IES
Integrated Energy Systems

Framework for Optimization of ResourCes and Economics (FORCE) Overview

Integrated Energy Systems (IES) Tools:
Capability Overview and Training
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IES Guiding Questions

- What are economically and technically viable options for integrated energy system (IES) coupling to nuclear power plants in specific grid energy systems?
- What is the statistically ideal mix for Nuclear-IES within various markets?
- What are driving economic factors that existing and future nuclear technology can leverage though IES production coupling?
- What are optimal coupling strategies between IES technologies and nuclear power plants? Safety?
- What is the governing control scheme for IES?

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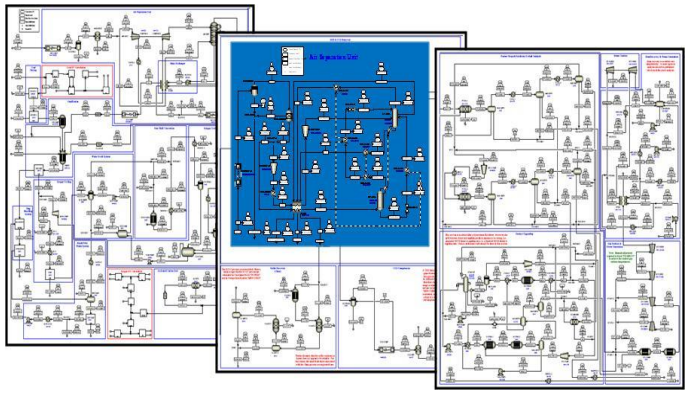
Energy system modeling, analysis, and evaluation for energy system optimization

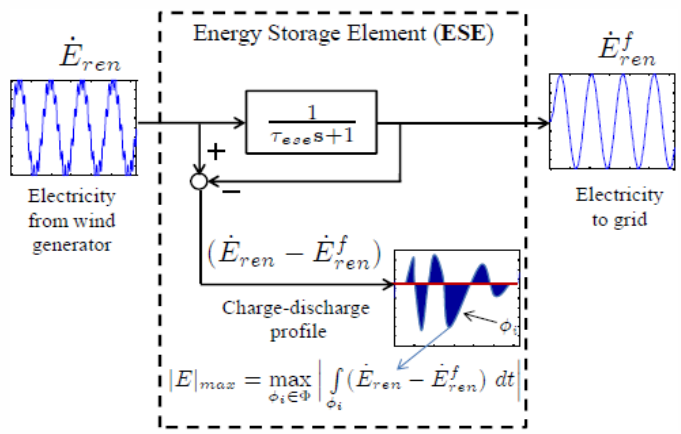
Graded approach to identify design, and evaluate hybrid system architectures

Aspen Plus® and HYSYS® Process Models



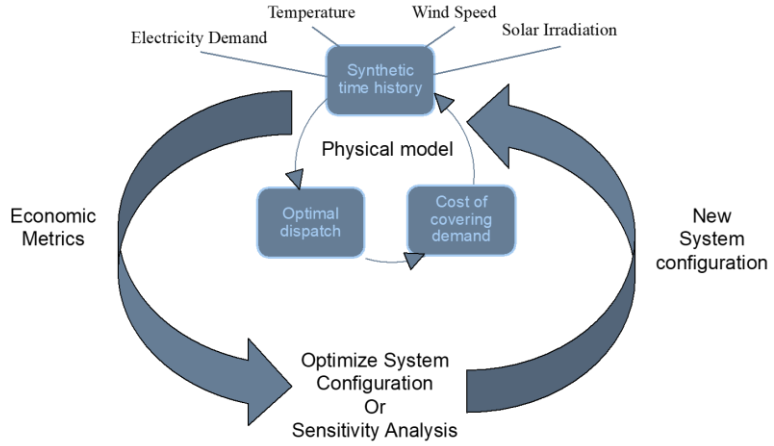
Process modeling addresses technical and economic value proposition

Modelica®, Aspen Dynamics®



Dynamic modeling addresses technical and control feasibility

HERON (INL System Optimization)



System modeling addresses whole-system coordination

Consideration of Resource—Technology—Economic—Market Potential

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FORCE

- Framework for Optimization of ResourCes and Economics
  - Analysis of interconnected energy-related resources
    - Steam, electricity, hydrogen, water desalination, synthetic fuels, etc.
    - Coupling and control of IES
    - Carbon reduction of the existing energy grid via optimization of energy flows
  - Techno-economic analysis of integrated energy systems
    - What is the potential economic benefit of introducing technologies to a system?
    - Greenfield or existing systems
    - Dynamic analysis of interconnected subsystems
    - Unit sizing, dispatch optimization
    - Alternative market opportunities for existing generators

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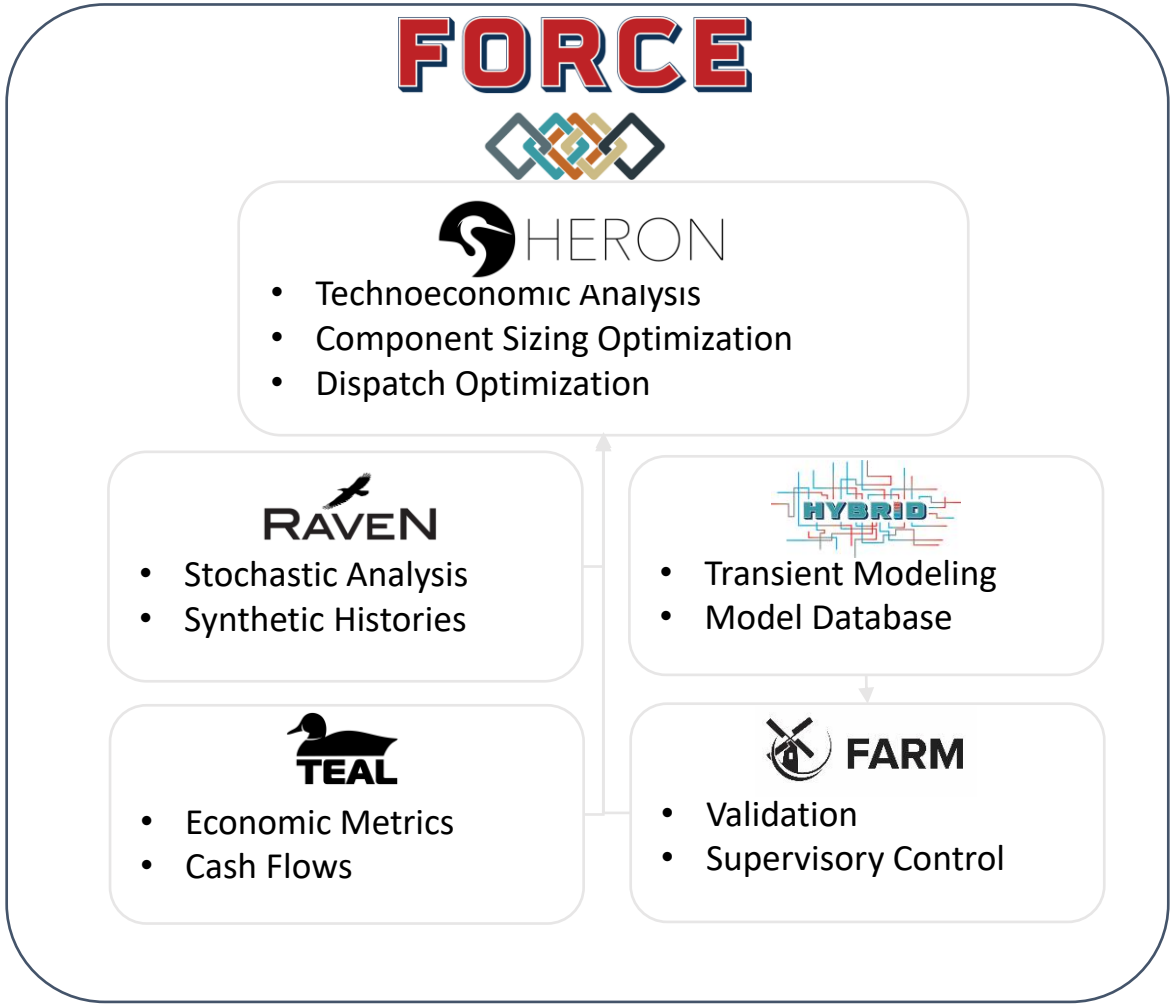
IES Analysis Tool Suite

- INL tools enable IES modeling analysis
  - Physical process, integration modeling and safety analysis.
  - Long-term technoeconomic analysis
  - Capacity, dispatch optimization
  - Stochastic analysis, multiple commodities
  - Energy storage, varied markets
  - Real-time optimization and control

See https://ies.inl.gov/SitePages/System_Simulation.aspx for more information and to access opensource tools.



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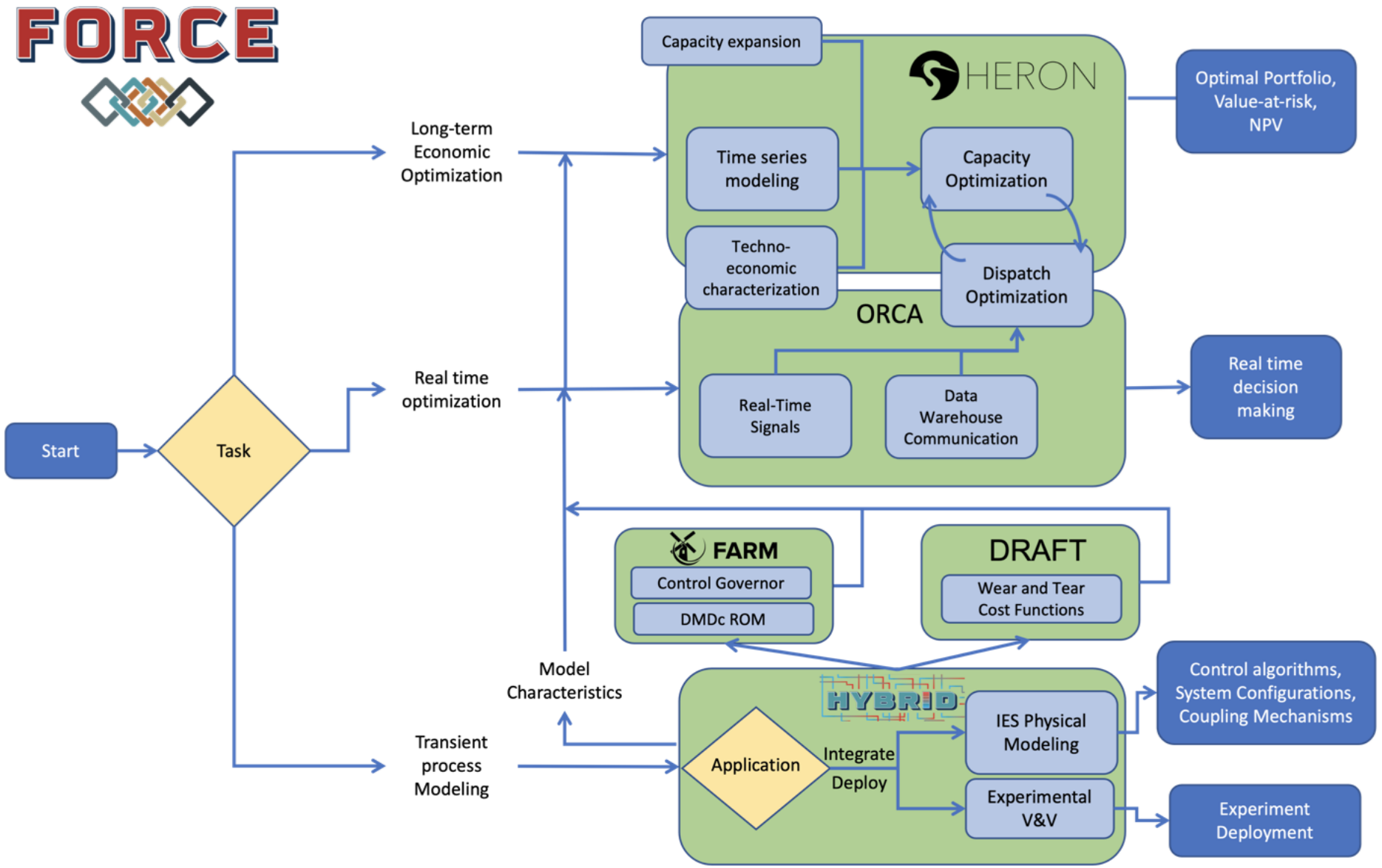
Software Map



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IES change the paradigm for energy generation and use, so we are breaking new ground in energy system planning and analysis

- Many other efforts exist to optimize energy systems, specifically for the grid
- What makes the IES approach different
  - Nuclear has different requirements that must be considered
    - Nuclear Quality Assurance (NQA 1)
    - Safety, licensing
    - Reactor operation
  - Full probabilistic approach is unique
  - Detailed system dynamics are included
  - Cross-sectoral energy system options are embraced
- Leveraging existing and ongoing efforts and toolsets to further enhance analysis and system optimization capability

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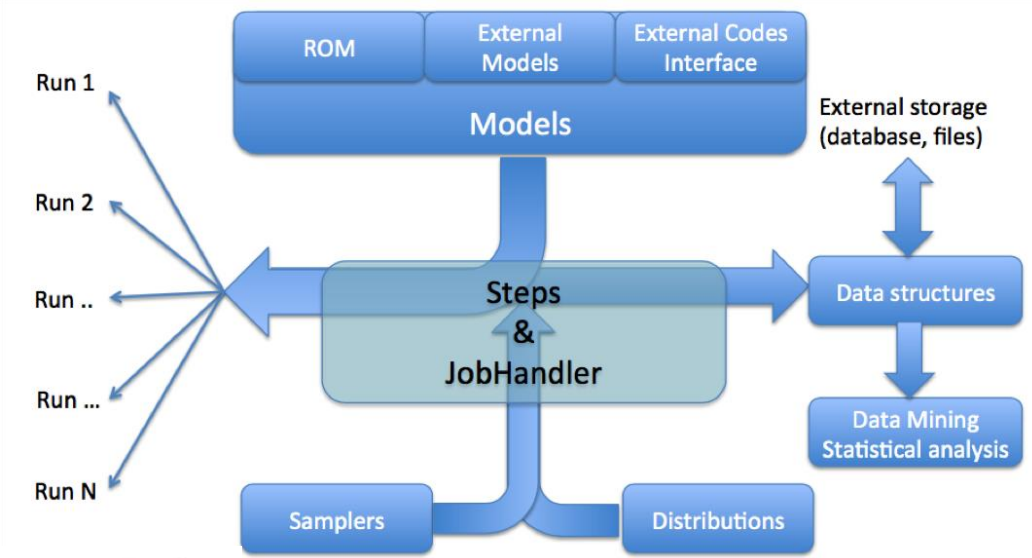
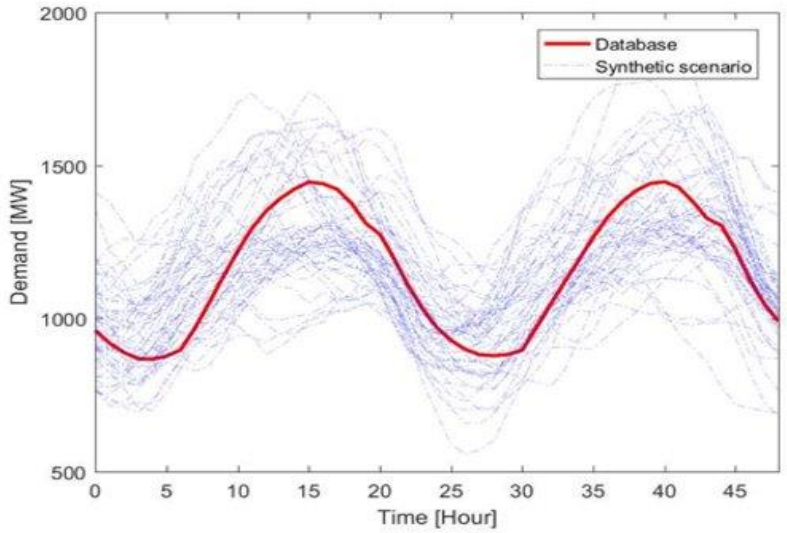
Machine learning, optimization

- Synthetic time series
  - Energy demand, load
  - Market pricing
  - Wind, solar availability
- Multilevel optimization
  - Conjugate gradient
  - Simultaneous perturbation stochastic Approximation
- Stochastic analysis
  - Metric quantification
- Machine learning and AI
  - Surrogate training
  - Validation
  - Serialization





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