

## P8.4. THE OTIS WEATHER TEST FACILITY AT OTIS ANGB, FALMOUTH, MA: AN AVIATION WEATHER RESOURCE

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### 1. INTRODUCTION

This paper presents a description of the Otis Weather Test Facility (WTF) and its capabilities for aviation weather-related studies and testing. The Otis WTF is located on the US Air National Guard Base (ANGB), Cape Cod, MA. The site is particularly well suited for visibility studies because of its climatology, which generally provides numerous opportunities for both all-season fog events and winter snowfall.

#### 1.1 Characteristics

*Location* – The Otis WTF is located on 155 acres on a relatively flat ridge within the grounds of the Otis Air National Guard Base (ANGB) on the western edge of Cape Cod. The facility is at 41.4° N Latitude and 70.3° W Longitude, a few miles north of Falmouth, MA and approximately 80 statute miles SSE of Boston, MA. Its location is shown in Fig. 1 (National Atlas of the United States, 2000).

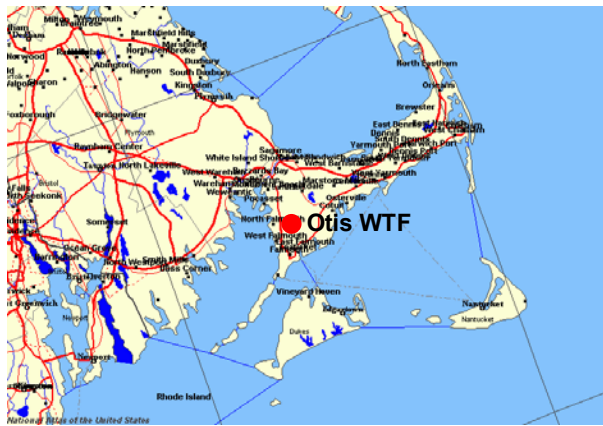


Fig. 1 – Map of the Otis Weather Test Facility Area.

The facility has weather instruments including ceilometers, anemometers and sensors for measuring visibility, present weather, temperature, relative humidity and atmospheric pressure. The anemometers are mounted on a complex of towers ranging from 10' to 200'. Provisions are available for data from these and other instruments to be sent to a 2,600 ft<sup>2</sup> secured building via several types of data acquisition systems. The building is also used for fabrication of instrument components, testing, analysis, storage, planning meetings and other activities. The analysis support includes specialized computing software for analyzing

transmissometer and forward scatter meter visibility data along with an array of computer hardware for data acquisition and facility support. A number of automated weather stations, including one at the Otis ANGB, are nearby to provide official surface weather reports for reference purposes and general weather and climate characterizations. Fig. 2 shows one of the first Automated Weather Observing Systems (AWOS), which was used by the WTF to test and evaluate the performance of the system's suite of sensors as well as for the development of the AWOS Data Acquisition System (ADAS).

Because of the propensity of the site to experience many instances of low visibility throughout the year, the WTF's 155 acres of flat land and instrumented towers have been ideal for both near-surface and slant range visibility testing.



Fig. 2 – Weather Instruments at Otis WTF.

*Climate* - Otis WTF has an ideal climate for a weather-related test facility. Weather conditions vary widely throughout the year. Its proximity to the ocean produces frequent nocturnal and early morning fogs and low clouds. The fog is often quite uniform and persistent, attributes that are most useful for testing the performance of visibility sensors. Fog usually occurs frequently throughout the year, typically producing several events most every month. The average annual percentage of time the cloud ceiling is 500 ft or less and/or the visibility is one mile or less is 11%. After fog, the next greatest effect on visibility derives from snowfall; the facility averages 37 inches of snow each year. An average of about 48 inches of precipitation falls each year at the facility. June and July are the driest

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months while November and December are the wettest months. The facility also experiences an average of 16 thunderstorms per year. Wind gusts are also frequent because of its location near major storm tracks and proximity to the sea. The annual average wind speed is about 9 knots. Wind gusts exceeding 40 knots have been occasionally recorded particularly during hurricane and winter seasons. Temperatures also vary considerably at Otis with an extreme maximum of 99° F (37° C) in summer and an extreme minimum of about -10° F (-23° C) in winter. A table of monthly averages and record highs and lows for nearby Falmouth, MA (Intellicast) is shown in Fig. 3.

**MONTHLY CLIMATOLOGY**

Falmouth, MA

Month	Record Low (F)	Average Low (F)	Average High (F)	Record High (F)	Average Precip (in)	Average Sun (%)	Water Temp (F)
January	-8	19.6	37.1	65	3.7	53	34
February	-12	20.3	37.5	64	3.6	56	35
March	-3	28.5	44.5	78	3.6	57	37
April	9	36.6	53.1	87	3.9	56	45
May	24	46.1	63.2	91	3.7	58	55
June	31	55.8	72.5	94	3.2	63	63
July	42	62.3	78.5	98	2.9	65	71
August	34	61.6	77.4	100	3.4	65	71
September	26	53.6	70.8	95	3.4	63	68
October	9	43.3	61.6	83	3.9	60	59
November	7	35.4	52.1	74	4.5	50	50
December	-10	25.1	42.2	65	4.2	52	41

**Fig. 3 – Monthly Averages for Falmouth, MA.**

**2. HISTORY**

The US Air Force Cambridge Research Laboratory (AFCRL) [now Air Force Research Laboratory (AFRL)] originally established the WTF in 1974 to develop and evaluate weather sensors and systems. In particular, the WTF was necessitated by AFCRL studies on the technological development and calibration of forward scatter visibility sensors at Hanscom AFB near Boston, MA (Chisholm and Kruse, 1974; Muench et al.; 1974). The USDOT Volpe National Transportation Systems Center also began using the Facility in 1983 through a cooperative arrangement with AFRL and later became the primary manager in 1999 when AFRL chose to terminate its operations. Throughout its existence, the WTF has been primarily involved in weather sensor development and testing for USAF and FAA programs. Sample activities have included:

- Concept exploration and definition; demonstration and validation of stages in USAF weather-sensor acquisitions.
- Procurement of databases for the evaluation of weather sensors and systems.
- Testing, validation and improvements of weather observing techniques, sensors, systems and automation methods.
- Development and staging of equipment in support of field programs.

One of the most significant uses of the Otis WTF was support of the USAF Tactical Ground Observing System

(TGOS) field tests. Instruments and systems tested included ceilometers, present weather sensors, visibility sensors, prevailing visibility systems (computer-controlled video-based imaging system, whole sky imaging of cloud cover and an automatic horizon scanner), anemometers and tactical weather stations.

The Volpe Center has used the Otis WTF for research and development support of major FAA weather systems including

- Automated Weather Observing System (AWOS) – testing of sensors and automated reporting systems.
- Automated Surface Observing System (ASOS) – evaluating the haze response of forward scatter meters under the Joint Automated Weather Observing Program (JAWOP).
- AWOS/ASOS Data Acquisition System (ADAS) – testing of remote access to AWOS/ASOS systems for consolidation of automated reports of surface weather on a regional basis.
- Low Level Windshear Alert System (LLWAS) – surveyed performance of wind velocity sensors for LLWAS suitability. Anemometer technologies tested included propeller and vane, cup and vane, thermal, sonic and pressure.
- Runway Visual Range (RVR) System – provides continuous validation testing of forward scatter sensors, using transmissometers as reference standards.
- Automated Lightning Detection and Reporting System (ALDARS) – demonstrated and tested the performance of ALDARS via its effective integration with AWOS/ADAS systems.
- Stand Alone Weather System (SAWS) – provided evaluation platform for the evaluation of candidate SAWS systems during the evaluation phase of the system’s procurement.
- Sensor for Optically Characterizing Ring-Eddy Atmospheric Turbulence Emanating Sound (SOCRATES) - developed and staged equipment for the instrumentation of airports to test the SOCRATES concept.
- Jet Blast at JFK International Airport – developed and staged the development of equipment to measure effects of jet blasts on aircraft operations on intersecting runways at JFK

As noted in the above, the WTF has also been used to support the development, testing and preparation of instrumentation for testing and research at airports throughout the country. The latter include: Denver International Airport, Dallas-Ft. Worth International Airport, JFK International Airport, St. Louis International Airport, Memphis International Airport and San Francisco International Airport. These latter activities have been in

support of wake turbulence monitoring and research, RVR sensor development and evaluation and a jet blast investigation.

In addition to the above, the Otis WTF also tested and evaluated visibility instruments from England, France, Germany, Belgium and the USA during the visibility tests of Phillips Laboratory, Geophysics Directorate (GD, now AFRL) and Transportation Systems Center [TSC, now USDOT Volpe Transportation Systems Center (1983-84)],

Numerous Federal agencies and other organizations have used the Otis WTF for testing instruments and systems.

1. NOAA Environmental Research Laboratories (ERL), Boulder, CO – 915 MHz wind profiler; studying the contribution of North America to Ozone and other chemical constituents.
2. Office of Naval Research, Ocean and Atmospheric Physics Division and the Pennsylvania State University – project “Erica” (intense winter storms), Radar wind profiler and RASS.
3. NASA/Goddard Space Flight Center – Raman water vapor profiler tested against Otis WTF balloon launches.
4. Atmospheric Sciences Laboratory (ASL), US Army White Sands Missile Range - Office of the Test Directorate, Test and Evaluation Division – Precision Guided Weapons Counter-measure tests.
5. Atmospheric Environment Service, Ontario, Canada – Radar present weather identifier test.
6. NOAA/Wave Propagation Laboratory (WPL), Boulder, CO – Present weather identifier test; Light Emitting Diode Weather Identifier (LEDWI).
7. Phillips Laboratory (now AFRL) and other USAF Laboratories – Lidar testing, navigation balloon launches, temperature profiler and fog testing support.

### 3. CURRENT ACTIVITIES

Current projects at the Otis WTF include RVR, SAWS, wake turbulence, and Fog Eye. The latter is a program to evaluate ultraviolet light as a means of improving airport visibility during foggy conditions. A partial list of related recent publications is listed in the Appendix. Aviation related programs at Otis WTF include:

*Visibility Sensor Development* – Recent and ongoing monitoring, testing and calibration of forward scatter meters is conducted including comparisons with reference transmissometers and other forward scatter meters. A photo of forward scatter meters and reference transmissometers used in recent tests is shown in Fig. 4.



**Fig. 4 – Visibility Sensors.**

*RVR* – Continued testing and monitoring of new generation RVR systems is conducted, including calibration of visibility sensors; comparison of visibility sensors with other, similar visibility sensors and with reference transmissometers and evaluations of ambient light sensors. The Otis WTF has also been used as a development and staging site for RVR testing and monitoring equipment deployed at other remote test sites and airports (e.g. DEN, ORD, Mt. Washington).

*SAWS* - Anemometer data are gathered and archived for evaluating and analyzing the performance of wind speed, direction and gust reporting algorithms. Anemometers types include propeller and vane and sonic.

*Wake Vortex Staging* – Data acquisition system development and testing; anemometer testing and calibration; equipment development, testing and staging in support of measurements at airports such as St. Louis, Denver and San Francisco.

*Fog Eye* –The feasibility of using the solar-blind region of ultraviolet (UV) light for developing video systems and sensors not affected by sunlight for aviation use is being studied at the Otis WTF. Applications include runway incursion avoidance and improving pilot visibility in adverse visibility conditions. Staging for recent tests at T. F. Green International Airport, Providence, RI has also been done.

*Weather Sensors* – Reference sensors such as anemometers such as the one shown in Fig. 5, thermometers, dew point sensors, ceilometers, rain gauges, visibility sensors, pressure sensors and present weather sensors are monitored and used for analysis in support of the RVR program and other projects.



Fig. 5 – Anemometer Atop Tower.

#### 4. SUMMARY

This paper presented an overview of the Otis WTF, located at the Otis ANGB near Falmouth, MA on Cape Cod and operated by the Volpe National Transportation Systems Center. The facility is ideally situated with a climate favorable for testing visibility and other weather sensors. The facility has a wide variety of weather and visibility instruments including visibility sensors, present weather sensors, anemometers and ceilometers. Otis WTF has tested weather and other instruments and systems in numerous transportation and military-related projects during its 30-year history. The facility also serves an important resource for instrumentation development, field testing and staging of equipment in preparation for their deployment at test sites throughout the country.

#### Acknowledgements

Many individuals contributed to the operation and maintenance of the Otis WTF during its approximately 30 years of existence. The authors wish to thank Leo Jacobs and Ralph Hoar for insights into the early operational period of the facility as well as for their current efforts and dedication in maintaining it as a national resource for aviation weather testing and research. The Appendix identifies other key individuals whose efforts and work at the facility truly made a difference by helping to make aviation safer and more efficient.

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#### APPENDIX – SELECTED PUBLICATIONS ILLUSTRATING ACTIVITIES AT THE OTIS WTF

The following is a representative list of reports and publications related to activities at the Otis WTF.

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