The quest for an OCO (Orbiting Carbon Observatory) re-flight

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ABSTRACT

The objective of the OCO (Orbiting Carbon Observatory) mission was to make the first space-based measurements of atmospheric carbon dioxide with the accuracy needed to quantify sources and sinks of this important greenhouse gas. Unfortunately, the observatory was lost as a result of a launch vehicle failure on 24 February 2009. The JPL (Jet Propulsion Laboratory) was directed to assess the options for the re-flight of the OCO instrument and recovery of the carbon-related measurement, and to understand and quantitatively assess the cost, schedule, and technical and programmatic risks of the identified options. The two most likely solutions were (1) a shared platform with the TIRS (Thermal Infrared Sensor) instrument and (2) a dedicated OSC (Orbital Sciences Corporation) LEOStar-2 spacecraft bus similar to that utilized for the original OCO mission. A joint OCO-TIRS mission study was commissioned and two specific options were examined. However, each presented technical challenges that would drive cost. It was determined that the best option was to rebuild the OCO observatory to the extent possible including another LEOStar-2 spacecraft bus. This lowest risk approach leverages the original OCO design and provides the shortest path to launch, which is targeted for no later than the February 2013 timeframe.

Keywords: atmospheric, carbon, carbon dioxide, OCO (Orbiting Carbon Observatory), re-flight

1. INTRODUCTION

OCO was selected for implementation in 2002 as an ESSP (Earth System Science Pathfinder) mission. The mission was designed to return space-based measurements needed for global estimates of atmospheric carbon dioxide with the precision, resolution, and coverage needed to quantify regional-scale sources (emitters) and sinks (absorbers). Evaluating their behavior over season and annual cycles will provide scientists with additional information and data to better understand how carbon dioxide, a major greenhouse gas, influences or drives the global climate change process.

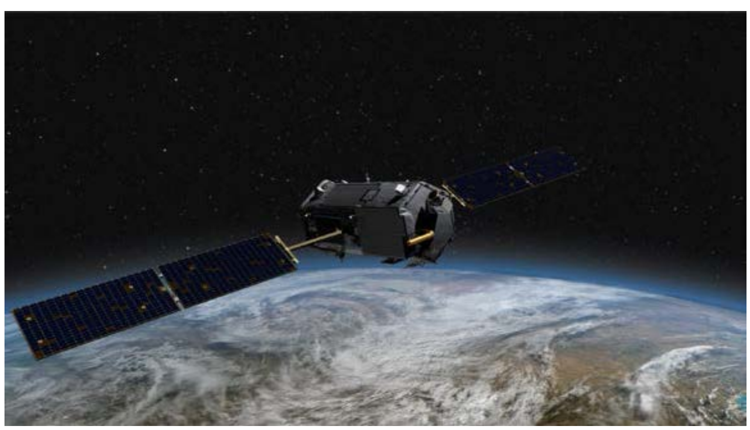

Figure 1. This is an artist rendition of the OCO-2 observatory operating in space.

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1.1 MISSION AND SCIENCE OBJECTIVES

Over the last fifty to sixty years human activity has resulted in approximately 200 billion metric tons of carbon being emitted into the atmosphere. However, scientists can only account for approximately one-half remaining in the atmosphere. The general consensus is that the other one-half is being absorbed by the terrestrial biomass and by the oceans. However, where exactly are these sinks? How do these sinks behave between seasons and annual cycles? Will the characteristics of these sinks change or their absorption efficiency diminish as more carbon is emitted into the atmosphere? The measurement of atmospheric carbon dioxide (CO_2) is still generally accomplished through a ground-based network of monitoring stations. Unfortunately, these tall towers are few, far between, and not evenly-spaced. They don't generally exist in isolated areas such as forests and oceans or in countries experiencing heavy industrialization. This makes it difficult, if not impossible, to find and study these sources and sinks. The Orbiting Carbon Observatory (OCO) was designed to return the space-based measurements needed to provide global estimates of CO_2 with the sensitivity, accuracy and sampling density needed to quantify carbon sources and sinks and characterize their behavior over the annual cycle. The mission was selected for implementation in 2002. Estimates of CO_2 or more accurately, the column-averaged dry air mole fraction of carbon dioxide (or X_{CO2}) on regional scales (≥1000 km), would be made. These retrievals would be derived from space-based measurements of the absorption of reflected sunlight by CO_2 and oxygen (O_2) during the nominal two-year mission. Space-based retrievals would then be compared with ground-based X_{CO2} retrievals from soundings collected during over-flights of ≥ 3 primary ground validation sites to identify and correct global-scale systematic biases in the former and to demonstrate a precision of ≤ 0.3% for collections of ≥100 cloud-free soundings (i.e., temporally correlated CO_2 and O_2 measurement sets).

1.2 KEY ORGANIZATIONS

OCO was a NASA (National Aeronautics and Space Administration) mission, specifically under the SMD (Science Mission Directorate). Program authority was granted through the ESD (Earth Science Division) to the ESSP (Earth System Science Pathfinder) program office. The Jet Propulsion Laboratory (JPL) was responsible for project management. There were two major contractors for the original OCO mission. HSC (Hamilton Sundstrand Corporation) was responsible for delivering the single instrument payload and OSC (Orbital Sciences Corporation) was responsible for providing the spacecraft bus, integrating the instrument with the spacecraft bus, and delivering the observatory to the launch site, Vandenberg Air Force Base, California, USA. OSC also provided the launch vehicle, a Taurus XL 3110, through a contract with the NASA KSC (Kennedy Space Center) LSP (Launch Services Program).

1.3 INSTRUMENT OVERVIEW

The instrument consisted of three co-boresighted, high-resolution grating spectrometers. The first spectrometer was designed to operate at a wavelength of 1.61 microns, is referred to as the "weak CO_2" channel, and is the primary source for column CO_2. The second spectrometer was designed to operate at a wavelength of 2.06 microns, is referred to as the "strong CO_2" channel, and provides aerosol, water, and temperature information as well as a secondary source for CO_2. The third spectrometer was designed to operate at a wavelength of 0.765 microns, is referred to as the O_2 A-band channel, and provides cloud/aerosol and surface pressure information. Light enters a single 200 mm f/1.8 stop telescope and channeled through a series of lens, mirrors, and filters to the appropriate spectrometer. The FPA (Focal Plane Arrays) had to be cooled to 180 K for the O_2 A-band channel and 120 K for the weak and strong CO_2 channels to provide the necessary detection sensitivity [Livermore and Crisp, 2008].

1.4 SPACECRAFT BUS AND OBSERVATORY OVERVIEW

The spacecraft bus was based on the LEOStar-2 design. The three-axis stabilized system was the sixth in a series of successful missions that utilized the same design. Most assemblies (e.g., X-band transmitter) were internally mounted to provide for thermal stability. Articulating solar array panels and a rechargeable battery were designed to provide electrical power while the observatory was operating in the sun and in the umbra, respectively. The 128 Gb SSR (Solid State Recorder) provided instrument data storage until the data could be transmitted to a ground station. Aside from the BCA (Baffle/Calibration Assembly), the radiators, and the vent pipe, the instrument was mounted internally to the spacecraft bus with a close-tolerance fit with respect to other assemblies and components. The observatory was to operate in the EOS (Earth Observation System) Afternoon Constellation, a.k.a. "A-Train". This provided for the orbit necessary for OCO-specific measurements, but would also have provided an opportunity for synergistic measurements and comparisons with the instruments mounted on the other observatories operating in the constellation.

2. LAUNCH ANOMALY

2.1 FINAL LAUNCH SITE PROCESSING AND THAT FATEFUL DAY

The launch preparation for the Taurus XL 3110 launch vehicle and its payload went well at VAFB, including all of the final briefings and the Launch Readiness Review held on 22 February 2009. The spacecraft arming plugs were also installed on the 22 February 2009. All of the launch vehicle ordnance were enabled on 23 February 2009, in anticipation of the launch early the following morning. Figure 2 shows the launch vehicle erection process.

Figure 2. An image of the launch vehicle erection process at VAFB.

The MOC (Mission Operations Center) at OSC in Dulles, Virginia, USA was ready for the opening of the launch window at 9:51 UTC (Coordinated Universal Time) or 1:51 am local time at VAFB. At the operations center and launch site, the staff assembled and took positions on console four hours before the launch, and the launch countdown began at launch minus 03:20:00.000. During the countdown another satellite had an emergency and there was a possibility of scrubbing the OCO launch due to reassignment of critical assets. However, the issue was resolved and the launch countdown resumed at approximately 12:30 am local. An issue with the flight termination system receivers postponed the launch time to 1:55:30 am local. At 1:55:31 am local, Stage 0 ignition took place with a successful 1 minute and 24 second burn. First stage ignition followed and completed at 2 minutes and 43 seconds after launch, followed by first stage separation. Following stage one separation stage 2 ignited followed 7 seconds later by the command sequence for payload fairing separation. Figure 3 is a long exposure view of the launch from VAFB [Credit: Matt Rogers of CSU (Colorado State University)].

At VAFB and the MOC where spacecraft telemetry was being monitored, everything was nominal until shortly after the command for payload fairing separation. The fairing separation indicators did not indicate a change in status, and combined with temperature readings caused the teams at both sites to rapidly assess and conclude that the payload fairing had not separated, and that the mission was lost. The OCO satellite did separated from the upper stage, but was contained within the still attached payload fairing. The OCO satellite and the vehicle coasted to an apogee of 615 km, (short of the desired 642 km) with an apogee velocity of 7.2 km/sec. This apogee was only 300 m/sec short of the desired orbital velocity. Failure to shed the payload fairing mass prevented the satellite from reaching its planned orbit; resulting in atmospheric reentry. Aerodynamic heating and reentry loads most likely caused break-up and/or burn-up. Any surviving pieces were dispersed in the Pacific Ocean near Antarctica.

Figure 3. The launch vehicle with its precious payload leaves VAFB. [Credit: M. Rogers, CSU]

The contingency was declared minutes later. The NASA LSP Interim Response Team (LSPIRT) impounded evidence and collected written witness statements in accordance with NASA policy and the NASA LSP Mishap Preparedness and Contingency Plan. Data was impounded at VAFB (from both NASA and the United States Air Force 30th Space Wing), NASA KSC (Kennedy Space Center), OSC, and JPL. Telemetry data from the down-range assets were also impounded. A NASA Mishap Investigation Board (MIB) was convened to assess the cause of the failure. The MIB started its investigation on 03 March 2009, and concluded its efforts on 15 June 2009 with a final report and a public release summary.

The investigation carried out by the MIB resulted in validation that the Taurus XL 3110 launch vehicle payload fairing failed to separate upon command. Fairing sensor data (microphone, temperature, acceleration) and the separation breakwire indicated that the fairing did not separate from the launch vehicle. The MIB analyzed the payload fairing system design, manufacturing, inspection, assembly, and testing, and associated telemetry in order to identify a more detailed cause. The MIB was unable to determine which component or subcomponent was the direct cause for the fairing not to separate, but identified a number of hardware components whose failure modes could be potential causes: the frangible joint that separates the payload fairing halves from each other and from the upper stage, an initiating signal from the electrical subsystem, the pneumatic system Hot Gas Generator (HGG) including its pressure cartridges, and FCDC (Flexible Confined Detonating Cord).

During the course of the mishap investigation, several observations related to quality control, configuration management and programmatic processes were noted by the MIB. Although these observations were not direct contributors to the mishap, the MIB determined that they could be beneficial for future programs.

All of the MIB findings and recommendations are being addressed in preparation for the next Taurus XL 3110 launch schedule for no-earlier-than 22 November 2010 for the NASA Glory mission.

2.2 INITIAL PROJECT RESPONSE

In the days following the devastating loss of the OCO mission, the team reassembled to respond to requests from NASA Headquarters about the state of spares that could be used for an OCO re-flight, and the costs and schedule for building another OCO observatory. These initial studies included options to launch OCO-2 on a different platform, including the options of sharing the platform with other instruments, co-manifested launches and single launch missions.

3. THE JUSTIFICATION FOR A RE-FLIGHT

Within weeks of the launch vehicle anomaly, the NASA ESD commissioned the OCO Science Team to prepare a "white paper" documenting the justification for a re-flight. The topics were to include (1) the current state of carbon cycle science, (2) advances in carbon cycle science since the selection of the OCO mission in 2002, (3) key issues given that the NRC (National Research Council) completed it's first decadal survey for Earth science missions and made specific recommendations for restoring U.S. leadership in Earth science and applications (NRC, 2007), GOSAT (Greenhouse gases Observing SATellite) was launched, and OCO was lost, and (4) the minimum science requirements for the next spaceborne mission.

The OCO Science Team documented the fact that measurements made by the international carbon cycle community improved the understanding of carbon sources and sinks and how they relate to the global climate change process. In general, these measurements were and continue to be made through collection and analyses of air samples, instruments mounted on tall towers, and instrumented aircraft. There are obvious limitations to this approach given the measurement frequency and the coverage possible. In recent years spaceborne thermal infrared sensors such as AIRS (Atmospheric Infrared Sounder) and TES (Tropospheric Emission Spectrometer) on the NASA EOS (Earth Observation System) Aqua and Aura platform, respectively have complemented this data set by providing measurements needed to estimate carbon concentration levels in the upper atmosphere with the desired frequency and coverage. Unfortunately, accurate retrieved estimates needed to quantify carbon sources and sinks, which are located closer to Earth's surface, require the precision and sensitivity (spatial resolution) of a near infrared sensor. GOSAT was launched in early 2009 and utilizes both thermal and near infrared sensors. While these measurements serve to increase carbon cycle science knowledge they are being made with lower precision and sensitivity and also reduced global coverage (i.e., density) than what OCO was designed to provide. The NRC decadal survey recommendations to NASA included another carbon monitoring mission called ASCENDS (Active Sensing of CO2 Emissions over Nights, Days, and Seasons). However, the relatively low technology readiness level at this time means that the mission is several years away from launch. Therefore, the OCO instrument is the only confirmed sensor that can provide the measurements needed to quantify carbon sources and sinks. The advances in carbon cycle science do not diminish the need for an OCO re-flight, but rather underscores the importance and urgency of a critical science measurement needed for improved understanding of the global climate change process.

4. RE-FLIGHT IMPLEMENTATION STUDY

Also within weeks of the launch vehicle anomaly, the NASA ESD directed the OCO Project to perform a study to identify and evaluate options for re-flight of the OCO instrument and recovery of the critical science measurements and to assess the cost, schedule, and technical and programmatic risks of each option. Project personnel were requested to initially consider multiple options, but to eventually focus on and perform a more in-depth assessment of the most viable options. The re-flight study was scheduled to be completed over a four-month period and culminate in a formal presentation to the NASA ESD.

4.1 SERVICE PLATFORM REQUIREMENTS

A set of service platform requirements were compiled and served as evaluation criteria for each option examined. The set included the obvious mass, power, data storage, electrical and mechanical interfaces, and operational orbit requirements. However, there were stringent, active attitude control-related requirements that needed to be adhered to in order for the instrument to return the measurements needed for precise retrieved estimates of X_{CO2}. Since sunlight is highly polarized, the spectrometer slits need to be maintained perpendicular to the "principal plane" - the plane that includes the observatory, the observation point on Earth's surface, and the sun – while the instrument is taking data on the sunlit side of the globe. Also, there are three observation or pointing modes: (1) nadir, (2) glint, and (3) target. Nadir mode operations follow the more common or typical approach of pointing the instrument boresight at or near the sub-satellite point. While this mode is acceptable for acquiring measurements over land, the lower SNR (Signal to Noise Ratio) over the dark ocean surface requires an alternative method. As the name implies, during glint mode operations the instrument boresight remains trained on the sun's glint spot to provide the performance necessary. OCO was to have alternated between nadir and glint mode operations after each 16-day orbit repeat cycle. During target mode operations the instrument boresight remains trained a stationary point on the globe. The nominal plan calls for one target location, a TCCON (Total Carbon Column Observation Network) site, to be viewed once per day. Depending on the option under examination, a polarization accommodation and/or pointing mechanism may have been needed if the option was selected for implementation.

4.2 OPTIONS SCREENED

The project identified as many options as possible at that start of the re-flight study without regard to the advantages and disadvantages of each. Once the list was compiled, a number of shared service platform options were screened from further study, since they were too far in the development life cycle to accommodate an OCO instrument payload. These included Glory, a mission scheduled for launch no-earlier-than 22 November 2010 and the joint NASA/CONAE (Comision Nacional de Actividades Especiales) Aquarius/SAC-D (Satelite de Aplicaciones Cientificas-D) mission scheduled for launch in 2011. Also, screened for further study were airborne options given that they would provide only limited benefit [e.g., improved understanding of BRDF (Bi-Directional Reflectance Distribution Function) for difference surfaces on the globe]. A number of other shared, but also dedicated service platforms were examined, but these as well as screened out. They included the Thales Alenia Space Proteus spacecraft bus used on missions such as Jason and the "heavy" version of the USAF (United States Air Force) STV (Space Test Program) SIV (Standard Interface Vehicle). It also became evident at this time that the OCO instrument physical configuration was such that a structure that would mimic the LEOStar-2 spacecraft bus used on the original OCO mission would be needed to 'adapt' the instrument for use on another type of spacecraft bus. Also examined was the ISS (International Space Station). Unfortunately, the lower inclination orbit limited the range of latitudes that could be viewed from the platform. In addition, the precession orbit did not allow for the spatial co-registration of observations over subsequent orbits. Therefore, the ISS was also ruled out as an option. The two most likely solutions were mounting the OCO instrument on a shared service platform with the TIRS (Thermal Infrared Sensor) instrument and on a dedicated LEOStar-2 spacecraft bus like the original OCO mission.

4.3 PRIMARY OPTION 1: SHARED PLATFORM WITH TIRS (THERMAL INFRARED SENSOR)

OCO Project personnel from JPL collaborated with LDCM (Landsat Data Continuity Mission) Project and TIRS instrument personnel from GSFC (Goddard Space Flight Center) and the USGS (United States Geological Survey) in determining the feasibility of a joint mission. The first scenario examined was a shared, but time-shared service platform with the OCO instrument and TIRS instrument as the two instrument payloads. In this scenario, the OCO instrument would be able to exercise one or more of three observation or pointing modes described earlier at certain times and the TIRS instrument would have command of the service platform at other times for a generally 50% duty cycle. Unfortunately, the stringent thermal stability requirements of the TIRS instrument would prohibit such an "arrangement" as the number of and extended duration of the thermal excursions caused by the necessary OCO instrument observation or pointing modes would have exceeded acceptable levels. The second scenario examined was a shared nadir-pointed platform with the OCO instrument and TIRS instrument as the two instrument payloads. While the addition of an OCO instrument polarization mechanism and as well as a pointing mechanism would seem to have made this a feasibility option as additional cost, the issue with this approach is that the TIRS instrument data needed to be co-registered with data from the LDCM OLI (Operational Lander Imager). Development and implementation of an operational approach would have driven the cost beyond an acceptable level. Finally, a dual-manifest launch scenario was examined. Here the OCO instrument would be mounted on a dedicated service platform and the TIRS instrument would be mounted on service platform (i.e., on the LDCM spacecraft along with the OLI instrument). To reduce cost, both missions would be launched aboard a single launch vehicle. An examination of feasible systems showed multiple physical envelope violations of the payload fairing.

4.4 PRIMARY OPTION 2: DEDICATED LEOSTAR-2 SPACECRAFT BUS

The other primary option was to build another LEOStar-2 spacecraft bus for use on the re-flight. Given that the OCO instrument was successfully integrated and tested with the LEOStar-2 spacecraft bus for the original OCO mission, this option presented the lowest risk approach. The original OCO design, management approach, processes, and key personnel would be leveraged to the maximum extent possible and present the shortest path to launch. Given this, the option was selected for implementation by the NASA ESD.

5. RE-FLIGHT IMPLEMENTATION STATUS

Even during the re-flight assessment phase, the OCO Project was authorized by the NASA ESD to place itself in a robust posture/position in the event an actual re-flight was authorized. This included mitigating parts obsolescence issues, evaluating necessary instrument and spacecraft bus hardware changes, and collaborating with the GOSAT (Greenhouse gases Observing SATellite) mission team. Initial authorization for the re-flight was received in December 2009 upon approval of the United States GFY (Government Fiscal Year) 2010 Omnibus spending bill. The President's signature on the bill authorized the Congressional Conference Committee's recommendation for NASA to spend no less than $50M for the initial costs associated with replacement of the original observatory.

5.1 MITIGATING PARTS OBSOLESCENCE

As a part of assessing the options for re-flight of the OCO instrument and recovery of the science measurement, the OCO Project team evaluated drawings, visited vendors to determine which parts are no longer in production, identified potentially obsolete parts, and evaluated parts procurement schedules. As an initial result, the team isolated four instrument-related items in the first group of long-lead procurements needed right away, so as not to preclude an expedited re-flight start-up. These four items were the 1) DSPs (Digital Signal Processors) for on-board data processing, 2) substrate-removed HgCdTe detectors from Teledyne Imaging Sensors, California, USA 3) collimator/camera lenses from Optimax, New York, USA, and 4) a number of EEE (electrical, electronic, and electro-magnetic) parts with longest delivery schedules. In April 2009, the NASA ESD authorized the project to procure the first set of schedule-driven long-lead items. In the subsequent months, the project continued to identify obsolete parts and components and receive authorization from the NASA ESD to mitigate parts obsolescence risks on a case-by-case basis.

5.2 EVALUATION NECESSARY HARDWARE CHANGES

Using existing documentation from the original OCO mission, the OCO Project team was authorized to assess variances from the as-built mission and provide an accounting of all variances and their impact for a notional OCO rebuild mission. The key hardware changes came to light from this assessment were the instrument cryocooler, spacecraft bus RAD6000 flight computer, and the instrument O_2 A-band channel detector. After the OCO rebuild option was selected for implementation, the OCO-2 project started to address the hardware changes in a comprehensive manner.

Instrument Cryocooler: The OCO instrument requires its detectors to be temperature controlled through the use of a cryocooler. The original OCO mission used the TES spare cryocooler and another copy does not exist. After months of research, the project located a spare two-stage, split tube cryocooler assembly belonging to the National Oceanic and Atmospheric Administration (NOAA) Geostationary Operational Environmental Satellite Series R (GOES-R) Program that could be modified to OCO-2 specifications. Since the time required for procurement of a new cryocooler and spare would have compromised the ability of an OCO re-flight mission to be ready for launch no later than the February 2013 timeframe, NASA and NOAA moved decisively to enter an inter-agency exchange Memorandum of Agreement (MOA) that allowed for the transfer of the GOER-R cryocooler assembly to the OCO-2 project. In July 2010, the anxiously awaited GOES-R cryocooler assembly arrived at the NGAS (Northrop Grumman Aerospace Systems) facility in Redondo Beach, California, USA for the required modification.

Spacecraft Flight Computer RAD6000: The re-design of the RAD6000 flight computer was needed to address an SRAM (Static Read-Only Memory) parts obsolescence problem had been identified as one of the top technical OCO re-flight risks. The project received authorization early on to fund OSC to work with BAE Systems on the re-design of the circuit to accommodate a replacement SRAM part. In December 2009, a delta CDR (Critical Design Review) for the RAD6000 flight computer was held at BAE Systems. The reviewers concluded that the updated design demonstrated a mature, low-risk approach to replacing the obsolete the SRAM 16-chip MCM (Multi-Chip Module) with newer "Millennium" SRAM modules. The electrical, structural, thermal, reliability, and radiation analyses indicate that the new RAD6000 unit will survive and perform successfully in the specified environments. In addition, based on recommendations from the reviewers, the project decided to procure an EDU (Engineering Development Unit) of the redesigned RAD6000 for mitigating technical risk (e.g., verify function and performance when integrated with other elements of the CEU (Central Electronics Unit) and for use later as part of the spacecraft bus testbed, a.k.a. "Flatsat".

Instrument Detector: During the original OCO mission, the O_2 A-Band FPA exhibited a significant residual image challenge. The project is pursuing two potential solutions: 1) replacing the original HyViSI (Hybrid Visible Silicon Imager) detector with a backside illuminated, substrate-removed HgCdTe detector, and 2) operating the HyViSI detector at 120 K as opposed to 180 K as recent tests indicate that there are no residual image concerns at the colder temperature. The final decision is pending further evaluation of detector and optical filter performance.

5.3 COLLABORATION WITH THE GOSAT MISSION TEAM

OCO was to have been the first NASA satellite designed to make global measurements of atmospheric CO_2 with accuracy, precision, and coverage needed to identify and characterize sources and sinks on regional scales at monthly intervals. To meet stringent measurement accuracy requirements, the science team on the original OCO mission developed and implemented several significant advances in ground-based calibration, validation, and remote sensing retrieval methods. These investments were not lost in the OCO launch failure. NASA regards the capabilities developed prior to launch as valuable assets. GOSAT was successfully launched on 23 January 2009. The OCO and GOSAT science teams formed a close partnership, which was formalized by a Memorandum of Understanding (MOU) between NASA and the Japan Aerospace Exploration Agency (JAXA).

During this partnership, the OCO science algorithm team as well as the science data processing team has had the opportunity to retool the OCO algorithms and data processing system using in-flight measurements collected by GOSAT. After 12 months of effort using GOSAT in-flight data, the OCO science data processing team has validated the OCO re-flight science operations approach, identified areas that need work, and has already reduced the uncertainties in producing retrieved estimates of atmospheric CO_2.

5.4 TAILORED FORMULATION PHASE

The OCO re-flight, now known as the OCO-2 Project formally became a NASA directed mission at the start of the Tailored Formulation Phase (TFP) in March 2010. The OCO-2 mission is not only a high priority for NASA, but those at the highest levels of the United States Government. Part of the TFP was funded by the American Recovery and Reinvestment Act (ARRA), as the mission is directly relevant to the immediate goals of ARRA by assisting to spurring economic activities, as well as being responsive to national goals as an OCO replacement was called out as a line item in the President's GFY11 proposed budget.

The TFP is unique to OCO-2 as it leverages the work performed during development of the original OCO mission as well as minimizing mission risk and cost. However, the OCO-2 Project will address all requirements associated with a formal Critical Design Review/Non-Advocate Review (CDR/NAR) scheduled for 25-26 August 2010. So far, the OCO-2 Project team has demonstrated in-depth understanding of the technical baseline, risks associated with the baseline, and mitigation strategies of those risks. This is evident in the successful completion of a series of system/subsystem technical reviews, almost all of which involved participation by one or more members of the NASA-appointed SRB (Standard Review Board). The project has also completed development of a high-fidelity LCC (Life Cycle Cost) estimate. The project as well as JPL senior management has confidence in delivering the observatory to the launch pad approximately 28 months after an Authorization to Proceed (ATP) is received and within the submitted cost.

6. CONCLUSIONS

The loss of the OCO mission as a result of a launch vehicle payload fairing anomaly resulted in a setback for the international carbon cycle science community. There have been and continue to be advances made leading to improved understanding of the global climate change process. However, the current set of ground-based, airborne, and spaceborne instrument and sensor measurements do not allow carbon sources and sinks to be quantified and examined over time. The OCO instrument is the only confirmed sensor that addresses not only science, but policy imperatives as well. A four month-long study to examine options for recovery of the critical scientific measurement resulted in a decision to rebuild the original OCO observatory to the extent possible. There are necessary changes to address parts obsolescence and the components or assemblies that are no longer in production, however, the majority of the design remains unaltered. The project team is confident in completing the tailored formulation phase activities and commitments in a timely and professional manner and successfully executing the implementation and operations phases. It should be noted that the study also included the examination of access to space options. However, in the end a competitive procurement process was followed for formal selected of the OSC Taurus XL 3110 launch vehicle. The return to flight effort for the Glory mission launch and the detailed evaluation of any changes and residuals risks will serve to increase confidence in using the Taurus XL 3110 for the OCO re-flight.

7. ACKNOWLEDGEMENTS

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