Chapter 2

PUBLIC HEALTH SYNDROMIC SURVEILLANCE SYSTEMS

In this chapter, we summarize the key local, state, national, and international syndromic surveillance systems and related ongoing research programs of interest covered in our study. This summary provides the needed background information and application contexts. It also offers a current snapshot of syndromic surveillance practice in general. Note that as our primary focus is on public health surveillance, closely-related issues such as response planning and resource allocations strategies after an event is confirmed (e.g., Carley et al., 2003) are beyond the scope of this study.

For each system surveyed, we list its main contributors and stakeholders. We also include an overall system/project description, relevant data sources, syndromes monitored, data analysis and outbreak detection methods implemented, frequency of data collection and analysis, whether a GIS component is used, and its deployment strategy and status.

Although our review is intended to be detailed and comprehensive, our effort has been hampered by the unavailability of the technical details of many syndromic surveillance systems from either the published literature or the publicly available sources such as project Web sites. Furthermore, despite our best effort, our literature review is unlikely to be exhaustive. As such, we may have missed some interesting and emerging local and/or international syndromic surveillance system implementations. Nonetheless, our review should provide the readers with a fairly detailed and up-to-date snapshot of the state-of-the-art research and successful implementations of syndromic surveillance systems for public health and biodefense.

1.   SUMMARY OF NATIONWIDE SYNDROMIC SURVEILLANCE SYSTEMS

Thirteen nationwide syndromic surveillance systems plus two open source global public health status monitoring systems have been identified in our study. Table 2-1 presents a summary of these systems. Below we provide additional information for each of these systems.

CDC's BioSense system is a national initiative to support early outbreak detection by providing technologies for timely data acquisition, near real-time reporting, automated outbreak identification, and related analytics (Bradley et al., 2005; Ma et al., 2005; Sokolow et al., 2005). BioSense collects ambulatory care data, emergency room diagnostic and procedural information from military and veteran medical facilities, and clinical laboratory test orders and results from LabCorp. BioSense also monitors over-the-counter (OTC) drug sales, and laboratory test results for environmental samples collected through the BioWatch effort. In its most recent implementation, BioSense aims to monitor 11 syndrome categories including fever, respiratory, gastrointestinal illness (GI), hemorrhagic illness, localized cutaneous lesion, lymphadenitis, neurologic, rash, severe illness and death, specific infection, and botulism-like/botulism.

The Real-time Outbreak Detection System (RODS) is grounded in public health practice and focuses on collecting surveillance data for algorithm validation and investigating different types of novel data for outbreak detection (Espino et al., 2004; Tsui et al., 2003). It has been connected to 500+ hospitals' emergency departments nationwide for syndromic surveillance pur-poses. RODS collects chief complaints from emergency rooms, admission records from hospitals, and OTC drug sales data in real-time. Syndrome categories including respiratory, GI, botulinic, constitutional, neurologic, rash, hemorrhagic, and others are monitored with a collection of data analysis methods.

In 1999, the Walter Reed Army Institute of Research (WRAIR) created the Electronic Surveillance System for the Early Notification of Community-based Epidemics (ESSENCE) (Lombardo et al., 2004). ESSENCE has been used to monitor the health status of military healthcare beneficiaries worldwide, relying on outpatient ICD-9 diagnostic codes for outbreak detection (Burkom et al., 2004; Lombardo et al., 2003, 2004). Military and civilian ambulatory visits, civilian emergency department chief-complaint records, school-absenteeism data, OTC and prescription medication sales, veterinary health records, and requests for influenza testing are used by ESSENCE to evaluate health status with a focus on cases of death, GI, neurological, rash, respiratory, sepsis, unspecified infection, and others. ESSENCE has been deployed in the

National Capital Area, and 300 military clinics worldwide by 2003 (Lombardo et al., 2003).

The Rapid Syndrome Validation Project (RSVP) is an Internet-based population health surveillance tool designed to facilitate rapid communications between epidemiologists and healthcare providers (Zelicoff, 2002; Zelicoff et al., 2001). Through RSVP, patient encounters labeled with syndrome categories (including flu-like illness, fever with skin findings, fever with altered mental status, acute bloody diarrhea, acute hepatitis, and acute respiratory distress) and clinicians' judgment regarding the severity of illness are reported to facilitate timely geographic and temporal analysis (Zelicoff, 2002).

The Early Aberration Reporting System (EARS) is used to monitor bioterrorism activities during large-scale events. Its evolution to a standard surveillance tool began in the New York City and the national capitol region following the terrorist attacks of September 11, 2001 (CDC, 2006a; Hutwagner et al., 2003). Emergent department visits, 911 calls, physician office data, school and work absenteeism, and OTC drug sales are monitored for 42 syndrome categories (Hutwagner et al., 2003). EARS has been implemented in emergency departments in the state of New Mexico. It was also used for syndromic surveillance purposes at the 2000 Democratic National Convention, the 2001 Super Bowl, and the 2001 World Series.

The National Bioterrorism Syndromic Surveillance Demonstration Program covers a population of more than 20 million people. This program monitors and analyzes disease cases for neurologic, upper/lower GI, upper/lower respiratory, dermatologic, sepsis/fever, bioterrorism category A agents (anthrax, botulism, plague, smallpox, tularemia, and hemorrhagic fever), and influenza-like illness (ILI). These data utilized are derived from electronic patient-encounter records from participating healthcare organizations including ambulatory-care encounters and urgent-care encounters (Lazarus et al., 2001, 2002; Platt et al., 2003; Yih et al., 2004). This project provides a testbed for analyzing various outbreak detection algorithms and implements a model-adjusted SaTScan approach and the SMART algorithm (Kleinman et al., 2004).

The Bio-event Advanced Leading Indicator Recognition Technology (BioALIRT) program examines the use of spatial and other covariate inform-ation from disparate sources to improve the timeliness of outbreak detection in reaction to possible bioterrorism attacks (Buckeridge et al., 2005a; Siegrist et al., 2004). In a number of regions including Norfolk, Virginia; Pensacola, Florida; Charleston, South Carolina; Seattle, Washington; and Louisville, Kentucky, the BioALIRT system monitors military and civilian outpatient-visit records with ICD-9 codes, and military outpatient prescription records for unusual ILI and GI occurrences.

BioDefend is another program that aims to develop an effective and practical approach for rapid detection of outbreaks (2006b; Uhde et al., 2005). Patient encounter information is collected automatically or manually from clinics, emergency departments, and first aid stations at the first point of patient contact. Syndrome categories monitored include respiratory tract infection with fever, botulism-like, ILI, death with fever, GI, encephalitis/meningitis-like illness, febrile, rash with fever, fever of unknown origin, sepsis, contact dermatitis, and nontraumatic shock.

Biological Spatio-Temporal Outbreak Reasoning Module (BioStorm) aims to integrate disparate data sources and deploys various analytic problem solvers to support public health surveillance. The framework is ontology-based and consists of a data broker, a data mapper, a control structure and a library of statistical and spatial problem solvers (Buckeridge et al., 2002; Crubézy et al., 2005). It monitors and analyzes data such as 911 emergency calls collected from San Francisco, emergency department dispatch data from the Palo Alto Veterans Administration Medical Center, and emergency department respiratory records from hospitals in Norfolk, Virginia. On the basis of a customized knowledge base, BioStorm has implemented a library of statistical methods analyzing data as single or multiple time series and knowledge-based methods that relate detected abnormalities to knowledge about reportable diseases.

BioPortal is another biosurveillance system that provides a flexible and scalable infectious disease information sharing (across species and jurisdictions), alerting, analysis, and visualization platform (Chen and Xu, 2006; Zeng et al., 2005b). The system supports interactive, dynamic spatial-temporal analysis of epidemiological, textual and sequence data (Chen and Xu, 2006; Thurmond, 2006; Zeng et al., 2005a). BioPortal makes available a sophisticated spatial-temporal visualization environment to help visualize public health case reports and analysis results. Similar to EARS, BioPortal uses customized syndrome categories, which were developed by the State of Arizona Department of Health Services and hospitals in Taiwan (Lu et al., 2008). A number of retrospective and prospective spatial-temporal clustering (hotspot analysis) approaches are developed and implemented in BioPortal for outbreak detection purposes. They are Risk-adjusted Support Vector Clustering (RSVC) (Zeng et al., 2004a), Prospective Support Vector Clustering (Chang et al., 2005, 2008), and space-time correlation analysis (Ma et al., 2006).

Bio-Surveillance Analysis, Feedback, Evaluation and Response (B-SAFER) is a Web-based infectious disease monitoring system that is part of the open source OpenEMed project (http://openemed.org/) for use in urgent care settings (Umland et al., 2003). It collects chief complaints, discharge diagnoses and disposition data for detection analysis concerning a group of syndromes including respiratory, GI, undifferentiated infection, lymphatic, skin, neurological,

and other. The collected data are analyzed daily by a first-order model that uses regression to fit trends, seasonal effects, and day-of-week effects (Brillman et al., 2005).

INtegrated Forecasts and EaRly eNteric Outbreak (INFERNO) incorporates infectious disease epidemiology into adaptive forecasting and uses the concept of an outbreak signature as a composite of disease epidemic curves (Naumova et al., 2005). The system has been tested with a dataset of emergency department records associated with a substantial waterborne outbreak of cryptosporidiosis that occurred in Milwaukee, Wisconsin, in 1993.
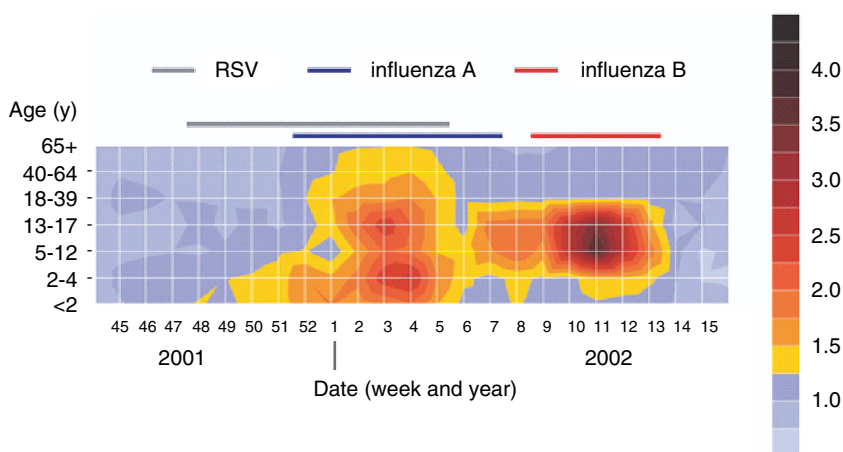

Figure 2-1. Surface-plot of scaled ED visits by age, with predominant RSV and influenza A and B periods indicated (Olson et al. 2007).

The DiSTRIBuTE project is a proof-of-concept, distributed, influenza surveillance system. DiSTRIBuTE uses aggregate, influenza-like illness (ILI), emergency department data from existing syndromic surveillance systems developed by state and local public health departments. Data are aggregated by age group and three-digit zip code. The DiSTRIBuTE project complements traditional influenza morbidity surveillance by providing a consistent, timely, year-round, high volume, regional, age-group-specific indication of febrile illness in the community (Figure 2-1).

Two other global scale real-time disease event detection and tracking systems are taking a different approach from the systems discussed above. The Argus and HealthMap projects monitor online media from global sources, instead of disease cases reported by hospitals, clinics, and other health facilities. The two systems are built on top of open sources, exemplifying an idea of open development for public health informatics applications. Argus,

developed at Georgetown University, relies on Internet technologies as "harvesting engines" to capture information relevant to the definitional criteria for biological-outbreak severity metrics. The system automatically collects official disease reports from WHO or unofficial international health status reports from ProMED as indicators of possible biological events, and relies on its team of multilingual analysts to evaluate the associations between the online media and existence of adverse health events.

HealthMap brings together disparate data sources to achieve a unified and comprehensive view of the current global state of infectious diseases and their effect on human and animal health. This freely available Web site integrates outbreak data of varying reliability, ranging from news sources (such as Google News) to curated personal accounts (such as ProMED) to validated official alerts (such as World Health Organization). Through an automated text processing system, these data are aggregated by disease and displayed by location for user friendly access to the original alert. HealthMap provides a jumping-off point for real-time information on emerging infectious diseases and has particular interest for public health officials and international travelers.

Table 2-1. Thirteen nationwide syndromic surveillance systems and two global online disease intelligence projects.

System	Stakeholders	Monitored datasets	Syndrome categories	Data analysis methods	Frequency	GIS
BioSense	CDC	Multiple	11	CUSUM,[1] EWMA,[2] and SMART[6]	Daily	Y
RODS	U. of Pittsburgh and Carnegie Mellon U.	Multiple	8	Autoregressive modeling, CUSUM, scan statistics, WSARE,[3] PANDA[4] and others	Every 8 h	Y
ESSENCE	DoD-GEIS[5] and Johns Hopkins U	Multiple	8	CUSUM, EWMA, WSARE, SMART, and scan statistics	Daily	Y
RSVP	NM Dept. of Health and clinicians, Los Alamos National Lab (LANL), U. of NM, Sandia National Lab and State of NM	Multiple	6	CUSUM, EWMA and wavelet algorithms	Daily	Y
EARS	CDC	Multiple	About 42	Shewhart chart, moving average, and variations of CUSUM (C1-MILD, C2-MEDIUM, and C3-ULTRA)	Daily	N
National Bioterrorism Syndromic Surveillance Demonstration Program	Harvard Medical School's Channing Lab	Multiple	12	Model-adjusted SaTScan™ approach and SMART	Daily	N
BioALIRT	DARPA, Johns Hopkins U., Walter Reed Army Institute of Research, U. of Pittsburgh and Carnegie Mellon U., etc.	Multiple	ILI, GI	Algorithms developed by RODS, CDC, ESSENCE, and IBM	Daily	N
BioDefend	U. of South Florida's Center for Biological Defense and Datasphere, LLC	Multiple	12	Time series pattern deviation detection, based on a 30-day rolling mean as threshold	Daily	N

System	Stakeholders	Monitored datasets	Syndrome categories	Data analysis methods	Frequency	GIS
BioStorm	Stanford U.	Multiple	Customized	A library of statistical methods and knowledge-based methods	N/A	N
BioPortal	U. of Arizona, U. of California, Davis, Kansas State U., National Taiwan U., Arizona/California Dept. of Public Health Services, New York State Dept. of Health DoD's National Biodefense Initiative and Dept. of Energy, in collaboration with the Los Alamos	Multiple	40+	RSVC, Prospective SVC, and correlation analysis	N/A	Y
B-SAFER	National Lab, U. of New Mexico Health Sciences Center, and the New Mexico Dept. of Health	Multiple	7	First-order model	Daily	N
INFERNO	Sponsored by National Institutes of Health	Multiple	GI	Retrospective daily time series	N/A	N
DiSTRIBuTE	International Society for Disease Surveillance (ISDS)	Multiple	ILI	Group aggregates by age and jurisdictional area	Daily	N
Argus	Argus Research Operations Center (AROC), ISIS Center, Georgetown University Medical Center	Multiple	N/A	Web Scanning, online media processing, epidemics caused social disruption detection, evaluation and tracking, Wilson – Collmann Scale heuristic staging model	N/A	N
HealthMap	Harvard Medical School and the Children's Hospital Boston Informatics Program	Multiple	N/A	Google Maps, xajax PHP AJAX library, Open Source Web Design (Blue Sky template by Jonas John), Fisher-Robinson Bayesian filtering	N/A	N (Google Maps)

[1]CUSUM: Cumulative Sums
[2]EWMA: Exponentially Weighted Moving Average
[3]WSARE: What is Strange About Recent Event
[4]PANDA: Population-Wide Anomaly Detection and Assessment
[5]DoD-GEIS: DoD-Global Emerging Infections Surveillance and Response System
[6]SMART: Small Area Regression and Testing

2.   SUMMARY OF SYNDROMIC SURVEILLANCE SYSTEMS AT THE LOCAL, COUNTY, AND STATE LEVELS

Twenty syndromic surveillance systems implemented at the local, county, and state levels have been identified in our study. Table 2-2 presents a summary of these systems. Note that technical information about these systems is often much more difficult to locate (in many cases unavailable publicly) when compared with nationwide systems.

The syndromic surveillance system implemented in New York City uses ETL (extract, transform, and load) middleware technology from iWay Software over secure, Web-based reporting channels to receive and process a high volume of daily reports at a central data repository. A custom analytical application based on spatial data analysis software SaTScan and ArcView desktop GIS and mapping software from ESRI is used to perform statistical analysis and related visualization functions (Heffernan et al., 2004a, 2004b).

Syndromic Surveillance Information Collection (SSIC) is a complex, heterogeneous database system intended to facilitate the early detection of possible bioterrorism attacks (with such agents as anthrax, brucellosis, plague, Q-fever, tularemia, smallpox, viralencephalitides, hemorrhagic fever, botulism toxins, staphylococcal enterotoxin-B, among others) as well as naturally occurring disease outbreaks including large foodborne disease outbreaks, emerging infections, and pandemic influenza (Karras, 2005).

The Automated Epidemiological Geotemporal Integrated Surveillance (AEGIS) system is a surveillance effort initiated by the Children's Hospital Informatics Program at the Harvard-MIT Division of Health Sciences and Technology since 2000 at the state of Massachusetts. The system adopted a modular design to address the challenges of scalability, robustness, and data security issues due to an emerging demand of integrating real-time public health surveillance systems into regional and national surveillance initiatives (Reis et al., 2007) (Figure 2-2). The system consists of modeling modules, detection modules, and client modules.

Table 2-2: 20 syndromic surveillance system implementations at local or state levels

System	Stakeholders	System description
Syndromic Surveillance Project in New York City	New York City Dept. of Health and Mental Hygiene (NYCDOHMH)	Central data repository, ETL data processing, and analytical tools based on SaTScan and ArcView desktop GIS
SSIC	U. Washington	Focus on early detection of possible bioterrorism attacks
Automated Epidemiological Geotemporal Integrated Surveillance (AEGIS)	Children's Hospital Informatics Program at the Harvard-MIT Division of Health Sciences and Technology	A modular design to facilitate multiple health surveillance systems integration
Syndromal Surveillance Tally Sheet	EDs of Santa Clara County, California	A manual system relying on triage nurses' counts of the numbers of patients presenting the syndromes of interest
Syndromic Surveillance Using Automated Medical Records	Greater Boston	Outbreak detection with health plan data in the Greater Boston area
New Hampshire (NH) Syndromic Surveillance System	Division of Public Health Services, NH Dept. of Health and Human Services (NH DHHS)	A system collecting syndromic data from multiple sites including EDs, schools, workplaces, as well as other electronic health surveillance systems such as BioSense
Connecticut Hospital Admissions Syndromic Surveillance	Connecticut Dept. of Public Health (CDPH)	The system monitors hospital admission data

Catalis Health System for syndromic surveillance in a rural outpatient clinic in Texas	Texas Dept. of State Health Services (DSHS)	In 2003, the Texas Regional Health Dept. piloted the Catalis software system monitoring three types of syndromes: Rash Fever illness, meningoencephalitis and ILI. The system proved to be 100 percent sensitive in reporting syndromes to the state
NC DETECT http://www.ncdetect.org/	North Carolina Division of Public Health (NCDPH)	NC DETECT provides statewide early event detection by monitoring data from EDs, the Carolinas Poison Center, and the Pre-hospital Medical Information System
SENDSS https://sendss.state.ga.us/sendss/login.screen	Georgia Division of Public Health	SendSS is a reporting and tracking tool of notifiable diseases deployed in Georgia. It is a web-based application allows case report, analysis and messaging among other functionalities
Syndromic surveillance system in Miami-Dade County	Office of Epidemiology & Disease Control, Miami-Dade County Health Dept.	The system monitors chief complaints data on a daily basis. The analysis system is coupled with ESNENCE. Public health status alerts are reviewed by an analyst each day
Early Event Detection in San Diego	San Diego County	The system monitors ER visits, paramedic transports, 911 calls, school absenteeism, and OTC sales for early event detection
Communicable Disease Reporting and Surveillance System https://cdrs.doh.state.nj.us/cdrss/login/login.jsp	New Jersey Dept. of Health and Senior Services (NJDHSS)	Since 2001, NJDHSS implemented the surveillance system to characterize ED visits/admissions trends, detect aberrations and generate daily reports (via e-mail or facsimile) of the number of ED visits and admissions from all 84 acute care hospitals with EDs statewide

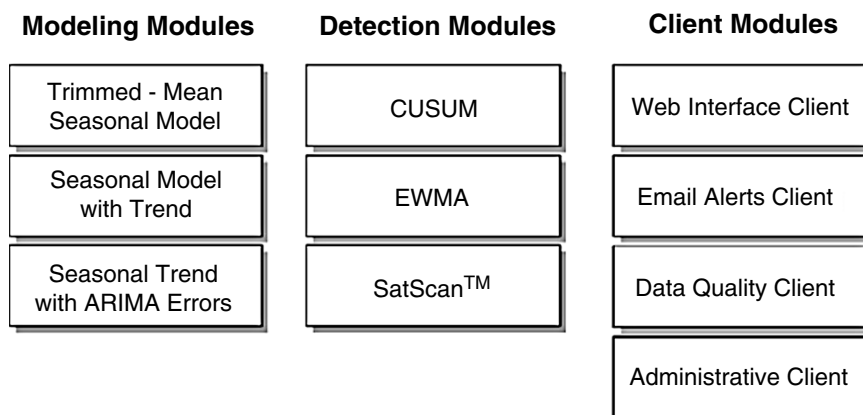| System	Stakeholders	System description
EED in South Carolina	South Carolina Dept. of Health and Environmental Control	Major capability of the system includes surveillance with BioSense, OTC sales, and Palmetto Poison Center
Indiana's pilot program for syndromic surveillance	Indiana State Dept. of Health	Include a variety of sources: coroners' reports, calls to the Indiana Poison Control Center, school absenteeism counts, lab test orders, veterinary lab results, and reports from day-care centers
National Capitol Region's ED syndromic surveillance system	Maryland, the District of Columbia, and Virginia	The system uses chief complaints for syndromic assignment
Michigan Disease Surveillance System Syndromic Surveillance Project	Michigan Dept. of Community Health (MDCH)	The Michigan system uses RODS developed at the University of Pittsburg for outbreak detection. By 2007, 65 facilities from across Michigan have participated the project
HESS and HASS	Missouri Dept. of Health and Senior Services	The state-wide syndromic surveillance uses ESSENCE and BioSense to analyze and visualize the syndromic data that are electronically reported by 85 hospitals across Missouri
North Dakota Department of Health Syndromic Surveillance Program	North Dakota Dept. of Health	Chief complaint data from nurse advice call center and EDs are analyzed for syndromic surveillance utilizing a commercial software RedBat®
Syndrome Reporting Information System (SYRIS)	Lubbock Health Dept.	The status of the health of the community can be instantaneously communicated among doctors, public health officials, or government officials via time series or GIS analysis and visualization

Modeling Modules   **Detection Modules**   **Client Modules**

Modeling Modules	Detection Modules	Client Modules
Trimmed - Mean Seasonal Model	CUSUM	Web Interface Client
Seasonal Model with Trend	EWMA	Email Alerts Client
Seasonal Trend with ARIMA Errors	SatScan™	Data Quality Client
		Administrative Client

Figure 2-2. Modeling, detection, and client modules implemented in the current AEGIS system (Reis et al., 2007).

The Syndromal Surveillance Tally Sheet program is based on the triage nurses' counts of the numbers of patients presenting the syndromes of interest collected from emergency departments of Santa Clara County, California (Bravata et al., 2002). (This manual system was proved to be staff and resource intensive and was replaced by an ESSENCE implementation in 2005).

The system used in the greater Boston area is for rapid identification of illness syndromes using automated records from 1996 through 1999 of approximately 250,000 health plan members in the area (Lazarus et al., 2001).

New Hampshire Syndromic Surveillance System collects information from multiple sites in New Hampshire including emergency departments, 23 city schools, 5 workplaces, participating pharmacies, as well as military and veteran medical facilities, and LabCorp through the BioSense program. Data are either key punched or electronically transferred into the Syndromic Tracking Encounter Management System (STEMS) for analysis and geocoding (Miller et al., 2003).

In the state of Connecticut, a Hospital Admissions Syndromic Surveillance system is implemented by the Connecticut Department of Public Health. This system monitors hospital admissions from the previous day rather than outpatient visits as most other syndromic systems do (Dembek et al., 2004, 2005).

Catalis Health System for syndromic surveillance in Texas interfaces with available clinic practice management systems to produce a standardized dataset via a point-of-care electronic medical record (EMR). This system supports data flows directly from clinic providers to the health department for syndromic surveillance. Rural counties with limited epidemiological resources have benefited from this approach (Nekomoto et al., 2003).

North Carolina Disease Event Tracking and Epidemiologic Collection Tool (NC Detect), formerly known as the North Carolina Bioterrorism and Emerging Infection Prevention System, analyzes a variety of data sources including the North Carolina Emergency Department Database (NCEDD) and the Carolinas Poison Center with the EARS software tool (2006d).

The Georgia Division of Public Health takes a centralized approach by comparing local data to those from other districts and state totals. The clinical and nonclinical data are collected, and the analysis results are displayed through a Web-based program called the State Electronic Notifiable Disease Surveillance System (SendSS) (2006k). The major functionalities of the Web-based application are shown in Figure 2-3.

The syndromic surveillance system in Miami-Dade County, Florida, is a Web-based system where syndromic data are transferred from emergency departments to an ESSENCE server for data analysis and anomaly detection (2006m). On a daily basis, 14 county hospitals automatically transmit deidentified chief complaint data to the surveillance system. Each chief complaint is then placed into one of 10 syndrome categories including respiratory, gastrointestinal, hemorrhagic, influenza-like, shock/coma, neurologic, fever, febrile, rash, botulism-like, and other. ESSENCE performs automatic data analysis, establishing a baseline with a 28-day average. Daily case data are then analyzed against this baseline to identify statistically significant increases. An MDCHD analyst evaluates all alerts and develops a summary report on each day (Zhang et al., 2007).
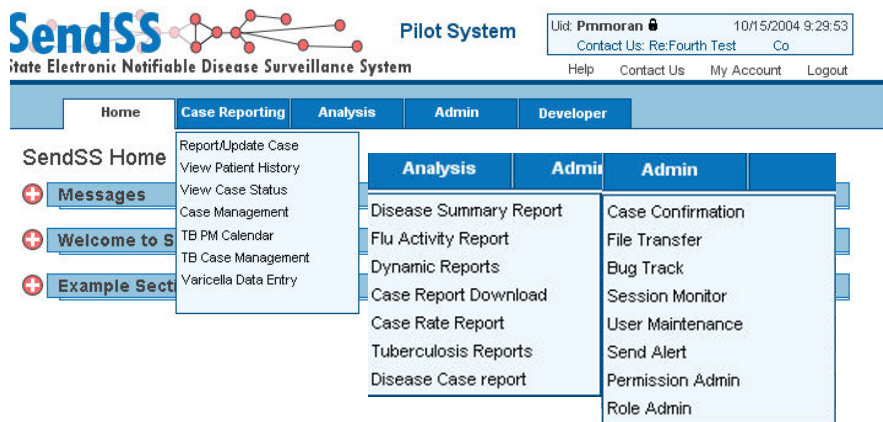

Figure 2-3. Homepage and menu navigation of SendSS Web application (2006k).

The Early Event Detection system in San Diego constantly monitors emergency room visits, paramedic transports, 911 calls, school absenteeism data, and OTC sales for early event detection. It supports interoperability with local SAS/Minitab installations, ESSENCE, and BioSense (Johnson, 2006).

The New Jersey syndromic system includes four components: emergency department-based surveillance using visit and admission data from participating hospitals statewide and a modified CUSUM method to detect aberrations, OTC pharmacy sales surveillance from RODS, an ILI surveillance module, and a Web-based Communicable Disease Reporting System (CDRS) for real time data transmission and reporting (Hamby, 2006).

The Early Event Detection (EED) system in South Carolina provides syndromic surveillance capabilities at the state/local level, using data from BioSense, OTC sales, and Palmetto Poison Center (Drociuk et al., 2004). The EED system is among a number of disease surveillance systems in South Carolina, including ESSENCE, BioSense, and sentinel providers network with ILI reporting. As of February 2006, there were 536 distinct sources providing OTC drug sales data.

Indiana's pilot program for syndromic surveillance is currently taking in data from 17 hospitals, most of them in Indianapolis. Indiana's system is expected to include a variety of sources: coroners' reports, calls to the Indiana Poison Control Center, school absenteeism counts, lab test orders, veterinary lab results, and reports from day care centers (Lober et al., 2002).

National Capitol Region's Emergency Department syndromic surveillance system is a cooperative effort between Maryland, the District of Columbia, and Virginia that uses chief complaints for syndromic assignment. Using a syndrome assignment matrix (Begier et al., 2003), the emergency department visits are coded into one of eight mutually exclusive syndromes: "death," "sepsis," "rash," "respiratory" illness, "gastrointestinal" illness, "unspecified infection," "neurologic" illness, and "other."

The Michigan Syndromic Surveillance Project tracks emergent care registrations per day (primarily ED, some urgent care) and Poison Control Call Center data using RODS. MDCH and participants exchange data in real-time using virtual private networks (VPNs) to secure the data and HL-7 as the messaging format. Detection algorithms run every hour and send email alerts to public health officials when deviations are found. State and regional epidemiologists are provided with Web access to the charts and maps of the data analytical results (2006g).

The Hospital Electronic Syndromic Surveillance (HESS) and hospital admission syndromic surveillance (HASS) systems, implemented in the State of Missouri, are designed to provide an early warning system of public health emergencies including bioterrorism events, and offer outbreak detection and epidemiologic monitoring functions. HESS collects data electronically from existing electronic systems and requires all hospitals to participate, whereas HASS receives data on a paper form from selected sentinel hospitals (2006f). They use ESSENCE and BioSense to analyze, visualize, and report electronically ED data collected through HESS Reporting Rule. By 2007, electronic feeds were being collected automatically from 85 hospitals across the state. Figure 2-4 shows statewide syndromic surveillance coverage in Missouri.
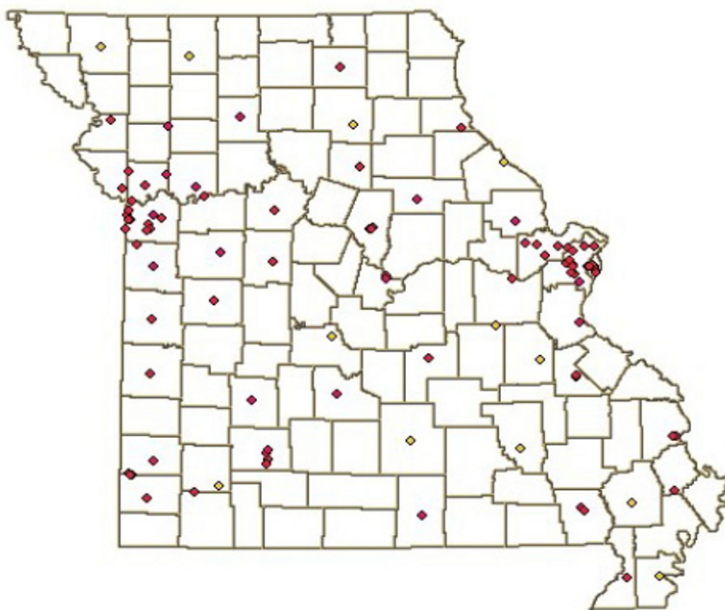

Figure 2-4. Missouri syndromic surveillance coverage; *lighter dots* are HASS, and *darker* are HESS hospitals (Resch et al., 2007).

The North Dakota Department of Health Syndromic Surveillance Program is based on chief complaint data received electronically from seven large hospital emergency departments located in North Dakota's four largest cities. In addition, data from a call center in North Dakota's largest city are received and reviewed daily. They use the natural language translation tool SympTran® to translate free text chief complaints into symptoms and then group those into six syndrome groups (Goplin et al., 2007). Data analysis functions are provided by the commercial software called RedBat. The RedBat system will be briefly introduced in the next section. Over 50% of the state's

population is currently involved in this program (2006h). They have also developed the North Dakota Electronic Animal Health Surveillance System for animal disease surveillance. The data analysis capability is provided by the CDC EARS.
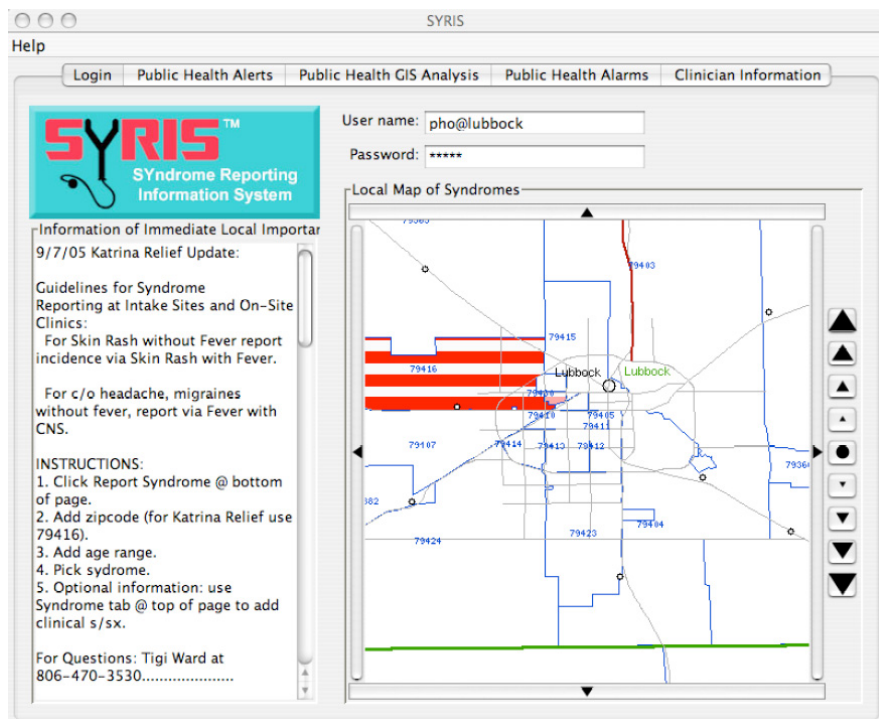

Figure 2-5. Screenshot of SYRIS system.

Syndrome Reporting Information System (SYRIS) is a Web-based, real-time, clinician-driven syndromic surveillance system implemented in Lubbock, Texas (Figure 2-5). It provides two-way communication between clinicians and public health officials for high specificity, high signal-to-noise ratio outbreak detection in both human and wildlife species diseases.

3. SUMMARY OF INDUSTRIAL SOLUTIONS FOR SYNDROMIC SURVEILLANCE

We now discuss seven representative industrial solutions for syndromic surveillance, as summarized in Table 2-3.

The Lightweight Epidemiology Advanced Detection and Emergency Response System (LEADERS) is an Internet-based integrated medical

Table 2-3. Seven industrial solutions for syndromic surveillance.

System	Company
LEADERS	Idaho Technology, Inc., Salt Lake City, Utah
FirstWatch Real-Time Early Warning System	Stout Solutions, LLC., Encinitas, California
STC syndromic surveillance product	Scientific Technologies' Corporation (STC), Tucson, Arizona
RedBat (Multi-use syndromic surveillance system for hospitals and public health agencies)	ICPA, Inc., Austin, Texas
EDIS (Emergisoft's Emergency Department Information System)	Emergisoft Corporate, Arlington, Texas
Spatiotemporal Epidemiological Modeler (STEM) tool	IBM Corporation, Almaden Research Center, California
Emergint Data Collection and Transformation System (DCTS)	Emergint, Inc., Louisville, Kentucky

surveillance system for collecting, storing, analyzing, and viewing critical medical incidents. LEADERS was deployed at the 1999 World Trade Organization Summit, the 2000 Republican and Democratic National Conventions, the Presidential Inaugural Activities, and the Super Bowl. Portions of LEADERS have been deployed by US military forces worldwide since 1998 (Ritter, 2002).

FirstWatch integrates data from 911 calling systems, emergency departments, lab tests, pharmacies, poison controls and paramedic practices, all of which are monitored in real-time. Real-time alerting and reporting are also supported (2006e).

The Web-based STC syndromic surveillance product is compatible with the CDC NEDSS Logical Data Module (LDM). Its current clients include public health departments in Connecticut, Louisiana, New York City, and Washington, DC. The analysis and alerting algorithms implemented in the system such as CUSUM, 3rd Sigma, and STC's Zhang Methodology are applied to a variety of data sources that include OTC sales, school nurse visits, and emergency rooms (2006l).

RedBat automatically imports existing data from hospitals and public health agencies. Besides outbreak detection, it is also capable of tracking injuries, reportable diseases, asthma, and disaster victims (2006i).

Emergisoft is a software solution for syndromic surveillance that has been employed in the 1996 Olympics in Atlanta and in the metropolitan areas of New York City and Los Angeles (Emergisoft, 2006).

A Spatiotemporal Epidemiological Modeler (STEM) tool, developed at the IBM Almaden Research Center, can be used to develop spatial and temporal models of emerging infectious diseases. These models can involve multiple populations/species and interactions between diseases. GIS data for every county in US have been integrated into the STEM application (Ford et al., 2005).

Emergint provides a syndromic surveillance system for data collection and processing. It can interface with care providers, laboratories, research organizations, and federal and state health departments. Emergint also provides data aggregation analysis as well as visualization functions (2004a).

4. SUMMARY OF INTERNATIONAL SYNDROMIC SURVEILLANCE PROJECTS

The National Health Service (NHS) in the UK operates a NHS Direct Syndromic Surveillance system that monitors the nurse-led telephone helpline data collected electronically by the Health Protection Agency from all 23 NHS Direct sites in England and Wales (Doroshenko et al., 2005). Syndromes monitored include cold/influenza, cough, diarrhea, difficulty breathing, double vision, eye problems, lumps, fever, rash, and vomiting. Data streams are analyzed every 2 hours by statistical methods such as confidence intervals and control chart methods (Cooper et al., 2004).

In Southeast Asia, the Association of Southeast Asian Nations (ASEAN) has developed the Early Warning Outbreak Recognition System (EWORS) for disease surveillance. EWORS collects data from a network of hospitals and provides technical approaches to distinguish epidemic from endemic diseases (EWORS, 2006). Free-text or ICD-9 coded symptom reports can be collected through EWORS to monitor a number of infectious diseases, including malaria and hemorrhagic fever due to Hantaan virus infection. Statistical analysis methods are used for daily data analysis and visualization. The system is currently implemented by public health departments of Indonesia, Cambodia, Vietnam, and Laos.

In some high-income countries, syndromic surveillance has been a very effective approach to supporting real-time public health monitoring. However, in developing countries, where public health is more in hazard, while the information communication infrastructure is more fragile, syndromic surveillance systems are more critically needed but difficult to implement. Chretien identified such difficulties, and discussed some of the successful syndromic surveillance implementation cases in a recent work. Availability of technologies for health data capture and transmission in these underdeveloped areas and countries are investigated. Operational experiences of systems such as EWORS are presented (Chretien et al., 2008).

Table 2-4. Ten international syndromic surveillance systems.

System	Agency
National Health Service (NHS) Direct Syndromic Surveillance	Operated by the National Health Service of UK
Early Warning Outbreak Recognition System (EWORS)	Association of South East Asian Nations
Alternative Surveillance Alert Program (ASAP)	Health Canada
Military syndromic surveillance for dengue fever outbreak	French Guiana in South America
Emergency Department Information System in Korea	Korea
Experimental Three Syndromic Surveillances in Japan	National Institute of Infectious Diseases, Japan
Australian Sentinel Practice Research Network (ASPREN)	The Royal Australian College of General Practitioners; the Dept. of General Practice, U. of Adelaide; Australian Dept. of Health and Ageing
New South Wales ED surveillance system	New South Wales, Australia
ILI surveillance in France	France
UMR S 707 ("Epidemiology, Information Systems, Modeling" project)	France

The Alternative Surveillance Alert Program (ASAP), initiated by Health Canada, currently monitors gastrointestinal disease trends by analyzing OTC antidiarrheal and anti-nausea sales data, and calls to Telehealth lines (Edge et al., 2003). The system is planned to be deployed at the community, provincial, and national levels.

A syndromic surveillance system called 2SE FAG system (Surveillance Spatiale des Epidémies au sein des Forces Armées en Guyane) was established to serve the military forces in French Guiana, a French overseas department in South America in 2004. The statistical analysis of military syndromic surveillance data with 2SE FAG is performed with Current Past Experienced Graph (CPEG) and the Exponential Weighted Moving Average (EWMA) method (Meynard et al., 2008). They showed that the system detected the dengue fever outbreak, which occurred in 2006 several weeks before traditional clinical surveillance, allowing quick and effective outbreak surveillance within the armed forces (Meynard et al., 2008).

In Korea, 120 emergency departments from 16 provinces and cities are now connected to the Korea Emergency Department Information System for daily analysis of acute respiratory syndrome. The system was initially developed for the 2002 Korea-Japan FIFA World Cup Games (Cho et al., 2003).

Japan's National Institute of Infectious Diseases (NIID) has developed a syndromic surveillance system based on EARS syndrome categories and

EARS software to analyze OTC sales data, outpatient visits, and ambulance transfer data in Tokyo (Ohkusa et al., 2005a, b). Approximately 5,000 sites nationwide in Japan are now connected to this system. The system was used for the 2000 G8 Summit and 2002 FIFA World Cup Games.

The Australian Sentinel Practice Research Network (ASPREN) is a national network of general practitioners who collect and report data on selected conditions such as ILI for weekly statistical analysis (Clothier et al., 2006). It is now being used by about 50 general practitioners nationwide in Australia.

The New South Wales ED surveillance system routinely collects computerized ED patient information from 30 EDs in New South Wales (Hope et al., 2008). The ED provisional diagnoses are classified into 37 syndromes, including gastrointestinal, influenza, pneumonia, other/unspecified respiratory infections, all injury and mental health presentations. Statistical control charts are used to automatically detect increases in syndrome activity, using Poisson z-scores of observed vs. expected day-of-week. Surveillance reports are updated four times per day (Muscatello et al., 2005).

Influenza-Like illness (ILI) surveillance is practiced in 11,000 pharmacies throughout France (about 50% of all pharmacies in France) in 21 regions. This ILI surveillance system is a Web-based system that collects medication sales and weekly office visit data to provide forecasts of influenza outbreaks using a Poisson regression model (Vergu et al., 2006).

The French "Epidemiology, Information Systems, Modeling," group headed by Guy Thomas has been developing a Web-based application for online epidemiological time series analysis. The application allows estimating the periodic baseline level and associated upper forecast limit. The latter defines a threshold for epidemic detection. The burden of an epidemic is defined as the cumulated signal in excess of the baseline estimate (Pelat et al., 2007).

5.   SYNDROMIC SURVEILLANCE FOR SPECIAL EVENTS

During natural or human-made disasters, real-time and comprehensive knowledge of public health conditions is critical to inform response and recovery activities. Priority health conditions include infectious disease cases, injuries, and mental health disorders.

In recent years, the world has been through a number of global scale deathly disasters. Some examples that have affected millions of lives include Hurricane Katrina in 2005, causing the most severe loss of life and property damage occurring in New Orleans, Louisiana; the outbreak of the

SARS pandemic in 2002. In addition to large scale disasters, special events such as the Olympic Games, FIFA World Cup, or G8 Summit often involve participation of large populations. The temporary and sudden surge of population density in the event location brings potential health hazards to the participants, such as intensified infectious disease transmission and surging healthcare utilization. For instance, the 2008 Olympics in Beijing brought a large influx of people into the metropolitan area for 2 weeks. Population surge caused by the influx of a large number of tourists would significantly alter healthcare utilization patterns. It is critical to quickly identify any localized infectious disease outbreaks and prevent them from taking place.

Therefore, in this section, we discuss the category of syndromic surveillance practice that is concerned with syndromic surveillance for special and large-scale events. Teams of public health officials often need to work together to monitor public health status for such events (e.g., the 2002 World Series in Phoenix (Das et al., 2003), the wildfire outbreak in San Diego, 2003 (Johnson et al., 2005)). During Korea-Japan FIFA World Cup 2002 in Japan (Suzuki et al., 2003) and Korea (Cho et al., 2003), syndromic surveillance systems also played a role in public health status monitoring. Another two examples are syndromic surveillance systems implemented for the 2002 Kentucky Derby (Goss et al., 2003) and the G8 Summit in Gleneagles, Auchterarder, Scotland in 2005 (2005a). Typically, during the events data from regional emergency departments will be collected. Information concerning a predefined list of symptoms and probable diagnoses will also b e collected manually using special-purpose forms or via a Web-based interface. Table 2-5 summarizes six representative efforts in this category.

Table 2-5. Six representative syndromic surveillance efforts for special events.

Syndromic surveillance systems for special events	Stakeholders/location
Syndromic surveillance for Korea-Japan FIFA World Cup 2002 in Japan	National Institute of Infectious Diseases, Japan
Communitywide syndromic surveillance for 2002 Kentucky Derby	University of Louisville Hospital and Jefferson County Health Dept.
Syndromic surveillance for Korea-Japan FIFA World Cup 2002 in Korea	Korea
Drop-in bioterrorism surveillance system for World Series 2002 in Phoenix, Arizona	Phoenix, Arizona
Syndromic surveillance during the wildfires outbreak in San Diego, 2003	San Diego County
Syndromic surveillance for G8 Summit in Gleneagles, Auchterarder, Scotland, July 2005	Scotland, UK

In addition to the surveillance efforts of varying scopes as summarized above, there has been an increasing need for the development of syndromic surveillance systems and efforts at the global scale. World Health Organization (WHO)'s Epidemic and Pandemic Alert and Response program represents one such effort toward global syndromic surveillance. Note that the challenge of implementing a global surveillance system is more of a policy and administration nature as opposed to technical.