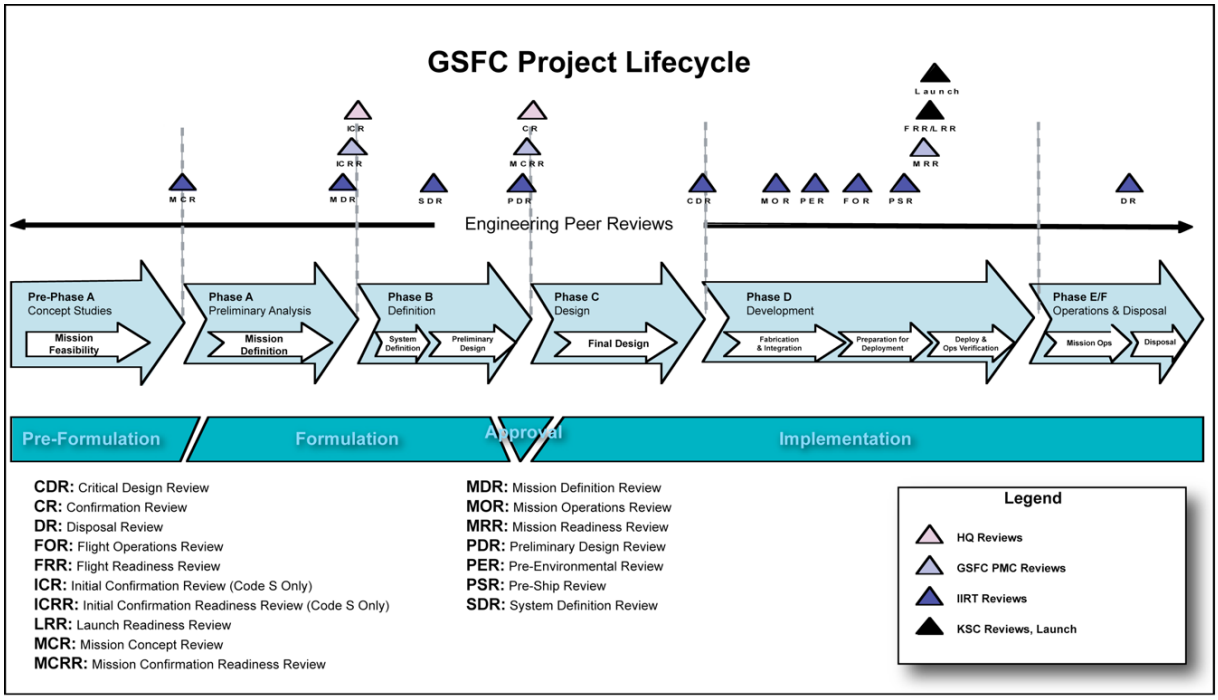
There is an expectation that GCC-F will be one of GSFC's most efficiently operated earth science missions and will set the precedent for the future GSFC small multi-satellite missions.

2 DEVELOPMENT REQUIREMENTS AND MISSION MILESTONES

Although earlier cubesat-based missions had often been considered experimental and allowed to be developed as Class D missions or as simple experiments, GCC-F with its planned scientific value and participation from other government organizations is to be developed as an NPR 8705.4 Class C mission with NPR 7150.2 Class B operational software. Detailed compliance standards are contained in the documents listed in the Applicable Documents section of the SES-II Request for Proposal (RFP). All work is unclassified.

The total lifecycle effort from the start of Phase B to the end of Phase E operations is 33 months and is fully contained within the period of performance of the SES-II contract. This is considerably shorter than the lifecycle of GSFC's more traditional single satellite missions. It is assumed that the traditional Phase A effort has already been completed by NASA civil servants. Phase F is not part of this sample problem.

The mission shall conform to the standard GSFC Project Lifecycle as shown in the diagram below, with key dates shown in the table that follows. Because of the compressed schedule, the mission management team is asking for suggestions on how to most-efficiently meet all key requirements.



PHASE	END-DATE	FINAL MILESTONE
Phase A	January 15, 2016	MDR (by gov't)
Phase B - Definition	April 30, 2016	PDR
Phase C - Design	October 1, 2016	CDR
Launch	January 15, 2018	--
Phase D – Development	February 17, 2018	Launch + 30 days
Phase E – Mission Operations	October 15, 2018	--

3 TECHNICAL ASSIGNMENT DESCRIPTIONS

The following sections identify the separate technical assignments to be issued as individual task orders for GCC-F:

3.1 Sample Problem 1A: GCC-F Systems Engineering Phase B/C

WBS Element:	4.1 - Software Systems Engineering, Studies and Analysis
Lead Organization:	Code 581
Start Date:	January 15, 2016
End Date:	October 15, 2016

The contractor shall be responsible for leading the key efforts of the GCC-F Phase B/C activities under the direction of the NASA GCC-F Ground Systems Manager?"

The contractor shall:

1. Create a dedicated GCC-F mission operations center for creating a broader capability to operate multiple GCCs or other advanced cubesat-class missions
2. Develop options for operations staffing based on orbit coverage analysis and optional levels of automation
3. Select a Telemetry, Tracking, and Commanding (TT&C) system among government owned/developed and commercial options, taking into account the need to support many individual satellites
4. Select a planning and scheduling system, to include the options of simple spreadsheets or algorithm-based planning
5. Develop a list of options for testing
6. Prepare and present CDR material

The contractor shall update the operations concept document and develop the ground system level 3 requirements document based on these trades preformed within the GCC-F project.

In Phase C, key activities for system design shifts to the appropriate design and development organizations. The contractor shall maintain a coordination role to support system-wide analysis efforts and to ensure process and product consistency across all of the ongoing SES-II GCC-F work areas. With the short schedule, it is anticipated that close coordination with the cubesat flight hardware teams, University of Maryland, and the remote data acquisition sites will still be required.

3.2 Sample Problem 1B: GCC-F Systems Engineering Phase D

WBS Element:	4.1 - Software Systems Engineering, Studies and Analysis
Lead Organization:	Code 581
Start Date:	October 1, 2016
End Date:	March 1, 2018 (Launch + 45 days)

In Phase D, the Software Systems Engineering, Studies and Analysis organization integrate and deploy the ground software systems for the GCC-F and shall maintain a lower-level coordination role to support system-wide analysis efforts and to ensure process and product consistency across all of the ongoing SES-II GCC-F work areas. The contractor shall coordinate all engineering reviews under this task.

The contractor shall be responsible for ensuring 580-owned products are capable of operating in a multi-satellite environment. The contractor shall lead the system integration efforts, the system-level test effort, the end-to-end integration test effort (including external interfaces), and the installation efforts into the GCC-F operations area. Other aspects of the MOC, including facility preparation, networking, equipment purchases, voice loops and video switching systems are outside the scope of this sample problem.

3.3 Sample Problem 2A: GCC-F Flight Software Systems Phases B/C/D

WBS Element:	4.2 - Flight Software Systems
Lead Organization:	Code 582
Start Date:	January 15, 2016
End Date:	March 1, 2018 (Launch +45 day transition to sustaining effort)

The contractor shall support the government in the design, development, integration, test, and delivery of the GCC-F Flight Software (FSW). The GCC-F FSW includes the Command and Data Handling (C&DH) and Attitude Control System (ACS) functions. The contractor shall design, build and development the C&DH and ACS FSW, FSW product integration, FSW system validation testing, and FSW verification and validation. The contractor shall also work with the GCC-F Flight Software Sustaining Engineering (FSSE) team to ensure meeting FSSE maintenance requirements. The SES-II contractor shall integrate and test all of the software components.

The contractor shall assess whether the GCC-F FSW should be built upon the FSW heritage FSW products or develop a specialized GCC-F-specific Operating System.

The Contractor shall lead the GCC-F FSW verification and validation (V&V) in the following areas:

- S/C Acceptance Test Execution Runs
- S/C Comprehensive Performance Testing
- S/C Mission Simulation testing

Flight Software Sustaining Engineering Support (FSSE) shall start several months before launch. The contractor shall support the GCC-F FSW Development team in specifying FSSE maintenance requirements, and shall also support FSW build, system, and acceptance testing.

3.4 Sample Problem 3A: GCC-F Ground Systems Phase C, D, and E

WBS Element:	4.3 - Ground Software and Systems
Lead Organization:	Code 583
Start Date:	March 30, 2016
End Date:	October 15, 2018

In Phase C, the contractor shall develop a detailed design of the ground system software required for the GCC-F mission. Where practical, the software updates to existing components should be planned such that the tools remain general purpose and available for support to other missions. Automation should be enabled to the greatest extent practical, allowing the operations personnel to only need a single shift. The contractor shall support the Sample Problem 1A task effort to create the overall ground system design, including the analysis of alternatives for ground system components. Note that flight dynamics software is out of scope of this sample problem.

Ground system software includes, but is not limited to, the areas of telemetry and command processing, planning and scheduling, alert notification, automation, trending, and data archive and distribution.

In Phase D, the contractor shall make the required updates to the components selected for the GCC-F mission and conduct component-level testing. The software team supporting this task shall serve as subject matter experts in the components in system integration efforts and shall provide training to the mission operations team.

Software and Documentation Releases shall be made in November 2016, March 2017, and September 2017. Maintenance releases shall be made only if necessary. The contractor may propose alternate delivery schedules.

In Phase E, the contractor shall:

- Maintain all GOTS mission operations control center software for the GCC-F mission.
- Resolve discrepancy reports and implement any new requirements approved by the GCC-F CCB.
- Provide expedited deliveries during the spacecraft checkout, launch, and on-orbit phases as needed.

3.5 Sample Problem 6A: GCC-F Science Data Processing System Phase C/D/E

WBS Element:	4.6 – Science System Development
Lead Organization:	Code 586
Start Date:	March 15, 2016
End Date:	October 15, 2018

The data distribution portion of the GCC-F Science Data Processing System (SDPS) will be located at GSFC and be developed under the SES-II contract. The SDPS includes: data file accountability, data archiving, data reformatting to append orbit and attitude metadata, and data distribution functions. The science team resides at the Agricultural Research Center and GSFC does not hold any of the actual science data processing requirements. The contractor shall develop tools responsible for sorting the received data by instrument and providing it to the appropriate external science team members

The contractor shall design, development, integration, test, and delivery of the SDPS. The SDPS includes data capture, data archiving, and data distribution functions. The contractor shall provide an interface document that the science team can use to understand the format of the files distributed from the GSFC GCC-F SDPS data distribution system.

The SES-II team shall serve as subject matter experts for this software area and provide training to the mission and science teams as needed. A low-level of sustaining engineering is expected through the operational phase of the mission for the science data processing system.

4 TECHNICAL ASSIGNMENT MODIFICATIONS

Section 3 of this Sample Problem described the initial task order plans for the GCC-F mission. In this section, the problem is expanded to cover modifications to the technical assignment that may occur during the life of an extended mission development effort. SES-II programmatic, process, and technical effort changes affecting multiple task plans may be required to meet the new challenges.

4.1 Budget Re-planning

Date of First Notification: March 1, 2016
Required Completion Date: 10 days later

The GCC-F team has just been notified that other critical GSFC missions require additional FY16 funding in order to meet their launch dates late in 2016. The Center has been asked to re-plan missions in their early development phases so the funds can be reprogrammed to the other missions. Any funds reallocated during FY16 will be "returned" for use in FY17. This is a cash-flow issue for the Agency, and it is hoped that it does not impact total cost or launch dates for any mission. The funds are to be reallocated on April 1, 2016.

The contractor is asked to submit a new GCC-F lifecycle schedule and high level staffing plan (total hours per month, not by labor category) showing the before and after plans. The revised plan must include a description of the change and discussion of the innovations and risks involved in maintaining the January 2018 launch date while helping the Center meet its pressing needs to the greatest extent practical.

4.2 Inclusion of the Next GCC Mission

Date of First Notification: March 1, 2017
Required Completion Date: 60 days later

Independent of GCC-F, the GCC-O team has been working on their development plans. Concerned about potential cost growth, they have decided to ask the SES-II GCC-F team for an analysis of the existing GCC-F system capabilities and ideas on using a copy of the system for GCC-O or enhancing the GCC-F system to also support GCC-O. As currently planned, there will be a 3-month overlap between the operations of the two missions. The SES-II team must look at the different tools and the system configuration to determine the risks, the potential changes, and costs involved with coupling the two missions. GCC-O will have similar data characteristics as GCC-F, but the six GCC-O satellites will be equally spaced in a single circular orbit inclined at 40 degrees.

The contractor is to identify the key assumptions, requirements and considerations that will contribute to the determination of the best approach to meeting the needs of GCC-O.

4.3 Additional Testing Required

Date of First Notification: Launch minus 4 months
Required Completion Date: 30 days later

Four months prior to launch, as several of the University antenna sites are being tested, it becomes clear that there have been different interpretations of a key interface control document. The problem means that the SES-II-maintained front-end processor may not be able to process the data received from three of the seven remote sites. The SES-II team is asked to rapidly develop tests to verify all external interfaces and to make changes to the GSFC front-end processor to accept the variants of the currently incompatible sites. To keep to the launch schedule, the effort must be completed in the next 30 days and will require SES-II support levels beyond those originally assigned to the GCC-F efforts.

The contractor is to explain a general approach to addressing the problem from both technical and surge staffing aspects.

5 ACRONYM LIST

ACS	Attitude Control System
ATRR	Acceptance Test Results Review
CCB	Configuration Control Board
CCR	Configuration Change Request
CCSDS	Consultative Committee for Space Data Systems
CDR	Critical Design Review
CFDP	CSDS File Delivery Protocol
cFE	Core Flight Executive
cFS	Core Flight Software
CMMI	Capability Maturity Model Integration
C&DH	Command and Data Handling
COTS	Commercial off the Shelf
CR	Confirmation Review
DR	Disposal Review
FOT	Flight Operations Team
FOR	Flight Operations Review
FRR	Flight Readiness Review
FSSE	Flight Software Sustaining Engineering
FSW	Flight Software
GCC	Goddard Space Flight Center CubeSat Constellation
GCC-A	GSFC CubeSat Constellation Atmospheric and Pollution Measurements
GCC-F	GSFC CubeSat Constellation Farming, Chemical, Moisture, and Vegetation Measurements
GCC-O	GSFC CubeSat Constellation Ocean Surface Measurements
GN&C	Guidance Navigation and Control
GOTS	Government off the Shelf
GPM	Global Precipitation Mission
GPS	Global Positioning Satellite
GSFC	Goddard Space Flight Center
HQ	Headquarters
ICD	Interface Control Document
ICR	Initial Confirmation Review
ICRR	Initial Confirmation Readiness Review
I&T	Integration and Test
IT	Information Technology
LRR	Launch Readiness Review
KSC	Kennedy Space Center
MCR	Mission Concept Review
MCRR	Mission Confirmation Readiness Review
MDR	Mission Definition Review
MOC	Mission Operations Center
MOR	Mission Operations Review

NASA	National Aeronautics and Space Administration
NPR	NASA Procedural Requirements
PDR	Preliminary Design Review
PER	Pre-Environmental Review
PSR	Pre-Ship Review
RFA	Request for Action
RFP	Request for Proposal
RTO	Representative Task Orders
S/C	Spacecraft
SES-II	Software Engineering Support - II
SDPS	Science Data Processing System
SDR	System Definition Review
SMEX	Small Explorer
SP	Sample Problem
SRR	Systems Readiness Review
STRR	System Test Readiness Review
V&V	Verification and Validation
WBS	Work Breakdown Structure
T&C	Telemetry & Command
TT&C	Telemetry, Tracking, and Commanding
TDRSS	Tracking and Data Relay Satellite System