

Memorandum of Understanding
between
the Indian Space Research Organisation (ISRO)
and the Federal Space Agency (Roscosmos)
on expansion of cooperation in the field of the exploration and use of
outer space for peaceful purposes

The Indian Space Research Organisation (hereinafter referred to as ISRO), on the one part, and the Federal Space Agency authorized federal executive body of the Russian Federation (hereinafter referred to as Roscosmos), on the other part, hereinafter referred to as "the Parties"

TAKING INTO ACCOUNT the provisions of the Agreement between the Government of the Russian Federation and the Government of the Republic of India on Cooperation in the Exploration and Use of Outer Space for Peaceful Purposes on December 3, 2004,

DESIRING to prompt cooperation in the exploration of outer space and application of space equipments and technologies for peaceful purposes,

COMMEMORATING the 40th Anniversary of launching of India's Aryabhata satellite by USSR launch vehicle,

HAVE REACHED UNDERSTANDING AS FOLLOWS :

1. The purpose of this Memorandum is to broaden mutually beneficial cooperation between Parties in the field of the exploration and use of outer space for peaceful purposes.

2. The Parties aim at developing practical and dedicated joint activities in the following areas of mutual interest:

- (a) human spaceflight programme;
- (b) launch vehicle development and propulsion engineering ;
- (c) satellite navigation and associated technologies and services;

- (d) remote sensing of the Earth from space;
- (e) space science and planetary exploration;
- (f) ground space infrastructure and its use;
- (g) other areas of cooperation between the Parties may be identified upon their mutual agreement in writing.

3. The cooperation within the areas mentioned in paragraph 2 may be carried out by the Parties in the following forms:

- (a) planning and implementation of joint projects using scientific, experimental and industrial capabilities;
- (b) mutual sharing of scientific and technical information, experimental data, results of conceptualization work, materials and equipment in various areas of space science and technologies;
- (c) production and delivery of various equipments and components including the associated ground-based means;
- (d) organization of personnel education and training programmes, exchange of scientists, technical and other specialists;
- (e) holding seminars, conferences and other scientific and technical meetings;
- (f) participation in specialized exhibitions, fairs and other similar events.
- (g) other forms of cooperation between the Parties may be identified upon their mutual agreement in writing.

4. The list of specific project proposals under the above areas of mutual interest is attached as Annexure to this Memorandum.

5. For the implementation of the joint activities within the framework of this Memorandum the Parties shall conclude contracts and agreements in order to determine the objectives, principles and procedures including, as necessary, financial issues related to the

implementation of specific programs, aiming at the development of space cooperation, based upon the principle of mutual benefit.

6. Financing of the joint activities carried out for the execution of this Memorandum will be defined upon mutual arrangements between the Parties according to their respective national legislation.

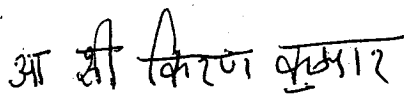
7. This Memorandum is concluded with a view to specifying priority areas of cooperation between the Parties and does not constitute an agreement binding upon the States of the Parties and/or their respective Governments under international law.

8. In order to bring out detailed cooperative proposals in the fields of mutual interest, coordinate national space projects, and involve industry and research entities of the Republic of India and the Russian Federation in the implementation of these projects the Parties have established the Joint Indian-Russian Working Group on space activities.

9. This Memorandum will come into effect to both Parties on the date of its signature for a period of five years. This Memorandum can be extended by means of mutual written notifications by the Parties. This Memorandum can be amended by the Parties upon their mutual agreement in writing. Either Party may terminate or suspend the application of this Memorandum at any time by forwarding a written notice to the other Party.

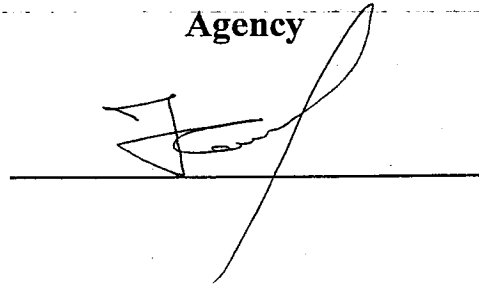
Done in Bangalore/ Moscow on May 25/ _____, 2015, in 2 (two) originals in English, Hindi and Russian languages. In case of any disparity in interpretation, the English text shall prevail.

**For the Indian Space Research
Organisation**



**A. S. Kiran Kumar
Chairman, ISRO**

**For the Federal Space
Agency**



Annexure

List of Specific Cooperation proposals

A. SATELLITE NAVIGATION

- A1 Establishment of Reference Stations in Russia and India to improve satellites orbit determination and clock estimation for Indian Regional Navigation Satellite System (IRNSS) and Russia's Global Navigation Satellite System (GLONASS) systems, respectively.
- A2 Joint research on space qualified frequency standards including physics package and electronics development.
- A3 Use of laser ranging stations in India and Russia to improve GLONASS and IRNSS satellites orbit determination, respectively.
- A4 Cooperation in the field of IRNSS and GLONASS system time scales differences monitoring and national time scales comparison to improve timing solutions accuracy.
- A5 Discussion on compatibility of IRNSS and GLONASS signals including the L1 Band.
- A6 Discussion on design of new IRNSS and GLONASS signals.
- A7 Joint research on interference detection and mitigation including jamming, and their impact on navigation signals.
- A8 Promotion of IRNSS and GLONASS use in the BRICS countries to improve accuracy based on PPP technologies.
- A9 Information exchange and specialists training in use of GLONASS/IRNSS technologies for various civil applications.
- A10 Cooperation on navigation applications.
- A11 Cooperation on time scales generation, international time determination and its modernization including issues of future continuous Coordinated Universal Time (UTC).

B. LAUNCH VEHICLE DEVELOPMENT

- B1 Development of specific technologies for advanced propulsion systems.
 - I Advanced Cryo Insulation Development.
 - II Development of Vortex cooled combustion chamber.
 - III Development of Pintle injector for Variable thrust engine.
- B2 Development of special materials, nanomaterials, advanced composites, Polymers, chemicals, nanotechnologies and manufacturing technologies.
- B3 Render assistance in sharing of wind tunnel test facilities, joint development of a complete software for aerodynamic and jet noise prediction and supply of ring/ annular strain gauge balance for jet simulation wind tunnel tests.
 - I Joint development of a complete software for aerodynamic and jet noise prediction.
 - II Supply of Ring/ annular strain gauge balance for jet simulation and wind tunnel tests.
- B4 Collaborative research in plasma arc and advanced propulsion systems in Indian and Russian research laboratories.

- I Facility support for performance testing of milli -Newton (N) level Arcjet thruster.
 - II Research Studies on Advanced Nozzles.
 - III Sharing of Plasma Wind Tunnel facilities for re-entry material characterization and R&D studies.
 - IV Design and development of hybrid and vortex hybrid combustors and thrusters.
 - V Instability studies of cryogenic and semi-cryogenic engines.
 - VI Development of Endothermic fuelled cooled Combustion Chambers.
 - VII Development of green propulsion system and related technologies like Hydrogen Peroxide (H_2O_2) /Ammonium-di-Nitramide (ADN) thruster, Development of high concentration H_2O_2 , ADN and a suitable catalyst.
- B5 Development of technologies for Liquid Oxygen (LOX)-kerosene engine, LOX-(Liquid Hydrogen (LH2) engines and LOX - Liquefied Natural Gas (LNG) engines.
- I Mixing of hot, oxidizer rich turbine drive gas with Liquid Oxygen at booster pump outlet and its condensation in the feedline to main oxidizer pump of a high thrust semicryo engine.
 - II Combustion stability analysis of Thrust chamber and preburner of high thrust Semicryo engine operating with LOX/Kerosene propellant combination.
 - III Supply and license production of low thrust LOX-LNG engine.
 - IV Development of ignition resistant coating for turbine of a high thrust semicryo engine.
- B6 Render assistance in collaboration with laboratories and industries for setting up of propellant production plants along with associated technologies and critical items.
- I Establishment of Di-Nitrogen-tetraoxide (N_2O_4) Production Plant with a capacity of 900 MT per annum.
 - II Establishment of Unsaturated Di Methyl Hydrazine (UDMH) Production Plant with a capacity of 225 MT per annum.
 - III Development of high performance solid propellants based on ADN for space applications.
 - IV Production of Mono propellant grade Hydrazine for use in thrusters of remote sensing satellites.
- B7 Development and also use of existing test facilities and simulation methods to test engines on ground and simulated high altitude environment.
- I Collaboration on Establishment of Combustion Laboratory facility.
- B8 Joint development of object-oriented software for modeling the working processes, including transients, in launch vehicle / satellite propulsion engines.
- I Modeling of Combustion in Liquid rocket Engine Combustion Chamber.
 - II Direct Simulation Monte Carlo modelling for Plume Impingement and Soil Erosion during Lunar Landing.
 - III Cryogenic Tank Process Modelling.
- B9 Development of electric propulsion system

C. CRITICAL TECHNOLOGIES FOR HUMAN SPACEFLIGHT

- C1 Development of appropriate radiation shielding solutions and compatible materials to protect astronauts.
- C2 Collaborative studies and development of technologies on micro particle impact mitigation.
- C3 Collaborative research and development of technologies for Personnel Hygiene Management including Waste Management System.
- C4 Configuration and design of test beds to validate crew module flights with the man-in-the loop real time simulation.
- C5 Development of rendezvous and docking mechanisms compatible with International Space Station (ISS) and ISRO's crew module.
- C6 Enabling collaborative research in Bioastronautics among academic and scientific institutes of India and Russia.
- C7 Development of life support system for India's crew module.
- C8 Joint experiments of mutual benefits in Russian orbital segment of ISS as part of developing techniques for future human spaceflights.
- C9 Reliability prediction, Risk assessment & criticality analysis for man-rated mission.

D. SPACE SCIENCE & PLANETARY EXPLORATION

- D1 Hosted payload opportunities in space science missions of both sides.
 - I Stratospheric and Space studies.
 - II High precision interplanetary navigation using X-ray pulsars: A technology demonstration experiment.
 - III Hard X-ray monitor using Fresnel Zone Plate (FZP).
 - IV Hard X-ray Spectro-Imager for Solar Flare Study.
 - V Infrared spectroscopy of Martian atmosphere.
- D2 Joint space science studies in the area of Atmospheric sciences, Astronomy & astrophysics and planetary science.
- D3 Sharing of ground facilities to support each other's space science and planetary exploration missions.
- D4 Procurement of specific components for future space science missions.
- D5 World Space Observatory (WSO) collaboration activities.

E. REMOTE SENSING

- E1 Hosted payload opportunities in Earth observation missions of both sides.
- E2 Joint development of advanced instruments for Earth observation missions.
 - I Joint development of Humidity Sounding Units at 183 GHz/360 GHz in LEO Orbit.
 - II Joint development of TeraHz (millimeter/ submillimeter wave) Passive & Active Sensors in Low Earth Orbit (LEO)/ Geosynchronous Equatorial Orbit (GEO) Orbits.
 - III Joint development of GNSS Receivers (IRNSS & GLONASS Signals) for Reflectometry on LEO satellites.
- E3 Sharing of data including direct reception from each other's Earth observation missions meant for Meteorology, Oceanography, Resource inventory and Cartography.

- I Sharing of data / direct reception from Earth observation missions of High Resolution, Hydro meteorological and Space Station.
- E4 Sharing of expertise in multi-mission data reception, processing and dissemination: Multi-mission Ground Segment for Earth Observation Satellites (IMGEOS) of India and Geographically Distributed Information System for Remote Sensing Data Receiving, Processing, Archiving and Dissemination (ETRIS-DZZ) of Russia.
 - I Acquisition and Processing of Russian satellites payload data viz. Resurs-P and KANOPUS-V at IMGEOS facility at Shadnagar.
- E5 Joint Studies in using Earth Observation data for Predicting Earthquakes.
- E6 Sharing of data and expertise in Cryosphere studies.
 - I Advanced energy and mass balance studies for understanding of cryospheric processes over polar and sub-polar regions.
- E7 Mutual use of Calibration and Validation sites to enhance the value of data products derived from each other's satellite missions.
 - I On-orbit Optical Sensor Calibration.
 - II SAR Sensor Calibration.
- E8 Training/ Capacity building in Data processing and analysis for hydro-meteorological and geological disaster related studies.

The Parties may add other areas of cooperation to the list by mutual agreement