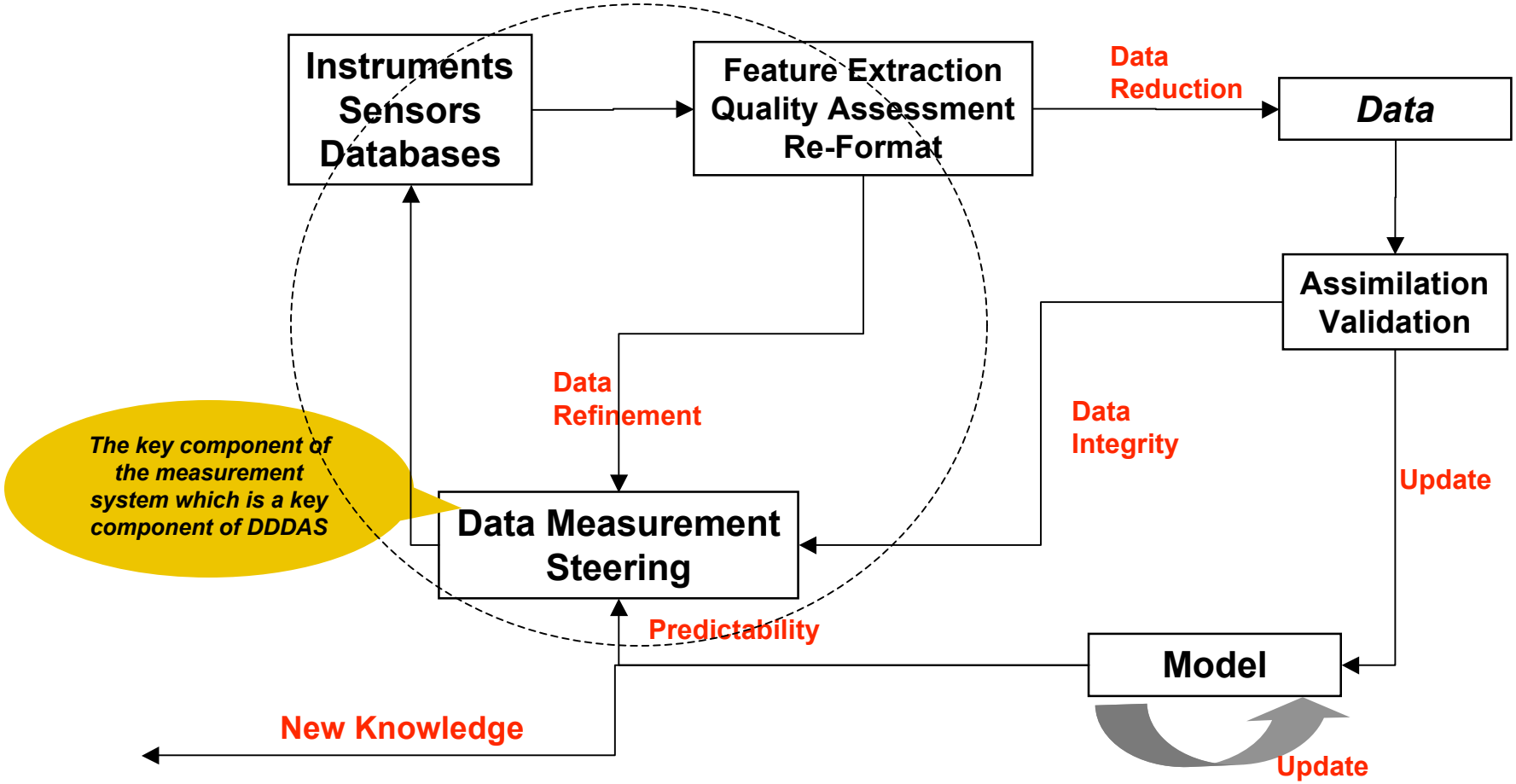
Measurement Systems

Kim Baldridge and Jonathan How
+ ~10 others

Measurement system within DDDAS Framework



- **Application / system software / algorithms impact all aspects of this process**
- **Issue: Need to be able to accurately predict the value of the measurements to perform the measurement redeployment**

Data Measurement Redeployment

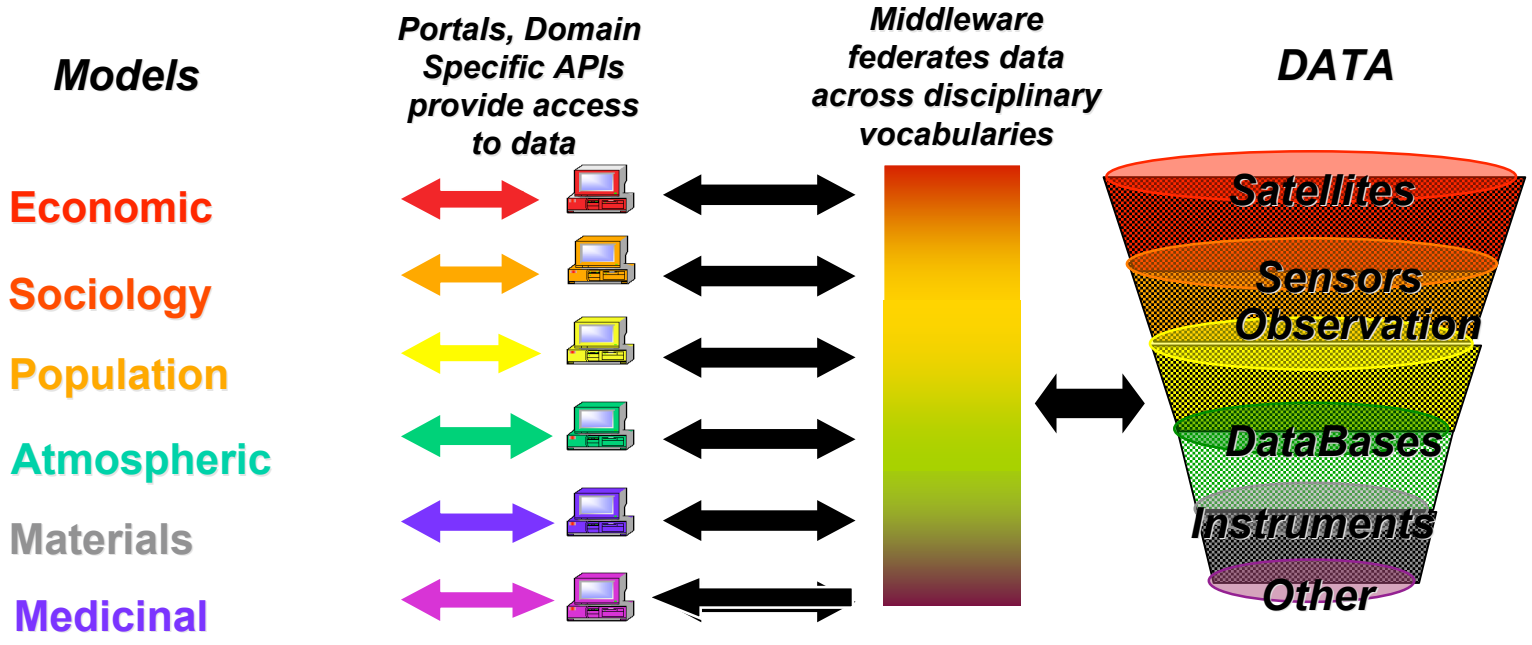
- Process depends on sensor types available and the application
- Different types of sensor selection choices
- **Static**: e.g., change sensor properties
  - Examples:
    - Many distributed structural sensors
- **Mobile**: e.g., change where measurements are taken and on what length/ time-scales
  - Mobile sensor networks (communication): UAVs, UUVs, Bouys
  - Distributed on-demand measurements, information consensus
    - Self-organizing, redeployment
  - Examples:
    - Aircraft flight plans loosely coupled to weather modeling → tighter coupling
    - River environmental sensing (passive deployment) → active deployment
- **Adaptive**: e.g., change what types of measurements are taken
  - Focus analysis of a camera image to different regions
  - Adaptive optics
  - Examples:
    - Real time 2D MRI slice → 3D
    - Fixed frequency spectrometers → different frequency ranges
    - Fixed grid → Adaptive grid (B. Plale)
  - When/where/which sensors to adapt
    - Adapt to what and at what price?

Redeployment Issues

- When data is collected, to sense or not to sense, what to sense?
  - How will we use the models/data to make these decisions?
- For some applications, it is not obvious what to measure
  - Can be a very indirect process for some complex systems (biological)
  - Need a good model of what the sensor does and how it interacts with the system to assess the value of the measurement → can we even write $y=h(x,t)$?
  - How can we use the data to directly improve this process.
  - What algorithms are used? (nonlinear estimation)
- For what reason – what is the objective / goal of the sensing?
  - To obtain new knowledge, for closed-loop control, to improve the model quality, to reduce the uncertainty in the loop, or to improve the system observability
    - Optimization
  - What are the cost/benefit of deployments - Use of finite resources (battery) - QOS of the sensor network (high BW over short periods or low BW over long periods)
- When - How dynamic is the system?
- Where to measure?
  - Measurement allocation process – analyze the utility of moving sensors to specific locations
  - Danger (e.g., Fire tracking)
  - Cost – retrievable? (e.g., Ocean)
- How to measure - Feedback to enhance the robustness of the measurement process
- How automate this process?
  - Can we prove that the process is stable and/or show that it is improving the model?

Issues 2: Limiting/Enabling Factors

- *Cost of measuring system*
  - *Cost of device/static vs mobile*
- *Power*
  - *e.g., battery life; reliability in extreme conditions; bandwidth of data collection limitations*
- *Uniformity of Interface to measurement process*
  - *protocols; standards*



Issues 2: Limiting/Enabling Factors

- Interdisciplinary nature from theory to expt - education/training need for more specialized education opportunities at the interface of disciplines
- Improvements in measurement systems:
  - Power, e.g., battery life; reliability in extreme conditions
    - collection bandwidth
  - Design/robustness of expt systems
- Improvements in means/methods of collecting data
  - Focus in regions of relevancy
  - Controlling sampling
- Assess the validity of data
  - Error bars; time stamps; quantification of uncertainty
  - Uniformity of data across instruments/sensors of the same type.
  - Sensitivity/quality of same data as measured across different types of instruments/sensors/databases
  - Failure indicators
  - Capacity to collect; percentage of noise

Issues 2: Limiting/Enabling Factors

- 'Features' in data
  - When to include data as 'rare' events (for training) and
  - when to assume it is a fault of the measuring device
  - How to recover from 'feature' events

- Decision as part of the measurement system:
    - New component offered by DDDAS
    - Feedback loop is the decision/prediction of what data is needed to improve model
  - Need for more data
  - Where to collect
  - Error correction
  - Quantification of uncertainty
  - Quality decision as a function of application type
    - fast/cheap/lower quality
    - slow/expensive/higher quality