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4.4 SAVING LIVES WITH L-REAC®, AN AIRBORNE HEALTH-HAZARD DECISION AID

Gail Vaucher*
U.S. Army Research Laboratory
White Sands Missile Range, NM

1. BACKGROUND

The primary goal of the U.S. Army Research Laboratory (ARL), Local-Rapid Evaluation of Atmospheric Conditions (L-REAC®) System is to improve situational awareness of environmental airborne hazards during potentially life-threatening events; to prevent human suffering and/or save lives. The L-REAC® System accomplishes this goal by mapping near-real-time wind field and toxic plume (when applicable) footprints over a given area of interest (AOI).

The L-REAC® System concept is a product of the 2003–2007 White Sands Missile Range (WSMR), NM, Urban Field Studies, which investigated the airflow and stability characterization around a single urban building and small building clusters. Concurrent disaster response drills executed during the *WSMR 2007 Urban Study* revealed a need for emergency first responders to have timely and locally-relevant atmospheric information (Vaucher, 2011a). In this same time period, CNN reported that U.S. Army Soldiers were experiencing airborne hazards overseas while working near the Iraqi burn pits (CNN Webpage, 2007). ARL conducted a survey of commercially available technology and confirmed a niche for developing a real-time, local-scale, atmospheric assessment system (Vaucher and Brice, 2010). From 2009–2011, the initial viewgraph technology evolved into a tangible Operational L-REAC® System.

The L-REAC® System consists of five primary modules: the Sensor Module, the Quality Control (QC) Module, the Model Module, the End User Display (EUD) Module, and the Archive Module. A dedicated sensor suite autonomously ingests and archives 1-min meteorological data samples. These data are processed and utilized as input for both the wind and plume models. The automated wind model runs at a resolution selected by the operator. These resolutions include: a building scale (5 m resolution), cantonment scale (50 m resolution) and regional scale (100 m resolution). When no toxic threat is present, the plume model runs using "place holder" data. Model outputs are sent to the EUD Module, where they are mapped onto a given AOI. Figure 1 summarizes the L-REAC® System data flow.

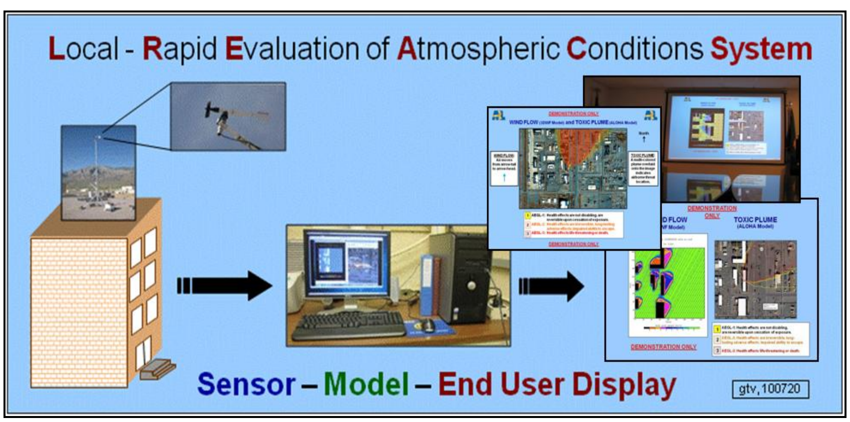

Figure 1. L-REAC® System data flow. Modules not shown include the QC Module and the Archive Module.

**Corresponding author address*: Gail Vaucher, U.S. Army Research Laboratory, RDRL-CIE-M, WSMR, NM 88002; e-mail: gail.vaucher@us.army.mil

Using an L-REAC® networked drive, authorized-users can view the mapped products from various approved terminals such as their office personal computer, a building lobby screen or shelter-in-place rooms. The near real-time, mapped atmospheric conditions are presented in two HyperText Markup Language (HTML) windows. On the “Building Scale” window, the wind and plume model results are graphically displayed in two separate, but equivalently-proportioned, maps. This window is called the “2-Plot” (or “2P”). Wind direction is shown via arrows and streamlines. Wind speeds are color-coded according to the long to short-wave color spectrum. Plume information is mapped using a 3-tier gradient of hazardous concentrations. See Figure 2.

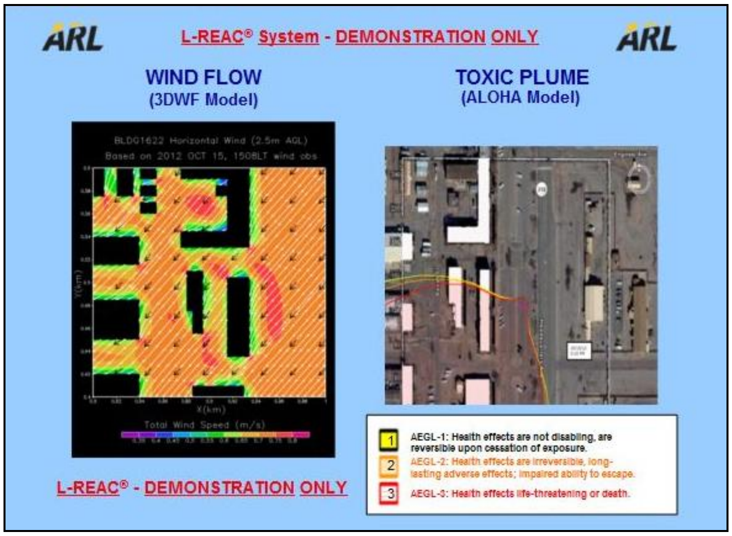

Figure 2. The L-REAC® System “2P” EUD window.

Wind and plume information is collated onto a single map, for the “1-Plot” (“1P”) window. The L-REAC® System operator can easily zoom-in or zoom-out on this map, showing as little as one wind vector, or as much as the entire wind vector and plume fields. An “Instant Save” function allows the operator to quickly send re-oriented images to users in the field. Quantitative measurements are tabulated on the 1P, in units relevant to emergency first responders. See Figure 3. The self-sustained system can run continually—24-h a day/7-days a week (24/7)—without an operator.

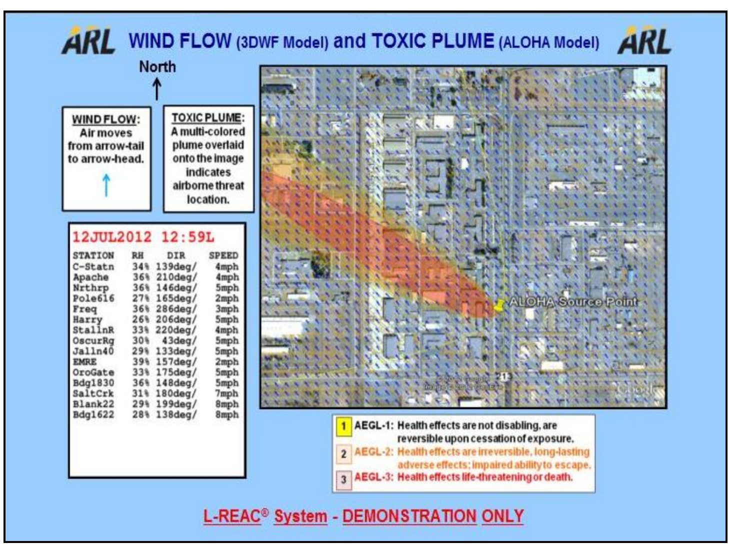

Figure 3. The L-REAC® System “1P” EUD window.

A QC Module allows the user to instantly inspect each sensor via a data time series from midnight to the current time. This graphical tool also allows an operator to visualize local meteorological trends, should that information be relevant to an incident.

An Archive Module routinely extracts and preserves 1-day of data. The user also has the option of saving the images sent to the EUD. These images and data resources are intended to assist with post-incident analyses.

2. L-REAC® SYSTEM CONTRIBUTES TO THE "NATION'S READINESS AND RESPONSIVENESS"

The L-REAC® System decision aid role in national readiness can be best understood through a simulated toxic airborne hazard scenario. Consider the following:

A tanker truck driving through a business district of an urban community accidentally hits a street light creating a leak in the chemical tank.

There are many types of decisions made during an emergency. For the given incident, a typical decision sequence might be:

(1) The onsite witnesses standing near the initial accident need to determine where a safe location is, so they can retreat from the potentially life-threatening situation.

(2) Building occupants near the incident must decide whether to shelter-in-place, evacuate or take the time to call for help.

(3) Building managers must decide how to advise building occupants and secure help.

(4) Help Dispatch (911) operators must decide how to advise residents. When they dispatch the response units, they have an opportunity to suggest how these units might safely approach the hazardous incident.

(5) Each emergency unit dispatched must determine the critical safety requirements with regard to their approach to the incident, and assigned tasks. For example: professional emergency responders may be assigned vehicle traffic management or crowd control in or near the airborne hazard. If their situation becomes life-threatening (safety gear fails), they will need to be aware of a safe and quick retreat.

(6) 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, would continue until the AOI is once again declared safe for public use.

The L-REAC® System can aid the above decision makers in making informed and potentially life-saving decisions by the following (numbers below correspond to the decision sequence numbers above):

(#1) The L-REAC® System demonstration units have a dedicated sensor suite mounted on a building roof, as per security and safety requirements. This location makes the dynamic movements of the wind monitor (anemometer) visible to those persons on the ground.

The persons witnessing the incident can visually inspect L-REAC® System's animated anemometer, to determine where "upwind" is, and evaluate whether to head in that direction.

(#2–4) Building occupants, custodians and dispatch persons who have determined to evacuate the area can utilize the near real-time L-REAC® System wind fields from their office computer, to identify the "upwind" region and assess if this area is the best choice for safety.

(#5) Professionals responding to the incident can reference the current airflow fields to determine hazardous and safe areas for their operations, as well as the implied atmospheric impacts on their individual responsibilities.

(#6) The Incident Commanders can integrate the mapped air flow into their scenario visualization.

A post-incident environmental remediation is not necessarily in a time-dependent, life saving decision category. However, using the archived L-REAC® System data can assist the remediation program, resulting in more effective long term environmental and health recovery actions.

The preceding description was an envisioned scenario. In April 2011, the L-REAC® System was invited to participate in its first real world, "test under fire" incident.

3. REAL WORLD INCIDENT APPLICATIONS

In April 2011, a fire broke out in the Organ Mountains of New Mexico. The proximity of the blaze threatened to evacuate the WSMR workforce and local community. Even though the L-REAC® System was still in development as a decision aid, the technology was mature enough to answer the call for assistance. Throughout the subsequent 3-day event, the L-REAC® System provided near real-time wind fields, which were used by the various fire fighting units and the New Mexico Bureau of Land Management. Figure 4 shows examples of the smoke patterns and wind fields observed during this "Abrams Fire" incident (Vaucher and O'Brien, 2012b). No chemically-created toxic plumes were identified; therefore, only the near real-time wind fields were utilized. The wind fields and quantitative airflow values were used for assessing public evacuation options, fire fighter helicopter water runs, incident approach and retreat strategies, etc.

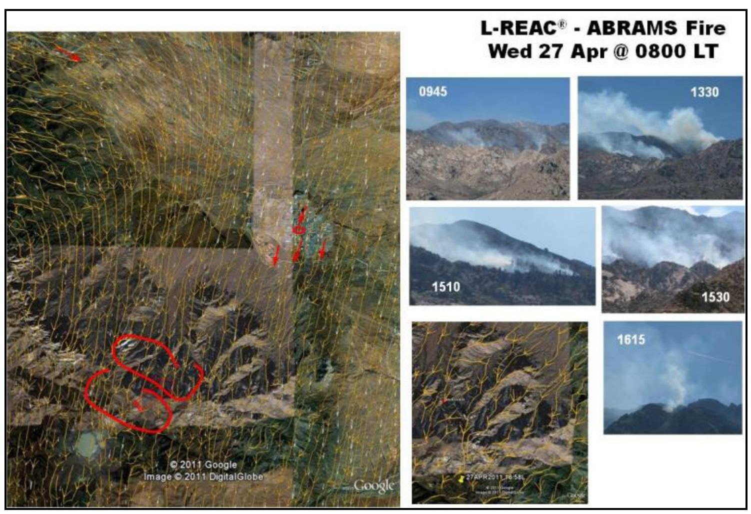

Figure 4. L-REAC® System contributed to the Abrams Fire countermeasures.

Based on the success of this impromptu System debut, the L-REAC® System was quickly advanced into operations as a 24/7, automated, atmospheric assessment resource for the WSMR first responder community. Training was provided, as the end user list expanded to include multiple emergency response organizations. This training included two levels of expertise: a User Level and an Operator Level. The User Level was the person in the field, interpreting the end products. The Operator was not only skilled in interpreting end products, but was experienced in bringing up the models, managing the computer visuals and working with the communication tools.

The L-REAC® System developers listened closely to the needs of the first responders during the Abrams Fire incident and throughout the training sessions. As part of the User Training, a 12-page detailed questionnaire provided both a "self-test" of the trainee's understanding (no grade was assigned to this anonymous* document), and the opportunity for them to bluntly voice their likes and dislikes of the L-REAC® System.

The only significant change made between the Abrams Fire and the fully operational design was adding a tabulated measurement summary to the “1 Plot” image. Measured atmospheric parameters were converted into engineering units used by the firefighters; only the most critical measurements were displayed (to avoid ‘too much’ information); and the date/time of the primary data input were inserted in bold red type at the top of the table. A sample of the user comments was published in *Urban Field Study Results in Operational Airborne Health Hazard Decision Aid* (Vaucher and O’Brien, 2012a). The complete summary was published in *Local-Rapid Evaluation of Atmospheric Conditions (L-REAC™) System, Volume 4 (System Evaluation)* technical report (Vaucher, 2011b).

4. MOBILE L-REAC® SYSTEM

Real-world incident experiences led to the development of a *Mobile* L-REAC® System “Proof of Concept.” Unlike the Operational L-REAC® System, this decision aid was built on a laptop, with two sensor input options. The fixed sensor suite (FSS) imitated the Operational design and allowed the Mobile System to service a community in 24/7 operational mode. The mobile sensor suite (MSS) utilized wireless technology, allowing the entire physical system to be mobilized within an AOI. The Mobile L-REAC® System demonstration unit used the Coastal Environmental Systems, Inc (CES) WEATHERPAK® Multiple Threat Response (MTR), which was designed specifically for Hazardous Material (HAZMAT) environments and incident responses. See Figure 5.

Figure 5. Two examples of HAZMAT meteorological sensor suites: WEATHERPAK MTR (left) and WEATHERPAK TRx (right). (Hemmingway, 2012)

Several system enhancements were added to the Mobile L-REAC® System. Most of these improved the infrastructure, including one option to operate the system in a “local” mode. This “local” mode facilitated the system’s need to be a “stand-alone” field system, as well as a contributor to the Operational L-REAC® System output.

5. L-REAC® SYSTEM “CORE AND 2ND TIER” DESIGN

With the successful MSS integration into the Mobile L-REAC® System, the physical tools were now available to validate an original vision for the L-REAC® System; namely, the L-REAC® System “Core and 2nd Tier” design.

*Users placed a randomly selected number in place of their names; only the trainees knew which number was theirs.

The "core" was envisioned as an L-REAC® System running 24/7, producing output over a given AOI every 2–10 min (depending on the wind/plume model resolution selected). The "2nd Tier" was visualized as an independent, computer platform running a slower, application-relevant model (or models). The end products of these two resources would be delivered to the end user, as they became available.

In a 2012 Feasibility Study, the "core" system was the Mobile L-REAC® System with the MSS, running a 5 m resolution wind model. The "2nd Tier" was the Operational L-REAC® System with the FSS, running a 100 m resolution wind model. Both systems fed their output to the standard EUD windows on the L-REAC® networked drive. The users received the "core" output every 1–2 min and the "2nd Tier" output every 8–10 min. In a second test, the wind and plume models were run, concurrently. The results of these four model resources were fed to the EUD windows. On a third test, the four model results were successfully communicated to users, through a newly-developed, restricted-access, L-REAC® System website.

6. L-REAC® IN A SYSTEM OF SYSTEMS

When national emergencies occur involving atmospheric impacts to human lives, there are several System of Systems (SoS) products ready to respond. Within this technology, there is still room for a near real-time, local-scale atmospheric conditions assessment tool. Recently, the L-REAC® System was invited to conduct a feasibility study on a SoS. This study tested the L-REAC® System's ability to contribute to a SoS and was executed in two parts.

First, the computer housing the SoS was approved for access to the L-REAC® System output. The L-REAC® System EUD startup software was loaded onto the SoS. Double clicking on the startup icon, the L-REAC® output was instantaneously visible. The 1P and 2P automated updates persisted without interruption throughout the test.

The second part involved ingesting a static L-REAC® System output (map of wind vectors) into the SoS software. The SoS software was designed as layers of mapped information. Matching location parameters, the L-REAC® System output was easily converted into an overlay on the SoS map. To ensure compatibility, one of the detailed SoS atmospheric plume models was subsequently run, and the plume output was allowed to automatically overlay itself on the L-REAC® System output as the "next layer." The results are shown in Figure 6.

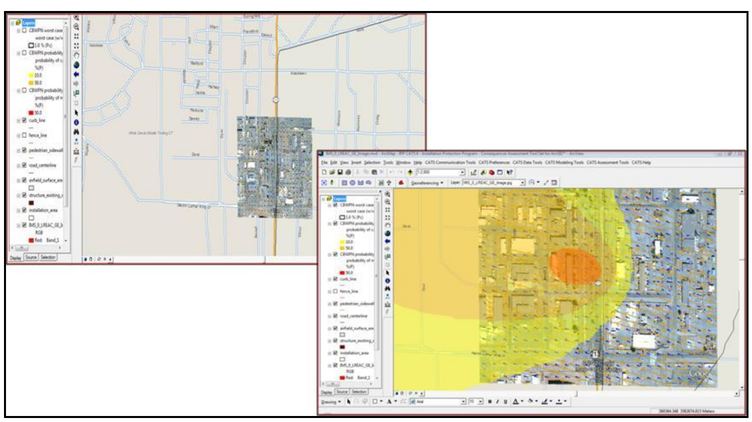

Figure 6. L-REAC® System wind field was inserted as a layer between the SoS foundational mapping display and SoS plume model.

Due to the proprietary nature of the SoS software, an automated insertion of L-REAC® System output was not pursued. However, since a manual insertion of the wind field was successfully demonstrated, the automated input was considered an implied feasible task.

7. FUTURE L-REAC® SYSTEM POTENTIAL

The potential future gleaned from the Mobile L-REAC® System "Proof of Concept" and the feasibility studies, is quite extensive. The first question generally asked after demonstrating the Mobile L-REAC® System is, "How many units can you field?" The L-REAC® System already has the ability to integrate mesonet data, and the Coastal Environmental Systems, Inc WEATHERPAK® MTR technology supports multiple unit integration. Consequently, the response to the inquiry would most likely be a function of cost, rather than technology.

With the ability to run multiple L-REAC® Systems (Operational and Mobile) concurrently, and in a "Core and 2nd Tier" design, we turn to the top two weather-related questions asked during an airborne hazard incident: "What are the winds now?" and "What will they be in 1–3 h?"

The L-REAC® System already answers the first question. One forward-looking vision is to let the "2nd Tier" run a 1–3 h forecast model, such as a Rapid Update Cycle (a.k.a. Rapid Refresh Weather Research Forecast (WRF)) model. This design would address both questions, fully empowering first responders with diagnostic and prognostic atmospheric assessments.

Looking beyond airborne hazards, any application requiring near real-time winds or atmospheric conditions can now be addressed. The automated "core" system would faithfully provide the local, real-time atmospheric conditions, while the "2nd tier" would assimilate these data into slower running application models. One such application model currently being considered is an aerial flight routing model.

8. SUMMARY

The L-REAC® System is an automated, 24/7, emergency response decision aid designed for airborne toxic release incidents on a local scale. The Operational L-REAC® System is composed of five core modules, which automatically ingest 1-min meteorological sensor data into wind and plume models that produce mapped airflow patterns and chemical concentrations. These end user displays are viewed in near real-time by authorized users.

In April 2011, the L-REAC® System was invited to participate in the Abrams Fire countermeasures that threatened the local community and workforce. As a consequence of this successful "real world" interaction, the L-REAC® System became operational and has been continuously serving the local community.

Recently, a mobile "Proof of Concept" version of the Operational L-REAC® System was constructed. This portable system can ingest either a fixed (FSS) or mobile (MSS) sensor suite. The Mobile L-REAC® System-FSS design mirrors the Operational L-REAC® System unit. Through a Feasibility Study, the MSS used the Coastal Environmental Systems, Inc WEATHERPAK® MTR, which is designed for HAZMAT scenarios, and allows users to move the L-REAC® System to alternate locations within a given AOI. A "local mode" option facilitates running the system independent of the Operational L-REAC® System.

Through other Feasibility Studies, the ability to integrate the L-REAC® System output into a larger national SoS package was demonstrated. This system capability was shown first, with a successful, automated communication link between L-REAC® System output and the SoS computer platform. Then, a static L-REAC® System wind field layer was successfully assimilated as an integrated layer of the SoS output.

A subsequent Feasibility Study proved that the original L-REAC® System "Core and 2nd Tier" design was functional. The dual processor design was demonstrated by using both the Operational and Mobile L-REAC® Systems, concurrently. The first test ran just wind models on both Systems. The subsequent test ran wind and plume models from both core and 2nd Tier Systems. The final feasibility study test viewed the 4-model output through the specialized L-REAC® network *and* a "new" website link.

The results of these successful feasibility studies have laid the groundwork for pursing multiple applications. A few were discussed within this article.

“Saving more lives” is one of the building blocks for the *First Symposium on Building a Weather-Ready Nation*. The L-REAC® System purpose is to provide timely and relevant, local-scale, atmospheric conditions to both professional and volunteer emergency first responders, as well as, those colleagues who have the unfortunate timing of being first-to-witness an incident. With the L-REAC® System Archive, the system contributes to post-incident environmental remediation and the after-incident ‘lessons learned’. In these attributes, the L-REAC® System hopes to make a difference in the mission of protecting and saving lives.

9. ACKNOWLEDGEMENTS

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10. REFERENCES:

CNN Webpage, *Toxic gas latest insurgent weapon in Iraq,* http://www.cnn.com/2007/WORLD/meast/02/22/iraq.main/index.html (accessed 2007 February 22).

Hemmingway, J., December 4, 2012: Coastal Environmental Systems, Inc., Private communication.

Vaucher, G., December 2011b: *Local-Rapid Evaluation of Atmospheric Conditions (L-REAC) System, Volume 4 (System Evaluation)*; ARL-TR-5848; U.S. Army Research Laboratory: White Sands Missile Range, NM.

Vaucher, G.; Brice, R., January 2010: *A Survey of Meteorologically-Based Systems for Airborne-Released Hazard Emergencies,* 16th Conference on the Applications of Air Pollution Meteorology, 90th AMS Annual Meeting, Atlanta, GA.

Vaucher, G.; O’Brien, S., January 2012a: *Urban Field Study Results in Operational Airborne Health Hazard Decision Aid,* 28th Conf on Interactive Information Processing Systems (IIPS), 92nd AMS Annual Meeting, New Orleans, LA.

Vaucher, G.; O’Brien, S., June 2012b: *A Case Study of the L-REAC® System Supporting Wildfire Suppression*, MORS Symposium,.

Vaucher, G.T., September 2011a: *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.