Canadian Space Agency

ANNEX A

Concept Study for an Air Quality and Greenhouse Gas Observation Mission focused on Northern Regions

Statement of Work (SOW)

Date: August 27, 2015

Canadian Space Agency | Agence Spatiale Canadienne

This Page Intentionally Left Blank

TABLE OF CONTENTS

PAGE

1 INTRODUCTION

1.1 SCOPE

This Statement of Work (SOW) defines activities to identify a mission concept for Air Quality and Greenhouse Gas (AQ-GHG) observations over the arctic, sub-arctic, and boreal regions, which includes the vast majority of Canada.

1.2 BACKGROUND

Environment Canada (EC) has identified the Arctic as a priority region that is significantly under-sampled, and has identified the need for increased observations to better monitor and understand sources and sinks of air pollution and greenhouse gases. A mission concept to provide observations of Air Quality and Greenhouse Gases in the Arctic, Canadian sub-Arctic, and Boreal regions falls under several priority areas of the Environment Canada's Science Strategy (2014-2019) [RD-1].

The northern high latitudes are a climatically sensitive region. In recent decades, the region has exhibited much larger temperature increases than lower latitudes, along with large reductions in both multi-year sea-ice and snow cover. Climate change also affects the carbon cycle of the Arctic, sub-arctic and boreal regions in a number of ways. The boreal forest growing season is lengthening, which impacts the seasonal cycle of atmospheric CO_2 across the entire northern hemisphere. Boreal forests and other Canadian forests are also experiencing increases in the release of carbon due to disturbances such as fires and insect infestations. Further north, Arctic and sub-arctic permafrost holds vast amounts of carbon, with evidence of thawing. When undergoing thaw, microbial activity releases some of this carbon to the atmosphere as CO_2 and CH_4. There is a high level of uncertainty as to whether the combined effects of such changes could tip the carbon balance of the Arctic, sub-arctic and boreal regions from an annual net carbon sink to a source. Combining spatially and temporally dense observations of atmospheric CO_2 and CH_4 with atmospheric transport models can help to better quantify the space and time distributions of CO_2 and CH_4 fluxes, which will lead to improved process-based models and improve our ability to make quantitative predictions of the carbon cycle of the future.

Historically, Arctic air pollution has been the result of long-range transport, primarily from Eurasia, leading to high concentrations of particles (the so-called Arctic haze) in winter and spring [RD-2].With the opening of the Arctic Ocean to commercial shipping and increased interest in oil drilling, local sources may soon begin to represent a significant contributor to Arctic pollution. The increase in area of open ocean from sea-ice loss could lead to increases in sulfate aerosol from dimethyl sulfate [RD-3] while NOx from the snow/ice would be reduced. There is evidence that ship traffic is already affecting the Arctic atmosphere [RD-4] and an increase in surface ozone (by a factor of 2-3, similar to mid-latitude levels) resulting from ship NOx emissions are predicted [RD-5]. The effects from an increase in Arctic oil drilling have not been estimated, but could also be substantial. There are also important links to climate. Increased soot deposition (from increased shipping) could accelerate sea-ice melting. Likewise, continued warming means more frequent boreal forest fires and hence greater pollution transport to the Arctic [RD-6].

As is the case with climate, high spatial and temporal resolution observations are required in order to understand, for the first time, the sources, ambient levels, and sinks of Arctic air pollution. Only through an effort such as this will air quality models be able to properly capture the physical and chemical processes necessary for accurate forecasting of air quality.

The Group on Earth Observations published the *GEO Carbon Strategy* in 2010 [RD-7] that calls for an Integrated Global Carbon Observing system (IGCO) to meet pressing needs for policy-relevant scientific information about the carbon cycle. Space-based observations are an important component of this strategy, and in response to the GEO Carbon Strategy, the Committee on Earth Observation Satellites (CEOS) published the *CEOS Strategy for Carbon Observations from Space* in 2014 [RD-8] which identifies important challenges and actions that CEOS and its agencies must take to meet the needs for climate relevant carbon observations from space. In addition, parallel recommendations for a constellation of satellites to monitor global air quality have also been made [RD-9] by CEOS, where the proposed observations include geo-stationary platforms to provide the requisite revisit and coverage to measure the diurnal variations of the key atmospheric species that effect air quality.

For both Air Quality and Greenhouse gases [RD-8, RD-9] the recommended integrated observing systems include a combination of Low Earth Orbit (LEO) and Geosynchronous Orbit (GEO) satellites, as well as ground based measurements, to provide the required latitudinal coverage and revisit. It is acknowledged that the coverage and revisit provided by GEO is ideal for these applications, though observing the high latitudes from GEO is problematic since viewing angles become too large beyond approximately 55°S/N. In contrast, circumpolar measurements are clearly possible from LEO, but with insufficient coverage and revisit as governed by the instrument swath and orbit parameters. The absence of appropriate measurements in polar regions has been identified in the World Meteorological Organization (WMO) Vision for a Global Observing System in 2025, in which Highly Elliptical Orbits (HEOs) are recommended for obtaining quasi-geostationary observations at high latitudes. Air Quality and Greenhouse Gas (AQ-GHG) observations over the Arctic, sub-Arctic and boreal regions from HEO would therefore fill a key gap in international observing capabilities, consistent with recent international recommendations for concerted efforts to provide global observations of greenhouse gases and air pollutants, and Canada is well positioned to meet this need. The precision, accuracy, and spatial resolution of such observations from HEO should be selected to be consistent with those of other missions in the constellation and can thus be guided by documents such as those above and the CEOS response to the Global Climate Observing System Implementation Plan (GCOS-IP) [RD-10].

To address the pending gap in dense observational coverage of the northern latitudes, Environment Canada's Air Quality Research Division (AQRD) and Climate Research Division (CRD) have requested the development of a mission concept building on past work for the Weather, Climate and Air quality (WCA) mission concept under the Polar Highly Elliptical Orbit Science (PHEOS) program. WCA was formally considered as a secondary payload on the Polar, Weather, and Communications (PCW) mission, but remains a CRD and AQRD priority. As such, this study will explore the possibility of effectively moving the WCA instruments to a standalone satellite(s) as a mission concept that would monitor air pollutants (e.g. CO, NO_2,

SO_2,O_3, HNO_3 and others) and greenhouse gases (CO_2 and CH_4) from space over Canada and the high-latitudes (Arctic/sub-Arctic/Boreal regions). This AQ-GHG mission would provide enhanced observations to increase understanding of the sources/sinks and impact of anthropogenic and natural CO_2 and CH_4, and air pollutants in order to strengthen air quality and climate monitoring and prediction. These observations also have the potential for application in monitoring and verification in support of future climate agreements, emissions trading systems, and the implementation of associated policy.

The work covered by this SOW will advance the AQ-GHG mission definition by analyzing payload options and developing a mission concept to fill the current and projected gap in AQ-GHG observation capability. This will include a review of Mission Objectives and Observation Requirements provided by EC, where the focus will be on the impacts of primary products related to Air Quality and Greenhouse Gases, but will also include an assessment of the impact of secondary products related to meteorological applications and atmospheric species considered to be of lower priority. The contractor will then propose various high-level options to provide the required data, and these approaches will be assessed through an initial trade where viable option(s) will be retained for further study. The Mission Objectives and Observation Requirements will then be flown-down into preliminary Instrument Requirements and Mission Requirements for the retained option(s), as appropriate, and a preliminary mission concept will be presented. The core of the work will then develop the concept for AQ-GHG mission, where the implications and impact of various trade studies (detailed in section 3.3.3) will be included and accompanied by contractor provided recommendations and analysis where appropriate. The developed Mission Concept will baseline a recommended option and be accompanied by a Mission Development Plan. Additional scope will include an analysis of potential commercial applications of the anticipated technology beyond the scope of the current mission, the identification of potential applications consistent with the baseline payload/mission concept and not considered by the initial Mission Objectives, as well as an identification of low-cost variations to the baseline payload/mission concept which would enhance mission value.

1.3 DOCUMENT CONVENTIONS

A number of the sections in this document describe controlled requirements and specifications and therefore the following verbs are used in the specific sense indicated below:

a) “Shall” or “Must” is used to indicate a mandatory requirement;

b) “Should” indicates a goal or preferred alternative. Such goals or alternatives must be treated as requirements on a best efforts basis, and verified as for other requirements. The actual performance achieved must be included in the appropriate verification report, whether or not the goal performance is achieved;

c) “May” indicates an option;

d) “Will” indicates a statement of intention or fact, as does the use of present indicative active verbs.

In the following, the term 'Contractor' is used to describe the team that will conduct the study, which could be a mixed team drawn from Canadian industry, universities or research institutes.

2 DOCUMENTS

2.1 APPLICABLE DOCUMENTS

This section lists the documents that are required for the bidder to develop the proposal.

AD No.	Document No.	Document Title	Rev. No.
AD-1	CSA-ST-GDL-0001	CSA Technology Readiness and Risk Assessment Guidelines ftp://ftp.asc-csa.gc.ca/users/TRP/pub/TRRA/	B
AD-2	CSA-ST-FORM-0001	Technology Readiness and Risk Assessment (TRRA) Worksheet ftp://ftp.asc-csa.gc.ca/users/TRP/pub/TRRA/Technology_and_Risk_Assessment_Worksheets%20_and_Rollup_Tool/	E
AD-3	CSA-ST-RPT-0002	Technology Readiness and Risk Assessment Data Rollup Tool ftp://ftp.asc-csa.gc.ca/users/TRP/pub/TRRA/Technology_and_Risk_Assessment_Worksheets%20_and_Rollup_Tool/	H
AD-4	CSA-ST-FORM-0003	Critical Technology Element (CTE) Identification Criteria Worksheet ftp://ftp.asc-csa.gc.ca/users/TRP/pub/TRRA/Technology_and_Risk_Assessment_Worksheets%20_and_Rollup_Tool/	A
AD-5	CSA-ST-RPT-0003	Technology Roadmap worksheet ftp://ftp.asc-csa.gc.ca/users/TRP/pub/TRM/	A

2.2 REFERENCE DOCUMENTS (RD)

The following documents provide additional information or guidelines that either may clarify the contents or are pertinent to the history of this document.

Table2.2-1: Reference Documents

RD No.	Document Number	Document Title	Rev. No.	Date
RD-1.		Environment Canada's Science Strategy (2014-2019)		2014
RD-2.	Science, 315, 1537-1540	Arctic Air Pollution: Origins and Impacts		2007
RD-3.	Tellus 57B, 391	The simulated response of dimethyl sulfide production in the Arctic Ocean to global warming		2005

RD No.	Document Number	Document Title	Rev. No.	Date
RD-4.	J. Geophys. Res. 111, 10.1029/2005JD006253	Summertime aerosol chemical components in the marine boundary layer of the Arctic Ocean		2006
RD-5.	Geophys. Res. Lett., 33, L13807, doi:10.1029/2006GL026180	Ozone pollution from future ship traffic in the Arctic northern passages		2006
RD-6.	International Journal of Wildland Fire, 18, 483-507	Implications of changing climate for global wildland fire		2009
RD-7.		GEO Carbon Strategy http://www.globalcarbonproject.org/global/pdf/GEO_CARBONSTRATEGY_20101020.pdf		June 2010
RD-8.		CEOS Strategy for Carbon Observations From Space http://ceos.org/home-2/the-ceos-carbon-strategy-space-satellites/		April 2014
RD-9.		A Geostationary Satellite Constellation for Observing Global Air Quality: An International Path Forward	Draft Version 4.0	April 12, 2011
RD-10.		2015 Update of Actions in The Response of the Committee on Earth Observation Satellites (CEOS) to the Global Climate Observing System Implementation Plan 2010 (GCOS IP-10		May 10, 2015
RD-11.	BOM-PHEMOS-0031	PHEMOS: Weather, Climate, and Air Quality Mission Science Payload Conceptual Design and Trade-Off Document	C	March 19, 2012
RD-12.	BOM-PHEMOS-0028	PHEMOS: Weather, Climate, and Air Quality Mission Mission Requirements Document	C	March 22, 2012

RD No.	Document Number	Document Title	Rev. No.	Date
RD-13.	BOM-PHEMOS-0030	PHEMOS: Weather, Climate, and Air Quality Mission System Requirements Document	D	March 22, 2012
RD-14.	BOM-PHEMOS-0018	PHEMOS: Weather, Climate, and Air Quality Mission User Requirements Document	E	March 27, 2012
RD-15.		Business Case Guide (Treasury Board of Canada Secretariat)		2009
RD-16.	Journal of Geophysical Research, 119(5), 2654-2673	Satellite observations of CO_2 from a highly elliptical orbit for studies of the Arctic and boreal carbon cycle		March 6, 2014

3 REQUIREMENTS

3.1 GENERAL

The Contractor must manage the project to effectively achieve project performance, scope, quality, cost and schedule requirements of this SOW. The Contractor must provide the management, technical leadership and support necessary to ensure effective and efficient performance of all project efforts and activities.

The Contractor must report project costs, schedule, technical, performance and risks issues as defined herein.

3.2 OBJECTIVES

The objectives of this study are to:

- Assess the feasibility and cost of current Mission Objectives and Observation Requirements.
- Examine options to provide the requisite data as preparatory work for a preliminary business case.
- Flow-down preliminary Mission and Instrument level Requirements from the Mission Objectives and Observation Requirements.
- Identify and analyze payloads and payload options to meet Observation Requirements for Air Quality and Greenhouse Gas (AQ-GHG) measurements at northern latitudes, perform trade-offs, and identify best options.
- Develop mission concepts to meet primary requirements for AQ-GHG measurements and assess the feasibility to meet the secondary mission objectives.
- Identify key Canadian technologies and propose a mission development plan.
- Assess the future commercial potential of the associated payload technologies.

3.3 DETAILED TASKS

3.3.1 Requirements Review

The Contractor shall first review the Mission and Science Objectives and Observation Requirements for a AQ-GHG mission, as well as previous developments related to the WCA payload associated with PHEOS [RD-11, RD-12, RD-13, RD-14]. The Mission and Science Objectives and Observation Requirements will be provided to the Contractor after contract award in the form of a draft Mission Objectives Document. This document will describe primary observational requirements related to AQ-GHG, and secondary requirements related to meteorological applications, atmospheric species or land surface properties considered to be of lower priority. The Mission Objectives Document will contain Mission and Science Objectives as well as Observation Requirements.

Tables 3.3.1-1 and 3.3.1-2 provide a preliminary list of the Mission and Science Objectives respectively. These Objectives are categorized as applicable to the mission as a whole (M),

Greenhouse Gases (GHG), Air Quality (AQ), or Meteorology (MET) and will be finalized by Environment Canada (EC). The tables are provided here for information only. The Contractor should allow enough time in its planning of activities to address changes that may be required before the study starts.

The Mission Objectives Document will also provide Observation Requirements for the different parameters to be retrieved. The preliminary Observation Requirements are provided in Table 3.3.1-3 where the requirements are split into primary and secondary categories. The Contractor should note, in contrast to the WCA payload, that Meteorological data products are now categorized as secondary. Again, the Contractor should allow enough time in its planning of activities to address changes that the User Team may require before the study starts. It is understood that achieving the science objectives by the User Team will involve the use of other available datasets, models and other necessary tools in addition to the potential observations resulting from this mission concept study.

Table 3.3.1-1 Preliminary Mission Objectives

M-1	To address the gap in diurnal observational coverage of GHG and AQ gases at northern high latitudes (>60°N) that cannot be met with GEO observations
M-2	To provide spatial and temporal overlap with other GHG and AQ missions such as GEO instruments positioned over North America (20-55°N), Europe and Asia, and LEO missions, for the purpose of cross-calibration
GHG-1	Provide CO_2 imaging for the quantification of natural and anthropogenic CO_2 sources and sinks in the Arctic and Boreal region, with reduced uncertainties relative to what is now achievable with LEO satellites, in situ measurements and ground-based remote sensing
GHG-2	Provide CH_4 imaging for the quantification of natural and anthropogenic CH_4 sources in the Arctic and Boreal region, with reduced uncertainties relative to what is now achievable with LEO satellites, in situ measurements and ground-based remote sensing
GHG-3	Provide co-located measurements of other atmospheric tracers (such as CO) and/or surface properties (such as chlorophyll fluorescence) that could aid in separating the biospheric and anthropogenic CO_2 and CH_4 emission signals
AQ-1	To better monitor and predict surface air quality (including UV) in the Arctic and Canadian Subarctic (Subarctic includes latitude 50-70°N)
AQ-2	To better understand the impact of anthropogenic and agricultural pollution and boreal forest burning on the Arctic and Canadian Subarctic and to better quantify their emissions
AQ-3	To monitor stratospheric ozone and ozone-related compounds
MET	Provide observations of relevant meteorological parameters at little to no additional cost

Table 3.3.1-2 Science Objectives

S-GHG1	Reduce uncertainties in contemporary Arctic and boreal biospheric CO_2 uptake and emission in order to improve representation of the carbon cycle in climate prediction models
S-GHG2	Reduce uncertainties in the spatial and sectoral attribution of CH_4 surface emissions
S-GHG3	Early detection of potential acceleration in CO_2 and CH_4 emission from permafrost thaw
S-GHG4	Improved estimation of northern (>45°N) anthropogenic CO_2 and CH_4 emissions at the scale of a city, town, or large industrial source
S-AQ1	Improve knowledge of current and the prediction of future air quality in the Arctic and Canadian Subarctic
S-AQ2	Understand how do episodic events impact air quality (and in particular the Air Quality Health Index) in the Arctic and Canadian Subarctic?
S-AQ3	Quantify What is the relative contribution to Arctic and Canadian Subarctic pollution from local sources and from long range transport?
S-AQ4	How is air pollution influencing climate change in the Arctic and Canadian Subarctic? And is climate change impacting Arctic and Canadian Subarctic pollution?

Table 3.3.1-3 Preliminary Observation Requirements [1]

Species	Objective	Spatial Resolution	Max. Bias	Precision (1 sigma)	Spectral Region
Primary					
CO_2 (X)[2]	GHG-1	4x4 km^2 (G), 7x7 km^2 (B), 10x10 km^2 (T)	0.05% (0.2 ppm) (G), 0.15% (0.6 ppm) (T)	0.25% (1 ppm) (G), 0.75% (3 ppm) (T)	1570-1620 nm, 1920-2080 nm, 750-770 nm
CH_4 (X)[2]	GHG-2	4x4 km^2 (G), 7x7 km^2 (B), 10x10 km^2 (T)	0.1% (2 ppb) (G), 0.3% (6 ppb) (T)	0.5% (9 ppb) (G), 1.5% (27 ppb) (T)	1620-1670 nm, 750-770 nm
O_3 (SC)	AQ-1,3	4x4 km^2 (G), 10x10 km^2 (T)	2% (G) 3% (T)	3% (G) 5% (T)	290-345 nm 540-650 nm
O_3 (TC)[3]	AQ-1,2	4x4 km^2 (G), 10x10 km^2 (T)	20% (G) 30% (T)	3% (G) 5% (T)	290-345 nm 540-650 nm
NO_2 (SC)	AQ-1,3	4x4 km^2 (G), 10x10 km^2 (T)	10% (G)[4] 15% (T)	3% (G) 5% (T)	400-470 nm
NO_2 (TC)	AQ-1,2	4x4 km^2 (G), 10x10 km^2 (T)	15% (G)[4] 20% (T)	10^{15} cm^{-2} (G)[5] $1.5x10^{15}$ cm^{-2} (T)	400-470 nm
CO (C)[3]	AQ-1,2, GHG-3	4x4 km^2 (G), 10x10 km^2 (T)	5% (G) 15% (T)	5% (G) 15% (T)	2080-2330 nm
Aerosol AOD (C)	AQ-1,2	4x4 km^2 (G), 10x10 km^2 (T)		0.03 + 15% (G) -	(1) 354, 388, 440, 555, 675[19] nm (2) O_2 A-band
SO_2 (C)	AQ-2	4x4 km^2 (G), 10x10 km^2 (T)		10^{16} cm^{-2} (G)[5] $1.5x10^{16}$ cm^{-2} (T)	305-345 nm
Secondary					
HCHO (C)	AQ-2	4x4 km^2 (G), 10x10 km^2 (T)			325-360 nm
BrO (C)	AQ-3	4x4 km^2 (G), 10x10 km^2 (T)			340-370 nm
OClO (C)	AQ-3	4x4 km^2 (G), 10x10 km^2 (T)			360-390 nm
CHOCHO (C)	AQ-2	4x4 km^2 (G), 10x10 km^2 (T)			420-465 nm
CO_2 (P)[3]	GHG-1	4x4 km^2 (G), 10x10 km^2 (T)	0.5% (G)	2.0% (G)	8400-14900 nm
CH_4 (P)[3]	GHG-2	4x4 km^2 (G), 10x10 km^2 (T)	0.8% (G)	2.5% (G)	5500-8400 nm
Solar Induced Fluorescence	GHG-3	4x4 km^2 (G), 10x10 km^2 (T)			500-780 nm (G), 740-772 nm (T) [7]
T (P)	MET	4x4 km^2 (G),		1%	Mid-IR

		10x10 km^2 (T)			
H_2O (P)	MET	4x4 km^2 (G), 10x10 km^2 (T)		10%	Mid-IR
Wildfire parameters	GHG-3	1x1 km^2 (G),[8] 4x4 km^2 (T)			10850-11850 nm 3800-4000 nm 2100-2350 nm 500-900 nm

Shading denotes species which may be required in near real time (NRT) for assimilation into AQ (or weather) models

(G) – Goal (An ideal requirement above which further improvements are not necessary)

(T) – Threshold (The minimum requirement to be met to ensure that data are useful)

(B) – Breakthrough (An intermediate level between "threshold" and "goal", which, if achieved, would result in a significant improvement for the targeted application. The breakthrough level may be considered as an optimum, from a cost-benefit point of view when planning or designing observing systems.

(X) – column-averaged dry air mole fraction

(C) - total vertical column (TC+SC)

(TC) - tropospheric vertical column density

(SC) - stratospheric vertical column density

(P) – vertical profile

[1] Measurements of all species relate to mission objectives 'M-1 and M-2'

[2] Column-averaged CO_2 and CH_4 dry air mole fractions (denoted XCO_2 and XCH_4) are based on the gas column density and knowledge of the total air column density, which can be derived from measurement of the O_2 *A* band.

[3] A secondary objective is to obtain some vertical profile information (through a combination of the total column and mid-IR observations)

[4] The accuracy of this parameter will be significantly impacted by the quality of the retrieval algorithm

[5] Vertical column density units (molecules/cm^2, or cm^{-2})

[6] Number of observations/day using solar reflectance (UV to NIR) will vary with season, especially at the highest latitudes, so a single number for revisit is not possible, but a mean revisit of at least ~4/day during daylight is desired.

[7] The ESA FLEX candidate mission spectral range covers 500-650 nm for the Photochemical Reflectance Index (PRI), and 650-800 nm for Photosystems I and II

[8] An even smaller footprint would still be desirable for fire parameters, but the goal was moderated to remain in the range of other observation requirements.

The Contractor review of the Mission and Science Objectives and associated Observation Requirements shall include the identification of key differences from PHEOS [RD-14], and an early assessment if the absent need for compatibility with the PCW mission potentially results in significant changes to the previously considered orbits [RD-10]. Additionally the review shall identify missing requirements, suggest refinements or clarifications, and identify driving and challenging requirements.

3.3.2 Options Analysis

The Contractor shall identify options to provide data consistent with the Mission Objectives Document. The purpose of this activity is to develop an Options Analysis Report as an input to a preliminary Business Case [RD-15]. The Options Analysis Report shall include the contractor review of the Mission Objectives and Observation Requirements discussed in section 3.3.2.1

The following options must minimally be considered:

- Hosted payload on commercial or international satellites
- Hosted payload on a Canadian mission (e.g. PCW)
- Access to foreign missions and products
- Access to commercially available data
- Setting up local stations to provide the AQ-GHG information
- Stand-alone Canadian satellite (Orbit: HEO, LEO, MEO)
- Constellation of Canadian satellites (Orbit: HEO, LEO, MEO)

It should be noted that for the options of a stand-alone Canadian satellite or a Canadian constellation the orbits (i.e. HEO, MEO, LEO) shall be assessed individually. For example, a stand-alone satellite in HEO should be assessed separately from a stand-alone satellite in LEO. Further, multiple HEO options shall be considered.

The Contractor must filter down the list of options to a smaller list of viable options that are feasible to implement. The screening process must include the reasons for selecting or rejecting particular options. The screening criteria should be potentially achievable, potentially affordable and potential to provide the required service. An option must meet all screening criteria in order to be considered viable (yes or no only, no degree at this stage).

For each viable option, the Contractor must perform a more detailed analysis by comparing the options based on the quality of the services, costs and risks. The output of the analysis should contain a table comparing the options without selection of a preferred option. The analysis and assumptions supporting the results must be presented. The criteria to be included in the comparison are, as a minimum:

- Alignment with the primary measurement objectives. To what degree does the option address the performance targets?
- Costs: Provide a Rough Order of Magnitude (ROM) estimation of the costs for each viable option.
- Risks: For each viable option, risk identification and assessment must be conducted.

This Options Analysis shall include the delivery of an Options Analysis Report which shall address the following:

- List of all options with ROM costing and duration
- Evaluation criteria, explanations, and associated weighting if applicable
- Status quo
    - Brief description (1 paragraph) of current status quo
    - Brief Description (1 paragraph) of long-term effectiveness of status quo
- Screening of Options
    - Options selected or rejected according to screening criteria
    - Eliminate obvious no-go options
- Rationale for Discounted and Viable Options
- Assessment of relative merit of Viable Options

Following the options analysis and the assessment of relative merit of the Viable Options, and assuming two viable options are identified, the two most promising options shall be retained for further study. These two options will be chosen in consultation with the CSA and EC.

3.3.3 Preliminary Concept and Mission Requirements

The Contractor shall flow-down the Mission and Science Objectives and associated Observation Requirements into preliminary Mission, Instrument, and System Requirements and develop a Preliminary Concept to meet these requirements. The Preliminary Concept is intended only to be presented on a block diagram level and it is anticipated that the Mission level Requirements will heavily leverage previous work performed for PHEOS [RD-11, RD-12, RD-13, RD-14]. The development of preliminary Mission, Instrument, and System Requirements as well as the high level Preliminary Concept shall be documented in a Preliminary Concept and Requirements Document which shall address the following:

- Mission, Instrument, and System Requirements
- Traceability matrix to Mission Objectives and Observation Requirements
- Reassessment of driving requirements
- Reassessment of viable options
- Preliminary Concept to meet Mission Requirements for two most promising viable options
    - Trade-study to reconfirm that the payload technologies baselined for WCA [RD-11] are optimal for the updated application.
    - Trade-study to determine spectral band configuration
    - Trade-study to support orbit identification. For example, for HEO, several specific orbits shall be considered
    - Brief trade-study to support constellation selection and geometry if applicable

- Block diagram of mission architecture
  - Payload
  - Spacecraft
  - Orbit
  - Constellation (if applicable)
  - Ground segment

The Preliminary Concept and Requirements Document shall also address the following questions which largely build on previous PHEOS-WCA work [RD-11, RD-12] with associated analysis, discussion, and recommendations as appropriate:

- Necessity for onboard propulsion to maintain a HEO, including the impacts on mission cost and lifetime. Necessity for onboard propulsion to maintain constellation geometry in HEO if applicable.
- Relative launch cost for a 500 kg (TBC) satellite to a Three Apogee Orbit compare with LEO (assuming 705 km) or GEO (assuming 35,786 km) from the same launch provider. This information must be gathered from multiple launch providers.
- Estimated cost for a single standalone satellite in a Three Apogee Orbit assuming the optimal instrument configuration from PHEOS-WCA Phase A (~82 kg) [RD-11].and the expected cost for 2 identical satellites. Both cases must include appropriate measures to deal with the anticipated radiation environment of the orbit.
- RD-11 stated the minimum FTS Field of Regard (FoR) as 3200x3200 km^2, while some recent simulated observations RD-16 for CO_2 assumed a FoR of 3360x4480 km^2 with the objective of covering more of Canada in a single FoR from a Three Apogee Orbit. Determine the considerations and potential limitations that would prevent a larger FoR to allow for flexibility for specific HEO orbit selection, and to minimize gaps in high latitude coverage (up to approximately 4000x8000 km^2). Further, assess the limitations in moving the FoR to higher or lower latitudes depending on the season.
- Assuming the optimal instrument configuration from PHEOS-WCA Phase A (~82 kg) [RD-11], assess the impact on instrument configuration, resource requirements, cost, and performance if the pixel size for both infrared (IR) and UV-visible channels was reduced to 7x7 km^2 or 4x4 km^2 or 1x1 km^2 while still yielding equivalent spatial and temporal coverage. The contractor shall consider the impacts on the required integration time, and instrument aperture size to maintain signal-to-noise ratio (SNR), as well as limiting influence of satellite motion (jitter and smear) to attain spatial resolutions relative to the pixel size.
- Assess the impact on instrument configuration, resource requirements, and cost if the O_2 A-band was widened from 13060-13168 cm^{-1} (0.760-0.766 microns) to 12950-13250 cm^1 (0.75-0.77) or wider (measured at 0.5 cm^{-1} spectral resolution) to capture the solar induced fluorescence from vegetation.

- Assuming the optimal instrument configuration from PHEOS-WCA Phase A (~82 kg) [RD-11], assess the impact on instrument configuration, resource requirements, and cost if the 700-1500 cm^{-1} (6.7-14.2 micron) and 1800-2700 cm^{-1} (3.7-5.6 micron) bands were removed. Determine to what degree the removal of these two thermal IR bands negates the need for a passive/active cooling system for the instrument. This trade study must be accompanied by a cost-benefit analysis and associated recommendation related to the inclusion of these spectral bands.

- Assess the impact on instrument configuration, resource requirements, and cost for the addition of spectral bands at 4200-5200 cm^{-1} (1.92-2.33 microns for CO) and/or 2500-2630 cm^{-1} (3.8-4.0 micron) band for wildfire-related measurements. Determine the limitations associated with detector saturation for the pixel footprints listed in Table 3.3.3-1 for the wildfire related measurements.

- Assess the impact on instrument configuration, resource requirements, cost, and performance if the instrument's sampling interval in the short wave infrared (SWIR) spectral regions was degraded from 0.25 cm^{-1} to 0.33 cm^{-1} or 0.40 cm^{-1}.

- Assuming the optimal instrument configuration from PHEOS-WCA Phase A (~82 kg) [RD-11] with a 15 cm aperture, which yielded a SNR of > 150 at 1.6 micron for a surface albedo of 0.4 and solar zenith angle (SZA) of 60°, Assess the impact on instrument configuration, resource requirements, and cost to achieve enhanced Signal-to-Noise Ratios (SNR) of 200, 250, and 300.

- Develop options and recommendations and assess the associated impact on instrument configuration, resources requirements, cost, and performance to relax integration time to enable adequate pointing stability associated with a smaller Ground instantaneous Field of View (GiFOV) (i.e. 4x4 km^2).

- For the UV-visible channels assess the impact on instrument configuration, resources requirements, cost, and performance for (i) one spectrometer covering 280-650 nm, (ii) one spectrometer covering 280-800 nm, and (iii) two spectrometers covering 280-800 nm. The additional spectral range will enable coverage of spectral bands associated with vegetation.

- Assess the relative merits of using CCD (Charged Coupled Device) vs. CMOS (Complementary Metal Oxide Semiconductor) detectors for the UV-visible spectral channels considering performance, space qualification, radiation tolerance, heritage, ITAR restrictions, and cost. Recommend an appropriate detector for UV-visible spectral channels.

- Develop recommendations for detectors for IR channels based on currently available technologies and formats. This must minimally consider the impact on system level performance and complexity, space qualification, radiation tolerance, heritage, ITAR restrictions, and cost. Approaches considering larger format detectors coupled with pixel

binning must also be considered to simultaneously meet primary data product requirements and the Goal and Threshold spatial resolution requirements associated with wildfire applications.

3.3.4 Mission Concept Design

Following the development of the preliminary Mission Concept and Requirements, the contractor shall advance the Mission Concept for the two most promising viable options. The Contractor must perform mission design analysis to work out the main elements of the proposed concepts in a draft Mission Conceptual Design Document.

At a minimum, the following elements must be included in the concept design:

- Payload Description
- Spacecraft Layout
- Constellation or Formation-Flying Description (if applicable)
- Coverage Analysis (including orbit description)
- Spacecraft Main Engineering Budgets, including: mass, power, data rates, on-board storage, ADCS, propulsion.
- Ground Segment and Operations
- Data Products and Data Latency
- Calibration and Validation
- Space-to-Ground Link
- Launch Options
- Compliance to Measurement Objectives
- Identify preferred option
- Assess relative merits / challenges / limitations of the 2 options
- Alternative Options and Applications

The mission concept shall focus on the primary mission objectives for AQ-GHG measurements, but the Contractor shall also report on the secondary mission objectives that can be met with the proposed concept, and report on possible options or extensions to the baseline mission to meet secondary objectives as well.

In addition, the Contractor shall determine if there are any unconsidered additional benefits of the preferred option such as additional applications not considered in mission objectives and identify possible variations to baseline concept such as alternative low cost variations to the payload concepts (example: spectral bands) to enable additional or secondary applications (e.g. cost-benefit analysis of weather products).

The proposed concept and proposed options/variations must be presented at the Mission Concept Review Meeting. The mission concept to be used for subsequent tasks of this SOW will be confirmed by CSA and EC within two weeks after the review.

3.3.5 Mission Development Plan

The Contractor must first update the mission concept design to take into account the inputs resulting from the Mission Concept Review.

For the confirmed mission concept, the Contractor must perform a Technology Readiness and Risk Assessment (TRRA) of key technologies foreseen to be used in the anticipated system in accordance with the requirements of CSA Technology Readiness and Risk Assessment Guidelines [AD-1]. This will be accomplished using the CSA provided worksheets–the Critical Technologies Elements Identification Criteria Worksheet [AD-4] and the Technology Readiness and Risk Assessment Worksheet [AD-2] for each Critical Technology Element and rollup using the Technology Readiness and Risk Assessment Data Rollup Tool [AD-3]. The TRRA shall describe the performance characteristics of the technology with respect to the needs of the targeted mission for the given target environment. The Contractor shall provide a Technology Development Plan, a.k.a. Technology Roadmap (TRM), including the required technology developments to meet targeted mission needs, and a plan and timeline to reach TRL 6 and 8. The Technology Roadmap Worksheet [AD-5].

The TRRA, TRM, and associated worksheets shall be included in a Mission Development Plan Document which shall also identify technologies that could be developed in Canada. The Mission Development Plan Document must minimally include the following elements:

- Technology Readiness and Risk Assessment (TRRA), TRRA worksheet, and TRRA Data Rollup tool
- Technology Road Map (TRM)
- Technology development activities to be performed, detailing the urgency, criticality and the main risks and challenges of each activity
- Possible technology demonstrations
- Estimated mission life cycle cost
- Estimated mission schedule including all major milestones
- Preliminary mission risk assessment
- Preliminary concept of operation
- Potential collaborations
- Proposed Canadian capabilities development strategy
- Recommendations for follow-on activities

Estimated costing provided in the Mission Development Plan must be as detailed as possible, and include itemized estimates for payload, spacecraft, launch, etc., so that all approximations and assumptions are clear to the reviewer.

3.3.6 Analysis of Commercial Potential

The CSA with support from EC will need to prepare a Business Case as per suggested guidelines [RD-15] to get approval from the Treasury Board of Canada. In addition to the previously discussed Options Analysis necessary to present the investment in a wider perspective, the Contractor shall determine potential commercial applications and alternative markets of the technology and/or data products associated with the AQ-GHG Mission Concept, such as planned or projected geosynchronous missions. In this context, the AQ-GHG Mission Concept can be interpreted as a technology or capacity demonstration mission.

Determinations of commercial potential shall be accompanied by market analysis and estimates of future returns to Canadian Industry enabled by investment in the AQ-GHG mission. These estimates shall be consistent with the time lines and mission scheduling of the Mission Development Plan. If alternative paths or strategies to the Canadian capabilities development outlined in the Mission Development Plan can enable earlier market penetration, they should be noted, and accompanied by recommendations. Findings of the commercial potential associated with AQ-GHG mission shall be documented in a Commercial Potential Document.

3.4 DELIVERABLES

The deliverables for the activity are listed in Table 3.4-1.

Table 3.4-1 Deliverables

Reports and Documents	**Due Date**
Options Analysis Report	M1 – 2 weeks (draft) M2 – 2 weeks (final)
Preliminary Concept and Requirements Document	M2 – 2 weeks
Mission Conceptual Design Document	M4 – 2 weeks (draft) FRM – 2 weeks (final)
Mission Development Plan	FRM – 2 weeks
Commercial Potential Document	M4 – 2 weeks (draft) FRM – 2 weeks (final)
Minutes/ Presentations	
Kick-off Meeting Presentation	KOM – 1 week
Options Analysis Review Presentation	M1 – 1 week
Preliminary Concept Presentation	M2 – 1 week
Mission Concept Interim Review Presentation	M3 – 1 week
Mission Concept Review Presentation	M4 – 1 week
Final Review Presentation	FRM – 2 week
Minutes of Meetings	Meeting Date + 1 week
Action Item Log for Reviews and Teleconference	Meeting Date + 1 day
Final Data Package	2 weeks before Contract End Date
Final Version of all documents	
Executive Report	
BIP and FIP Disclosure Report	
Technical Notes	As required.
Software used for performance analysis	

3.5 SCHEDULE

The work described in this SOW must be completed within 14 months.

3.6 MEETINGS

Table 3.6-1 lists the meetings planned for this activity.

TABLE 3.6-1 MEETINGS

Meeting	Date	Location
Kick-off Meeting [KOM]	ARO + 2 weeks	Contractor
Options Analysis Review Presentation [M1]	ARO + 3 months	Teleconference
Preliminary Concept Presentation [M2]	ARO + 6 months	Contractor
Interim Review Meeting [M3]	ARO + 8 months	Teleconference
Mission Concept Review Presentation [M4]	ARO + 12 months	EC (Toronto)
Final Review Presentation [FRM]	ARO + 14 months	CSA
Technical Interchange Meetings [TIM]	monthly	Teleconference

3.7 DOCUMENTATION AND NAMING CONVENTION

Documentation, reporting and other deliverables must be according to instructions provided in Appendix B of this SOW, which also provides naming convention. Presentation material must be in Power Point format. Documents provided in Adobe PDF format must not be protected against copy of text and figures.

Documents shall be delivered in the original software application format. One electronic copy of each deliverable document shall be transferred to the CSA to the address and in the format specified in DID-0000, Appendix B. No paper copy is to be delivered.

All simulation scenarios that have been considered (e.g. with STK) must be delivered in CD-ROM or DVD-ROM format.

All documents must be provided 10 working days prior to the specified Review/Meeting unless otherwise indicated.

3.8 PROJECT MANAGEMENT REQUIREMENTS

The Contractor is responsible for establishing and maintaining a project management control system necessary to meet the requirements provided in the next sub-sections.

3.8.1 Team Organization

The Contractor must set up and maintain a project organization specific to this project. The Contractor must provide and maintain a current Project Organizational Chart showing personnel assignments by name and function, and showing subcontractor-reporting relationships.

The Contractor must nominate a Project Manager, who will be responsible for all aspects of the work carried out by the Contractor and will act as single point of contact within its project organization for communications between the Contractor and the Technical Authority (TA). In the absence of the single point of contact, the Contractor must designate an alternate to maintain continuity of communication between the Contractor and the TA.

The Contractor must also identify other key personnel who are considered essential to the performance of the contract. The Contractor must assign personnel with appropriate qualifications and experience to all posts within the project organization.

The Contractor must include, within its program management structure, the necessary leadership to effectively manage the performance of subcontractors in keeping with the project objectives.

3.8.2 Communications and Access

The Contractor must establish and maintain a close management and technical interface with CSA technical and project authorities to assure a coordinated program effort and monitoring of the total program cost, schedule and performance.

The Contractor must provide access to its plant and personnel, at mutually agreeable dates, by representatives of CSA and EC or other organizations nominated by the CSA, for review of program status.

The Contractor must provide temporary accommodation and other facilities for the use of the CSA representatives (and the nominated attendees) visiting the Contractor's premises for reviews, meetings, audits, liaison, etc.

The accommodation must be adequate for the purposes of the visit and the facilities provided must include telephone, faxing, photocopying and Internet access.

All documentation and data generated by the Contractor for the project must be accessible to the TA for review.

3.8.3 Project Meetings

The Contractor must hold the meetings described in section 3.6. Some or all of these meetings may be attended by representatives of the CSA, and/or other organizations nominated by the CSA. CSA reserves the right to invite additional knowledgeable people (Public Servants or others under NDA) to these meetings.

All meetings will be held between the Contractor and the TA at a mutually agreeable time. The Contractor must provide formal notification of the proposed meeting date to the TA no less than 10 working days before the meeting.

For meetings held at government venues, the Contractor must inform the TA of the names of Contractor and Subcontractor attendees no less than 10 working days before each meeting.

Technical Interchange Meetings are to be held by teleconferences monthly, and additional teleconferences or face-to-face review meetings may be held if necessary when mutually agreed to by the Contractor and the CSA project manager.

Meetings can be alternatively replaced by videoconference or teleconferences for cost and/or time savings and when appropriate to support the scope of the meeting.

3.8.3.1 Kick-off Meeting

Within two weeks of the contract award (or at a date mutually agreeable to by the PA, the TA and the Contractor) a Kick-Off Meeting should be scheduled by the Contractor. The Contractor should provide the meeting agenda at least five working days before the meeting. The presentation should include the following content:

- Review of contract deliverables;
- Work requirements;
- Foreground Intellectual Property (FIP) and Background Intellectual Property (BIP);
- Licensing issues if any;
- Project's funding and expected cash-flow;
- Presentation to include the required copyrights and intellectual property disclosure;
- Other items as deemed appropriate.

This meeting will be held at Contractor Facilities.

All key participants under the contract, including at least one representative from each subcontractor, must attend this meeting.

3.8.3.2 Review Meetings

During the contract, various meetings will be necessary to evaluate progress of the work. The Meetings will be held according to the schedule in Table 3.6-1. The Meetings are intended to provide an opportunity for the Contractor, the PA, the TA, and other invited attendees to review and discuss the following in detail, as necessary:

- The contents of the contract deliverables;
- The technical work of each task;
- Foreground Intellectual Property (FIP) and Background Intellectual Property (BIP);
- Discuss project management issues;

- Presentation to include the required copyrights and intellectual property disclosure;
- Other items as deemed appropriate.

The Contractor's project manager, the systems engineer and all key Contractor participants, including at least one representative from each Subcontractor, must attend all Review meetings.

3.8.3.3 Final Review Meeting

The Final Review Meeting will be held at the Canadian Space Agency at the end of the contract. The specific intent of this meeting will be to discuss in detail the results obtained and the proposed follow-on activities. The Final Review Meeting is intended to provide an opportunity for the Contractor, the PA, the TA and other invited attendees to review and discuss the project.

- Contract deliverables;
- Foreground Intellectual Property (FIP) and Background Intellectual Property (BIP);
- Licensing issues if any;
- Final Funding and cash-flow;
- Discuss project management issues;
- Presentation to include the required copyrights and intellectual property disclosure;
- Other items as deemed appropriate

The Contractor must submit the Final Data Package 10 working days before Contract End Date; document versions must be as per the CDRL.

The Contractor's project manager, the systems engineer and all key Contractor participants, including at least one representative from each Subcontractor, must attend the Final Review Meeting.

3.8.3.4 Technical Interchange Meetings

Technical Interchange Meetings [TIM] shall be held monthly to discuss Contract progress and consolidate input from the CSA and EC or other nominated organizations.

3.8.4 Agendas, Minutes and Action Item Log

The Contractor must provide a Meeting Agenda for all reviews and meetings including teleconferences and must deliver these to the TA no less than 5 working days before the meeting and must have it approved by the TA.

The Contractor must produce the minutes for all reviews and meetings including teleconferences and must deliver these to CSA no more than 5 working days after the meeting.

The Contractor must maintain a detailed Action Item Log (AIL) throughout the project to track actions resulting from all reviews and meetings including teleconferences using the following red-yellow-green stoplight method:

- 'Green' implying that the action item will be completed on-time.

- 'Yellow' implying that there exist an issue which will prevent meeting the deadline, and
- 'Red' implying that the action is past due.

Also, a chart indicating how many action items are open and how many are closed since the beginning of the project shall be produced at the meetings. The AIL must be delivered the next business day following the review or meeting (including teleconference).

3.8.5 Project Reporting

3.8.6 Documents Deliverables

The Contractor must deliver all documentation listed in the CDRL tables (Appendix A) as a minimum. The format and content of the deliverables must be in accordance with the requirements specified in the Data Item Descriptions (DIDs) (Appendix B), both the specific DID identified in the CDRL and the General Preparation Instructions, DID-0000.

Except for the documents that will remain CSA documents, the Contractor may propose documents in a contractor's format provided the purpose, scope and content equal or exceed the DID requirements. Subject to CSA approval, the content of the Contractor's document will replace the content of the document specified in the DID.

SI units must be used/supplied by the Contractor. Conversion factors must be supplied for all non-SI units used in the deliverable documents (including dates as YYYY-MM-DD).

The Contractor must obtain approval from the CSA for all CDRL Documents so indicated in the CDRL table (see Section 3.8.6.1).

3.8.6.1 Documents Delivered for Approval

The term “Approval” as used in this document and in other documents referred to herein, means written approval by CSA, of documents submitted by the Contractor. Once approved, the document is authorized for further use by CSA. The TA does not take responsibility for the validity of the data, or statements, and the Contractor is fully responsible for the content and secondary effects derived there from. The document may not be changed without the TA’s approval. No request or document for which approval is required must be acted upon or implemented by the Contractor until such approval is provided. Such requests and documents will be reviewed promptly by the TA and the necessary written approval or disapproval will be provided after their receipt by CSA. In the event of a failure by the TA to approve or disapprove the document within 15 calendar days, the documents may be deemed approved. In the event that a request or document is disapproved, the TA will advise the Contractor in writing as to the reasons for such disapproval and will define the additions, deletions or corrections that the TA deems necessary to render the request or document acceptable. Disapproved requests or documents that are subsequently amended by the Contractor and resubmitted for approval will be either approved or disapproved by the CSA.

3.8.6.2 Documents Delivered for Review

The term “Review” as used in this document and in all other documents referred to herein, means, unless specifically stated otherwise, a CSA review of the documents submitted for that

purpose by the Contractor. The acceptance by the TA of a document for review shall imply that the document has been reviewed, commented on, revised as necessary, and has been determined to meet the requirements. The TA does not take responsibility for the validity of the data, or statements, and the Contractor is fully responsible for the content and secondary effects derived there from. In the event that the TA does not concur with a document submitted for review, the TA will so notify the Contractor. Such notification will include a full explanation of the reasons for the lack of concurrence and will recommend the additions, deletions or corrections that the TA deems beneficial to the needs of the project.

The Contractor is obligated to consider implementation of the changes suggested by CSA insofar as the changes are in accordance with the relevant DID in Appendix B and this SOW. If written notification of concurrence is not provided by CSA within 15 calendar days of the receipt of the document, the document will be deemed to have been reviewed by the TA without comment.

3.8.7 Subcontract Management

The Contractor must be fully responsible for implementation and execution of all tasks, including those subcontracted to others. Whenever this is the case, the Contractor must prepare and maintain subcontract Statements of Work, technical requirements documents, etc., necessary to effectively manage the subcontractors' work. At the request of the TA, copies of subcontractor documentation must be delivered to the TA.

The Contractor must ensure that all of the relevant requirements of this Statement of Work are flowed down to the subcontract Statements of Work.

3.8.8 Product Assurance

There are no applicable product assurance requirements in this study.

3.9 INTELLECTUAL PROPERTY

The Contractor shall prepare Background and Foreground Intellectual Property (BIP and FIP) Report, identifying the BIP and FIP that will be generated in this study.

4 GOVERNMENT FURNISHED EQUIPMENT AND INFORMATION

No GFE.

APPENDICES

APPENDIX A CONTRACT DATA REQUIREMENTS LIST (CDRL)

This Appendix defines the documentation to be delivered by the Contractor.

LEGEND:
A = Approval (in the Approval Category)
CF = Contractor's format
X = Ad-hoc, as and when requested

TABLE A-1: CDRL

Title	DID No.	Approval Category
Meeting Agenda	0004	A
Minutes of Meetings	0005	A
Action Items Log (AIL)	0006	A
Options Analysis Report	0200	A
Preliminary Concept and Requirements Document	0210	A
Mission Conceptual Design Document	0220	A
Mission Development Plan	0230	A
Commercial Potential Document	0240	A
BIP and FIP Disclosure Report	0250	A
Executive Report	0260	A
Technical Notes	CF	X

APPENDIX B DATA ITEMS DESCRIPTIONS (DIDs)

DID-0000 - General Preparation Instructions

PURPOSE:

This DID describes the standard format for the preparation of deliverable project documentation. All documentation must be written in English and must be delivered in electronic format. Documentation must be prepared in the Contractor's format, however it must meet the requirements of this DID.

PREPARATION INSTRUCTIONS:

1. GENERAL INSTRUCTIONS

1.1. Electronic Copies

Electronic documents must be prepared using the most appropriate tool (Microsoft Word, Excel, MS Project, etc.); released versions must be delivered in electronic format and may be in PDF. Schedules must be submitted in Microsoft Project format. Documents must be delivered via e-mail or direct transfer (FTP). For direct transfer, a notification of the document's readiness and location on a Contractor repository must be sent.

The electronic file name and the identification number written on the document itself must have the following format:

WXYZ-CDRL-NUM-CIE_ContractNumber_sent2007-03-30

where:

WXYZ:	A 4-8 letter acronym of the project
CDRL-NUM:	The CDRL Identifier
CIE:	Name of the Company (no space, no hyphen)
Contract Number:	For example: _9F028-07-4200-03
_sentYEAR-MONTH-DAY:	Date Tracking Number

Electronic documents or notifications of their availability on Contractor repositories must be sent to the e-mail address of the TA.

Emails are to contain the project/program acronym or equivalent identifier in the "Subject" line and include the CDRL identifier under which deliverable documents are being submitted. Hard copy and media deliverables are to be addressed to:

Attention:
Canadian Space Agency
6767, Route de l'Aéroport
Longueuil, QC, J3Y 8Y9
CANADA

The DVD-ROM label must present the following information:

a) Company Name

b) Document Title
c) Document Number and Revision Status
d) CDRL Number
e) Contract Number

1.2. Electronic Documents Format

Electronic copies of text documents must be formatted for printing on 8.5" x 11" paper.

1.2.1. Page Numbering

General format of documents should include page numbers and be formatted according to the Contractor's normal standard. If the document is divided into volumes, each such volume must restart the page numbering sequence.

1.2.2. Document Numbers

All pages must contain the Document Number at the top of the page. Document Numbers must include revision status and volume identification as applicable.

2. DOCUMENT STRUCTURE AND CONTENT

2.1. Overall

Except as otherwise specified, all documents must have the overall structure as follows:

a) Cover/Title Page;
b) Table of Contents;
c) Scope;
d) Applicable and Reference Documents;
e) Body of Document; and
f) Appendices
g) The following property notice of all internal pages: ***Use, duplication or disclosure of this document or any of the information contained herein is subject to the Property Notice at the front of this document.***

2.2. Cover/Title Page

The title page must contain the following information:

- Document Number and date: Volume x of y (if multivolume)
- Rev. indicator / date of Rev.
- Document Title
- Project Name
- Contract No.
- CDRL Item No. or Nos., if one document responds to more than one CDRL, subject to prior approval from the TA.
- Prepared for: Canadian Space Agency
- Prepared by: Contractor name, CAGE Code, address, and phone number
- Product tree identifier, if applicable
- © HER MAJESTY THE QUEEN IN RIGHT OF CANADA [YEAR]
- The following property notice: ***This document is a deliverable under contract no. _____. It contains information proprietary to the***

Crown, or to a third party to which the Crown may have legal obligation to protect such information from unauthorized disclosure, use or duplication. Any disclosure, use or duplication of this document or of any of the information contained herein for other than the specific purpose for which it was disclosed is expressly prohibited outside the Government of Canada except as the Crown may otherwise agree to in writing.

2.3. Table of Contents

The table of contents must list the title and page number of each titled paragraph and subparagraph, at least down to the third level inclusive. The table of contents must then list the title and page number of each figure, table, and appendix, in that order.

2.4. Scope

This section must be identified as section 1 and must, as a minimum, provide the following information:

a) Identification (number, title) of the system, hardware, or software to which the document applies;

b) A brief overview of the system to which the document applies; and

c) A summary of the purpose and content of the document.

The requirements specified in the following DIDs are the minimum expected. The Contractor must include in all documents all additional information required in order to ensure that the document provided will achieve its purpose as stated in the DID.

2.5. Applicable and Reference Documents

This section must list by Document Number and title, all applicable and reference documents. This section must also identify the source of all applicable and reference documents and the revision indicator.

2.6. Body of Document

The body of the document must be prepared in accordance with the content and format requirements defined in the specific Data Item Description.

2.7. Appendices

Appendices may be used to provide information published separately for convenience of document maintenance.

3. DOCUMENT REVISIONS

Changes in revised documents must be identified by a sidebar.

4. SUBMISSION OF DATA

Data must be submitted via Letter of Transmittal (or an electronic equivalent as mutually agreed by the TA and the Contractor), and acknowledged. The Letter of Transmittal will contain as a minimum, the Contract Serial Number, the CDRL Number and the Title. The Letter of Transmittal must be forwarded by the Contractor in two copies; one copy of acknowledgement to be signed and returned to the Contractor by the recipient.

DID-0004 – Meeting Agenda

PURPOSE:

To clarify the purpose, content and timings of a meeting.

PREPARATION INSTRUCTIONS:

The meeting agendas must contain the following information, as a minimum.

1. **DOCUMENT HEADER:**
    a. Title;
    b. Type of meeting;
    c. Project title, project number, and contract number;
    d. Date, time, and place;
    e. Chairperson; and
    f. Expected duration.

2. **DOCUMENT BODY:**
    a. Introduction;
    b. Opening Remarks: CSA;
    c. Opening Remarks: Contractor;
    d. Review of previous minutes and all open action items;
    e. Project technical issues;
    f. Project management issues;
    g. Other topics;
    h. Review of any action items as a result of the current meeting and
    i. Set or confirm dates of future meetings.

DID-0005 – Minutes of Meetings

PURPOSE:

The minutes of reviews or meetings provide a record of decisions and agreements reached during reviews/meetings.

PREPARATION INSTRUCTIONS

Minutes of meeting must be prepared for each formal review or meeting and must include the following information, as a minimum:

1. Title page containing the following:
    a. Title, type of meeting and date,
    b. Project title, project number, and contract number,
    c. Space for signatures of the designated representatives of the Contractor and the CSA,
    d. Name and address of the Contractor;
2. Purpose and objective of the meeting;
3. Location;
4. Agenda;
5. Summary of the discussions, assumptions, decisions and agreements reached;
6. List of the attendees by name, position, phone numbers and e-mail addresses as appropriate;
7. Listing of open action items and responsibility for each action to be implemented as a result of the review;
8. Other data and information as mutually agreed; and
9. The minutes must include the following statement:

"All parties involved in contractual obligations concerning the project acknowledge that minutes of a review/meeting do not modify, subtract from, or add to the obligations of the parties, as defined in the contract."

The list of action items must include the following information:

1. the action item number;
2. a description of the action required;
3. the date the action item was opened;
4. the person responsible for ensuring that the action is carried out;
5. the due date for the action;
6. the status of the action (open or closed); and
7. any comments or remarks relevant to the action.

Once an action item is closed, the action item list should also indicate the date the action was complete.

DID-0006 – Action Items Log

PURPOSE:

The Action Item Log (AIL) lists, in chronological order, all items on which some action is required, allows tracking of the action, and in the end provides a permanent record of those Action Items (AI).

PREPARATION INSTRUCTIONS:

The AIL must be in a tabular form, with the following headings in this order:

1. Item Number;
2. Red, yellow, green stoplight
3. Item Title;
4. Open Date;
5. Source of AI (e.g. MCR meeting, RID, etc.);
6. Originator;
7. Office of Prime Interest;
8. Person responsible (for taking action);
9. Target/Actual Date of Resolution;
10. Status (Open or Closed);
11. Remarks; and
12. Chart of graphical representation of open, closed, and total action items.

The date in column 9 will be the target date as long as the item is open, and the actual date once the item is closed.

DID-0200 – Options Analysis Report

PURPOSE:

To identify options to meet the Air Quality – Greenhouse Gas measurement objectives, perform trade-off on those options and identify viable approaches to be used as inputs for future Business Case.

PREPARATION INSTRUCTIONS:

The document must include as a minimum:

1. Review of AQ-GHG Mission and Science Objectives
2. Review of AQ-GHG Observation Requirements
3. Initial Assessment of Orbit required to achieve Observation Requirements
4. Status quo
    a. Brief description (1 paragraph) of current status quo
    b. Brief Description (1 paragraph) of long-term effectiveness of status quo
5. List of all potential options with ROM costing and duration
    a. Hosted payload on commercial or international satellites
    b. Hosted payload on a Canadian mission (e.g. PCW)
    c. Access to foreign missions and products
    d. Access to commercially available data
    e. Setting up local stations to provide the AQ-GHG information.
    f. Stand-alone Canadian satellite (Orbit: HEO, LEO, MEO)
    g. Constellation of Canadian satellites (Orbit: HEO, LEO, MEO)
6. Evaluation criteria, explanations, and associated weighting if applicable
7. Screening of Options
    a. Options selected or rejected according to screening criteria
    b. Eliminate obvious no-go options
8. Rationale for Discounted and Viable Options.
9. Assessment of relative merit of Viable Options, including an output table comparing the options according to the following criteria as a minimum:
    a. Quality of Services
    b. Costs (ROM)
    c. Risks.

DID-0210 – Preliminary Concept and Requirements Document

PURPOSE:

To flow-down the AQ-GHG Mission and Science Objectives and Observation Requirements into preliminary Instrument, System, and Mission level requirements that will be used to assess the ability of the Mission Concept to meet the primary Mission Objectives and the feasibility to meet the secondary objectives. This document will also propose preliminary concepts to fulfill these requirements.

PREPARATION INSTRUCTIONS:

The document must include as a minimum:

1. Mission, Instrument, and System Requirements
2. Traceability matrix to Mission Objectives and Observation Requirements
3. Reassessment of driving requirements
4. Reassessment of viable options
5. Preliminary Concept to meet Mission Requirements for two most promising viable options
    a. Trade-study to reconfirm that the payload technologies.
    b. Preliminary Trade-study to determine spectral band configuration
    c. Trade-study to support orbit identification.
    d. Trade-study to support constellation selection and geometry if applicable
    e. Block diagram of mission architecture
        i. Payload
        ii. Spacecraft
        iii. Orbit
        iv. Constellation (if applicable)
        v. Ground segment
6. Response and Recommendations related to Requested Trades/Questions detailed in section 3.3.3

DID-0220 – Mission Conceptual Design Document

PURPOSE:

To develop mission concepts for the two viable options with the most merit. Assess the ability to meet primary objectives and report on the feasibility to meet the secondary mission objectives.

PREPARATION INSTRUCTIONS:

The document must include as a minimum:

1. An introduction including the scope, the purpose and a list of assumptions (if any);
2. Payload description;
3. Spacecraft Layout;
4. Orbit Description
5. Constellation of formation-flying geometry (if applicable);
6. Coverage Analysis (including orbit description)
7. Spacecraft Main Engineering Budgets, including: mass, power, data rates, on-board storage, ADCS, propulsion;
8. Ground Segment and Operations;
9. Data Products and Data Latency;
10. Calibration and Validation;
11. Space-to-Ground link;
12. Launch Options;
13. Compliance to Measurement Objectives;
14. Identify preferred option
    a. Assess relative merits / challenges / limitations of the 2 options
15. Alternative Options and Applications

DID-0230 – Mission Development Plan

PURPOSE:

To define the programmatic activities required to initiate and develop the mission.

PREPARATION INSTRUCTIONS:

The plan must include the following:

1. An introduction including the scope, the purpose and a list of assumptions (if any);
2. A description of the mission including its objectives;
3. Technology Readiness and Risk Assessment (TRRA);
4. Technology Roadmap (TRM);
5. Technology development activities to be performed, detailing the urgency, criticality and the main risks and challenges of each activity;
6. Possible technology demonstrations;
7. Estimated mission life cycle cost;
8. Estimated mission schedule including all major milestones;
9. Preliminary mission risk assessment;
10. Preliminary concept of operation;
11. Potential collaborations;
12. Proposed Canadian capabilities development strategy;
13. Recommendations for follow-on activities.

DID-0240 – Commercial Potential Document

PURPOSE:

To assess the commercial potential of technology and data products associated with the AQ-GHG Mission Concept. This may be used as inputs for future Business Case.

PREPARATION INSTRUCTIONS:

The report must include the following:

1. Overview of market for the technology:
    a. terrestrial
    b. space
2. Overview of Canadian Capacity
3. Business potential and alternative markets for the:
    a. technology
    b. data products
4. Relevance to planned or projected geosynchronous missions
5. Market analysis
    a. Estimates of future returns
6. Alternative strategies to the Canadian capabilities and technology development
7. Recommendations for market development

DID-0240 – FIP and BIP Disclosure Report

PURPOSE:

To fully disclose all FIP and BIP resulting from the study.

PREPARATION INSTRUCTIONS:

The report shall include the following:

- an introduction including the scope and the purpose;
- a list and description of all FIP resulting from the study; and
- a list and description of all BIP required by CSA for use of the FIP resulting from the study.

DID-0250 – Executive Report

PURPOSE:

To provide a summary of the work accomplished during the contract.

PREPARATION INSTRUCTIONS:

The Executive Report will be placed in the public domain (e.g. CSA's library, publication and/or website).

The report should not exceed ten (10) pages.

The Contractor should submit an electronic copy of the Executive Report in the Final Data Package. The structure for the Executive Report is as follows:

1) Introduction;
2) Project Objectives;
3) Approach / Project Tasks;
4) Accomplishments;
5) Science/Technology:
    a) Innovative Aspects;
    b) Application Fields;
6) Business Potential, Benefit and Impact on the organization;
7) Ownership of Intellectual Property; and
8) Publications / References.

The CSA and the Contractor, or others designated by them, have the right to unrestricted reproduction and distribution of the Executive Report. The report should include the following proprietary notice ("Owner of FIP" being either the CSA or the Contractor):

Copyright 20XX by Canadian Space Agency

Permission is granted to reproduce this document provided that written acknowledgement to the Canadian Space Agency is made.

APPENDIX C ACRONYMS AND ABBREVIATIONS

AOD	Aerosol Optical Depth
ARO	After Receive Order
AD	Applicable Document
ADCS	Attitude Determination and Control Subsystem
AI	Action Items
AIL	Action Items Log
AQ	Air Quality
AQRD	Air Quality Research Division
BIP	Background Intellectual Property
CA	Contract Authority
CCD	Charge Coupled Device
CEOS	Committee on Earth Observation Satellites
CDRL	Contract Data Requirements List
CMOS	Complementary Metal Oxide Semiconductor
CRD	Climate Research Division
CSA	Canadian Space Agency
DID	Data Item Description
EC	Environment Canada
FIP	Foreground Intellectual Property
FoR	Field of Regard
FRM	Final Review Meeting
GCOS-IP	Global Climate Observing System-Implementation Plan
GEO	Geostationary or geosynchronous Orbit
GFE	Government Furnished Equipment
GHG	Green House Gas
GiFOV	Ground instantaneous Field of View
GOSAT	Greenhouse Gases Observing Satellite
GRIP	Government Related Initiatives Program
HEO	Highly Elliptical Orbit
IGCOS	Integrated Global Carbon Observing System
IP	Intellectual Property
IR	InfraRed
ITAR	International Traffic in Arms Regulation
KoM	Kick-off Meeting
LEO	Low Earth Orbit
MEO	Medium Earth Orbit

MCR	Mission Concept Review
NDA	Non-Disclosure Agreement
NRT	Near Real Time
OCO-2	Orbiting Carbon Observatory 2
OGD	Other Government Departments
PA	Project Authority
PCW	Polar Communications and Weather
PHEOS	Polar Highly Elliptical Orbit Science
RD	Reference Document
ROM	Rough Order of Magnitude
RT	Review Team
SNR	Signal to Noise Ratio
SOW	Statement Of Work
SWIR	Short Wave InfraRed
SZA	Solar Zenith Angle
TA	Technical Authority
TBC	To Be Confirmed
TBD	To Be Determined
TEMPO	Tropospheric Emissions: Monitoring of Pollution
TIM	Technical Interchange Meeting
TN	Technical Note
TRL	Technology Readiness Level
TRM	Technology Roadmap
TRRA	Technology Readiness & Risk Assessment
UV	Ultraviolet
Vis	Visible
WBS	Work Breakdown Structure
WCA	Weather Climate Air quality
WMO	World Meteorological Organization