Boeing Research & Technology

Dreaming
Collaborating
Innovating
Exploring
Trailblazing

High Performance Computing at Boeing

Joerg Gablonsky

Technical Fellow, Chair Enterprise HPC Council,
Boeing Research & Technology Applied Mathematics Group

September 5th, 2024

Producing
Leading
Creating
Researching
Analyzing

Acknowledgements

Current Boeing Employees

- Craig Bosma
- Andrew Cary
- Kevin Castleman
- Adam Clark
- Bill Coulter
- Mark Fisher
- Stephen Fralich
- Konrad Goc
- Robb Gregg-III
- Marna Kagele
- Sergio Larrondo
- John Liu
- Robert J. Mayer
- Forrest J. Mobley
- Bob Narducci
- Nam Nguyen
- John Sabino
- Tyler Smith
- David Skinner
- Jeffrey Slotnick
- Joel Thompson
- Adam J. Wells
- Kris Williams
- And many, many others

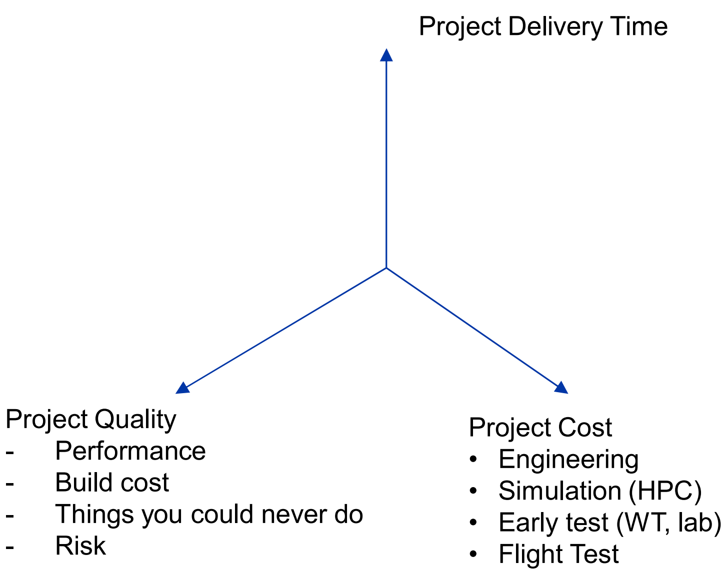
Former Boeing Employees

- Doug Ball
- John Bussoletti
- Jim Glidewell
- Joe Hafner
- Cindy Hasselblad
- Ralph Jorstad
- Barry Sharp
- Suresh Shukla
- Greg Siekas
- Matt Smith
- And many, many others

Why are we using HPC?

HPC is a critical enabler for engineering productivity

- HPC and high-fidelity simulations are tools that engineering is using to deliver on their projects
  - Example projects:
    - Product Development
    - Flight Testing
- Demand for HPC is driven by program needs
- Engineering wants to find the best point in this trade-space to enhance safety, quality and integrity of projects with results that also benefit time and cost
  - Can we use more HPC to improve the quality / reduce risk?
  - What is the best balance between simulation, early test (Wind tunnel, labs), and flight test?



Trade-space for engineering projects

Examples of projects that were and are impacted by HPC

Most Boeing engineering projects leverage HPC

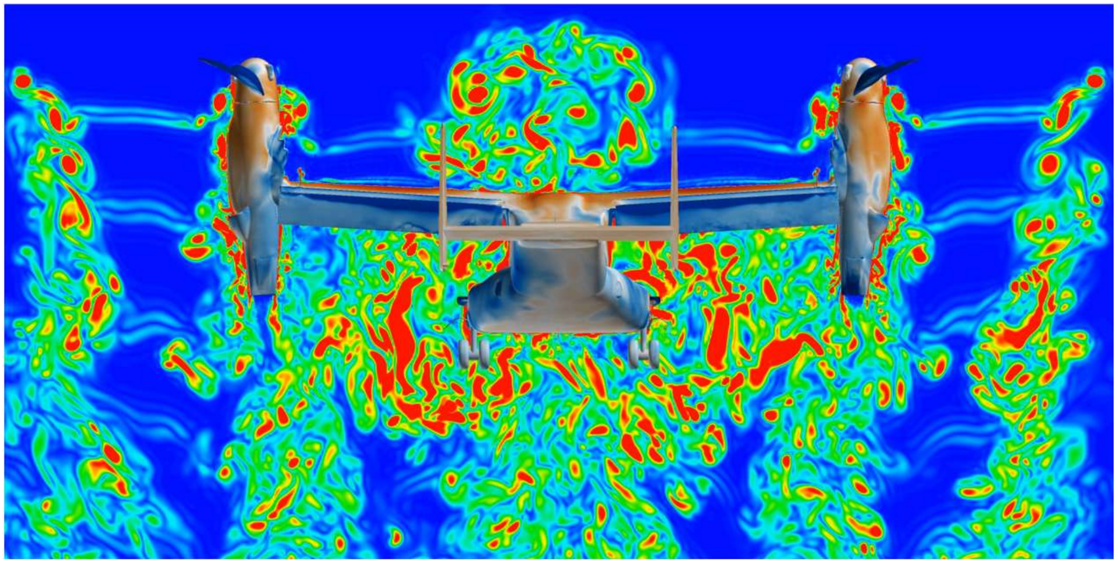
- eT-7 leveraged Computational Fluid Dynamics (CFD) Simulations on our internal HPC Systems
- Centralized service allowed program to meet aggressive schedule

HPC is a critical enabler of Boeing's engineering organizations

CFD Simulations of a Hovering Tiltrotor in Ground Effect

Rotorcraft simulations are very complex and drive computational demand

- Video shows simulation of the Bell-Boeing V-22 Osprey during hover over ground
- Computations show a dynamic flow field that creates an asymmetric environment surrounding the V-22
- Simulation required about 390 hours on 800 CPU cores → 312K core hrs
- HPCMP CREATE-AV Helios CFD was used to run this simulation
  – This combines 3 CFD codes
- More information can be found in
  CFD Simulations of a Hovering Tiltrotor in Ground Effect, Robert P. Narducci, John Liu, Adam J. Wells, Forrest J. Mobley and Robert J. Mayer, AIAA 2024-1115, Session: Special Session: Rotorcraft in Hover II Published Online:4 Jan 2024 https://doi.org/10.2514/6.2024-1115



Animation courtesy of Robert P. Narducci, John Liu, Adam J. Wells, Forrest J. Mobley and Robert J. Mayer

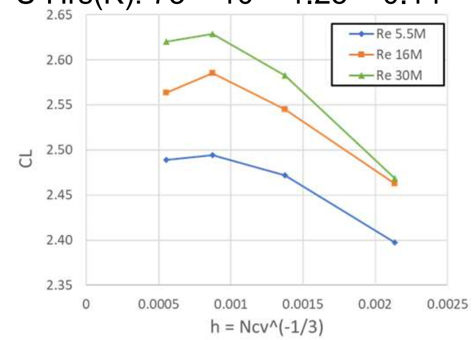
High-fidelity simulations allows engineers to answer program questions

Modelling the effects of aircraft icing

Can computational methods deliver similar results to experimental results using artificial roughness?

- To capture the impact of roughness in CFD, computational grids require several points per roughness height → 16X computational demand over clean configuration runs
- DoE Incite award on Frontier allows us to:
  - Verify that WMLES can capture the correct physics when explicitly capturing ice geometry
  - Develop alternative modeling approaches that simulate effects of roughness, without requiring dense grids
  - Understand grid-convergence which is out of reach with traditional systems → Higher confidence in every day runs
- Reynolds number increments are critically important in understanding how wind-tunnel answers scale to a full scale aircraft

GPU Hrs(K): 73 – 10 – 1.25 – 0.14



Reynolds number increments for clean configuration results

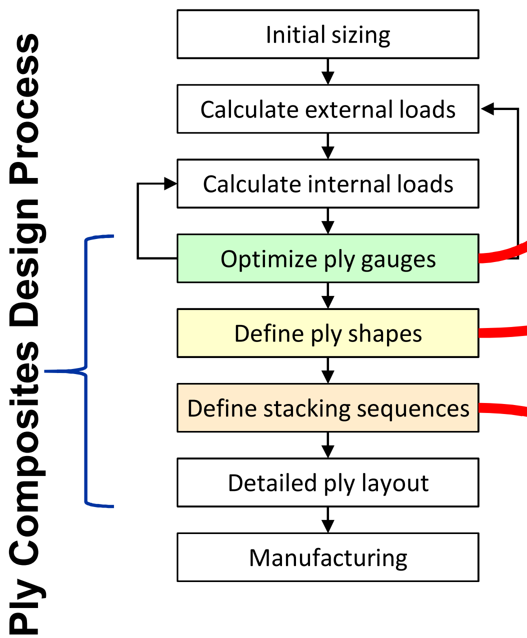
An award of computer time was provided by the INCITE program (ARD173). This research also used resources of the Oak Ridge Leadership Computing Facility, which is a DOE Office of Science User Facility supported under Contract DE-AC05-00OR22725.

Slide courtesy Adam Clark, Konrad Goc, Jeffrey Slotnick, Andrew Cary

Note: The GPU hours shown are calculated per Graphics Compute Die of the AMD MI250X. To convert to Frontier node hours divide by 8.

COMBINATORIAL OPTIMIZATION EXAMPLE: COMPOSITE PLY DESIGN PROCESS

- Optimizing the composites in an airplane wing is a computationally difficult optimization problem.
- Classical methods exist to piecewise determine an optimal solution
- Assess utility of using quantum methods to optimize the final step – the stacking sequence

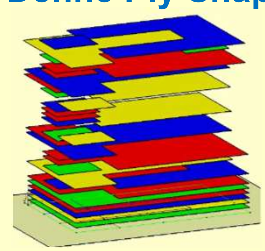


Optimize Ply Gauges

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1																															
2	143																														
3	146	124	98	87	84																										
4	134	125	91	84	87	100	61	61																							
5	134	133	89	71	79	111	56	51	59	56	59	59	61																		
6	132	125	83	65	73	86	57	53	57	59	57	59	59	67	73	68	72														
7	132	115	127	65	66	74	60	57	53	63	56	63	56	64	68	71	74	72	61	84	79	76									
8	132	109	119	77	61	65	57	59	57	64	58	67	60	67	65	98	72	69	70	77	76	72	67	75	98	77	81	66	78	68	63
9	131	109	113	133	60	61	54	63	84	63	85	64	76	67	65	97	70	68	69	80	76	71	75	109	75	83	69	71	75	68	72
10	131	125	107	112	58	58	56	63	88	62	105	63	113	71	65	66	69	64	105	83	73	69									
11	132	119	110	103	52	59	85	62	57	60	65	61	88	72	63	74	73														
12	128	110	110	107	51	59	99	58	51	62	55	62	62																		
13	128	106	103	97	61	63	98	61																							
14	126	111	93	90																											

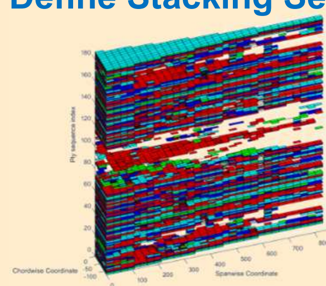
Determines total number of plies needed in a particular geometric location

Define Ply Shapes



Determines ideal shapes/drops through the stack

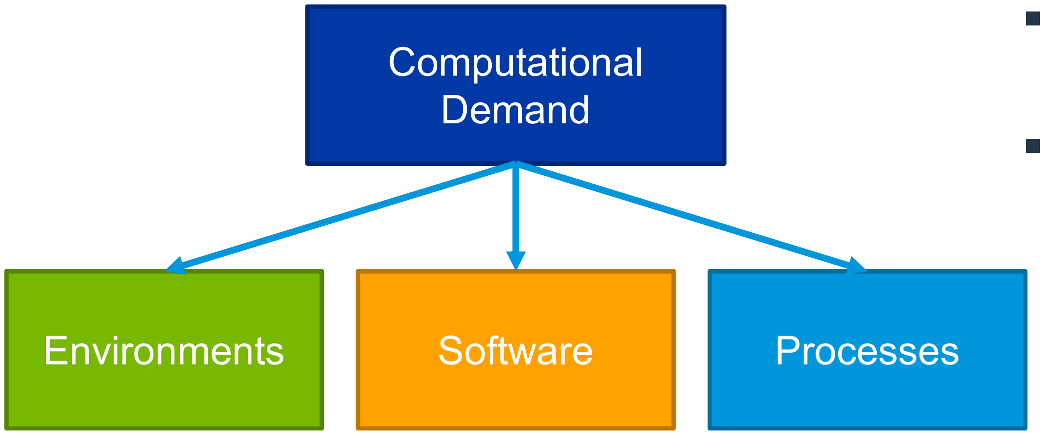
Define Stacking Sequences



Determines detailed stacking order of all plies throughout ply stacks

How to address the demand

We have significant demand growth, and need to address it in multiple dimensions



- All three core aspects can help address the needs of the engineering community
- Impacts can be multiplicative:
  - Porting SW to GPU and moving to cloud could allow us to reduce cost and decrease solution time over time

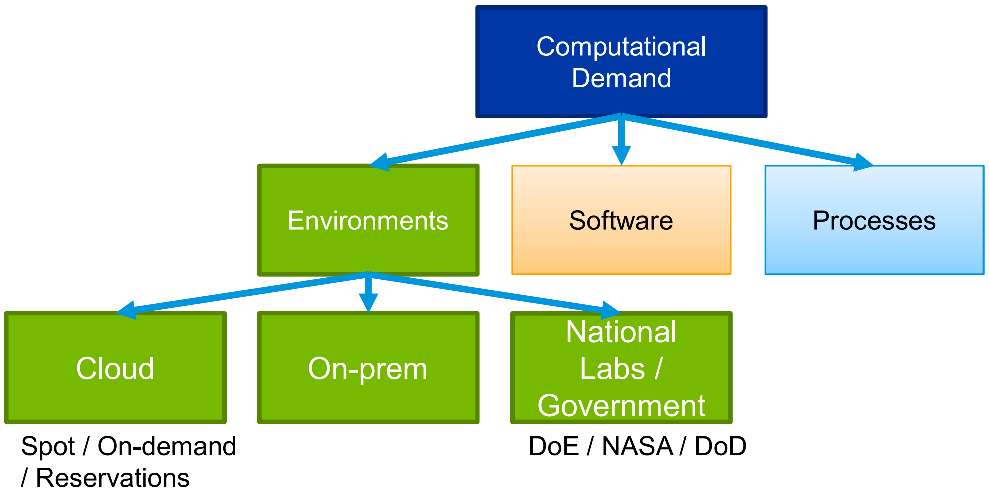
Ways to address the demand curve, cost, and improve quality

IT

Delivery of computational power

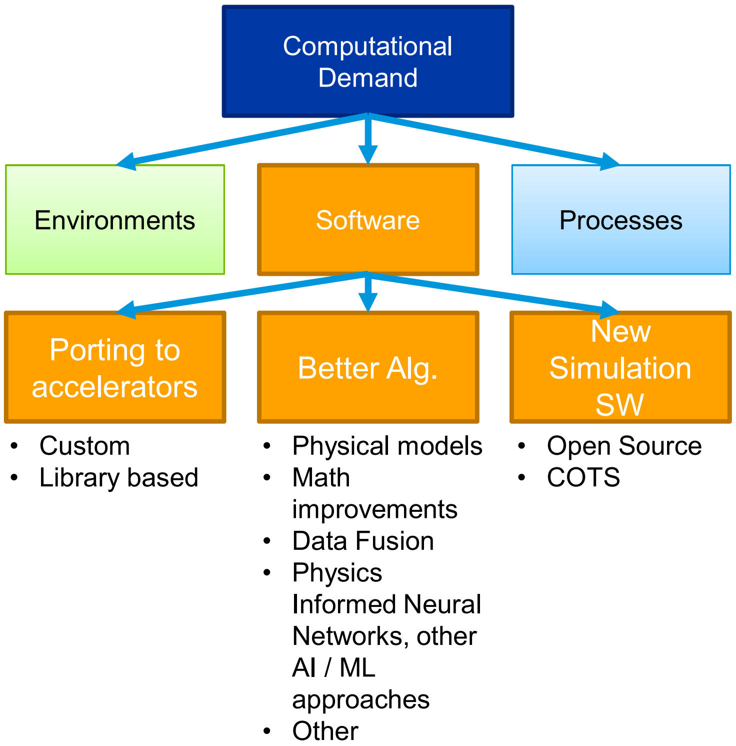
Cloud is a delivery mechanism with common and some unique characteristics

- Cloud, on-prem, and National Labs / government resources are similar from a HPC software perspective
- In cloud finding the optimal mix between business models will significantly impact spend
- Accessing Government resources often requires extra effort with regard to data movement and access, and has limits on what projects can leverage them



You need to have an all-of-the-above approach to access to computational power

Software investments can drive new capabilities and lower cost



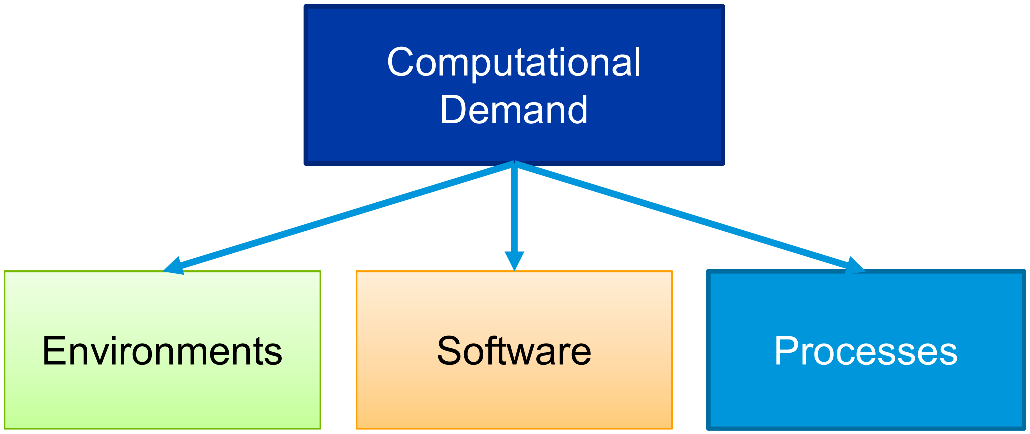
- Porting to accelerators lowest risk toward lowering cost per solution
- Algorithmic improvements are longer term with even larger pay-offs
- AI / ML for physics based simulations active research space
- Bringing in new software and certifying it for use inside Boeing is a multi-year effort

Investments in SW is important, and long-term planning required to leverage new tools

Users

Optimizing overall processes that drive computational demand

Changing the number of runs required at what fidelity can impact the demand



- Database generation via computing needs to leverage planning and taking into account differences to physical tests
- Some advances might drive computational cost but enable better insight and time to solution

- Workload planning and optimization
- Data Management
- Process automation
- MDAO methods and processes
- Design of Experiments
- Fidelity of Simulations
- Data Fusion
- Surrogate Modeling, including Advanced Kriging, Machine Learning, Reduced Order Modeling

Addressing processes is most disruptive to engineering

Quantum Computing promises breakthrough performance

For specific subsets of simulation needs

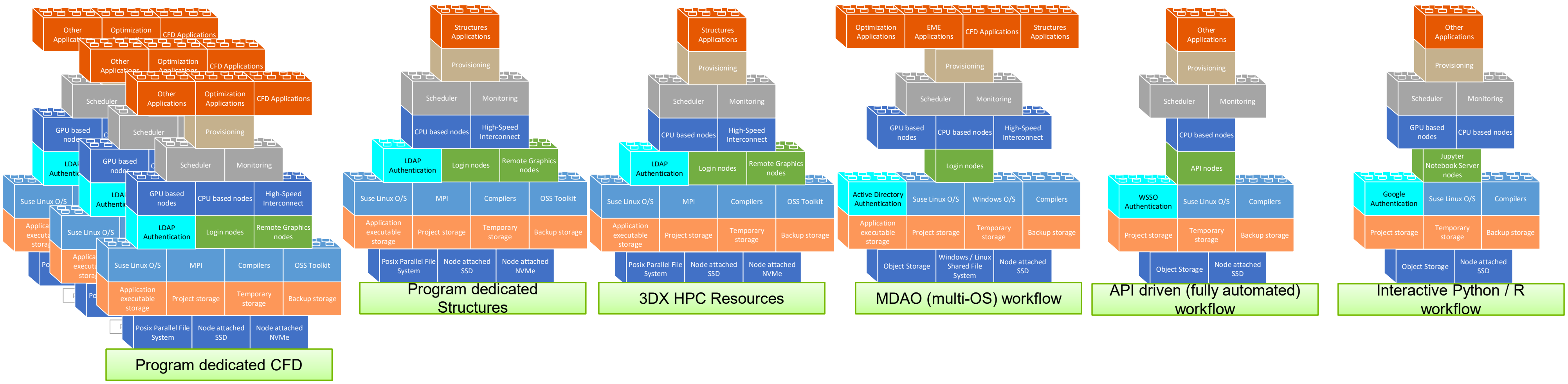
- We foresee the need to combine traditional HPC and Quantum Computing capabilities
  - Composite Ply Optimization process prime example
- Transitioning research progress into industrial usable software and processes will be a significant effort
  - All three aspects discussed in the prior slides apply

Quantum will be another tool in our toolbox

Thoughts on cloud and HPC

Future workload-optimized HPC environments / patterns

Unique HPC environments for specific workloads / teams in additional to shared environments



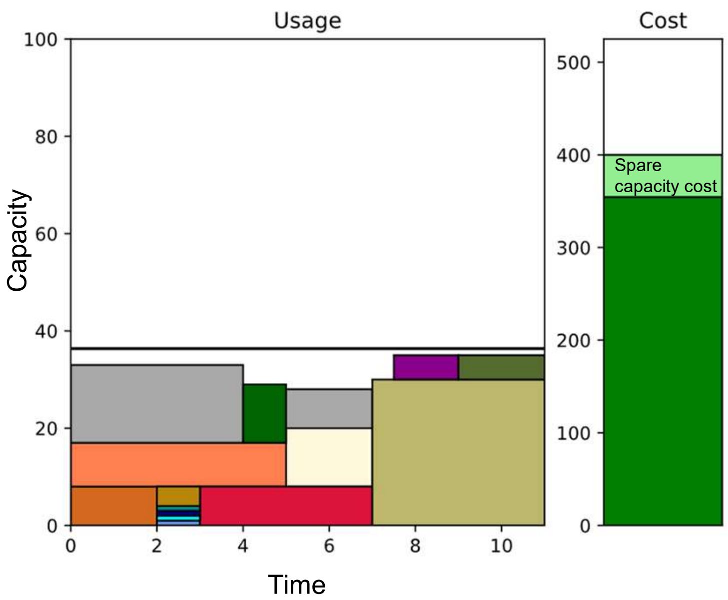
- Environments might be hosted in cloud or On-Prem, in the USA or International depending on user needs
- HPC embedded into other environments (web front-ends, other systems)
- This is a key enabler to move HPC workloads to a DevSecOps deployment model
- Cost-optimization requires understanding of application characteristics and cloud components
- Combine the availability of a shared environment with the ability to stand up dedicated environments

Optimize capabilities and minimize access instead of / in addition to a shared environment

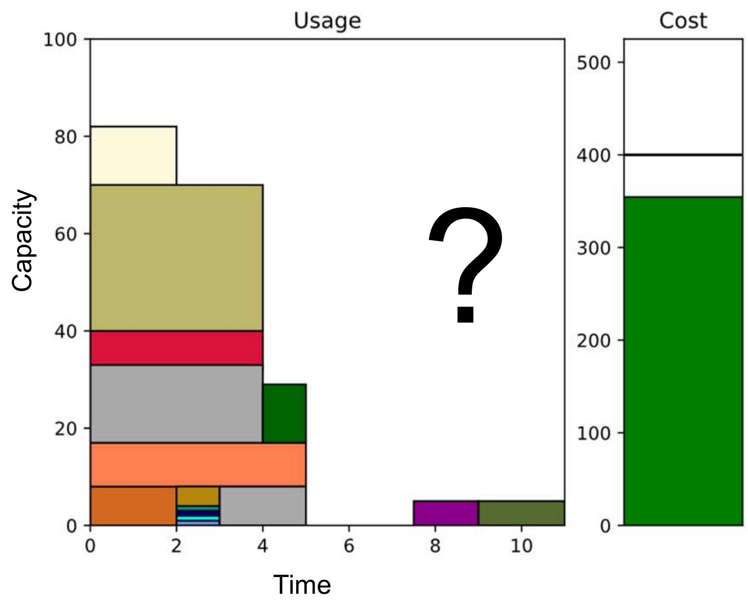
Is cloud going to solve your capacity issues?

Simplified cost model in this example:

Node hour on-prem and in cloud has same cost, on-prem you pay for capacity



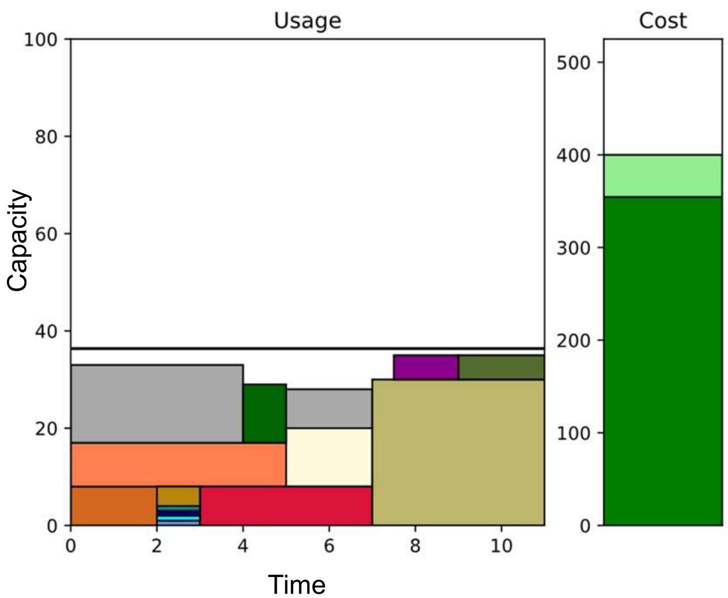
On-prem



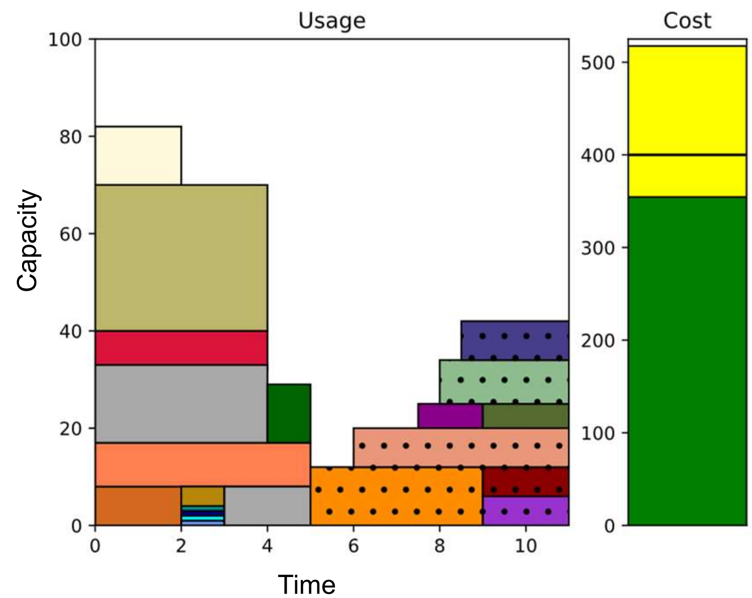
Cloud

Is cloud going to solve your capacity issues? – It changes them!

Forecasting is going to be key since cloud shifts your capacity issues from HW to $$$



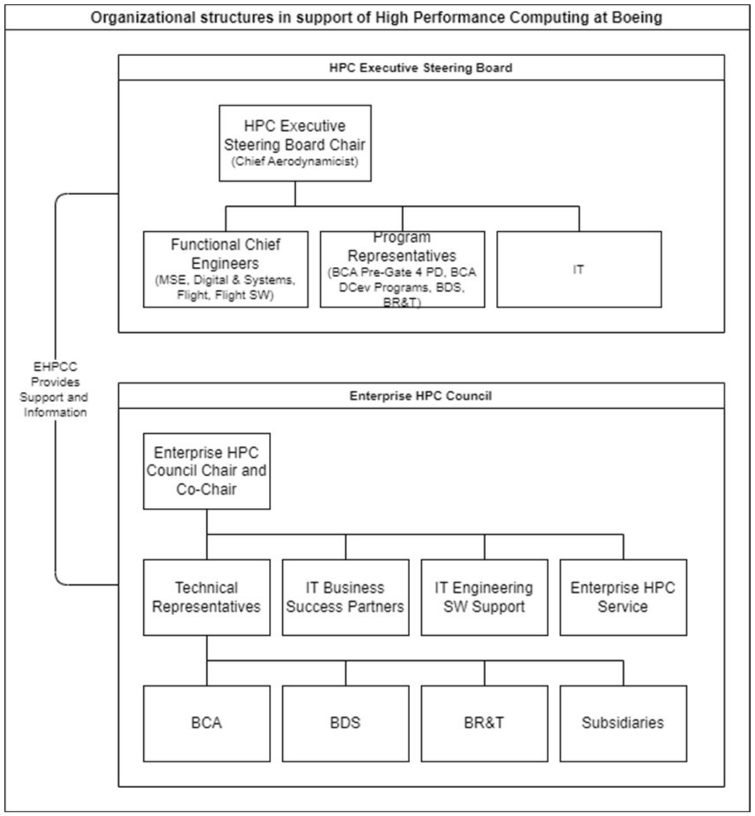
On-prem



Cloud

Budgeting and deciding what to do when becomes a lot more complicated when your cost is variable

Managing HPC demand and priority through a multi-tiered structure



HPC Executive Steering Board

- Future Engineering HPC demands, including budget alignment
- Strategic Directions for HPC (including 5-10 year plans)
- Prioritization of very large surge demand not handled by EHPCC

Enterprise HPC Council (EHPCC)

- Demand forecasting by organizations
- Prioritization of surge demand
- Input on strategic directions
- Coordination of HPC activities, including leveraging external entities (DoE, DARPA)

Buy-in at all levels of the company required

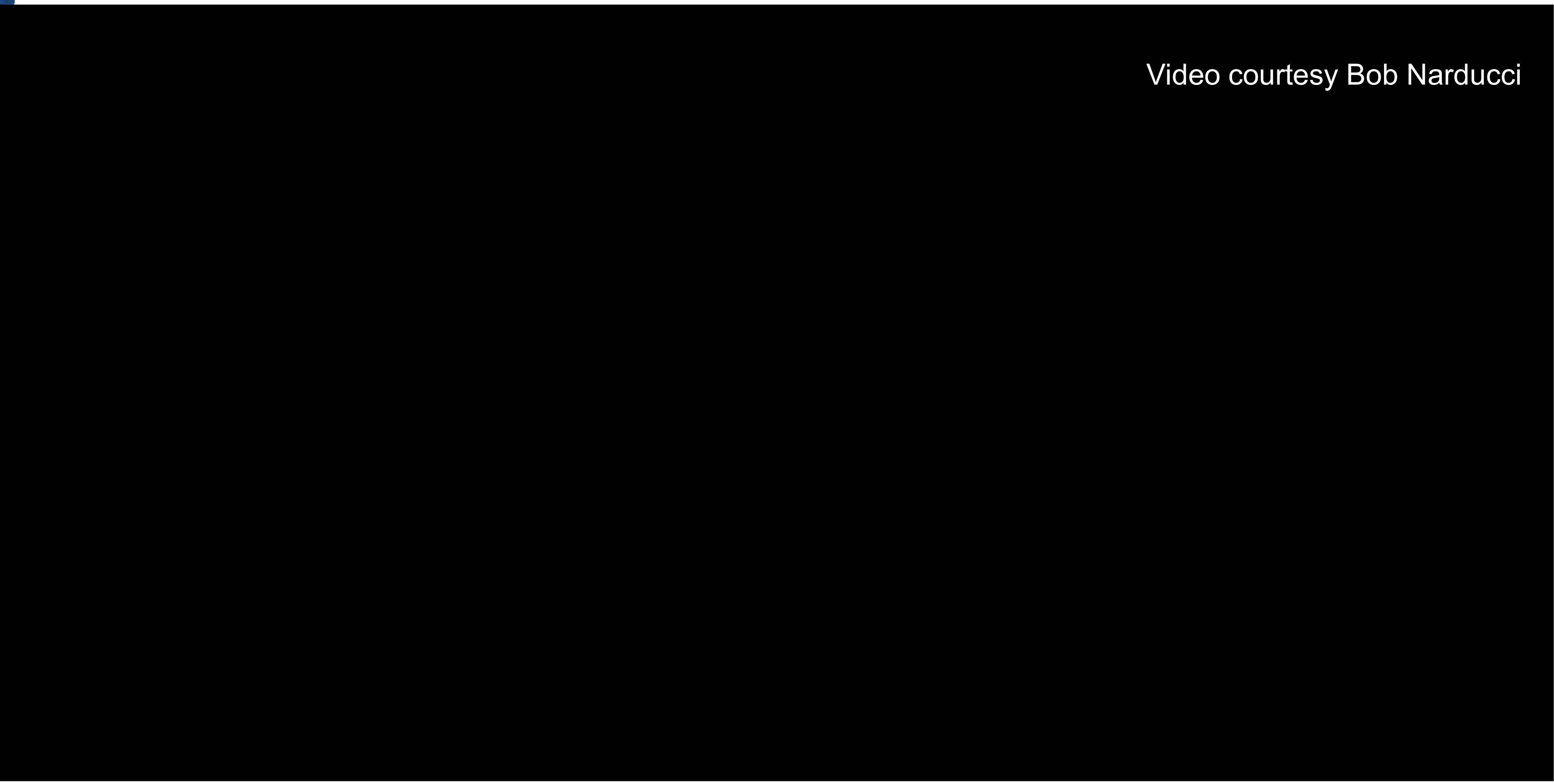
Conclusions

HPC is a critical enabler for Boeing

- Digital transformation will continue to increase demand for computational resources
- Both the use cases for simulation are expanding, as are the ways to deliver computational capabilities
- Addressing the computational demand requires a multi-pronged approach and partnership between IT, SW teams, mathematicians, and end-users
- Forecasting and managing spending will be key to maximize capabilities provided by cloud
- Boeing will continue to adopt modern computing platforms to design and support our current and future products

High fidelity computer simulations are paced by HPC capability

Questions?



Video courtesy Bob Narducci

Boeing Research & Technology