THE OHIO STATE UNIVERSITY

Progress in the Development of the Simulation Toolset for Adaptive Remote Sensing (STARS)

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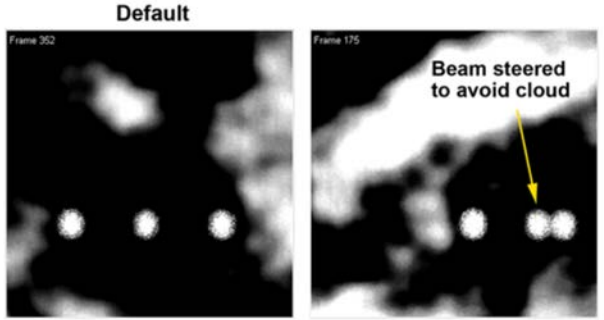
ESTO
Earth Science Technology Office

Motivation

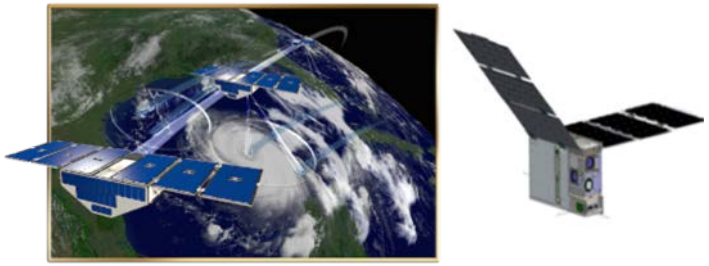
- Future satellite sensing missions will most likely include
  - Adaptive sensors
  - Collaborating constellations
  - Resource constraints
- Next generation modeling and simulation tools are needed
- Therefore AIST funded the Simulation Toolset for Adaptive Remote Sensing



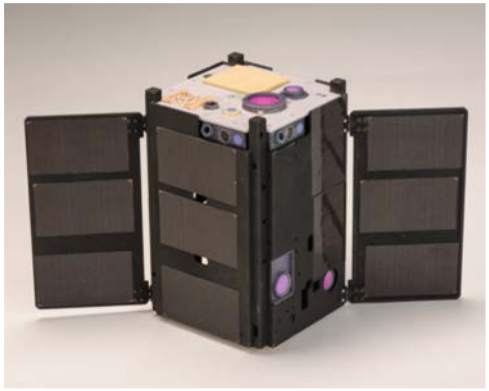
3 beam cloud avoidance demonstration showing default position of beams.

Beams are deflected to closest cloud-free position from their default position.

Ball Aerospace adaptive lidar system steering beams to avoid clouds



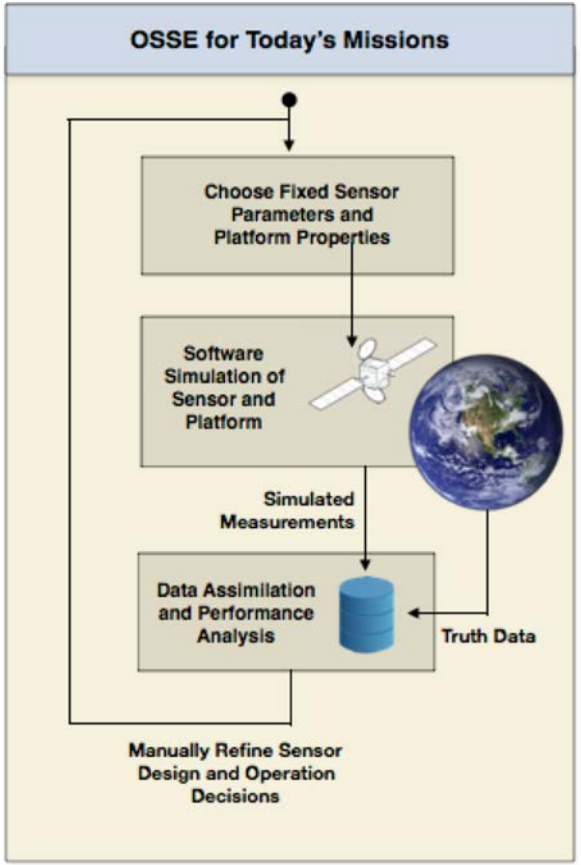
CYGNSS & CubeRRT small sat missions have started to highlight resource constraint challenge for future missions



The Optical Communications and Sensor Demonstration CubeSats will demo high speed links an small sat collaboration

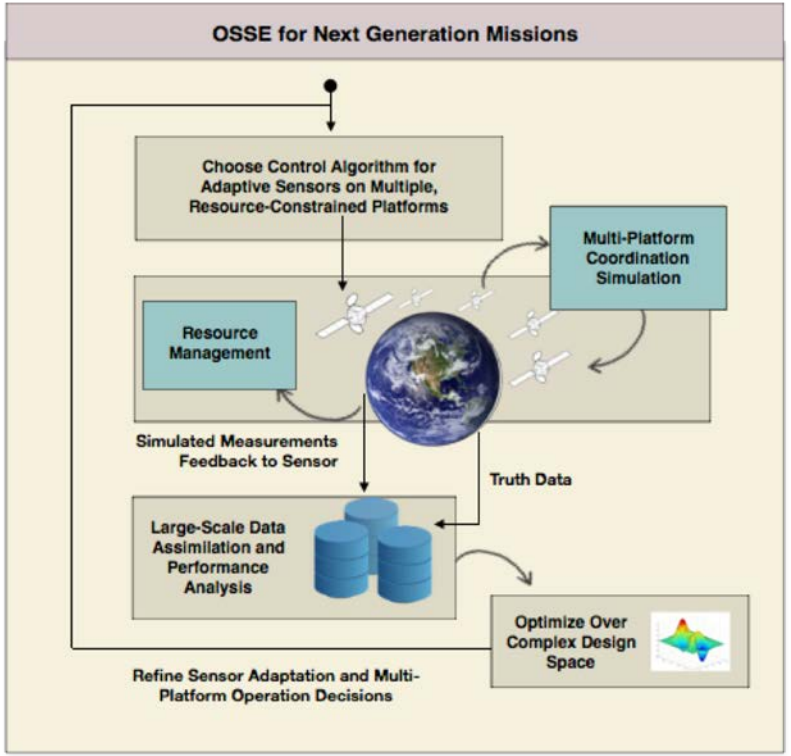
Current OSSE

- Observing System Simulation Experiments (OSSEs) are key tools in the design of Earth Science remote sensing missions
  - Begin with simulated Earth environment and geophysical properties of interest
  - Simulate sensor observations of moving platform, including sensor errors
  - Simulated data used in retrieval processing and retrieved geophysical information compared to original “truth”
  - Results used to optimize sensor or retrieval tools
- Existing OSSEs developed for traditional sensors that operate with fixed sensing parameters



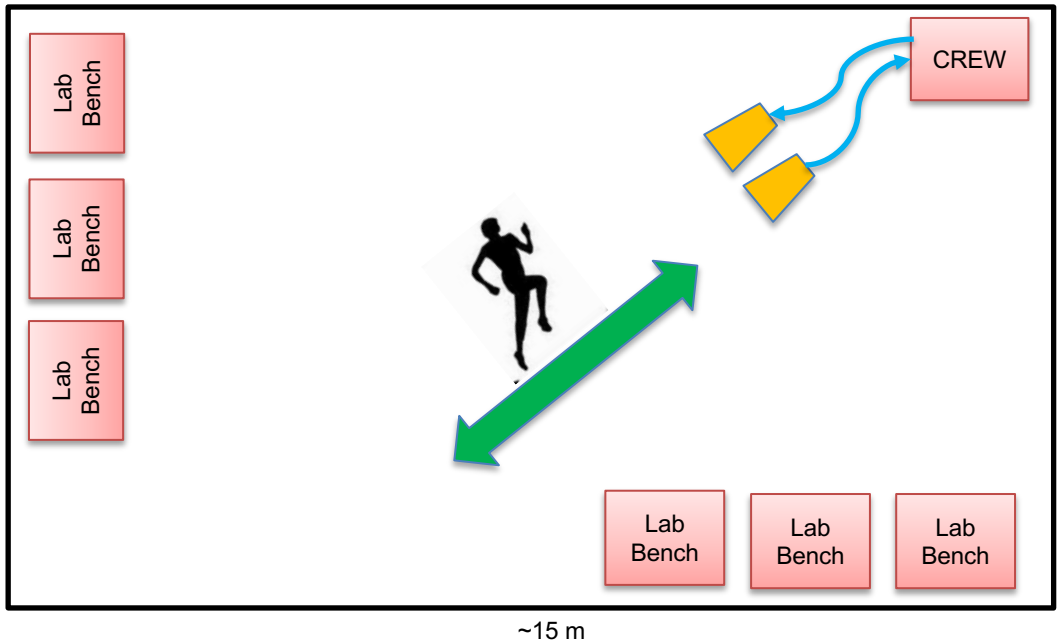
Concept For Future OSSE

- Emerging adaptive sensors not easy to simulate in existing OSSEs
  - Sensors may vary parameters in response to scene observed
  - On board processors may select datasets to record in response to science ‘value’ of a measurement given platform resource constraints
  - Sensor constellations may collaborate to maximize science value
- Must incorporate principled methods for managing these capabilities
- OSSE tool for adaptive sensors could be used to assess and to plan algorithms to control adaptive sensor behavior
- Crucial to incorporate appropriate sensor error models so that adaptation and its effects are captured effectively



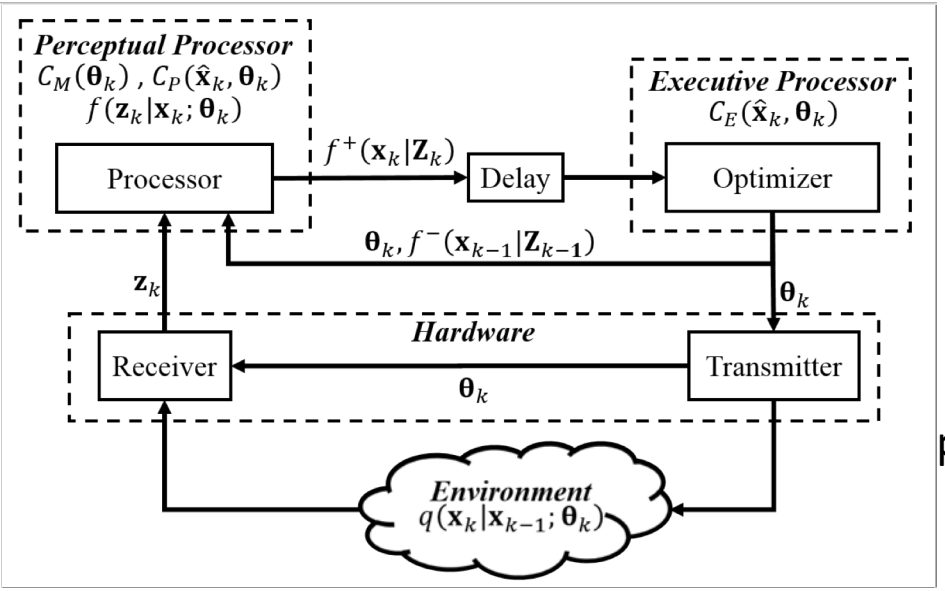
Proof Of Concept (1)

- Single target tracking using fully adaptive radar framework
- Conducted at The Ohio State University using the CREW
- Have full simulation to support experiments



Proof of Concept (2)

- Created a general purpose fully adaptive radar framework
  - Instantiate for task
  - Implement for specific methods
  - Can be used for any sensor
  - Weight measurement cost against information gain



$$\boldsymbol{\theta}_k = \underset{\boldsymbol{\theta}}{\operatorname{argmin}} C_M(\boldsymbol{\theta}) \; s.t \begin{cases} \sigma_\rho(\hat{\mathbf{r}}_k, \boldsymbol{\theta}) \le \sigma_\rho^\dagger \\ \sigma_{\dot{\rho}}(\hat{\mathbf{r}}_k, \boldsymbol{\theta}) \le \sigma_{\dot{\rho}}^\dagger, \\ \boldsymbol{\theta} \in \boldsymbol{\Theta} \end{cases}$$

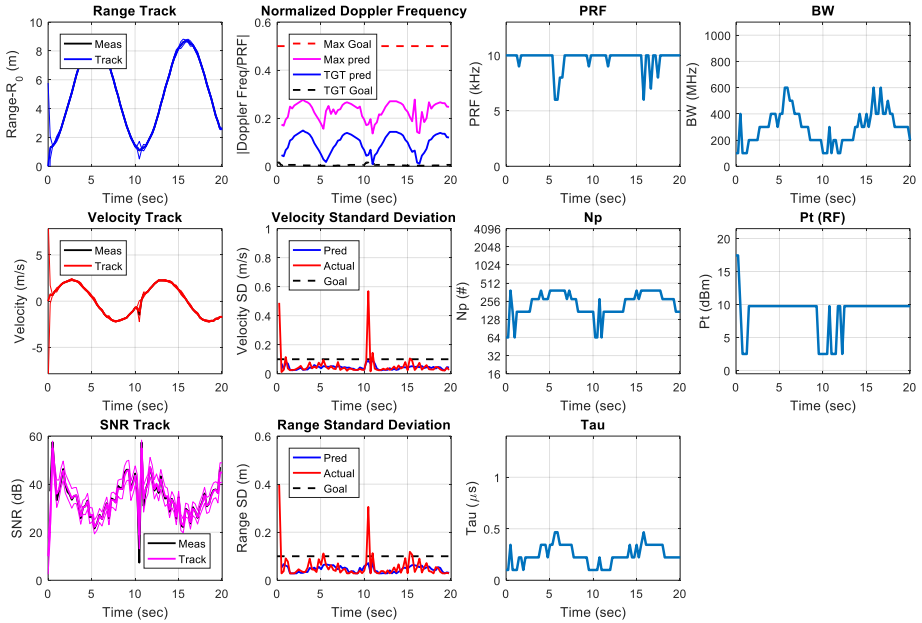
Selected parameters

Measurement cost

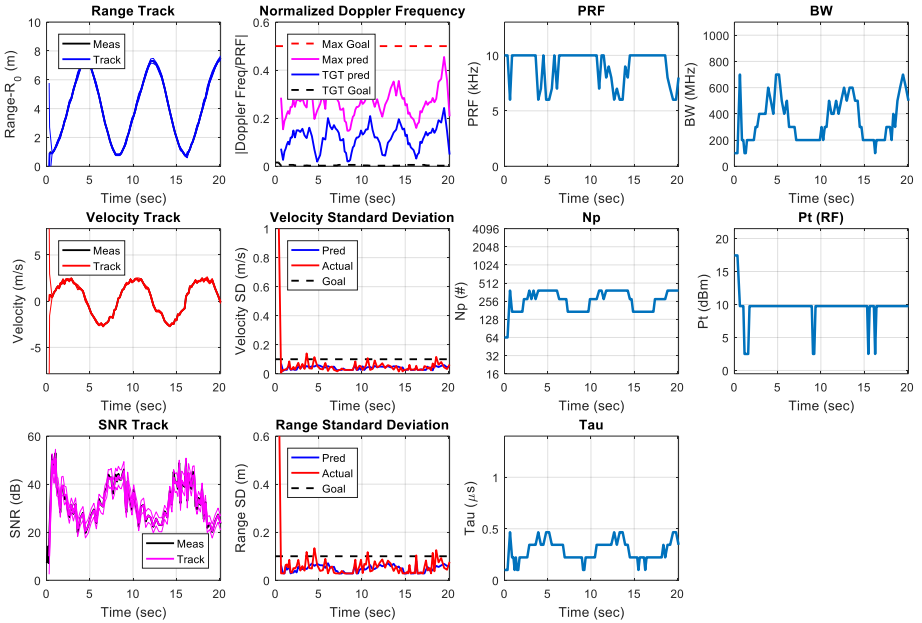
Information gain

Proof Of Concept (3)

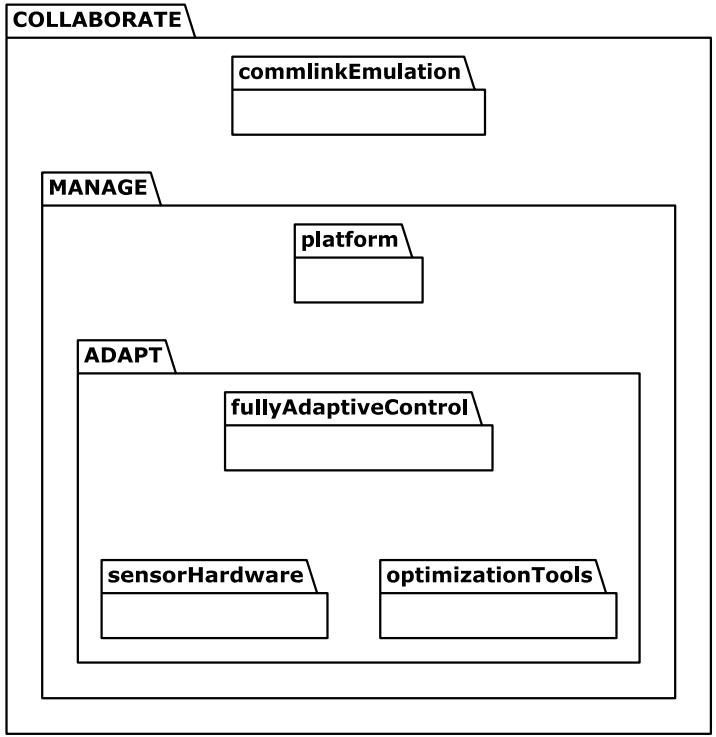
Simulated Results



Experimental Results

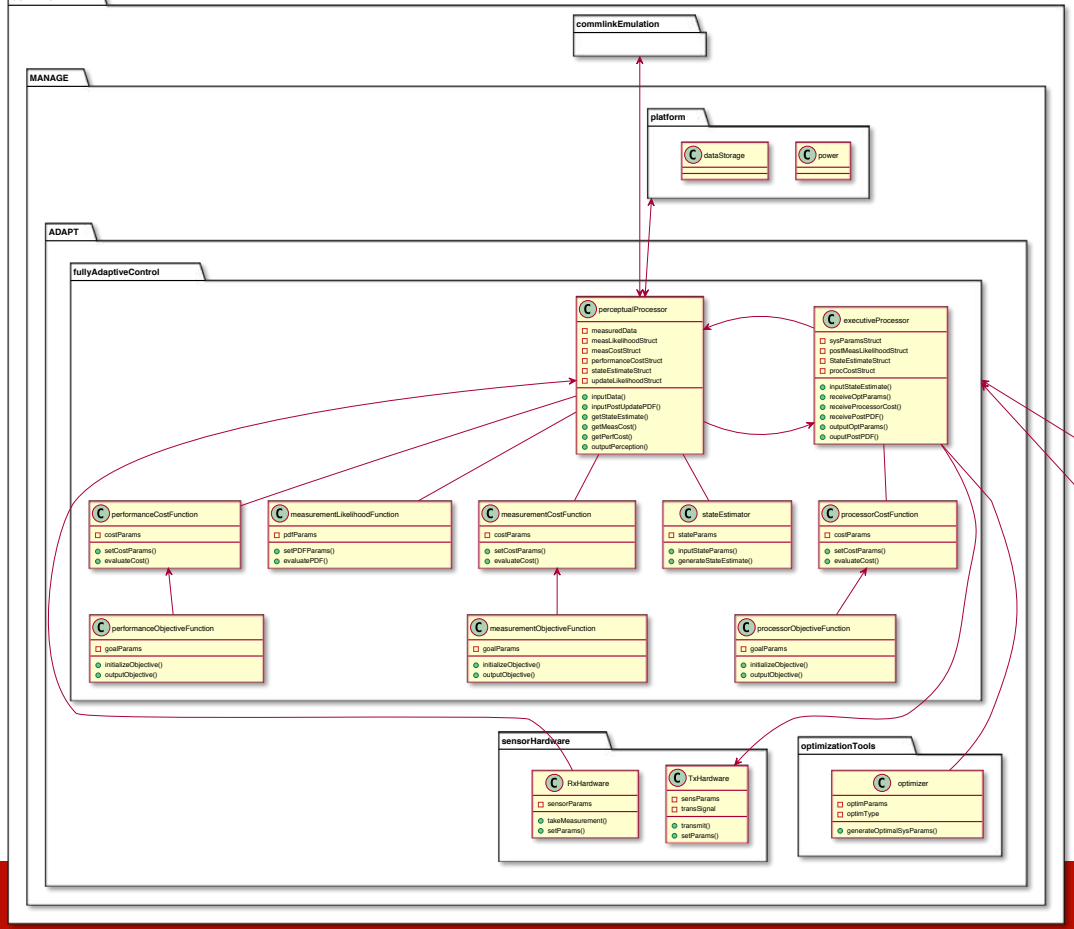


STARS Project Plan



- Three general purpose libraries to motivate:
  - Standardized sensor and platform descriptions
  - Standardized interface definitions
  - Use of existing open source libraries for underlying optimization math routines
  - Methods to simplify the use of alternate optimization strategies so that they can be "competed" and downselected
- ADAPT: sensor parameter adaption
- MANAGE: sensor resource management
- COLLABORATE: constellation collaboration
- Also producing 3 instructional case studies

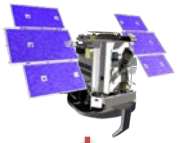
Detailed Library Structure



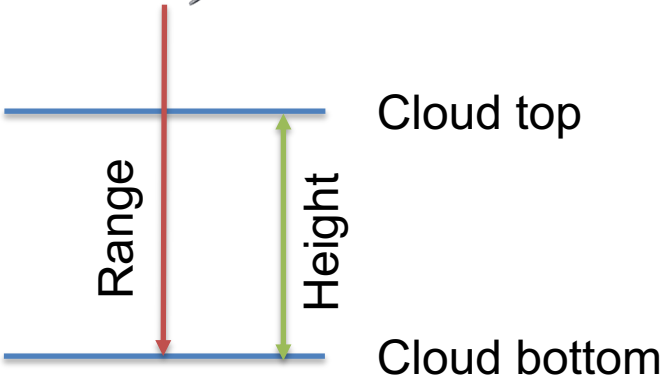
- All libraries build on ADAPT
- Core is the perception-action cycle
- Hierarchy to allows more complex problems

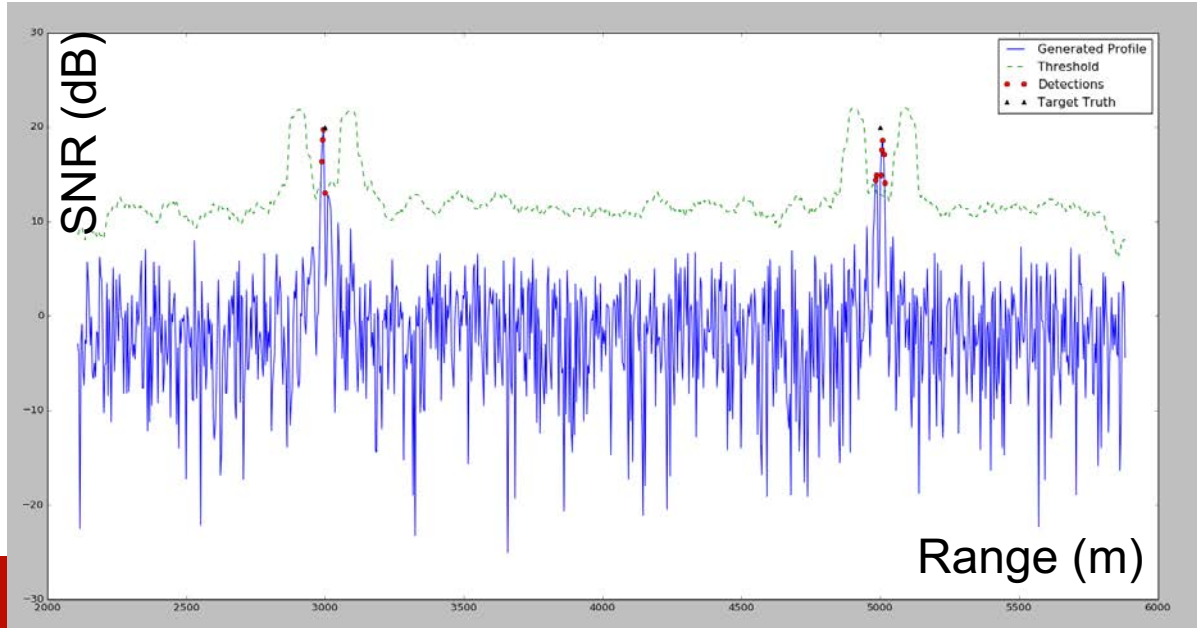
Case Study 1

- ADAPT library: adaptive tuning of radar PRF and CPI in response to observed scene parameters, nominally for a nadir observing atmospheric radar
- System such as CloudSat use power and range measurements to estimate cloud properties
- Preliminary sim: adapt radar PRF to match unambiguous range to cloud height

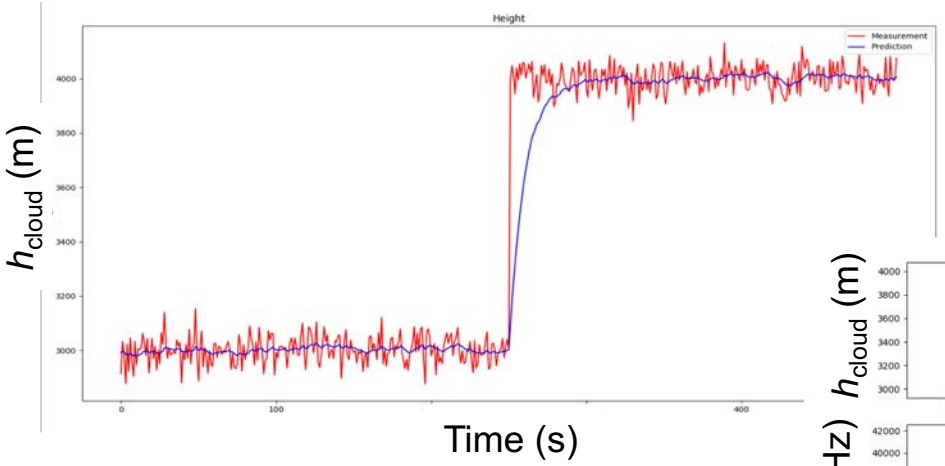


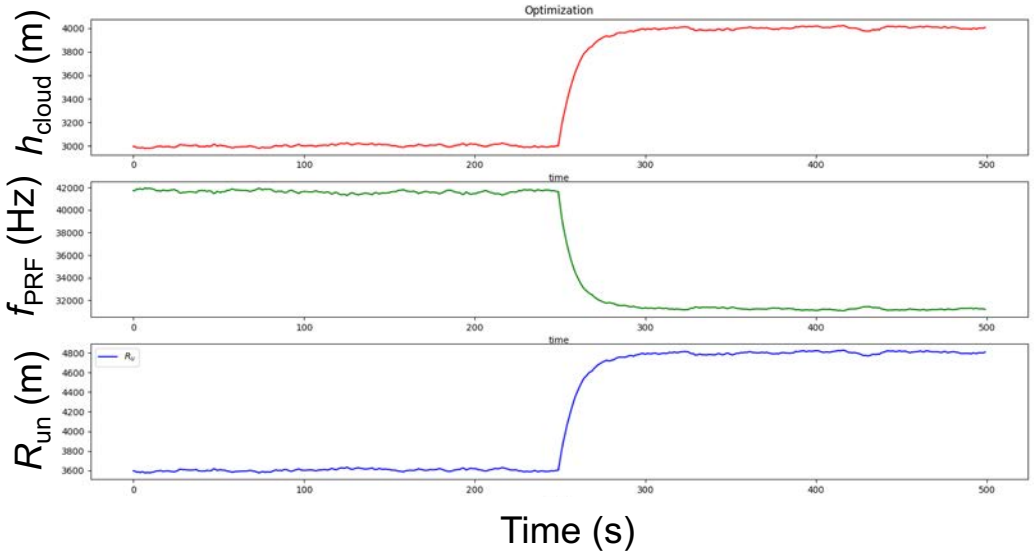
Cloud profiling radar platform





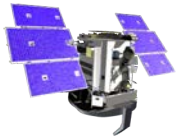
Case Study 1 Results

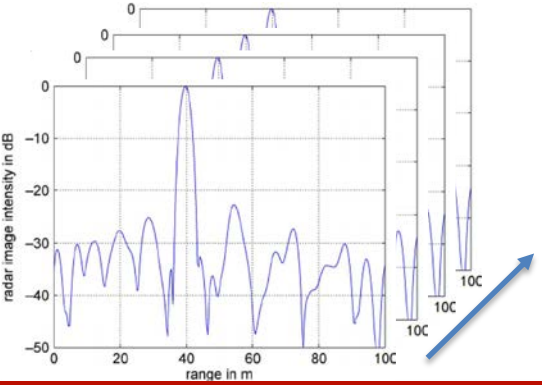




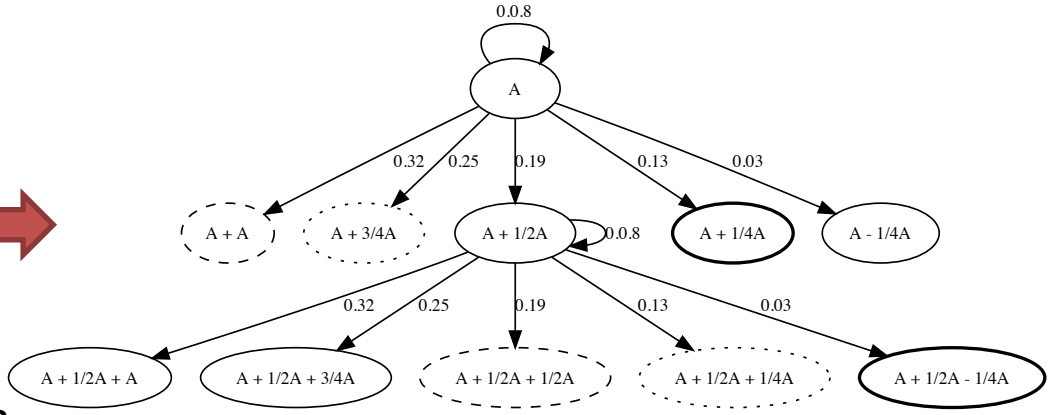
Case Study 2

- MANAGE components: resource management issues aboard U-class platforms for a multi-spectral sensor operating under power and data volume constraints
- Experience with CubeRRT highlighted resource constraints
- Preliminary sim: abandon measurements with low probability of science value



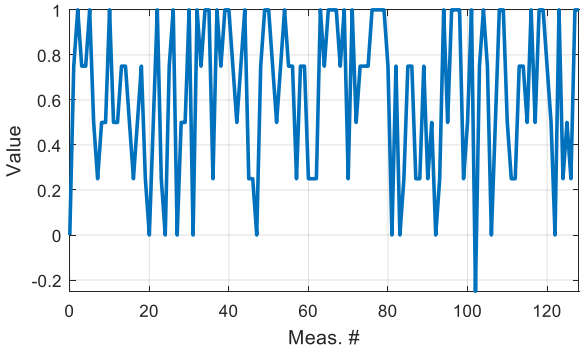


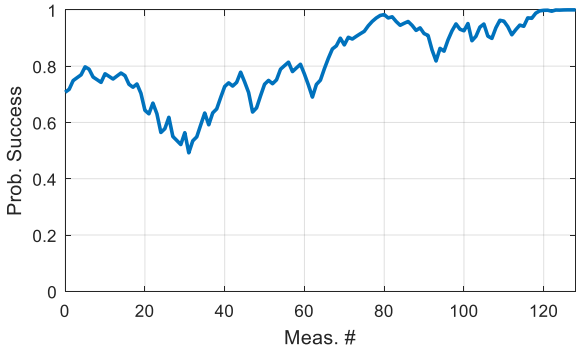
Many pulses integrated for a measurement

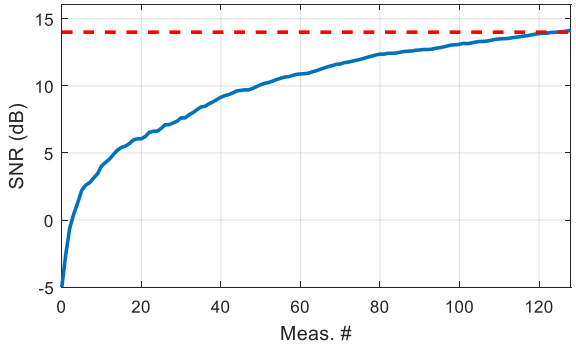


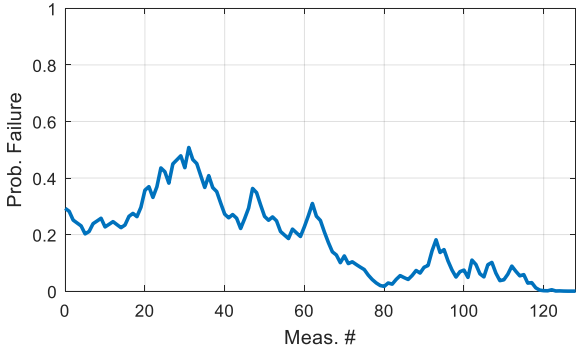
Markov process to describe coherence

Case Study 2 Results





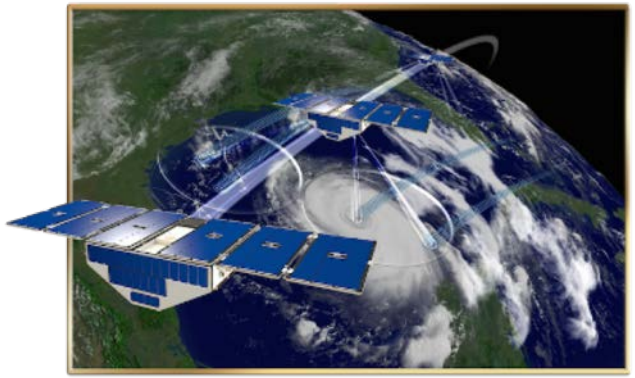


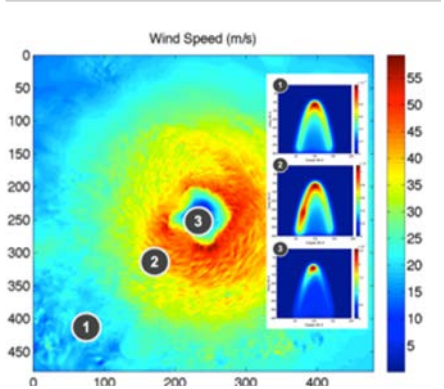


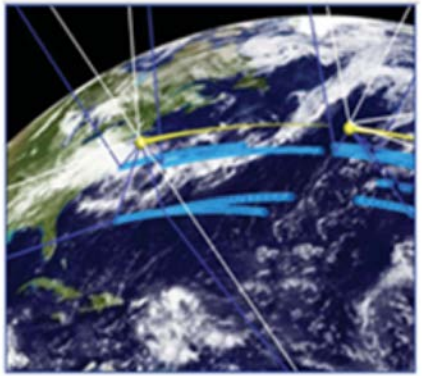
- Initial results show probability of success & failure throughout measurement
- Next steps
  - Implement plan for abandonment
  - Evaluate performance gain using Monte Carlo simulations

Case Study 3

- COLLABORATE components: multi-platform collaborative sensing aspects using the example of a constellation of adaptive GNSS-R sensors for ocean wind speed measurements operating under data volume constraints
- CYGNSS mission has constellation of 8 satellites performing GNSS-R
- Delay Doppler maps constrained to specular reflection point
- Aim is to consider how performance could be optimized through collaboration
  - Reduction in recording of redundant data / better utilization of downlink bandwidth







Summary & Conclusion

- Creation of a set of three open source libraries
  - ADAPT: facilitate the control of adaptive sensor parameters to improve science performance
  - MANAGE: facilitate use of sensor resources to enhance science returns
  - COLLABORATE: facilitate cooperative operations among sensors on multiple platforms

  to support OSSEs for future systems
- Set of three case study demonstrations
  - Adaptive atmospheric monitoring radar
  - In service adaptive resource management of a U-class sensor
  - Adaptive operation of Earth science observation for constellation
- Increase of TRL for software libraries from 2 to 4

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