RTCA SC-230 Plenary #19 Meeting Minutes (November 12-14, 2019)

Attendance list:

<table>
<thead>
<tr>
<th>November 12th - WG10</th>
<th>November 13th - WG11</th>
<th>November 14th - WG11/10</th>
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<tbody>
<tr>
<td>Name</td>
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<tr>
<td>Karan Hofmann</td>
<td>RTCA</td>
<td>Karan Hofmann</td>
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<tr>
<td>Lee Nguyen</td>
<td>FAA</td>
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<td>Thibault Lefez</td>
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<td>Jean-Baptiste Berthier</td>
<td>Airbus</td>
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<td>Kenny Ren</td>
<td>Boeing</td>
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<td>Dawn Gidner</td>
<td>Honeywell</td>
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<td>Jan Lukáš</td>
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<td>Jeff Finley</td>
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<td>Venkata Sishtla</td>
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<td>William Blake</td>
<td>Garmin</td>
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<td>Steven Harrah</td>
<td>NASA</td>
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<td>Fred Proctor</td>
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<td>Patricia Hunt</td>
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<td>Justin Strickland</td>
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<td>Ivan Clark</td>
<td>NASA</td>
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<td>Bob Avjian</td>
<td>MITRE</td>
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<td>Rockee Zhang</td>
<td>OU</td>
<td>Shumpei Kameyama</td>
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<td>Greg McFarquhar</td>
<td>OU</td>
<td>Shiki Nakagawa</td>
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<td>Jiaxi Hu</td>
<td>OU/NSSL</td>
<td>Rockee Zhang</td>
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<td>Greg McFarquhar</td>
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November 12th, 2019 (11:00-14:00 EDT)

Administrative and agenda review:

[Announcement] WG-10 Co-chair change: Jean-Baptiste will take over from Thibault


Introductions/Agenda/Minutes Approval - Minutes were approved without comment.

Review WG-10 Schedule and Deliverables –
Presented by Jeff within the agenda presentation which will be posted on the RTCA workspace. Detailed WG-10 Agenda presented by Thibault:
Refer to Jeff’s schedule’s slides

**WG-10 Agenda 11/12/2019**

- OU presentations:
  - NWC overview and Past HAIC flight campaigns
  - Polarimetric radar estimation of HIWC
- HAIC requirements document:
  - Introduction of the requirements into DO220B – Dawn
  - Comments & Actions review – ALL
    - Operational needs capture status – ALL
    - Thresholds –ALL
- Roadmap to build the V&V demonstration:
  - NASA status
  - NASA nuisance fault performances
  - Algorithm exposure & cross check with NASA observation

**DR McFarquhar presents OU overview and HIWC in-situ measurement overview**
Refer to slides uploaded to SC-230 Workspace
Steve: NASA 2018 flight campaign. 80% certainty at high IWC, some difficult at low IWC. Good at cold temperature, some difficulties around 0 degrees (SWERLing technique).

HIWC has more negative relationship to particle size MMD (MediumMassDiameter)

**DR Ryzhkov presents Polarimetric radar estimation of HIWC**
Refer to slides uploaded to SC-230 Workspace

Polarimetric techniques provide elegant solution to Ice Water detection

**Polarimetric radar variables**

- **Differential reflectivity** $Z_{\text{D}}$ – a difference between the powers of radar return at horizontal and vertical polarizations
- **Differential phase** $\Phi_{\text{D}}$ – a difference between the phases at orthogonal polarizations
- **Specific differential phase** $\Phi_{\text{D}}$ – a radial derivative of $\Phi_{\text{D}}$

In ice / snow, $Z$ is proportional to the 4th moment of the particle size distribution whereas $\Phi_{\text{D}}$ is proportional to its 1st moment. Therefore, $\Phi_{\text{D}}$ is much more sensitive to small ice particles than $Z$

The estimate of $\Phi_{\text{D}}$ is very robust because it is immune to radar miscalibration, attenuation, partial beam blockage, and deposition of rain / ice on the antenna
Estimation of IWC using \( K_{DP} \) and \( Z_{DR} \)


\[
IWC = 2.9 \times 10^{-2} \frac{K_{DP}}{\lambda} \quad (1)
\]

\[
IWC = 4.0 \times 10^{-3} \frac{K_{DP}}{1 - Z_{DR}^{-1}} \quad (2)
\]

\([\text{IWC}] = \text{g/m}^3, \ [K_{DP}] = \text{deg/km}, \ [\lambda] = \text{mm}\)

- \( Z_{DR} \) (dB) = 10 log \( Z_{DR} \)

**S band (\( \lambda = 11.0 \text{ cm} \))**

\[
IWC = 3.22 K_{DP}
\]

\[
IWC = 0.44 \frac{K_{DP}}{1 - Z_{DR}^{-1}}
\]

**X band (\( \lambda = 3.2 \text{ cm} \))**

\[
IWC = 0.93 K_{DP}
\]

\[
IWC = 0.13 \frac{K_{DP}}{1 - Z_{DR}^{-1}}
\]

- Relation (1) is more robust with respect to the measurement errors but is prone to the uncertainty in shapes and orientations of the ice particles.
- Relation (2) is immune to the variability of shapes and orientations but is prone to the measurement errors of \( Z_{DR} \).

---

Quasi-vertical profiles of polarimetric variables measured by the KMHX WSR-88D radar (Morehead, NC) during hurricane Irene on 27 August 2011

Low values of \( Z \) (< 20 dBZ) combined with high values of \( K_{DP} \) above the melting layer indicate high concentration of small crystals.
IWC estimated by the polarimetric algorithm is an order of magnitude higher than the one obtained with the IWC(Z) relation and is in much better agreement with in situ measurements in tropical cyclones.

K_{DP} is a robust parameter for IWC measurement, easily attainable through the use of polarimetric techniques.

**DO220B review:**

[Action group] to add other papers to reference materials section

Group walked through the HAIC incorporation structure into DO220B

2.2.6.10, Ven commented his concern about putting turbulence and red reflectivity at the same priority

**Comments & Actions review**

Comment sheet row 25/26 regarding distance/time attribute and peak vs distance/time:

Will Blake asked about the storm characteristics regarding IWC size:

Typically, the surveyed storms have 2-5km for high concentration IWC radius, over 60NM for moderate IWC radius.

Range/thresholds:

Range:
Range will be defined as a parameter in the performance index calculation, though range will not be specified in MOPS, it will be defined by Aircraft OEM.

Threshold:

FAA agrees flexible thresholds can be allowed.

Radar performance:

Jeff proposes using performance index for HIWC.

Update: Steve is currently working on a paper that could be used as the V&V section appendix to address radar performance index (assuming SWERling technique is to be used)

[Action Jeff and select members (Ven, Steve, Rockee, Jan)] write performance index appendix, it will feed into a mutually agreed V&V approach. Then this info will be used to construct section 2.2.6.2 Ice Water Content (IWC) Concentration Thresholds

Jan presents Honeywell HIWC must detect/must not detect potential issues

[Action Steve/Jan] Generate probability density, group to assess if appendix is needed, to support Jan’s analytical approach.

[Action Jan] upload presentation material to workspace
November 13, 2019 (17:00-20:00 EDT)

Administrative and agenda review:

**Introductions/Agenda** - RTCA Opening remarks on Anti-Trust Laws, IP Policy, and Membership Policy provided by Karan Hofmann. Jeff led introductions.

Review **WG-11 Schedule and Deliverables** - Shared by Jeff and captured in the agenda to be posted on the RTCA workspace.

**Schedule:**

**Day 2: WG-11 Lidar Proposed Agenda:**
- Progress Since Last Plenary
  - Summary of SNR Calculation
  - Investigation on LiDAR Measured Spectrum Width
  - CAT Probability of Detection Derivation
- Feasibility report comments review
- Action items from June plenary
- Next WG Meeting time

**Status:**

**Action item and schedule review:**
Upcoming WG11 milestone: March/April 2020 FRAC, PMC May 2020

**Direct Detection study (Patrick)**

[Action] Request slides upload

Lee commented on expanding Lidar’s capability in feasibility report (HAIC/Volcanic ash, etc)

Due to global climate change, CAT events are expected to increase (4-5 times increase)

**Direct detection technique (SC-230 WG-11 requirements focused):**
Direct-Detection lidar sensitivity study
CAT remote measurement + Turbulent gust load alleviation (GLA) on close-range

- Procedure to size needed instrumentation based on requirements
  - Metric for instrumentation: Power-to-Aperture-Product P.A.P.
  - from req. to P.A.P

- today: start from SNR

Direct-Detection lidar sensitivity study
CAT remote measurement + Turbulent gust load alleviation (GLA) on close-range

- SNR determination (both cases)

- From lidar equation → number of photons → \( SNR_{ss} = \sqrt{\frac{\rho_{det} \eta_{det} \cdot c \cdot B \cdot n_{los}(h) \cdot T_{atm}(R)}{4 \cdot \Phi \cdot B \cdot R^2}} \cdot \frac{N_{meas}}{PRF \cdot f_{refresh}} \)

  - Synthetic SNR for averaged pulses: \( SNR_{av} = SNR_{ss} \cdot \sqrt{N_{meas}} \)
  - Introducing range gate length for det. system bandwidth: \( B = \frac{c}{4 \cdot \Delta \delta} \)
  - Finally including: P.A.P. = \( E_p \cdot PRF \cdot A_{Rx} \)

- \( SNR_{av} = \left( \frac{\rho_{det} \eta_{det}}{c} \right)^{1/2} \cdot \left( \frac{\rho_{los}(h) \cdot T_{atm}(R) \cdot c}{R} \right)^{1/2} \cdot \left( \frac{P.A.P. \cdot \Delta R}{\tau_{refresh}} \right) \)

- Now: need to know required \( SNR_{av} \) from requirements

constant for given (typical) lidar performance values
atmospheric contribution, is constant for a given altitude \( h \) and distance \( R \)
system design variables to meet requirements
Direct-Detection lidar sensitivity study
CAT remote measurement + Turbulent gust load alleviation (GLA) on close-range

- From SNR to instrumentation (with further requirements), to P.A.P.:
  - setting $\Delta R = 50m$ and $r_{\text{refresh}} = 0.275Hz$ (40s fullrefresh, 11 directions)

![Graph showing Power-Aperture-Product at 12NM (with $AP = 2 \times 10^{-1} \text{ Wm}^2$)]

Clear-Air-Turbulence of the MOG-class (moderate or greater) may be detected with reasonable laser* powers (<10W) and telescope sizes of ≈10 - 15cm diameter and state-of-the-art detection equipment for all altitudes up to 12km.

Ex.: $P.A.P. = 0.08 \text{ Wm}^2 = \pi/40 \text{ Wm}^2$  
$\Delta 10W & 10cm$

**Review Section 5.3 compliance matrix.**

*[Action Jeff/Steve] convert EDR (Eddie Dissipation Rate) to G load (spectral width):*

**Note:** consider limitation on differences of pulse volumes between Lidar/Radar. With big Radar volume, Gaussian particle distribution can be assumed, may not be the case for Lidar.

*[Action Group/Ven/Lidar Manufacturers] Add a section in the end of the feasibility report (perhaps in the conclusions sections around compliance matrix) to study **trade off in discussion form:**

- Thresholds (Moderate vs Severe)
- Range
- Angular display (very difficult in terms of aircraft integration)
- Refresh rate
- Power (PAP)
- Optical size (PAP)
- Equation that ties the important trade-offs together
How does different Lidar technologies (coherent vs direct measurement) trade off on the refresh rate vs threshold of detection?
(List in order)

DELICAT current weight: ~80kg (laser + electronics + mirror + cooling). System weight/power can be optimized if intended for production installation use.

[Action LiDAR mfrs] in the conclusion/trade off section. Provide Trade of different Lidar architectures for GLA (scanning single beam vs multi-beam/receiver).

FAA comment: GLA system should have a hazard category of Hazardous or Major.

**Mitsubishi presents updates:**
Patrick’s atmospheric back scattering scatter plot
Agenda review:
[Action Ven/Shumpei] Hold more frequent working group meeting to resolve any issues with the feasibility report.

Feasibility report review:
[Action Patrick/Ivan] Need to further investigate on the feasibility of CAT detection in low-altitude terrain induced phenomenon (mountain rotors)

Must clearly define CAT in the last sentence of background section 1. (Include Thunderstorm induced and Mountain Rotors as part of CAT)
November 14, 2019 (17:00-20:00 EDT)

WG11-LIDAR overflow topics:

[Action Ven] Update definition of CAT:
1. First state official definition of CAT
2. State LiDAR feasibility of detecting the different types of CAT events (storm induced + terrain induced)
3. Then state the scope of this document:
   a. Will investigate following phenomenon:
      i. Near cloud Turbulence (subset of CIT (convectively induced turbulence) storm induced
      ii. terrain induced (mountain waves)
      iii. Terrain induced (mountain rotors)
   b. Ivan discovered the history to why the separate categories were created

Section 4.2.1:
[Action OEM] provide discussion on performance trade-offs between using single (Vz) and using full (Vx,Vy,Vz) vectors:
[info from Patrick] Using full vector will increase hardware complexity and slow refresh rate (by ~ factor of 2)

[Action: Ivan /Patrick] exchange reference documents to provide correct historical reference to section 1.4.2 projects and campaigns in United States.

[Action Reviewers] Get the review in ASAP, by end of November/first week of December.

[Action Ven] Hold WG-11 working session in December (Wednesday December 11th 4pm-6pm Central), Dawn will get the commented copy by 12/19
**WG10 Overflow topic-HIWC V&V presented by Steve:**

Specific to SWERLing technique:

Compared to real flight test campaign data, TASS generated HIWC models are consistent with the measured. The variability term is modeled by applying a uniform variability across all TASS cells in ADWRDS.

TASS is also capable of generating ice crystals of different shape and sizes, need to work with Rockee and OU team to translate those to polemetric (in ADWRS).

**Action** Steve Harrah] to provide a description of ADWRS change for Swerling modulation by end of January.

**Action** Steve] requested that SC-230 team members examine their flight test data in order to validate Swerling technique.
**Next meetings:**

Jan 21-23 (Virtual), dates tentative:

Lidar Feasibility report review

[Action group] review and confirm April 7-April 9 (FRAC resolution, RTCA HQ onsite), by 11/20

Prioritize WG-11.

[Action Karan] send out tentative date email to group to solicit
## Action item summary

<table>
<thead>
<tr>
<th>Action Item #</th>
<th>Action</th>
<th>Person(s)</th>
<th>Estimated Completion Date</th>
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<tbody>
<tr>
<td>Day 1 WG-10 – HAIC: See WG-10 Meeting Minutes and Comments sheet</td>
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<td>Day 3 WG-11:</td>
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<tr>
<td>1</td>
<td>Update definition of CAT (reference notes in November 14, 2019 meeting minutes)</td>
<td>Ven</td>
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<td>Feasibility study document reviewers</td>
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**Day 3 WG-10:**

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<tr>
<td>1</td>
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<td>3</td>
<td>Review and confirm April 7-April 9 (FRAC resolution, RTCA HQ onsite), by 11/20. Prioritize WG-11.</td>
<td>group</td>
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**September 2019 items**

See WG-11 Meeting Minutes and Comments sheet

**Open items from June 2019**

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<tr>
<th>No.</th>
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<tr>
<td>3</td>
<td>Open Find past work performed on coupled flight controls analysis by Boeing as a part of NASA contract [action], Ivan to scan and send the NASA contract/report</td>
<td>Kenny</td>
<td>next WG Meeting</td>
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CERTIFIED as a true and accurate summary of the meeting.

Kenny Ren, SC-230 Secretary

Jeff Finley, SC-230 Co-chair

Dawn Gidner, SC-230 Co-chair