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Food and Agriculture Systems Contamination Modeling and Simulation

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Outline

- Research questions
- Research approach & methods
- Results
- Implications
- Future work & partnering with industry

Contamination is vast, complex, and dynamic

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- **How can contamination events be prevented?**
- **If they cannot be prevented, how can we reduce the consequences of contamination events?**
- **How can contamination risk be mitigated cost effectively?**

Risk Characterization

- Food system attributes that contribute to risk
  - Historical Precedent
  - Speed of Distribution & Consumption
  - Contaminant Survives Processing & Distribution
  - Distribution Favors Broad Dissemination
  - Imported Ingredients
  - Employment Practices Facilitate Access
  - Potential for High-Magnitude Human Consequences
  - Vulnerability of Transportation Modes
  - Contaminant Detection Unlikely
- Contaminant attributes that contribute to risk
  - Lethality
  - Ease of Production
  - Pertinent Properties
  - Political or Fear Factor
  - Time to Symptoms
  - Historical Precedent

Food System Model Research Questions

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- **Where in the food system must agents be introduced to harm the consumer?**
- **Will contaminants make it to the consumer in a sufficient harmful dose?**
- **Do we have to be concerned about all harmful agents?**
- **Which agents should we be most concerned about?**

Food System Model (a.k.a. Bloodhound)

- Detailed system characterization
- Internal facility processes
- Includes amplification & kill steps
- Includes volume and/or mass
- Transportation
- Seeding the food system with agents
- Prediction of adverse health effects

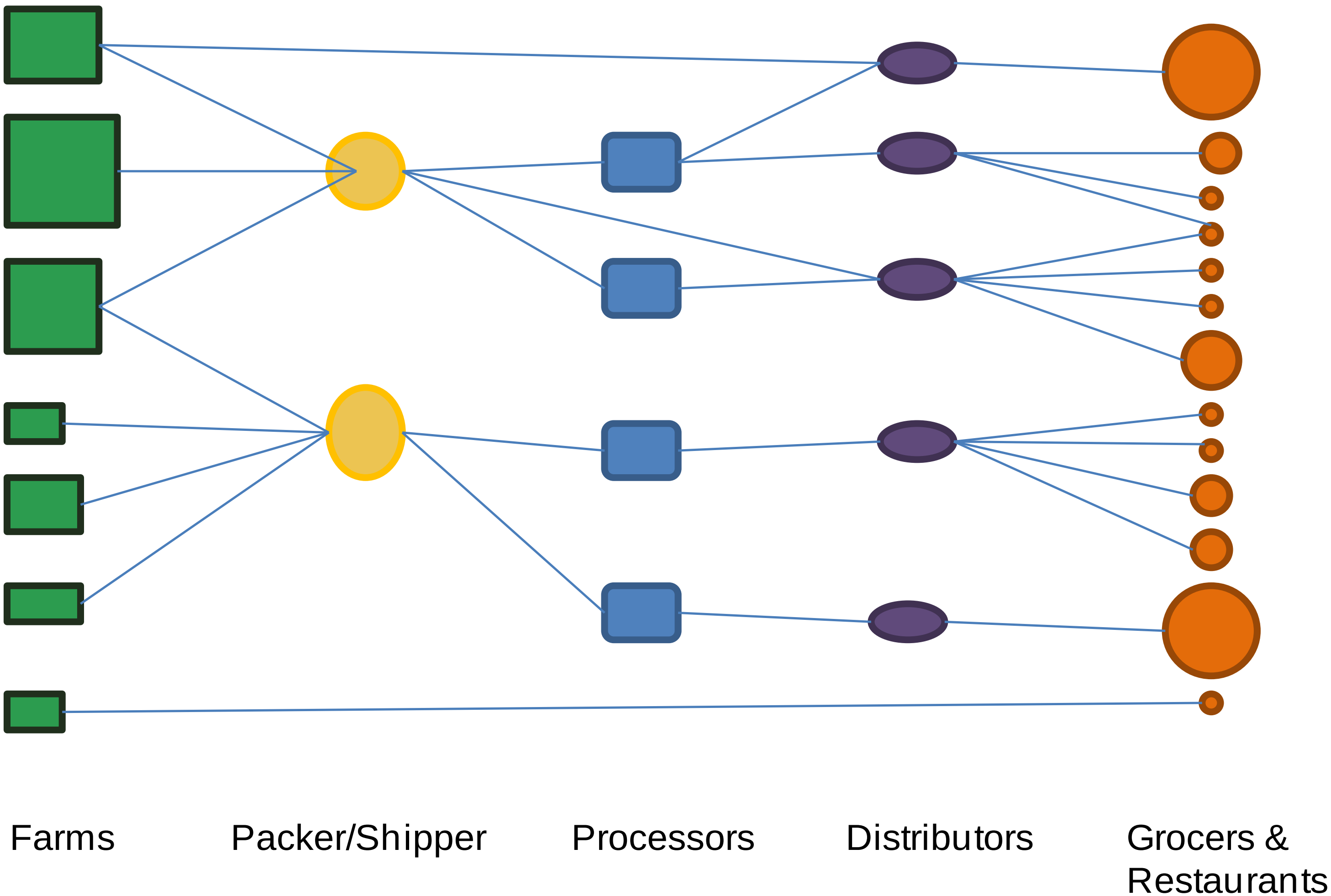
Developing Bloodhound

- There is no textbook describing the characteristics of food marketing networks. Luckily, abundant tacit knowledge about these systems exists within industry and academia.
- For a specific agricultural sector, we define:
  - the nodes
  - the rules that describe the operational behavior of each node
  - the rules that describe the interaction between nodes (links)
  - the probabilities of interactions
- Incomplete data represent a significant source of uncertainty in creating the network topologies
- Monte Carlo analysis is used to explicitly incorporate uncertainties
- Stochastic network maps are used to display and analyze the results of simulations

Bloodhound Modeling Assumptions

- Companies use First In / First Out (FIFO) policies
- No product is thrown out or removed from the supply chain
- All points in the supply chain are vulnerable to attack
- All servings make it to the consumers

Harnessing Complexity: Bloodhound Data Points



Test Case: Feeding the Sprout Model

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Three complementary approaches to information gathering:

- Review of open sources to identify produce business models to identify information on network characteristics

- Analysis of food, transportation, economic, and business databases for additional information on network topology (e.g., Red Book Credit Services, Sprout Association, data directly obtained from industry)

- Interviews with food service providers and growers to validate conceptual model assumptions and to identify additional data sources

The Topological Map

- Where data are changing too quickly, or are unavailable, there will be uncertainties, reflected in the Monte Carlo analysis.
- A probabilistic representation shows the possible pathways from the producer to the consumer.
- Using the probability map produced by the model results, we should be able to see temporally and geospatially where:
  1. products definitely went
  2. where they definitely did not go
  3. where they might have gone and the likelihood of each pathway
  4. where additional data collection is warranted.

Bloodhound Metrics

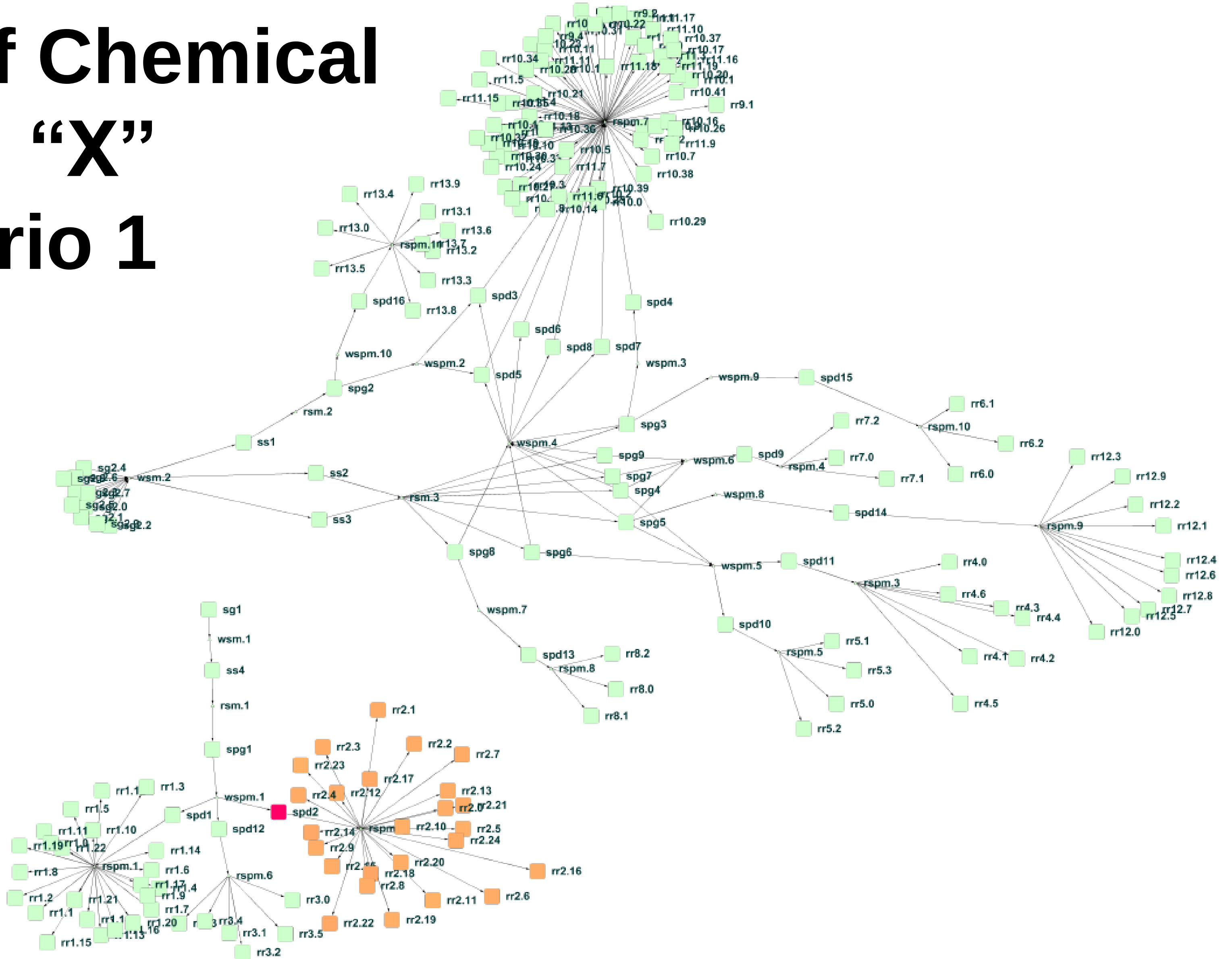
- Incorporates batch sizes & seeding
- Measures contaminant flow through facilities and across the food system
- Measures the LC/LD/ID at the point in the system where the food is consumed

Chemical Seed Examples

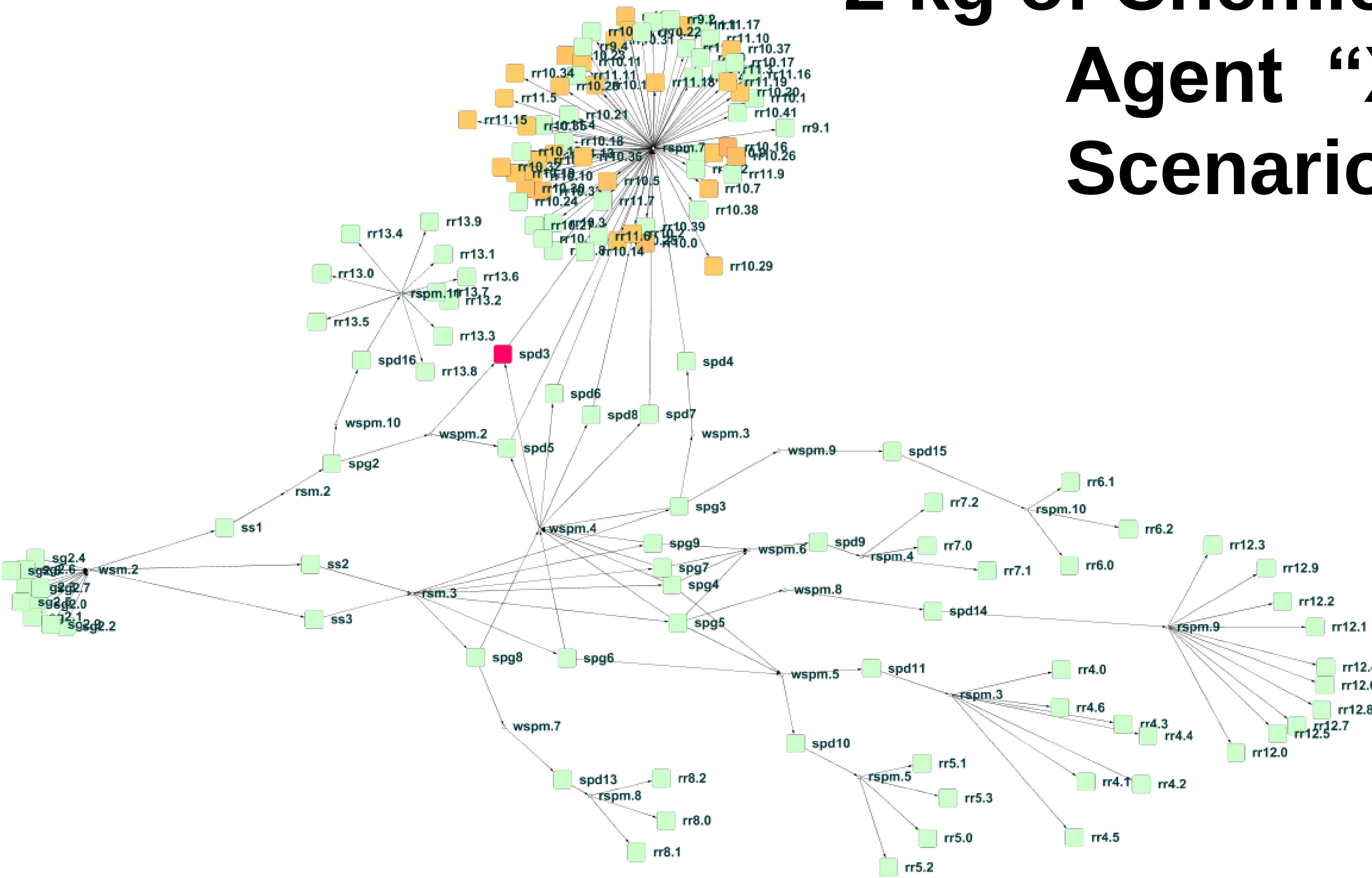
Chemical	IC 50x (mM)	Oral Rat or Mouse LD50 (mmol/kg)	Oral Rat or Mouse LD50 (mg/kg)	Infant LD50 10 (mg/kg)	Child LD50 30 (mg/kg)	Teen LD50 50 (mg/kg)	Adult LD50 70 (mg/kg)
2,3,7,8-Tetrachlorodibenzo-p-dioxin	0.0002	0.00035	0.1	1	3	5	7
Mercury II chloride	0.015	0.0037	1.0	10	30	50	70
Triethylene melamine	0.00078	0.005	1.0	10	30	50	70
Busulphan	0.046	0.0076	1.9	19	57	95	133
Cycloheximide	0.00059	0.0071	2.0	20	60	100	140
Disulfoton	0.11	0.0073	2.0	20	60	100	140
Parathion	0.093	0.0069	2.0	20	60	100	140
Disulfoton	0.000012	0.0068	3.0	30	90	150	210
Phenylthiourea	0.54	0.02	3.0	30	90	150	210
Epinephrine bitartrate	0.028	0.012	4.0	40	120	200	280
Aflatoxin B1	0.034	0.016	5.0	50	150	250	350
Triethyltin chloride	0.00046	0.021	5.1	51	153	255	357
Colchicine	0.000054	0.015	6.0	60	180	300	420
Actinomycin D	0.0000081	0.0057	7.2	72	216	360	504
Potassium cyanide	1.12	0.15	9.8	98	294	490	686
Nitrogen mustard * HCl	0.0026	0.052	10.0	100	300	500	700

Results: SW Sprout Supply Chain

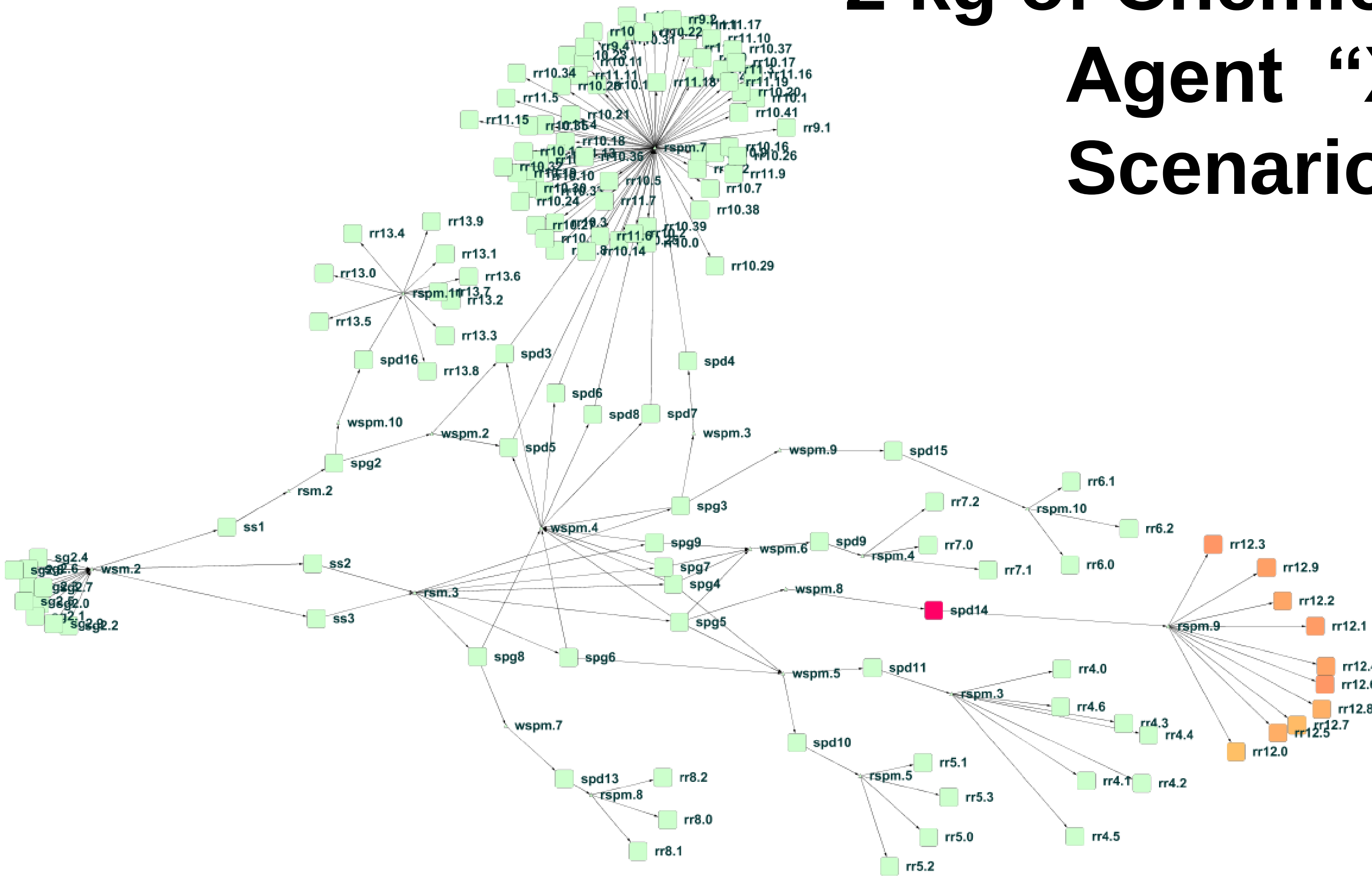
2 kg of Chemical Agent "X" Scenario 1



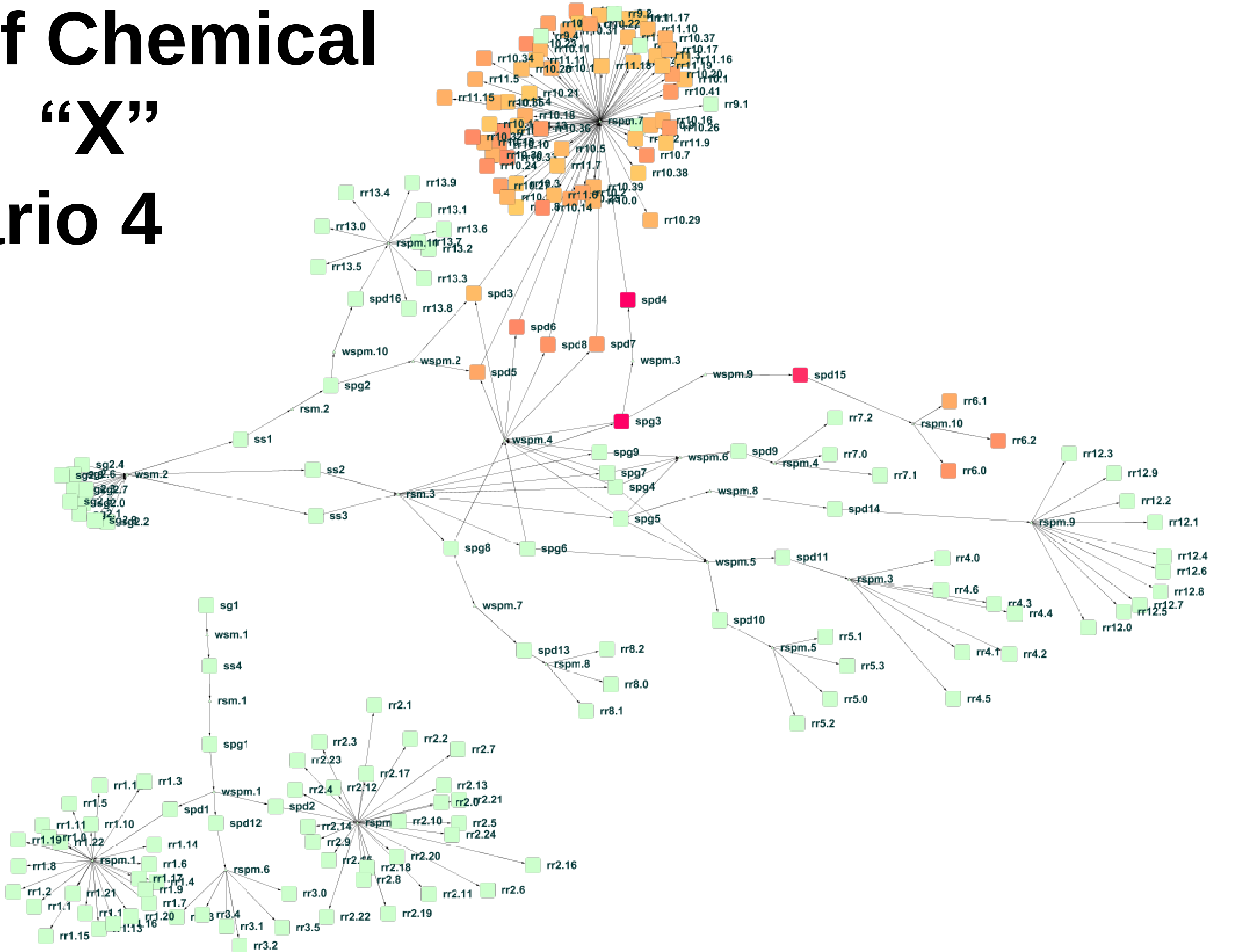
2 kg of Chemical Agent “X” Scenario 2



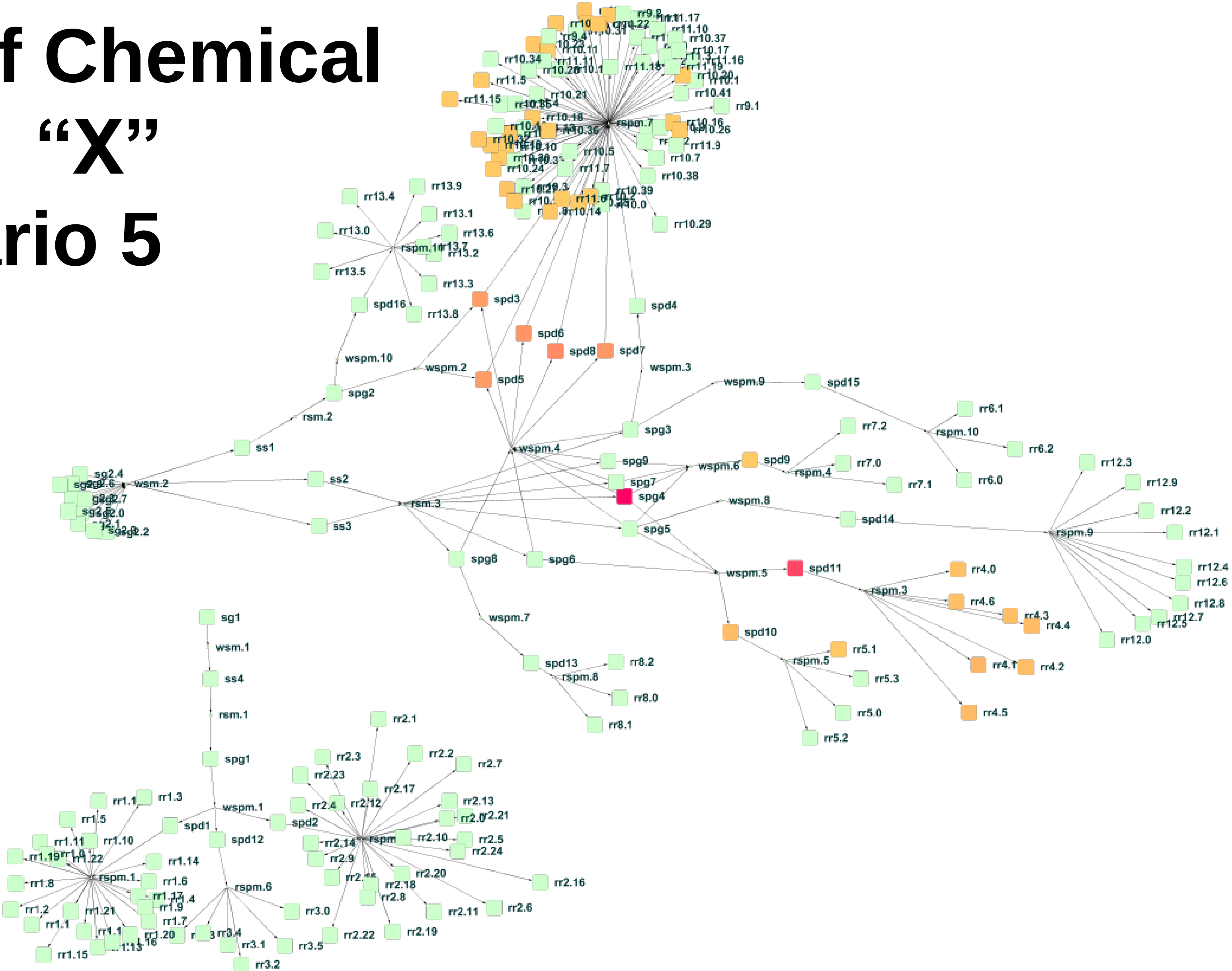
2 kg of Chemical Agent "X" Scenario 3

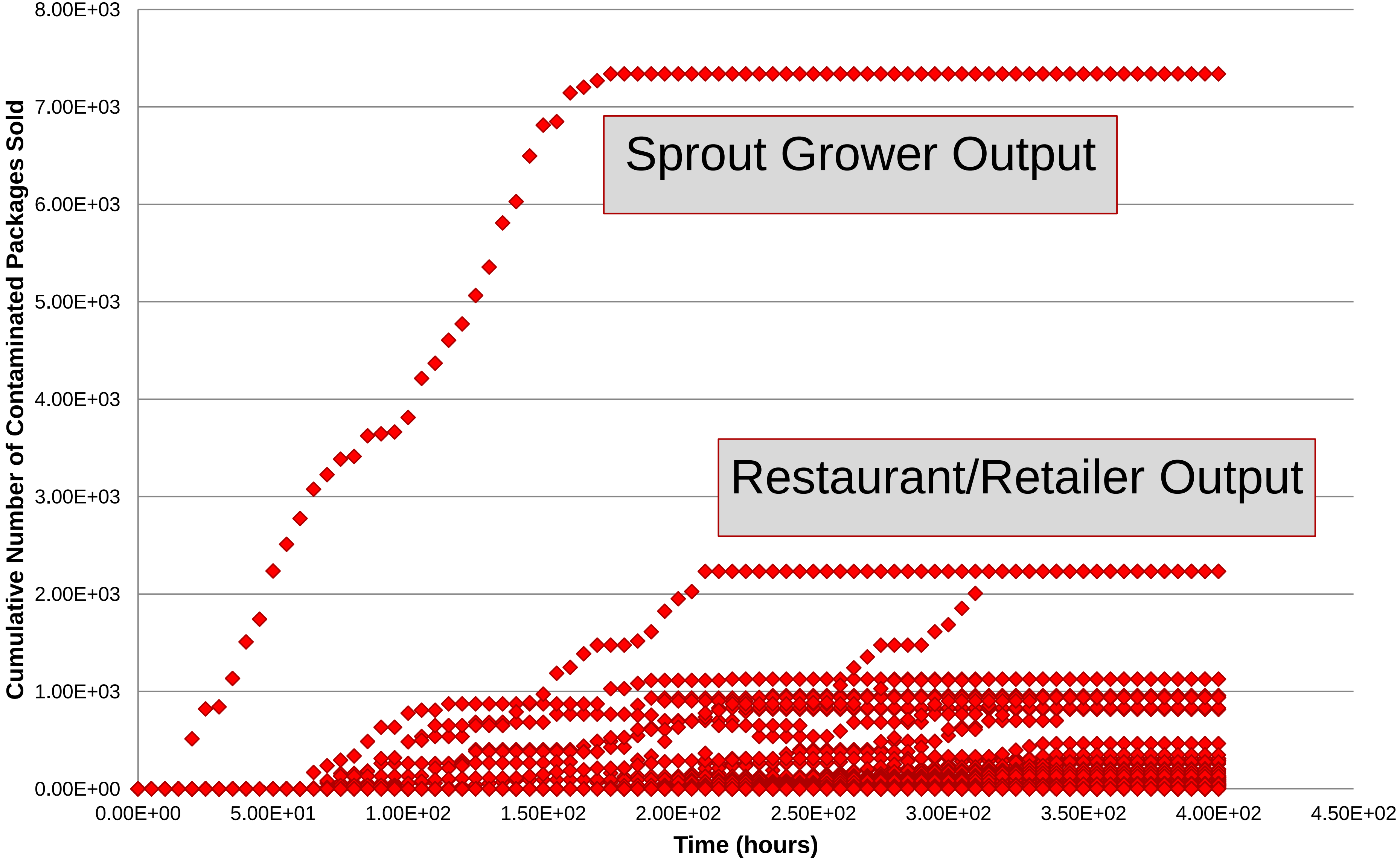


2 kg of Chemical Agent "X" Scenario 4



2 kg of Chemical Agent "X" Scenario 5




Cumulative Number of Contaminated Packages Sold
8.00E+03
7.00E+03
6.00E+03
5.00E+03
4.00E+03
3.00E+03
2.00E+03
1.00E+03
0.00E+00
0.00E+00
5.00E+01
1.00E+02
1.50E+02
2.00E+02
2.50E+02
3.00E+02
3.50E+02
4.00E+02
4.50E+02
Time (hours)
Sprout Grower Output
Restaurant/Retailer Output

Further Refinement of Agents: Taste, Flavor, & Olfaction

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Chemical	Flavor (Yes/No)	Taste Notes	Olfaction	Color	Absorption
2,3,7,8-Tetrachlorodibenzo-p-dioxin	Yes	Manure	Manure - Silicon/Plastic	colorless	?
Mercury II chloride	?	earthy, styptic, metallic taste	?	colorless or white solid	highly soluble
Triethylene melamine	?	?	?	white crystals	soluble
Busulphan	Yes	rotten / boiled eggs	?	white crystals	?
Cycloheximide	No	tasteless	none	white crystals	?
Disulfoton	Yes	unidentifiable unique	odorless	colorless	?
Parathion	?	?	rotten eggs / garlic	tan color	?
Disulfoton	Yes	sour / possibly unami	v	yellow power	?
Phenylthiourea	Yes	Bitter / tasteless	?	needles	?
Epinephrine bitartrate	Yes	intensely bitter	?	white	?
Aflatoxin B1	No	none	none	blue	?
Triethyltin chloride	Yes	salt/metallic	unpleasant	colorless liquid	not soluble
Colchicine	Yes	garlic aftertaste	odorless	yellow	soluble
Actinomycin D	Yes	salty, bitter, metallic	none	dark red	?
Potassium cyanide	Yes	acrid, burns	musty, old sneaker smell	white	highly soluble
Nitrogen mustard * HCl	Yes	spicy	horseradish, mustard	yellow	soluble
Indomethacin	Yes	spicy	sulfer or garlic	yellow	soluble

Lessons Learned

- Many agents do not pose a significant risk
- Identification of critical points in the system helps to determine where to increase physical security and where to place sensors
- Many of the agents of concern are molecularly similar, broad spectrum testing

Key Findings

- Most contaminants do not make it to the customers in high enough doses to pose human health risks
- Contaminant risk mitigation is most effective, and the least expensive, when a systems-based approach is used

New Bio-Sensors Released! $5 each

Examples: *B. anthracis, S. typhimurium,* and others

Free Assistance: We are here to help!

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- Working with stakeholders and industry to address their needs
- Run simulations on industry's internal facilities or across the system
- Provide detailed information of where in processes and in the system sensors/tests should be placed

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Questions?

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