ARMY RESEARCH LABORATORY

Local-Rapid Evaluation of Atmospheric Conditions (L-REAC™) System, Design and Development Volume 3 ("Operational L-REAC™")

by Gail Vaucher, Robert Brice, Saba A. Luces, and Sean O'Brien

ARL-TR-5727 September 2011

Approved for public release; distribution is unlimited.

NOTICES

Disclaimers

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

Citation of manufacturer‟s or trade names does not constitute an official endorsement or approval of the use thereof.

Destroy this report when it is no longer needed. Do not return it to the originator.

Army Research Laboratory

White Sands Missile Range, NM 88002-5513

ARL-TR-5727 **September 2011**

Local-Rapid Evaluation of Atmospheric Conditions (L-REAC™) System, Design and Development Volume 3 ("Operational L-REAC™")

Gail Vaucher, Robert Brice, Saba A. Luces, and Sean O'Brien
Computational and Information Sciences Directorate, ARL

Approved for public release; distribution is unlimited.

REPORT DOCUMENTATION PAGE	***Form Approved OMB No. 0704-0188***

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED (From - To)**
September 2011	Final	October 1, 2010–September 1, 2011

4. TITLE AND SUBTITLE

Local-Rapid Evaluation Of Atmospheric Conditions (L-REAC™) System, Design and Development, Volume 3 ("Operational L-REAC™ ")

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Gail Vaucher, Robert Brice, Lou Luces, and Sean O‟Brien

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

U.S. Army Research Laboratory
Computational and Information Sciences Directorate
Battlefield Environment Division (ATTN: RDRL-CIE-D)
White Sands Missile Range, NM 88002-5501

8. PERFORMING ORGANIZATION REPORT NUMBER

ARL-TR-5727

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

The U.S. Army Research Laboratory (ARL) has been investigating various aspects of the urban environment, including the airflow and stability characterization around a single urban building, and small building clusters. Experience and results from these studies led to the design and development of a decision aid called the *Local-Rapid Evaluation of Atmospheric Conditions (L-REAC™) System*. The ultimate goal for L-REAC™ is to improve soldier/civilian situational awareness of environmental airborne hazards during potentially life-threatening events. This goal is accomplished by mapping a near-real-time wind field and, once defined, an airborne-threat plume footprint over the subject area. Volume 1 presented the L-REAC™ "Proof of Concept" System. In Volume 2, we described an improved system, the L-REAC™ Prototype. In this third volume, we describe the development of an operational system which was evaluated by users and used in a real world event (the 2011 April Abrams Fires). The development efforts included gaining a better understanding of the users‟ requirements and determining methods for getting the results to the user in a quick, automated, secure and reliable manner. This volume concludes with a sample of the evaluation results, which will be published in a separate report.

15. SUBJECT TERMS

L-REAC™ System, airborne hazard assessment, wind field model, plume model, meteorological sensors

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**	UU	48	Gail Vaucher
Unclassified	Unclassified	Unclassified			**19b. TELEPHONE NUMBER** (*Include area code*) (575) 678-3237

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

Contents

List of Figures

List of Tables

Acknowledgments

The authors of this report wish to acknowledge the contributions of SERCO in assisting with several computer-related hurdles; specifically, Ms. Alma Parra and Ms. Melissa Blood, for their assistance in resolving various operational U.S. Army Research Laboratory (ARL) Production Networking hurdles; Mr. Edward Sano, for his assistance with the Demilitarized Zone (DMZ) network.

The Operational Local-Rapid Evaluation of Atmospheric Conditions (L-REAC™) System demonstration unit utilizes two independent models (note that the L-REAC System trademark is owned by the Department of the Army, Washington DC, 20310). Therefore, we would like to thank Dr. Yansen Wang, ARL for permitting us to include the Three-Dimensional Wind Field (3DWF) Model and Mr. Mark Miller (representing the National Oceanic and Atmospheric Administration/Environmental Protection Agency [NOAA/EPA]) for the ALOHA /CAMEO/ MARPLOT Model guidance.

Appreciation is extended to Mr. Ed Ellison (Acting Chief of the White Sands Missile Range [WSMR] Meteorological Branch-Army Test and Evaluation Command [ATEC]) and his associates, for the provision of the WSMR Surface Automated Meteorological System (SAMS) data access.

To the Technical Publishing Branch at WSMR, specifically Mr. Jim LeNoir and Ms. Sherry Larson, for their consistent efficiency in editing materials for publication, we thank you!

Finally, we would also like to thank our supervisor, Dr. Donald Hoock, for his consistently supportive guidance and technical feedback throughout the system design and development stages.

INTENTIONALLY LEFT BLANK.

Executive Summary

The Problem: To Protect Soldiers and Civilians from Airborne-released Hazards.

This report documents the fiscal year 2011 (FY11) advancement of the U.S. Army Research Laboratory (ARL) *Local-Rapid Evaluation of Atmospheric Conditions (L-REAC™)* System* decision aid technology, from "Prototype" to "Operational System." To better understand the term "operational," consider the following scenario and consequential decisions:

Truck tires squeal loudly outside your office window. The sound of thick metal submitting to the immobility of a multi-story concrete building turns your eyes to the window. A strange, un-friendly odor begins to fill the air. ...and the emergency "first response" decisions begin.

In any emergency, there will be many levels of decisions. These decisions begin with the building occupants who must decide whether to shelter-in-place (SIP), evacuate or take the time to call for help. Building custodians and supervisors must decide how to best advise the building occupants and secure help. The Help Dispatch (911 operators) must decide how to advise residents and determine which response units to dispatch (security, safety and property preservation) and suggest how these units might safely approach the hazardous incident. Each emergency unit dispatched must determine the critical safety requirements with regard to their approach, their attire, and their assigned tasks. And then there are the Incident Commanders (at a command center and/or in the field) who need to conceptualize the extent of the incident"s impact and advice field units accordingly. All these critical decisions, as well as other cascaded choices will continue until the area of interest (AOI) is once again declared safe for public use.

What common use tool is there that will aid each of the decision makers listed above?

ARL has been developing a decision aid beneficial to each of the above decision makers. This technology is a product of three detailed ARL urban field studies that characterized the airflow and stability around a single urban building. Three disaster response exercises were included in the last urban field study. From these experiences, the need to bring timely and relevant atmospheric conditions to emergency response decision makers, in a user-friendly format, came into focus. ARL answered this requirement by developing the L-REAC™ System. The ultimate goal for this tool is to improve military and civilian situational awareness of the natural environment and to better respond to potentially life-threatening airborne hazard events.

The L-REAC™ System is composed of five foundational hardware/software subsystems (or Modules) linked by specialized networks. These subsystems consist of: (1) a Sensor Module, (2) a Model Module, (3) an End User Display (EUD) Module, (4) a data Quality Control (QC) Module, (5) and an Archive Module. The Sensor Module was designed to provide timely

* The L-REAC System trademark is owned by the Department of the Army, Washington DC, 20310.

(current) and relevant atmospheric data from a single and/or an ensemble of meteorological sensors. The Model Module interprets these data by generating an air flow field over a given AOI within 2–10 min (depending on the domain size) of receiving the atmospheric data. The EUD continually displays the current wind field to authorized end users, for a given AOI. If an airborne hazard is defined, the user enters this information; the EUD Module-plume model evaluates the current atmospheric conditions and produces a mapped toxic plume. The EUD Module-display then collates this mapped hazardous image to the perpetual wind field updates. These results are distributed to authorized users over established communication networks. These networks ensure a timely information flow (on the order of minutes) from the atmospheric sensors and models, to the decision-maker EUD displays.

In this third volume documenting the development of the ARL L-REAC™ System, we briefly describe the research that prompted the L-REAC™ System concept, and the two predecessor units (Proof of Concept and Prototype) leading to the current Operational L-REAC™ System. The Operational L-REAC™ System is presented by Modules. The discussion section of this report includes some of the future development being pursued. One of the highlights to this year‟s development effort was having the L-REAC™ System participate in real world events and Force Protection Exercises. Another was having the system evaluated in detail, by professional first responders. A preliminary summary capturing a sample of the very positive feedback given by these emergency first responders precedes the final comments. This report concludes the Department of Defense Technology Readiness Level five (out of nine) journey.

1. Background

This report documents the fiscal year 2011 (FY11) advancement of the U.S. Army Research Laboratory (ARL) *Local-Rapid Evaluation of Atmospheric Conditions (L-REAC™)*[*] *System* decision aid technology, from "Prototype" to "Operational." To better understand the term "operational," we present a scenario that captures both the problem being addressed by this technology and the niche in which the Operational L-REAC™ System fills.

The Problem: To Protect Soldiers and Civilians from Airborne-released Hazards.

Truck tires squeal loudly outside your office window. The sound of thick metal submitting to the immobility of a multi-story concrete building turns your eyes to the window. A strange, un-friendly odor begins to fill the air. …and the emergency "first response" decisions begin.

In any emergency, there will be many levels of decisions. For the given incident, an airborne hazard leaking from an impacted chemical tanker vehicle–here is a typical sequence of decisions put in chronological order:

1. Building occupants of the impacted and neighboring buildings must decide whether to SIP, evacuate or take the time to call for help.
2. Building custodians and supervisors must decide how to best advise building occupants and secure help.
3. The Help Dispatch (911 operators) must decide how to advise residents: SIP or evacuate. They also determine which response units to dispatch (security, safety and property preservation) and suggest how these units might safely approach the hazardous incident.
4. Each emergency unit dispatched must determine the critical safety requirements with regard to their approach and their assigned tasks. For example:

    4.1 Airborne hazards may require special protective gear for participants, in order to protect the human body.

    4.2 Security: Police assigned to security and traffic control need to know the hazards of their assigned duty site and task, which may be securing a building, directing traffic, etc.

    4.3 Safety: Medical units need to establish Hazard Control Zones for addressing the incident, for detoxifying personnel/equipment, and for providing a safe environment in which their multiple support activities can function. They also need to triage/prioritize rescue locations of victims by the vulnerabilities to the victims and to themselves.

---

[*] The L-REAC System trademark is owned by the Department of the Army, Washington DC, 20310.

Fire crews need to select appropriate protection attire for entering any structure involved in an airborne hazard incident.

4.4 Property: Fire units need to address structural hazards involved in the incident. (Often the safety and property functions run in parallel.)

5. Incident Commanders (at a command center and/or in the field) need to conceptualize the extent of the incident‟s impact and advise field units accordingly.

All these critical decisions, as well as other cascaded choices, will continue until the area of interest (AOI) is once again declared safe for public use.

How can these decision makers make informed and potentially life-saving decisions? ARL has been developing a decision aid that provides timely and relevant atmospheric information to civilian and military emergency first responders. This decision aid is called the L-REAC™ System. The research that prompted the creation of L-REAC™ System is described next, followed by a description of the system.

1.1 Research Leads to a New Technology

The foundational research for the L-REAC™ System Project began in the early 2000s, when ARL conducted three progressively more complex urban field studies. The first study, called *White Sands Missile Range (WSMR) 2003 Urban Study* (*W03US),* studied airflow and stability around a single urban building. This study sought to verify the 1994 Environmental Protection Agency (EPA)/National Oceanic and Atmospheric Administration (NOAA) wind tunnel results by sampling atmospheric data at strategic locations around a rectangular office building. Seven airflow features were identified for verification. Figure 1 displays six of the seven features: fetch flow, velocity acceleration, velocity deficit, cavity flow, leeside corner eddies/vortices and the re-attachment zone. The seventh feature not diagramed was a "canyon flow," an accelerated flow that occurs between two parallel buildings. Based on the successful *W03US* results, two subsequent urban studies were executed around the same urban environment, each with an increased density of dynamic and thermodynamic measurements. These studies were called *WSMR 2005 Urban Study (W05US)* and *WSMR 2007 Urban Study (W07US)*, respectively. ARL technical reports documenting these studies and their findings include: Vaucher, 2006; Vaucher et al., 2008 (*Volumes DP-1, DP-2, DP-3; 2007*); Vaucher, 2007 (*Volume AS-1; 2007*); Vaucher, 2008 (*Volume AS-2; 2007*); Vaucher, 2011 (*ARL-TR-5706: W07US, Data Analysis, Volume DA-1*). During *W07US*, simulated disaster response drills were run concurrently with the data acquisition. From this experience, the concept for a near real-time atmospheric evaluation system was identified.

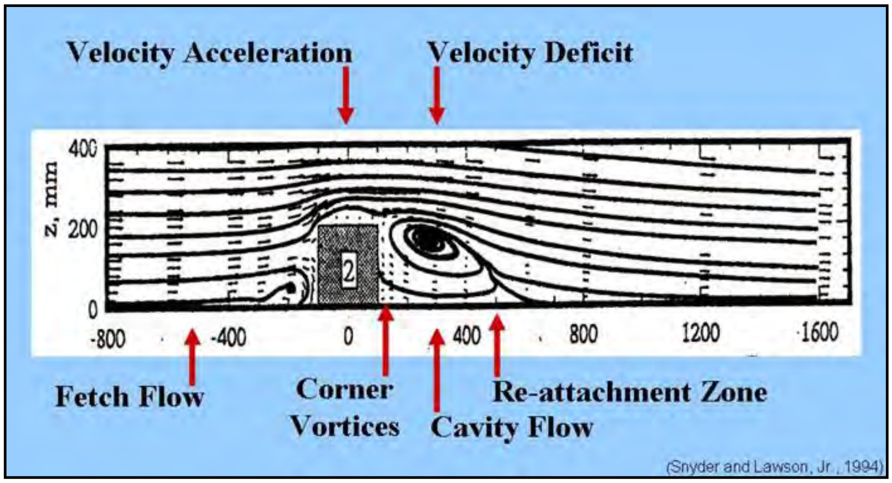

Figure 1. EPA/NOAA wind tunnel results show the airflow pattern around a single building. Streamline flow is from left to right. The "canyon flow" is not shown. (Snyder and Lawson, Jr., 1994).

In 2009, the near real-time atmospheric evaluation system concept was labeled the L-REAC™ System and was manifested in a tangible, Linux-Windows dual operating system (OS) Proof of Concept (PoC). The L-REAC™ System PoC included three core modules linked by specialized networks. These modules consisted of a Sensor Module, a Model Module, and an End-User-Display (EUD) Module (see figure 2). The details for each module will be presented in later sections. The L-REAC™ System PoC was documented in the *Volume 1* (Vaucher et al., 2009).

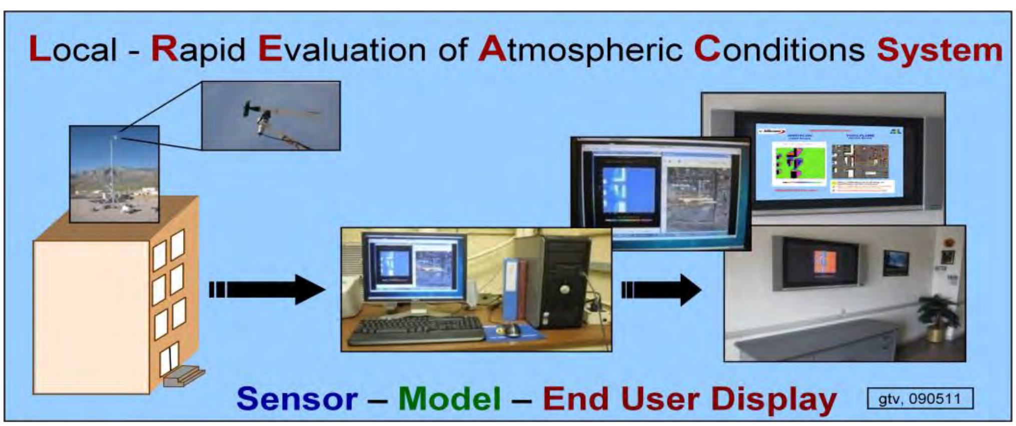

Figure 2. The L-REAC™ System PoC included sensors continually acquiring data from a representative location in the AOI, a Wind Field Model continually interpreting the wind flow conditions based on the sensor input, a Plume Model assessing the airborne hazard scenario, and an EUD communicating both the near real-time wind flow and hazard assessments.

In 2010, a single Windows OS L-REAC™ System "Prototype" was constructed. Within this "Prototype", the three core modules were significantly enhanced, and two system features within the earlier design were re-designated as full modules. The two features were labeled the Quality

Control (QC) Module and Archive Module. Additional details for each of these Modules will be expounded on in a later section. The "Prototype" System was documented in the *Volume 2* (Vaucher et al., 2010).

In FY11, improvements to each system module continued, and the end product was called the Operational L-REAC™ System. One of the primary goals for the Operational L-REAC™ System was to bring the operational system into a field environment, where professional emergency first responders would provide a practical end user‟s evaluation. A sample of the results from these evaluations is included within this report.

1.2 The Basic L-REAC™ System Design

The L-REAC™ System is an automated, 24/7, emergency response decision aid for airborne toxic release incidents. The current L-REAC™ System design is composed of five core modules, three of which comprise the foundational hardware/software subsystems linked by specialized networks. These subsystems include a Sensor Module, a Model Module, and a EUD Module. The Sensor Module is designed to provide timely (real-time) and relevant atmospheric data from a single and/or an ensemble of meteorological sensors. The Model Module interprets the contemporary data by generating a local wind field over the AOI. This wind field is continuously updated by the Sensor Module data feed and the output is displayed by the EUD Module. When an airborne hazard occurs, a trained operator keys in the hazard specifications (for example, hazard type, amount, release method, and so forth) to a quick processing, emergency response plume model, which is also part of the EUD Module. This third module automatically assimilates and synchronizes the wind and plume model outputs into both building- and regional-scaled images for the end user to utilize for assessing safe/hazard zone decisions. The EUD output is distributed to end users over their established networks. Updates to the wind field (and plume) outputs are automatically transmitted to the end users after each wind field model run is completed. A System-specific network ensures a timely information flow (on the order of minutes for building scales and 8–10 min for regional scales) from the atmospheric sensors and models, to the decision-maker EUD displays. An "Instantaneous Save" option allows the system operator to zoom in/out on an end-user-specified area and immediately transmit those results, between the automated cycles.

Since model output is highly dependent on the quality of data ingested, a data QC Module allows the user to instantly evaluate the status of all the L-REAC™ System sensors. An Archive Module saves the ingested L-REAC™ data, and when the user selects the option, saves all incident EUD imagery as well. These archive files can be used for incident reviews and Post-Event data analyses.

1.3 Defining an Operational System

The operational environment for the L-REAC™ System technology was described in an earlier section. We address the concept of what an operational system is, here. One definition of an operational system is a system that is easy to download, easy to set up, capable of running in most environments (geographical and computational), reliable, and accurate. However, this report is not describing the usual operational system. We are describing a system that solves very specific customer requirements, on a developer-chosen computer system, using specific inputs and requiring specific knowledge of the geographical site. Therefore, this system was considered operational if it could run reliably and produce results that would satisfy the requirements of our intended customers. Given these constraints, we believe the Operational L-REAC™ System has been successfully accomplished.

1.4 The L-REAC™ System Demonstration Unit

To prove the L-REAC™ System design, a demonstration unit was created and evolved into what is today the Operational L-REAC™ System. While the system design was purposefully constructed around flexible modules, the demonstration system uses specific features. In this section, we briefly re-cap some of the key features of the current demonstration system.

The PoC showed that an L-REAC™ System could be built on a dual OS. However, the Operational L-REAC™ System was built on the simplicity of the Prototype‟s single OS. The specialized networks linking each system element, ranged from Production and Standard internet to a Demilitarized Zone (DMZ) network. These networks facilitated the opportunity to ingest regional meteorological data. For the operational system, the regional data were ingested from the Surface Automated Meteorological System (SAMS) data network.

The dedicated sensor suite sub-components continue to be based on Model input requirements and the anticipated hard-power loss often associated with an incident. Consequently, the required wind sensor remained a Wind Monitor (see figure 4), which was able to display the critical wind directions even when power was not supplied to the meteorological sensor suite. This choice ensured that the onsite victims would have a visual reference for where the „upwind‟ safe zone was located. Data from all sensors were acquired every 1 min and archived for post-event analysis or reviews.

A pre-compiled Wind Model (*Three-Dimensional Wind Field* (3DWF) Model-Version 1) was initially run on a Linux platform for the PoC. For the Prototype, the L-REAC™ System wind model expanded the AOI scale from a building only area to a building and cantonment AOI. For the Model Module, this action required replacing the original Linux 3DWF-Version 1 with a Windows 3DWF-Version 2, as well as, securing additional meteorological data resources and the additional office building descriptions to support the larger domain of high resolution wind output. The Operational L-REAC™ System Model Module continues to run 3DWF-Version 2, but supports a third, larger-scaled regional output. (Wang et al., 2005)

The Plume Model selected for L-REAC™ System demonstration unit was a pre-compiled EPA/NOAA *Areal Locations of Hazardous Atmospheres* (ALOHA) dispersion model. To automatically ingest data into this model, ARL and EPA/NOAA created specialized software (*ALOHA User's Manual*, 2007). Visualization improvements at the request of users were added to the Operational L-REAC™ System plume model.

The wind and plume models generated output once per minute on the PoC. With the additional mesonet data ingested and consequently an Objective Analysis, this time was lengthened to 1–2 min for data processing. When the cantonment scale wind field model was run, the required increased, again. The maximum time required for the Operational L-REAC™ Systems regional scale wind field model run was 8–10 min.

Note: The L-REAC™ design is not limited to the 3DWF (wind field) and ALOHA (plume) models. These were chosen to demonstration the feasibility of the L-REAC™ System concept and to satisfy user requirements. Section 2 includes some of the experimental investigation into alternate models.

The L-REAC™ System output included two incident visualization images. The first EUD Module-Display image included a separate graphic for the wind and plume outputs. In this configuration, the wind model used a Grid Analysis And Display System (GrADS) (September, 2007) plan view of the subject area, overlaid with 2.5-m above ground level (AGL) wind vectors, wind streamlines, and color contour wind speeds. The Plume Model output showed a static, plan view overlaid with the ALOHA hazard footprint. The model update plots were shown side by side in an end-user display. This display was automated using the platform independent HyperText Markup Language (HTML). The final results were displayed on the L-REAC™ System and remote terminals.

A second EUD Module-Display output consisted of a single image founded on a Google Earth satellite map with wind field and plume overlays written in keyhole markup language (*kml*) format. In this format, the output could easily be tilted to show the flow over and around the mountains, zoomed in until there is only one arrow in the scene, or zoomed out to show the overall atmospheric scenario.

A Visual Basic Script (VBScript) performed automated archiving of output files and executed instant data QC time-series displays for each variable of the dedicated L-REAC™ sensor suite.

The total L-REAC™ System was designed to function independent of an operator and 24/7.

2. Operational L-REAC™

In this section, we describe the advances made in the construction of the Operational L-REAC™ System. This section begins with the foundational structure of the computer platform and networking challenges, followed by a description of each module.

2.1 Computer System Administration and Networking

The first major change from the original PoC was a re-design of the L-REAC™ infrastructure. The Prototype still required both the Windows and Linux operating environments to support the wind and plume models, as well as the communication functions. However, with the change from a Local Network to a Production Network, the default single computer platform became a Windows Vista OS. The Linux functions were accommodated through a *cygwin* software package. Later in the development, meteorological data outside of the Production Network had to be ingested, which introduced Web transfer utilities.

The Operational L-REAC™ System kept the Prototype"s infrastructure design, with the addition of the DMZ Network. The primary function of the DMZ network was to communicate with the "outside world." For simplicity, the networking features will be explained later, in the context of their applications. A schematic overview of the Operational L-REAC™ System configuration is shown in figure 3. The System scripts used to initiate, automate, and terminate the L-REAC™ System will also be presented later, after each module has been described.

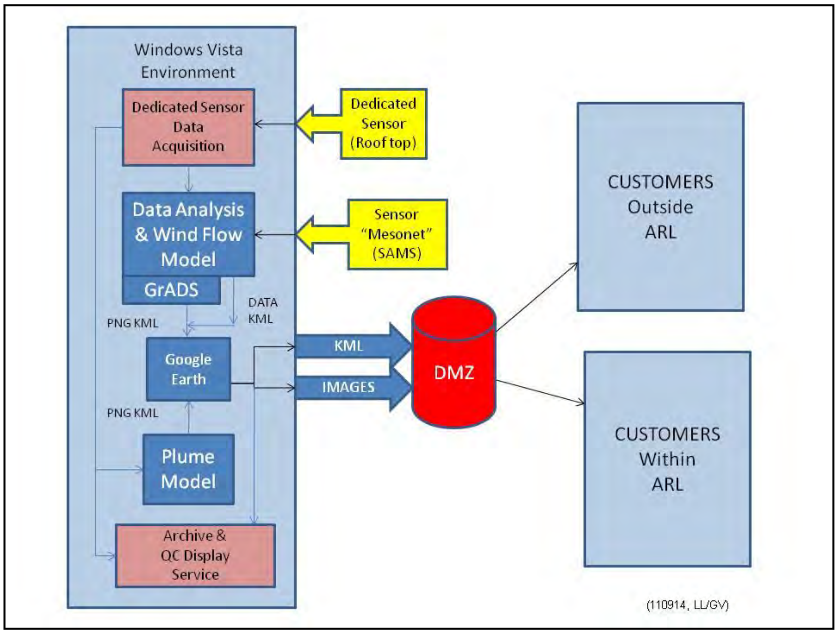

Figure 3. Operational L-REAC™ System schematic.

2.2 Sensor Module

The Operational L-REAC™ System Sensor Module was designed after the successful Prototype-Sensor Module. That is, it consists of a dedicated meteorological resource attached to and managed by the L-REAC™ System. In support of the larger AOI requirements, the Sensor Module also continues to ingest other mesonet meteorological data resources. Since the "ownership" of these regional data were not part of the L-REAC™ System, their physical setup and layout are not included in this report. The Operational-Sensor Module design consisted of five major areas: (1) Sensor Hardware, (2) Sensor Layout, (3) Sensor Preparation, (4) Sensor Software, and (5) Sensor Network and Functionality. The following sections describe each area.

2.2.1 Sensor Module Hardware

The Operational Sensor Module‟s dedicated meteorological resources consisted of hardware, based on the model input requirements. While the models were upgraded, the sensor requirements remained the same. Therefore, no new sensors were added to (or removed from) the configuration. Table 1 summarizes the variables and sensors utilized by the Operational-Sensor Module. For a more detailed description of the Sensor Module, see *Volume 1* (Vaucher et al., 2009).

Table 1. Sensor Module hardware. For additional information on the sensors, see *Volume 1* (Vaucher et al., 2009).

Variable	Sensor	Manufacturer	Model	Units
Pressure	Barometer	Vaisala	PTB-101B	Millibars
Temperature	Thermometer		107-L	Celsius
Temperature/ Relative Humidity (RH)	Thermometer/ Hygrometer	Vaisala	HMP45AC	Celsius/Percent
Wind Speed and Wind Direction	Anemometer (Wind Monitor)	RM Young	05103	Meter/Second, and Degrees
Solar Radiation	Pyranometer	Kipp/Zonen	CM3	$Watts/Meter^2$
Micrologger	ALL	Campbell Scientific	CR23X	
Weather-Resistant Enclosure	ALL	Campbell Scientific	ENC 16/18	

Note: The L-REAC™ System used calibrated hardware components from previous field tests. This resource insured that the components had a proven durability and that system development costs would remain very low.

2.2.2 Sensor Module Layout

The original L-REAC™ System Sensor Module hardware configuration was able to survive the harsh desert environment for over a year, even withstanding wind gusts in excess of 100 miles per hour (mph). Therefore, the Operational-Sensor Module began by adopting the Prototype sensor configuration, to include the ability to ingest the sensor data via an RS-232 connection. The physical layout of the "Operational" instruments on the 6-m tripod is tabulated in table 2. A schematic and photo of the tripod and sensor placement is shown in figure 4.

Table 2. Operational L-REAC™ System Prototype sensor tripod layout.

Sensor Variable	Height (Above Roof Level)
Wind Speed/Direction	6 m
Temperature–Upper	5.7 m
Temperature–Lower	0.7 m
RH/Temperature	2 m
Solar Radiation	2 m
Pressure	0.25 m

While designing the Operational-Sensor Module, we considered feeding the L-REAC™-Sensor Module data into an alternate computer system. This second system would imitate a dual processing function, which would later prove or disprove the feasibility of supporting a second tier of slower application models being run on a dual processor L-REAC™ System design. Three options were considered:

1. First, with the current L-REAC™ System still operational, a quest to simultaneously feed the data from the single tripod to two competing L-REAC™ Systems was undertaken. This option proved to be very difficult. We tried making a data tap cable of our own supplies, with only partial success. We then tried two different commercially bought data taps, one did not work at all and the other worked once for a couple of hours and then never again. We abandoned this design.

2. The second option was to use an independent tripod of meteorological sensors placed near the current L-REAC™ roof tripod. The placement of this second sensor suite would be non-trivial, since there was a heating vent to be considered, and due to limited real-estate, there was the possibility of introducing a systematic data error by the two tripods interfering with (shadowing) each other. We did not use this design because of the high potential for non-representative data measurements.

3. The third option required permission to send a copy of the data collected on the current L-REAC™ System to an alternate computer via an internal private network. When we asked for permission, our Information Technology colleagues suggested we reverse the data flow, sending it to the alternate computer first, and then the current L-REAC™ System. Because the alternate computer used a Linux OS, it was considered easier to take the incoming data from there and send a copy to the current L-REAC™ System via the private network. However, resolving the competition for resources of this process with the other active L-REAC™ Windows services still presented an impassible challenge.

After running the latter option for two weeks, we discovered that the transfer script would miss data lines, duplicate lines, or be delayed by other processes far too often, to be useful. This option also had to be abandoned and we instead, went back to the old manual style switch and performed a manual update of the tower data at least once a week.

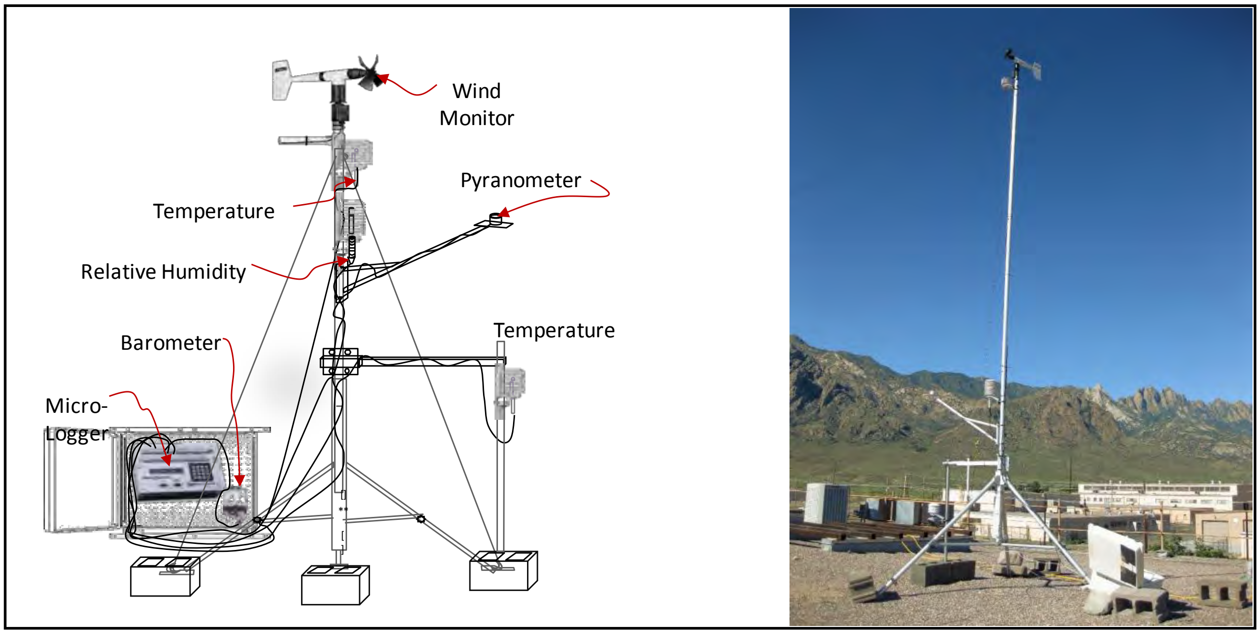

Figure 4. A schematic and photo of the L-REAC™ System Operational-Sensor Module hardware mounted on a tripod, which was located on a subject building roof.

2.2.3 Sensor Module Preparation

Prior to the sensor and tripod installation on the roof, the tripod was laid out to identify required heights, fasteners, grounding cables, cable tie-downs, data cables, tower cross-arms, and instrument placing. Each sensor was individually calibrated against a standard and the CR23X micrologger software was tested (see figures 5 and 6).

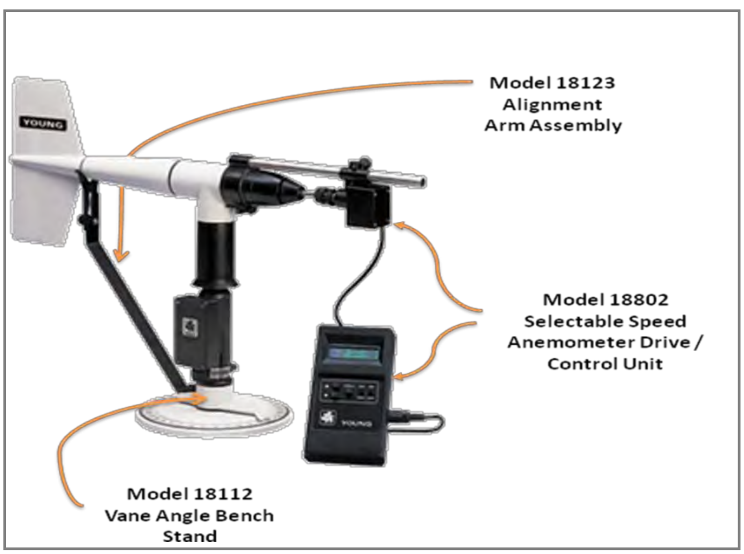

Figure 5. RM Young 5103 Wind Monitor and Calibration Equipment. To calibrate wind speed, the Wind Monitor was attached to a motor, which was calibrated to a predetermined velocity. Wind direction was calibrated using the fixed compass reading at the base of the calibration instrument.

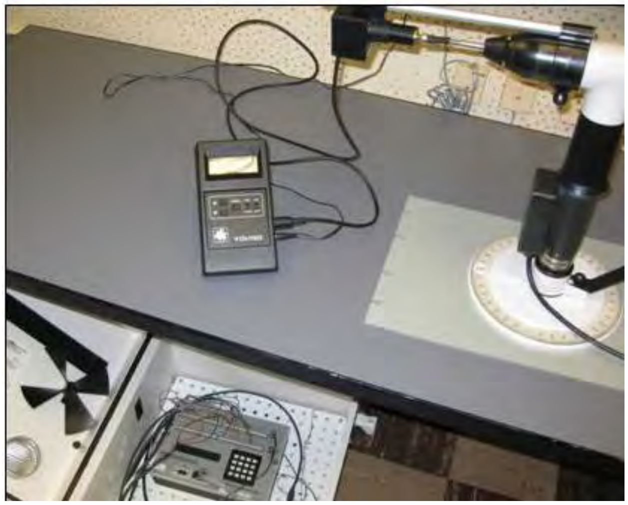

Figure 6. RM Young 5103 Wind Monitor and Calibration Equipment. The wind monitor recorded the calibrated velocities on a Campbell CR23X micrologger (in the white box under the table).

2.2.4 Sensor Module Software

As previously stated, the Operational-Sensor Module began with an outward appearance of the PoC. However, the internal design maintained the Prototype configuration. That is, since security protocols on the networked Operational L-REAC™ computer required that each user have a different login and password, the standard LoggerNet software was replaced with an Administrator (ADM) Version 4.0. This LoggerNet ADM version allowed the acquisition programs to run as a Windows service, instead of a local user service. In other words, LoggerNet would continue to run, even when no one was logged on to the machine.

The Campbell Scientific, LoggerNet ADM was backward compatible, so the original data acquisition program for the tripod mounted suite could be downloaded onto a new Campbell CR23X micrologger (Campbell Scientific, Inc., 2004). The micrologger and an uninterruptable power supply (UPS) were co-located in a Campbell Scientific ENC 16/18 Weather-Resistant Enclosure at the base of the tripod on which all the Operational L-REAC™ sensors were mounted. The program"s function was to control the data collection and distribution. Specifically, the program sampled atmospheric conditions every 10 s, then output 1 min averages. A sample of the micrologger program is included in Volume 2 (Vaucher et al., 2010).

2.2.5 Sensor Network and Functionally

In the Operational-Sensor Module, all sensors were hard-wired into the CR23X micrologger located in a weather-resistant enclosure at the bottom of the tripod. This data-logger was then wired to COM port 1 on the Operational L-REAC™ computer via an RS-232 connection. Through this cabled connection, we were able to manipulate the program in the CR23X micrologger and do near real-time data quality control screening which is explained in more detail in section 2.3.

During the dual system data access task, which was described in section 2.2.2, we experimentally switched the sensor feed back to an alternate computer and wrote a Bourne shell script to acquire the sensor data from the alternate computer over the private network. The data source provided one minute of data in a single line. The operational script acquired that line, ensured that line ended with a carriage return. A "new line" character then appended that line to the current day‟s data file. This file was supposed to be equivalent to the direct data feed generated by the original CR23X LoggerNet output and could also have near real-time quality control screening performed on it. While most of the time this worked, as we mentioned in section 2.2.2, this design ran into trouble because of network delays and became too error prone to continue pursuing. Another disadvantage was that we could no longer control the micrologger from the Operational L-REAC™ computer. Instead, all programming and manipulation of the micrologger could only be done through the alternate computer.

One successful resolution to the quest of bringing data into more than one computer, was to connect the roof data into a four position switch box via an RS-232 connection. The alternate computer was connected to output A, the Operational L-REAC™ computer was connected to output B, and a developmental computer was connected to output C. The down side with this design was that we could not use live data on more than one computer at once. The upside was that there was no data corruption and we could control the micrologger from each of the computers when they are selected on the data switch.

2.3 Data Quality Control Module

The data QC Module was created in response to a need for a quick data quality review on the Operational L-REAC™ System. The Module‟s concept was first developed and tested on the L-REAC™ System PoC. Once successful, the software was converted into Production Network code for the Prototype and now the Operational L-REAC™ System.

The QC Module design begins with the 1-min average micrologger output data being stored in a "live" archive file at the beginning of each minute. The archiver script "trims" this archive file, storing the previous day (or multi-day) sensor data in a date-stamped archive file and removing these data from the live archive file. The live archive then contains only current-day data, starting at midnight and ending at the last archived minute. This editing operation simplifies the coding of a Graphics Layout Engine (GLE) script that displayed line plots of sensed meteorological parameters as functions of time for the current day. This script was originally designed to display wind speed and direction plots only, but the simplicity and modularity of the GLE scripting syntax allowed an expansion of the display to include all of the sensed parameter histories on a single screen containing six plot boxes and seven parameter (and one derived parameter) curves.

The position, size, scale, and content of each plot were configured by GLE commands in six serially executed plot blocks. The plot blocks display wind direction, wind speed, air temperatures at 1- and 6-m above the roof surface, 6-m dewpoint temperature, air temperature gradient (derived from the 1- and 6-m temperatures), RH at 2-m above the surface, station barometric pressure, and solar irradiance for the current day. The latest 1-min average value for each parameter is also captured from the micrologger file and displayed in a message string at the top of each plot box. The GLE script obtains dewpoint temperature from the logged temperature and humidity data using a standard conversion. With RH given in percent and ambient temperature *T* given in degrees Celsius (C), the saturation water vapor pressure e_s (in units of millibars) may be expressed as:

$$e_s = 6.112\ exp\left(\frac{17.67\ T}{T+243.5}\right).$$

The RH then yields the ambient water vapor pressure *e* (in millibars):

$$e = \left(\frac{RH}{100}\right) e_s .$$

The dewpoint temperature T_d (in degrees C) may then be expressed as:

$$T_d = \frac{243.5\ ln(e/6.112)}{17.67-ln(e/6.112)}.$$

Figure 7 displays a typical screen of sensor QC data plots from the micrologger.

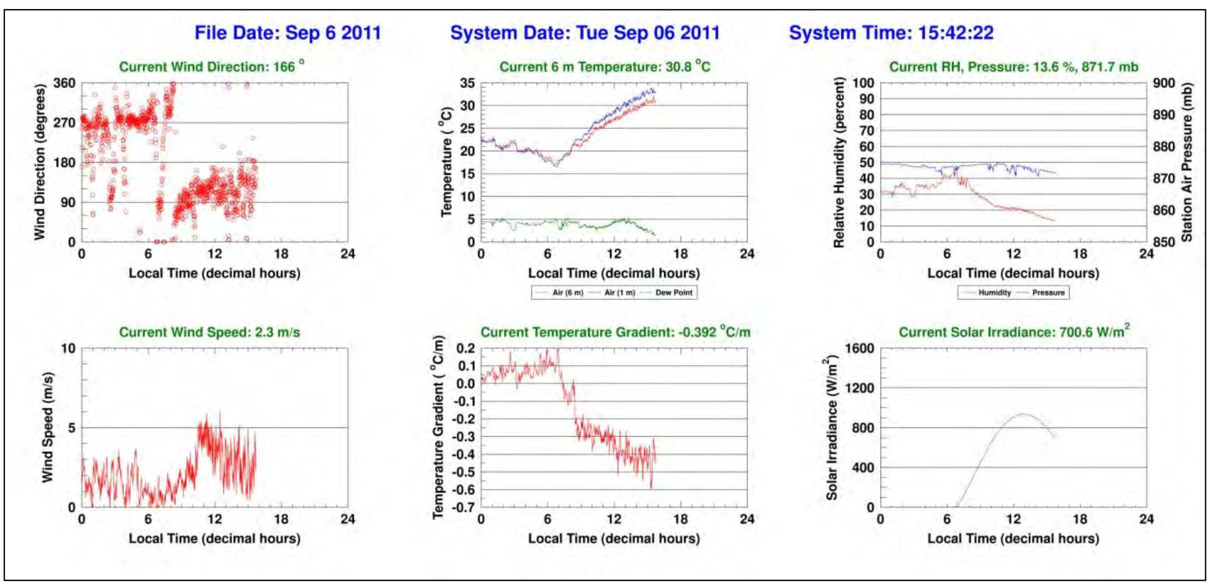

Figure 7. Example of GLE plot screen for quality control and monitoring of Current Sensor Module data.

These plots have utility beyond simply verifying nominal sensor suite operation. They also allow the user to assess trends and variability in the environment that might prove to be especially significant in the context of airborne hazard transport and diffusion. For example, a relatively stable wind direction and speed would probably (though not always) indicate that modeled air flow fields are also nearly steady in the neighborhood of the sensor suite. Another example might be the indication of a strong negative temperature gradient (or lapse rate) that would enhance buoyant plume rise during advection. Some airborne biohazards are sensitive to cumulative ultraviolet exposure. The levels for such exposure can be readily deduced from the solar irradiance plot series, which might be especially useful under conditions of partial cloud cover.

Another application for the QC Module is to examine the quality and consistency of modeled air flow solutions. Highly variable winds will cause modeled wind fields to change abruptly from one display cycle to the next. Extremely light winds will also cause plume dispersion model predictions to “bloom” out over large areas. The QC data time series provide a “sanity” check on such model results either in near-real time or as part of a post-event analysis. Indeed, a version of the QC Module screen generator has been created to examine whole-day archive files for post-event investigation. Figure 8 shows an example of the archival version of the QC Module display.

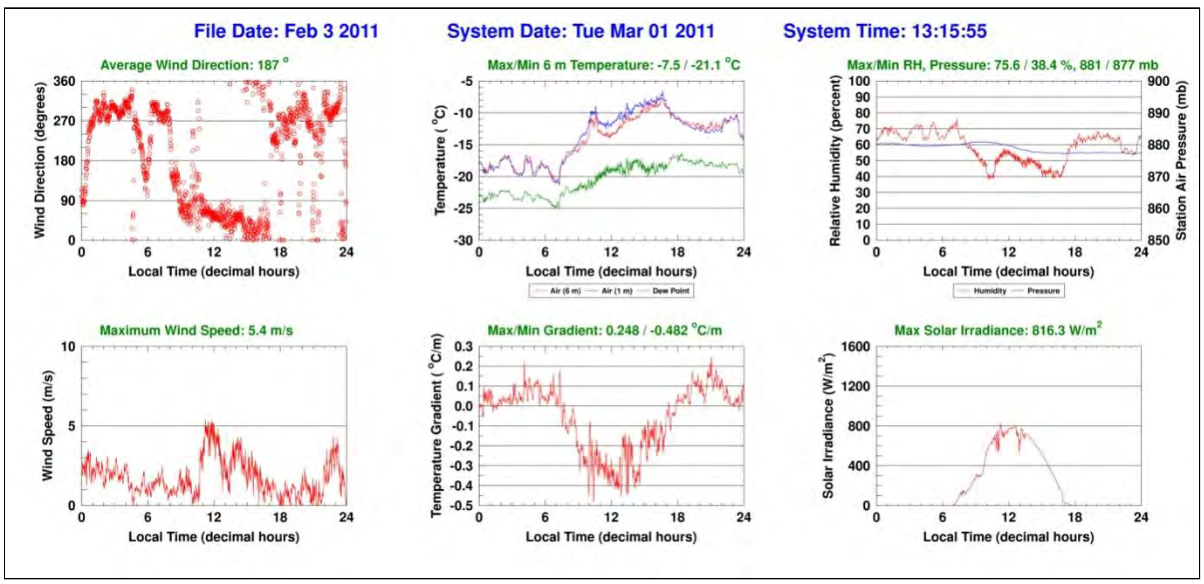

Figure 8. Example of GLE plot screen for daily archival data.

The archival version of the QC display screen is similar to the near-real time version with the exception that the “current” value headers above each plot are replaced by diurnal averages (for wind direction), maxima (for wind speed and solar irradiance), or maxima/minima (for air temperature, temperature gradient, RH, and station atmospheric pressure). The header information content is easily modified to accommodate mission-specific derived parameters such as least-squares fits to last-hour data (to display trends) or to calculate recent variances in parameter values.

2.4 Model Module

The Operational-Model Module was designed with three model domains. In section 2.4.1, these domains are described. The challenges of making a system operational and a future vision for the Model Module are presented in section 2.4.2.

2.4.1 Operational System Model Domains

The Operational-Model Module continued to support the functions described in the L-REAC™ System Prototype. One of the distinguishing features of the Operational-Model Module was the three resolution outputs. Each scale was designed with its own domain and reason for existence. The 5-m grid resolution was chosen as the best representation of the building scale (figure 9). The 50-m resolution captured winds in the nearby mountains, as well as the entrances to the selected cantonment AOI (figure 10). The 100-m resolution, or regional scale, was chosen as a slightly lower resolution for getting both the 50-m resolution domain and designated important areas of the cantonment (figure 11). Although the 100- and 5-m resolutions are the only ones actively used, all three domains are shown in figure 12.

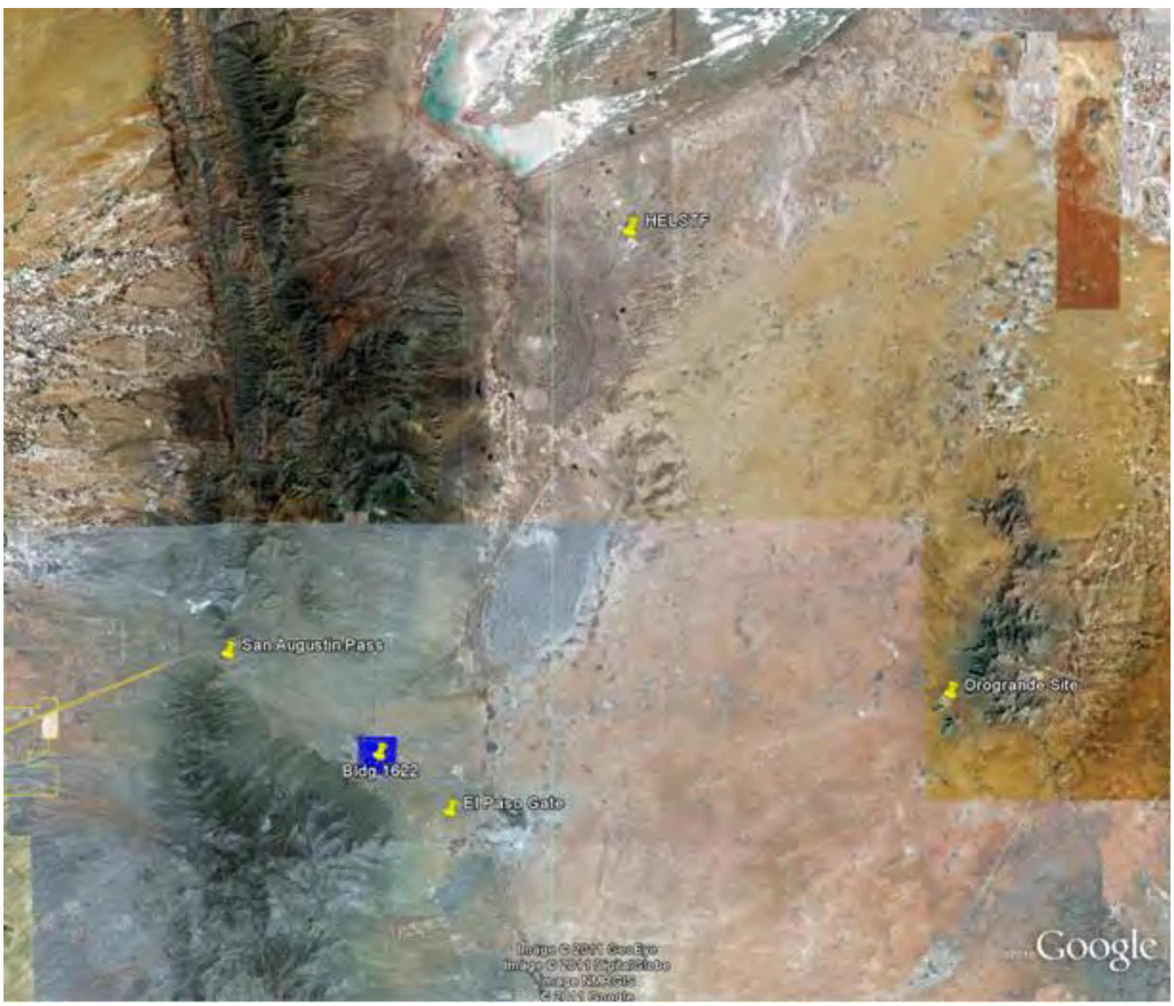

Figure 9. Domain of the 5-m Resolution Model (in blue, at the 1622 pushpin).

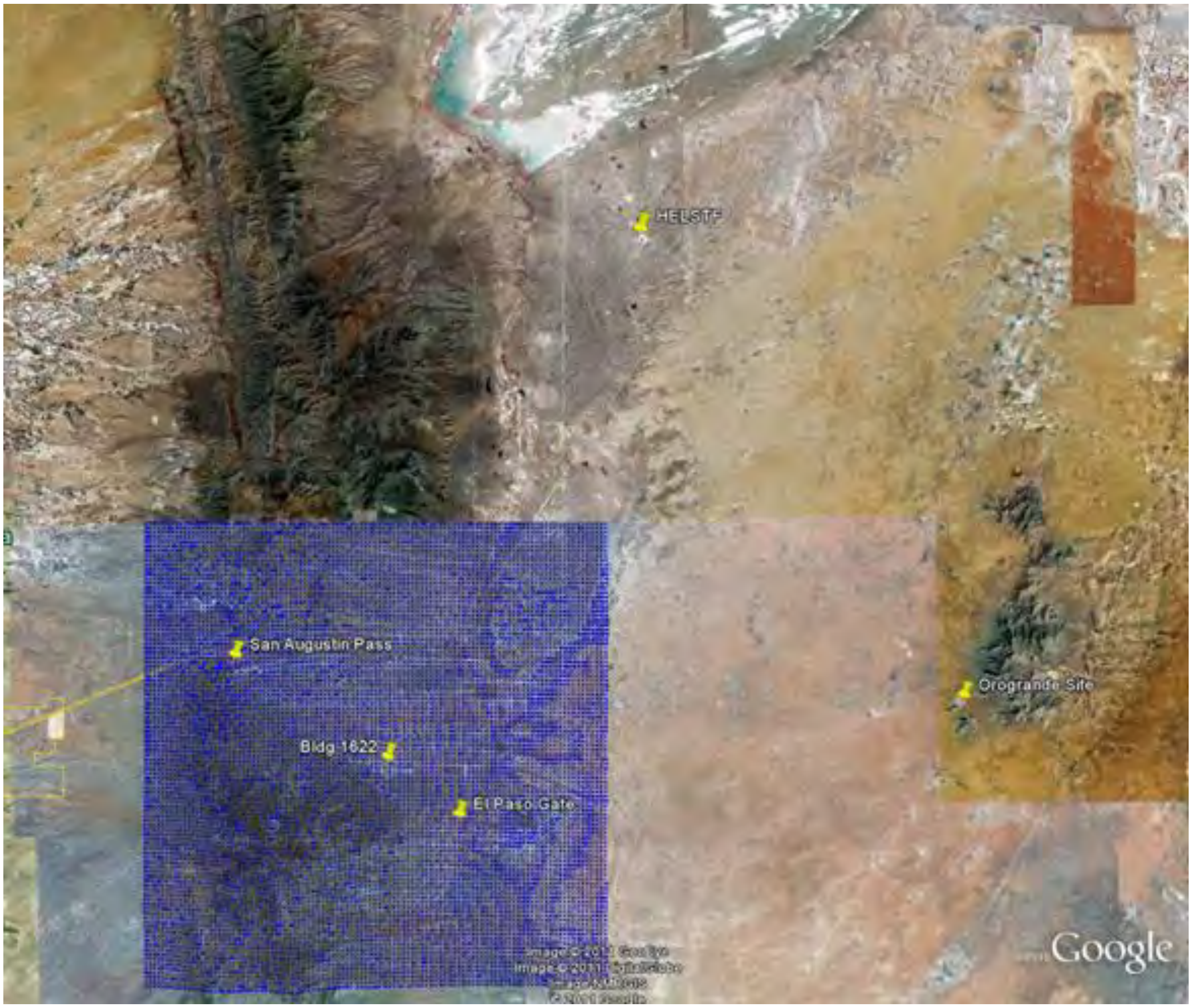

Figure 10. Domain of the 50-m Resolution Model (in blue).

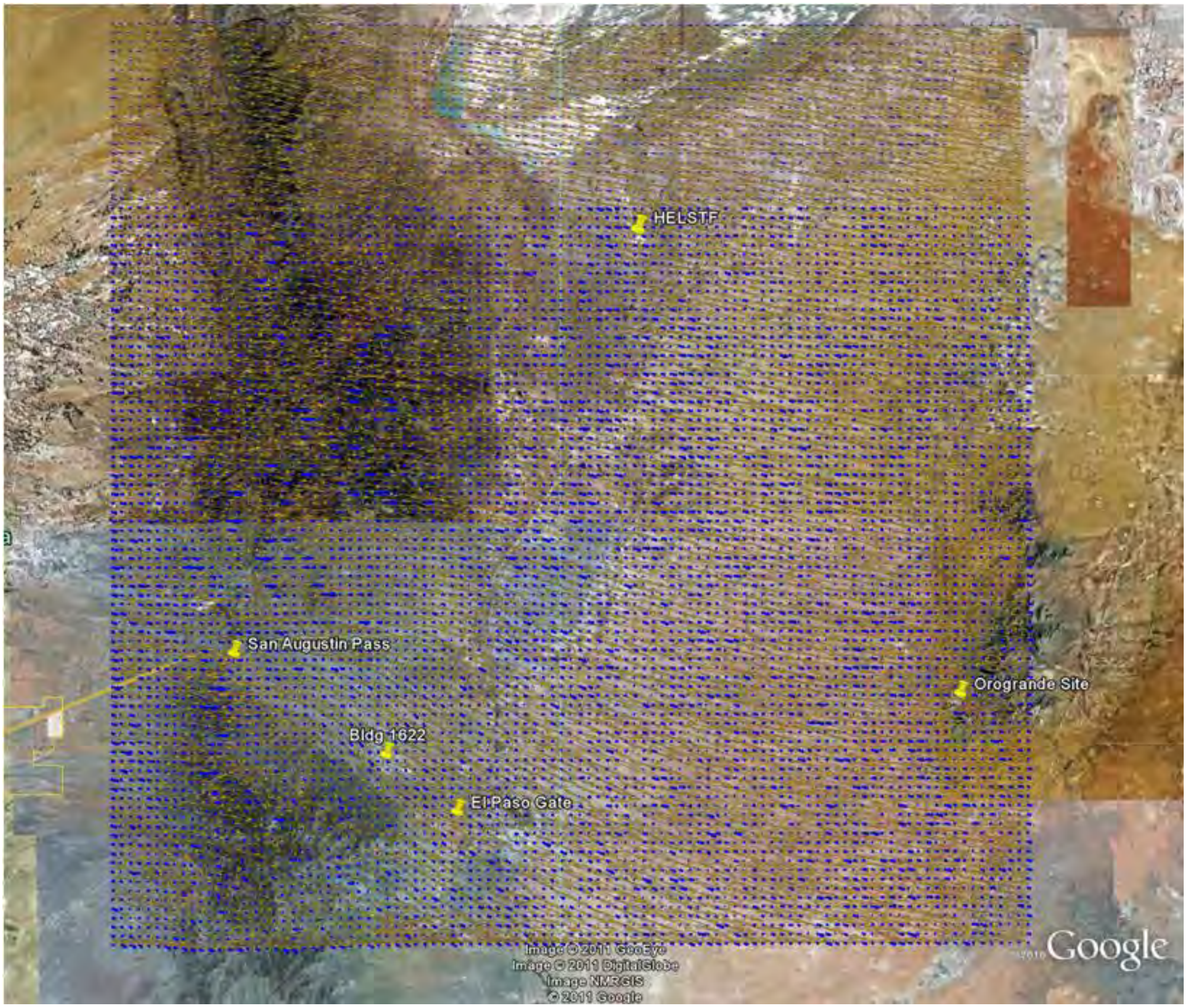

Figure 11. Domain of the 100-m Resolution Model (small blue arrows and yellow streamlines).

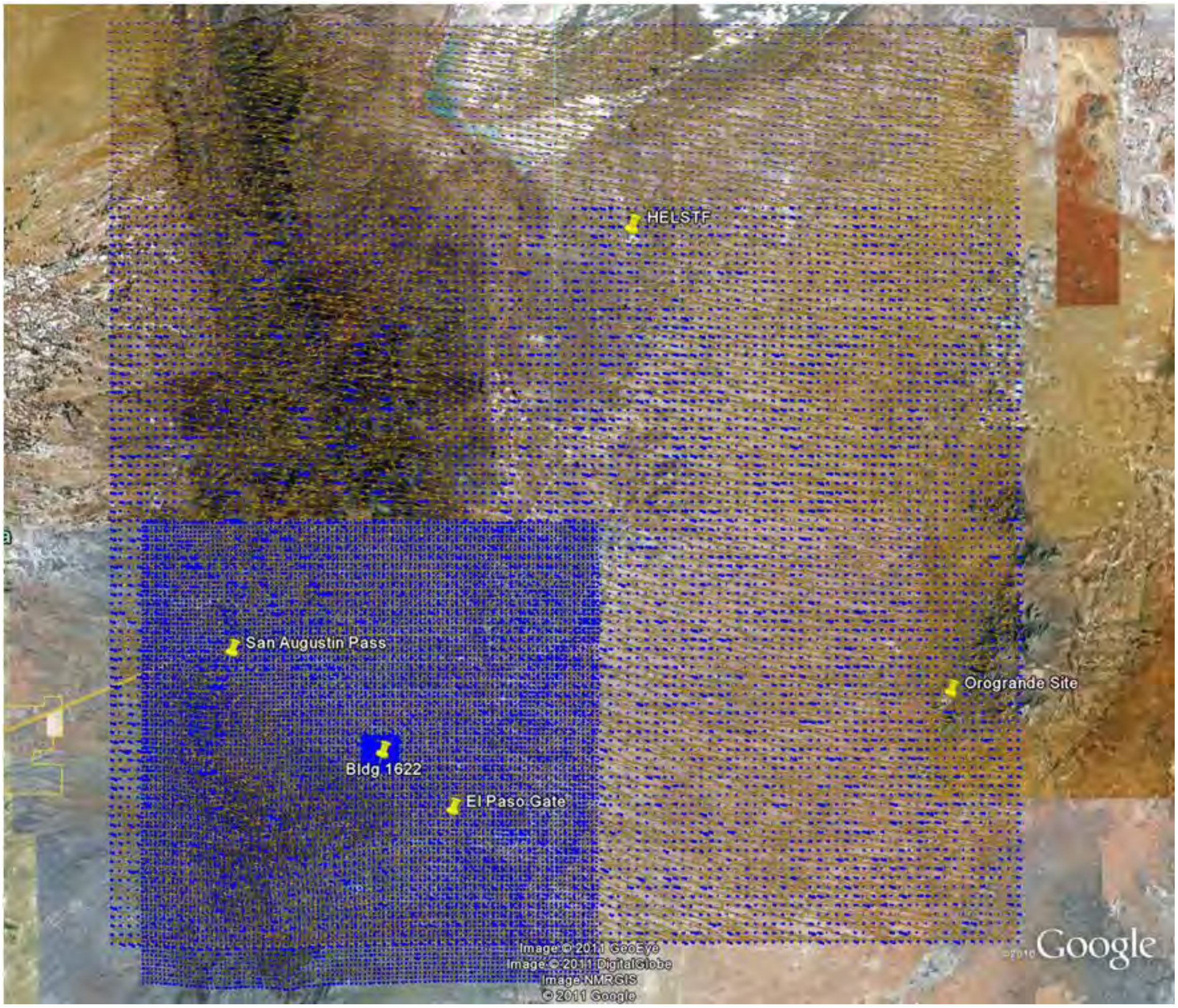

Figure 12. Comparison of three domains.

2.4.2 Requirements for the Model Module in the Operational System

The requirements for an Operational-Model Module were extremely difficult to know *a priori*. Therefore, our steps toward an Operational-Model Module utilized common sense, responding to every local emergency and exercise that presented itself and most importantly, responding to the customer feedback. Independent of customer input, the initial task was to “bullet-proof” the Module code.

2.4.2.1 “Bullet-Proofing” the Module

Common sense clearly showed that no data quality problems affecting the reliability or accuracy of the Model Module should be allowed. Since the L-REAC™ System is a near real-time response unit, ensuring the data quality in an equally near real-time response was quite a challenge. The data QC Module attempts to ensure the best quality of data enters the Model Module. Normally, one would like to apply a climatological limit to the acceptable weather data, but surface winds have such a climatological range that this was not effective. In addition, winds may be very strong in some parts of an AOI and not in other parts due to mountains, fronts, or local forcing factors. And, the point of using a three dimensional wind model is that airflow will have different wind directions over an operational AOI, due to buildings and terrain. That means that an eagle perched on top of a wind sensor (actual occurrence, figure 13) will affect the wind direction reported at that sensor but unfortunately, that effect will not be captured by the efforts to “bullet-proof” the model input. What can be captured are missing winds in a mesonet surface observation and a data report that is more than 31 min old. Both of these “bullet-proofing” features were integrated into the Operational-Model Module.

The loss of all data except the dedicated input causes model output degradation but not complete failure. This scenario was experienced by the Operational L-REAC™ System numerous times, as network connectivity to the mesonet resources was not always reliable. Fortunately, the only Operational-Sensor Module failure recorded occurred after an extended power outage during an un-manned time period.

Figure 13. Eagle Perched on Wind Vane Photo by Pam Birley using the racerocks.com remote controlled camera 5 at Race Rocks Ecological Reserve. Courtesy of Lester B. Pearson College, Victoria, BC. Canada (Birley, 2011).

2.4.2.2 Refinements Added

Thanks to customer feedback on L-REAC™ during a local wildfire emergency, refinements were added to enhance the usefulness of the model module. These refinements included a listing of the available mesonet observations with the model run time, the RH and the winds. Also, output was made available to the display module at two levels (2.5 and 10 m; human height level and standard observation level, respectively). Using firefighter comments, winds were considered important at the level of the fire fighters, the underbrush, the treetops and heights significant to aerial fire suppression efforts, which include both fire suppressant drops and tank refill. In addition, the RH was defined as crucial for fire motion forecasts.

2.4.2.3 Future Model Module Refinements

There are five highly desired refinements identified for a future Operational-Model Module: (1) the use of lower resolution model output to act as the first guess analysis of the observations, (2) a simple setup procedure for new locations, (3) re-locatable higher resolution windows within the lower resolution output, (4) two forms of model output to initialize the plume model, and (5) the use of a prediction model output to determine the upper level winds. There are uses and hindrances associated with each effort.

Using the lower resolution (larger domain) model solutions to initialize the higher resolution (smaller domain) model runs, insures that terrain outside those smaller domains and away from available observations would be taken into consideration. Executing this task requires reading the lower resolution output, taking the proper part of the larger domain and interpolating it to the higher resolution. The most efficient way of implementing the task would be to take the results of the lower resolution data at the same height of the surface observations, interpolate the entire field to the proper resolution, and make a separate output file. Since the larger domain takes longer to run, this process would not be run as often as the higher resolution model, and the proposed output file might be quite old when used as the input for the smaller domain run.

To re-locate the Model Module to a new location will require terrain and building information. Although there are several sources for terrain information, most of the sources are difficult to convert into the form required for the model. Also, most terrain sources are not suitable for the resolution required by the model. The most promising terrain source is the National Elevation Dataset (NED) data set, which covers the continental United States at 90- and 30-m resolutions, as well as, a small part of the United States at about 10-m resolution. For worldwide terrain coverage, there is the Department of Defense (DoD) product called Digital Terrain Elevation Data (DTED), which is readily available to the DoD at 30-m resolution. The setup for a new location will require a dedicated period for gathering terrain and building data. This task needs to be done before responding to any emergencies in a new area. A first responder will want to see high resolution output in the vicinity of a hazardous incident.

Although the current high resolution output is in the region of the most probable AOI, this configuration will not always be applicable. Therefore, a re-locatable higher resolution window may be more useful to the first responders and incident managers. To make this possible, higher resolution terrain and building footprints are required for the entire domain of the lower resolution run. However, there are three challenges: First, while getting terrain at high resolutions in the cantonment AOI is relatively easy because it is flat and open for interpolation– this is not true for the rest of the larger domain. Second, selecting and getting the flow for a location at higher resolution will often be required in the midst of an emergency situation. Thus there would be no time to get the terrain and building information from original sources. Third, the method of communicating the location of the re-locatable window is not obvious. In fact, the location used to determine the high resolution window would also have to be used to determine the new location of the plume window and the location of the streamline overlay image, leading to additional complexities in the display of the output.

The constraints of the two previous refinements requires a technique that provides the low and high resolution terrain at the Model setup time, as well as, the re-locatable windows using the pre-computed high resolution terrain selected for only the window location (no interpolation required). Using red for not started, blue for under construction and white for complete, this technique is proposed in figure 14.

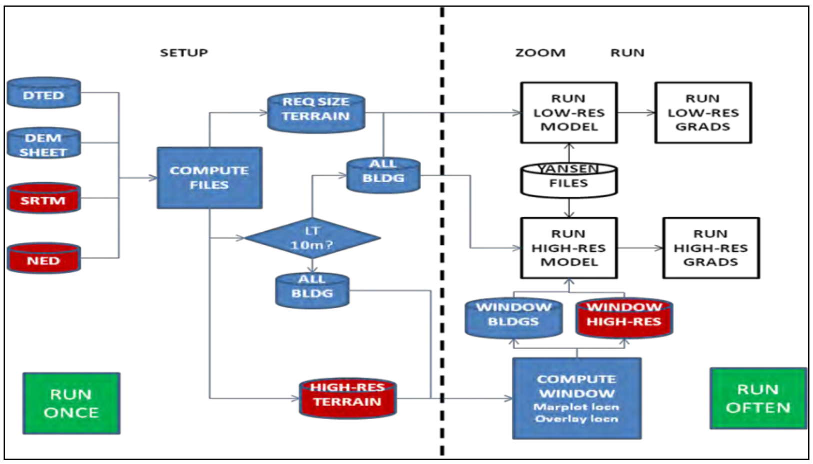

Figure 14. Initial versus re-locatable high resolution window setup.

As currently operated, the L-REAC™ plume model is based on a single wind location from the trusted, dedicated Sensor Module. However, model evaluations have shown that the wind used for the plume is not always representative of the entire area. This problem would certainly become more distinct when the higher resolution model is re-locatable throughout the entire low resolution domain. There are three potential methods for solving this problem. First, one could choose the nearest observed wind to the plume release point. Second, model output (from either the model results or from the model initialization field) could be used. Third, a combination of the two choices could also be used, such as using the nearest observation within 100 m and if this option is not available, then using a model wind. Each of these solutions has the additional problem that the winds are not the only parameters used to initialize the plume model. Some method must be found to provide the other required thermodynamic parameters.

Finally, there is a need to anchor the upper level winds, even in boundary layer volumes. Unfortunately, standard upper air wind observations are taken too seldom to be useful for this time-constrained application. A microwave wind profiler might be useful, but represents a volume measurement that may or may not be applicable. In the absences of measured upper level winds, a mesoscale weather prediction model (such as the community Weather Research and Forecasting [WRF] model) might be able to fill the void. There are two ways such a model could be used. First, the output from the model at 10-m AGL could be interpolated horizontally and in time, to serve as the first guess for the regional model initialization. Second, the winds above a level representing the boundary layer could also be interpolated horizontally and in the time dimension, in order to form the upper air winds. These upper air wind speeds and directions could be blended on top of the initialization formed from the surface observations.

2.5 EUD Module

The Operational EUD Module design continued the successful dual configuration of the Prototype: (1) a EUD Module-Plume Model, which for demonstration purposes was the NOAA/EPA ALOHA dispersion model; and (2) a EUD Module-Display, which consisted of a continuous stream of the latest available outputs from both the Wind and Plume models.

As with the Prototype, the EUD-Plume Model was initialized by the user only when an incident occurred, then run automatically by the system, employing the latest sensor data updates. The EUD Module-Display included two screens: (1) a single plot which showed both wind field and plume footprints over a Google Earth satellite image, and (2) a two plot slide consisting of the building scale wind field and plume footprint. When no plume was present, a default text indicating “no known hazard” replaced the plume entry.

2.5.1 Operational EUD Module-Plume Model

The Operational EUD Module-Plume Model remained the EPA/NOAA ALOHA dispersion model for demonstration purposes. The Quick Urban and Industrial Complex (QUIC) model created by the Los Alamos National Laboratory was also installed on the operational system. A feasibility study showed that this alternate plume model was also able to function as an application model and included the timeliness for processing, required by the original L-REAC™ System concept. The Hazard Prediction and Assessment Capability (HPAC) and “X-PAC” (a modification of HPAC) were two other application models investigated for potential inclusion in the L-REAC™ demonstration design. Based on end user interest levels, no feasibility studies were pursued.

2.5.2 Operational EUD Module-Displays

The operational system underwent a detailed evaluation by professional first responder end users. While the specific findings of the results will be published in a separate document, some of their recommendations were already implemented in the Operational L-REAC™ System.

Based on the end user feedback, the Two-Plot EUD Display (figure 15) required no changes. The users said they could easily discern orientation, the general wind field and the plume gradient information.

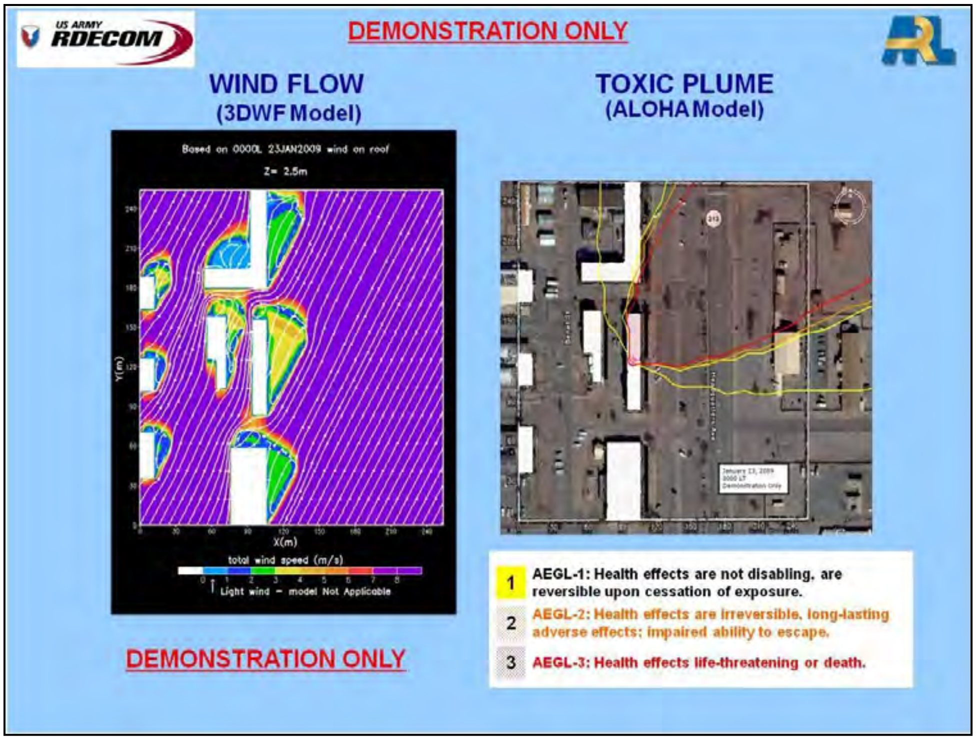

Figure 15. Example of the Operational L-REAC™ System EUD Module-Two plot output.

The "1-Plot" EUD Display (figure 16) was redesigned to include several additional pieces of information. As explained in the Model Module, the fire department expressed a need to have numerical winds in "miles per hour" and RH in "percentages." The process to create this text resource required the Model Module to save the meteorological values ingested from the dedicated L-REAC™ sensor module and the mesonet resource. Using a VBScript, these values were tabulated and saved as an image. After re-designing the HTML 1-plot template, the data-list image was inserted onto the EUD-Display and automatically updated with each Model Module run.

Concurrent with the data-list request was a preference for a larger time stamp. Therefore, the local date and time information were extracted from the dedicated sensor module resource and inserted into the tabulated data listing described above. By using larger font and a bright red color to distinguish this text from the data-list, the end users "quick read" request was satisfied. The conversion of the tabulated data into an image meant that the time stamp would automatically be archived for future reference. We elected to keep the time stamp in local time. This decision was based on the fact that the system is designed for a "Local" rapid evaluation of atmospheric conditions. The probability that the AOI might extend to another time zone is limited for now.

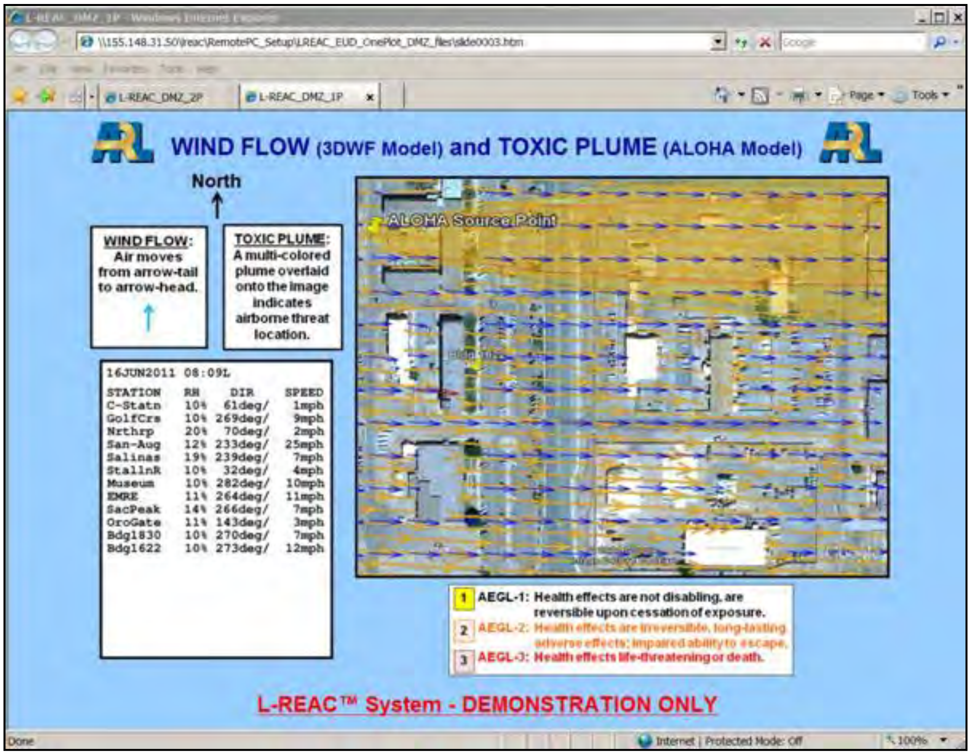

Figure 16. Example of the Operational L-REAC™ System EUD Module-One plot output.

2.5.3 Automated EUD Updates

The Operational automatic updates of the latest Wind and Plume (if applicable) Model outputs used specialized JavaScript code that was integrated into an HTML program, and a winBatch executable.

With the expansion from building and cantonment scale AOI to a regional-scale AOI, the EUD Module required additional flexibility in the automated functions updating the output. The most significant change was increasing the time needed to save the results from a 100-m resolution run versus a 5-m resolution run, without compromising system efficiency.

The end user evaluations indicated impatience toward waiting the 8–10 min for a 100-m resolution model run. Consequently, an "instant save" button was created. This automated save button would allow an operator to zoom in or out of an AOI, and instantly save the new perspective for the waiting end user. The time needed to go through the entire save routine was between 20–28 seconds (s). For this smaller interval, the end users were willing to wait.

2.5.4 Accessing the Operational EUD Module Display

The L-REAC™ PoC output display used a Sony Vega Plasma high definition television (HDTV) screen located in the lobby of an office building and a strategically-placed networked computer with a digital screen projector. When non-local emergency professionals requested near real-time access to the L-REAC™ System PoC output, a procedure to manually transfer approved output onto a restricted-access Web site was developed.

The Prototype simplified the complexity of the remote access methods by automatically sending the results through an approved network linked to an end-user accessible location (such as a SIP location or an Emergency Operations Center [EOC]). With a double click of the mouse, the end user initiated resident L-REAC™ software, to view the L-REAC™ output with automated updates.

The Operational L-REAC™ System method for communicating the EUD Module-Display continued the use of an approved network link, using an access-restricted directory on a DMZ network. Confined by security requirements, the automated L-REAC™ sent the final outputs to this DMZ directory, from which the approved end users could independently access the latest information. The remote site users would get automated updates prompted by the L-REAC™ System software resident on the DMZ directory and activated on the end user‟s computer. Flat files of the wind and plume plots were included in this directory to allow end users to e-mail needed information to hand-held blackberry devices in the field. While viewing the results on these hand-held devices was challenging, the concept was seen as worth pursuing. At the time of this writing, the authorized users of the near real-time Operational L-REAC™ System output included the WSMR Installation Operations Center (IOC), the WSMR EOC, the WSMR Fire Department, approved ARL workforce from three different directorates, and the ARL SIP room.

In the future, we want to bring the L-REAC™ EUD Module-Display output to a true server, where the only limitation is on what technology the user can read/view an Internet/HTML file.

2.6 Archive Module

The Operational L-REAC™ System-Archive Module used the Single Editing Pass (SEP) configuration that was developed for the Prototype L-REAC™ System and described in Volume 2 of this technical report series (Vaucher et al, 2010). A condensed description of the layout and operation of that module were adapted from the Volume 2 report here for the reader‟s convenience.

2.6.1 Workstation (SEP) Version of the Archive Module

Automated operation of the Operational L-REAC™ System data archiving VBScript in the ARL networking environment requires installation of a proprietary Windows process-as-a-service utility known as Fire Daemon. Fire Daemon allows user applications to be run as Windows services, which can persist between user logins and can execute user applications on a periodic schedule. However, the archiving script was designed to rely on system timing as little as possible.

The data archiving script employs a SEP concept, where the Julian Day (JD) (day number for the given year, ranging from 1 to 365 or 366) field of the logger data file is used to automatically edit the logger data file into individual-day archive files. Before performing its archive generation operation, the script does make two references to the system clock (see figure 17).

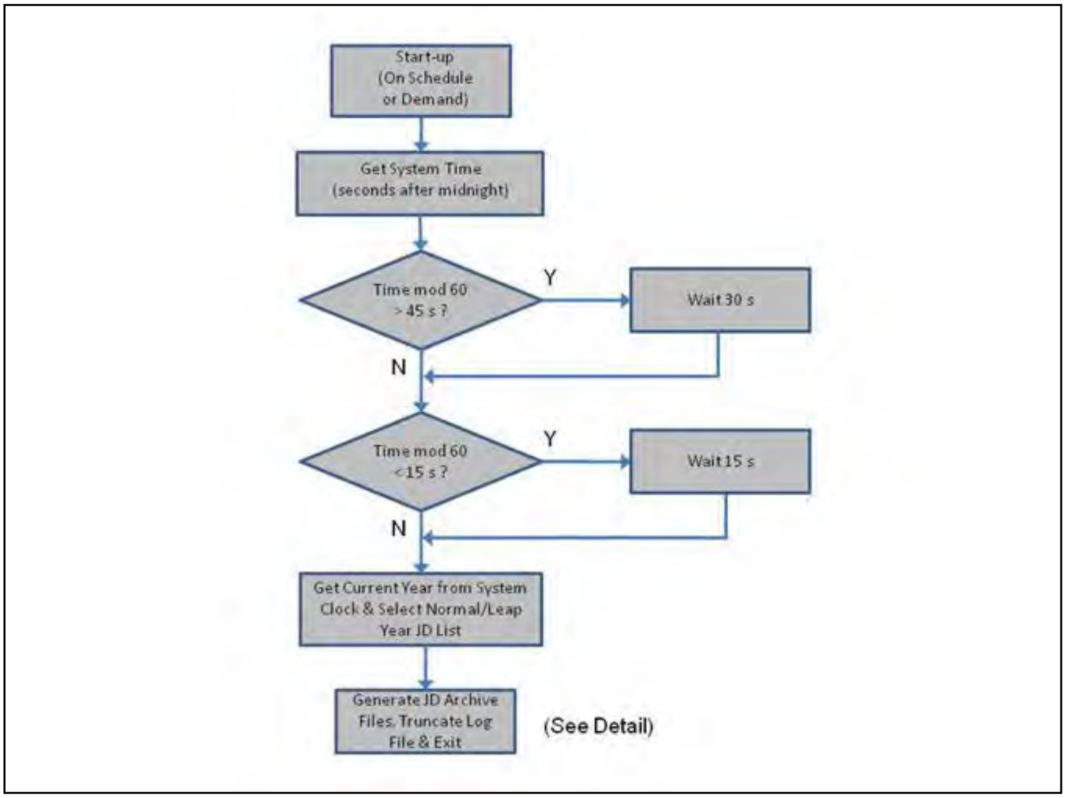

Figure 17. SEP archiving VBScript logic flow diagram overview.

The first reference is to the current time, expressed as seconds past midnight for the current day. The number of seconds past the beginning of the current minute for the current time is then determined through a modulo 60 operation. The final step of the archive creation cycle (see figure 18) is to overwrite the data logger file with a truncated version of itself, which only contains today"s data. The logger writes to the log file at the beginning of each minute, so the archiver script delays its overwriting operation when it is executed within ±15 s of that time (figure 17). The second reference to the system clock is used to get the current year; a modulo 4 operation then determines whether or not the current year is a leap year and assigns the appropriate end-of-month JD values to a monthly array.

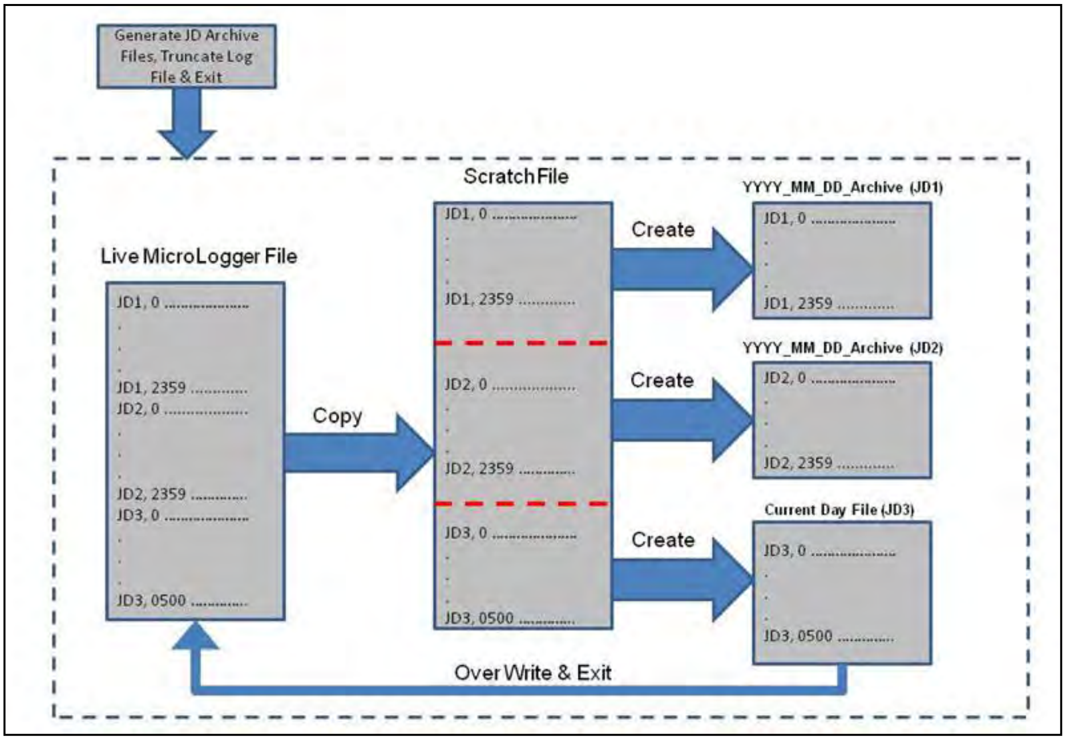

Figure 18. SEP VBScript archive generation and update cycle (detail view from figure 17).

This array, combined with line-by-line reads from a scratch file copy of the data log file, is used to decode the JD of each data record, encode an appropriate archive file name, write the data record to that file, and then close the file after all records having that same JD tag have been processed (figure 18).

This SEP version of the script may be run interactively (by double-clicking the file icon) or as a Fire Daemon-administered service. The script was tested both ways and works as designed. Currently, the Fire Daemon service runs this script at 0500 local time each day.

2.7 Scripts and Automation

L-REAC™ System Start Up Scripts: The operational system uses a two step "start up" process. In step one, the user double clicks on a script that initiated the data conversion routine for the plume model. In step two, the user double clicks on a second script that initiated both the wind and plume models. When no plume model is required, the foundational software still runs in the background, waiting for the chemical data to be defined. For the "no plume" status, the end user is informed on the EUD Module-Display that "there is no known airborne threat."

End User Access: The authorized end user gains access to the Operational output through HTML display programs that remained resident on a designated DMZ directory. These programs are located both locally on the operational system, and at an accessible remote site location. A special, single script is created at the designated remote site, so the user can double-click on the script icon, and the L-REAC™ EUD Module-Display HTML programs self-initiate, and automatically update.

L-REAC™ System Shutdown Script: When the Operational L-REAC™ System is no longer needed, the operator of the L-REAC™ System utilizes a "shutdown" script. This single script terminates all operational L-REAC™ System software, except the LoggerNet, the mesonet data ingest, and the daily Archive Module. These data ingest and storage functions remain as background jobs, in preparation for future operational L-REAC™ System usage.

3. Discussion

In this section, we flag attributes of the current operational system that have not yet reached their full maturity, as well as a future vision for the L-REAC™ System.

The L-REAC™ System-Sensor Module design calls for a dedicated sensor suite as well as a mobile sensor suite. The dedicated sensor has already been demonstrated and proven. The mobile sensor has yet to be demonstrated. The key attributes of this mobile suite would be the ability to assemble such a unit within minutes, while being fully attired in a professional Hazardous Materials (HAZMAT) suit. The purpose of the mobile sensor suite would be to provide L-REAC™ with in situ measurements. These data points would especially strengthen the applicability of the plume model output. These data sampled would not be limited to just meteorological parameters. As with the dedicated sensor suite, airborne hazard sniffers have also been envisioned for the Sensor Module. The L-REAC™ System design calls for these features; however, until funding becomes available, they remain on paper only.

To bring additional data into the L-REAC™ System requires a flexible ingest code. One vision for the Sensor Model was to create a radio button where multiple, known data formats could be ingested. Along this same thought, model data ingest requirements could also be designed around a radio button option capable of reformatting data files.

The models chosen for the L-REAC™ System demonstration unit were not the only models the system was designed to accommodate. In section 2, a feasibility study was conducted to determine the practical requirements for inserting alternate and additional (second tier) models. With this feature, if another wind field or plume model was required by a customer site, the L-REAC™ System could accommodate the requirement. The design would insert the alternate model as new primary wind or plume models; or these models would be built as slower second tier models to run on another computer processor in the background. The only requirement that the L-REAC™ designers would put on the new models, is that models designated as "primary" would be able to provide timely and relevant data to the end users.

The Model Module has numerous areas in which to expand. Regarding local airflows, some additional features that could be added to the current model would include slope flow, shadows, surface radiation balance and upper level winds. Another suggestion for the Model Module was to have all sensors report at the same frequency. This attribute may not be practical; however, it would simplify the objective analysis.

Communicating with the "outside" world using a controlled access network was one of the greatest challenges to the L-REAC™ System demonstration unit design. After exploring many options, the designers will be working with the ARL and WSMR webmasters to get L-REAC™ output published onto a security-acceptable website. This task may seem trivial, but working within the guidelines of DoD Cyber Security, it is very challenging at best. The current design calls for an L-REAC™ button on the front page of the DoD Web site. When a user clicks on this L-REAC™ icon, his/her access is verified as acceptable and allowed to enter the read only area. If an individual is certified to operate the L-REAC™ System, he/she would be able to login and start the plume model, or adjust the view of the output maps, to meet the immediate need of an incident.

The use of hand-held displays is a definite vision for this system. This option was proven feasible during the Prototype development. Only the lack of time and resources prevented the integration of this feature into the operational system.

4. System Evaluation by Professional First Response End Users

The Operational L-REAC™ System was introduced to the "real world" operational environment through an unexpected invitation to assist with a local fire actively threatening the local and work communities. The 2011 April event was called "the Abrams Fire." This three-day event gave the system access to practical feedback. The L-REAC™ System had already been through numerous site exercises, which allowed this "real world" experience to be positive for both the developers and the professional first responders.

As a consequence of the Abrams Fire, we were asked to train the local IOC and Fire Department personnel on the L-REAC™ System. Eleven training sessions were conducted, producing potential L-REAC™ System operators from the IOC, the Fire Department, the EOC and ARL (not including the developers).

In the course of the training sessions, we included two multiple-page evaluation questionnaires. From these questionnaires, we learned that the output was user-friendly, that the most popular choices regarding recommendations for L-REAC™ users were the IOC, EOC, police, and incident commanders; and, that the majority of evaluators thought all elements included in the EUD output were "most important" to their decision making responsibilities. Additional evaluation material will be published separately.

5. Summary and Final Comments

This report is the third of three reports documenting the L-REAC™ System development, which was funded by ARL mission resources. There are nine technology readiness levels required to bring this system from concept to maturity. With this report, we have completed five levels. The feedback from professional first responders has been most encouraging. It is the authors" hope that the opportunity to transfer this technology into an Army resource will continue, and as we saw in the "real world" event, that this decision aid will continue to make a difference in the mission of saving civilian and Soldier lives.

6. References

ALOHA User's Manual, The CAMEO Software System, EPA/NOAA, February 2007.

Birley, Pam; *The Highest Point on Race Rocks,* courtesy of Lester B. Pearson College, Victoria, BC, Canada. http://www.racerocks.com/racerock/abiotic/wind/eaglevane.htm (accessed 2011 September 6).

Campbell Scientific, Inc, 2004: *CR23X Micrologger, Operator's Manual Rev 11/2006*, Logan, Utah, http://www.campbellsci.com/documents/manuals/retired/cr23x.pdf (accessed 2009 June 25).

Grid Analysis and Display System (GrADS), http://grads.iges.org/grads/grads.html (accessed September 2010).

Snyder, W.; Lawson, Jr., R. *Wind-Tunnel Measurements of Flow Fields in the Vicinity of Buildings*, 8th Conference on Applied Air Pollution Meteorology with A&WMA, Nashville, TN, AMS, Boston, pp 244–250, January 1994.

Vaucher, G. T. *Urban-Small Building Complex Environment: Comparing Stable Patterns from Two Similar Urban Field Studies, Volume AS-1*; ARL-TR-4456; U.S. Army Research Laboratory: White Sands Missile Range, NM, September 2007.

Vaucher, G. T. *Urban-Small Building Complex Environment: W07US Stability Analysis and Inter-Study Comparison, Volume AS-2*; ARL-TR-4452; U.S. Army Research Laboratory: White Sands Missile Range, NM, May 2008.

Vaucher, G. T. *White Sands Missile Range Urban Study: Flow and Stability Around a Single Building, Part 1: Background and Overview*; ARL-TR-3851; U.S. Army Research Laboratory: White Sands Missile Range, NM, July 2006.

Vaucher, G. T.; Brice, R.; D‟Arcy, S.; Bustillos, M.; Cionco, R. *White Sands Missile Range 2007 Urban Study: Data Processing - Volume DP-1 (Sonic Calibration)*; ARL-TR-4439; U.S. Army Research Laboratory: White Sands Missile Range, NM, September 2008.

Vaucher, G. T.; Brice, R.; D‟Arcy, S.; Bustillos, M.; Cionco, R. *White Sands Missile Range 2007 Urban Study: Data Processing - Volume DP-2 (Main Dataset)*; ARL-TR-4440; U.S. Army Research Laboratory: White Sands Missile Range, NM, September 2008.

Vaucher, G.T.; Bustillos, M. *White Sands Missile Range 2007 Urban Study: Data Processing - Volume DP-3 (Airflow Qualitative Assessment)*; ARL-TR-4441; U.S. Army Research Laboratory: White Sands Missile Range, NM, May 2008.

Vaucher, G.T.; Luces, A.; O'Brien, S.; Brice, R.; Bustillos, M.; D'Arcy, S. *Local-Rapid Evaluation of Atmospheric Conditions (L-REAC) System, Design and Development, Volume 1 ("Proof of Concept")*; ARL-TR-4958; U.S. Army Research Laboratory: White Sands Missile Range, NM, September 2009.

Vaucher, G.T.; Luces, A.; O'Brien, S.; Brice, R. *Local-Rapid Evaluation of Atmospheric Conditions (L-REAC) System, Design and Development, Volume 2 ("Prototype")*; ARL-TR-5332; U.S. Army Research Laboratory: White Sands Missile Range, NM, September 2010.

Vaucher, G.T. *White Sands Missile Range 2007 Urban Study (W07US): Data Analysis, Volume DA-1 (Analysis of Disaster Response Drills and Concurrent Atmospheric Data)*; ARL-TR-5706; U.S. Army Research Laboratory: White Sands Missile Range, NM, September 2011.

Wang, Y.; Williamson, C.; Garvey, D.; Chang, S.; Cogan, J. Application of a Multigrid Method to a Mass-consistent Diagnostic Wind Model. *J. Appl. Meteorol.* **2005**, 44, 1078–1089.

List of Symbols, Abbreviations, and Acronyms

3DWF	Three-Dimensional Wind Field
ADM	Administrator
AGL	above ground level
ALOHA	Areal Locations of Hazardous Atmospheres
AOI	area(s) of interest
ARL	U. S. Army Research Laboratory
C	Celsius
DMZ	Demilitarized Zone
DoD	Department of Defense
DTED	Digital Terrain Elevation Data
EOC	Emergency Operations Center
EPA	Environmental Protection Agency
EUD	End User Display
FY11	fiscal year 2011
GLE	Graphics Layout Engine
GrADS	grid analysis and display system
HAZMAT	Hazardous Materials
HDTV	high definition television
HPAC	Hazard Prediction and Assessment Capability
HTML	HyperText Markup Language
IOC	Installation Operations Center
JD	Julian Day
kml	keyhole markup language
L-REAC™	Local-Rapid Evaluation of Atmospheric Conditions System

mph	miles per hour
NED	National Elevation Dataset
NOAA	National Oceanic and Atmospheric Administration
OS	operating system
PoC	Proof of Concept
QC	Quality Control
QUIC	Quick Urban and Industrial Complex
RH	relative humidity
s	second
SAMS	Surface Automated Meteorological System
SEP	Single Editing Pass
SIP	shelter-in-place
UPS	uninterruptable power supply
VBScript	Visual Basic Script
W03US	*White Sands Missile Range 2003 Urban Study*
W05US	*White Sands Missile Range 2005 Urban Study*
W07US	*White Sands Missile Range 2007 Urban Study*
WRF	Weather Research and Forecasting
WSMR	White Sands Missile Range
XPAC	A modified version of Hazard Prediction and Assessment Capability model

No. of Copies	Organization
1 (PDF)	ADMNSTR DEFNS TECHL INFO CTR DTIC OCP 8725 JOHN J KINGMAN RD STE 0944 FT BELVOIR VA 22060-6218
3 HCs	US ARMY RSRCH LAB ATTN RDRL CIO MT TECHL PUB ATTN RDRL CIO LL TECHL LIB ATTN IMNE ALC HRR MAIL & RECORDS MGMT 2800 POWDER MILL ROAD ADELPHI MD 20783-1197
6 CDs 10 HCs	US ARMY RSRCH LAB G VAUCHER ATTN RDRL CIE D BLD 1622 WSMR NM 88002
1 CD	US ARMY RSRCH LAB R BRICE ATTN RDRL CIE D BLDG 1622 WSMR NM 88002
1 CD	US ARMY RSRCH LAB S LUCES ATT RDRL CIE D BLDG 1622 WSMR NM 88002
1 CD	US ARMY RSRCH LAB S OBRIEN ATT RDRL CIE D BLDG 1622 WSMR NM 88002
Total 23	(1 PDF, 13 HCs, 9 CDs)

INTENTIONALLY LEFT BLANK.