Rapid Deployment of On-Site Analysis and Response to Critical Chem-Bio Emergencies

Course Notes, Part 1

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Why You Are Here
You work within or are interested to learn about new tools, methods, systems, and practical techniques relating to Environmental Analysis, Homeland Defense, Laboratory-on-a-chip/Microfluidics, Laboratory Information and Management, Sample Preparation, and Sensors.

Overview
This is an introduction to the use of a fully-equipped mobile laboratory (including GC/MS, FTIR, XRF) with on-site personnel and a remote base station. Students are introduced to the use of several LIMS-related interfaces to GIS and mapping utilities for generating real-time Situation Awareness and Response reports and projections pertaining to the location, isolation, and forecasted distribution of target chemical (including radioisotope) and biopathogen compounds in the examination area of a plant, port or residential district. Particular attention is directed to issues of infrastructure integrity, redundancy, fault-tolerance, and abilities of the mobile lab equipment and staff to respond to unexpected “outlier” and anomalous events, such as may occur frequently in emergency or disaster situations.

Objectives
Training in the use and maintenance of mobile analytical and response instrumentation and also online telemonitoring and team conferencing, as well as in techniques for coordination among emergency hazmat, health, safety and security personnel in environments where critical infrastructures including particular communications and site security have been compromised by natural incidents or intentional aggression.

Outline
The “half-day” course is divided into segments, each of which will provide lecture, Q&A, team simulation exercise(s), and group discussion. The use of small break-out sessions for participants to work together and then share outcomes with the larger group is a key part of the course plan for enabling differences of method and opinion to be explored in greater depth and then shared for constructive criticism.

Scenario Introduction
- Plant and Environment
- Practices and Protocols
- Incident Model
- Simulation - “Rules of the Game”

EcOasis PodLab - A Specific Model and Case Study
- Underlying Architecture
- Analytical Instrumentation
  - GC/MS, FTIR, XRF
- Auxiliary Equipment
  - Water and Gas Generation
  - Hybrid Electric Power
- Software Resources
  - GIS
  - LARS
  - Open Net
  - Shumeru
  - Information Security
- Redundancy and Fault Tolerance
- Instrumentation Communications
- Power Supply & Control

Infrastructure Collapse and Decay Issues

Fault Tolerance and QA/QC

Situation Awareness Development and Continuity
- PANDA Model
- CASE Model
- EAGLE model
- TANGRAM model
- Nomad Eyes as a Specific Model and Case Study

Simulation Team Session(s)

Post-Facto Analysis and Feedback

Recap and Discussion

Materials

There are two sets of hand-outs provided, Part 1 (this document) and Part 2 (a slide set). In order to minimize unnecessary printing, these are comparatively small documents. Most of the course materials are being provided in electronic form and will be available online.

Organization and Presentation

This course is being conducted in segments that will have logical breaks, for accommodating both physical breaks for rest and refreshment, and simulation breaks, whereby the class, divided into teams of four or five participants, will engage in the simulation parts of the exercise. All of the material being presented will be through PowerPoint-type slides. The material in both of the hand-out documents (Parts 1 and 2) are provided for background notes and for following and referencing the course as it is conducted and as participants discuss things in their small-team break-out sessions.

Here in Part 1 are provided no slides but additional text material including papers and notes that relate to the segments of the course. Printed and bound material is in black-and-white only, while the versions used during the course will include color text and graphics.

Text Material List

Changing Currents in Environmental Analysis

How Global Climate Change Issues are Impacting the Need for Specialization and New Approaches in Ambient and Emission-specific Analysis

Martin Dudziak, PhD
TETRADYN, LLC

Conventional models, particularly for air analysis at industrial and community sites, have traditionally been based upon meeting standards and sustaining compliance with regulations set by state and federal agencies. This focus has driven the selection of procedures and schedules for a wide variety of testing, following well-established standard methods. In the majority of situations, sampling and testing has focused upon the determination of emissions and contaminants within a particular stream of physical media that is part of an isolated manufacturing or distribution process. Alternatively, the general ambient environment surrounding a particular plant or other location of specific interest due to extraction, transport, industrial processing, storage, or consumption has been the target for emission sampling and monitoring. Historically, there has been little consideration for how multiple systems, including those of manmade origin, react with one another (for example, outside urban and industrial zones, and in newly developing economic regions such as China with significant eco-cultural differences). There has also been little consideration until quite recently about how diverse production systems can collectively be employed to support measures that will enhance positively the impacts of a highly industrialized and energy-rich society upon the ecosystem. As two examples, there is biomass waste from agricultural products used in ethanol production, and pyrolisis processing of rubber and plastic waste, both producing a variety of synthetic gases. These bring in beyond the usual emission concerns the positive prospects of electric power generation through use of what is otherwise a byproduct.

The impact of the global climate change crisis upon society and industry, like the very issue of what is or is not ongoing and predictable within regional and global climate patterns, is characterized by interdependency and uncertainty. While specific trends and consequences may still be unclear and unpredictable, and even more so for specific causes, the rise in aggregate emissions, especially of types contributing to CO_2 releases and upper-atmosphere ozone depletion, are indisputable. Likewise there is the evident higher-impact effect from virtually any non-linear climate events (floods, droughts, storms) upon increasingly dense population centers.

The ability of society, from the level of corporate plants and small residential communities up to the scale of states and nations, to move rapidly, efficiently and economically in response to non-linear atmospheric and terrestrial environment shifts, as well as the ability to support a broad-based plan of attack for the reduction of CO_2 through lower emissions and higher retention and storage, is dependent upon having a different kind of knowledge about the states and trends of emissions going into the airstreams and waterstreams. Heretofore the focus has been upon tracking levels of compounds and even predicting future levels – but of individual types, not considering much about long-term build-ups, reactions, or positive re-uses. What is desirable and necessary now is an ability to build accurate and dynamic network models of environmentally significant emission concentrations and interactions, not only for the well-understood toxic compounds but for many that can be useful in regional and global management of air, water and land resources.

Such a network model is not entirely dissimilar from network models employed in power distribution, traffic control, and telecommunication systems. What has been missing, for the most part, has been sufficient and broad data flow with highly accurate analysis of chemical compounds in the manner by which these analyses have been conducted to date for high-risk or high-emission producers such as petroleum, chemical, electronics, and heavy equipment plants. The established methods are there for the detailed field and lab chemistry. The network paradigms and mathematics exist for integrating large data sets into cohesive predictive models. The economics of synergy to find better ways to clean, re-use and recycle that will proactively counter global climate change effects, particularly with respect to the carbon cycle, may be simpler than initially imagined, if a more complete and detailed map of chemical processes and contents in our atmosphere and waterways can be made instead of being forced to work with low-res vision.

The realistic technology to implement a practical new generation of environmental analysis "en masse" has only emerged within the past five years. It involves a confluence of micro and small-scale, low-cost sensors, reduced costs for detailed formal lab analysis, and massive, ubiquitous, all-purpose communications including wireless and remote sensing. It is practical for a vast number of businesses and organizations to be analyzing and monitoring all facets of what goes in and what comes out of their buildings and operations, starting with the most important streams of air and water. What has been ongoing for years now at major oil refineries and plastics plants can and should now be ongoing in virtually all major consumers and transformers of energy, as well as in virtually all major public thoroughfares and concentrations of large populations. The assessment of such large data streams is computationally a fait accompli by virtue of applying inverse methods, large-scale nonlinear thermodynamical statistics and other modeling techniques. What specific energy and climate benefits will emerge is not any more clear today than the specific issues and threats we face over the next two, five, or one hundred years, but we can safely assume that there will be far more benefit to pursuing this type of course of action than to avoid doing so. If it is a process that can change the air or water in composition or temperature, then we need to monitor and understand those dynamics and determine how those changes can be used to balance or counterbalance something else in our ecosystem in order to stabilize and gain better control over what could otherwise rapidly become a world quite out of control for living beings.

Summary of General Specifications for Equipment including Water Production

for an EcOasis PodLab (emergency response configuration)

General (non-proprietary) system features

Pod Module

<u>Pod Structure</u>

[standard Pod]

8' x 16' ruggedized trailer with towbar, rear double-door, side door, two windows (transportable by standard pickup truck, helicopter, or other conventional craft)

[expanded Pod]

10' x 40' ruggedized container, dual double-doors, side door, four windows (transportable by semi-trailer, heavy-duty helicopter, rail, barge)

<u>Interior Fixtures</u>

- Fixed mounting racks, shelving, and cabinetry
- Two mobile racks (wheel-mounted with sled runners)
- Pull-down quad-function workspace and living compartment (150 kg capacity, 2m x 1m sleeping area, snap-in modules for lab, desk, kitchen, and sleep functions)
- Panel flooring for access to cabling and piping and subfloor storage compartments
- Roof-mounted storage containers
- External subfloor storage containers
- Roof-mounted and side-mounted base panels for equipment fixtures

Power Module

TETRAD QuadSource Load-Balanced Power System

<u>Power Sources</u>

- Petrol 5 kW generator (gas or diesel options)
- Cyclone C5000 Multi-fuel 5 kW generator and power-drive engine
  - Engine-generator with fast powerdrive transmission
  - Combustion Unit with fast dynamic coupling
    - Standard combustion unit: gas, diesel, kerosene, biodiesel, biomass powder
    - [optional] Macrobiomass combustion unit: wood, coal, other biomass
- Apollo solar power system (dual CIGS and CPF technology)
- [optional] H-Bank fuel cell system (5 kW capacity)

[optional] Additional and larger capacity units

<u>Power Management</u>

- Automated Load Balancer Switch
- Li-ion Battery Pack
- UPS and surge/shock protection hardware
- Power Monitor (LAN-enabled)
- Vehicle (truck) power interface

- Gear and Pulley Erector Kit (enables dual operation of power generator and accessory low-power (individual/table-top) mechanical equipment such as saw, grinder, mill, mixer, other rotary end-user equipment)

Water Module

Water Purification System [see additional specs below]

- 20K – 50K per day output
- Source filtration tank and hoses
- Multi-spigot output assembly

[optional] Desalinization module
[optional] 5-gal. carboy bottling module
[optional] 1/1.5-liter bottling module

- Maintenance and Repair Kit
- Average reverse osmosis membrane replacement – 5000 to 7000 hrs. depending on water type
- Chemical maintenance – weekly
- Cartridge filter replacement – 15 – 30 days depending on water type
- Permanent mounting in rear of the Pod (unit may be removed by handtools and carried by 4-6 persons; minimum assembled weight @ 750 lbs.)

Portable Ceramic Filtration Kit

- Package of four (4) dual-filter Solo water purification units (12 – 20 gal./day passive filtration capacity)

[optional] Additional Kits, as need and storage capacity allow

Water Storage and Transport

- Bagua Water Bags (300)
    - Each holds 3 gal., stands securely when filled, has rugged handles, and stores flat

[optional] Additional bags, as need and storage capacity allow

Shelter Module

High-performance, high-strength, impact-resistant air-inflated shelter

- Air tube construction
- Arched design, 10’ high center, 18’ wide, 36’ long
- Two (2) end doors, zippered with Velcro
- Four (4) windows, zippered with velcro
- Electric air pump for inflation and deflation
- Fault-tolerant structure allows for sustainable use even with failure of multiple air tubes

[optional] Additional units, or larger capacity, as need and storage capacity allow

Netting and Shading Kit

Two (2) 16’ x 10’ mylar net tent extensions with zippered panels (mount onto top of Pod side wall)

Health Sustainability Module

Biosensor Kit

Rapid Diagnosic Kits

Anthrax
Cholera
Ricin
Staph Eneterotoxin
Y Pestis
Tularemia
Botulism Toxin

Collection Kits

SWIPE I, II, III, IV

Food Testing

E.coli
Ghirardia
Salmonella

Emergency Medical Response Kit

- Individual Respiratory-Assistance Ventilators (2)
- Individual Cardiac Defibrillator (1)
- Burn Treatment Pack (1)
- Standard emergency treatment kit (bandages, bite and wound treatment)
- Standard examination kit (thermometer, sphygmomanometer)
- Pharmaceutical Kit (standard medications)

[optional] Additional units as need and storage capacity allow

Antimicrobial BioProtection Kit

- TETRAD BioProt applicator unit for spray treatment of surfaces (minimum 1000 m3 capacity) (Note: all surfaces of the Pod and contact-accessible equipment and instrument surfaces are fully BioProt-treated, providing protection against all known gram+ and gram- bacteria, viruses, fungi)

[optional] Additional BioProt supplies for extending the treatment capacity as needed

Biofluids Monitoring Kit

- *MPA-1 Anti-Oxidant Analyzer*
  - Desktop operation
  - Battery-enabled
  - LAN-enabled
  - Supply kit (6-mo. normal operation)
- *Hydration Testing Kit*
  - Desktop operation (handheld unit in 2009)
  - Saliva/urine sample basis
  - LAN-enabled
  - Supply kit (6-mo. normal operation)

Environmental Analysis Module

[optional] MicroFAST GC (gas chromatography) mobile system for ambient air and samples
GC and supply cases, LAN-enabled

[optional] FTIR portable detection and analysis system for solids and liquids
Handheld operation, wireless interface, LAN-enabled
[optional] XRF portable detection and analysis system for solids and liquids
Handheld-operation, wireless interface, LAN-enabled
[optional] Radiation Monitoring and Analysis Kit
[optional] gas cylinders for GC calibration

Communications Module

Hardware

- Satellite internet transceiver unit (roof-mounted)
- Router-modem with local wireless capability
- Rack-mounted server, 2GB RAM, 500GB disk capacity
- Two (2) laptop PCs, 1GB RAM, 120GB disk, 17" display
- Network switch, 8-port
- VOIP interface
- Two (2) cordless phones
- Two (2) videocams
- Two (2) microphones
- Isolated (redundant) UPS

[optional] Wireless camera security network with six (6) LAN-enabled night-vision-enabled cameras
[optional] 26" LCD display for internal mounting
[optional] 46" LCD display for external mounting on Pod side wall

Software

- Standard PC, Server, LAN, Wireless, Web software
- Open Net (e-collaboration)
- Shumeru (e-presentation and webcast)
- Gaea (Content Management System)
- PodMon (Pod system management tools)

[optional] LARS (Laboratory Analytics Resource System)
[optional] LabView (data acquisition, routing, database archiving, and instrument analysis)
[optional] ChemView (analytical chemistry instrument management)

Tools Module

Mechanical Toolkit

- Standard handtools for maintenance of Pod, vehicle, and equipment
- Hydraulic jack

[optional] Other tools as needed or appropriate for operating environment

Construction Toolkit

- Standard handtools and powertools for working with wood, metal, and other materials
- Shovels (2), pick, sledgehammer, auger
- Axes (2), hand-axe, 26" chain saw, 24" wood saw, 48" two-man wood saw

[optional] Other tools as needed or appropriate for operating environment

Water Purification Unit – some of the types available at present:

- Bottling Plant System (BPS) designed to provide a full capability bottling plant that can be installed in 4 hours and handle all types of plastic water bottles found around the world. All this at 40 to 60% less than traditional water plant systems.
- Commercial Plant System (CPS) provides a complete water purification and supply system that meets requirements for high quality water for hotels, resorts, clinics, hospitals, buildings and manufacturing plants worldwide.
- Emergency Plant System (EPS) is a fast set up (less than 4 hours) that can supply the drinking water needs in an emergency to a population of 3,000 to 5,000 persons per day. EPS is designed for fast transport delivery via helicopter, plane or truck and fast installation.

Water purification specs:

	Bottling Plant System (BPS)		Commercial Plant System (CPS)	
	With Salt Removal	Without Salt Removal	With Salt Removal	Without Salt Removal
Monoblock Dimensions (LxWxH)	75" x 53" x 79"	75" x 53" x 79"	62" x 40" x 79"	62" x 40" x 79"
Storage - Pretreatment Tank[1]	48" x 40" x 40"	48" x 40" x 40"	48" x 40" x 40"	48" x 40" x 40"
Weight	800 lbs when shipped	750 lbs when shipped	660 lbs when shipped	610 lbs when shipped
Electrical	30A @ 220VAC 60 Hz.	20A @ 220VAC 60 Hz.	25A @ 220VAC 60 Hz.	15A @ 220VAC 60 Hz.
Capacity[2]	up to 100 - 5 Gal. bottles/hr max. 20 hr/day		up to 600 Gal. per hour max. 23 hr/day	
Area Requirement	16 ft x 16 ft	16 ft x 16 ft	12 ft x 12 ft	12 ft x 12 ft
Water Source[3,4]	Varies, see notes bellow (3)	See notes below (4)	Varies, see notes bellow (3)	See notes below (4)

	Emergency Plant System (EPS)			
	With Salt Removal		Without Salt Removal	
	With Waterbag Filler	With Spigots Only	With Waterbag Filler	With Spigots Only
Monoblock Dimensions (LxWxH)	75" x 53" x 79"	62" x 40" x 79"	75" x 53" x 79"	62" x 40" x 79"
Storage - Pretreatment Tank[1]	48" x 40" x 40"	48" x 40" x 40"	48" x 40" x 40"	48" x 40" x 40"
Weight	800 lbs when shipped	660 lbs when shipped	750 lbs when shipped	610 lbs when shipped
Electrical	30A @ 220VAC 60 Hz.	25A @ 220VAC 60 Hz.	20A @ 220VAC 60 Hz.	15A @ 220VAC 60 Hz.
Capacity[2]	up to 250 - 2 Gal. Bags/hr	up to 600 Gal/hr	up to 250 - 2 Gal. Bags/hr	up to 600 Gal/hr
Area Requirement	16 ft x 16 ft	12 ft x 12 ft	16 ft x 16 ft	12 ft x 12 ft
Water Source[3,4]	Varies, see notes below (3)	Varies, see notes below (3)	See notes below (4)	See notes below (4)

Maintenance topics, parts lifespan, repair & maintenance cycles, operator training levels

The plants require about a 5% to 10% replacement maintenance. The maintenance schedule is as follows:

Weekly: Chemical tank filling. This include anti-scalent for reverse osmosis, soap for cleaning jugs (5 gal) and chlorine feed tank. All tanks are 5 gallon tanks and thus very easy to mix solutions in them.

15- 30 days: replacement of cartridge filter, which are standard 10" particle filter found worldwide

Every 5000 to 7000 hours of operation: replacement of reverse osmosis membrane (about a ½ day job)

Volume output

The water purification subsystem allows for production in four scales, each module occupying a 5' x 5' footprint in the Pod:

A: 3,000 to 6,000 gal/day (very simple system no electronic control)

B: 5,000 to 10:000 gal/day (more control and monitoring including SCADA data collection and logging)

C: 10,000 to 20,000 gal/day

D: 20,000 to 50,000 gal/day

Coordinative Unified Biothreat Intervention and Treatment (CUBIT)

Martin Dudziak, PhD
(2006)

CUBIT is an architecture for systems that will mitigate epidemic-scale disease transmissions emerging from the introduction of new or unexpected pathogens into a population. A system designed and built according to CUBIT principles incorporates sensors and data collectors, human observers and monitors, an informational framework of autonomous cooperating software agents, bioprotectant and/or decontamination procedures, compact and rapid-turnaround diagnostic tests, population control protocols, and clinical treatment plans. A CUBIT system is designed to be employed as a preventive and responsive component that can be embedded within larger public health, emergency management and homeland security operations for specifically addressing the emergence of particular biothreats that, regardless of type (bacteria, viral) or origin (natural, accidental, terrorist), pose an unpredictable set of long-term threats to one or more populations (human or animal).

What makes CUBIT unique as a system architecture is that it is a set of medical and physical processes, instruments and protocols – incorporating a diversity of physical devices, chemical compounds, and information processing applications, that are organized as scalable, modular components capable of dynamic and adaptable interaction – and it capitalizes upon the use of system designs drawn from classical computing and information technology. CUBIT is an application of “plug and play,” “platform independence,” and “object oriented” design principles into the domain of environmental biosurveillance and pathogen detection and the domain of emergency incident management and medical response. An alternative way of describing CUBIT is that it is a system architecture for coordinating and unifying the identification, forecasting, and necessary intervention including diagnostics, antimicrobial protection and decontamination, and medical treatment including vaccination, quarantine and mitigation of vectors, for situations in which there is a risk of high-consequence infection and transmission.

As an example, consider a system that is intended for providing biothreat intervention directed at transmission through airports and other pubs of public transportation. The necessary logical components include monitoring and sensing to detect incidents of pathogen presence and transmission vectors, plus communication with other systems that are sources of information on events outside the logical space of airports, commercial aircraft, public transportation and the general community. In addition there are logical components for analysis and prediction including simulators of airborne, waterborne or host-carried bioagents. Next there are necessary components providing for several types of responsive action – population and vehicle control including quarantine and culling operations, diagnostic testing, inoculation, antibiotic and other pharmacological treatment, and follow-up observations. Collectively these components will be under constant restructure and revision due to the need for accommodating highly dynamic and unpredictable changes in geography, climate and weather conditions, population behavior (especially where wildlife are concerned), traffic flow, responder availability, resource supplies including those for both diagnosis and medication, and adaptive pathogen biology. It is therefore mandatory that all of the components have some flexibility in terms of how they will interact and communicate among one another. A flexibility tensegrity structure will be more suitable than a rigid skeleton, in bioresponse system design just as it is naturally within biology.

Prior to the introduction of the CUBIT architecture, there has been a consistent and chronic problem of mission within biothreat intervention, situation awareness and response. This has been the absence of a coordinative and unifying network of dynamic and intelligent communications, precisely the type of logic that has been the focus of development and experimentation within other sectors of defense, intelligence and crisis management, especially within combatant military forces. Composable Heterogeneous Agents for Intelligent Notification (CHAIN) and Collaborative Analyst/System Effectiveness (CASE) are two projects, the former completed and now being extended into multiple applications including maritime domain awareness for CBRNE threat intervention, that exemplify what can serve well the biosecurity and epidemiology communities. Another, the Intelligent Services Layer (ISL) is a computational integration framework for sensors, analytical applications and actuator devices to dynamically register their presence in a network, discover available resources, identify data and formats for exchange, and manage publish/subscribe functions among an open-ended network of agents. These technologies have grown out of a common matrix of research and development at Global Infotek,Inc. sponsored by a number of defense and intelligence programs [1]. Collectively they provide in turn the building blocks for a CUBIT architecture and implementations into the biomedical sphere.

Figures 1 and 2 on the following pages illustrates the major components of a CUBIT system. There are five major categories of components which interface with one another through a critical "operating system" layer of dynamic registration, discovery and exchange logical agents responsible for handling all of the communications. These are: sensing and detection, analysis and forecast, diagnostics, protection and decontamination, and treatment. This comprises the "anatomy" of a CUBIT instantiated system.

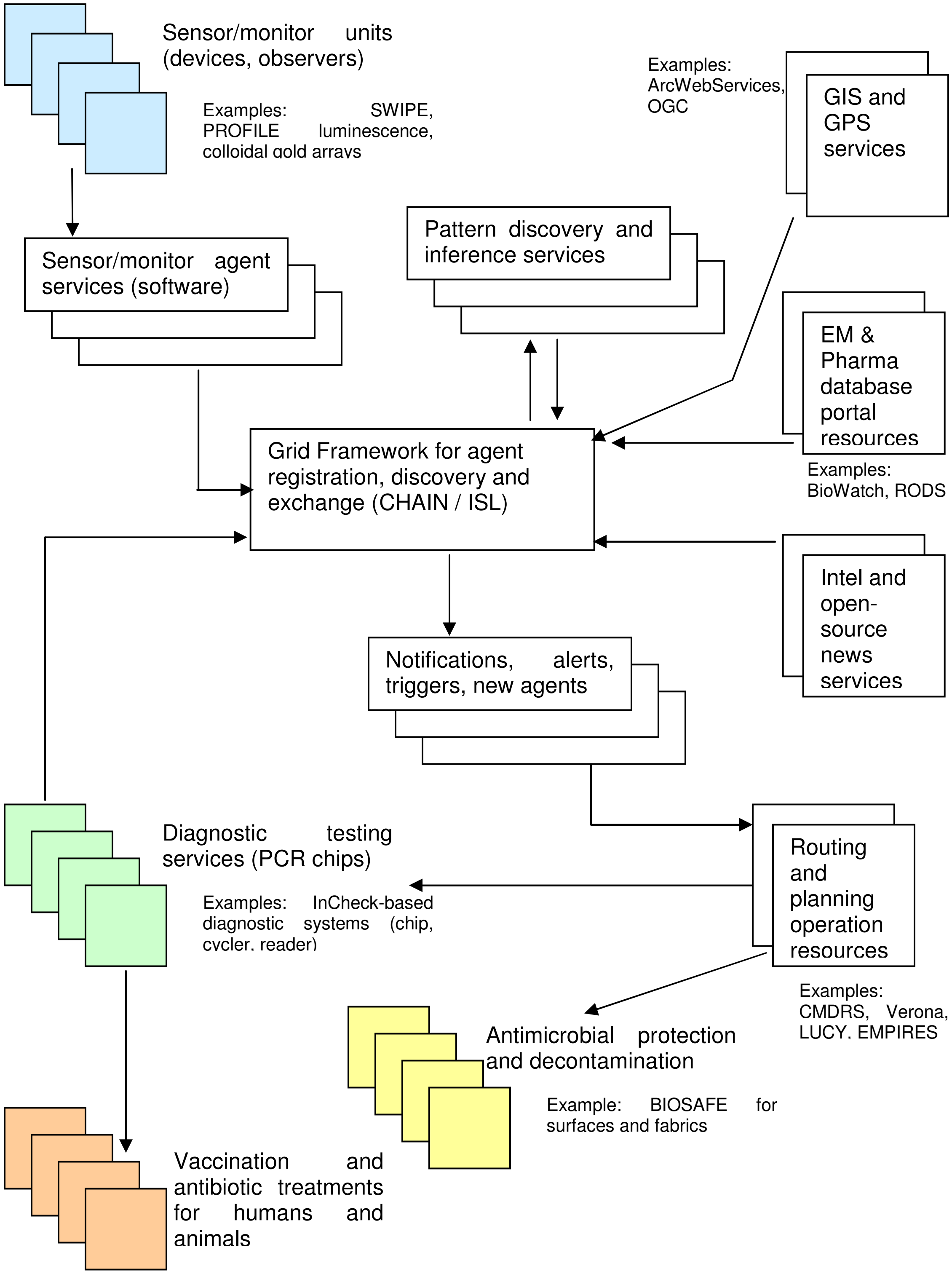

Figure 1 – Basic CUBIT system architecture

Figure 2 – Rendition of One Possible Instantiation of CUBIT System Components

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