(12) **United States Patent**
Maurer et al.

(10) **Patent No.: US 7,257,493 B1**
(45) **Date of Patent: Aug. 14, 2007**

(54) CHEMICAL, BIOLOGICAL, RADIOLOGICAL, AND NUCLEAR WEAPON DETECTION SYSTEM COMPRISING ARRAY OF SPATIALLY-DISPARATE SENSORS AND ENVIRONMENTAL ACUITY

(75) Inventors: **Scott M. Maurer**, Haymarket, VA (US); **Mark J. Derksen**, Bristow, VA (US); **Kevin J. Kofler**, Bristow, VA (US)

(73) Assignee: **Lockheed Martin Corporation**, Bethesda, MD (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 506 days.

(21) Appl. No.: **10/882,041**

(22) Filed: **Jun. 30, 2004**

(51) **Int. Cl.**
G06F 19/00 (2006.01)
G01W 1/00 (2006.01)

(52) **U.S. Cl.** **702/19**; 702/3

(58) **Field of Classification Search** .... None
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,930,596 B2 * 8/2005 Kulesz et al. 340/506

* cited by examiner

Primary Examiner—John S Brusca
(74) *Attorney, Agent, or Firm*—DeMont & Breyer LLC

(57) ABSTRACT

A chemical, biological, radiological, and nuclear weapons detection system is disclosed that comprises an array of spatially-disparate hazardous material sensors that all feed into a centralized system control center. This enables the embodiment to receive and coordinate in one place all of the hazardous material sensors spread over a wide area, and, therefore, enables an alarm to be quickly issued in the event of a real attack. To accurately reduce false alarms, the illustrative embodiment requires that at least N of M neighboring stations report an alarm for the same hazardous material within an interval of time, and that the values of at least one of N and M change and are based on at least one environmental factor.

20 Claims, 11 Drawing Sheets

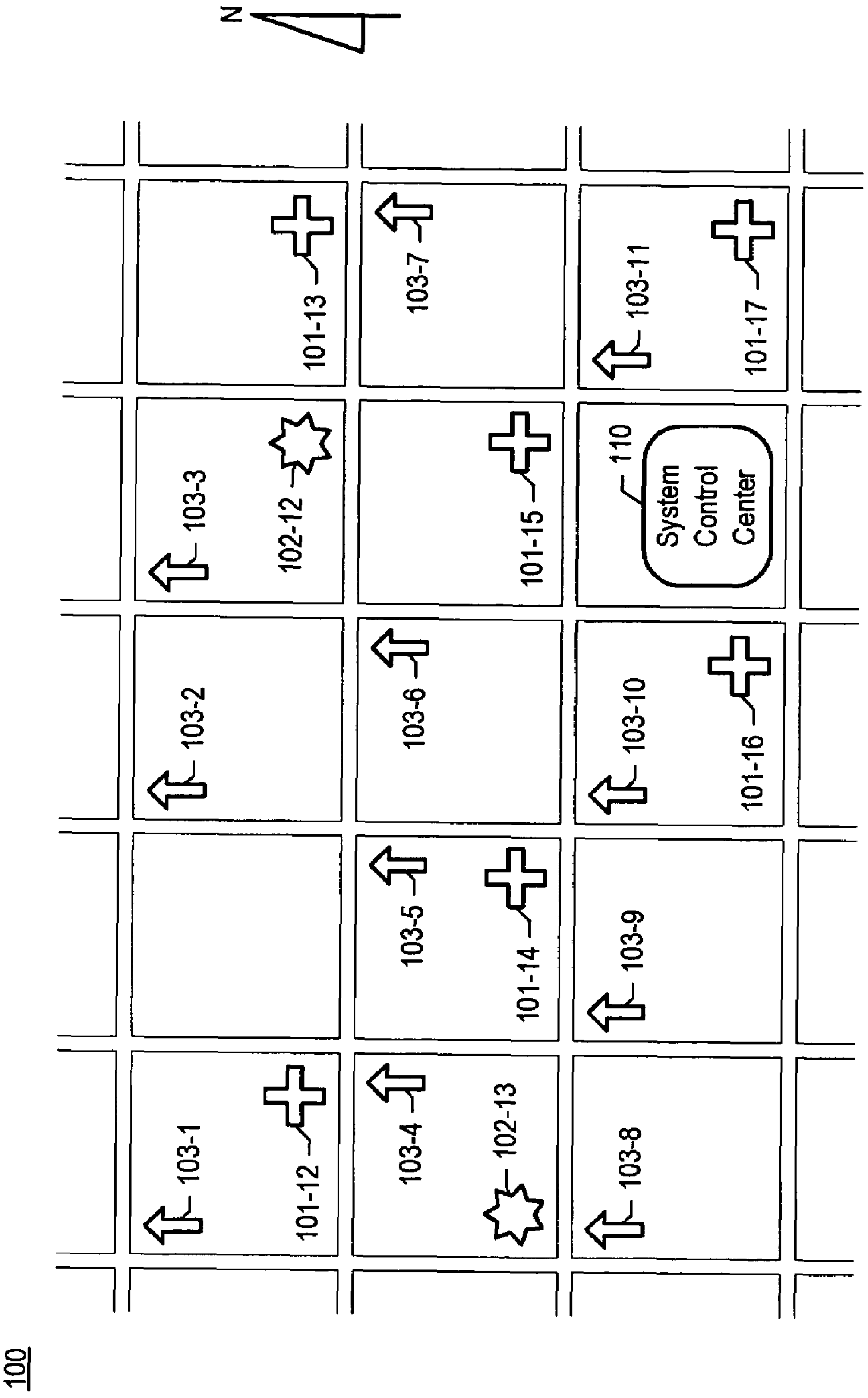

N
103-1
101-12
103-4
102-13
103-8
103-5
101-14
103-9
103-2
103-6
103-10
101-16
103-3
102-12
101-15
110
System Control Center
103-7
101-13
103-11
101-17
100

Figure 1

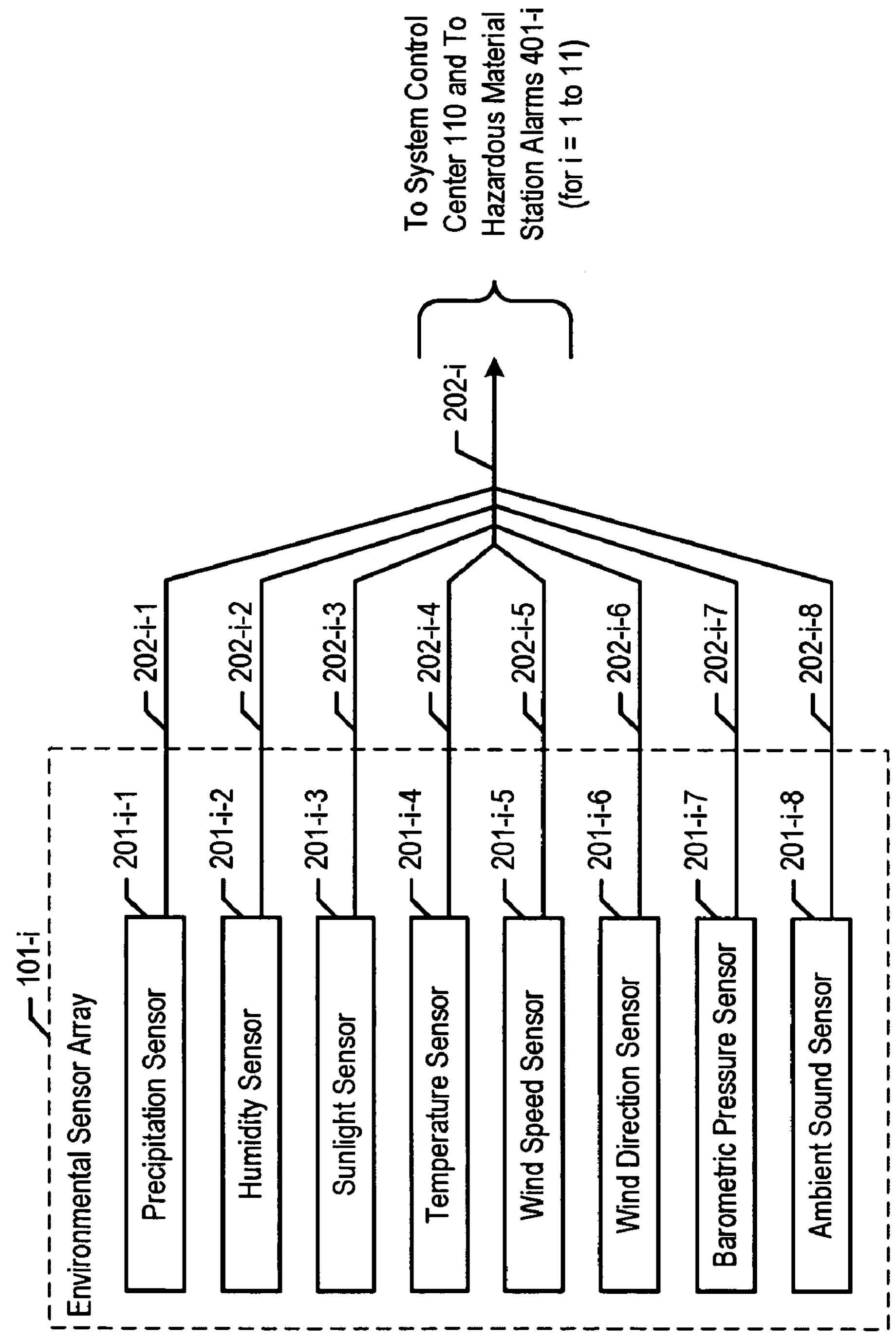

101-i
Environmental Sensor Array
Precipitation Sensor
Humidity Sensor
Sunlight Sensor
Temperature Sensor
Wind Speed Sensor
Wind Direction Sensor
Barometric Pressure Sensor
Ambient Sound Sensor
201-i-1
201-i-2
201-i-3
201-i-4
201-i-5
201-i-6
201-i-7
201-i-8
202-i-1
202-i-2
202-i-3
202-i-4
202-i-5
202-i-6
202-i-7
202-i-8
202-i
To System Control Center 110 and To Hazardous Material Station Alarms 401-i (for i = 1 to 11)

Figure 2

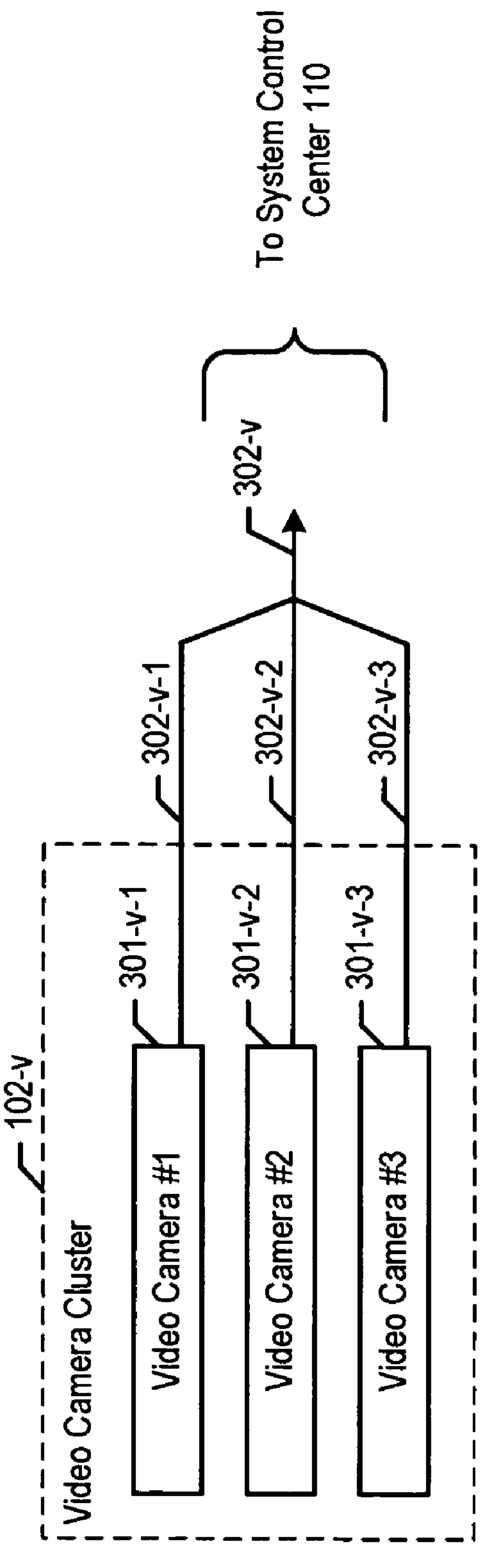

Video Camera Cluster
102-v
Video Camera #1
Video Camera #2
Video Camera #3
301-v-1
301-v-2
301-v-3
302-v-1
302-v-2
302-v-3
302-v
To System Control Center 110

Figure 3

Figure 4

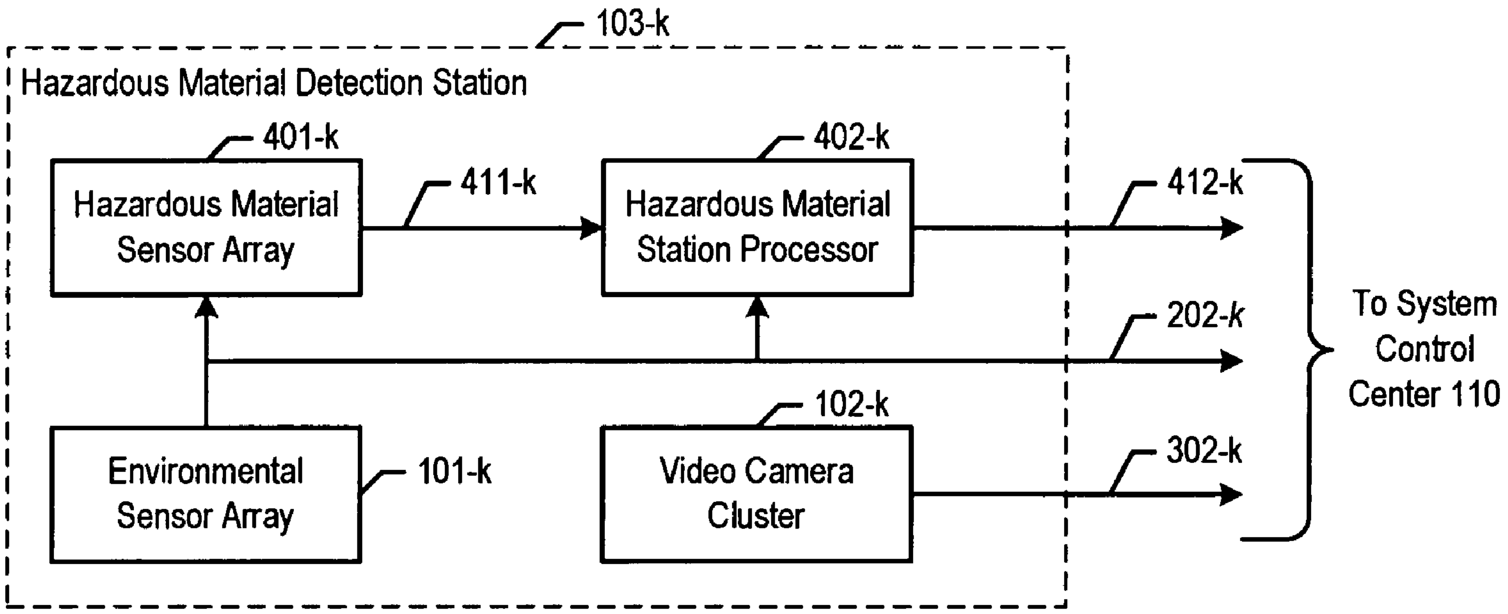

103-k
Hazardous Material Detection Station
401-k
Hazardous Material Sensor Array
411-k
402-k
Hazardous Material Station Processor
412-k
202-k
102-k
Environmental Sensor Array
101-k
Video Camera Cluster
302-k
To System Control Center 110

Figure 5

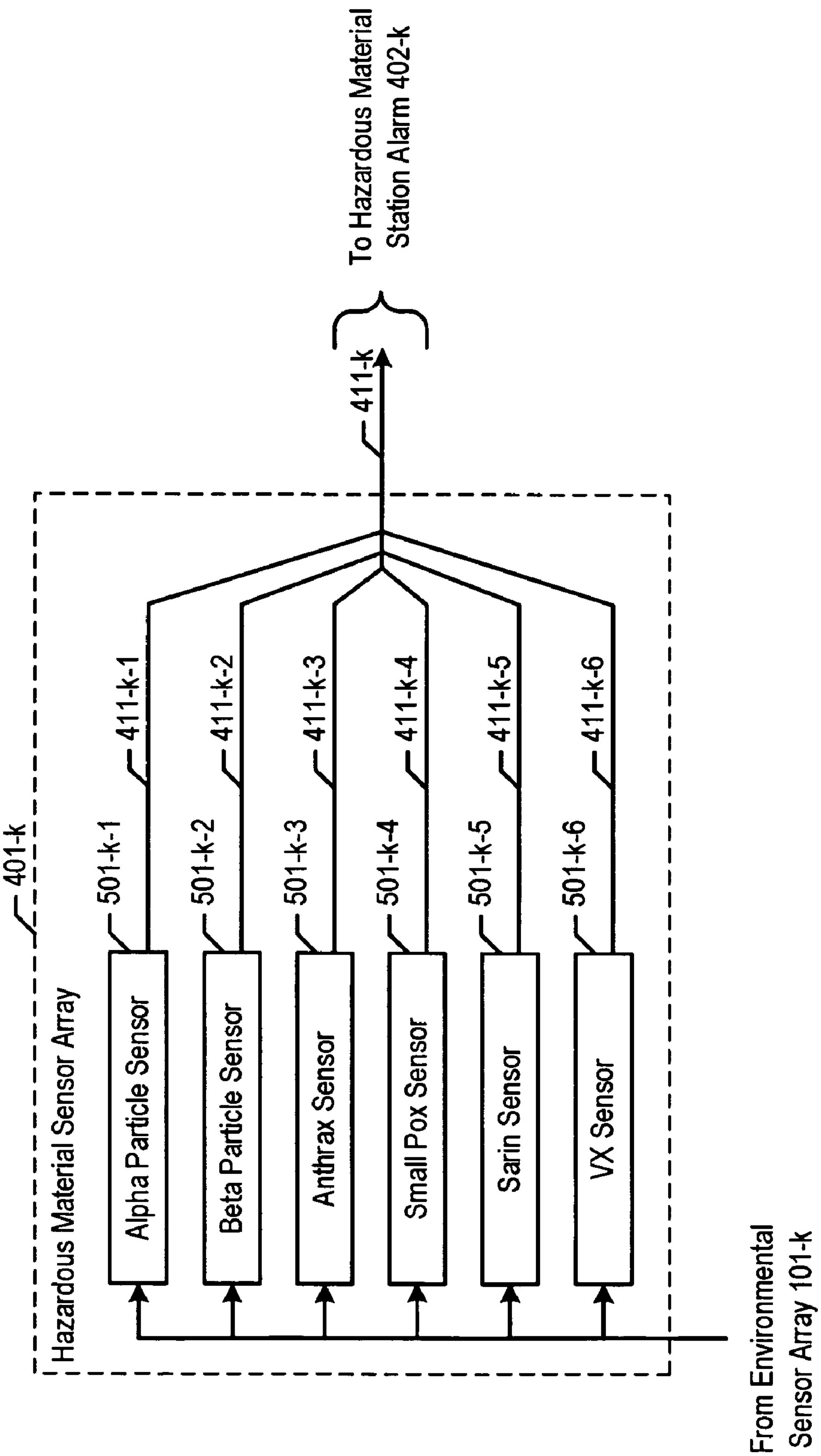
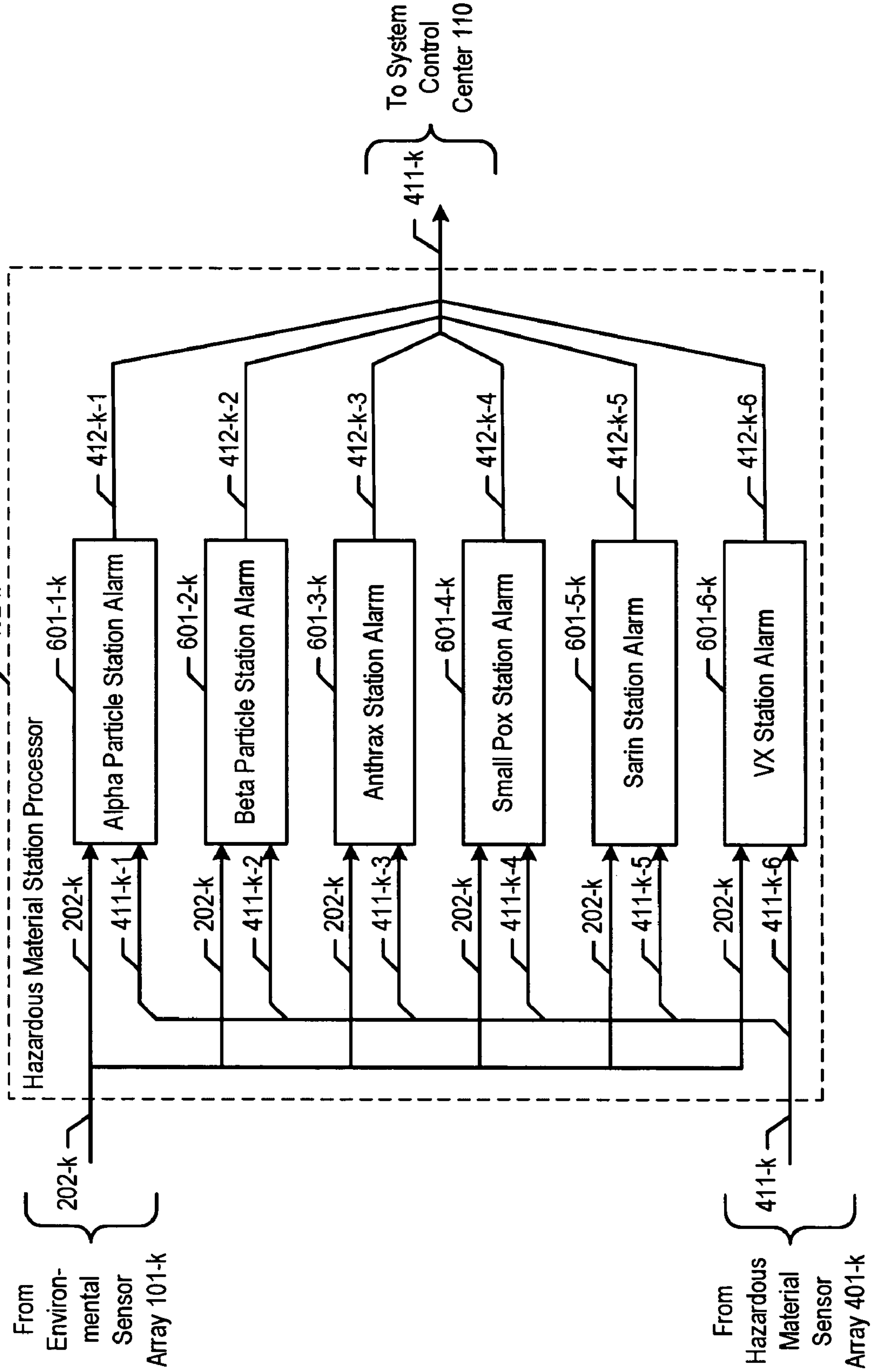

Hazardous Material Sensor Array
401-k
Alpha Particle Sensor
Beta Particle Sensor
Anthrax Sensor
Small Pox Sensor
Sarin Sensor
VX Sensor
501-k-1
501-k-2
501-k-3
501-k-4
501-k-5
501-k-6
411-k-1
411-k-2
411-k-3
411-k-4
411-k-5
411-k-6
411-k
To Hazardous Material Station Alarm 402-k
From Environmental Sensor Array 101-k

Figure 6


From Environmental Sensor Array 101-k
202-k
From Hazardous Material Sensor Array 401-k
411-k
Hazardous Material Station Processor
402-k
202-k
411-k-1
Alpha Particle Station Alarm
601-1-k
412-k-1
202-k
411-k-2
Beta Particle Station Alarm
601-2-k
412-k-2
202-k
411-k-3
Anthrax Station Alarm
601-3-k
412-k-3
202-k
411-k-4
Small Pox Station Alarm
601-4-k
412-k-4
202-k
411-k-5
Sarin Station Alarm
601-5-k
412-k-5
202-k
411-k-6
VX Station Alarm
601-6-k
412-k-6
411-k
To System Control Center 110

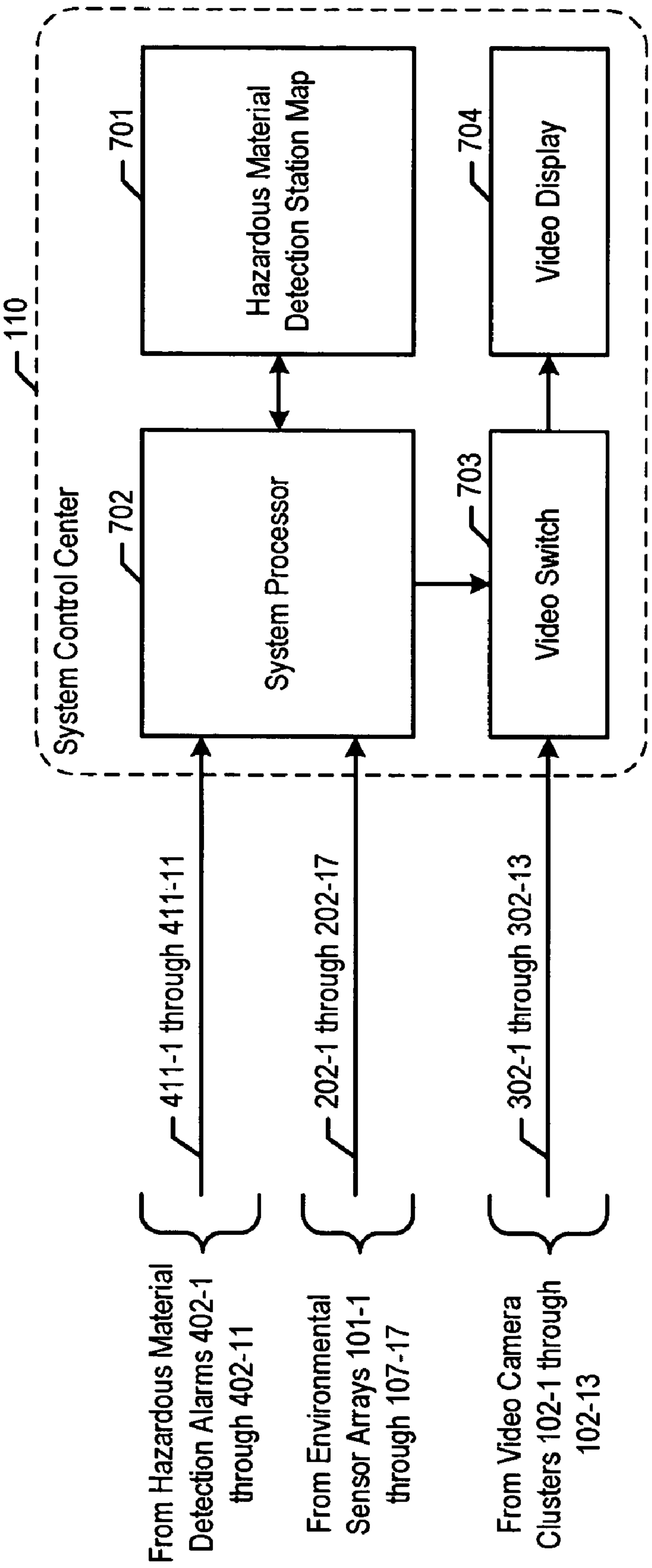

110
System Control Center
702
System Processor
701
Hazardous Material Detection Station Map
703
Video Switch
704
Video Display
411-1 through 411-11
202-1 through 202-17
302-1 through 302-13
From Hazardous Material Detection Alarms 402-1 through 402-11
From Environmental Sensor Arrays 101-1 through 107-17
From Video Camera Clusters 102-1 through 102-13

Figure 7

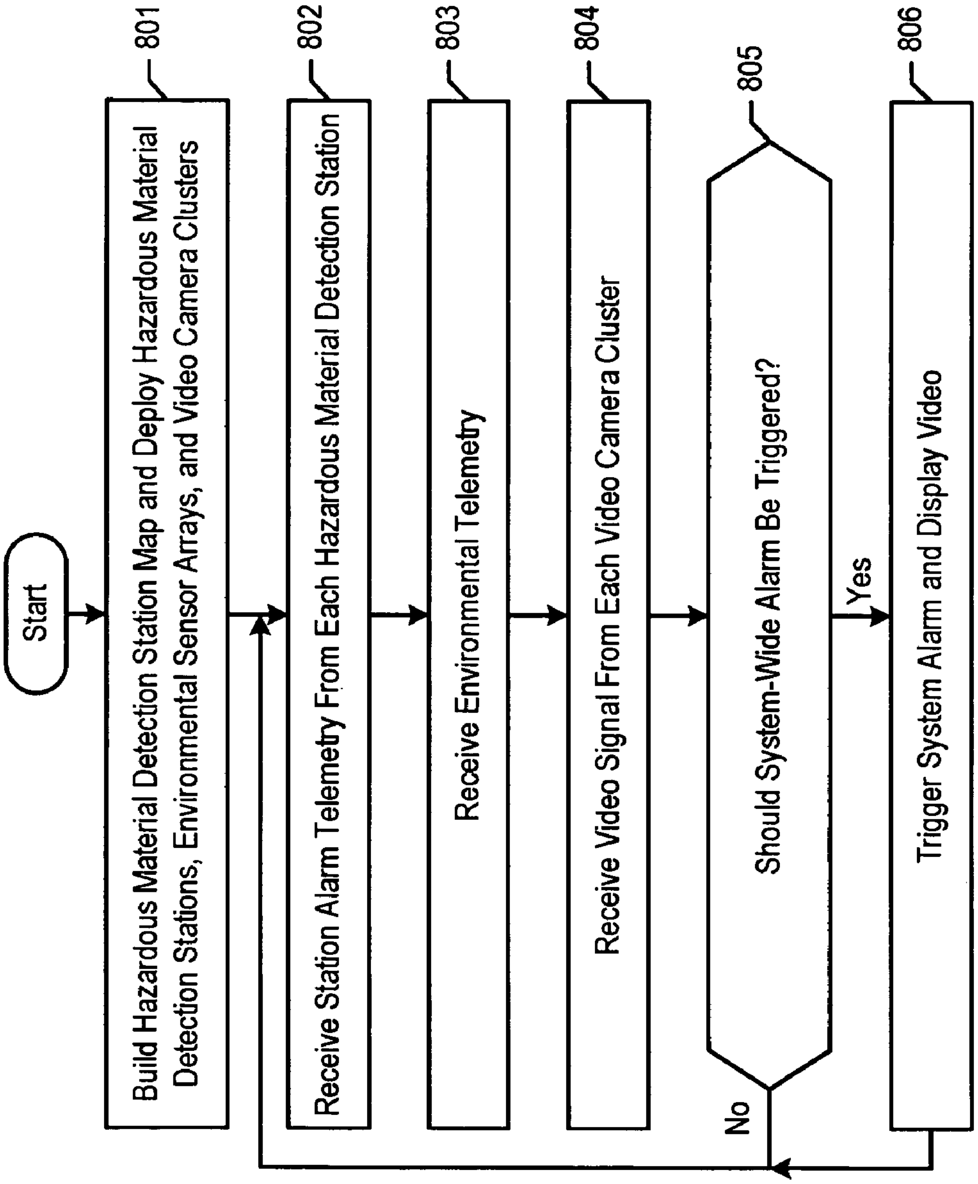

Start
801
Build Hazardous Material Detection Station Map and Deploy Hazardous Material Detection Stations, Environmental Sensor Arrays, and Video Camera Clusters
802
Receive Station Alarm Telemetry From Each Hazardous Material Detection Station
803
Receive Environmental Telemetry
804
Receive Video Signal From Each Video Camera Cluster
805
Should System-Wide Alarm Be Triggered?
Yes
No
806
Trigger System Alarm and Display Video

Figure 8

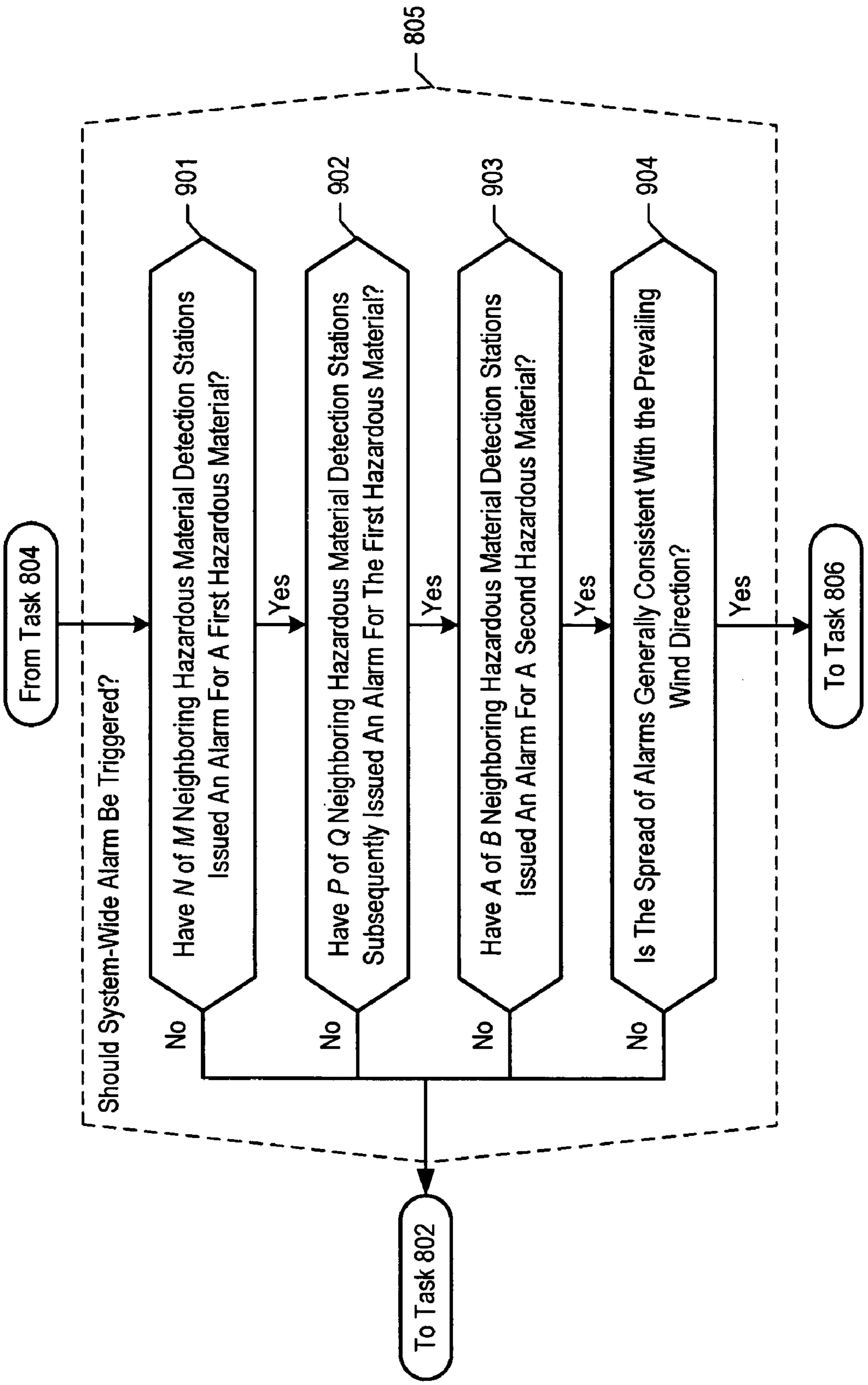
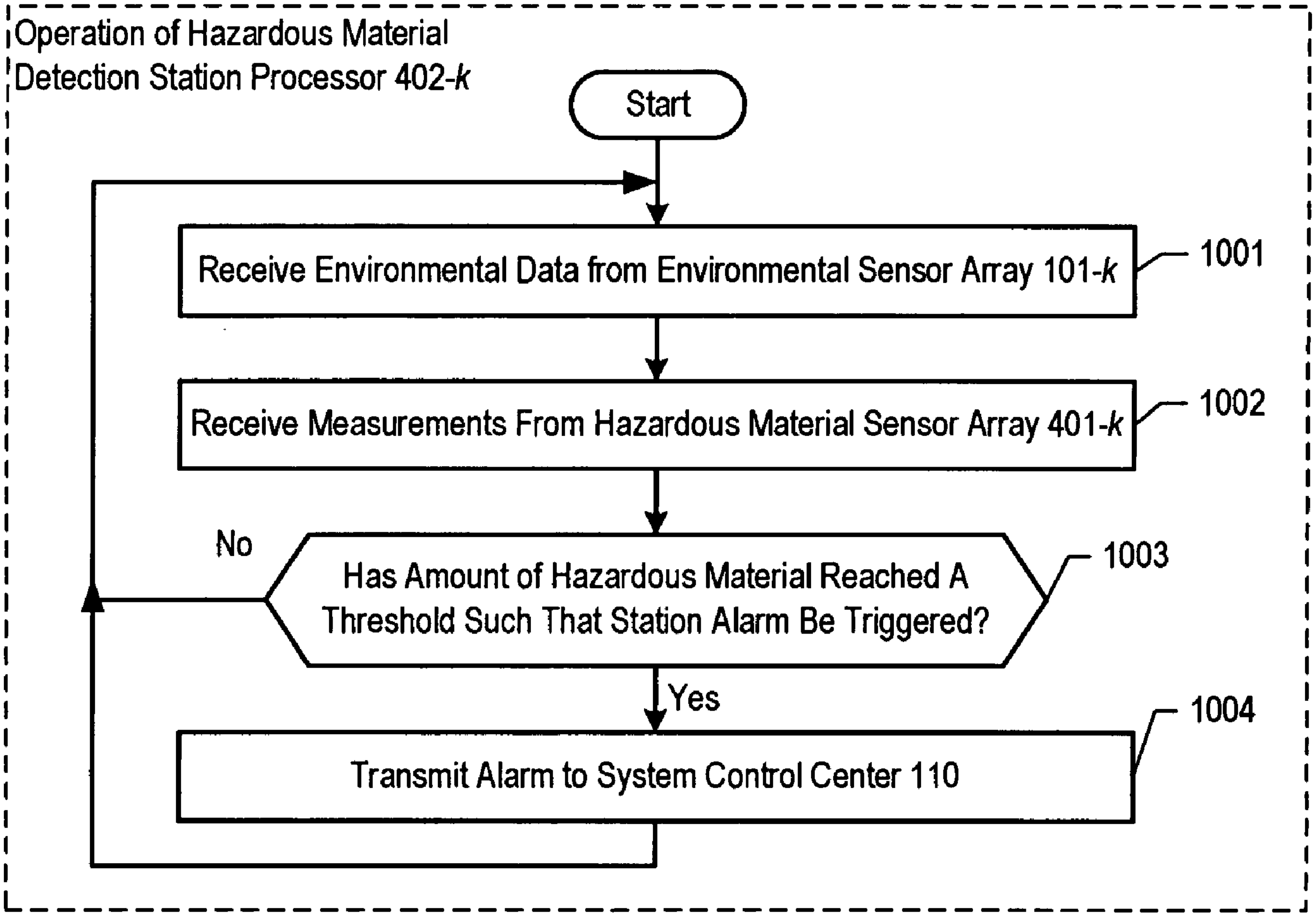

805
Should System-Wide Alarm Be Triggered?
From Task 804
901
Have *N* of *M* Neighboring Hazardous Material Detection Stations Issued An Alarm For A First Hazardous Material?
Yes
No
902
Have *P* of *Q* Neighboring Hazardous Material Detection Stations Subsequently Issued An Alarm For The First Hazardous Material?
Yes
No
903
Have *A* of *B* Neighboring Hazardous Material Detection Stations Issued An Alarm For A Second Hazardous Material?
Yes
No
904
Is The Spread of Alarms Generally Consistent With the Prevailing Wind Direction?
Yes
No
To Task 806
To Task 802

Figure 9

Figure 10


Operation of Hazardous Material
Detection Station Processor 402-*k*
Start
Receive Environmental Data from Environmental Sensor Array 101-*k*
1001
Receive Measurements From Hazardous Material Sensor Array 401-*k*
1002
Has Amount of Hazardous Material Reached A Threshold Such That Station Alarm Be Triggered?
1003
No
Yes
Transmit Alarm to System Control Center 110
1004

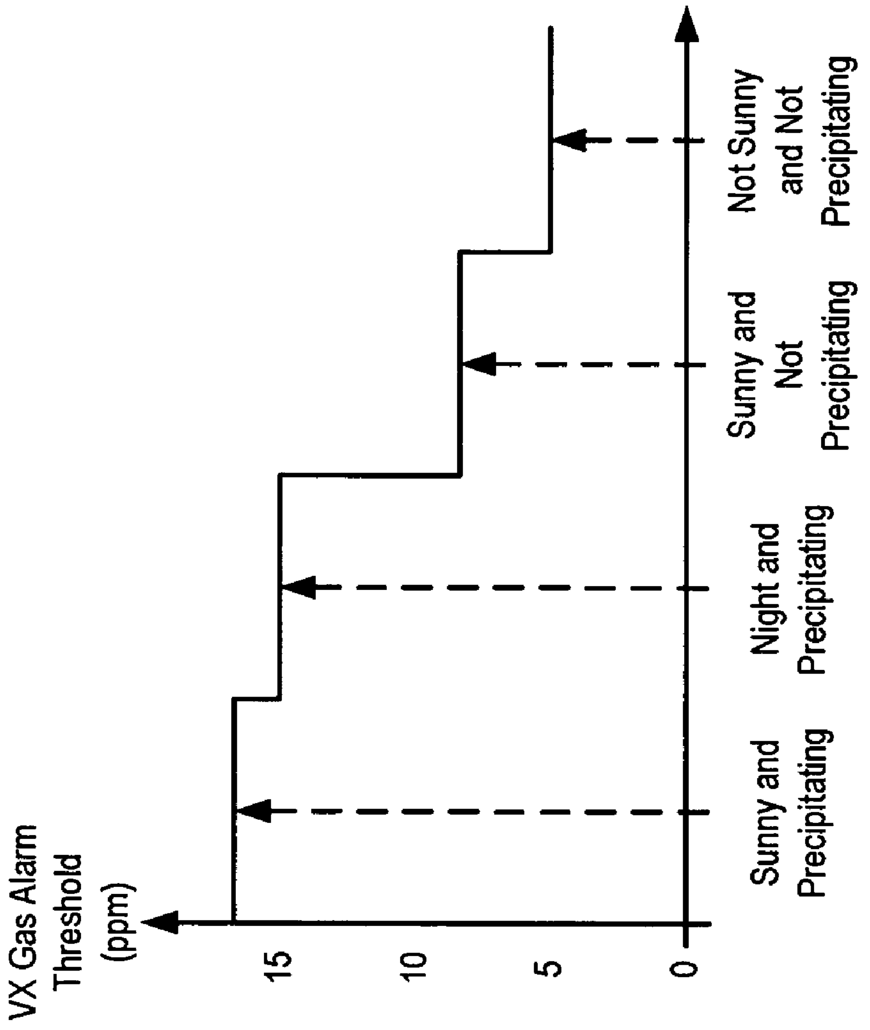

VX Gas Alarm Threshold (ppm)
15
10
5
0
Sunny and Precipitating
Night and Precipitating
Sunny and Not Precipitating
Not Sunny and Not Precipitating

Figure 11

CHEMICAL, BIOLOGICAL, RADIOLOGICAL, AND NUCLEAR WEAPON DETECTION SYSTEM COMPRISING ARRAY OF SPATIALLY-DISPARATE SENSORS AND ENVIRONMENTAL ACUITY

FIELD OF THE INVENTION

The present invention relates to civil defense in general, and, more particularly, to chemical, biological, radiological, and nuclear weapon detection systems.

BACKGROUND OF THE INVENTION

A chemical, biological, radiological, or nuclear attack on a civilian population is a dreadful event, and the best response requires the earliest possible detection of the attack so that individuals can flee and civil defense authorities can contain its effects. To this end, chemical, biological, radiological, and nuclear weapons detection systems are being deployed in many urban centers that will give civil defense authorities almost instant notification that an attack has occurred.

SUMMARY OF THE INVENTION

A terrorist seeks to impose his or her will on a government by convincing its citizenry that conciliation—and not confrontation—will make the threat disappear. If the government is able to protect its citizens from violence, the policy of confrontation will be deemed successful and the terrorist's agenda will be thwarted. In contrast, if the terrorist is able to strike wherever and whenever it desires, the policy of confrontation will be deemed unsuccessful and the terrorist's agenda will be promoted by those who favor conciliation.

In either case, the government and the terrorist are locked in a struggle to undermine the citizenry's respect and confidence in the other. It warrants repeating that the salient traits that the government and the terrorists vie for are respect and confidence, and, therefore, any factor—however apparently remote—that enhances or detracts either's respect and confidence is important.

One way that the government earns and maintains the respect and confidence of the citizenry is by quickly and accurately informing the public when an attack has occurred and by taking the appropriate action. This means that there are two ways in which the government can lose the respect and confidence of the citizenry. First, the government can fail to inform the public when an actual attack has occurred, and second, the government can inform the public that an attack has occurred when in fact there has been so such attack. Therefore, it's important for the government to inform the public of an attack when an attack has in fact occurred, but that it is also important for the government not to issue false alarms. To this end, the respect in the government is best enhanced by a chemical, biological, radiological, and nuclear weapon detection system that both: (1) quickly issues an alarm in the event of a real attack, and (2) accurately withholds false alarms.

To achieve this, the illustrative embodiment of the present invention comprises an array of spatially-disparate hazardous material sensors that all feed into a centralized system control center. This enables the embodiment to receive and coordinate in one place all of the data from all of the hazardous material sensors that are spread over a wide area, and, therefore, enables an alarm to be quickly issued in the event of a real attack.

Furthermore, to accurately reduce false alarms, the illustrative embodiment requires that at least N of M neighboring stations report an alarm for the same hazardous material within an interval of time. This is based on the assumption that a real attack is more likely to be detected by multiple stations that are near each other than by stations that have no proximity.

And still furthermore, the illustrative embodiment of the present invention incorporates a mechanism that heightens its acuity and alertness when it senses that a chemical, biological, radiological, or nuclear weapon attack is more likely. For example, it is well understood that a chemical gas attack is likely to be less effective when it is raining than when it is clear because the rain will suppress and dilute the chemical agent. Therefore, the likelihood of a chemical gas attack is higher when it is clear. In light of this and similar knowledge, the illustrative embodiment changes the values of at least one of N and M change based on at least one environmental factor.

The illustrative embodiment comprises: a first environmental sensor for monitoring a first environmental factor; K spatially-disparate hazardous material detection stations, wherein each of the K hazardous material detection stations issues a first alarm when the amount of a first hazardous material reaches a first threshold; and a first system-wide alarm that is triggered when N of M of the neighboring hazardous material detection stations issues the first alarm; wherein N, M, and K are positive integers and $1<N\leqq M\leqq K$; and wherein at least one of N and M change based on the first environmental factor.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** depicts a city map and the location of the salient components of the illustrative embodiment of the present invention on that map.

FIG. **2** depicts a block diagram of the salient components of each of environmental sensor arrays **101-1** through **101-17**.

FIG. **3** depicts a block diagram of the salient components of each of video camera clusters **102-1** through **102-13**.

FIG. **4** depicts a block diagram of the salient components of each of hazardous material detection stations **103-1** through **103-11**.

FIG. **5** depicts a block diagram of the salient components of hazardous material sensor array **401**-*k*.

FIG. **6** depicts a block diagram of the salient components of hazardous material station processor **402**-*k*.

FIG. **7** depicts a block diagram of the salient components of system control center **110**.

FIG. **8** depicts a flowchart of the salient tasks associated with the deployment and operation of the illustrative embodiment.

FIG. **9** depicts a flowchart of the salient tests in task **805** of FIG. **8**.

FIG. **10** depicts a flowchart of the salient tasks associated with the operation of hazardous material detection processor **402**-*k*.

FIG. **11** depicts the threshold for VX Gas in parts per million (ppm) as a function of both precipitation and whether or not it is sunny.

DETAILED DESCRIPTION

FIG. **1** depicts a city map and the location of the salient components of the illustrative embodiment of the present invention on that map. The illustrative embodiment comprises:

i. seventeen (17) spatially-disparate environmental sensor arrays **101-1** through **101-17**,
ii. thirteen (13) spatially-disparate video camera clusters **102-1** through **102-13**,
iii. eleven (11) spatially-disparate hazardous material detection stations **103-1** through **103-11**, and
iv. system control center **110**.

Environmental sensor arrays **101-1** through **101-11** and video camera clusters **102-1** through **102-11** are not distinctly shown in FIG. **1** because they are co-located with and contained within hazardous material detection stations **103-1** through **103-11**, respectively.

Environmental sensor arrays **101-1** through **101-17**, video camera clusters **102-1** through **102-13**, and hazardous material detection stations **103-1** through **103-11** are deployed throughout city **100** to enable the comprehensive environmental, video, and hazardous material surveillance of city **100**. In accordance with the illustrative embodiment, all of environmental sensor arrays **101-1** through **101-17**, video camera clusters **102-1** through **102-13**, and hazardous material detection stations **103-1** through **103-11** are outdoors, but after reading this specification it will be clear to those skilled in the art how to make and use embodiments of the present invention in which some or all of the environmental sensor arrays, video camera clusters, and hazardous material detection stations are indoors. Furthermore, although the illustrative embodiment is depicted as deployed in an urban environment, it will be clear to those skilled in the art, after reading this specification, how to make and use alternative embodiments of the present invention that are deployed or deployable in other environs (e.g., on ship board, in a rural area, in suburbia, etc.).

Each of environmental sensor arrays **101-1** through **101-17** monitors eight environmental characteristics (e.g., precipitation, humidity, sunlight, temperature, wind speed, wind direction, barometric pressure, ambient sound, etc.) at a different location and reports its findings to system control center **110**. Furthermore, each of environmental sensor arrays **101-1** through **101-11** reports its findings to hazardous material detection stations **103-1** through **103-11**, respectively. In accordance with the illustrative embodiment, the reporting is accomplished through wireline telemetry in well-known fashion. It will be clear to those skilled in the art, however, after reading this specification, how to make and use alternative embodiments of the present invention in which some or all of the reporting is accomplished through wireless telemetry. The details of environmental sensor arrays **101-1** through **101-17** are described below and with respect to FIG. **2**.

Each of video camera clusters **102-1** through **102-13** monitors a location, in well-known fashion, and transmits its video signals to system control center **110** via wireline telemetry. It will be clear to those skilled in the art, however, how to make and use alternative embodiments of the present invention in which some or all of the video signals are transmitted via wireless telemetry. The details of video camera clusters **102-1** through **102-13** are described below and with respect to FIG. **13**.

Each of hazardous material detection stations **103-1** through **103-11** measures the amount of six (6) hazardous materials (e.g., nuclear warfare agents, chemical warfare agents, biological warfare agents, etc.) and transmits an alarm status for each hazardous material to system control center **110** via wireline telemetry. It will be clear to those skilled in the art, however, how to make and use alternative embodiments of the present invention in which some or all of the alarms are transmitted via wireless telemetry. Although each of hazardous material detection stations **103-1** through **103-11** detects six (6) hazardous materials, it will be clear to those skilled in the art, after reading this specification, how to make and use embodiments of the present invention that detect any number of hazardous materials. The details of hazardous material detection stations **103-1** through **103-11** are described below and with respect to FIGS. **4** through **6**.

Although the illustrative embodiment comprises 17 environmental sensor arrays, 13 video camera clusters, and 11 hazardous material detection stations, it will be clear to those skilled in the art, after reading this specification, how to make and use embodiments of the present invention that comprise any number of environmental sensor arrays, video camera clusters, and hazardous material detection stations. Furthermore, it will be clear to those skilled in the art, after reading this specification, how to make and use alternative embodiments of the present invention in which one or more of the hazardous material detection stations lacks a video camera cluster or an environmental sensor array or both.

System control center **110** receives the telemetry from environmental sensor arrays **101-1** through **101-17**, video camera clusters **102-1** through **102-13**, and hazardous material detection stations **103-1** through **103-11** and determines, in the manner described below, whether or not to issue a system-wide alarm. The operation of environmental sensor arrays **101-1** through **101-17**, video camera clusters **102-1** through **102-13**, hazardous material detection stations **103-1** through **103-11**, and system control center **110** are described in detail below and with respect to FIGS. **8** through **11**.

FIG. **2** depicts a block diagram of the salient components of each of environmental sensor arrays **101-1** through **101-17**. Environmental sensor array **101-*i***, for i=1 through 17, comprises:

i. precipitation sensor **201-*i*-1**,
ii. humidity sensor **201-*i*-2**,
iii. sunlight sensor **201-*i*-3**,
iv. temperature sensor **201-*i*-4**,
v. wind speed sensor **201-*i*-5**,
vi. wind direction sensor **201-*i*-6**,
vii. barometric pressure sensor **201-*i*-7**, and
viii. ambient sound sensor **201-*i*-8**.

The illustrative embodiment measures these eight environmental factors because each of them can—for the reasons described below—be correlated to the efficacy, and, therefore, the likelihood of a chemical, biological, radiological, or nuclear weapons attack.

In accordance with the illustrative embodiment, each of environmental sensor arrays **101-1** through **101-17** comprises the same eight sensors. It will be clear to those skilled in the art however, after reading this specification, how to make and use alternative embodiments of the present invention in which each sensor array has any subset of these sensors. Furthermore, it will be clear to those skilled in the art, after reading this specification, how to make and use alternative embodiments of the present invention that measure one or more additional environmental factors that can be correlated to the efficacy, and, therefore, the likelihood of a chemical, biological, radiological, or nuclear weapons attack.

The output of each sensor is multiplexed into environmental telemetry feed **202-*i*** in well-known fashion and transmitted to system control center **110** and, for k=1 through 11 to hazardous material station alarms **402-*k***, respectively. It will be clear to those skilled in the art how to make each of environmental sensor arrays **101-1** through **101-17**.

FIG. **3** depicts a block diagram of the salient components of each of video camera clusters **102-1** through **102-13**. Video camera cluster **102**-*v*, for v=1 through 13, comprises: video camera #1, video camera #2, and video camera #3. The output of each camera is multiplexed in well-known fashion and transmitted to system control center **110** via wireline telemetry feed **302**-*v*. It will be clear to those skilled in the art how to make each of video camera clusters **102-1** through **102-13**.

In accordance with the illustrative embodiment, each of video camera clusters **102-1** through **102-13** comprises three cameras. It will be clear to those skilled in the art however, after reading this specification, how to make and use alternative embodiments of the present invention in which each video camera cluster has any number of video cameras (including only one (1) camera).

FIG. **4** depicts a block diagram of the salient components of each of hazardous material detection stations **103-1** through **103-11**. Hazardous material detection station **103**-*k*, for k=1 through K, comprises:

i. hazardous material sensor array **401**-*k*,
ii. hazardous material station processor **402**-*k*,
iii. environmental sensor array **101**-*k*, and
iv. video camera cluster **102**-*k*,

interconnected as shown.

Hazardous material sensor array **401**-*k* comprises six hazardous material sensors for measuring the amount of alpha particles, beta particles, anthrax, small pox, sarin gas, and VX gas present at the array. In accordance with the illustrative embodiment of the present invention, hazardous material sensor array **401**-*k* receives measurements on the current environmental factors from environmental sensor array **101**-*k* and uses them to determine how frequently—and with what sensitivity—it should sample the ambient environment for the hazardous materials. This is because a chemical, biological, radiological, or nuclear attack is more likely to occur when some environmental factors are present than at other times, and, therefore, the illustrative embodiment is more diligent in looking for an attack when the environmental factors are more favorable for an attack.

Hazardous material sensor array **401**-*k* does not determine whether the amount of a measured hazardous material should trip an alarm; this is performed by hazardous material station processor **402**-*k*. To this end, the measurements made by hazardous material sensor array **401**-*k* are transmitted to hazardous material station processor **402**-*k* via wireline feed **411**-*k*. The details of hazardous material sensor array **401**-*k* are described below and with respect to FIG. **5**.

Hazardous material station processor **402**-*k* takes the measurements from hazardous material sensor array **401**-*k* and the measurements from environmental sensor array **101**-*k* and determines whether or not to transmit a "station" alarm to system control center **110** via wireline telemetry feed **412**-*k*. In accordance with the illustrative embodiment, an alarm is not issued when the measured amount of a hazardous material reaches a static threshold. Instead, an alarm is issued when the amount of a hazardous material reaches a dynamic threshold, wherein the threshold changes and is based on at least one environmental factor. The purpose of having the threshold change as a function of one or more environmental factors is to recognize that a chemical, biological, radiological, or nuclear attack is more likely to occur when some environmental factors are present than at other times, and, therefore, the threshold for issuing an alarm should lower when the environmental factors are more favorable for an attack than when the factors are unfavorable for an attack. The threshold for each hazardous material can be changed independently of the threshold for the other hazardous materials, and the threshold for each threshold can be determined using a different function of the environmental factors. The details of hazardous material station processor **402**-*k* are described in detail below and with respect to FIG. **6**.

Hazardous material station processor **402**-*k* comprises a general-purpose digital processor that performs an adaptive algorithm that sets the dynamic threshold based on measurements from environmental sensor array **101**-*k*. In some alternative embodiments of the present invention, hazardous material station processor **402**-*k* is a neural network.

FIG. **5** depicts a block diagram of the salient components of hazardous material sensor array **401**-*k*, which comprises:

i. alpha particle sensor **501**-*k*-**1**,
ii. beta particle sensor **501**-*k*-**2**,
iii. anthrax sensor **501**-*k*-**3**,
iv. small pox sensor **501**-*k*-**4**,
v. sarin gas sensor **501**-*k*-**5**, and
vi. VX gas sensor **501**-*k*-**6**,

interconnected as shown. Each of the six sensors is a point sensor and receives one or more measurements of the current ambient environment factors as observed by environmental sensor array **101**-*k* and uses them to change the schedule or when—and with what care—it should sample the ambient environment for its specific hazardous material. In some alternative embodiments of the present invention, one or more of the sensors are stand-off sensors, in contrast to point sensors, and it will be clear to those skilled in the art, after reading this specification, how to make and use embodiments of the present invention which comprise point sensors, stand-off sensors, or a combination of point sensors and stand-off sensors.

In general, a chemical, biological, radiological, or nuclear attack is more likely to occur:

i. when it is not precipitating (e.g., raining, snowing, sleeting, etc.) because the precipitation frustrates the dissemination and enervates the efficacy of the hazardous materials;
ii. when it is lower humidity, for the same reasons;
iii. when it is night (i.e., there is no sunlight) because the sunlight tends to breakdown the biological and chemical agents, because attacks are more psychologically terrifying at night, and because inversion layers typically occur at night;
iv. when the temperature is not extreme;
v. when the wind is blowing because the wind helps to the disseminate the hazardous materials;
vi. when the wind is blowing in a constant direction because it also helps to disseminate the hazardous materials;
vii. when a rising barometric pressure suggests that fair weather is coming; and
viii. shortly after a sound that could be caused by a chemical explosion.

Therefore, the schedule for checking for each hazardous material should be faster or more frequent when the conditions are ripe for an attack with that type of material. The rate for checking for each hazardous material can be different than the rate for the other hazardous materials, and the rate for checking for each hazardous material can be a different function of environmental factors. After reading this specification, it will be clear to those skilled in the art how to make and use alpha particle sensor **501**-*k*-**1**, beta particle sensor **501**-*k*-**2**, anthrax sensor **501**-*k*-**3**, small pox sensor **501**-*k*-**4**, sarin gas sensor **501**-*k*-**5**, and VX gas sensor **501**-*k*-**6**.

FIG. **6** depicts a block diagram of the salient components of hazardous material station processor **402**-*k*, which comprises:

i. alpha particle station alarm **601**-*k*-**1**,
ii. beta particle station alarm **601**-*k*-**2**,
iii. anthrax station alarm **601**-*k*-**3**,
iv. small pox station alarm **601**-*k*-**4**,
v. sarin gas station alarm **601**-*k*-**5**, and
vi. VX gas station alarm **601**-*k*-**6**,

interconnected as shown.

Each of these six station alarms receives:

i. one or more measurements of the current ambient environment factors as observed by environmental sensor array **101**-*k*, and
ii. a stream of measurements from its corresponding sensor in hazardous material sensor array **401**-*k*,

and uses them to determine when an alarm for that hazardous material should be transmitted to system control center **110** via wireline **411**-*k*. Each of the six station alarms is issued when the amount of a hazardous material reaches a threshold, and an alarm is stopped when the amount of the hazardous material falls below the threshold. A station can issue one or more alarms concurrently.

The thresholds are not static, however, but change and are at least partially based on one or more of the measurements of the current ambient environment factors as observed by environmental sensor array **101**-*k*. In particular, a chemical, biological, radiological, or nuclear attack is more likely to occur when some environmental conditions are present, and, therefore, the individual thresholds for each alarm are higher when those environmental conditions do not exist. For example, the threshold for sarin as is higher when it is precipitating than when it is not precipitating, lower when it is lower humidity than higher humidity, lower when it is night than when it is day, and lower when it is windy than when it is not windy. The operation of hazardous material station processor **402**-*k* is described in detail below and with respect to FIGS. **8** through **11**.

FIG. **7** depicts a block diagram of the salient components of system control center **110**, which comprises:

i. hazardous material detection station map **701**,
ii. system processor **702**,
iii. video switch **703**, and
iv. video display **704**,

interconnected as shown.

One of the advantages of the illustrative embodiment is that it incorporates mechanisms that seek to thwart false system alarms. One of these mechanisms is based on the understanding that a chemical, biological, radiological, or nuclear weapon attack is more likely to issue when there are alarms from multiple stations that are near each other than when there are alarms from multiple stations that are not near each other (e.g., are randomly distributed around the area that is monitored, etc.). To facilitate this analysis, the illustrative embodiment comprises a map—hazardous material detection station map **701**—that associates each hazardous material detection station to its location (e.g., latitude and longitude, etc.).

Another of the mechanisms that the illustrative embodiments uses to prevent false system alarms is based on the understanding that alarms from multiple stations are more likely to occur temporally in the same direction as the wind—as the hazardous material is blown downwind and into contact with the various hazardous material detection stations. To facilitate this analysis, hazardous material detection station map **701** also associates each environmental sensor array to its location.

In accordance with the illustrative embodiment, hazardous material detection station map **701** is a data structure, such as that depicted in Table 1.

TABLE 1

Hazardous Material Detection Station Map 701

	Latitude	Longitude
Hazardous Material Detection Station 411-1	40° 35' 56.03" N.	140° 35' 46.44" E.
Hazardous Material Detection Station 411-2	40° 34' 26.83" N.	140° 36' 36.02" E.
. . .	. . .	. . .
Hazardous Material Detection Station 411-11	40° 36' 36.14" N.	140° 38' 56.33" E.
Environmental Sensor Array 101-12	40° 35' 56.66" N.	140° 33' 14.03" E.
Environmental Sensor Array 101-13	40° 36' 49.35" N.	140° 35' 06.55" E.
. . .	. . .	. . .
Environmental Sensor Array 101-17	40° 37' 35.93" N.	140° 35' 52.83" E.

It will be clear to those skilled in the art how to make hazardous material detection station map **701**.

System processor **702** receives the telemetry from hazardous material detection alarms **411-1** through **411-11**, the telemetry from environmental sensor arrays **101-1** through **101-17**, and the location data from hazardous material detection station map **701** and determines whether or not to issue a system alarm. In accordance with the illustrative embodiment, system processor **702** is a general-purpose processor that is programmed to perform the functionality described herein and with respect to FIGS. **8** through **11**.

When system processor **702** determines that an attack has occurred or is occurring, it issues a system alarm to the personnel who monitor the illustrative embodiment (who are not shown in FIG. **7**) and it directs video switch **703** to automatically route the video feed(s) for the area(s) where the attack has occurred or is occurring to video display **704**. This enables the personnel who monitor the illustrative embodiment to further verify the attack. For example, if system processor **702** determines that a chemical gas attack is occurring in Times Square, then video of people collapsing and convulsing in Times Square will enable the personnel who monitor the illustrative embodiment to verify that indeed a gas attack has occurred. In contrast, if system processor **702** determines that a chemical gas attack is occurring in Times Square, then video showing people going about their business as usual will suggest to the personnel who monitor the illustrative embodiment that it is a false alarm or that it should be investigated more thoroughly.

Video switch **703** is controllable by system processor **702** as it is well known to those skilled in the art, and video display **704** is also well known to those skilled in the art.

FIG. **8** depicts a flowchart of the salient tasks associated with the deployment and operation of the illustrative embodiment.

At task **801**, hazardous material detection station map **701** is built and environmental sensor arrays **101-1** through

101-17, video camera clusters **102-1** through **102-13**, and hazardous material detection stations **103-1** through **103-11** are deployed throughout city **100** in accordance with hazardous material detection station map **701**. It will be clear to those skilled in the art, after reading this specification, how to perform task **801**.

At task **802**, system processor **702** in system control center **110** continually receives the station alarm status from each of the six station alarms for each of the eleven hazardous material detection stations (i.e., system processor **702** periodically receives the station alarm status for all 11×6=66 station alarms). In the best of cases, system processor **702** does not receive any station alarms.

At task **803**, system processor **702** in system control center **110** continually receives the environmental telemetry transmitted from each of the eight environmental sensors for each of the sixteen environmental sensor arrays (i.e., system processor **702** periodically receives the environmental data for all 16×8=128 environmental sensors).

At task **804**, system processor **702** in system control center **110** continually receives the video signals from each of the thirteen video surveillance clusters. In accordance with the illustrative embodiment, tasks **802**, **803**, and **804** are performed concurrently, but it will be clear to those skilled in the art, after reading this specification, how to make and use alternative embodiments of the present invention in which tasks **802**, **803**, and **804** are performed in any order.

At task **805**, system processor **702** in system control center **110** determines whether a system-wide alarm should be issued. In accordance with the illustrative embodiment, system processor **702** determines whether to issue a system-wide alarm based on:

i. the number of station alarms that are received,
ii. the number of hazardous materials that are detected,
ii. the proximity of the station alarms, when there is more than one station alarm,
iv. the temporal sequence in which the station alarms are received, when there is more than one station alarm, and
v. the environmental conditions (including wind direction).

It will be clear to those skilled in the art, however, after reading this specification, how to make and use alternative embodiments of the present invention that omit one or more of these factors. When system processor **702** determines that an alarm should be issued, control passes to task **806**; otherwise control returns to task **802**. The details of task **805** are described below and with respect to FIG. **9**.

At task **806**, system processor **702** issues a system-wide alarm and directs video switch **703** to direct the video telemetry from areas where the station alarms are coming to video display **704**. After task **806** has been performed, control returns to task **802**.

FIG. **9** depicts a flowchart of the salient tests in task **805** of FIG. **8**. It will be clear to those skilled in the art, after reading this specification, how to make and use embodiments of the present invention that omit one or more of the tests.

At test **901**, system processor **702** determines whether at least N of M neighboring hazardous material detection stations issued an alarm for a first hazardous material, wherein N and M are positive integers, wherein $2 \leqq N \leqq M \leqq K$, and wherein at least one of N and M change based on an environmental factor. Test **901** incorporates three different mechanisms for reducing the probability that a false system-wide alarm will be issued.

The first mechanism requires that at least N (wherein $2 \leqq N$) stations report an alarm for the same hazardous material within an interval of time. This prevents a false alarm from one hazardous material detection station from issuing a false system-wide alarm. If the probability of a station issuing a false alarm is p and the probability of each station issuing a false alarm is independent of another station issuing a false alarm, then the probability that the illustrative embodiment will issue a false system-wide alarm is no higher than p^N. The implication is that the probability of issuing a false system-wide alarm is affected by the value of N. High values of N lower the likelihood of a false system-wide alarm, but also increase the likelihood that a real system-wide alarm will not issue. It will be clear to those skilled in the art, after reading this specification, how to select values for N based on the acceptable likelihood of a false system-wide alarm and on the likelihood that a real system-wide alarm will not issue.

The second mechanism requires that the N stations reporting an alarm for the same hazardous material within an interval of time be a subset of M neighboring stations (i.e., have some proximity to each other). For the purpose of this specification, M stations are "neighboring stations" if and only if a circle exists that contains all M stations and no other stations. System processor **702** uses Hazardous Material Detection Station Map **701** to determine if a circle exists that contains all M stations and no other stations.

The purpose of this mechanism is to issue a system-wide alarm only when the N stations reporting an alarm for the same hazardous material within an interval of time have some proximity to each other. This is based on the assumption that a real attack is more likely to be detected by stations that are near each other than by stations that have no proximity. Small values of M lower the likelihood of a false system-wide alarm, but also increase the likelihood that a real system-wide alarm will not issue. It will be clear to those skilled in the art, after reading this specification, how to select values for M based on the acceptable likelihood of a false system-wide alarm and on the likelihood that a real system-wide alarm will not issue.

The third mechanism changes the values of at least one of N and M based on at least one environmental factor (e.g., precipitation, wind speed, the amount of sunlight, etc.) to cause the threshold for a system-wide alarm to be higher when the environmental factor(s) suggest that an attack is less likely. For example, the ratio of N:M will be higher when it is precipitating, when it is not windy, and when it is sunny. It will be clear to those skilled in the art, after reading this specification, how to change the values of N and M based on environmental factors based on the acceptable likelihood of a false system-wide alarm and on the likelihood that a real system-wide alarm will not issue.

In some alternative embodiments of the present invention, test **901** determines whether A % of the hazardous material detection stations within B meters issued an alarm for a first hazardous material, wherein A and B are positive real numbers, wherein $0\% \leqq A\ \% \leqq 100\%$, and wherein at least one of A and B change based on an environmental factor.

At test **902**, system processor **702** determines whether at least P of V neighboring hazardous material detection stations issued an alarm for the first hazardous material, wherein P and V are positive integers, $2 \leqq P \leqq V \leqq K$, $N \leqq P$ and wherein at least one of P and V change based on an environmental factor. The purpose of test **902** is to ensure that a system-wide alarm is only issued when the extent of the stations reporting an alarm expands, as would be expected in a real attack.

Test **902** incorporates three different mechanisms for reducing the likelihood that a false system-wide alarm will be issued, and these three mechanisms are analogous to those in test **901**. Therefore, it will be clear to those skilled in the art, after reading this specification, how to select values for P and V and how to change them based on environmental factors based on the acceptable likelihood of a false system-wide alarm and on the likelihood that a real system-wide alarm will not issue.

In some alternative embodiments of the present invention, test **902** determines whether C % of the hazardous material detection stations within D meters issued an alarm for the first hazardous material, wherein C is a positive real number, wherein $0\% \leqq C\% \leqq 100\%$, and wherein at least one of C and D change based on an environmental factor.

At test **903**, system processor **702** determines whether at least R of S neighboring hazardous material detection stations issued an alarm for a second hazardous material, wherein R and S are positive integers, wherein $2 \leqq R \leqq S \leqq K$, and wherein at least one of R and S change based on an environmental factor. The purpose of test **903** is to ensure that a system-wide alarm is only issued when a second hazardous material is detected in addition to the first hazardous material, as would be expected in some types of real attacks. For example, in a nuclear attack, the detection of alpha particles might be accompanied by the detection of beta particles. There are, of course, other kinds of attacks that involve only one type of hazardous material.

In some alternative embodiments of the present invention, test **903** determines whether E % of the hazardous material detection stations within F meters issued an alarm for a second hazardous material, wherein E is a positive real number, wherein $0\% \leqq E\% \leqq 100\%$, and wherein at least one of E and F change based on an environmental factor.

Test **903** incorporates three different mechanisms for reducing the likelihood that a false system-wide alarm will be issued, and these three mechanisms are analogous to those in test **901**. Therefore, it will be clear to those skilled in the art, after reading this specification, how to select values for R and S and how to change them based on environmental factors based on the acceptable likelihood of a false system-wide alarm and on the likelihood that a real system-wide alarm will not issue.

At test **904**, system processor **702** determines whether the spread of station alarms is generally consistent with the prevailing wind direction, as would be expected in a real attack as the hazardous material is blown downwind. To do this processor **702** uses it knowledge of the position of the stations reporting alarms, hazardous material detection station map **701**, and its knowledge of the prevailing wind direction, which it gleans from the environmental sensor arrays in the vicinity of the stations reporting alarms. It will be clear to those skilled in the art, after reading this specification, how to make and use embodiments of the present invention that decide whether the spread of station alarms is generally consistent with the prevailing wind direction.

FIG. **10** depicts a flowchart of the salient tasks associated with the operation of hazardous material detection processor **402**-*k*.

At task **1001**, hazardous material detection processor **402**-*k* receives the environmental data from environmental sensor array **101**-*k*. It will be clear to those skilled in the art how to make and use embodiments of the present invention that perform task **1001**.

At task **1002**, hazardous material detection processor **402**-*k* receives the hazardous material measurements from hazardous material sensor array **401**-*k*. It will be clear to those skilled in the art how to make and use embodiments of the present invention that perform task **1002**. Furthermore, it will be clear to those skilled in the art, after reading this specification, how to make and use embodiments of the present invention that perform tasks **1001** and **1002**, concurrently or in any order.

At task **1003**, hazardous material detection processor **402**-*k* determines, based on the measurements received in task **1002** and the environmental data received in task **1001**, whether the amount of a hazardous material has reached a threshold such that the station's alarm should be issued. When hazardous material detection processor **402**-*k* determines that the alarm should be issued, control passes to task **1004**; otherwise control returns to task **1001**.

Hazardous material detection processor **402**-*k* incorporates a mechanism to reduce the probability that a false station alarm will be issued. In particular, hazardous material detection processor **402**-*k* changes the threshold for each hazardous material based, at least in part, on the environmental data received in task **1001**. For example, FIG. **11** depicts the threshold for VX Gas in parts per million (ppm) as a function of both precipitation and whether or not it is sunny. From FIG. **11**, it can be seen that the threshold is higher when it is precipitating and sunny than when it is not precipitation or not sunny or neither precipitating nor sunny.

At task **1004**, hazardous material detection processor **402**-*k* transmits a station alarm to system control center **110**, via wireline **412**-*k*. After task **1004**, control returns to task **1001** to determine if an alarm for a second hazardous material should be issued and to determine if the amount of the first hazardous material has fallen (or the threshold raised) such that the alarm should be discontinued.

It is to be understood that the above-described embodiments are merely illustrative of the present invention and that many variations of the above-described embodiments can be devised by those skilled in the art without departing from the scope of the invention. For example, in this Specification, numerous specific details are provided in order provide a thorough description and understanding of the illustrative embodiments of the present invention. Those skilled in the art will recognize, however, that the invention can be practiced without one or more of those details, or with other methods, materials, components, etc.

Furthermore, in some instances, well-known structures, materials, or operations are not shown or described in detail to avoid obscuring aspects of the illustrative embodiments. It is understood that the various embodiments shown in the Figures are illustrative, and are not necessarily drawn to scale. Reference throughout the specification to "one embodiment" or "an embodiment" or "some embodiments" means that a particular feature, structure, material, or characteristic described in connection with the embodiment(s) is included in at least one embodiment of the present invention, but not necessarily all embodiments. Consequently, the appearances of the phrase "in one embodiment," "in an embodiment," or "in some embodiments" in various places throughout the Specification are not necessarily all referring to the same embodiment. Furthermore, the particular features, structures, materials, or characteristics can be combined in any suitable manner in one or more embodiments. It is therefore intended that such variations be included within the scope of the following claims and their equivalents.

What is claimed is:

1. A system comprising:

a first environmental sensor for monitoring a first environmental factor;

K spatially-disparate hazardous material detection stations, wherein each of said K hazardous material detection stations issues a first alarm when the amount of a first hazardous material reaches a first threshold; and

a first system-wide alarm that is triggered when N of M neighboring hazardous material detection stations issues said first alarm;

wherein N, M, and K are positive integers and $1<N\leqq M\leqq K$; and

wherein at least one of N and M change based on said first environmental factor.

2. The system of claim **1** wherein said first system-wide alarm is triggered when first P of Q of said K hazardous material detection stations issues said first alarm and then when N of M neighboring hazardous material detection stations issues said first alarm;

wherein P and Q are positive integers, $1<P\leqq Q$, $Q<M$, and said Q neighboring hazardous material detection stations are a proper subset of said M neighboring hazardous material detection stations; and

wherein at least one of P and Q change based on said first environmental factor.

3. The system of claim **1** wherein each of said K hazardous material detection stations issues a second alarm when the amount of a second hazardous material reaches a second threshold; and further comprising:

a second system-wide alarm that is triggered when R of S of said K hazardous material detection stations issues a second alarm;

wherein R and S are positive integers, $R\leqq S\leqq K$, and $R\neq N$; and

wherein at least one of R and S change based on said first environmental factor.

4. The system of claim **1** wherein said first environmental factor is precipitation.

5. The system of claim **4** wherein the ratio of N:M is higher when it is precipitating than when it is not precipitating.

6. A method comprising:

monitoring a first environmental factor;

receiving a first alarm status from K spatially-disparate hazardous material detection stations;

triggering a first system-wide alarm when N of M neighboring hazardous material detection stations issues said first alarm; and

changing the values of at least one of N and M based on said first environmental factor;

wherein N, M, and K are positive integers and $1<N\leqq M\leqq K$.

7. The method of claim **6** wherein said first system-wide alarm is triggered when first P of Q of said K hazardous material detection stations issues a first alarm and then when N of M neighboring hazardous material detection stations issues a first alarm;

wherein P and Q are positive integers, $1<P\leqq Q$, $Q<M$, and said Q neighboring hazardous material detection stations are a proper subset of said M neighboring hazardous material detection stations.

8. The method of claim **6** further comprising:

receiving a second alarm status from said K spatially-disparate hazardous material detection stations; and

triggering a second system-wide alarm when R of S of said K hazardous material detection stations issues a second alarm; and

changing the values of at least one of R and S based on said first environmental factor;

wherein R and S are positive integers, $R\leqq S\leqq K$, and $R\neq N$.

9. The method of claim **6** wherein said first environmental factor is precipitation.

10. The method of claim **9** wherein the ratio of N:M is higher when it is precipitating than when it is not precipitating.

11. A system comprising:

a first environmental sensor for monitoring a first environmental factor;

K spatially-disparate hazardous material detection stations; and

a first system-wide alarm that is triggered when A % of said K hazardous material detection stations within B meters issues an alarm for a first hazardous material;

wherein K is a positive integer, A and B are positive real numbers, and $0\%<A\ \%\leqq 100\%$; and

wherein at least one of A and B change based on said first environmental factor.

12. The system of claim **11** wherein said first system-wide alarm is triggered when first A % of said K hazardous material detection stations within B meters issues said first alarm for a first hazardous material and then when C % of said K hazardous material detection stations within D meters issues an alarm for said first hazardous material;

wherein C and D are positive real numbers, and $0\%<C\ \%\leqq 100\%$; and

wherein at least one of C and D change based on said first environmental factor.

13. The system of claim **11** further comprising a second system-wide alarm that is triggered when first A % of said K hazardous material detection stations within B meters issues said first alarm for a first hazardous material and then when E % of said K hazardous material detection stations within F meters issues an alarm for a second hazardous material;

wherein E and Fare positive real numbers, and $0\%<E\ \%\leqq 100\%$; and

wherein at least one of E and F change based on said first environmental factor.

14. The system of claim **11** wherein said first environmental factor is precipitation.

15. The system of claim **14** wherein the ratio of N:M is higher when it is precipitating than when it is not precipitating.

16. A method comprising:

monitoring a first environmental factor;

receiving a first alarm status from K spatially-disparate hazardous material detection stations; and

triggering a first system-wide alarm when A % of said K hazardous material detection stations within B meters issues an alarm for a first hazardous material;

wherein K is a positive integer, B is a positive real number, and A is a positive real number, and $0\%<A\ \%\leqq 100\%$; and

wherein at least one of A and B change based on said first environmental factor.

17. The method of claim **16** wherein said first system-wide alarm is triggered when first A % of said K hazardous material detection stations within B meters issues said alarm for said first hazardous material and then when C % of said K hazardous material detection stations within D meters issues an alarm for said first hazardous material;

wherein C and D are positive real numbers, and 0%<C %≦100%; and

wherein at least one of C and D change based on said first environmental factor.

18. The method of claim **16** further comprising triggering a second system-wide alarm when E % of said K hazardous material detection stations within F meters issues an alarm for a second hazardous material;

wherein E and Fare positive real numbers, and 0%<E %≦100%; and

wherein at least one of E and F change based on said first environmental factor.

19. The system of claim **18** wherein said first environmental factor is precipitation.

20. The system of claim **19** wherein the ratio of N:M is higher when it is precipitating than when it is not precipitating.

* * * * *