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TITLE

Engineering service to support CIRA-IWT calibration for SLD conditions

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Engineering service to support CIRA-IWT calibration for SLD conditions

ABSTRACT:

This document defines the technical requirements for cloud physics support for preparatory activities related to the CIRA-IWT calibration under Freezing Drizzle (FZDZ) cloud conditions, currently planned for the period of May-July 2021. The preparatory activities include configuration of data analysis tools, testing of those tools, and instrumentation calibration support and data analysis. . Second, this activity will provide support for the CIRA tunnel cloud calibration activity, mainly to support data collection and analyse PSD data and bulk hot-wire LWC data.

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* *PT = PARTIAL*
A = ALL

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0 FOREWORD

CIRA is planning a calibration effort of the CIRA-IWT for FZDZ cloud conditions with potential extension to FZRA clouds. Development activities are ongoing to define an additional spray nozzle setup able to reproduce FZDZ clouds features, in agreement with CFR FAR Part 25 Appendix O requirements.

To this end, and in order to harmonize the calibration methodology between CIRA and NASA facilities, CIRA is funding the update of the OAP260X probe, the same Particle Size Distribution (PSD) probe technology used for NASA IRT calibration.. The aim is to upgrade the probe to novel faster electronic technologies, while maintaining the performance of the old probe configuration. This will also cover the gap poorly represented by legacy instruments used in CIRA-IWT, especially in the high-speed configuration.

The activities described herein are focused on the software algorithms to integrate with this updated OAP260X probe's electronic technology. The software must provide accurate data analysis, as per the most up-to-date community research standards, where correction algorithms to address the main SLD cloud particle measurement issues must be applied. Furthermore, the work must provide an analysis of upgraded and standard OAP260X probe calibration data, supplied by CIRA from a spinning glass disc calibration with dense coverage of the sample area with small steps in x and y directions.. Finally, an OAP260X validation test campaign will be performed in an icing wind tunnel for probe and software validation, but also to compare upgraded and standard technologies. At the end of these OAP260X software and calibration activities, the work will include support to the CIRA researchers in the calibration of CIRA-IWT for SLD cloud conditions, where LWC and PSD data set must be accurately collected by the team for calibration purpose. This support will include participation in the design and execution of the calibration effort, and in analysis of the OAP260X PSD data and the hot-wire LWC data. Efforts must include an effort to estimate uncertainty of MVD and LWC, to support the accurate definition of CIRA-IWT FZDZ cloud envelope

0.1 SCOPE

This document defines the technical requirements for cloud physics support for preparatory activities related to the CIRA-IWT calibration under Freezing Drizzle (FZDZ) cloud conditions, currently planned for the period of July-October 2021. The preparatory activities include configuration of data analysis tools, testing of those tools, and instrumentation calibration support and data analysis. . Second, this activity will provide support for the CIRA tunnel cloud calibration activity, mainly to support data collection and analyse PSD data and bulk hot-wire LWC data.

0.2 APPLICABILITY

This technical specification is for the purchase of the cloud physics services to support preparatory activities of the CIRA-IWT calibration in SLD cloud conditions . These activities will include configuring and testing software provided by a third party for data analysis from the upgraded OAP260X probe technology, analysis of calibration data collected with the upgraded and standard OAP260X probes, and support and data analysis for the CIRA-IWT calibration in SLD cloud conditions. The subject of this document is covered by job number 9907690000 “Spray Bar System Upgrade to SLD-FZDZ”..

0.3 SYMBOLS AND ABBREVIATIONS

ADA	Airborne Droplet Analyser
CIRA-IWT	Centro Italiano Ricerca Aerospaziali - Icing Wind Tunnel Laboratory
FAR	Federal Aviation Regulation
FZDZ-In	Freezing drizzle with MVD < 40 um, no drops > 500 um
FZDZ-Out	Freezing drizzle with MVD > 40 um, no drops > 500 um
IB	Icing Blade
ICD	Ice Crystal Detector
IG	Icing Grid
LWC	Liquid Water Content, g m-3
MTS	CIRA-IWT Main Test Section configuration
MVD	Medium Volumetric Diameter, um
NCAR	National Center of Atmospheric Research
PMS	Particle Measuring Systems
PSD	Particle Size Distribution
SAT	Static Air Temperature
SBS	Spray Bar System
SLD	Supercooled Large Droplet
SODA	Simple Ocean Data Assimilation
T_d	Droplet temperature

0.4 REFERENCES

1 L. Vecchione, P. de Matteis, and G. Leone “An Overview of the CIRA Icing Wind Tunnel”- 41st Aerospace Sciences Meeting and Exhibit, Reno, NV, AIAAA, AIAA 2003-900

2 14 CFR Parts 25 and 33, “Airplane and Engine Certification Requirements in Supercooled Large Drop, Mixed Phase, and Ice Crystal Icing Conditions”. Federal Aviation Administration, Department of Transportation. Vol. 79, No. 213, November 4, 2014.

3 B. Esposito et. ali “ICE-GENESIS (Deliverable D3.1) - Definition of the target requirements for test facilities operating envelopes for App O: improvements and remaining gaps”,CIRA-DTS-19-0690, May 23rd, 2019

4 Optical Array Cloud Droplet Spectrometer Probe PMI Model OAP-260X – Operating and Servicing Manual.Particle Metrics, Inc. P/N 10096-12

1 GENERAL DESCRIPTION OF CIRA IWT FACILITY

The CIRA Icing Wind Tunnel (IWT) is one of the largest refrigerated tunnel in the world, with the following additional main features [1]:

- De-pressurisation / pressurisation system able to achieve low static pressure (0.39 bar abs – altitude simulation up to 7000 m) and high static pressure (1.45 bar abs – to achieve higher Reynolds number during the aerodynamic tests) in the test sections;
- Aerodynamic tunnel layout for both bi-phase fluid simulation and better flow-quality performance for aerodynamic tests;

- Four test section configurations;
- Humidity control system;
- Engine flow simulation for engine inlet tests;

In order to change the test sections static pressure, a large plenum around the test leg is present in the IWT layout.

In the following figure 1 the main characteristics of IWT with main test section configuration are listed:

CIRA-IWT Main Test Section (MTS)		
Height	(m)	2,35
Width	(m)	2,25
Length	(m)	7
Max speed	(ms-1)	135
Max Model Blockage		30
Min Temperature	(°C)	-32
LWC meas. Range	(gm-3)	0,1 - 4
MVD range	(µm)	10 - 300
Altitude	(m)	0 - 7000

Figure 1: CIRA IWT MTS characteristics, and cloud conditions to be used for testing instrumentation.

1.1 ENVIRONMENTAL CONDITION

The limiting conditions in the plenum are:

Static Pressure range	: from 0.39 to 1.45 bar (abs)
Static Temperature range	: from –40°C to +40°C
Humidity range	: 100% from –40°C to 0°C

The above environmental condition changes in function of the IWT configuration and spray conditions.

1.2 SPRAY BAR SYSTEM

The IWT Spray Bar System (SBS) (figure 1) is designed to generate water droplets with diameters (MVD) and liquid water content (LWC) covering mostly of the envelope prescribed by the FAR 25 and FAR 29 Appendix C (figure 2) for both continuous and intermittent cloud conditions. The SBS has 20 bars having a low drag aerodynamic shaped section whose main feature is a low sensitivity to flow separation. Each bar is equipped with 50 spraying nozzle positions for a maximum total of 1000 possible spraying positions over 20 bars. To optimise the losses, the system is equipped with 500 active spraying nozzles only. The remaining 500 nozzle positions are plugged or can be used for different spray nozzle set-up. The number of operating nozzles may be changed during a run using the Facility Management System Software. The SBS is fed by:

- pressurised demineralised water with electrical resistance R > 2 Mega Ohm x cm; the temperature Tw can be controlled up to nominal 80 °C at the entrance of the bar and the water pressure can be set between 0.2 < Pw < 10 bar (abs). The maximum flow rate is about 2 Kg/sec.
- Dry compressed hot air at temperature Ta up to nominal 150 °C, dew point – 40 °C; the air pressure can be set between 0.2 < Pa < 11.5 bar (abs). The maximum flow rate is about 2.3 Kg/sec.

Each nozzle water supply line is equipped with a solenoid valve that can be remotely shut off and on. All parts of the Spray Bar System in contact with pressurised air and demineralised water (e.g. pipes, boxes, and SBS airfoil) are made of stainless steel. A local control of individual spray bars is done by the "Control Box", mounted inside of the instrumentation box of each spray bar, which main task are to control air and water pressure, the spray nozzle activation, etc. A closed loop control system managed by FMS can maintain constant values for air and water pressure at the IWT Spray Bar within 5%. As a consequence, stability and reproducibility of both MVD and LWC values can be assured.

Figure 2: CIRA-IWT Spray bar view from the test section.

2 TECHNICAL REQUIREMENT FOR NEXT SBS IMPROVEMENT AT SLD CONDITIONS

The test program is focused on the assessment of the SLD cloud characteristics generated by SBS upgraded with CIRA-IWT in the Main Test Section (MTS) configuration to fulfil the requirements defined in . reference [2]. Table 2.1 summarises the SLD requirement to achieve in the MTS of CIRA-IWT in agreement to what has been defined in this reference.

Subset	MVD	Maximum Drop Size in Distribution
App. C (ZC)	Less than 40 µm	Less than 100 µm
FZDZ/**L** (ZL)	**L**ess than 40 µm	100 µm to 500 µm
FZDZ/**G** (ZL)	**G**reater than 40 µm	100 µm to 500 µm

Table 2.1: Average spectra for each subset used as a representative icing conditions

More detailed requirements specifically for the icing wind tunnels performances' target to achieve for SLD conditions are finding in the reference [3].

3 OAP260X DESCRIPTION AND SOFTWARE ALGORITHM

This probe, originally designed by Particle Measuring Systems Inc.(PMS) [4], is being upgraded by CIRA to obtain the dual-mode operation. The objective is to generate two probe data output streams (1) the standard PMS 1D spectra characterized by an optical magnification at 15 µm of size resolution, and (2) monochromatic 2D images of particles (64 diodes at 15 µm size resolution) generated by adding or modifying optics and electronic components. The 2D imagery will allow for a separate estimation of the PSD, where a more rigorous treatment of false images and sizing corrections can be applied. The upgraded probe will also have a much higher frequency response, circumventing some of the problems associated with the standard technology, but also requiring a more sophisticated image analysis to obtain accurate PSDs.

CIRA will adopt a sophisticated analysis package for the computation of PSDs from 2D imagery that has been developed by the National Center of Atmospheric Research (NCAR), and is in use by many research agencies worldwide. The software package is called SODA *(Simple Ocean Data Assimilation)*, and is in the public domain. SODA supports most of the PSD imaging probes in common use in the community. It implements the most up-to-date image correction algorithms such as elimination of shattered, and particle breakups, and correction for out-of-focus oversizing. SODA implements three different definitions of effective sample volume (particle all-in, center-in, and extended area). NCAR has also developed an optical model using probe performance characteristics and Fresnel diffraction to assist in the interpretation of probe imagery under different conditions. The SODA lead scientist is an organizer of international workshops to compare products from different similar 2D image processing algorithms used throughout the cloud physics community. He has agreed as part of his NCAR-sponsored continuing support for SODA, to assist in the implementation of SODA for the new upgraded OAP260X.

4 WORK PLAN

The work plan will include some joint activities between CIRA and the Contractor, technical contents of which are defined in the following sections.

4.1 WP1 - IMPLEMENT THE SODA SOFTWARE FOR THE UPGRADED OAP260X, AND PROVIDE SODA PSD RESULTS FOR OAP206X TESTING AND CALIBRATION

Task 1.1: Implement SODA for the CIRA upgraded OAP260X

Objective: Provide a working 2D analysis algorithm, using the NCAR SODA software package configured for the CIRA upgraded OAP260X (alias 1D2DX), to produce PSDs optimized for the tunnel SLD spectra. Define the requirements for improvement of SODA software to the updated version of OAP260X (1D + 2D output streams) to limit main measurement issues (e.g. droplet's coincidence, out-of-focus, droplet shattering, droplet fragmentation reconstruction,…) for wind tunnel SLD environment characterization.

Approach: (1) The Contractor will work with the SODA lead scientist, and the company performing the OAP260X upgrade, to coordinate the adaptation of SODA for the upgraded OAP260X under the M300 data format for the upgraded probe. Interact with the SODA lead scientist to ensure that SODA features are functional. Demonstrate with a sample dataset.

Milestone: 31-Dec-2020

Deliverable: PowerPoint demonstration of SODA working with the upgraded OAP260X 2D data format for a sample data set supplied by the OAP260X upgrade supplier. Demonstrate that major capabilities (coincidence handling, out-of-focus size adjustment, shattering rejection) are functional. Provide 1D OAP260X data stream PSD examples, with comparison to SODA PSD.

Notes: This work is dependent on the OAP260X upgrade supplier providing sample data sets to NCAR, and NCAR adapting SODA for the new data format. The Contractor will analyse the sample dataset and provide analyses of the OAP260X SODA-derived PSDs, and comparison to the standard 1D OAP260X data stream.

Task 1.2: Provide analysis of OAP260X spinning disk calibration data to characterize sizing accuracy on standard and upgraded probe.

Objective: Characterize the size calibration and depth of field of the OAP260X, for both the standard and upgraded data streams for comparison. Determine the efficacy of the SODA out-of-focus sizing correction by applying to spinning disk data.

Approach: (1) The Contractor will be provided 1D and 2D data streams of a spinning disk calibration, to be performed by a third party. It is assumed that this dataset will consist of approximately 20 discrete locations along the depth of field, each taken at 3 locations across the diode array, and for 3 different spinning disk spot sizes (total of 180 spectra). Data should be sampled for 20 seconds at each location, and notes must be providing identifying the start time of each spectrum.

(2) The Contractor will analyse the 1D data stream, providing standard PSDs at each of the locations within the sample volume, along with average diameters at each location. The Contractor will also provide an overall mean PSD and its mean diameter assuming equal weight to each position. This will represent the composite PSD and diameter. The effective depth of field will be defined by the limits of the distance of the data collection. This analysis will be performed for each spinning disk diameter.

(3) The Contractor will analyse the 2D data stream using SODA. PSDs will be computed for all the cases as in (2), also providing the mean PSD and its mean diameter. The Contractor will analyse the 2D data with the out-of-focus size correction and without it, for comparison.

(4) The Contractor will provide comparisons of the results of the standard 1D and SODA-derived 2D data streams, and assemble all results into a PowerPoint presentation.

Milestone: Delivery of OAP260X 1D and 2D processed results. 28-Feb-2021

Deliverable: PowerPoint presentation with summary of results, including figures of all ~180 spectra for each probe, final composite PSD and mean diameter for the standard 1D and upgraded 2D datasets, the latter with and without out-of-focus oversizing correction. PowerPoint will include figures of effective DOF.

Notes: This work is dependent on CIRA providing the spinning disk dataset, and that approximately 180 test points are to be analysed.

<u>Task 1.3:</u> Perform the analysis and comparison of the hot-wire sensors' responses for the same reference conditions provided by the NRC-AIWT facility. The Contractor must process and analyses the datasets collected by following LWC hot-wire probes: SEA Multi-Ext S/N 2069; SEA Multi-Ext S/N 2086; SEA Robust Probe S/N 3010; SEA ICD S/N 4005; Nevzorov probe with single cup (std 8 mm).

Objective: Assess the performance of <u>five</u> hot-wire techniques and data analysis, comparing different instrumentation technologies and available analysed datasets during an icing wind tunnel test campaign.

Approach: (1) For each test point, playback the data with M300 and calculate average LWCs over the spray interval (nominally 2 minutes), using EXCEL or a contractor-written program.

(2) Summarize results in a PowerPoint presentation, including final average LWC for each test point.

Milestone: (a) 1 month after the data sets and accompanying run notes are available to the Contractor, final dataset analyses in PowerPoint form.

Deliverable. PowerPoint presentation with summarized results as detailed in (2) above.

Notes: It is assumed that the dataset will consist of a maximum of 25 test matrix points, repeated at most once each. CIRA will provide to the Contractor detailed notes specifying the start and end time of each run, with identification of the test point. If the dataset is such that it is impossible to analyse, the Contractor will notify CIRA, and the Contractor will be paid for hours expended to that point.

Task 1.4: Provide support for collection of an OAP260X dataset at the NRC AIWT (or alternatively the NASA IRT). Analyze the OAP260X and compare to facility reference measurements.

Objective: Assess the performance of both the OAP260X and SODA data analysis, comparing different instrumentation technologies and available analysed datasets during an icing wind tunnel test campaign.

Approach: (1) Provide support to CIRA for the design of the wind tunnel experiment test matrix, and general planning. Participate and provide advice in telecoms and email exchanges between CIRA and the host wind tunnel staff.

(2) Participate on-site for the collection of the OAP260X dataset. Take detailed notes, monitor the data stream, and notify the OAP260X upgrade company representative of any data problems.

(3) For each test point, calculate average PSDs over the spray interval (nominally 2 minutes), for both the 1D data stream, using EXCEL or a contractor-written program, and the 2D data stream, using SODA.

(4) Obtain the latest PSD calibrations from the host facility.

(5) Summarize results in a PowerPoint presentation, including final average PSD spectra (1D versus 2D from SODA versus host) for each test point. Compare two versions of 2D PSDs from SODA, with and without out-of-focus oversizing correction. For each of the PSD option summarized above and each test point, include in a table the 10th, 50th, and 90th percentile volume diameter and LWC.

Milestone: (a) Up to the start of testing, preparatory assistance via telecoms and emails (b) 3 months after the data sets and accompanying run notes are available to the Contractor, final dataset analyses in PowerPoint form.

Deliverable. Pre-testing advice and consultation, on-site participation in wind tunnel testing, run notes if applicable, and PowerPoint presentation with summarized results as detailed in (5) above.

Notes: It is assumed that the wind tunnel testing will be performed over 3 days, either at the IRT or the AIWT. It is further assumed that the dataset will consist of a maximum of 15 test matrix points, repeated at most once each. If the Contractor is not permitted to the host facility due to COVID, detailed notes specifying the start and end time of each run must be provided to the Contractor, with identification of the test point. If the dataset is such that it is impossible to analyse, the Contractor will notify CIRA, and the Contractor will be paid for hours expended to that point. The quote is valid for a single dataset analysis.

4.2 WP2 - Support the Execution of CIRA-IWT Calibration Under Appendix O Cloud Conditions

Task 2.1: Wind Tunnel Calibration Definition

Objective: Collaborate with CIRA in the definition of the test plan integrating the instrumentation requirements with the equipment available for cloud calibration (M300, 2D traversing, spray bar procedures,…) and define the tunnel calibration matrix in agreement to the measurements procedures to use for each calibration phase.

Approach: (1) The Contractor will consult with CIRA to establish an overview of the scope of the objectives of the wind tunnel calibration (MVD range, LWC range, airspeed range, temperature, LWC and MVD spatial mapping etc.). This will be accomplished by email exchanges and telecoms, and will include continual updates and changes. The Contractor will provide one day per month in such consultation over the 12-month period leading up to the calibrations.

(2) The calibration plan will be assembled by CIRA as a draft document, which the Contractor will review, make suggestions, and add material, within the limit of one day per month of consultation.

Milestones: (a) Email and telecom consultation each 3 month for the 12 month period leading up to the calibrations, related to the IWT calibration test plan.

Deliverables: Consultation, review, and modifications to the CIRA-developed IWT calibration test plan, up to a maximum of 12 days of Contractor time

Task 2.2: Test capability calibration in FZDZ conditions with potential extension to FZRA

Objective: Support the measuring activities during the CIRA-IWT calibration for both bulk LWC multi-wire devices and PSD characterization with OAP260X.

Approach: (1) travel to CIRA, and participate onsite during 3 weeks of SLD calibrations at the CIRA IWT. Attend each calibration, assisting in calibration as required, taking detailed notes required for post-calibration data analysis, and providing advice as the calibration evolves.

(2) During the calibration, periodically perform rudimentary inspection of OAP260X and hot-wire datasets to ensure fidelity and adequacy for post-campaign analysis.

Milestones: Completion of on-site participation in CIRA IWT calibrations (estimated 31-Oct-2021 completion).

Deliverables: (a) On-site participation in CIRA IWT calibration, (b) a set of detailed IWT run notes delivered to CIRA after the completion of the calibration.

Notes: Contractor participation is subject to travel advisories and restrictions, for example due to COVID-19. Labour estimates are based on 3 weeks of 5-days of work per week, plus 2 days of travel to and from Italy.

Task 2.3: Wind Tunnel Calibration Data Reduction and Analysis

Objective: Support CIRA in the analysis of the wind tunnel calibration data, processing bulk LWC hot-wire data and OAP260X PSD data.

Approach: (1) For estimation, it is assumed that the CIRA calibration will produce approximately 75 LWC points, and 75 PSD points for analysis, including repeats.

(2) The Contractor will analyse wind tunnel LWC calibration data from two of the following three possible hot-wire probes: SEA MultiWire (MW), SEA Ice Crystal Detector (ICD), and/or SEA Robust Probe (RP).

(3) The Contractor will analyse wind tunnel PSD calibration data from the two data streams of the OAP260X data, the regular 1D data stream, and the upgraded 2D images data stream, the latter using the NCAR SODA 2D processing algorithm. Average LWC spectra for each test point, table of 10%, 50%, 90% Volume diameter and LWC for each PSD test point (for both standard OAP260X and SODA-derived 2D PSDs), and the two OAP260X data streams will be produced. CIRA will provide provision of the csv or xls files for the other probes to the Contractor to combine them into single PSD data files for the same test matrix point.

(4) For the center-point LWC calibration, the contractor will calculate LWCs from raw hot-wire voltages, currents, and tunnel auxiliary parameters. CIRA will provide estimated LWC efficiencies for each hot wire for the particular MVD and airspeed of

the test point. The LWCs will be averaged over a stable period to be determined for each test point, nominally 2 minutes to be compatible with other tunnels. Time histories, a table of average LWC, and comparative plots for two hot-wires will be produced including each test point.

(5) For the tunnel LWC mapping, the contractor will provide either average LWCs at discrete mapping locations, or continuous profiles curves, depending on the approach to be used.

(6) Results will be provided in a detailed PowerPoint. An optional formal report is outlined in (7)

(7) Prepare an optional formal report detailing the collection of the OAP260X and hot-wire data sets, and the results.

Deliverables: PowerPoint presentation all products listed in (3-5) above. A formal report can be produced as an option.

Milestones: PowerPoint 2 months after data are provided to the Contractor. If a formal report is required, 2.5 months after data are provided to the Contractor.

4.3 WP3 - Assess and Validate the SLD-FZDZ Cloud Envelope in CIRA-IWT Through International Instrumentation Comparison Experiment

<u>Task 3.1:</u> Definition of wind tunnel conditions and test plan for facility inter-comparison experiment

Objective: Assist in the planning and organization of the CIRA SLD Instrumentation Inter-Comparison Experiment, and development of a draft test plan.

Approach: (1) During the 12-month period before the CIRA SLD Instrumentation Inter-Comparison Experiment, the Contractor will participate in weekly 1.5 hour telecoms with CIRA. The purpose of the telecoms is for the Contractor to provide planning advice for the experiment as it evolves to the test date.

(2) The Contractor will contact the NASA IRT and NRC AIWT and acquire the most up-to-data calibration matrix used by each facility.

(3) Based on Facility Intercomparison testing results from 2017 and 2018, and the CIRA calibration results resulting from Task 2.3 above, the Contractor will provide a <u>draft test matrix</u> of common points for all SLD Instrumentation Intercomparison at CIRA in 2021/2022. The matrix will select the most important intercomparison points that will result in the most meaningful comparison to the other facilities, given that only an subset of CIRA calibration points can be used due to time limitations for the intercomparison.

(4) The Contractor will discuss with the CIRA Principal Investigator (PI) the practical limitations of instrument changes, number of test points per day, number of simultaneous instruments to be tested, the requirements for instrument checkout, and the available test time, and will provide a <u>draft day-by-day schedule</u> for the instrument testing. This is expected to be an iterative process with the CIRA PI, due to the multiple affecting issues.

Deliverables: (a) Weekly telecom consultation for the planning and organization of the CIRA SLD Instrumentation Intercomparison, (b) draft points for test matrix of experiment, and (c) draft day-to-day schedule for instrument testing during experiment.

Milestones: (a) Periodic telecoms over a 12-month period, (b) 3 months after CIRA IWT calibration effort, deliver draft test point matrix for SLD Instrumentation Inter-Comparison Experiment. (c) Six months prior to SLD Instrumentation Inter-Comparison Experiment, provide draft day-by-day schedule. Both should be short concise reports.

5 TIME SCHEDULE

The activities shall be conducted taking into account the available icing wind tunnel time slots (NASA-IRT or NRC-AIWT, and CIRA-IWT) that may change on the base of other priority that can be found after the program's launch. The time schedule for the project is reported on Appendix A.

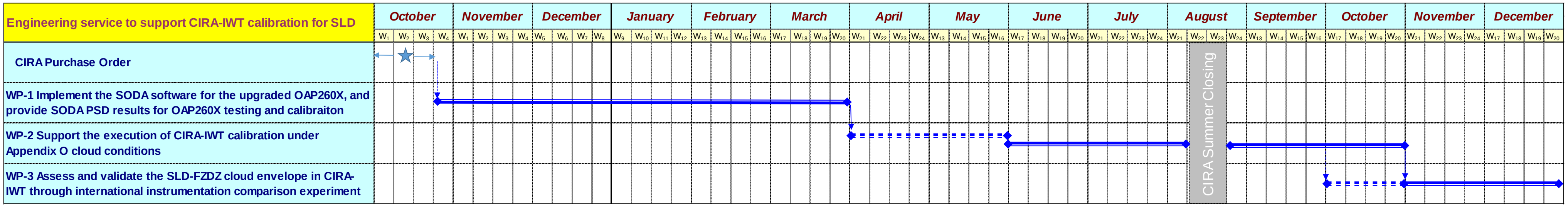
6 DELIVERY SCHEDULE

This project foresees the following milestones related to each the work-package:

- MWP 1.1 Implement SODA for the CIRA upgraded OAP260X – Due date: 3 months after CIRA delivery of first test dataset.
- MWP 1.2 Provide analysis of OAP260X spinning disk calibration data to characterize sizing accuracy on standard and upgraded probe. – Due date: 3 months after CIRA delivery of dataset.
- MWP 1.3.1 Support the analysis of hot wire datasets (AIWT#1) at the NRC tunnel.- Due date: 1 month after CIRA delivery of hot-wire datasets and supporting NRC dataset.
- MWP 1.3.2 Support for collection and analysis of OAP260X dataset (AIWT#2 or alternatively the NASA IRT) at the NRC tunnel.- Due date: 2 months after CIRA delivery of hot-wire dataset and supporting NRC dataset.
- MWP 2.1 Wind Tunnel Calibration Definition.- Due date: On delivery of wind tunnel draft plan and schedule, no later than two months before CIRA calibration start.
- MWP 2.2 On-site support for CIRA wind tunnel calibrations.- Due date: Detailed notes per run required for post-calibration data analysis at the end of CIRA wind tunnel calibration.
- MWP 2.3 CIRA Calibration Data Reduction and Analysis.- Due date: 2 months after CIRA delivery of datasets.
- MWP 3.1 Provide weekly telephone support for planning CIRA SLD Instrumentation campaign effort.- Due date: One year after contract star.
- MWP 3.2 Provide draft test matrix.- Due date: One month after CIRA calibration.
- MWP 3.3 Provide day-by-day instrument test plan.- Due date: 6 months before CIRA SLD Instrumentation testing campaign

Appendix A

Time Schedule


Engineering service to support CIRA-IWT calibration for SLD
October
November
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January
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March
April
May
June
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August
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October
November
December
CIRA Purchase Order
WP-1 Implement the SODA software for the upgraded OAP260X, and provide SODA PSD results for OAP260X testing and calibraiton
WP-2 Support the execution of CIRA-IWT calibration under Appendix O cloud conditions
WP-3 Assess and validate the SLD-FZDZ cloud envelope in CIRA-IWT through international instrumentation comparison experiment
CIRA Summer Closing