SPACE COOPERATION

Oceansat-2 Activities

Implementing Arrangement Between the
UNITED STATES OF AMERICA
and INDIA

Signed at Ahmedabad and Washington
March 20 and 26, 2012

NOTE BY THE DEPARTMENT OF STATE

Pursuant to Public Law 89—497, approved July 8, 1966 (80 Stat. 271; 1 U.S.C. 113)—

". . .the Treaties and Other International Acts Series issued under the authority of the Secretary of State shall be competent evidence . . . of the treaties, international agreements other than treaties, and proclamations by the President of such treaties and international agreements other than treaties, as the case may be, therein contained, in all the courts of law and equity and of maritime jurisdiction, and in all the tribunals and public offices of the United States, and of the several States, without any further proof or authentication thereof."

INDIA

Space Cooperation: Oceansat-2 Activities

Implementing Arrangement signed at
Ahmedabad and Washington
March 20 and 26, 2012;
Entered into force March 26, 2012.

IMPLEMENTING ARRANGEMENT

BETWEEN

THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

AND

THE INDIAN SPACE RESEARCH ORGANISATION

FOR

COLLABORATION ON OCEANSAT-2 ACTIVITIES

TABLE OF CONTENTS

PREAMBLE

The United States National Aeronautics and Space Administration (NASA) and the Indian Space Research Organisation (ISRO) (hereinafter jointly referred to as "the Parties");

Considering the desirability of enhanced cooperation between the Parties for the use of space for research in the Earth sciences and global change, with potential benefits to all nations;

Recalling the terms of the *Framework Agreement between NASA and ISRO for Cooperation in the Exploration and Use of Outer Space for Peaceful Purposes*, signed on February 1, 2008 (hereinafter referred to as the "Framework Agreement"); and

Recognizing that ISRO and the United States National Oceanic and Atmospheric Administration (NOAA) have similar interests in cooperation in utilizing Oceansat-2 data and will conclude a separate Implementing Arrangement under the *NOAA-ISRO Agreement for Cooperation in Earth Sciences and Earth Observation*;

Have reached the following arrangement:

ARTICLE 1
PURPOSE

The purpose of this Implementing Arrangement (hereinafter referred to as the "IA") is to set forth the respective responsibilities of the Parties for the terms and conditions under which they will cooperate on the Oceansat-2 mission. The focus of the IA is on cooperation involving instruments on-board Oceansat-2, specifically, the Ocean Color Monitor-2 (OCM-2) and the Ku-band pencil beam Scatterometer (OSCAT) for calibration/validation and data utilization.

ARTICLE 2
REFERENCE TO FRAMEWORK AGREEMENT

This IA, concluded pursuant to Article 4 of the Framework Agreement, incorporates by reference and is subject to the terms and conditions of the Framework Agreement. In the event of a conflict between the provisions of this IA and the Framework Agreement, the terms of the Framework Agreement will govern.

ARTICLE 3
DEFINITIONS

Level 0Data: Reconstructed unprocessed instrument data at full resolution; and any and all communications artifacts (*e.g.*, synchronization frames, communications headers) removed.

Level 1A Data: Level 0 data with all supplemental information appended for use in subsequent processing; basic data products.

- Level 1A data for OCM-2: Raw products
- Level 1A data for OSCAT: Scan mode data in engineering units

Level 1B Data: Level 0 data with radiometric and geometric correction applied to produce parameters in physical units.

- Level 1B data for OCM-2: Radiance product
- Level 1B data for OSCAT: Sigma-0 product at slice level in scan mode, with ancillary data sufficient for geolocation and independent calibration of the instrument

Level 2A and 2B Data: Derived environmental variables at a comparable temporal and spatial resolution to the Level 1 source.

- Level 2A/2B data for OCM-2: Chlorophyll-*a* concentration, Total Suspended Matter (TSM), Diffused Attenuation Coefficients, Aerosol Optical Depth (AOD) at 865 nanometers (nm)
- Level 2A data for OSCAT: Co-located (outer and inner beam) Sigma-0 product in swath grid (at 50 kilometer [km] spacing)
- Level 2B data for OSCAT: Wind product in swath grid with 50 km spacing

Level 3 Data: Data or retrieved environmental variables which have been spatially and/or temporally re-sampled. Such re-sampling may include averaging and/or compositing.

- Level 3 data for OCM-2: Weekly, monthly, and yearly binned products at 1 km
- Level 3 data for OSCAT: Global gridded wind products (0.5 degree resolution)

ARTICLE 4
BACKGROUND

ISRO successfully launched the Oceansat-2 satellite on September 23, 2009. Oceansat-2 carries a Ku-pencil beam Scatterometer (OSCAT) capable of measuring ocean surface vector winds (OSVW); the Ocean Color Monitor (OCM-2), which retrieves sea spectral reflectance; and the Agenzia Spaziale Italiana's Radio Occultation Sounder for Atmospheric studies (ROSA) instrument, which provides the vertical profile of the atmosphere. Oceansat-2 is ISRO's second in a series of satellites dedicated to ocean research. It provides continuity to the services and applications of the Oceansat-1 OCM data along with additional data from OSCAT. Oceansat-2 is a three-axis, body-stabilized spacecraft placed into a near circular Sun-synchronous orbit, at an altitude of 720 kilometers (km), with an equatorial crossing time of around 1200 hours.

ISRO and NASA share the common goal of optimizing the quality and maximizing the utility of the Oceansat-2 data for the benefit of future global and regional scientific and operational applications.

Discussions between India and the United States regarding collaboration on Oceansat-2 have been ongoing since early 2007. Discussions progressed and on November 18, 2009, ISRO, NOAA, and NASA signed a Letter of Intent (LOI) for the *Proposed Collaboration on Oceansat-2 Activities Among the Indian Space Research Organisation, Department of Space, Government of India and the National Oceanic and Atmospheric Administration, Department of Commerce,*

United States of America and the National Aeronautics and Space Administration, United States of America.

Under the LOI, NOAA, NASA, and ISRO have accomplished the following activities:

- NASA provided the following QuikSCAT data: (i) 57 revolutions of Level 1B and Level 2A data from July 1-4, 2005 with supporting user's manual; and (ii) Level 2A and Level 2B data from October 2009 to November 23, 2009, to ISRO to aid in validation of wind retrieval algorithms.

- NASA provided ISRO with documentation for a model function, based on experience with NASA Scatterometer (NSCAT) and Quick Scatterometer (QuikSCAT), which reflects those incidence angles used by OSCAT. The model function is required for converting the basic scatterometer backscatter measurements into useful science data products.

- ISRO provided NASA with an assessment of the capability of the algorithms developed by ISRO to retrieve winds from the QuikSCAT Level 2A data by comparing them with the corresponding Level 2B data that are publicly available.

- JPL submitted to the U.S. Department of State, a Technical Assistance Agreement (TAA) to allow the disclosure of technical information and data as identified within the scope of the two Framework Agreements and the IAs.

- ISRO provided NASA and NOAA with Level 2A (Sigma-0) and Level 2B (vector winds) OSCAT data for November 2009 in early 2010, and provided the remainder of the initial 6-month dataset (L1B, L2A, L2B) during July and August 2010.

- NASA and NOAA have subsequently provided preliminary calibration and validation feedback based on their analyses of the first 6-months of OSCAT data.

- ISRO has established joint calibration and validation (cal/val) and science teams for coordinating activities among Indian entities.

- ISRO, NOAA, and NASA have established a Joint Oceansat-2 OCM-2 and OSCAT Calibration and Validation Science Team (hereinafter referred to as the Joint Cal/Val Science Team [JST]). ISRO, NOAA, and NASA have agreed to the following Terms of Reference for the JST:

    - Define, implement, and evaluate data interfaces, particularly those required to provide timely access to OCM-2 and OSCAT data in support of U.S. field cal/val campaigns such as aircraft under-flights and operational requirements.

    - Develop, update, implement, and evaluate cal/val plans, schedules, deliverables, and milestones with the goal of optimizing the OCM-2 and OSCAT data products

for operational use as well as applications including general research and climate studies.

- Coordinate joint OCM-2 and OSCAT cal/val and science activities outside India for the duration of the Oceansat-2 mission. It will manage OCM-2 and OSCAT cal/val collaboration, as well as inter-sensor validation of global data products; operational use of data products; and the exchange of scientists.

- Have access to and use of all data pertaining to its activities and make available the scientific data for public access as soon as practicable.

- Have access to commissioning phase data soon after launch with continuing OSCAT *Sufficient for Independent Calibration of the Instrument* (SICI) data (including Level 1B data) available in a timely fashion. Timely access to selected data is needed: (i) as input for planning aircraft flight paths in field campaigns, and (ii) to facilitate evaluation of products by operational forecasters. The OSCAT SICI data includes parameters needed to solve the radar equation (*e.g.*, antenna pattern, power out, spacecraft attitude) and geolocation of the data.

- The initial meeting of a Joint Oceansat-2 OCM-2 and OSCAT Science Team was held March 10-12, 2010, at ISRO's Space Applications Centre (SAC) in Ahmedabad, India.

- A meeting of an interim calibration/validation group including JPL and ISRO scatterometer scientists was held September 13-15, 2010, at ISRO SAC in Ahmedabad, India.

- A meeting of the Oceansat-2 OSCAT Technical Team was held October 4-8, 2010, at ISRO SAC in Ahmedabad, India. This meeting:

  a. Discussed low-level OSCAT data processing issues and addressed aspects related to operationalization of OSCAT data; and
  b. Identified the data pathways for operational OSCAT data transfer including data interfaces, participating nodes, timing constraints, backup alternatives/plans, and the timetable for implementation and evaluation in preparation for the operational phase of OSCAT data release.

- NOAA has made available spectrally weighted MOBY data for OCM-2 on the NOAA CoastWatch/OceanWatch website.

- In order to make Level 1B, Level 2A, and Level 2B products available within 180 minutes from start of the data acquisition on the spacecraft, ISRO established in March 2011 necessary infrastructure for data reception, processing, and dissemination at the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) Headquarters in Darmstadt, Germany. NOAA and NASA will receive these products from EUMETSAT.

ARTICLE 5
ISRO RESPONSIBILITIES

ISRO will use reasonable efforts to carry out the following responsibilities:

1. General

a. Organize post-launch calibration/validation (cal/val) meetings for both the OCM-2 and OSCAT in India to share calibration and validation results.

b. Provide to NASA free access through portal/ftpofOCM-2 Global Area Coverage (GAC) and global OSCAT data, and authorization for NASA researchers to generate high-level, publicly available enhanced data products from Oceansat-2 data for use in research leading to open-literature publications and for operational purposes.

c. Provide all down-linked and archived OSCAT (at Levels 1A [where applicable for calibration], 1B, 2A, and 2B) and OCM-2 GAC data, received prior to date of signature of the IA, for research applications and continuation of climate data records. The historical OSCAT data will include the QuikSCAT overlap period (November 2009) and subsequent data to the beginning of operational data transfer.

2. Oceansat-2 Scatterometer (OSCAT)

a. Collaborate in the improvement of model function including extension to high winds and incidence angles and algorithms for wind vector retrieval within nadir zone, at nadir, and outer swath for the OSCAT; any publications, arising out of joint effort, describing the new development/improvement of this model function will involve researchers from both India and the United States.

b. Derive independent calibration and validation for the OSCAT instrument, document the results, and share with NASA.

c. Collaborate in the development of high-resolution algorithms to obtain wind products as near to the coast as possible.

d. Provide global OSCAT data at Level 1B, 2A, and 2B (and ancillary data and documentation required for calibration and processing), orbit-by-orbit, for operational use within 180 minutes of collection on the spacecraft for the duration of the mission.

e. Provide Level 1B data as soon as processed, without waiting for Level 2A or 2B data processing.

f. Provide OSCAT data as needed to develop an optimized calibration scheme for noise subtraction.

g. Notify NASA of any changes to the operational processing algorithm prior to the change taking effect. Provide NASA with at least one week of data processed with modified algorithm and allow for at least two weeks validation period before the change formally takes effect.

3. Ocean Color Monitor-2 (OCM-2)

a. Provide OCM-1 oceanographic field data archive collected in open ocean waters for inclusion in the algorithm development dataset (NASA bio-Optical Marine Algorithm Data set [NOMAD]).

b. Provide electronic access to Level 1B Global Area Coverage (GAC) calibrated observed radiances to all international users and make available to JST members documentation on lower level source data and the calibration/geolocation information required to generate Level 1B.

c. Provide pre-launch characterization and calibration documentation for OCM-2, as well as participate in protocol and round-robin experiments for calibration/validation activities and measurements.

d. Provide access to the Lakashdweep Sea/Kavaratti *in situ* buoy data for vicarious calibration and field validation of NASA sensors.

e. Collaborate in the development of geophysical retrieval algorithms for complex coastal (*e.g., Case 2*) waters.

f. Provide direct broadcast transmissions of full-resolution data from OCM-2 over U.S. coastal waters, as well as software to unencrpyt and process these data from Level 0 to Level 1 to Level 2 data and standard geophysical products, and provide all necessary information for NOAA and NASA to write codes to independently generate Level 0, Level 1, and Level 2 data from the files, *e.g.,* data of instrument calibration and characterization, navigation, solar-sensor geometry, raw and calibrated radiances, and appropriate documentation for the operational use of NOAA subject to satellite and mission constraints.

g. Provide suitable arrangements to support quick turnaround operational needs like real-time cruise planning.

h. Collaborate in assessing and enhancing quality and long-term stability of OCM-2 radiometry and derived ocean color products, including Level 3 sensor-to-sensor and Level 2 sensor-to-field data analyses, and application of on-board calibration *(e.g.,* lunar measurements).

i. Ensure that global OCM-2 GAC Level 1B, Level 2, and Level 3 data are available for research and near-real time GAC data for operational use.

ARTICLE 6
NASA RESPONSIBILITIES

NASA will use reasonable efforts to carry out the following responsibilities:

1. General

Share with ISRO any new OCM-2- or OSCAT-related algorithm developed for generating high-level enhanced data products from Oceansat-2 data, which are not addressed by the JST.

2. Oceansat-2 Scatterometer (OSCAT)

a. Collaborate in the improvement of model function including extension to high winds and incidence angles and algorithms for wind vector retrieval within nadir zone, at nadir, and outer swath for the OSCAT; any publications, arising out of joint effort, describing the new development/improvement of this model function will involve researchers from both India and the United States.

b. Derive independent calibration and validation for OSCAT, document the results, and share with ISRO.

c. Collaborate in the development of high-resolution algorithms to obtain wind products as near to the coast as possible.

d. Develop the capability to reprocess OSCAT data for the entire Oceansat-2 mission to generate climate data to extend and continue the QuikSCAT ocean vector winds data set, and make such data available to all international users.

e. Provide Level 1A QuikSCAT data as needed to develop an optimized calibration scheme for noise subtraction of OSCAT data.

3. Ocean Color Monitor-2 (OCM-2)

a. Provide access to data from *in situ* sources for use in the vicarious calibration and validation of OCM-2.

b. Collaborate in the development of geophysical retrieval algorithms for complex coastal (*e.g.*, *Case* 2) waters.

c. Make high resolution OCM-2 data available only to academic and cooperative research institutions and Federal, state, and local government institutions in the United States who are directly undertaking work for the benefit of the public good; such data will not be made available for commercial use.

d. Share experience in the use of lunar measurements to ensure the stability of satellite radiometer measurements required for support of climate change research.

e. Facilitate access to Sea-viewing Wide Field-of-view Sensor (SeaWiFS) and Moderate Resolution Imaging Spectro-radiometer (MODIS) data for cross calibration and sensor inter-calibration studies to assess the stability of the OCM-2 within the multi-mission time series.

f. Organize and conduct an OCM-focused SeaDAS training workshop in India, possibly in conjunction with a JST meeting.

g. Collaborate in assessing and enhancing quality and long-term stability of OCM-2 radiometry and derived ocean color products, including Level 3 sensor-to-sensor and Level 2 sensor-to-field data analyses, and application of on-board calibration *(e.g.,* lunar measurements).

h. Support lunar calibration analysis of OCM-2 by providing U.S. Geological Survey RObotic Lunar Observatory (ROLO) lunar model output for any OCM lunar measurements.

i. Share SeaDAS display and analysis support for the ISRO-defined Level 1B OCM-2 format and the SeaDAS-derived Level 2 and Level 3 OCM-2 products.

ARTICLE 7
POINTS OF CONTACT

Regarding the overall IA:

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For NASA, OSCAT and vector winds designated programmatic point of contact:

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ARTICLE 8
OWNERSHIP OF EQUIPMENT

Equipment provided by NASA pursuant to this IA will remain the property of NASA. Equipment provided by ISRO pursuant to this IA will remain the property of ISRO. Each Party agrees to return any of the other Party's equipment in its possession to the other Party at the conclusion of the project.

ARTICLE 9
AMENDMENT

This IA may be amended through mutual written agreement by the Parties.

ARTICLE 10
ENTRY INTO FORCE AND TERMINATION

This IA will enter into force on the date of the last signature appearing below and will remain in force for a period of five (5) years. Either Party may terminate this IA at any time by giving ninety (90) days written notice of such intention to the other Party. Termination of the Framework Agreement will not affect activities being carried out under this IA.

Done in two originals at .....(place), on the day ..... of March 2012, in the English language.

FOR THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Michael O'Brien
Associate Administrator
Office of International and Interagency Relations

March 26, 2012
Date

Washington, DC
Place

FOR THE INDIAN SPACE RESEARCH ORGANISATION

R.R. Navalgund
Director
Space Applications Centre

March 20, 2012
Date

Ahmedabad
Place

↑
"Ahmedabad (India)"