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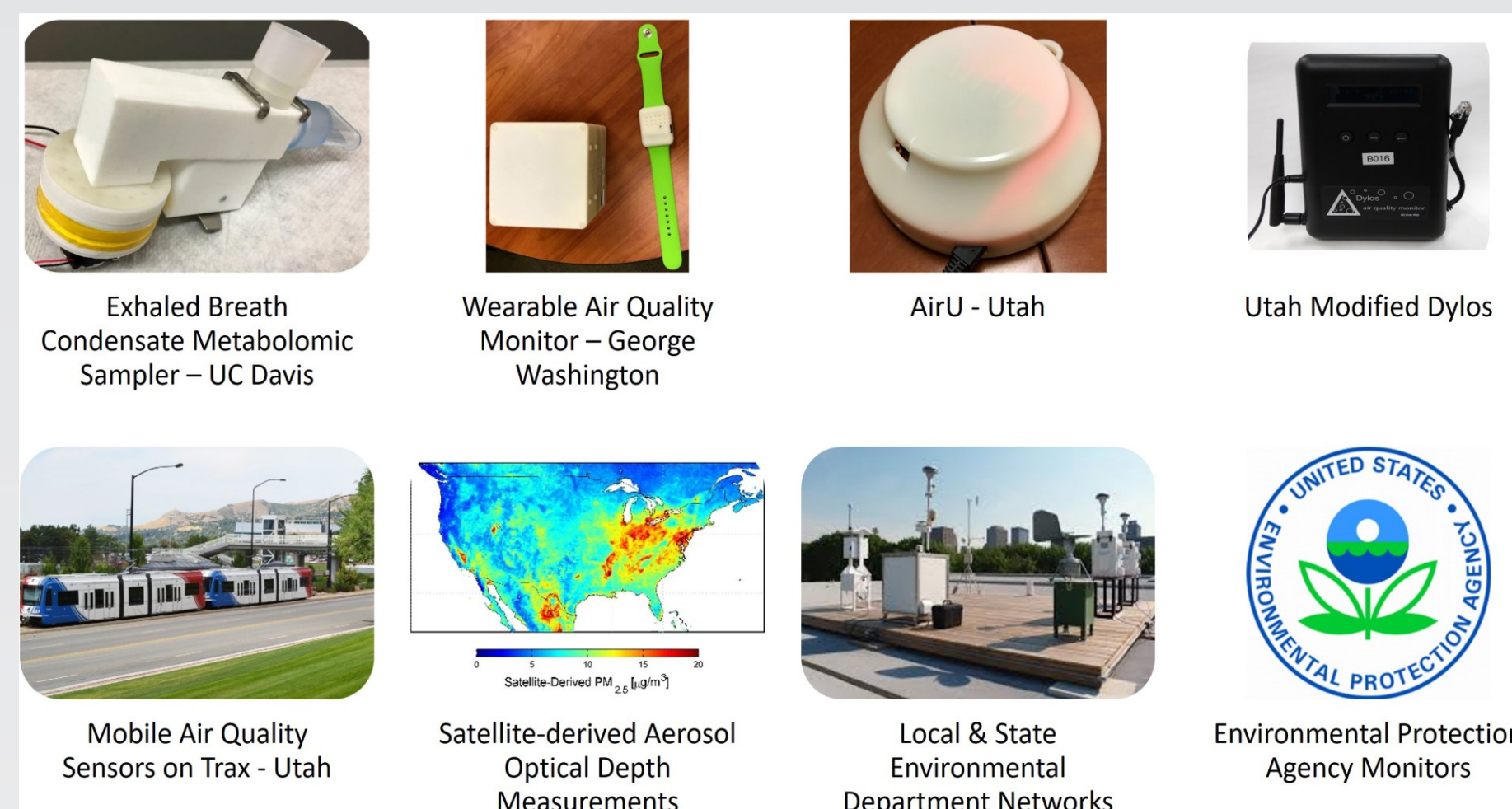
Clinical & Translational Science Institute

Exposure Health Informatics Ecosystem: An Infrastructure for Generating and Utilizing Exposomes for Translational Research

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Biomedical Informatics

Generating Exposomes

- Quantifying effects of the modern environment on health requires taking into account data from environmental exposures (exposome) which can span endogenous processes within the body, biological responses of adaptation to environment, and socio-behavioral factors.
- Exposomic research is translational in nature as the exposome includes direct biological pathway alterations as well as mutagenic and epigenetic mechanisms of environmental influences on the phenome.
- Generating exposomes requires integration of data from wearable and stationary sensors, environmental monitors, physiology, medication use and other clinical data, genomic and other biospecimen-derived, person-reported and computational models.
- This aggregation and integration requires to support variable spatio-temporal resolutions due to differences in study, experimental and analytical designs.
- Gaps in measured data may need to be filled with modeled data along with characterization of uncertainties.

Exposure Health Informatics Ecosystem[1]

- We are developing a scalable computation infrastructure, the Exposure Health Informatics Ecosystem[1] (EHIE) to address these needs.
- EHIE is a comprehensive, standards-based, open-source informatics platform that provides semantically consistent, metadata-driven, event-based management of exposomic data.
- Using an event-driven architecture allows the modeling and storage of activities related to the study and its operations in primitive form as events on a timeline, which can be transformed to higher/analytical models based on use-cases.
- It is aligned with the goals of modern *total environmental health* research by supporting meaningful integration of sensor and biomedical data.

Exposure Health Informatics Ecosystem

Data Acquisition Pipeline | Participant Facing Tools | Computational Modeling & Uncertainty Characterization | Central Big Data Integration Platform | Researcher Facing Platforms

Exhaled Breath Condensate Metabolomic Sampler – UC Davis
Wearable Air Quality Monitor – George Washington
AirU - Utah
Utah Modified Dylos
Mobile Air Quality Sensors on Trax - Utah
Satellite-derived Aerosol Optical Depth Measurements
Local & State Environmental Department Networks
Environmental Protection Agency Monitors

Hardware and software tools, wireless networking, and protocols to support easy system deployment, robust sensor data collection, and feedback to study participants[2]. Data acquisition occurs either through a central gateway or directly from the sensors. Data acquisition is sensor platform agnostic and greatly simplified due to a generalized metadata framework.

Tools and processes for researchers undertaking exposomic studies for a variety of experimental designs and for clinical care. Real-time data visualization tools can help researchers understand events as they occur.

Collect and annotate patient reported and activity data, as well as inform participants on their clinical and environmental status. Information feedback loops can be formed with participants through real-time survey assessments (EMA) triggered by sensor activity. Visualization tools can assist in managing conditions and provide a simple mechanism for facilitating interventions.

REDCap
- Generic HIPAA-compliant online platform for surveys and research data collection

eAsthmaTracker
- Integrated asthma patient self-management, education and clinician communication platform with alerts.
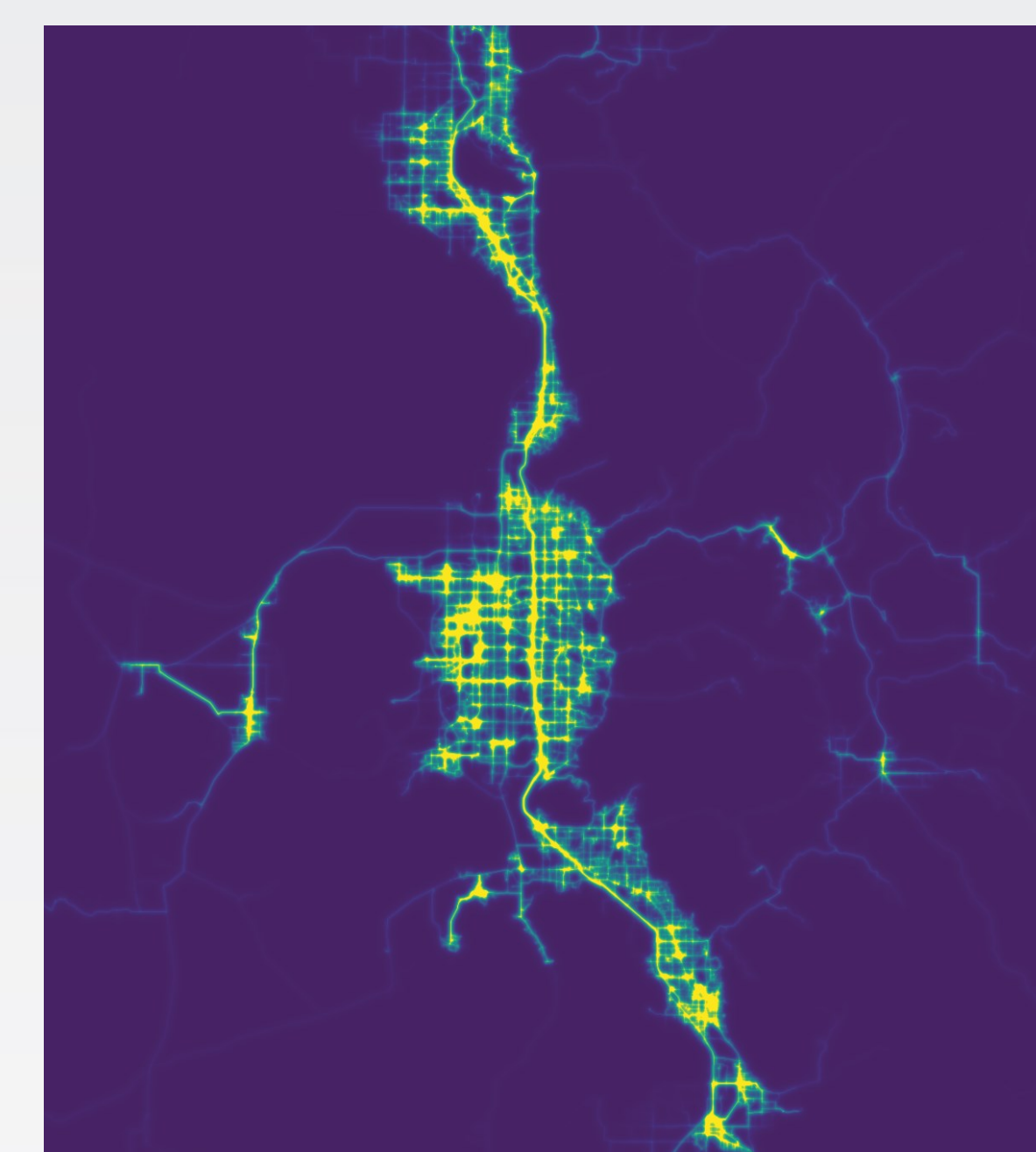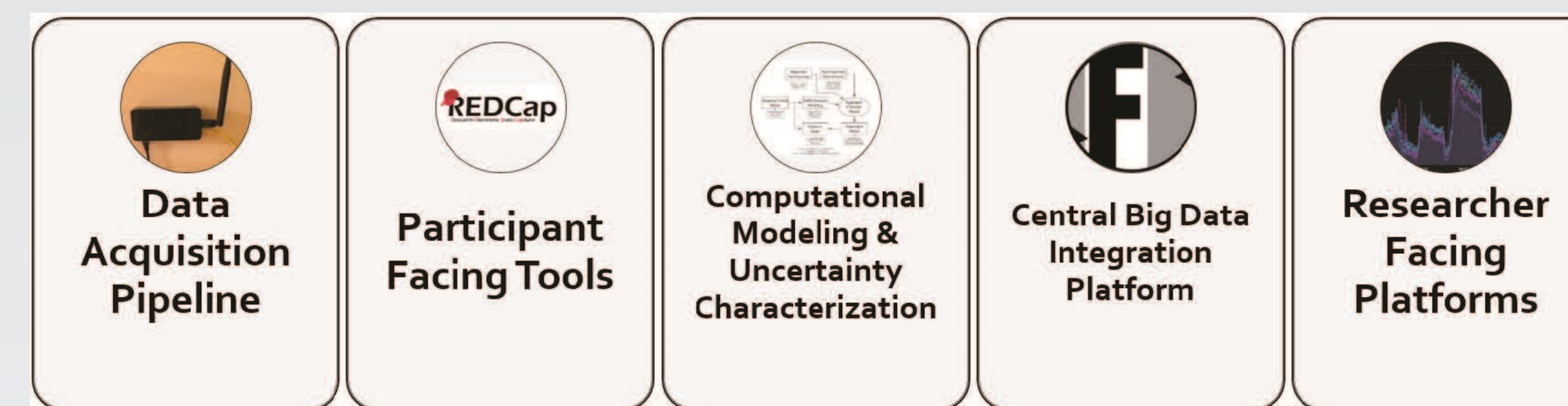
Activity Annotator
- Tool for research participants to annotate sensor events.

Ecological Momentary Assessments
- Capture participants' current behaviors and experiences in real time, in subjects' natural environments.

High resolution spatio-temporal modelling can be used to infer environmental states that are unable to be measured directly, informing researchers about potential confounders or uncertainty in their measurements. When combined with EPA and mobile sensing, population level assessments can be performed that would otherwise be impossible.
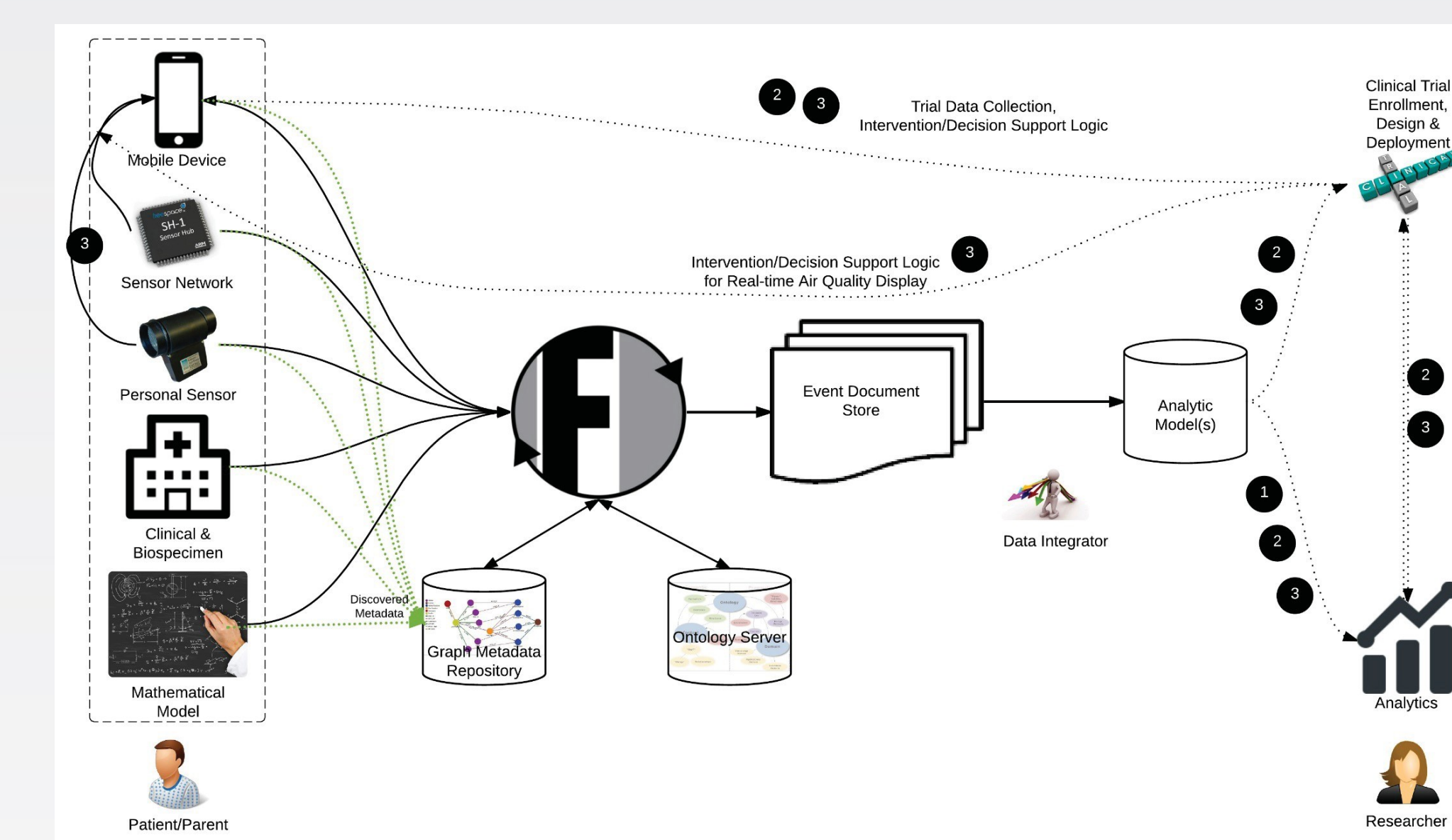
Left: Modelled travel activity in the Wasatch Front, 100 m resolution density estimate, 15 minute time slice

Standards-based, central big data federation & integration platform: open-access infrastructure that integrates measured and computationally modeled data with biomedical information along with characterizing uncertainties associated with using these data[3].

Utilizing Exposomes in Translational Research Studies[4]

- Feasible approach for longitudinal cohort studies.
- Indoor & outdoor sensors captured time stamped PM counts every minute.
  - PRISMS – 10,228,569 sensor readings over 18 months (7 homes)
  - ECHO – 4,358,194 sensor readings over 2 months (28 homes)
- Most participants were supportive of using their personal Wi-Fi for sensor data transmission.
- Need for flexible data transmission and storage methods.

- Preliminary Analysis: (PRISMS cohort, 12 months of data, sensor readings aggregated to daily). Mixed modeling:
  - Daily PM2.5 and PM10 PM counts were lower indoors than outdoors ($p<0.001$).
  - Indoor PM counts were not related to ACT scores/rescue medication usage ($p>0.05$).
  - Outdoor PM2.5 WAS related to worsened ACT scores/ increases in asthma treatment ($p<0.001$)
  - But outdoor PM10 counts were not related ($p=0.52$)

- EHIE is a generalizable multi-scale and multi-omics platform providing robust pipelines for reproducible exposomic research using real-time, low-cost air quality sensors to provide spatio-temporal records of particulate matter exposures.
- ECHO and PRISMS pilot studies demonstrate participant acceptance of personal and Internet-of-Things sensor monitoring; and integration of sensor and clinical/patient data to generate and utilize exposure profiles.

[1] Gouripeddi R, Lundrigan P, Kasera SK, Cummins MR, Collingwood SC, Facelli JC, Sward K. Exposure Health Informatics Ecosystem. In: Phillips KA, Yamamoto DP, Racz L, editors. Total Exposure Health: An Introduction [Internet]. CRC Press; 2020., [2] Min, K, Lundrigan P, Patwari N, Sward K, & Collingwood S, Smart home air filtering system: A randomized controlled trial for performance evaluation, 3rd IEEE / ACM Conference on Connected Health: Applications, Systems, and Engineering (CHASE 2018), Washington D.C., [3] Gouripeddi R, et al. FURTHeR: An Infrastructure for Clinical, Translational and Comparative Effectiveness Research, 2013 American Medical Informatics Association Annual Symposium, Washington DC, USA, (2013), [4] Collingwood S, Gouripeddi R, Wong B, Sward K, Environmental influences on health outcomes—integrating real-time exposure measures from homes into longitudinal cohort studies: Lessons from the field. The Joint Annual Meeting of the International Society of Exposure Science and the International Society for Environmental Epidemiology (ISES-ISEE 2018), Ottawa, Canada. **Contact:** Ram Gouripeddi (Ram.Gouripeddi@utah.edu)