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New Generation Runway Visual Range (RVR) Final Operational Test and Evaluation Report: Volume I

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16. Abstract This report summarizes Operational Test and Evaluation (OT&E) activities for the New Generation Runway Visual Range (RVR) system. Testing consisted of an initial OT&E, seven individual retests and several specialized tests. DOT/FAA/CT-TN92/37 provides results of the initial OT&E conducted in March 1992. This document summarizes results of seven retests as well as specialized tests conducted from August 1992 through June 1994. The purpose and intent of OT&E was to verify RVR National Airspace Requirements (NAS) and to verify the operational effectiveness and suitability of the RVR within the NAS environment. At the completion of the retest and specialized test efforts results indicated that the most significant sensor and system problems had been resolved via permanent design changes as well as interim "work-arounds." It was recommended that the RVR system be deployed nationally under the following conditions: a. Additional data be obtained indicating RVR performance during Category IIIb visibility; and b. Problems currently having interim work-around solutions be resolved with permanent corrections. This volume contains a summary of the retest and specialized tests performed during the aforementioned period.					
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EXECUTIVE SUMMARY

This document will summarize the Operational Test and Evaluation (OT&E) activities for the New Generation Runway Visual Range (RVR) from April 1992 to June 1994. Testing outlined herein consisted of seven individual retests of the RVR system conducted in an operational setting, as well as several specialized tests conducted in nonoperational settings. The retests and specialized tests followed initial OT&E conducted in February and March of 1992. The RVR system was plagued by significant discrepancies in system performance during initial OT&E and during much of the retest effort. Despite numerous software and hardware modifications, resolution of the major problems affecting the system were not resolved to the satisfaction of ACW-200 until early 1994.

The New Generation RVR system is a terminal navigation aid designed for use with precision runways in support of takeoff and landing operations during Category I, II, IIIa/b visibility conditions. The functions of the RVR include determination of the atmospheric scattering coefficient, the ambient luminance, and the runway light intensity. This information is processed to yield distances that a pilot can expect to see along the departure or approach path of a runway. The New Generation RVR equipment will decrease maintenance load and installation difficulties associated with current RVR system designs. Future expansion capabilities will be easier and less costly.

The purpose of the OT&E testing was to verify the RVR National Airspace System (NAS) requirements as identified in the NAS System Specification (NAS-SS-1000). The testing was also intended to verify the operational effectiveness and suitability of the RVR within the NAS environment.

While retests allowed evaluations of the RVR in an operational environment (as required by FAA-ORDER-1810.4B), specialized testing permitted evaluations of RVR sensors under real and simulated weather conditions such as blowing precipitation and heavy fog. The specialized tests were instrumental in developing and evaluating software and hardware modifications aimed at correcting the more difficult performance problems.

Results of the final retest conducted in June 1994, as well as results from specialized tests, indicate the most significant sensor and system problems have been resolved. This was accomplished by permanent design changes as well as implementation of interim "work-arounds." As a result, ACW-200B recommended national deployment of the RVR system with the conditions that additional Category IIIb performance data be acquired and that problems currently having interim work-around solutions be resolved in full.

1. INTRODUCTION.

This report will summarize the Operational Test and Evaluation (OT&E) activities for the New Generation Runway Visual Range (RVR) system from February 1992 to June 1994. Testing described herein was conducted over a 26-month period following the conclusion of initial OT&E. Initial OT&E took place from February to March of 1992, and the results are detailed in FAA Technical Report, DOT/FAA/CT-TN92/37.

During the period covered by this report, the RVR underwent seven separate retests as well as specialized tests designed to evaluate sensor performance. A discussion of the results, problems, and issues is provided for each test in subsequent sections of this report. This report was developed in accordance with FAA-STD-024B and FAA-ORDER-1810.4B.

1.1 PURPOSE OF REPORT.

The purpose of this report is to provide results of New Generation RVR OT&E from the period following initial OT&E testing to the issuance of a national deployment recommendation. The report also provides recommendations for future testing and data collection.

1.2 SCOPE OF REPORT.

This report will provide a summary of results from retest and specialized testing performed on the RVR following initial OT&E. Results of initial OT&E will not be discussed in detail; however, significant findings from initial OT&E that relate to retest objectives are discussed. In addition to individual test results, this report will discuss system changes which evolved as a result of problems identified during testing. Actual test procedures will not be discussed in detail. Rather, an overview of each test session will be provided along with significant findings and conclusions.

1.3 BACKGROUND.

The New Generation RVR has undergone extensive OT&E. The primary test site for the RVR was the Kansas City International Airport (MCI). However, because of problems identified during initial OT&E and during accuracy evaluations of the Visibility Sensor (VS), additional specialized testing was required at other locations such as the Cold Regions Research and Engineering Laboratory (CRREL) in Hanover, NH, and Mount Washington Observatory, Mt. Washington, NH. The nature of the specialized testing is discussed in subsequent sections.

1.3.1 Initial OT&E.

Initial OT&E Operational, Integration, and Shakedown testing of the RVR system took place in February and March of 1992 at MCI. Significant deficiencies were identified in the RVR system and with supporting documentation. A summary of these deficiencies is provided in paragraph 4.1.1.1. As a result of the system deficiencies, ACW-200B recommended against deployment at the conclusion of testing.

1.3.2 Visibility Sensor Evaluation.

As noted in DOT/FAA/CT-TN92/37, an evaluation of the RVR VS was conducted to determine sensor accuracy. The evaluation was conducted by personnel from the Volpe National Transportation System Center (VNTSC) using data from several test sites. A draft report, DOT-TSC-FAA-92-xx, was issued in September 1992. This report was reviewed by ACW-200B and AOS-220. Significant findings of the report included problems encountered with sensor calibration, accuracy, and system response to precipitation. The findings are discussed in the following subparagraphs. In addition, as noted by AOS-220, no significant data existed for system response in actual Category IIIb visibility conditions (visibility less than 700 feet).

1.3.2.1 Calibration.

Numerous problems involving sensor calibration were noted during the testing conducted by VNTSC. Problems included disparities between New Generation RVR sensors and airport transmissometers, inconsistencies in unit calibrations, and apparent variations in manufacturing tolerances. In addition, it was observed that the sensor calibration for snow differed from that of fog by approximately 30 percent. This result meant that system accuracy would be affected if calibration was not automatically adjusted for snow versus fog events.

1.3.2.2 Precipitation Effects.

"Window Signals" originating from the RVR's window contamination detection circuitry were found to be adversely affected by precipitation hitting the lens or "window" (figure 1) of the VS. These signals are actually voltage levels which are proportional to the amount of contamination detected on the sensor lens. Window contamination includes any substance such as snow, water, dirt, etc., that might strike or collect on the sensor window. Effects of precipitation striking the sensor window ranged from errors in extinction coefficients to sensor shutdowns. Because of shutdowns, it was necessary to disable the software modules involved in contamination correction. This effectively eliminated a major functionality of the system.

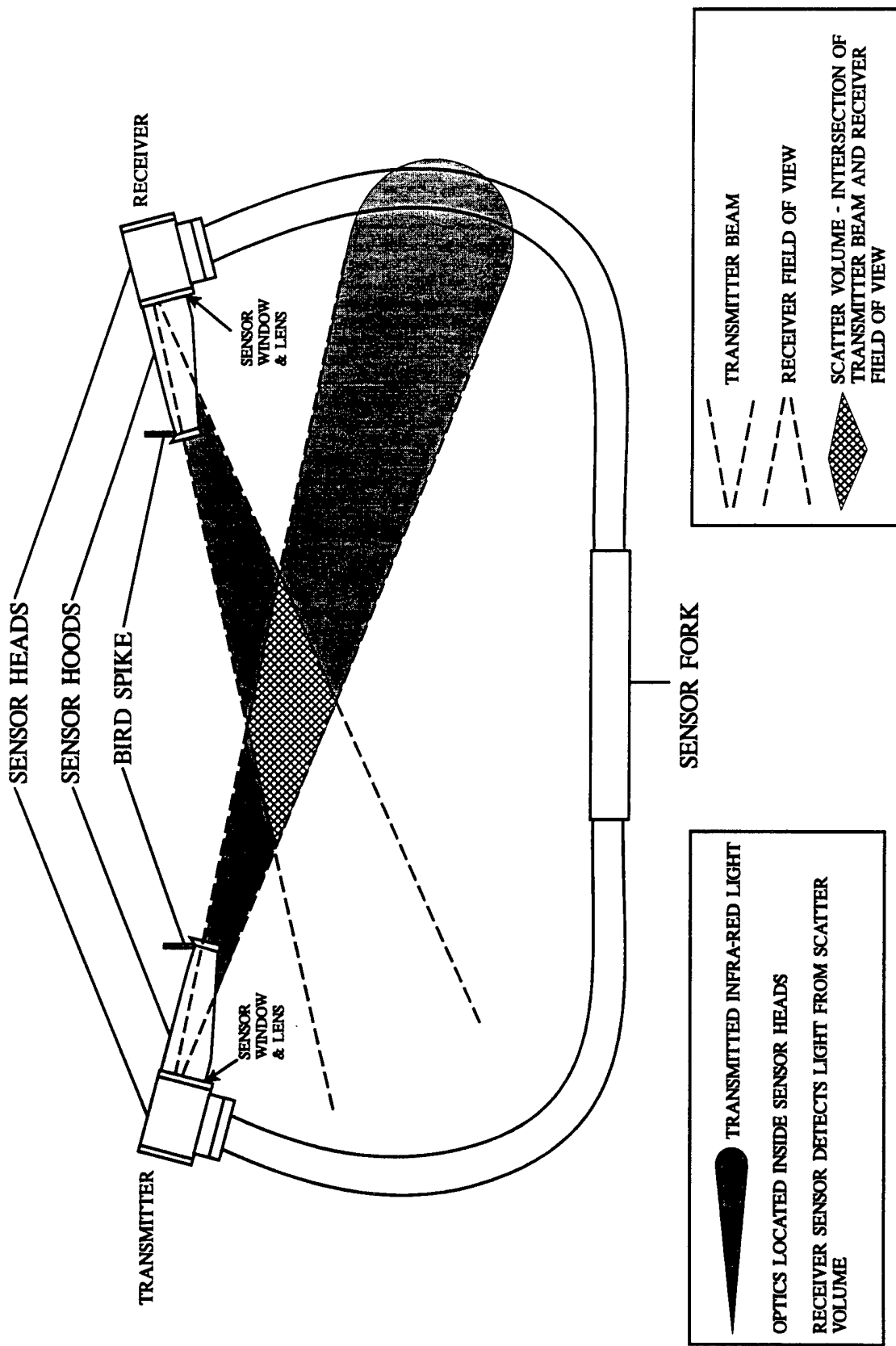


FIGURE 1. LOOK-DOWN VISIBILITY SENSOR COMPONENTS

1.3.2.2.1 Snow Clogging.

Snow and ice buildup (figure 2) on the VS hood and window was observed during conditions of blowing frozen precipitation.

NOTE: Although not specifically stated in the VNTSC report, snow and ice buildup not actually making contact with the sensor lens will not be detected by window contamination circuitry. The result of an undetected blockage would be higher-than-actual RVR readings.

1.3.2.2.2 Ambient Light Sensor.

Because the orientation of Ambient Light Sensor (ALS) optics (figure 3) is similar to that of the VS, the ALS was also susceptible to the problems noted in paragraphs 1.3.2.2 and 1.3.2.2.1.

1.3.2.3 Category IIIb Accuracy.

Following the review of the VNTSC VS evaluation report, ACW-200 and AOS-220 concluded that the lack of actual tests under Category IIIb conditions constituted a deficiency in accuracy validation of the system. ACW-200B requested that additional testing be conducted along with theoretical analysis of system response in order to quantify and validate Category IIIb performance.

1.3.3 Specialized Testing.

The lack of naturally occurring Category IIIb conditions, as well as infrequent and unpredictable blowing precipitation events, created a need for specialized testing to address problems identified during VS accuracy testing. Testing for snow clogging and response was conducted with VS and ALS at CRREL in Hanover, NH. Category IIIb testing was conducted at the Mount Washington Observatory, Mount Washington, NH. See paragraph 4.2 for test descriptions and results.

1.3.3.1 Data Collection Sites.

In order to maximize the amount of collected data and enhance understanding of RVR system performance under adverse conditions, automated data collection sites were established at the following locations:

- a. Sea-Tac Airport (SEA), WA,
- b. University of Colorado, Mountain Research Station (MRS), Nederland, CO,
- c. St. John's, Newfoundland (YYT), Canada, and
- d. Otis Weather Test Facility, Cape Cod, MA.

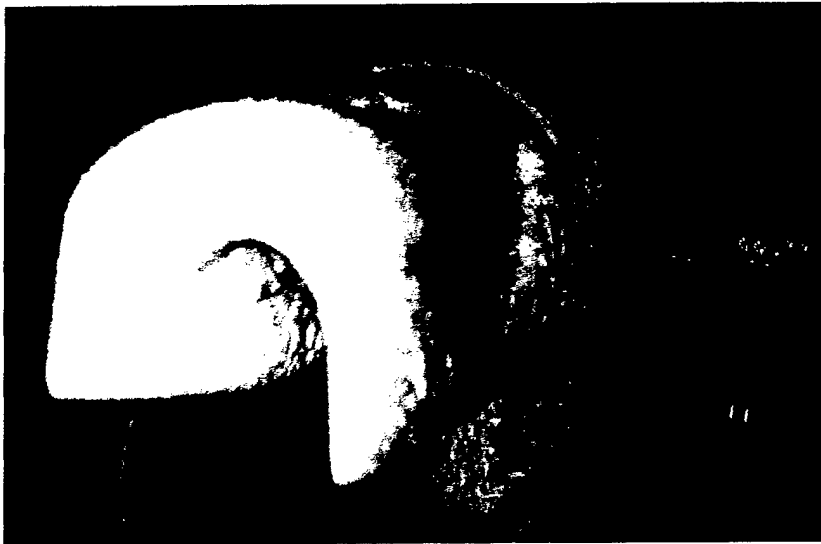


FIGURE 2. VISIBILITY SENSOR SNOW CLOGGING

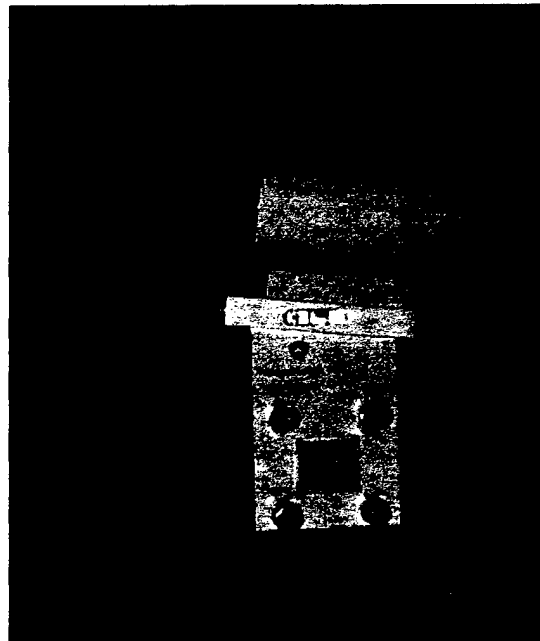


FIGURE 3. AMBIENT LIGHT SENSOR

SEA, YYT, and the Otis Weather Test facility were previously established test sites used during the original VS accuracy tests (paragraph 1.3.2). MRS was established specifically for snow calibration and clogging research following identification of problems during VS accuracy tests. These sites were remotely monitored and data was automatically retrieved. The data from these sites represented VS and ALS performance during natural weather phenomena (i.e., blowing precipitation and fog). This data was evaluated as a supplement to the data from CRREL and Mt. Washington.

1.3.4 OT&E Retest.

Retest of the RVR system began in August of 1992. Seven separate OT&E retest sessions were conducted. Each retest involved modifications of system software, and in some cases, modifications to hardware. Although no specific procedures were conducted for operational testing, any items affecting the operational suitability of the system were noted by the test team.

Specialized tests (paragraph 1.3.3) were considered to be part of the overall OT&E process; however, their purpose was more developmental in nature and typically focused on a single aspect of system performance. They are not considered as retest in a system sense. The results of these tests were crucial to correcting major discrepancies in the RVR system; therefore, a general description of the tests and results will be presented. Individual test reports are attached as noted.

1.3.4.1 Test Schedule/Locations.

Table 1 provides a summary of the designation and type of testing performed, the dates and location, and general comments concerning the system configuration or test.

1.3.5 Design Modifications.

There were numerous design changes made to the RVR system throughout OT&E. These modifications were made primarily to system software in an effort to correct ongoing problems. After several rounds of retest, as well as additional specialized testing, it became apparent that software modifications would not be sufficient to eliminate the more serious problems affecting the RVR system. This was particularly true for problems with sensor failure and system outages during blowing precipitation.

TABLE 1. TESTING ACTIVITIES

TEST	DATE	TEST TYPE	LOCATION	COMMENTS
Initial OT&E	Feb-March, 1992	Integration/ Shakedown/ Operational	Kansas City International Airport, MO	
Retest 1	Aug 17-21, 1992 Sept 1-4, 1992	Integration/ Shakedown/ Operational	Kansas City International Airport, MO	Software Engineering Prototype
Retest 2	Nov 9-17, 1992 Dec 1-11, 1992	Integration/ Shakedown/ Operational	Kansas City International Airport, MO	Software Engineering Prototype
Retest 3	June 14-25, 1993 June 18-25, 1993	Shakedown/ Integration/ Operational	Kansas City International Airport, MO	Formal Software Release
Specialized Test 1	July 19-26, 1993 Aug 2-6, 1993 Aug 16-23, 1993	Performance with Blowing Precipitation	CRREL Hanover, NH	Evaluation of Look-Down VS and ALS
Retest 4	Aug 16-20, 1993	Shakedown/ Operational	Kansas City International Airport, MO	Software Engineering Prototype
Specialized Test 2	Sept 13-21, 1993	Cat IIIB Performance	Mt. Washington, NH	VS Accuracy Validation
Retest 5	Sept 19-23, 1993	Integration/ Operational	Kansas City International Airport, MO	Formal Software Release
Retest 6	Dec 6-10, 1993	Integration/ Shakedown/ Operational	Kansas City International Airport, MO	Formal Software Release
Retest 7	June 6-10, 1994 June 13-20, 1994	Integration/ Shakedown/ Operational	Kansas City International Airport, MO	Formal Software Release

As a result, the feasibility of significant hardware modifications was studied. The results of the studies indicated that a combination of hardware and software modifications to the VS and ALS would be more effective at eliminating sensor performance discrepancies.

The modified sensors and algorithms underwent thorough testing at CRREL to determine the extent of performance improvements (paragraph 4.2.1). Tests included performance under blowing precipitation and Category IIIb accuracy.

NOTE: Although Category IIIb testing was performed at CRREL, difficulties were encountered in maintaining Category IIIb conditions and discerning actual sensor performance during testing. As a result, the Category IIIb performance data was not considered usable.

The original and modified sensor designs are discussed in the following subparagraphs.

1.3.5.1 Look-Across Visibility Sensor.

The original VS utilized sensor heads that were oriented parallel to the ground (figure 4). Because of this orientation, it is referred to as a "Look-Across" or look-out VS. OT&E and Specialized test results indicated that this sensor was susceptible to calibration problems, failures, and questionable RVR readings. The latter two items being particularly prevalent during blowing rain or snow. Problems were attributed to the relative ease with which precipitation could strike the sensor window and to the system's inability to adequately compensate when this occurred.

As mentioned in paragraph 1.3.2.2.1, undetected contaminants blocking the infrared light path to or from the "scatter volume" (figure 1) can cause higher-than-actual RVR readings. This phenomenon was observed during snow events which produced snow "clogs" (figure 2) in the look-across sensor.

1.3.5.2 Look-Down Visibility Sensor.

Reevaluation of the original VS design led to the conclusion that it was possible to orient the sensor heads in a downward-looking configuration. It was felt that this, in conjunction with a longer more enclosed hood, would prevent precipitation from striking the sensor lenses under most conditions. Several prototypes of the new design were built to assess the improvements. Because of the orientation of the sensor heads, this version of the VS is referred to as the Look-Down VS (figure 5).

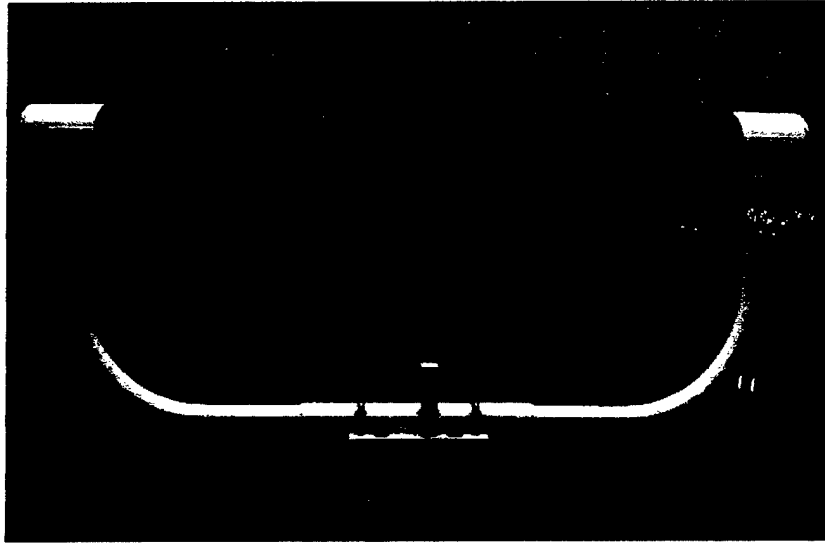


FIGURE 4. LOOK-ACROSS VISIBILITY SENSOR

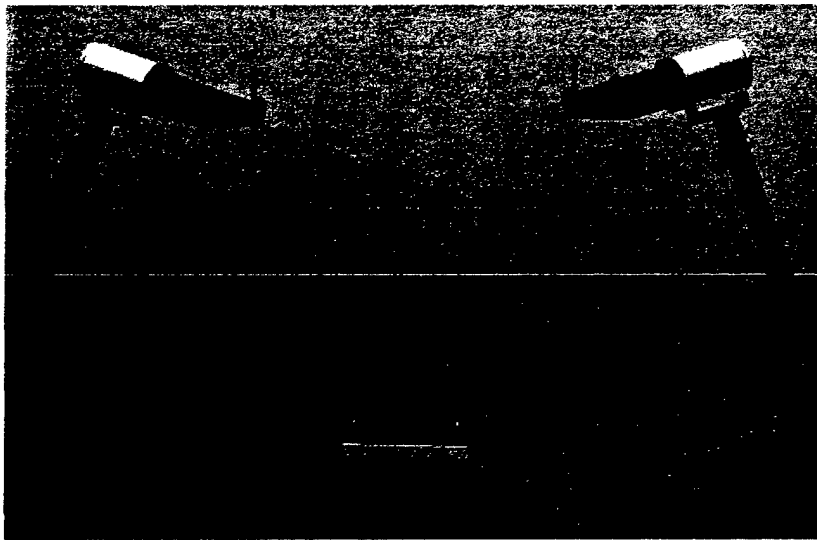


FIGURE 5. LOOK-DOWN VISIBILITY SENSOR

1.3.5.2.1 Snow/Rain Calibration.

An added benefit of the look-down design was the ability to orient the sensor heads at an angle that would result in nearly equal calibration values for snow and rain. This would eliminate the need for any automated process of changing calibration values for snow versus fog. The optimum angle for equal snow and fog response was determined by analysis to be 42°. Data was collected during specialized tests to verify correct calibration values.

1.3.5.2.2 Additional Changes.

The following modifications were also implemented in the Look-Down VS:

- a. Improved lens filter,
- b. Resized, lower wattage window heaters,
- c. Higher wattage hood heater with more conformal heat distribution, and
- d. Addition of bird spike and insect repellents.

The objectives of these design changes included the following:

- a. Remove dynamic components of sunlight that adversely affect extinction coefficient readings;
- b. Minimize the possibility of snow clogging;
- c. Eliminate sensor shutdowns caused from high window contamination;
- d. Minimize the possibility and effects of icicle formations on the sensor; and
- e. Reduce the possibility of inaccurate RVR readings due to birds or insects entering the receiver or transmitter beam.

1.3.5.3 Ambient Light Sensor.

Because the physical design of the ALS is similar to that of the Look-Across VS, it too was susceptible to contamination and clogging problems. However, unlike the VS, the ALS requires an unobstructed view of the North sky at a 6° elevation. This requirement prevented any changes to the sensor head orientation. Other hardware changes were incorporated in an effort to improve the sensor's ability to respond to blowing precipitation and to prevent snow clogging.

Hardware design changes made to the ALS included the following:

- a. Higher wattage heater with more conformal heat distribution;
- b. Resized and lower wattage window heater;
- c. Elimination of "ledge" under sensor head which allowed snow to build up; and
- d. Repositioning of grounding lug to the rear of sensor.

2. REFERENCE DOCUMENTS.

The following documents were used in preparation of this report:

Preparation of Test and Evaluation Documentation	FAA-STD-024B August 22, 1994
FAA NAS Test and Evaluation Policy	FAA-ORDER-1810.4B October 22, 1994
Interim Certification and Maintenance of the New Generation Runway Visual Range	N 6560.16 November 11, 1994
Runway Visual Range (RVR) Operational Test and Evaluation (OT&E) Integration and OT&E Operational Test Report	DOT/FAA/CT-TN92/37 April 1993
RVR System On-Site Requirements	TI 6560.17 September 1994
Runway Visual Range System Specification Amendment 4	FAA-E-2272, April 25, 1990
Functional and Performance Requirements for the NAS Specification	NAS-SS-1000 Volumes III and V
Remote Maintenance Monitoring System Interface Control Documents	NAS-MD-790, 792, 793

3. SYSTEM DESCRIPTION.

3.1 MISSION REVIEW.

The New Generation RVR is designed to replace transmissometer systems (e.g., Tasker 400, 500) currently in use at U.S. airports. It will provide a measurement of runway visual range at specific points along a precision runway in support of instrument landings during Category I, II, IIIa/b visibility conditions (specification FAA-E-2772). The functions of the RVR include determination of the following:

- a. Atmospheric scattering coefficients,
- b. Ambient light intensity, and
- c. Runway light intensity.

The above information is processed to yield distances that a pilot can expect to see along the departure or approach path of a runway. The New Generation RVR equipment will decrease the maintenance load and installation difficulties associated with current RVR system designs. Future expansion capabilities will be easier and less costly.

3.2 TEST SYSTEM CONFIGURATION.

For each retest, the RVR system at MCI consisted of the following components and interfaces:

Components

- a. Visibility Sensor. Three^{1,2} total, located at the touchdown, midpoint, and rollout segments of runway;
- b. Ambient Light Sensor. One located on top of the airport control tower;
- c. Runway Light Intensity Monitor (RLIM) Sensors. Three located in the airport power vault;
- d. Sensor Interface Electronics (SIE) enclosures. One located with each sensor;
- e. Data Processing Unit (DPU). One located in the electronics equipment room of the airport control tower; and

¹ Four visibility sensors were installed at MCI for Retests 6 and 7.

² Look-across configuration sensors were used during Retests 1 through 5, look-down version was used in Retests 6 and 7.

- f. Controller Display (CD). Four total, located in the control tower cab, the Terminal Radar Control (TRACON) area, and the electronics equipment room of the airport control tower; and
- g. Firmware for the DPU, VS, ALS, CD, and RLIM.

Interfaces

- a. Maintenance Data Terminal (MDT). MDT interfaces were contained in SIE enclosures and the DPU;
- b. Maintenance Processor Subsystem (MPS). The MPS interface was contained within the DPU; and
- c. External User (EU). The EU port was contained within the DPU.

Specialized test results from CRREL and Mt. Washington are discussed in paragraphs 4.2.1 and 4.2.2. Refer to these paragraphs for a description of the system configuration during testing.

3.3 ADDITIONAL INTERFACES.

Testing of the Tower Control Computer Complex (TCCC) and the Automated Surface Observing System (ASOS) National Airspace System (NAS) subsystem interfaces was deferred. The interfaces were not available at the time of testing.

4. TEST AND EVALUATION DESCRIPTION.

This section describes retest and specialized testing conducted on the RVR following completion of initial OT&E. Retests are presented in chronological order along with results. Specialized tests are presented after the retests. See referenced reports for detailed descriptions of test procedures and results.

In addition to the testing discussed herein, system performance was remotely monitored by AOS-220 during the periods between retests. System anomalies discovered during these periods will be included in retest discussions.

4.1 RETESTS.

Retests were conducted to verify resolution of problems found during initial OT&E or subsequent tests. The test philosophy was to conduct individual procedures to verify correction or continued existence of each discrepancy. Upon completion of individual tests, overall system functionality was checked to ensure that modifications had not affected other areas of system operation.

Tests were conducted using a subset of the original integration and shakedown procedures. Additional procedures were developed during testing when warranted.

Information and pass/fail requirements for additional test procedures were derived from the following documents:

- a. TI 6560.17,
- b. FAA-E-2272,
- c. NAS-SS-1000, and
- d. NAS-MD-790/NAS-MD-792/NAS-MD-793.

4.1.1 Retest 1.

The following subparagraphs describe the conduct and results of the first retest performed on the RVR system following initial OT&E. Testing was intended to evaluate changes made in response to the initial OT&E report. Reference appendix A for individual test reports.

4.1.1.1 Background.

RVR modifications consisted primarily of system software changes. System software was delivered for Retest 1 as an engineering prototype and was not officially released.

Initial OT&E results indicated significant problems in the areas listed below. Additional details pertaining to the problem areas are provided in the following subparagraphs:

- a. Sensor performance,
- b. System documentation,
- c. Maintenance,
- d. Personnel safety,
- e. Remote Maintenance Monitoring (RMM), and
- f. Controller Display.

4.1.1.1.1 Sensor Performance.

Discrepancies which would affect system accuracy were observed during initial OT&E and during VS evaluations (paragraph 1.3.2). The more significant problems appeared to be caused by blowing precipitation, and affected the operation of both the VS and ALS. The discrepancies included fluctuating extinction coefficient readings and occasional sensor shutdowns.

Inconsistencies with sensor calibration were also noted during the course of testing. Calibration problems included an unequal response of the sensor during snow and fog conditions. This resulted in inaccurate RVR readings during snow events.

Problems with the RLIM were also observed during initial OT&E at MCI. These problems were related to an apparent violation of fail-safe requirements and incomplete fault detection for the RLIM sensor.

In addition, after reviewing results of VNTSC sensor evaluations, AOS-220 noted that data collected did not include occurrences of Category IIIb conditions; therefore, no data existed which validated sensor performance in this visibility range.

4.1.1.1.2 System Documentation.

In several areas, the On-Site Manual (TI 6560.17) was insufficient to determine if RVR operation was correct. These areas included maintenance procedures along with sensor operation and performance. Appropriate safety warnings were missing from the documentation, as well as procedures for handling failures in RVR components. Additionally, the Off-Site Manual (TI 6560.18) was unavailable for evaluation.

4.1.1.1.3 Maintenance.

Significant maintenance problems found included the following:

- a. Insufficient monitoring of SIE batteries;
- b. Loss of archived data;
- c. Violation of fail-safe requirements and inability to detect faults in RLIM sensors;
- d. Insufficient performance capabilities of lightning protection circuitry and the inability to detect failures in these components;
- e. Difficulty in accessing DPU power supply test points;

- f. Display of invalid products at the CD without proper notification; and
- g. Excessive corrosion of SIE enclosures.

4.1.1.1.4 Remote Maintenance Monitoring.

Problems in this area included system control conflicts between the MPS and MDT, and loss of communication and data when the system was on battery power.

4.1.1.1.5 Personnel Safety.

Safety issues included electrical shock hazards in SIE enclosures and hazards to technicians when raising and lowering VS for maintenance.

4.1.1.1.6 Controller Display.

Problems noted with the CD included the following:

- a. Misrepresentation of RVR products;
- b. Ability to inadvertently change display configurations;
- c. Loss of data during power fluctuations;
- d. Failures in self-test operations;
- e. Day/night readability; and
- f. Lack of alarm capability when system failures were present.

4.1.1.2 Test Date and Location.

Testing was performed from August 17 through August 21 (Integration), and from September 1 through September 4 (Shakedown), 1992. Tests were conducted at MCI, Kansas City, Missouri.

4.1.1.3 Participants.

Personnel from the following organizations conducted and supported OT&E retest:

<u>Organization</u>	<u>Role</u>
ACW-200B	Test Director
ACN-100D	Test Engineering
ANN-140	Observer
MCI Airway Facilities Sector Field Office (AFSFO)	Technicians
Kansas City Air Route Traffic Control Center	System Administrators
AOS-220	Shakedown Test Engineering

4.1.1.4 Specialized Test Equipment.

Test equipment included protocol analyzers and remote maintenance simulation software. No additional specialized test equipment was required.

4.1.1.5 Test Objectives.

The primary objectives of testing were to verify corrections to problems previously identified and to ensure the operational suitability of the RVR system. This round of testing was intended to verify improvements and performance in the areas noted in paragraph 4.1.1.1.

4.1.1.6 Test Descriptions.

Test procedures were essentially a subset of those performed during initial OT&E. When necessary, procedures were changed to isolate system responses and problems.

When possible, conditions under which problems were first identified were reproduced. If successive attempts to duplicate a problem failed and no degraded performance was observed, the discrepancy was identified as resolved.

4.1.1.7 Data Collection and Analysis.

Test conduct forms were maintained during testing and discrepancy reports were created as necessary. Data communication log files were also established for analysis purposes.

4.1.1.8 Test Results.

Test reports for Retest 1 can be found in appendix A.

With the exception of some improvements in RMM and fault detection, the major problems noted during initial OT&E remained relatively unchanged.

The improvements in RMM included elimination of local/remote control conflicts, as well as correction of other minor discrepancies. Fault detection improvements included the addition of the following:

- a. RLIM SIE link error values,
- b. Hard Alarms when AC power is lost,
- c. Hard Alarm threshold values for DPU power supplies, and
- d. Site Data reports after issuance of fault diagnostic commands.

The more significant systematic deficiencies remained uncorrected. Test results indicated existing and/or new problems in the following areas:

- a. Sensor Performance,
- b. System Documentation,
- c. Maintenance,
- d. Personnel Safety,
- e. Remote Maintenance Monitoring, and
- f. Controller Display.

Additional details are provided in the following subparagraphs.

4.1.1.8.1 Sensor Performance.

Discrepancies in VS and overall RVR accuracy were observed. Performance was particularly suspect during the following conditions:

- a. VS lens contamination; and
- b. Transitions from day/night operation.

Discrepancies were also noted in the operation of rain and snow filters. These filters are incorporated through software and were intended to allow the system to compensate for transient window signals (paragraph 1.3.2.2) caused by precipitation hitting the sensor lenses.

4.1.1.8.2 System Documentation.

System documentation had not been updated. Discrepancies were essentially the same as noted in paragraph 4.1.1.1.2. In addition, updates were missing from the CD manual.

4.1.1.8.3 Maintenance.

Although improvements were made in fault diagnostic software, fault detection and fail-safe protection for the RLIM was still deemed inadequate.

Other problems noted included the following:

- a. Use of the MDT to enter or read system parameters was complicated by the need to use a calculator to convert the information to a usable format using scaling factors; and
- b. One-hour archiving function entered an endless loop.

Previously reported problems remained as stated in paragraph 4.1.1.1.3.

4.1.1.8.4 Remote Maintenance Monitoring.

As discussed in paragraph 4.1.1.8, some improvements were noted in RMM performance. However, new problems were observed.

Problems occurred in the following areas:

- a. Communication failures between the Maintenance Processor Subsystem (MPS) and the RVR Remote Monitoring Subsystem (RMS);
- b. Command execution and format failures during MPS to RVR RMS communication;
- c. Failures in alarm generation; and
- d. Failure to clear alarm conditions as required by specification.

4.1.1.8.5 Personnel Safety.

Problems remained as stated in paragraph 4.1.1.1.5.

4.1.1.8.6 Controller Display.

Previous problems noted with the CD remained. An additional discrepancy discovered was the absence of audible alarms at the CD when RVR equipment failures existed.

4.1.1.9 Recommendations.

Based on the continued existence and seriousness of problems observed during initial OT&E, as well as newly discovered anomalies, ACW-200B recommended that the RVR system not be approved for national deployment.

4.1.2 Retest 2.

The following subparagraphs describe the conduct and results of the second retest performed on the RVR system. Testing was intended to evaluate RVR modifications made in response to results from initial OT&E and Retest 1. Reference appendix B for individual test reports.

4.1.2.1 Background.

Following Retest 1, modifications were made to RVR system software to correct existing deficiencies (paragraph 4.1.1.8). Significant in the changes were modifications to the rain and snow filters. The modified software was delivered for Retest 2 as an engineering prototype and was not officially released.

4.1.2.2 Test Date and Location.

Testing was conducted November 9 through November 17 (Integration), and December 1 through December 11 (Shakedown), 1992, at MCI, Kansas City, Missouri.

4.1.2.3 Participants.

Personnel from the following organizations conducted and supported OT&E retest:

<u>Organization</u>	<u>Role</u>
ACW-200B	Test Director
ACN-100D	Test Engineering
ANN-140	Observer
AOS-220	Shakedown Test Engineering
MCI AFSFO	Technicians
Kansas City Air Route Traffic Control Center	System Administrators

4.1.2.4 Specialized Test Equipment.

Test equipment included protocol analyzers and remote maintenance simulation software.

4.1.2.5 Test Objectives.

Test objectives were the same as those stated in paragraph 4.1.1.5. This round of testing was intended to verify improvements and performance in the discrepancy areas noted in Retest 1 results. More specifically, the objectives were to determine the status of issues in the following areas:

- a. Sensor Performance,
- b. System Documentation,
- c. Maintenance,
- d. Personnel Safety,
- e. Remote Maintenance Monitoring, and
- f. Controller Display.

4.1.2.6 Test Descriptions.

Reference paragraph 4.1.1.6.

4.1.2.7 Data Collection and Analysis.

Test conduct forms were maintained during testing and discrepancy reports were created as issues occurred. Data communication log files were also established for analysis purposes.

4.1.2.8 Test Results.

Test results indicated some improvements in sensor performance and maintainability.

Sensor improvements were noted in the improved ability of the VS to compensate for lens contaminants; however, the RVR system continued to malfunction during real and simulated precipitation events.

The addition of RLIM configuration parameters and the correction of errors in product archiving aided in improving system maintainability. Other maintenance improvements included the retention of sensor calibration data during system restarts and shutdowns.

Minor problems were corrected in the RMM area. Progress included the closing of trouble reports in the following areas:

- a. MPS to RMS communications,
- b. Execution of fault diagnostic commands,
- c. Alarm generation and clearing, and
- d. RMS Message formatting.

Test results also indicated existing and/or new problems in the following areas:

- a. Sensor Performance,
- b. System Documentation,
- c. Maintenance,
- d. Remote Maintenance Monitoring,
- e. Personnel Safety, and
- f. Controller Display.

Additional details are provided in the following subparagraphs.

4.1.2.8.1 Sensor Performance.

Despite modifications to rain and snow filters, critical failures were observed in the VS and ALS. Failures included loss of calibration during normal operation, and sensor shutdowns for extended periods. Of particular note was a 4-hour outage recorded during a snow event and two separate outages during blowing rain conditions. During the snow event, the existing transmissometer system remained operational and recorded minimum visibility between 2,000 and 3,000 feet. The shutdowns were attributed to high window signals caused by precipitation striking the VS and ALS lenses.

Additional operational failures were noted in VS hood heaters. The hood heaters failed to activate at required temperatures.

Other previously identified problems and issues (paragraph 4.1.1.8.1) remained.

4.1.2.8.2 System Documentation.

System documentation problems remained as stated in paragraph 4.1.1.8.2. Additional documentation deficiencies were noted and included missing information for SIE MDT screens.

4.1.2.8.3 Maintenance.

As mentioned in 4.1.2.8, corrections were made to the data archiving function; however, additional maintenance related problems were observed. These included:

- a. Communication failure between MDT and DPU/SIE;
- b. Incorrect operation of fault diagnostic tests;
- c. Improper MDT/SIE configuration screen identification;
- d. Failure to regain sensor calibration data after power outages; and

- e. Improper operation of function keys.

With the exception of data archiving, the problems as identified in paragraph 4.1.1.8.3 remained unresolved.

4.1.2.8.4 Remote Maintenance Monitoring.

Despite progress noted, additional problems were discovered with the remote maintenance subsystem interface.

The additional problems found included the following:

- a. The RVR RMS intermittently sends data frames to the MPS instead of sending one continuous data stream; and
- b. The RMS failed to provide the proper response while in "Disconnect" Mode.

4.1.2.8.5 Personnel Safety.

All personnel safety problems remained as stated in paragraph 4.1.1.1.5.

4.1.2.8.6 Controller Display.

CD remained as stated in paragraph 4.1.1.8.6.

4.1.2.9 Recommendations.

The corrections and modifications made to the RVR software produced only marginal improvements in the areas containing critical performance problems. As a result, ACW-200 again recommended against a national deployment decision.

4.1.3 Retest 3.

Test description and results of Retest 3 are discussed in the following subparagraphs. As in previous tests, the purpose of Retest 3 was to verify the most recent modifications made to the RVR system. Reference appendix C for individual test reports.

4.1.3.1 Background.

In the period between Retest 2 and Retest 3, an officially released version of software was installed in the RVR system at MCI airport. This software included modifications which allowed for an increase in the number of VSS. The expansion was incorporated to support RVR system installations at larger airports such as the new Denver International Airport (DVX). The expansion increased the RVR's VS capacity from 12 to 18. Although RVR sensor capacity was increased, no additional VS were installed at MCI.

Failure to obtain a deployment recommendation for the RVR after the second retest elevated program office concerns related to having a system available for the opening of the new DVX. As a result, efforts became more focused on fixing or finding work-arounds for the major sensor problems. ACW-200 accepted this approach with the stipulation that Denver be the only site to receive the system, and that the Denver RVR would be upgraded as soon as a national deployment configuration was achieved. Modifications to the RVR software following Retest 2 reflected the new focus, and the version was dubbed the "Denver Configuration."

4.1.3.2 Test Date and Location.

Testing was conducted during the following periods: from June 14 through June 18 (Shakedown), and June 18 through June 25 (Integration), 1993, at MCI, Kansas City, Missouri.

4.1.3.3 Participants.

Personnel from the following organizations conducted and supported OT&E retest:

<u>Organization</u>	<u>Role</u>
ACW-200B	Test Director
ACN-100D	Test Engineering
AOS-220	Shakedown Test Engineering
ANN-140	Observer
MCI Airway Facilities	
Sector Field Office (AFSFO)	Technicians
Kansas City Air Route Traffic Control Center	System Administrators

4.1.3.4 Specialized Test Equipment.

Test equipment included protocol analyzers and remote maintenance simulation software.

4.1.3.5 Test Objectives.

Test objectives were essentially the same as those stated in paragraph 4.1.1.5. This round of testing was intended to verify improvements and performance in the areas noted in paragraph 4.1.2.8, with emphasis on items preventing deployment to Denver. In addition, testing was intended to define the extent of performance degradation to be expected as a result of deploying the system with known discrepancies. Results would be provided to airport personnel prior to system commissioning.

4.1.3.6 Test Descriptions.

Reference paragraph 4.1.1.6.

4.1.3.7 Data Collection and Analysis.

Test conduct forms were maintained during testing and discrepancy reports were created as issues occurred. Data communication log files were also established for analysis purposes.

4.1.3.8 Test Results.

Sensor performance was again found to be unacceptable during testing. The RVR experienced rain related shutdowns as described in following subparagraphs.

Improvements were noted in the maintenance and RMM areas. MDT screens relating to RVR product/edit override capabilities were corrected. Improvements were made in communications between the MDT and the RVR DPU when performing configuration changes. Progress in the RMM area included the completion of command error messages and the resolution of some MPS software issues.

Test results again indicated continuing problems in the following areas:

- a. Sensor performance,
- b. System documentation,
- c. Maintenance,
- d. Personnel safety,
- e. Remote Maintenance Monitoring, and
- f. Controller Display.

Additional details are provided in the following subparagraphs.

4.1.3.8.1 Sensor Performance.

As in previous tests, system shutdowns due to sensor failure were observed. In particular, a system shutdown lasting for several hours occurred during a rain event at the airport. The existing transmissometer based RVR system remained operational throughout the event, and airport operations were unchanged. The shutdown was later attributed to a failure in the ALS caused when rain struck the lens of the sensor.

4.1.3.8.2 System Documentation.

The Off-Site Technical Instruction book was not available for review. Corrections to the On-Site Technical Instruction manual had not been accomplished.

4.1.3.8.3 Maintenance.

Maintenance problems remained as stated in paragraph 4.1.2.8.3. Additionally, incorrect values were noted for two data points within the VS SIE parameter screens. The incorrect values occurred while the parameters were in an alarm state.

4.1.3.8.4 Remote Maintenance Monitoring.

Despite improvements in RMM as stated in paragraph 4.1.3.8, additional problems were observed during testing. Significant problems included the following:

- a. RMS tendency to reset during the execution of remote control commands; and
- b. Incorrectly prioritizing RMS messages to MPS.

4.1.3.8.5 Personnel Safety.

Previously observed personnel safety problems remained as stated in paragraph 4.1.1.1.5.

4.1.3.8.6 Controller Display.

CD discrepancies remained as stated in paragraph 4.1.1.8.6. An additional discrepancy was noted involving alarms sounding when runway light settings were less than step 3.

4.1.3.9 Recommendations.

In response to the test results, ACW-200B recommended against limited or national deployment of the RVR system. AOS-220 and ACW-200B also recommended that, following modifications, the RVR be retested specifically for performance under blowing precipitation conditions. It was also recommended that accuracy testing be performed to validate RVR performance under Category IIIa/b conditions.

4.1.4 Retest 4.

The following subparagraphs detail the test and results of the fourth retest performed on the RVR. Testing was intended to verify system modifications designed to support RVR operations at DVX. Refer to appendix D for individual reports.

4.1.4.1 Background.

Modifications made in preparation for this test were aimed primarily at providing a system which was "operationally acceptable" for use at DVX. At the time of the test, DVX was scheduled for opening in December 1993.

Operationally acceptable was defined by the following conditions:

- a. Work-arounds would be implemented for significant problems that could not be corrected prior to deployment at DVX;
- b. Description of problems and their operational impact delivered to appropriate users and technicians;
- c. Completion of a full retest of the RVR; and
- d. No additional significant problem areas discovered during a full retest.

Consideration for deploying the RVR system at DVX in a somewhat degraded capacity was made necessary by the lack of an alternate means of providing an RVR capability at the new airport. The RVR system was not considered by ACW-200 to be ready for national deployment. ACN-100D and AOS-220 were in agreement with this assessment.

At the time of the test, additional performance evaluations were underway at Teledyne Controls, Inc., and CRREL. The intent of these evaluations was to facilitate rapid prototype and assessment of system modifications in an effort to provide an acceptable system for DVX as well as national deployment.

Test and modification efforts which followed Retest 3 were directed at problem areas not related to the RMS interface. As a result, ACW-200B made the decision to conduct only OT&E Shakedown tests for Retest 4. It was expected that a limited deployment recommendation for DVX would follow a full retest to be conducted at a later date.

In response to RVR shutdowns that occurred during the previous retest, additional modifications were made to the software involved in lens contamination response of the ALS and VS. The changes were designed to allow the sensors to be less sensitive to the effects of precipitation striking the sensor window.

In particular, the modifications consisted of specific additions to the window contamination algorithms. The additions are briefly described below:

- a. "Signal variance" precipitation detection,
- b. Precipitation detection periods, and
- c. Alarm delay periods.

4.1.4.1.1 Signal Variance Precipitation Detection.

The signal variance precipitation detection is a measurement of the change in window signals over a specified "precipitation detection period." The signal variance is used to determine the "mode" of the sensor. If the window signals of the VS or ALS are changing rapidly, it is assumed to be a transient type of contamination, e.g., rain. The "precipitation mode" is then enabled. Conversely, if the change in the window signals is gradual, as would be expected with the slow buildup of dust or salt, the "dirt mode" is enabled. Normal operation of the sensor would be the dirt mode. Enabling the precipitation mode introduces alarm delays and filtering to prevent the sensor from overreacting to the transient signals caused by precipitation striking sensor lenses.

4.1.4.1.2 Precipitation Detection Period.

The contamination algorithm measures window signal variance over a span of time which is designated the Precipitation Detection Period. This detection period is a parameter that is configured via the DPU MDT. The default value is 3 minutes.

4.1.4.1.3 Alarm Delay Period.

The alarm delay period is also part of the window contamination algorithm. The delay period allows window signal levels to temporarily exceed thresholds without triggering alarms. Signals remaining above thresholds beyond the delay period will trigger contamination alarms. Extremely large window signals will trigger alarms immediately. Like the precipitation detection period, the alarm delay period is configurable via the DPU MDT.

4.1.4.2 Test Date and Location.

Testing was conducted from August 16 through August 20, 1993, at MCI, Kansas City, Missouri. OT&E Shakedown tests were conducted during this period.

4.1.4.3 Participants.

Personnel from the following organizations conducted and supported OT&E retest:

<u>Organization</u>	<u>Role</u>
ACW-200B	Test Director
AOS-220	Shakedown Test Engineering
MCI AFSFO	Technicians

4.1.4.4 Specialized Test Equipment.

No specialized test equipment was required.

4.1.4.5 Test Objectives.

The primary objective of this test was to assess the effectiveness of modifications made to the ALS and VS. Testing concentrated on evaluation of sensor performance in the presence of precipitation and window contamination. Modifications to the On-Site Technical Instruction manual were also reviewed during the test period. Other previously identified problems and issues were not evaluated during this period.

4.1.4.6 Test Descriptions.

Testing included performing calibration procedures and observing sensor performance under simulated precipitation conditions.

4.1.4.7 Data Collection and Analysis.

Test conduct forms were maintained during testing and discrepancy reports were created as issues occurred.

4.1.4.8 Test Results.

Some difficulties were encountered with sensor calibration during testing; however, test results indicated an apparent performance improvement during simulated precipitation conditions. In particular, the operation of the precipitation detection and alarm delay periods, and the signal variance precipitation detection appeared to reduce sensor shutdowns during test conditions.

Although test results indicated significant improvement, results were inconclusive, because sensor performance under actual precipitation conditions was not observed. More extensive testing was recommended by ACW-200 and AOS-220 to determine if sensor performance would hold up under all weather conditions experienced at U.S. airports.

Test results indicated continuing problems in the following areas:

- a. Sensor performance, and
- b. System documentation.

The following areas were not evaluated during test and were assumed to be unchanged:

- a. Maintenance,
- b. Personnel safety,
- c. Remote Maintenance Monitoring, and
- d. Controller Display.

Additional details are provided in the following subparagraphs.

4.1.4.8.1 Sensor Performance.

Significant problems encountered during testing included an unacceptable number of calibration attempts before calibration was successful. Discrepancies were also noted with the calibration apparatus and in the documentation supporting the calibration procedure.

Inconsistencies were also noted for the VS and ALS window contamination gain parameters. The actual values for these parameters did not match the default settings contained in the software.

4.1.4.8.2 System Documentation.

Significant updates were made to the On-Site Technical Instruction manual. However, it was noted that additional modifications to this documentation were required.

4.1.4.8.3 Maintenance.

Maintenance problems remained as stated in paragraph 4.1.3.8.3.

4.1.4.8.4 Remote Maintenance Monitoring.

RMM problems were not evaluated during testing.

4.1.4.8.5 Personnel Safety.

Personnel safety problems remained as stated in paragraph 4.1.1.8.5.

4.1.4.8.6 Controller Display.

The CD was not evaluated during testing.

4.1.4.9 Recommendations.

The following recommendations were made by ACW-200 and AOS-220 following the completion of testing:

- a. Conduct more extensive tests during simulated and actual blowing precipitation conditions to fully evaluate sensor performance with the newly modified window contamination algorithms;
- b. Investigate and correct difficulties encountered during the calibration of the VS; and
- c. Correct and update the Technical Instruction manual.

As mentioned previously, this was not a complete retest. A complete retest involving OT&E Integration and Shakedown tests was scheduled to take place in Retest 5. No deployment recommendation was made by ACW-200B.

4.1.5 Retest 5.

Retest 5 was a complete test of the RVR designed to determine if the system could meet minimum operational requirements for DVX. In addition to verifying the resolution of problems found during previous testing, this test was intended to obtain optimum values for software algorithm parameters under actual field conditions. Refer to appendix E for individual test reports.

4.1.5.1 Background.

Software used in this test was officially released after the completion of factory software quality control tests. As in the previous test, software modifications were primarily intended to allow the system to be used at the DVX which was scheduled to open in December of 1993.

Prior to the start of Retest 5, performance discrepancies were noted with the ALS during factory qualification tests. The discrepancies were related to unexplained window signals from the ALS when no apparent stimulus existed. It was noted that these symptoms were exhibited when the sensor was placed in sunlight. This problem was not corrected prior to commencement of OT&E Integration and Shakedown tests.

In conjunction with the modifications discussed in paragraph 4.1.4.1.1 through 4.1.4.1.3, several significant hardware changes were made to the VS and ALS (paragraph 1.3.5). These hardware modifications were combined with software changes as part of a "rapid prototyping" effort to produce an RVR system for use at DVX.

Due to limitations in equipment, weather conditions, and time, these modifications could not be fully evaluated during Retest 5. Specialized tests at CRREL and Mt. Washington (paragraph 4.2.1, 4.2.2) were established to conduct these evaluations. These tests were conducted concurrent with Retests 4 and 5 and were developmental in nature.

It was planned to retrofit RVR systems installed at MCI and DVX following successful conclusion of specialized tests and implementation of final sensor design changes.

4.1.5.2 Test Date and Location.

Testing was conducted during the following periods: from September 20 through September 24, 1993, at MCI, Kansas City, Missouri. OT&E Shakedown tests were conducted from September 20 through September 24, and OT&E Integration testing was accomplished from September 22 through September 23, 1993.

4.1.5.3 Participants.

Personnel from the following organizations conducted and supported OT&E retest:

<u>Organization</u>	<u>Role</u>
ACW-200B	Test Director
ACN-100D	Test Engineering
AOS-220	Shakedown Test Engineering
ANN-400	Observer
MCI AFSFO	Technicians
Kansas City Air Route Traffic Control Center	System Administrators

4.1.5.4 Specialized Test Equipment.

Test equipment included protocol analyzers and remote maintenance simulation software.

4.1.5.5 Test Objectives.

Test objectives were the same as those stated in paragraph 4.1.1.5. This round of testing was intended to verify improvements and performance in the areas noted in paragraph 4.1.3.8 and 4.1.4.8. Also, as in Retest 3, test objectives included defining the extent of performance degradation expected as a result of deploying a system with known discrepancies.

4.1.5.6 Test Descriptions.

The test descriptions were the same as stated in paragraph 4.1.1.6.

4.1.5.7 Data Collection and Analysis.

Test conduct forms were maintained during testing and discrepancy reports were created as issues occurred. Data communication log files were also established for analysis purposes.

4.1.5.8 Test Results.

Test results indicated the further corrections within the RMM area. RMS interface corrections included the proper prioritizing of various MPS messages and the elimination of incomplete MPS messages.

Test results again indicated continuing problems in the following areas:

- a. Sensor performance,
- b. System documentation,
- c. Maintenance,
- d. Personnel safety,
- e. Remote Maintenance Monitoring, and
- f. Controller Display.

These problem areas are discussed in the following subparagraphs.

4.1.5.8.1 Sensor Performance.

Contrary to expectations, VS failures were again observed during a rain event and during simulated rain tests. The VS receiver appeared more sensitive to the effects of rain on the sensor lens than the transmitter.

Unexplained window signals were observed in the VS when exposed to sunlight. These were similar to those observed in the ALS during factory qualification tests. In what appeared to be a related problem, it was noted that the sensors appeared particularly sensitive to precipitation in the presence of sunlight. This sensitivity resulted in sensor failures during testing.

Although VS calibration did not require repeated attempts as in the previous test (paragraph 4.1.4.8), the calibration plates were not within the tolerance specified by the Technical Instruction book.

It was also noted that insect repellent paint, used on the VS to prevent spiders from nesting in the sensor hoods, did not appear to be effective. The repellent paint was one of several methods attempted in an effort to prevent spiders from interfering with sensor operation.

4.1.5.8.2 System Documentation.

System documentation remained as stated in paragraph 4.1.4.8.2.

4.1.5.8.3 Maintenance.

Maintenance problems remained as stated in paragraph 4.1.3.8.3.

4.1.5.8.4 Remote Maintenance Monitoring.

Corrections to RMM discrepancies were limited to those noted in paragraph 4.1.5.8. Other previously identified problems remained. For the first time, no additional problems were noted during testing.

4.1.5.8.5 Personnel Safety.

Personnel safety problems remained as stated in paragraph 4.1.1.8.5.

4.1.5.8.6 Controller Display.

CD discrepancies remained as stated in paragraph 4.1.3.8.6.

4.1.5.9 Recommendations.

Continued existence of sensor problems again prevented consideration of the RVR system for national deployment. Consideration for deployment at DVX was not ruled out, because testing of the Look-Down VS (paragraph 4.2.1) at CRREL had proven the design successful in preventing difficulties with precipitation.

Based on test results at MCI and CRREL, the test organizations and the Program Office were in agreement that the Look-Across VS design should be abandoned. However, because the software modifications to date had been somewhat successful, the decision was made to continue to refine the contamination algorithms. The software modifications would be the only means of desensitizing the ALS with respect to precipitation related shutdowns.

4.1.6 Retest 6.

Retest 6 was intended to qualify an interim version of RVR software for deployment at DVX. It was also intended to be a full retest and as such, satisfy part of the conditions required for an operationally acceptable system. Refer to appendix F for individual test reports.

4.1.6.1 Background.

In the period between Retest 5 and Retest 6, results of specialized testing were discussed at several test assessment and design review meetings. Results indicated that major problems and areas of uncertainty were very close to being resolved. In anticipation of a deployment decision for both DVX and national deployment, discussions focused on determining what corrections and modifications to the system had to be done predeployment, and which could be accomplished post-deployment.

Retest 6 included production release software and new prototypes of the CD, ALS, and Look-Down VS. In addition, modifications to the CD were incorporated in response to previous comments from air traffic controllers. As in the previous test, this version of hardware and software was designated as the Denver Configuration.

4.1.6.2 Test Date and Location.

Testing was conducted from December 6 through December 10, 1993, at MCI, Kansas City, Missouri. OT&E Integration and Shakedown tests were conducted using day and evening shifts during this period.

4.1.6.3 Participants.

Personnel from the following organizations conducted and supported OT&E retest:

<u>Organization</u>	<u>Role</u>
ACW-200B	Test Director
ACN-100D	Test Engineering
AOS-220	Shakedown Test Engineering
ANN-400	Observer
MCI Air Traffic Controllers	User Evaluations
MCI AFSFO	Technicians
Kansas City Air Route Traffic Control Center	System Administrators

4.1.6.4 Specialized Test Equipment.

Test equipment included protocol analyzers and remote maintenance simulation software.

4.1.6.5 Test Objectives.

In addition to fulfilling those stated in paragraph 4.1.1.5, test objectives included assessing improvements to problems as stated in paragraph 4.1.5.8 and conducting a performance evaluation of the newly installed Look-Down VS. An additional objective was to have air traffic controllers evaluate the new CD prototype.

4.1.6.6 Test Descriptions.

Because this was considered to be a predeployment test for DVX, the number of procedures conducted was expanded to ensure a thorough exercise of system functionality.

4.1.6.7 Data Collection and Analysis.

Test conduct forms were maintained during testing and discrepancy reports were created as issues occurred. Data communication log files were also established for analysis purposes.

4.1.6.8 Test Results.

As opposed to Retest 5, calibration of the VS was achieved without repeated attempts. Sensor calibration plates were within the tolerance specified by the Technical Instruction manual.

Problems continued in the areas shown below:

- a. Sensor performance,
- b. System documentation,
- c. Maintenance,
- d. Personnel safety,
- e. Remote Maintenance Monitoring, and
- f. Controller Display.

These problem areas are discussed in the following subparagraphs.

4.1.6.8.1 Sensor Performance.

This was the first retest performed with the look-down configuration VS. Performance discrepancies related to RVR product calculations and sensor shutdowns were still observed during test scenarios using simulated precipitation.

It was noted, however, that the VS seemed more sensitive to water falling through the sample volume than actually hitting the sensor lens. Testing proved this phenomena to be directly related to the presence of sunlight during the simulated precipitation. The problem was later attributed to an inability of the sensor to compensate for dynamic components of sunlight.

Discrepancies with ALS window contamination readings were noted during simulated precipitation. The discrepancies were determined to be caused by an incorrect contamination gain value. This result indicated the need for further evaluation and adjustment of the contamination gain value.

It was noted by the test team that it was difficult to evaluate proper operation of the contamination alarms because there was no indication as to what mode (e.g., precipitation, dirt) the sensor was in.

4.1.6.8.2 System Documentation.

Although significant updates to the On-Site Technical Instruction manual were previously incorporated, additional errors were found in the manual. Correction of the errors was recommended prior to delivery of the manual to DVX.

4.1.6.8.3 Maintenance.

Continued existence of maintenance problems and issues was observed during testing. In particular, the inability of the SIE to be reset while on battery power was noted. This problem was determined to be related to a previously identified problem involving a lack of communication between the SIE and the DPU when the SIE operated on battery power.

4.1.6.8.4 Remote Maintenance Monitoring.

Previously identified problems as stated in paragraph 4.1.3.8.4 remained.

4.1.6.8.5 Personnel Safety.

Previously observed personnel safety problems remained as stated in paragraph 4.1.1.1.5.

4.1.6.8.6 Controller Display.

MCI Airport air traffic controllers conducted a daytime evaluation of the RVR CD at the MCI TRACON and the control tower cab. In general, controllers were pleased with the changes incorporated.

Controllers recommended the following minor changes:

- a. The ability to adjust brightness of the power switch and the Health LED; and
- b. Separate backlighting controls for the product display and keypad.

The Test Director noted concerns that the evaluation was not conducted under a variety of lighting conditions.

4.1.6.9 Recommendations.

Shutdowns were much more difficult to produce, and those observed were short-lived. In addition, shutdowns now appeared to be primarily related to the presence of sunlight during precipitation. Although any occurrence of shutdowns was considered unacceptable, the likelihood of operational impacts caused by sunlight-related shutdowns was considered to be remote.

Retest 6 results provided the basis for a limited deployment recommendation for DVX. The system and ongoing activities met the criteria for minimum "operational acceptability" as defined in paragraph 4.1.4.1.

Justification was as follows:

- a. Test results indicated no new significant problem areas existed;
- b. Work was started on a notice, INTERIM CERTIFICATION AND MAINTENANCE OF THE RUNWAY VISUAL RANGE SYSTEM, TYPE FA-10268, N 6560.16 detailing work-around procedures and existing problems that should be monitored by maintenance technicians. This notice was planned for distribution to appropriate personnel at DVX;
- c. Activities for resolving existing problem areas were on-going and were expected to resolve remaining significant issues before national deployment of the RVR; and
- d. A complete retest of the RVR system was accomplished during this time period.

Further evaluation and adjustment of the contamination gain value parameter, and the correction of errors to the On-Site Technical Instruction manual were recommended.

Additionally, since new modes of operation (e.g., rain and dirt) were incorporated in the VS and ALS, it was recommended that an indication of these modes be incorporated in the system.

Based on the above test results, ACW-200B continued to consider the RVR system not ready for national deployment. Requirements for national deployment included additional blowing precipitation tests along with a more thorough assessment of system performance and accuracy during Category IIIb visibility.

4.1.7 Retest 7.

Results of specialized testing, along with improvements resulting from additional system modifications, indicated that the RVR was finally ready for national deployment. In preparation for this final retest, RVR hardware and software were officially released as First Articles after completing factory qualification tests. Retest 7 was expected to be the final test of the RVR system prior to a deployment decision. Refer to appendix G for individual test reports.

4.1.7.1 Background.

As mentioned in paragraph 4.1.6.1, RVR modifications in response to noted problems were planned for predeployment as well as post-deployment. Retest 7 marked the conclusion of planned predeployment corrections.

Incorporated improvements are listed below:

SIE

- a. Increase corrosion resistance of enclosures;
- b. Increase accessibility of internal components;
- c. Reduce safety hazards during maintenance;
- d. Add needed MDT maintenance parameters; and
- e. Increase Electromagnetic Interference resistance;

CD

- a. Improve daytime/nighttime readability;
- b. Incorporate data loss protection; and
- c. Add software expansion capabilities;

VS

- a. Reduce potential of ice/snow clogging;
- b. Reduce noise in ambient light readings; and
- c. Reduce potential of sensor failures resulting from window contamination.

ALS

- a. Reduce potential of sensor failures resulting from window contamination; and
- b. Reduce potential of snow/ice accumulation.

DPU

- a. Elimination of failures during communication with subsystems;
- b. Complete remote and local maintenance capabilities; and
- c. Reduce potential for safety hazards during maintenance.

In preparation for post-deployment modifications, interim design changes were implemented into the system. These included additional control cables, connectors, and thermal sensors for the VS and ALS. The addition of these components was part of an effort to further reduce the potential for snow and ice clogging by using a more complex heater control scheme. The complete functionality of the modified scheme will be realized when post-deployment modifications are completed.

VS accuracy and performance data were obtained from data collection sites during the period between Retest 6 and Retest 7. As mentioned in paragraph 1.3.3.1, these locations were established to collect sufficient amounts of data on VS performance under actual blowing precipitation conditions and fog.

Data from the collection sites, as well as results of specialized tests, indicated that the look-down configuration VS was extremely effective in reducing sensor failures due to snow and ice clogging. The look-down design also eliminated large window signals caused by precipitation striking the VS lens.

Reduced visibility testing indicated that this configuration was capable of operation within tolerance during actual Category IIIb conditions (paragraph 4.2.2.11).

4.1.7.2 Test Date and Location.

Testing was conducted during the following periods: June 6 through June 10, 1994 (Shakedown), and June 13 through June 20 (Integration) at MCI, Kansas City, Missouri.

4.1.7.3 Participants.

Personnel from the following organizations conducted and supported OT&E retest:

<u>Organization</u>	<u>Role</u>
ACW-200B	Test Director
ACN-100D	Test Engineering
AOS-220	Shakedown Test Engineering
ANN-400	Observer
MCI Air Traffic Controllers	User Evaluation
MCI AFSFO	Technicians
Kansas City Air Route Traffic Control Center	System Administrators

4.1.7.4 Specialized Test Equipment.

Test equipment included protocol analyzers and remote maintenance simulation software.

4.1.7.5 Test Objectives.

Test efforts were focused on an in-depth evaluation of the First Article components. The primary objective was to ensure that all predeployment modifications had been completed and were working as intended.

4.1.7.6 Test Descriptions.

The test descriptions were the same as stated in paragraph 4.1.6.6.

4.1.7.7 Data Collection and Analysis.

Test conduct forms were maintained during testing and discrepancy reports were created as issues occurred. Data communication log files were also established for analysis purposes.

4.1.7.8 Test Results.

Test results indicated resolution of nearly all items identified as predeployment critical.

Work-around solutions were implemented or planned for problems which could not be totally resolved before national deployment.

A discussion of results is provided in the following subparagraphs.

4.1.7.8.1 Sensor Performance.

Modifications to ALS window contamination algorithms were successful in preventing failures during simulated precipitation tests. Modifications also resulted in window contamination readings which appeared to be accurate throughout test scenarios.

In general, VS were more resistant to failures occurring from precipitation striking the receiver and transmitter lenses than in previous tests. When failures occurred, recovery time was significantly shorter than in previous tests. It should be noted that the likelihood of precipitation striking the VS lenses during typical rain or snow storms was greatly reduced by the look-down design.

Despite addition of optical filters, erratic performance was again observed during simulated precipitation with bright sunlight. However, due to the infrequent occurrence of precipitation with bright sunlight and the high runway visibility associated with these conditions, this problem was considered noncritical.

Difficulties were again encountered with VS calibration; however, it appeared that the problem was related to cloudy weather conditions. Although this problem was considered noncritical, ACW-200 recommended an investigation into the cause followed by a post-deployment resolution.

4.1.7.8.2 System Documentation.

The On-Site Technical Instruction manual contained nearly all of the updates requested by the test organizations. Some procedures and chapters were still deficient in content or contained errors. In particular, the battery checkout procedure was in error and did not reflect differences between VS and ALS SIEs. Additional updates and correction of noted errors were recommended for the On-Site Technical Instruction manual.

4.1.7.8.3 Maintenance.

Most maintenance problems were resolved with the advent of First Article SIEs, DPU, and maintenance procedures. In particular, problems noted with SIE corrosion and lightning protection were resolved. Battery monitoring problems were resolved by incorporating additional monitoring capabilities into the SIEs and by adding maintenance procedures to eliminate the possibility of undetected battery failures.

Maintenance displays on the MDT were modified to allow reading and setting of RVR parameters without using conversion factors to change numbers to common units.

Outstanding problems included the inability of the RLIM to detect sensor faults. The solution for this problem was an addition to the On-Site manual notifying airport technicians of the sensor limitations. All other maintenance problems were considered non-critical.

4.1.7.8.4 Remote Maintenance Monitoring.

Test results indicated the correction of most RMM problems described previously. In particular, significant problems with failures in alarm generation or clearing were corrected. Also, problems including RMS message formatting and the execution of fault diagnostic commands were corrected.

Significant in the outstanding problems was the occurrence of communication failures between the RVR RMS and the MPS. Effects of this problem include the failure of the RVR RMS to send priority messages to the MPS. This had been noted in previous test results, but was not resolved due to difficulties in consistently reproducing the problem. It was expected that an automated work-around solution could be implemented after testing. ACW-200 requested the work-around be developed immediately and be implemented in any system scheduled for commissioning. No other significant problems were noted during testing.

4.1.7.8.5 Personnel Safety.

Nearly all personnel safety issues were resolved. Electrical shock hazards were reduced by moving voltage terminals and adding terminal block covers. Warning labels were also added.

The potential for physical injury while raising or lowering VS poles continued to be an issue. A modification to the mechanical lift hardware was recommended to resolve this problem.

4.1.7.8.6 Controller Display.

The ability to adjust display and function key brightness was incorporated. Data loss protection and additional memory were added.

4.1.7.9 Recommendations.

In light of the resolution of the more serious system discrepancies, as well as many of the less significant problems, a national deployment recommendation was issued by ACW-200B. This recommendation was subject to the following conditions:

- a. The immediate investigation and implementation of an automated work-around solution for the communication problem involving the RVR RMS interface;

- b. The implementation of a final solution to the RMS interface communication problem after national deployment;
- c. Additional testing to better define the response of the system to precipitation during sunlight;
- d. Collection of additional performance data under Category IIIb conditions; and
- e. Investigate and correct calibration difficulties related to cloudy weather conditions.

4.2 SPECIALIZED TESTS.

Specialized testing of RVR components began following Retest 3. The lack of any real progress in eliminating weather related sensor problems dictated the need to initiate a more focused development and test effort in this area. The need was intensified by pressures to field an acceptable system at DVX, even though a national deployment system was still considered to be months away. The specialized test effort was conducted on an accelerated schedule which ran concurrent with the schedule for Retests 4 and 5.

4.2.1 Cold Regions Research and Engineering Laboratory Tests.

CRREL tests were intended to assess the performance of the VS and ALS under blowing precipitation and Category IIIb conditions. These tests were conducted during the same time period as Retest 4. Refer to appendix H for detailed reports concerning test activities at CRREL.

4.2.1.1 Background.

The CRREL is a facility owned by the U.S. Army. It has the capability to provide simulations of cold weather phenomenon including below zero temperatures, snow, and freezing rain. The laboratory includes various temperature chamber rooms and apparatus for reproducing diverse weather conditions.

Deficient performance during blowing precipitation was known to be a problem throughout RVR test history. Modifications such as the addition of precipitation filters and enhanced precipitation algorithms were unsuccessful in preventing serious problems including sensor failures, erratic visibility readings, and system shutdowns.

4.2.1.4 Specialized Test Equipment.

Various equipment was used in the simulation of blowing precipitation conditions and for data collection. A listing of the apparatus used in the simulation of blowing precipitation are provided as follows:

- a. Temperature chambers,
- b. Wind tunnels,
- c. Snow generation apparatus,
- d. Mist generators, and
- e. Fog generators.

Data collection devices included the following:

- a. Data acquisition computers,
- b. Infrared video cameras, and
- c. Video cameras.

4.2.1.5 Test Objectives.

In general, the objectives of testing were to find ways to improve VS and ALS performance under blowing precipitation and to acquire data to verifying Category IIIb performance.

Because the RVR system had consistently shown weaknesses in performance during blowing precipitation, CRREL tests were designed to:

- a. Assess severe weather performance under controlled conditions;
- b. Provide data for development of system modifications;
- c. Provide direct comparisons between different configurations of VS and ALS;
- d. Determine optimum sensor design; and
- e. Gain a better understanding of the effects of blowing precipitation; particularly, snow and ice clogging, high window signal levels, and extinction coefficient readings.

4.2.1.6 System Configuration.

Because CRREL tests were intended primarily to evaluate the VS and ALS, a complete system configuration was not required. As a result, RLIMS, CDs, and the RMS interface were not used. The exclusion of these system components had no effect on test results.

For the CRREL tests, the RVR system consisted of the following components and interfaces:

Components

- a. Visibility Sensors (2). One look-down configuration and one look-across configuration, installed inside of test chamber;
- b. Ambient Light Sensor (1). Installed inside of test chamber;
- c. Data Processing Unit (1). Installed outside of test chamber; and
- d. Sensor Interface Electronics enclosures (3). Installed inside of test chamber.

Interfaces

- a. Maintenance Data Terminal. The MDT interface was used to monitor system parameters during testing; and
- b. External User. The EU interface was used throughout testing for the collection of system parameter data.

4.2.1.7 Test Descriptions.

The tests performed fell under one of two main categories of evaluations; blowing precipitation or low visibility (fog). Descriptions are provided in the following subparagraphs.

4.2.1.7.1 Blowing Precipitation.

Blowing precipitation tests consisted of various scenarios of blowing snow, rain, and mist directed at the sensors for sustained intervals. As weaknesses or trends were observed in sensor performance, additional test scenarios were created to obtain more information. For example, if it appeared that snow accumulation or high window contamination readings were dependent on the direction of precipitation, additional test scenarios would be created to determine which directions caused problems.

Any weaknesses observed were noted by the test team. Information was collected via video film recordings, DPU monitoring, and written observations. Included in the assessment were direct comparisons between the look-down and look-across configurations under identical test conditions.

Effects of blowing precipitation, such as snow/ice accumulation, window signal patterns, and extinction coefficient fluctuation, were observed and noted by the test team. Testing was designed to determine the limits of sensor tolerance to blowing precipitation for each of the sensor prototypes.

4.2.1.7.2 Low Visibility Tests.

To assess Category IIIb performance, fog was simulated with test equipment. Testing consisted of comparing RVR readings with an Optec transmissometer under the same Category IIIb conditions. The Optec was modified to operate over a short baseline to accurately measure Category IIIb visibility.

4.2.1.8 Data Collection and Analysis.

Extensive data were collected in the form of computer and video files as well as observation notes. Data analysis consisted of a review of sensor performance after each test scenario.

4.2.1.9 Test Results.

Results of blowing precipitation and low visibility tests are summarized in the following subparagraphs.

4.2.1.9.1 Blowing Precipitation.

Prototype VS and ALS designs exhibiting improved blowing precipitation performance were established. The design improvements were successful in reducing the probability of sensor failures; and hence, system shutdowns during test conditions.

Design prototypes included the Look-Down VS with extended hood heaters; and an ALS with a higher power and more conformal hood heater design. Results also prompted the removal of a mounting ledge on the ALS which significantly reduced its susceptibility to snow clogging.

4.2.1.9.2 Low Visibility Tests.

A significant amount of Category IIIb data was obtained; however, due to problems in sustaining Category IIIb conditions, as well as erratic and uncorrelated VS readings, Category IIIb test results were considered inconclusive.

4.2.1.10 Recommendations.

Based on test results, additional modifications were recommended by the test team. The recommended modifications included additional changes to the hood and window heater designs of the Look-Down VS and the ALS. The addition of more sophisticated heater control schemes to further reduce the possibility of ice or snow accumulation was also recommended.

Although it appeared that a significant improvement in performance could be attained with the new sensor designs, the acquisition of test data during actual blowing precipitation conditions was strongly recommended by the test team; hence, it was recommended that data be collected from the automated data collection sites identified in paragraph 1.3.3.1.

4.2.2 Category IIIb Validation.

This section describes results of Category IIIb testing performed on the RVR system. The intent of the tests was to provide RVR performance data during actual Category IIIb visibility conditions. Refer to appendix I for individual reports.

4.2.2.1 Background.

Although it had been shown, in theory, that the New Generation RVR could perform within specification throughout the Category IIIb range, little data existed for performance under actual conditions. This was the first evaluation of the RVR conducted specifically to evaluate performance under actual Category IIIb weather conditions.

The Category IIIb tests were part of the rapid-prototyping effort started with the CRREL tests. As part of this effort, the look-down and look-across configuration VS were compared for accuracy, and resistance to extreme weather conditions. Category IIIb tests were conducted during the same timeframe as Retest 5.

4.2.2.2 Test Date and Location.

Testing was conducted from September 13 through 21, 1993, at the summit of Mt. Washington in New Hampshire.

4.2.2.3 Participants.

Personnel from the following organizations conducted and supported this test:

<u>Organization</u>	<u>Role</u>
VNTSC	Test Engineering
AOS-220	Test Engineering
ACW-200B	Test Director
Mt. Washington Observatory	Resource Support

4.2.2.4 Specialized Test Equipment.

Specialized equipment used during testing is listed below. The purpose for each device is briefly described in subsequent paragraphs.

- a. Runway centerline light fixture,
- b. Variac power supply,
- c. Rackmount data acquisition computer,
- d. Optec Long-Path Visibility Transmissometer, and
- e. Portable PC with RVR measurement software.

4.2.2.4.1 Runway Centerline Light Fixture.

A centerline light fixture, identical to those used at most U.S. airports, was used as a high-intensity target to measure viewing distances by test team observers.

4.2.2.4.2 Variac Power Supply.

A variac power supply was used to provide the required power to the runway light fixture for operation at the standard light settings used in airports. Standard runway light settings one through five were used during testing.

4.2.2.4.3 Rackmount Data Acquisition Computer.

A rackmount data acquisition computer was used to record RVR and transmissometer data during testing. This information was accessed via the RVR EU port and a data port on the Optec Transmissometer.

4.2.2.4.4 Optec Long-Path Visibility Transmissometer.

The Optec Transmissometer was used as a reference for comparing RVR readings during test scenarios. Because this transmissometer is normally used to measure distances greater than those in the Category IIIb range, it was modified (the baseline was shortened) to measure distances required during testing.

4.2.2.4.5 Laptop PC and RVR Measurement Software.

A laptop PC and RVR measurement software were used to facilitate the process of conducting observations by the test team. The RVR measurement software was a duplication of the algorithm used in the RVR to calculate runway visual range. It was designed to utilize sensor data from the EU port to provide the RVR normally displayed at the CD. Using the PC and RVR measurement software, the test team was able to record human observations and RVR system output simultaneously.

4.2.2.5 Test Objectives.

The primary objective was to provide data reflecting RVR performance during the full range of Category IIIb conditions.

Secondary objectives included:

- a. Comparing RVR readings from the Look-Down and Look-Across VS to identify any inconsistencies between the designs; and
- b. Noting any significant effects of weather on VS measurements.

4.2.2.6 System Configuration.

Category IIIb tests were evaluations of sensor performance as opposed to system performance; consequently, RLIMs and CDs were not required. RLIM values for calculating RVR were input manually by the test team.

The test configuration was as shown below:

Hardware

- a. Visibility Sensors (3). One look-down and two look-across were installed on 12-foot poles at the mountain summit;
- b. Ambient Light Sensor (1). Installed on a 12-foot pole at the mountain summit;
- c. Data Processing Unit (1). Installed inside the Mt. Washington Observatory; and
- d. Sensor Interface Electronics enclosures (4). Collocated with each sensor.

Interfaces

- a. Maintenance Data Terminal. The MDT interface was used to monitor system parameters during testing; and
- b. External User. The EU interface was used throughout testing for the collection of system parameter data.

4.2.2.7 Test Descriptions.

Testing consisted of making and comparing the visibility measurements of a human observer, a transmissometer, and the RVR VS.

Refer to the "Category IIIb test report for the New Generation Runway Visual Range" in appendix I for a detailed description of test procedures.

4.2.2.8 Data Collection and Analysis.

Data was collected via the data acquisition system and notes taken by the test team. Analysis was conducted throughout the testing period. Graphs were developed showing the relationship of visibility measurements of the RVR sensors, the Optec Transmissometer, and human observers.

4.2.2.9 Test Limitations.

Because the Category IIIb testing was conducted under real weather conditions, scientific controls were difficult to implement and limitations were inherent in the procedures and equipment. These limitations are discussed in the following subparagraphs.

4.2.2.9.1 Limitations in Test Equipment.

The RVR system calculations assume the use of an aged, dirty runway centerline light. The light used for testing was new and clean.

4.2.2.9.2 Limitations in Test Setup.

In general, the test setup was a simplified approach for measuring runway visibility. The amount of space available for use at the summit of Mt. Washington was limited. As a result, the entire Category IIIb range could not be tested.

In addition, the sensors and the observers were not collocated for most of the observations; equal fog densities at both locations could not be guaranteed.

Lastly, for short observation distances (e.g., less than 100 feet), observers were outside the primary path of the runway light beam. Visibility conditions during the test period provided very few observations in this range.

4.2.2.9.3 Limitations in Test Conduct.

For some daylight conditions, RVR calculations are based on a black target instead of a runway light. This is done because, under certain lighting conditions, the black target presents more contrast than the runway light. For the Category IIIb tests, observers used only the runway centerline light.

4.2.2.9.4 Limitations in Analysis.

No accepted standard exists for RVR measurement. Therefore, performance evaluation was done by cross comparison of different methods of measuring RVR. Methods of measurement for this testing included the New Generation RVR, the Optec Transmissometer, and human observers. This lack of a standard, as well as the use of human observers, leads to an inherent subjectivity in test results.

4.2.2.10 Test Results.

Test results indicated that the average difference between RVR readings and observed visibility was within 100 feet. One hundred feet equates to one reporting unit of the RVR system and is within the requirements of the RVR specification. It should be noted that although the average measurements were within specification, some out-of-spec measurements were recorded. See appendix I for details on measurements and possible rationale of out-of-spec data.

Test results also indicated that, due to its inability to perform during severe weather conditions at Mt. Washington, data from the Optec transmissometer was not reliable for measurement comparisons.

4.2.2.11 Recommendations.

Results showed generally acceptable performance of the sensors and system; however, to reduce uncertainties due to limitations noted above, additional Category IIIb tests were recommended by ACW-200B. Specifically, test conditions which significantly reduce the subjectivity of measurements were advised.

5. SUMMARY OF OT&E TESTING.

The RVR OT&E period lasted approximately 2½ years, commencing with initial OT&E tests in March 1992, and ending with Retest 7 in June 1994. In addition to seven retests and two specialized test efforts, Factory, Software, and Design Qualification tests were conducted for each design change.

A review of the test efforts reveals that most problem areas and issues were discovered during initial OT&E testing. Many of the problems discovered in later tests were related to those found initially. For example, system shutdown problems were noted early in testing and continued throughout. Initial testing showed the shutdowns to be related to water contamination on sensor lenses. When the sensors were made more tolerant to water on the lenses, it was discovered that shutdowns could be caused by simulating precipitation in the sample volume during sunlight conditions. The involvement of sunlight in shutdowns was not understood prior to correction of lens contamination problems.

The possibility of snow/ice clogging of the VS presented an area of large concern for the test team. Any buildup of snow or ice in front of, but not actually touching, the VS lens would go undetected by the window contamination sensors. Transmitted light from the sensor would then be blocked by the snow or ice, with the result mimicking a high visibility situation. Testing and review of previously collected data revealed instances where clogging could be induced under weather conditions not uncommon in the United States. Because tests with increased heater power proved unsuccessful, the look-down design was implemented. The Look-Down VS with conformal hood heaters was shown to be very reliable under all weather conditions.

Maintenance, RMM, and documentation were areas that initially had a large number of discrepancies. The discrepancies were a concern to the test team by virtue of their sheer number, rather than the severity. As opposed to the difficulties with sensor shutdowns, problems in the maintenance and documentation areas became fewer as testing progressed. The exceptions being the continued lack of an Off-Site Maintenance Manual and the failure to completely correct RMS communication failures.

Although each test effort was valuable in verifying the resolution or occurrence of problems, specialized tests provided the most information in the shortest period of time. Because of their narrow focus, these tests provided a rapid method of modifying the system and verifying performance. This method proved instrumental in finally correcting the major system problems and obtaining a national deployment decision.

6. FINAL RECOMMENDATIONS.

The New Generation Runway Visual Range (RVR) system which was fielded at the completion of Operational Test and Evaluation (OT&E) is considered by ACW-200 to be a very capable and reliable system. The sensors and software differ drastically from those initially tested in February of 1992.

The following specific recommendations are made in light of the final test results:

- a. Additional testing should be conducted to further define system performance under Category IIIB conditions. This should include comparison testing with the certified RVR systems currently in use in the United Kingdom;
- b. The use of "smarter" heater control algorithms should be investigated. This would include determination of conditions where heaters would not keep up with heat loss, and whether shutting heaters off under these conditions would prevent snow or ice buildup;
- c. The RVR Off-Site manual should be completed;
- d. All system documentation should be updated and validated;
- e. The Remote Monitoring Subsystem (RMS) communication problems should be corrected, and the work-around solution removed from the system software;
- f. Automated Surface Observing System (ASOS) and Tower Control Computer Complex (TCCC) interfaces should be incorporated; and
- g. All other open issues should be corrected as soon as possible.

In light of the lengthy test effort required for the RVR system, the following general recommendations are made for future RVR modifications as well as future procurements:

- a. Prior to developmental testing, an assessment should be made to determine if environmental test procedures will adequately determine system performance under adverse weather conditions. If, as with the RVR, laboratory tests cannot approximate real weather conditions that might affect the system, special testing should be considered;

- b. If retests are required, a brief plan outlining goals and procedures should be prepared for each retest. Schedule pressures should not be allowed to circumvent this process;
- c. Retests should not be conducted on unreleased software. If it is necessary to evaluate engineering prototypes at the key site, the test should be conducted by the system developers and witnessed by OT&E test members;
- d. If initial OT&E results in discovery of significant problems, retest should only be conducted when developers have shown that all discrepancies have been rectified; and
- e. The test team should ensure that the system is ready for retest by witnessing factory qualification and verifying that a new software version has been released.

7. ABBREVIATIONS AND ACRONYMS.

ACW	Engineering, Integration, and Operational Evaluation Service
AFSFO	Airway Facilities Sector Field Office
ALS	Ambient Light Sensor
AOS	Operational Support Directorate
ASOS	Automated Surface Observing System
CD	Controller Display
CRREL	Cold Regions Research and Engineering Laboratory
DVX	Denver International Airport
DOT	Department of Transportation
DPU	Data Processing Unit
EU	External User
FAA	Federal Aviation Administration
MCI	Kansas City International Airport, Kansas City, MO.
MDT	Maintenance Data Terminal
MPS	Maintenance Processor Subsystem
MRS	Mountain Research Station
NAS	National Airspace System
OT&E	Operational Test & Evaluation
PC	Personal Computer
RLIM	Runway Light Intensity Monitor
RMM	Remote Maintenance Monitoring
RMS	Remote Monitoring Subsystem
RVR	Runway Visual Range
SEA	Seattle-Tacoma Airport, Seattle, WA
SIE	Sensor Interface Electronics
TCCC	Tower Control Computer Complex
TRACON	Terminal Radar Approach Control
TSC	Technical Services Contract
TTR	Test Trouble Report
YYT	St. John's Newfoundland
VS	Visibility Sensor