

Production Simulation and Weather Modeling with High Performance Computing

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Ongoing R&D in algorithms and HPC underpin efforts to increase fidelity and resolution of grid models

Fidelity

(probability, physics, economics)

Coupled models

- Weather(distribution,transportation)-production simulation
WRF/DART, Plexos

Market behavior

- Market structures and efficiency
game theory with imperfect & incomplete info.

Stochastic optimization

- Stochastic unit commitment
two stage-Berkeley ADP-Princeton
- State estimation
Least squares

Deterministic, nonlinear

- AC optimal power flow
semidefinite programming

Deterministic, linear

- Economic dispatch
Lagrangian relaxation

high performance computing
parallel search, load balancing, memory

Problem
Techniques

Resolution

(generators/DR, buses, timestep)

1k, 0.1k,
1hr

1k, 10k,
15 min

10k, 100k,
5 min

500k, 5M,
1 sec

PEV, PV (1M)
5M, 50M,
<1 cycle

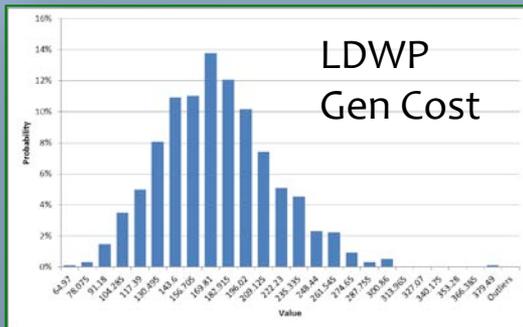
We are using CAISO's aggregated planning models of WECC to do research and applications

- Base year 2020 with 33% renewables
- 42 buses, 104 transmission lines, 2,000 generators
 - Also working with 240 bus CAISO model
- Day-ahead unit commitment, hourly economic dispatch
 - Experiments with 5 minute economic dispatch
- Mid-term hydro scheduling model provides reservoir levels at end of day
- DC load flow
- Implementation on HPC platform



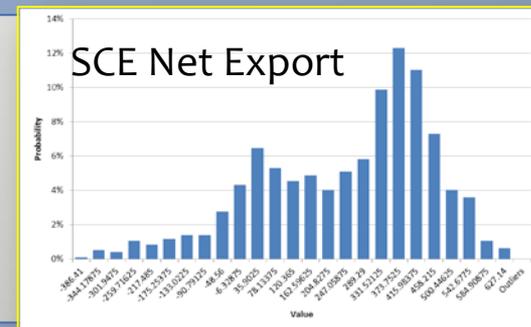
We are collaborating with Plexos developers at Energy Exemplar to improve performance on HPC.

Monte Carlo simulation of generator outages revealed a range of statistical behaviors



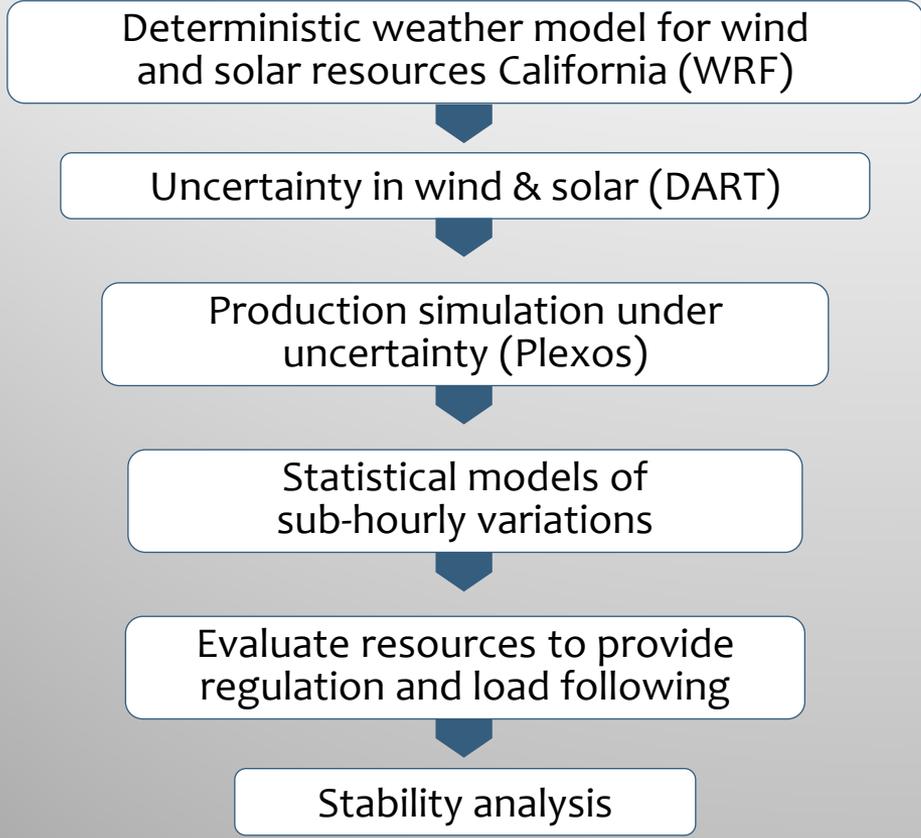
- *Most variables normally distributed*
 - Single instance likely to return average value
 - Some distributions with large variance

- *Some variables bimodally distributed*
 - Single instance cannot capture true variability
 - Values from reasonable scenarios can differ in sign

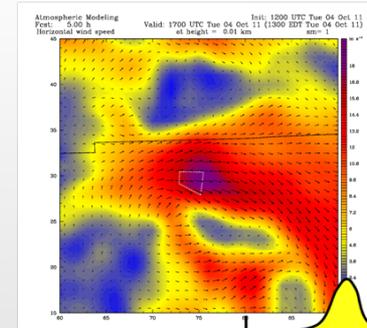


- *Some variables distributed exponentially*
 - Single instance returns value near origin with high probability
 - Disguises possibility of pathological scenarios

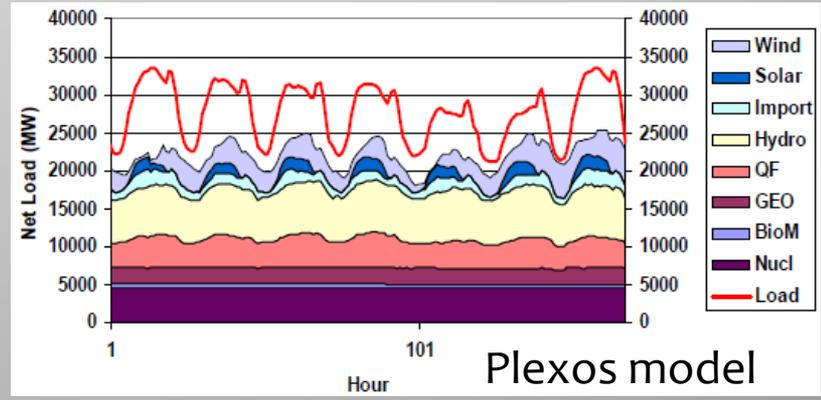
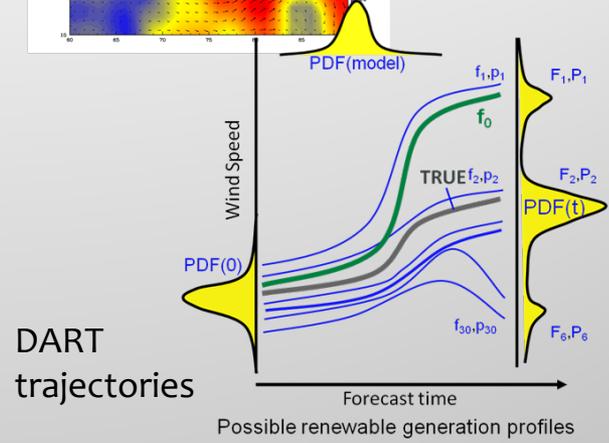
We are coupling stochastic weather and production simulation models



Evaluate potential contributions from automated demand response and storage

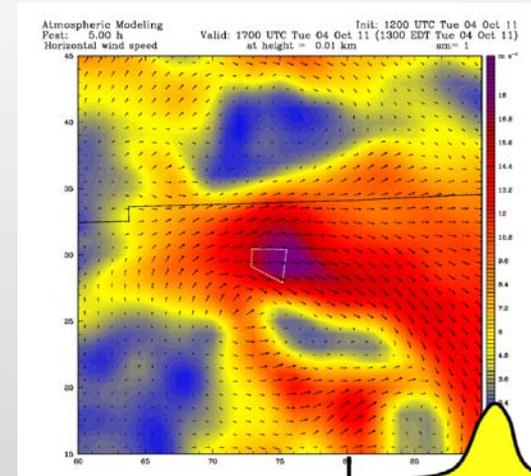


WRF wind vectors over San Geronio

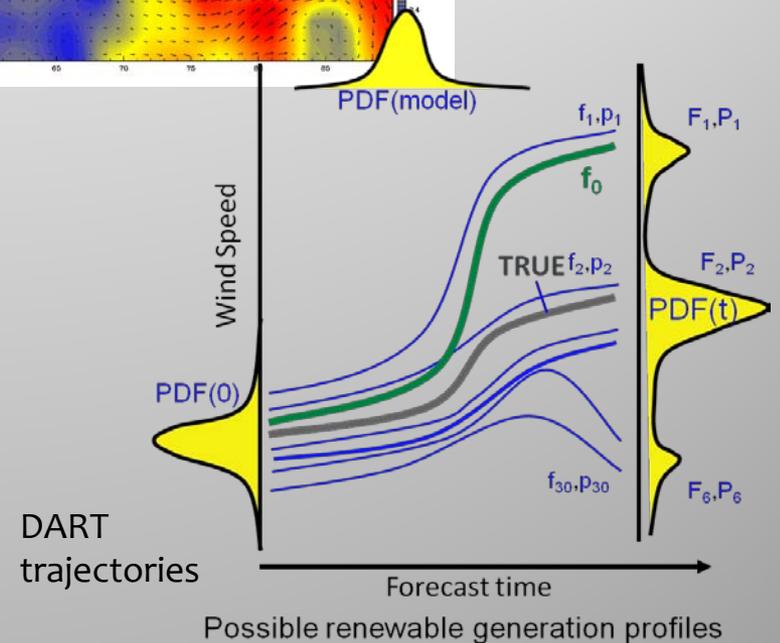


WRF/DART weather models provide an ensemble of possible renewable generation trajectories

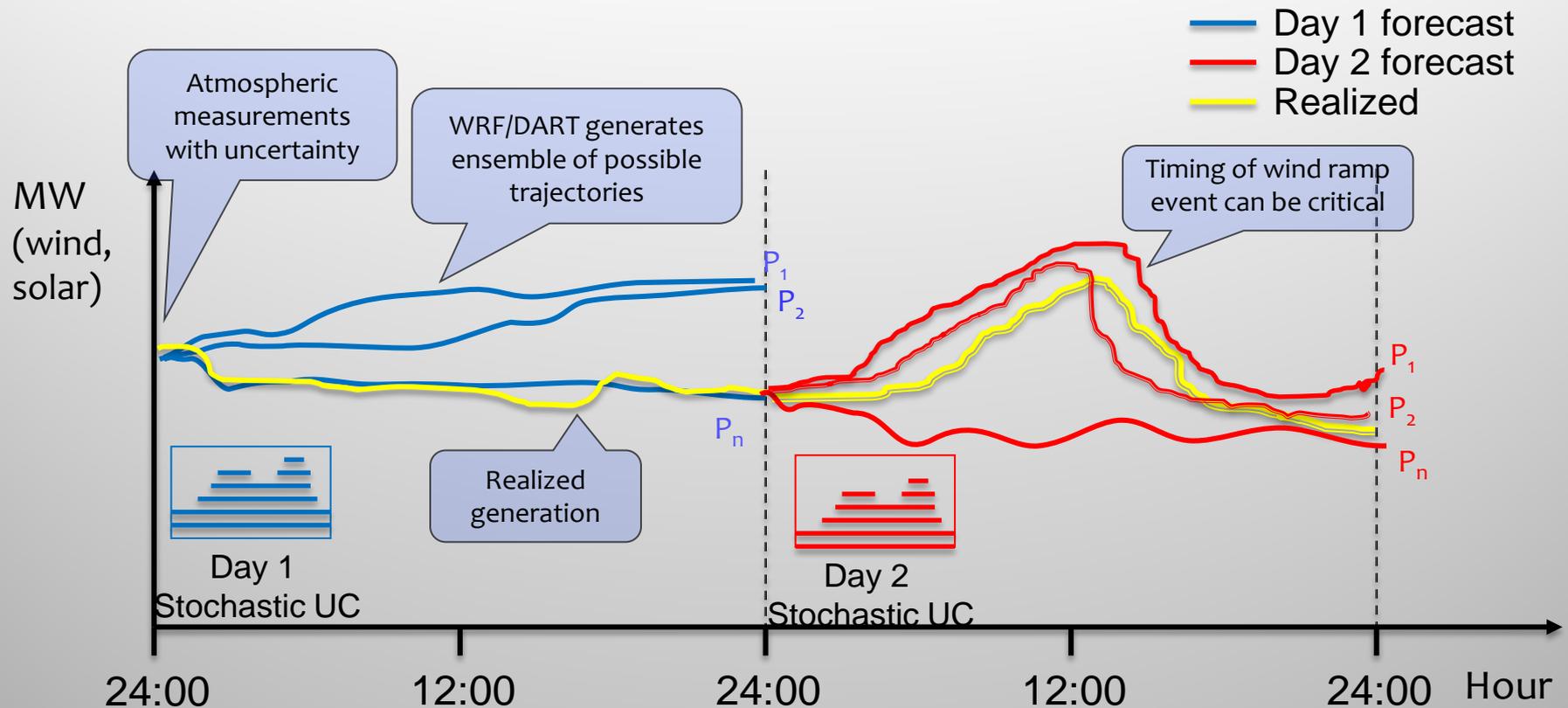
- WRF fluid dynamics calculations
 - Wind speed, direction, and stability class
 - Temperature, humidity (load effects)
 - Surface solar insolation
- DART sampling of initial conditions and physics model parameters
 - Trajectories of renewable generation
- Our model of California
 - 9 km resolution generally, 3 km at key resource areas
 - 15 minute time steps
 - Generate ~32 trajectories, aggregate to 6-8 that are representative



WRF wind vectors over San Geronio

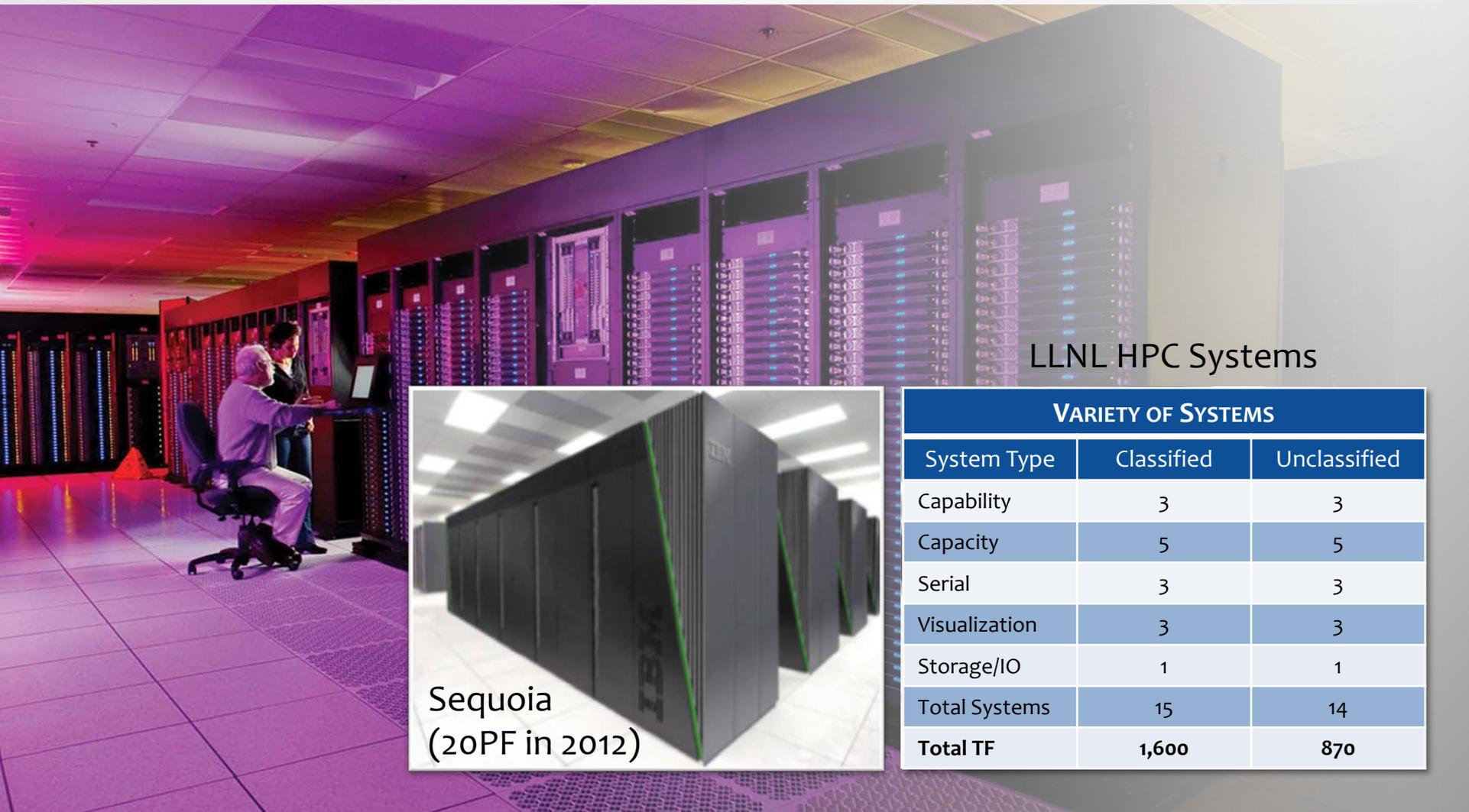


WRF/DART forecasts drive the Plexos stochastic unit commitment algorithm



- Deterministic economic dispatch with realized generation and load
- Stitch multiple days together
- Mid-term model for hydro scheduling

HPC platforms are used to perform weather modeling and production simulation research and applications



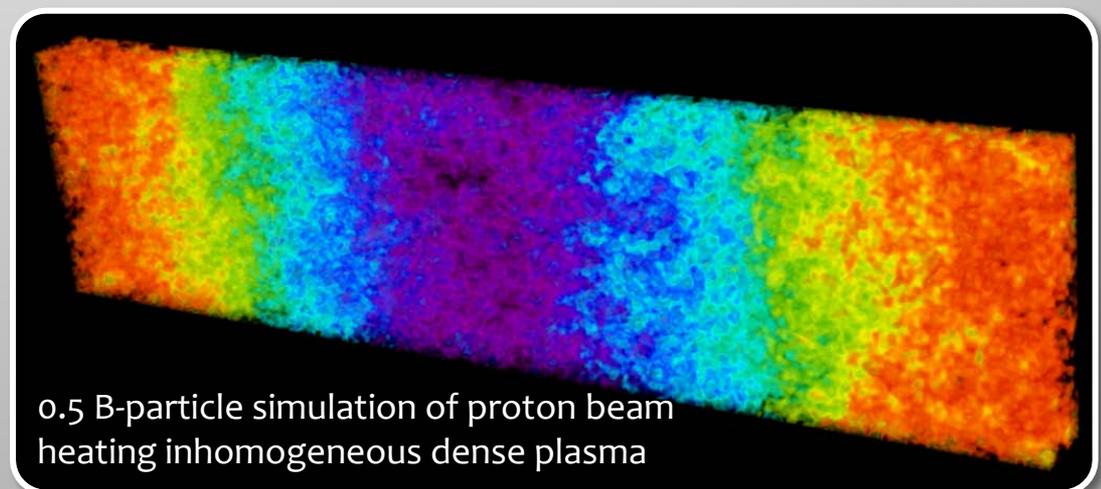
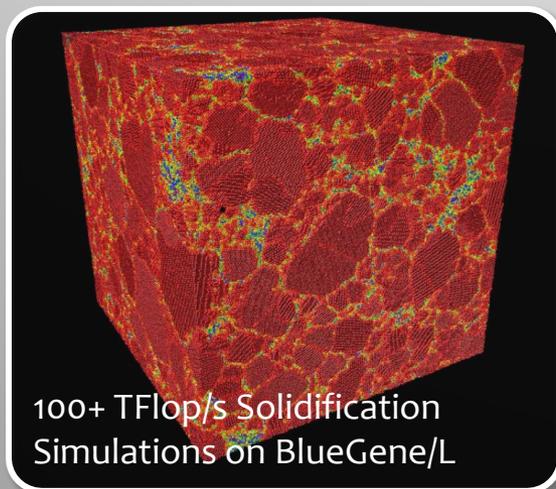
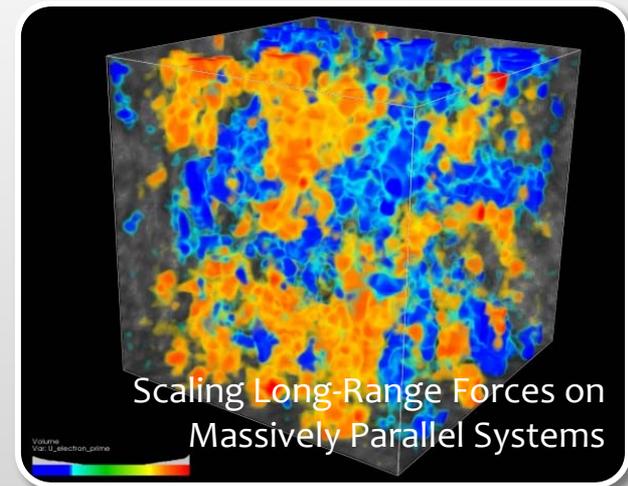
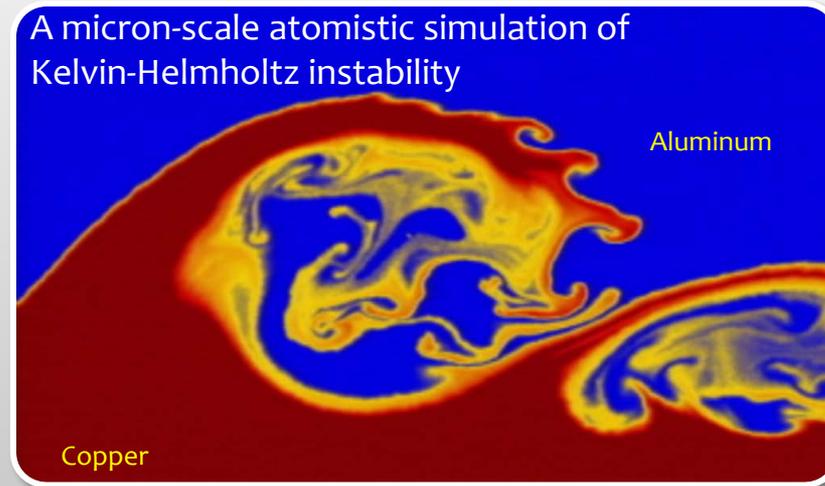
LLNL HPC Systems



Sequoia
(20PF in 2012)

VARIETY OF SYSTEMS		
System Type	Classified	Unclassified
Capability	3	3
Capacity	5	5
Serial	3	3
Visualization	3	3
Storage/IO	1	1
Total Systems	15	14
Total TF	1,600	870

HPC enables increases in problem size, scale, and complexity needed to capture important behaviors



Thank you.

Backups

HPC has dramatically reduced design costs in the aerospace industry

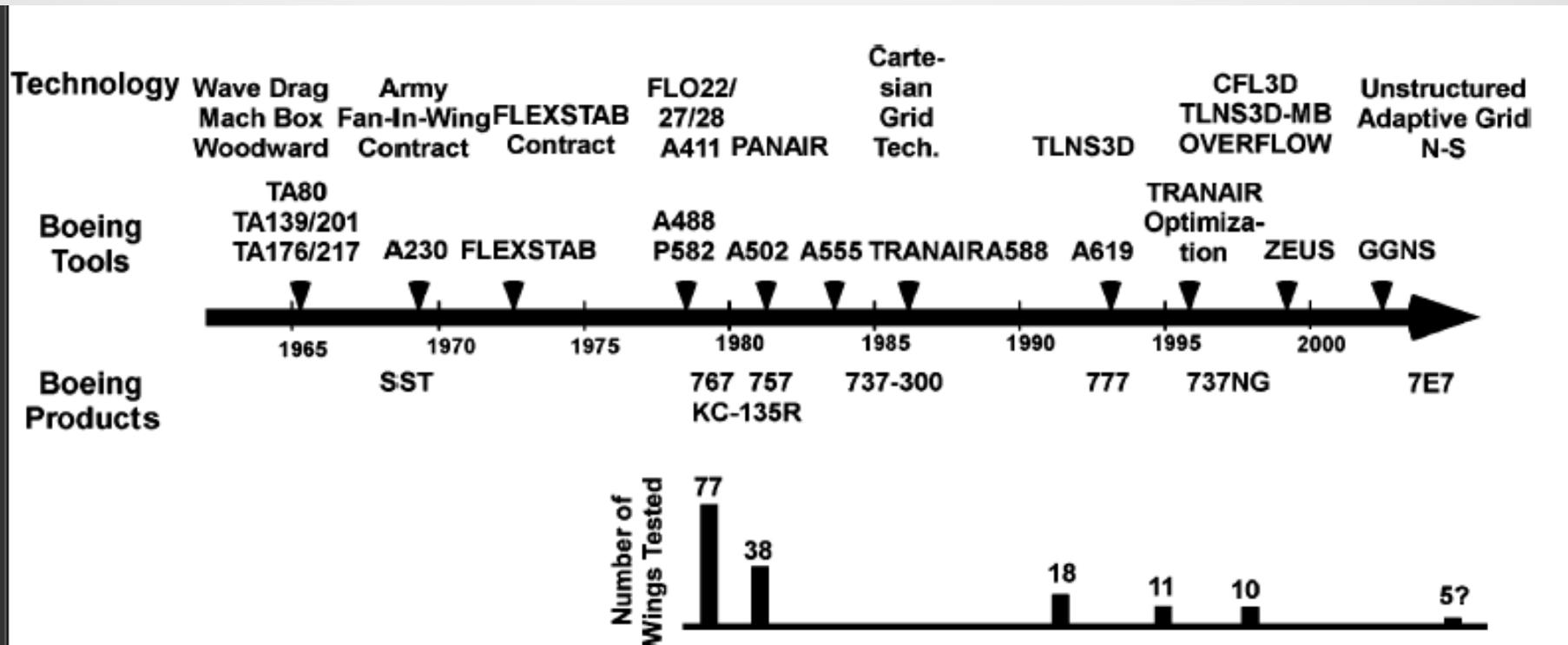
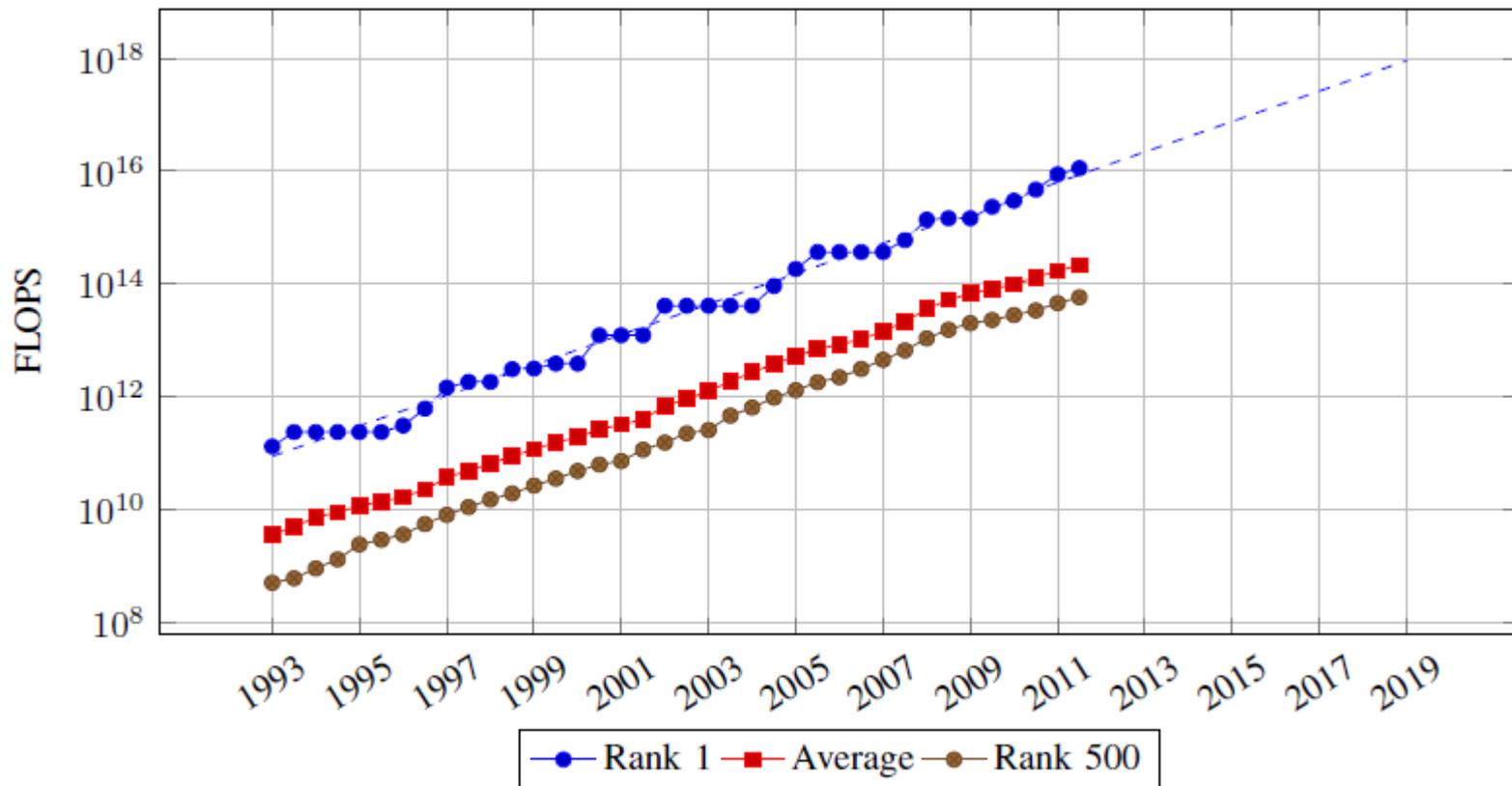


Fig. 1. Boeing code advances showing the reduction in the number of wing prototypes that required testing. [2]

Logarithmic growth in HPC performance to 20 PF this year

Performance of Top500 Supercomputing Sites Since 1993



Performance of top ranked, bottom rank, and average of the top 500 supercomputers based on the LINPACK benchmark. [3]

Shmuel Oren and Anthony Papavasiliou are using HPC for stochastic UC

