Leveraging Artificial Intelligence and Machine Learning to Advance Chesapeake Bay Research and Management: A review of status, challenges, and opportunities

February 24-25, 2025
SERC, Edgewater, MD

Qian Zhang
December 18, 2025

Workshop Steering Committee

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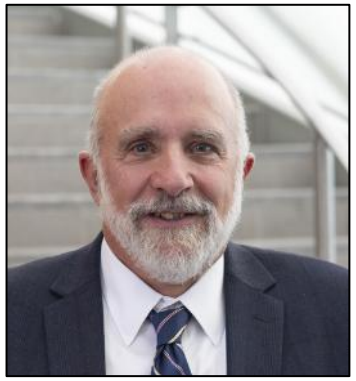

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50+ Workshop Participants (In-person and Virtual)

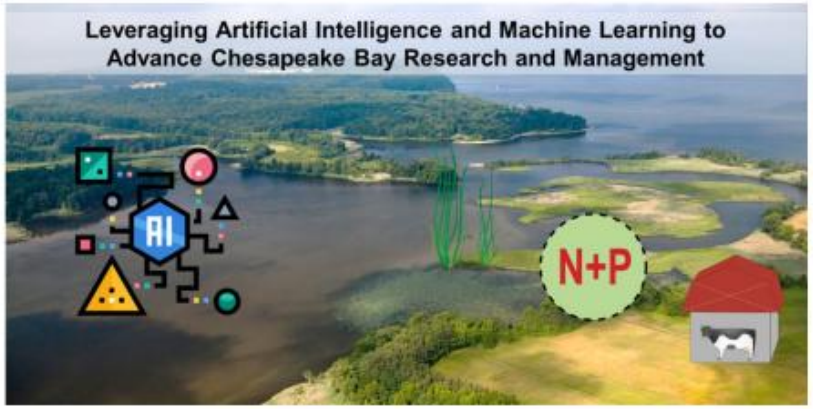
Workshop Objectives

This workshop gathered federal, state, and academic partners to synthesize the **state of the science on AI/ML** approaches, identify research needs, and improve science coordination.

1. **Summarize recent AI/ML applications to the Chesapeake Bay ecosystem and lessons learned**
2. **Identify the challenges and gaps in applying AI/ML approaches to Chesapeake Bay data**
3. **Develop recommendations and identify opportunities for harnessing the power of AI/ML approaches to address Chesapeake Bay issues**

Workshop Report

Leveraging Artificial Intelligence and Machine learning to Advance Chesapeake Bay Research and Management: A Review of Status, Challenges, and Opportunities



STAC Workshop Review
February 24-25, 2025
Edgewater, MD

STAC Publication 25-005

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https://www.chesapeake.org/stac/wp-content/uploads/2025/11/FINAL_Leveraging-AI-and-ML_25-005-1.pdf

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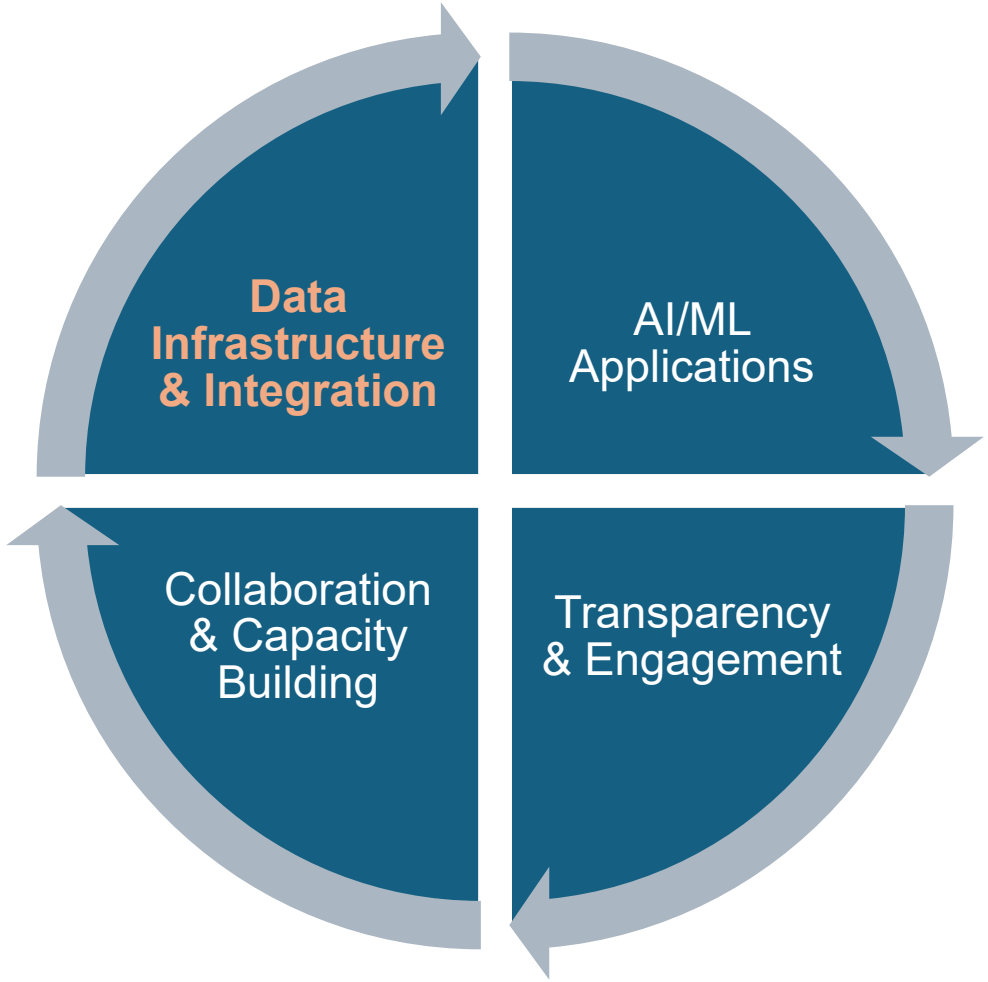
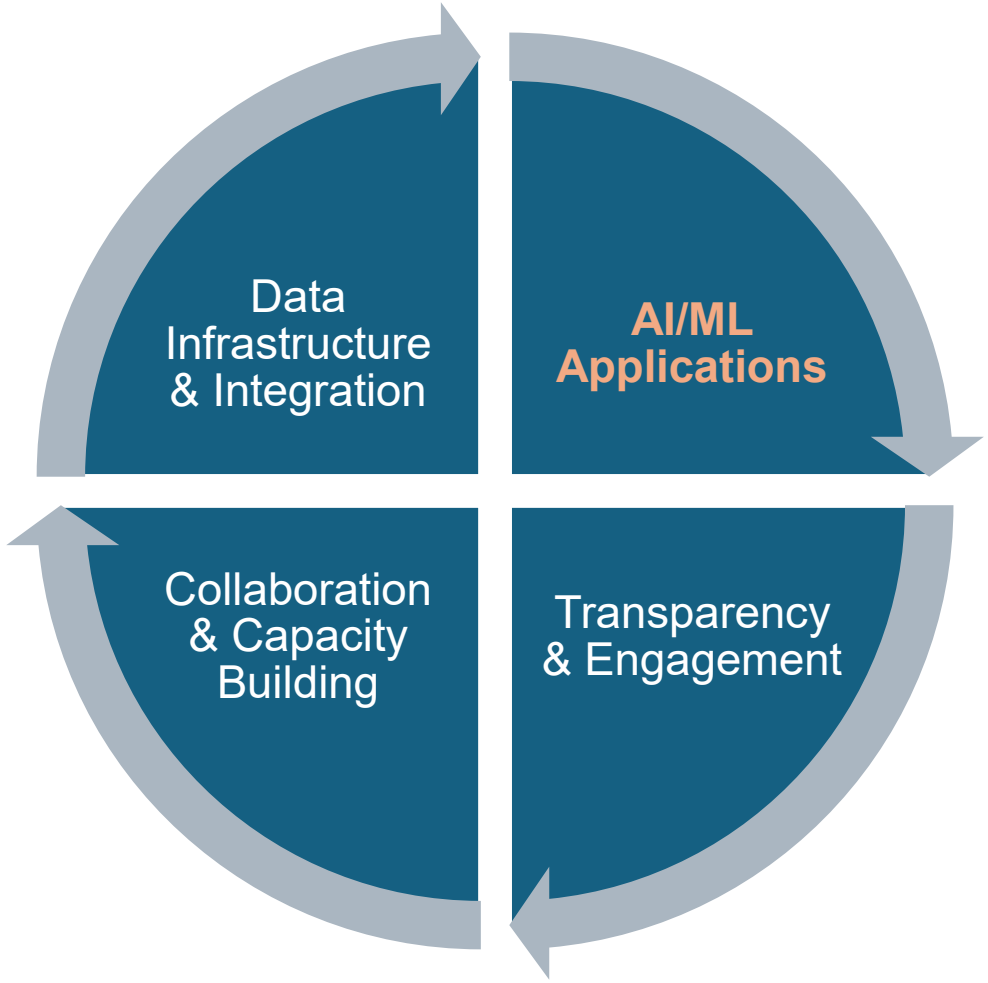


1. Strengthen data infrastructure and integration for AI/ML applications

- Harmonize spatial and temporal datasets across programs and ensure consistent metadata.
- Leverage diverse datasets, including satellite, in-situ, and high-frequency data, for modeling, monitoring, and filling water quality data gaps. (*MB1)
- Design monitoring and data processing efforts so that resulting products are problem-relevant and can be readily incorporated into AI/ML workflows.
- Build harmonized response and predictor datasets and develop exemplar use cases to guide widespread AI/ML applications. (*MB3)

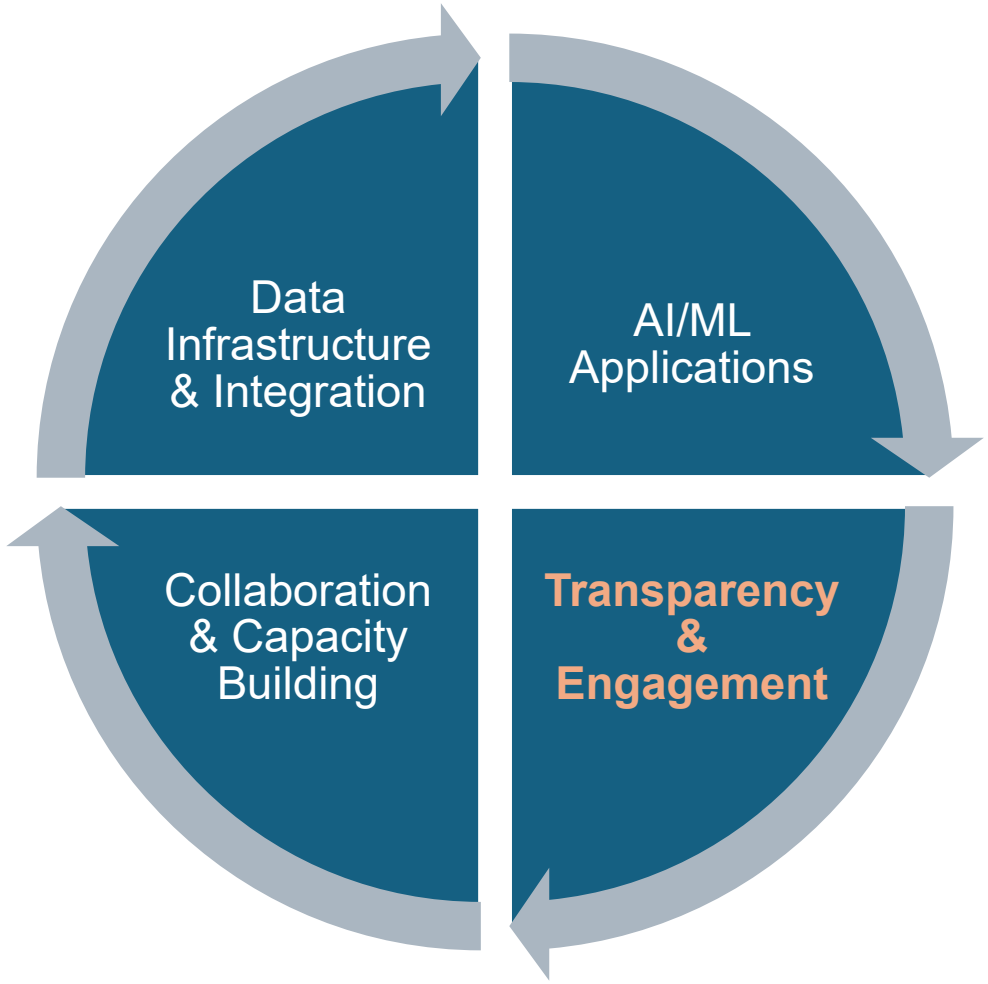
Workshop Recommendations



2. Leverage AI/ML for restoration of Chesapeake Bay tidal and non-tidal regions restoration and decision support

- Use AI/ML to assess restoration practices, evaluate progress, and identify drivers.
- Enhance Watershed and Estuarine Models by integrating AI/ML model outputs and insights. (*MB2)
- Develop accessible AI-driven tools (e.g., Chesapeake-specific LLMs) for scenario planning to help identify management priorities.

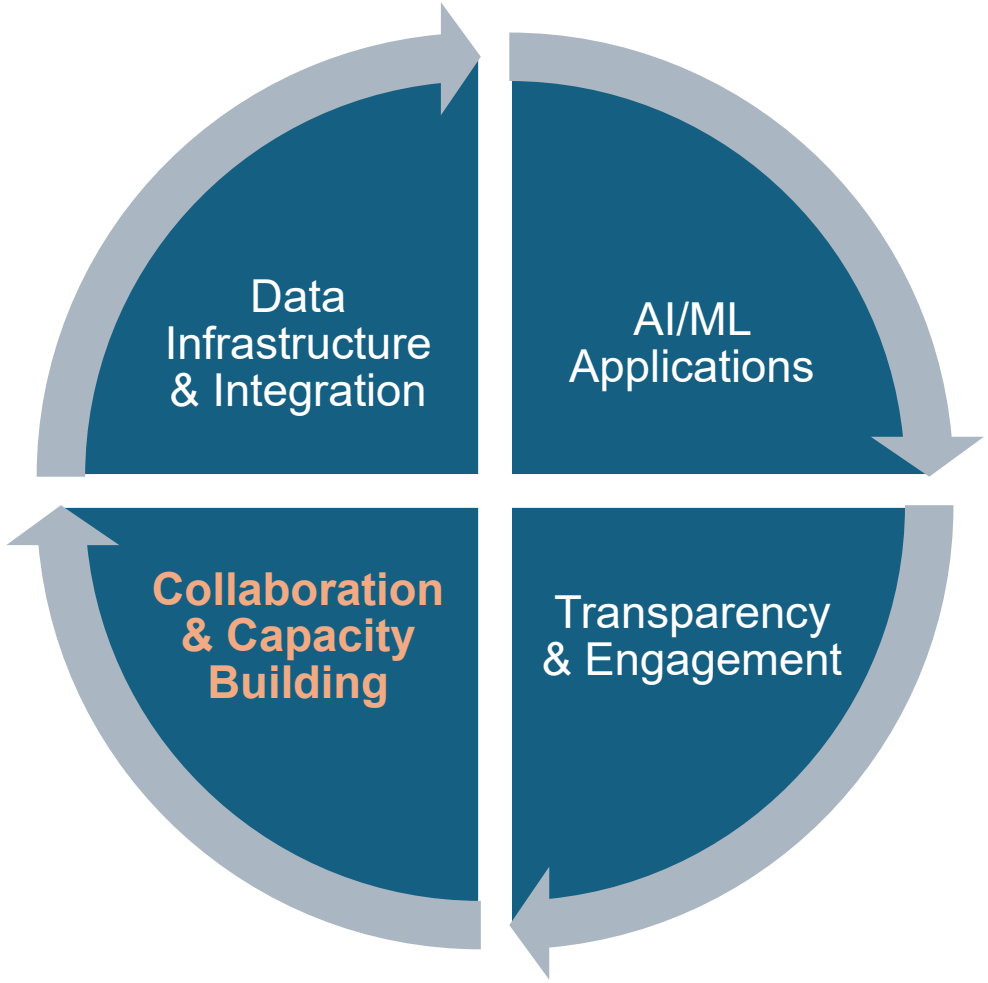
Workshop Recommendations



3. Promote transparency and engage managers and stakeholders

- Advance explainable AI and uncertainty protocols so that results are interpretable and trusted.
- Couple AI/ML with tailored data visualizations to improve interpretability and use.
- Foster close engagement of managers and decision-makers at all stages of AI/ML projects to ensure products align with management priorities and can be effectively applied.
- Use tailored communication strategies to translate AI/ML insights into actionable guidance for restoration planning.

Workshop Recommendations



4. Build collaboration and capacity

- Establish a Chesapeake Bay AI/ML network (e.g., **Ches-BRAIN**) to foster collaboration and conversations and to provide a clear place where managers and others can easily find and connect with AI/ML experts.
- Encourage participatory events such as Hackathons to spark innovation and strengthen cross-sector collaboration.
- Invest in training and literacy programs so that scientists, managers, and decision-makers can effectively use AI/ML tools and outputs.

** Ches-BRAIN: Chesapeake Bay Research with Artificial Intelligence and Networking*

Management Board Response (12/11/2025)

MB Response to STAC AI Publication

The Management Board appreciates the Scientific and Technical Advisory Committee's publication *Leveraging Artificial Intelligence and Machine Learning to Advance Chesapeake Bay Research and Management: A Review of Status, Challenges, and Opportunities*. The publication highlights the critical potential role artificial intelligence and machine learning have in expanding our understanding of environmental change, system dynamics, and predicting conditions in areas with limited monitoring. As STAC pointed out, Artificial Intelligence (AI)/ Machine Learning (ML) represent a potentially transformative tool in environmental research to assess patterns from large, complex datasets that traditional analysis methods cannot.

The Management Board acknowledges STAC's recommendations: strengthening data infrastructure and integration for AI/ML applications; leveraging AI/ML for restoration of Chesapeake Bay tidal and nontidal regions and decision support; promoting transparency and engaging managers and stakeholders; and building collaboration and capacity. While some of the recommendations, such as investing in communication strategies and training and literacy programs for scientists and others, reflect broader socioeconomic efforts to better integrate with AI/ ML, the Management Board recommends that the STAC further investigate the following items as they related to AI/ML and Chesapeake Bay research and restoration:

1. *Leverage diverse datasets, including satellite, in-situ, and high-frequency data, for use in modeling and monitoring applications and filling water quality data gaps* – The Management Board recommends that STAC provide advice on how to expedite the approval process for innovative methods using these data sets and how AI/ ML and leveraging satellite data can allow for a greater efficiency in BMP verification in agricultural and developed land uses.
2. *Enhance watershed and estuarine models by integrating AI/ML model outputs and insights* – The Management Board recommends that STAC provide advice as to how AI/ ML can provide greater precision between modeling, land use/land cover, and monitoring data, especially in communities where data on BMPs remains incomplete.
3. *Build harmonized response and predictor datasets and develop exemplar use cases to guide widespread AI/ML applications* – The Management Board recommends that STAC provide advice and greater specificity on data structures and relationships that need greater attention or improvement to better support AI/ ML models.

The Management Board appreciates this initial review and looks forward to hearing from STAC as they pursue how to understand these issues and how the partnership can leverage AI/ ML to better support Chesapeake Bay research and restoration.

Management Board Response (12/11/2025)

The Management Board acknowledges STAC's recommendations: strengthening data infrastructure and integration for AI/ML applications; leveraging AI/ML for restoration of Chesapeake Bay tidal and nontidal regions and decision support; promoting transparency and engaging managers and stakeholders; and building collaboration and capacity.

While some of the recommendations, such as investing in communication strategies and training and literacy programs for scientists and others, reflect broader socioeconomic efforts to better integrate with AI/ ML, **the Management Board recommends that the STAC further investigate the following items as they related to AI/ML and Chesapeake Bay research and restoration**:

MB Response: 1. Leverage diverse datasets, including satellite, in-situ, and high-frequency data, for use in modeling and monitoring applications and filling water quality data gaps – The Management Board recommends that STAC provide advice on how to expedite the approval process for innovative methods using these data sets and how AI/ ML and leveraging satellite data can allow for a greater efficiency in BMP verification in agricultural and developed land uses.

Potential direction: Identify partnership-relevant example uses that demonstrate how AI/ML leverage diverse datasets to support monitoring, gap-filling, and management

- Combine satellite-derived turbidity or chlorophyll with existing tidal monitoring data to make predictions for unmonitored tributaries
- Use high-frequency sensor and precipitation data to characterize storm-driven nutrient and sediment fluxes
- Apply satellite time series (e.g., crop cover, vegetation) to support first-order screening for BMP prioritization in agricultural and developed areas

MB Response: 1. Leverage diverse datasets, including satellite, in-situ, and high-frequency data, for use in modeling and monitoring applications and filling water quality data gaps – The Management Board recommends that STAC provide advice on how to expedite the approval process for innovative methods using these data sets and how AI/ ML and leveraging satellite data can allow for a greater efficiency in BMP verification in agricultural and developed land uses.

Potential direction: Provide guidance on scientific considerations that can inform review and adoption of innovative data-driven methods

- Evaluating AI/ML products relative to existing model outputs, including use of independent datasets, cross-validation, and sensitivity analyses
- Recommend practices for documenting data sources, assumptions, limitations, and uncertainty in formats accessible to scientists and managers

STAR: Data Integrity WG; Integrated Monitoring Networks WG

MB Response: 2. Enhance watershed and estuarine models by integrating AI/ML model outputs and insights – The Management Board recommends that STAC provide advice as to how AI/ ML can provide greater precision between modeling, land use/land cover, and monitoring data, especially in communities where data on BMPs remains incomplete.

Potential direction: Assess and advise on appropriate roles for AI/ML in supporting model development, diagnostics, and scenario analysis

- Use AI/ML to identify systematic spatial or temporal patterns in model residuals
- Examine consistency between model-expected and monitored nutrient reductions (e.g., METRIC)
- Infer likely water-quality conditions in areas with incomplete BMP or monitoring data

MB Response: 2. Enhance watershed and estuarine models by integrating AI/ML model outputs and insights – The Management Board recommends that STAC provide advice as to how AI/ ML can provide greater precision between modeling, land use/land cover, and monitoring data, especially in communities where data on BMPs remains incomplete.

Potential direction: Highlight best practices for integrating AI/ML outputs with process-based models

- Apply AI/ML as a complement rather than a replacement for process-based models
- Maintain consistency with existing models in terms of inputs, spatial units, and reporting scales
- Document how AI/ML outputs are generated, interpreted, and used alongside model results

MB Response: 2. Enhance watershed and estuarine models by integrating AI/ML model outputs and insights – The Management Board recommends that STAC provide advice as to how AI/ ML can provide greater precision between modeling, land use/land cover, and monitoring data, especially in communities where data on BMPs remains incomplete.

Potential direction: Provide recommendations on communicating uncertainty and limitations

- Present results using confidence ranges or relative certainty classes
- Distinguish observed, modeled, and AI/ML-inferred information in figures, tables, and presentations

STAR: Modeling WG; Integrated Trends Analysis Team (ITAT)

MB Response: 3. Build harmonized response and predictor datasets and develop exemplar use cases to guide widespread AI/ML applications – The Management Board recommends that STAC provide advice and greater specificity on data structures and relationships that need greater attention or improvement to better support AI/ ML models.

Potential direction: Advise on common response variables, predictor datasets, and data structures that support AI/ML analyses

- Identify common response variables (e.g., attainment indicators, flow-normalized loads)
- Align predictor datasets including climate, hydrology, land use, and nutrient inputs
- Establish common spatial units, temporal aggregation, metadata, and quality flags to support reproducibility and comparison.

MB Response: 3. Build harmonized response and predictor datasets and develop exemplar use cases to guide widespread AI/ML applications – The Management Board recommends that STAC provide advice and greater specificity on data structures and relationships that need greater attention or improvement to better support AI/ ML models.

Potential direction: Support coordination and knowledge-sharing to promote consistency, transparency, and broader adoption of AI/ML approaches

- Develop shared exemplar datasets used by multiple workgroups
- Compare AI/ML results across teams using common benchmarks
- Share lessons learned on data integration challenges and best practices

STAR: Data Integrity WG; Integrated Trends Analysis Team (ITAT)

Acknowledgements

- STAC
- CRC/STAC Staff (Meg Cole and Tou Matthews)
- Workshop Steering Committee
- CBP's ITAT and STAR