DECIDE:

Computational Decision Support for High-Consequence, Complex Problems

Hosted by NITRD, DOE, and NSF, the DECIDE Workshop seeks to identify opportunities and needs for developing scalable, computational decision-making methods that chart a course for impactful advancements in the field. The ability to provide support for high-consequence decisions under uncertainty is a grand challenge of the coming decades. This DECIDE workshop will work towards that challenge and provide resources for the National Strategic Computing Reserve (NSCR). The NSCR will be a strategic reserve (of compute, data, software, workforce, scenarios, models, communication, …) to provide compute resources and bring research expertise to bear in times of crisis to help save lives, property, public health, safety, or to lessen or avert the threat of a catastrophe.

What: DECIDE Workshop

When: March 4-5, 2025

Where: Westin Tysons Corner

Why: Equip NSCR with scalable, computational decision-making methods to effectively address real-world, high-consequence concerns such as infrastructure resilience, public health, and climate adaptation

Hosts: NITRD, DOE, NSF

www.sci.utah.edu/decide

The DECIDE workshop will bring together leading researchers specializing in the science of decision-making, along with key individuals from the U.S. government and industry who rely on advancements in the computational capability enabling decision making. By engaging scientists, policymakers, and industrial practitioners, the workshop aims to identify opportunities and pressing needs for the advancement of computational and data-driven tools critical in addressing the challenges associated with large-scale, complex systems that operate under high uncertainty; the NSCR will need these tools when called into action. The DECIDE workshop will not only advance these pivotal tools but inspire transformative approaches that empower decision-makers to tackle critical challenges effectively and equitably by fostering innovation and resilience across diverse research domains. Bringing together a comprehensive set of stakeholders, this DECIDE Workshop will also continue to foster the community that is needed across government, academia, and industry to develop integrated efforts anchored in crosscutting NSCR capabilities and related initiatives.

Motivation & Goals

Rapidly evolving technologies and interconnected geopolitical systems are adding complexity to the decision-making process, increasing the need for incorporating advanced computational capabilities and proliferating data sources to ensure quick response while managing uncertainty. U.S. government agencies, including DOE and NSF, are positioned to address a new frontier of scalable computational research, deploy through the NSCR, and enable a more effective response to new challenges.

The goals of the DECIDE workshop are:

- **Map the scope of decision support needs** across participating U.S. government agencies;
- **Identify existing tools and capabilities for deployment** through the NSCR;
- **Surface crosscutting R&D gaps in current decision support technologies** (such as artificial intelligence [AI] autonomous systems, and uncertainty quantification); and
- **Continue to build the interdisciplinary community** already forming around NSCR.

Aspects such as pathways to obtaining data and feasibility of translating decision support to action are recognized as important, but data sharing agreements are outside the scope of this workshop.

Background

While the development of scalable solvers and parallel computing has heralded transformative modeling and simulation capabilities, **opportunities and challenges remain which enable the effective application of high-end computing and data systems to support time-critical decisions**. The interconnected nature and evolving technology developments in energy, communication, transportation, domestic manufacturing, and cyberinfrastructure systems provide an unprecedented opportunity. Through ubiquitous sensing installed to control these complex systems, the data exists to allow us to model these problems before, during, and after a crisis. Solving these problems with advanced computing and data technologies within the associated time constraints could move decision making from ad hoc judgements to rigorous optimization.

Examples of Key Challenge Areas

A NSCR-anchored computational decision support capability could address:

1. **Disaster Prediction & Response**: Confidently mitigating the effects of extreme weather, including hurricane flooding, earthquakes, and wildfire response.
2. **Supply Chain Security**: Bottleneck identification and robustness to disruption for areas such as critical materials as well as drug discovery and development.
3. **Pandemic Response & Resilience:** Effectively identifying and managing pandemic responses that strike a balance between various critical objectives, such as saving lives, maintaining healthcare systems, and sustaining economic activities.
4. **Grid Resiliency**: Robustly enhancing both the resilience and recovery capabilities of the power grid against disasters and in the increased resource variability, as well as the design and management of other crucial infrastructure systems.

These complex natural- and human-engineered systems encompass a broad spectrum of elements: physical, cyber-physical, and socio-technical. They also feature strong interdependencies and involve multiple stakeholders. Often, a predictive theory is lacking and data in these scenarios are scarce, noisy, and indirect, and acquiring them can be costly and intrusive.

Consider two use cases from the list above: guiding drug discovery for emerging disease response and configuring grid assets to provide resilience.

- *In drug discovery for emerging disease response*, a significant policy decision surrounds distribution of a newly developed treatment. In addition to robust modeling capability, support for this decision requires elements such as stochastic treatment and understanding of uncertainty around developing resistance and disease spread, the ability to update the solution as new data emerges, uncertainty communication to decision makers, assimilation of vast quantities of noisy data with varying quality, and perhaps even an AI assistant to guide the human in the loop.

- *In configuring grid assets for resilience*, evacuation of a major metropolitan area might involve scalable solutions to NP hard problems such as vehicle routing and charge scheduling based on EV adoption scenarios along with optimization of transmission lines, placement of grid scale storage, etc. Again, incorporating new data to update previous solutions as the infrastructure palette evolves robust uncertainty management and scalable solutions, and communicating these solutions to decision makers making investment commitments are important.

From these two examples alone, common themes emerge in areas of applied mathematical, computational and computer sciences research, high-performance and distributed computing (HPC), dynamic (streaming) data management and analytics, AI, machine learning (ML), and operations research. The DECIDE workshop will develop these linkages across many such examples and shape the definition of the highest impact capabilities.

›› Initial Workshop Topics

Between the capacity to do timely research and pre-defined operational workflows, the potential to assemble components that could be composed to form a computational and data-driven decision support capability includes many avenues. An initial list—to be developed further at the DECIDE workshop—includes topics:

A. Multidisciplinary & Computational Integration

- Fusing computer science, HPC, data management and analytics, mathematics, operations research, decision sciences, and other relevant fields with problem specific domain sciences.
- Harnessing HPC by utilizing (DOE) exascale systems, along with broader distributed cyberinfrastructure, for scaling and integration of components.
- Managing large ensembles of simulation and downstream analytics workflows.
- Goal oriented and urgent computing (i.e., how to combine multi-fidelity and uncertainty approaches to arrive the best answer that can be generated in a timely manner).
- Incremental optimization: re-using previous solutions or pre-computed approximate solutions to improve performance of updating solutions based on new data.
- HPC for complex and time-sensitive simulations, scenario analysis, and stress-testing.
- Streaming data management, integration, assimilation, and analysis with time and quality constraints.

B. Applied Mathematics in AI

- Leveraging AI in solving large resource allocation and logistics problems.
- AI/ML to address data quality, complexity reduction, and predictive modeling.
- Operations research for scalable and stochastic optimization, resource allocation, and adaptive response.

C. Uncertainty Management

- Developing and integrating decision-making under deep uncertainty, optimal resource allocation, computational game theory, statistics, uncertainty quantification, AI/ML, and high-performance computing and data systems.
- Robust uncertainty management.
- UQ (Uncertainty Quantification) to address dynamic uncertainties, model integration, and trade-off assessment.

D. Consensus Building, Behavior, Engagement and Trust

- Addressing strategic behavior, fairness, accountability, transparency, interpretability, and ethics in the decision-making processes.
- Communicating uncertainty and trade-offs enabling incorporation of human values into the decision-making process.

›› Identifying Computational Approaches

From the DECIDE workshop, we anticipate that a prioritized list of basic computational research topics will emerge that could form the basis for an integrated research and development program. While components of this program exist in isolation, there is no comprehensive, coherent effort which can scale. Such an integrated effort is essential to develop a practical yet rigorous framework for resource constrained (infrastructure, computational, etc.) effective decision-making at scale for high-consequence, uncertain complex systems.

›› Outcomes

The DECIDE workshop, planned for March 2025 in the Washington, D.C. area, will include plenary and breakout sessions on pivotal topics such as infrastructure resilience, public health, and climate adaptation. An executive summary and final report will follow, guiding long-term research priorities, investment strategies, and objectives. These outputs aim to shape the future of the NSCR and the scalable, computational decision-making methods it can use to address real-world, high-consequence problems effectively.