*International Civil Aviation Organization*

**Seventh Meeting of the Surveillance Implementation Coordination Group (SURICG/7)**

Video Teleconference, 24 – 27 May 2022

**Agenda Item 8:** Update on surveillance activities and explore potential cooperation opportunities

a) States/Administrations

# INTRODUCTION TO THE TEST OF THE WAM TECHNOLOGY IN THE FINAL APPROACH MONITORING

(Presented by China)

**SUMMARY**

This paper introduces the construction of the WAM test system in the final approach of the airport, and carries out the data accuracy analysis of the WAM system.

## 1. INTRODUCTION

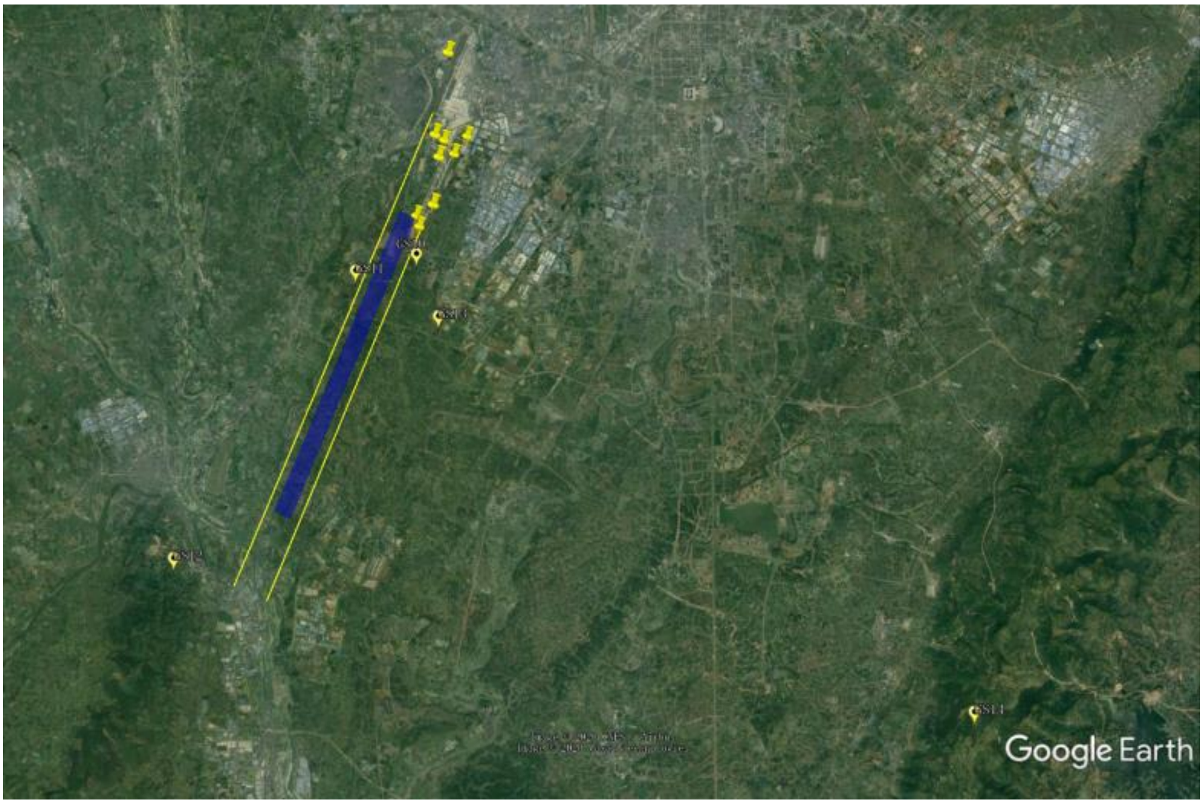
1.1 From 2020 to 2021, the ATMB of CAAC has carried out research and verification of the Wide Area Mutilateration (WAM) technology in the final approach monitoring.

1.2 The working group completed the construction of the WAM test system with the minimum cost, using WAM for final approach monitoring at Chengdu Shuangliu Airport, and evaluated the position accuracy of the WAM data.

## 2. THE PROGRESS OF THE TEST

2.1 The scale of the minimum test system is determined by site selection on the map, field exploration, coverage analysis and GDOP analysis. Since the Mode S interrogator near the airport has good coverage, the test system is passive multilateration system (without transmitting station). The system directly uses the MODE S downlink response triggered by the MODE S interrogator to perform the positioning solution.

2.2 The WAM test system deploys 5 receiving stations (RXU) around the runways' extended centerline, use 9 RXU of the airport MLAT as its supplement, deploy central processor to collated for the purposes to measure target position through TDOA calculation, and assembling target reports for output from the WAM test system.

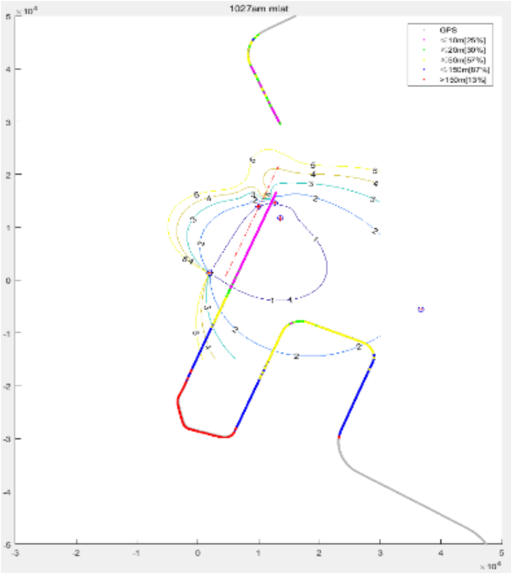


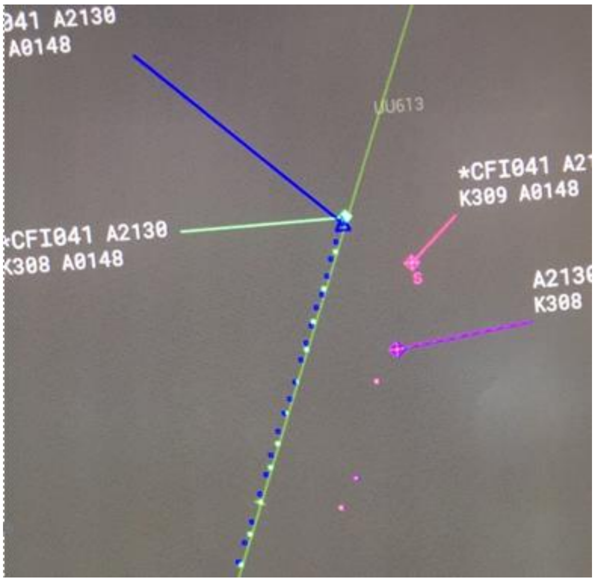

2.3 According to the WAM general technical specifications of the CAAC (MH/T 4037), the working group compiled the test document and flight check program, and completed the system test and flight check: the information processing and data output format, data transmission protocol, target report update rate, horizontal positioning accuracy, probability of position detection and probability of code detection of the WAM test system are verified. In addition, the WAM data processing capabilities of the ATM Automation System and Integrated Tower system are verified, including target accuracy, emergency code, data item processing, etc.

## 3. DATA ANALYSIS

3.1 The working group compared the Mode S radar data, ADS-B ground station data, WAM test system data, with the RTK(Real Time Kinematic) data of the fight check aircraft (Reference source for true aircraft position of known quality) respectively , and analyze the positioning accuracy of different surveillance sources.

3.2 Horizontal position accuracy analysis result: compared with the RTK data, the position accuracy of WAM is about 6-7 meters, the position accuracy of ADS-B is about 20 meters, and the position accuracy of Mode S radar is about 200 meters. The test proved the WAM has high horizontal position accuracy in detecting aircraft position, the potential for high accuracy and high update rate provided by WAM is ideally suited to Precision Runway Monitoring (PRM) applications, and could provide controllers with more accurate situation prediction.






3.3 Detection performance analysis: Probability of position detection (PD), the target detection probability is 99.8%. Probability of false detection(PFD), the detection target is a false target, or the output target deviates from the real position by more than 2100m at a 10km control interval, or the probability of the detected position deviates from the real position by more than 1690m at a 6km control interval is less than $10^{-3}$.

## 4. SUGGESTION

4.1 The site of ground station is recommended to be placed in a location with good visibility on both sides of the runway extended centerline to ensure the effective coverage of the system. During the site selection stage, the shielding and radio interference of buildings near the proposed site should be fully analyzed to avoid the influence of signal reception caused by environmental factors.

4.2 The selection of WAM site is flexible and has low requirements for the electromagnetic environment, but it is necessary to consider the balance of the layout of each site in the system network. The site selection and construction need to comprehensively consider factors such as GDOP, operation and maintenance costs, and implementation difficulty.

## 5. ACTION BY THE MEETING

5.1 The meeting is invited to:

a) note the information contained in this paper; and

b) discuss any relevant matter as appropriate

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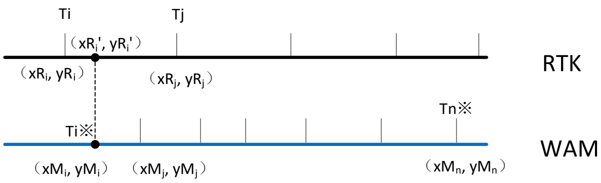
**Appendix**

1. **Horizontal position accuracy:** the quantitative bound of certainty in the calculated position for a target as related to the true position of that target and is expressed as a Root Mean Square (RMS) of an absolute distance error. (ED-142 TECHNICAL SPECIFICATION FOR WIDE AREA MULTILATERATION (WAM) SYSTEMS, 6.4.5)




1) Variable definition.
   xM_i= x Cartesian coordinate of the MLAT position (east-west)
   yM_i= y Cartesian coordinate of MLAT position (north-south)
   xR_i = x Cartesian coordinate of GPS position
   yR_i = y Cartesian coordinate of GPS position
2) Calculate the error between the X axis and the Y axis for each data point, and then calculate the horizontal deviation distance.

$$eX_i = xM_i - xR_i, \quad eY_i = yM_i - yR_i, \quad dr_i = \sqrt{eX_i^2 + eY_i^2}$$

3) Calculate the RMS for all targets.

$$RMS = \sqrt{\frac{\sum_{i=1}^{N} dr_i^2}{N}}$$

Where $dr_i$ = absolute error in the horizontal plane, N = number of track points

2. **Probability of position detection** : the probability of generating a Target Report during the defined Update Interval where the Target Report has derived the target position from at least one Valid Position Detection occurring within the Update Interval. (ED-142, 6.4.1)

Record the system output data for at least 8 hours through the message analysis software, and calculate the system location detection probability.
The step for calculating the position detection probability.
1) Calculate the expected number of update intervals. tc = total test time the test aircraft flew in the coverage area, UI = update interval, E = number of desired update intervals

$$E = \frac{(t_c)}{UI}$$

2) Calculate the position detection probability.

$$PD = \left(\frac{D}{E}\right) \times 100$$

D = the number of update intervals reported in the defined coverage area with at least 1 target in the period. The above calculation method comes from "ED-142" 6.4.1.

**3. Probability of false detection:** the ratio of the total number of *False Target Reports* to the number of all *Target Reports* output by the WAM system (ED-142,6.4.2) :

The step for calculating the probability of false detection.
1) Define the variable.
   xM_i = x Cartesian coordinate of the MLAT position (east-west)
   yM_i = y Cartesian coordinate of the MLAT position (north-south)

xR_i = x Cartesian coordinate of GPS position
yR_i = y Cartesian coordinate of GPS position

2) Calculate the error between the X axis and the Y axis for each data point, and then calculate the horizontal deviation distance.

$$eX_i = xM_i - xR_i$$
$$eY_i = yM_i - yR_i$$
$$dr_i = \sqrt{eX_i^2 + eY_i^2}$$

3) Count the number of false targets.
4) Calculate the false detection probability.

$$PFD = \frac{\overset{N}{\underset{i=1}{COUNT}}[dr_i > de]}{N} \times 100$$

de = false target definition, 3NM interval is 1690 meters, 5NM interval is 2100 meters
dr = absolute deviation from the horizontal plane (meters)
N = total number of target reports

4. **Probability of code detection**: the probability of outputting at least one correct and validated code (Mode A, Mode C) within an Update Interval in which a Target Report has been output.(ED-142, 6.4.3)

1) Calculate the MODE S address detection probability.

$$PCD\_S = \left( \frac{\sum_{i=1}^{N} N\_MS\_CORRECT_i}{\sum_{i=1}^{N} N\_UI_i} \right) \times 100$$

N_MS_CORRECTi = number of update intervals where target trajectory i contains at least 1 correct ICAO 24-bit aircraft address,
N_UIi = number of update intervals where target trajectory i contains at least 1 MODE S target report,
N = total number of trajectory segments.

2) Calculate the Mode A code detection probability.

$$PCD\_A = \left( \frac{\sum_{i=1}^{N} N\_MA\_CORRECT_i}{\sum_{i=1}^{N} N\_UI_i} \right) \times 100$$

N_MA_CORRECTi = number of update intervals where target trajectory i contains at least 1 correct and valid MODE A code,
N_UIi = number of update intervals where target trajectory i contains at least 1 MODE S target report,
N = total number of trajectory segments.

3) Calculate the Mode C code detection probability.

$$PCD\_C = \left( \frac{\sum_{i=1}^{N} N\_MC\_CORRECT_i}{\sum_{i=1}^{N} N\_UI_i} \right) \times 100$$

N_MC_CORRECTi = the number of update intervals for which the target trajectory i contains at least 1 correct and valid MODE C code,
N_UIi = the number of update intervals for which the target trajectory i contains at least 1 mode S target report, and
N = the total number of trajectory segments.

**5. Probability of false code detection:** the ratio of the number of Target Reports containing an incorrect but validated code to the total number of Target Reports which contain a validated code (Mode A, pressure altitude). (ED-142,6.4.4)

1) Calculate the MODE S address error detection probability.

$$PFCD\_S = \left( \frac{\sum_{i=1}^{N} N\_MS\_DIS_i}{\sum_{i=1}^{N} \left( N\_ALL_i - N\_MS\_NONE_i \right)} \right) \times 100$$

N_MS_DISi = number of tracks for target track i with correct ICAO 24-bit aircraft address,
N_ALLi = number of all tracks for target track i,
N_MS_NONEi = number of tracks for target track i without MODE S address,
N = total number of track segments quantity.

2) Calculate the ACID error detection probability.
N_MS_DISi = number of tracks for target track i with correct ACID,
N_ALLi = number of all tracks for target track i,
N_MS_NONEi = number of tracks for target track i without ACID,
N = total number of track segments.

$$PFCD\_D = \left( \frac{\sum_{i=1}^{N} N\_MD\_DIS_i}{\sum_{i=1}^{N} \left( N\_ALL_i - N\_MD\_NONE_i \right)} \right) \times 100$$

3) Calculate the MODE A code error detection probability.

$$PFCD\_A = \left( \frac{\sum_{i=1}^{N} N\_MA\_DIS_i}{\sum_{i=1}^{N} \left( N\_MA\_ALL_i - N\_MA\_NONE_i \right)} \right) \times 100$$

N_MS_DISi = number of tracks for target trajectory i with correct valid MODE A codes,
N_ALLi = number of all tracks for target trajectory i,
N_MS_NONEi = number of tracks for target trajectory i without MODE A codes,
N = total number of track segments .

4) Calculate the MODE C code error detection probability.

$$PFCD\_C = \left( \frac{\sum_{i=1}^{N} N\_MC\_DIS_i}{\sum_{i=1}^{N} \left( N\_MC\_ALL_i - N\_MC\_NONE_i \right)} \right) \times 100$$

N_MS_DISi = number of tracks for target trajectory i with correct valid MODE C codes,
N_ALLi = number of all tracks for target trajectory i,
N_MS_NONEi = number of tracks for target trajectory i without MODE C codes,
N = total number of track segments.