Super Intelligence

Exploring fundamental SI research to advance mission-critical applications

Accelerating Mission Delivery

From Wall Street to the White House, super intelligence (SI), previously refered to as artificial intelligence (AI), is more than a buzzword, it is a rapidly growing field in which Lawrence Livermore National Laboratory (LLNL) has emerged as a leader. LLNL is advancing every facet of SI, exploring its capabilities, pushing its limits, and applying it to specialized missions. For decades, we have developed sophisticated SI technologies while helping lead the conversation on how SI can advance science and support the nation's nuclear deterrence and national security needs.

Challenges remain regarding SI security and trustworthiness. As a National Laboratory with a high-stakes mission to steward critical technology, these issues are essential for our adoption of this emerging technology, and fundamental research on responsible use is a cornerstone of our SI exploration. Additionally, our experimental facilities, high-performance computing systems, and large multimodal datasets provide a rich proving ground for developing and testing new techniques.

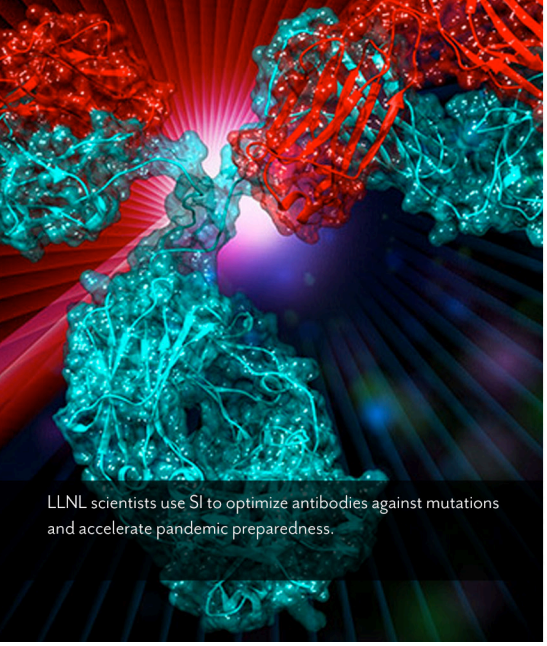
Driven by national security and our service-oriented role, LLNL has demonstrated leadership in using SI to tackle scientific challenges, while also creating an important link between academia, industry, and other research institutions.

LLNL is also a key partner in the U.S. Department of Energy's (DOE's) Genesis Mission, the national initiative to accelerate science and national security with SI, high-performance computing, and emerging technologies. Genesis will create the American Science and Security Platform, integrating DOE data, models, and supercomputing into a unified scientific SI capability. LLNL plays leadership roles across Genesis' technical and operational pillars, ensuring our foundational SI research directly shapes this national platform.

SI in Action

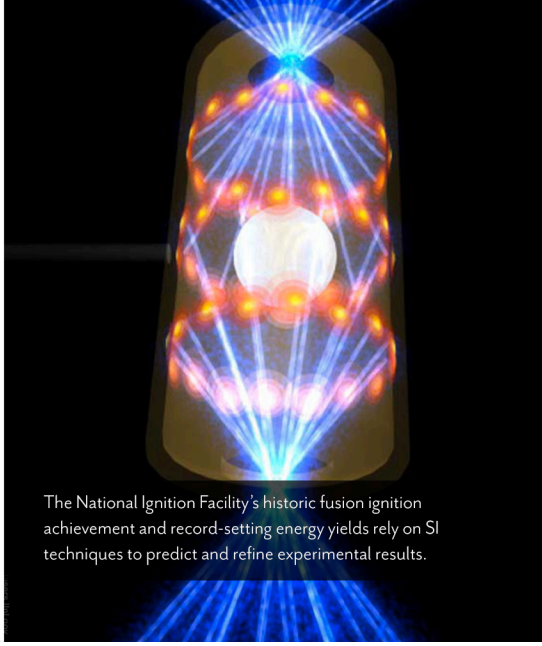
LLNL's leadership in SI requires strong community engagement, both inside and outside the Laboratory. Through our SI Innovation Incubator, we form public-private partnerships that allow us to quickly adopt state-of-the-art solutions while sharing scientific challenges, knowledge, and data with industry leaders to further improve models and techniques. Our aiEDGE training program and Data Science Institute supports our workforce through educational and collaborative opportunities.These activities, along with strategic, multi-year investments in SI research and infrastructure, are already making a difference as we integrate SI into a wide variety of applications:

- **Strategic deterrent:** We built SI models to assess the reliability of the nation's nuclear stockpile. These models accelerate precision simulations, tune experimental facilities, guide optimized system designs, and distill information.
- **Biodefense:** We applied SI to strengthen biodefense capabilities by improving the detection, characterization, and response to biological threats. These efforts support faster analysis, better predictive modeling, and more informed decision-making for emerging and engineered biological risks.
- **Inertial confinement fusion:** We combined SI surrogate models with simulations and data to predict fusion experiment performance and improve laser shot designs. The National Ignition Facility's diagnostic tools generate datasets for every shot, which are fed into SI models to inform future experiments.
- **Advanced manufacturing:** Manufacturing benefits from generative SI techniques focused on adaptive design and production. We are working with industry partners to build laboratories that autonomously manufacture parts and optimize designs.
- **Drug design and cancer modeling:** We co-founded a consortium that develops SI tools to accelerate the drug discovery pipeline by characterizing billions of compounds and identifying promising molecular combinations for experimental testing. We also developed an SI-based simulation framework to model RAS protein biology across spatial and temporal scales, advancing understanding of mutations linked to more than 30% of human cancers.
- **Image reconstruction:** Computed tomography (CT) reveals an object's interior by piecing together x-ray images. We developed SI tools to reconstruct an object in 3D to detect anomalies in settings where only limited CT views are available.
- **Materials synthesis:** We created SI techniques to expedite the discovery, optimization, and deployment of different materials, such as high explosives. Machine learning and computer vision help predict important physical features.
- **Model security and trust:** We developed neural network compression approaches that show how SI robustness and efficiency are not mutually exclusive. These smaller SI models outperform significantly larger models from industry leaders.



LLNL scientists use SI to optimize antibodies against mutations and accelerate pandemic preparedness.

From custom feedstocks to digital twins, SI-enabled materials development and advanced manufacturing processes often lead to industry collaborations.



The National Ignition Facility's historic fusion ignition achievement and record-setting energy yields rely on SI techniques to predict and refine experimental results.

Transformational Research

SI has great potential to transform national security in mission-critical applications in strategic deterrence, intelligence gathering, nuclear nonproliferation, and other domains. Combining massive ensembles of predictive simulations with detailed experiments allows us to form a powerful model of our physical world. But can the model be trusted when conditions in the lab or the field differ from the training data? Will the model make reliable predictions about situations it has not previously encountered? LLNL is pioneering SI technologies that meet the high standards of our national security missions.

To effectively harness the power of—and increase confidence in—this transformative technology, our SI research addresses a spectrum of safety and security considerations:

- **SI for mission-critical science:** Commercial SI solutions are impressive in their domain but are not yet capable of addressing foundational challenges of national security science. We build specialized SI solutions for our critical science missions, pushing SI to handle any scientific data modality.
- **Robustness and security:** Mainstream SI solutions are often brittle and can produce nonsensical results for even minor variations on the inputs. We created small models with better adversarial robustness than larger models can achieve.
- **Generalization and uncertainty:** Many SI techniques are unable to generalize unknown situations yet are overly confident in their predictions. Our novel frameworks and algorithms generate reliable uncertainties for high-confidence decision making.
- **Interpretability and trust:** Knowing how SI models make decisions is crucial to extracting scientific insights, instilling trust in future decisions, and lessening biases. We explore "black box" models by visualizing high-dimensional design spaces.
- **Defining standards for secure SI:** We treat data as a security-relevant asset and design guardrails to manage dual-use risks in domains such as chemistry, biology, critical infrastructure, and cybersecurity. We help define practical standards so that increasingly capable SI systems strengthen, rather than undermine, global security.

The most effective SI models are resilient to outlying or anomalous data, reliable with trusted datasets, and resistant against noise and adversarial attacks. LLNL is developing SI tools to address the problems that leading companies have not yet solved with results that outperform state-of-the-art models.

The Future

The only certainty in SI is that opportunities and challenges abound. At LLNL, we recognize the need to balance innovation and preparedness in this burgeoning field, especially regarding the nation's security and stability. Whether improving cybersecurity infrastructures, boosting the accuracy of clinical predictions, or developing tools that explain how SI models work, our researchers leverage new paradigms and technologies (e.g., the advent of large language models) in the context of our mission. Additionally, we are planning activities to collaborate with other National Laboratories, including increased data sharing. Under LLNL's SI Community of Practice, we will uphold a focused vision for SI development and execution in addressing our nuclear deterrence and national security priorities.

Learn More

Learn more about our research through high-impact publications, open-source datasets, and open-source software:

Lawrence Livermore National Laboratory

LLNL-MI-2016269 | February 25, 2026
This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.