D/2: Facilities Preparation Inside the Building

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D/2 Facilities Preparation – Scope of Activity

- **Scope**- Facilities preparation inside the Building
  - *Reference the D1 session for the Facilities Preparation outside the building*

  - Getting building/floor space ready
  - Timeline for activities
  - Platform operational requirements and tolerances
    - Power/electrical distribution requirements
    - Cooling temperature
    - Weight
    - Environmental conditions
  - Level of effort for the activity
  - Cost

Scope of activity - What needs to be done?

- Set expectations and establish boundary conditions:
  - Facilities upgrades need to balance the anticipated lifetime/timeframe of the transformer/switchboard/chiller (20+ yrs) to the anticipated lifetime of the compute system (5 years).
  - (Best Practice) Provide this information to bidders through the RFP process to reduce risk to a specific solution that may introduce longer term operating issues.
  - Leverage ASHRAE standards for water quality and temperature. Example - Reference 2011 Thermal Guidelines.
  - Industry-standard products reduce installation cost, reduce incompatibilities, reduce conflicts. Example - Separation of primary cooling loop from system-specific cooling loops;
  - Does the use of new pipe products, such as thick-wall polypropylene, instead of black pipe/carbon steel, introduce restrictions on the community of HPC and systems vendors?
    - IBM was concerned about leaching, water pressure, etc. These concerns were alleviated through IBM/independent testing. Poly has a 180F limit. Fire marshal(AHJ) may also have an issue with poly in a plenum space. (introduces a new issue of fire protection/suppression in those plenum spaces)

What Needs to Be Done – Determine Facility Limitations

- Decision- Retrofit/New/Colo?
  - In the facility, **what is enduring, what is not enduring**. What can go? How can the space be refitted? Are there critical design points that preclude use of that space (weight restrictions, hard pipe limitations, electrical distribution capacity) ?
  - Use of Colo is a new/emerging concept, where there may already be facilities that can provide the space. Challenges include adequate bandwidth, separate networks, cyber and physical security concerns.
  - Some **cost points** for retro/new
    - $10M for 6,000 square feet (LLNL)
    - For new buildings, something between $2.5-3M/MW (NREL design point)
    - For clean adds, something like $1M-1.5M/MW. (ANL, ORNL budgetary estimates)
    - Pods? Modular containers? ~$1M+ each. These may have a place for commodity equipment, but strategic assets typically require more infrastructure. Perhaps a place in Disaster Recovery planning, with 1-2MW total load requirements.
- Process
  - Identify available capacity, and shortfall
  - Identify long term energy efficiency cost savings, TCO, ROI for new facility versus retrofit.
  - How are the existing and new facilities integrated in to the larger Site/Master Plan?
  - Identify methods/systems/equipment for covering those shortfalls
  - Detailed engineering plan that includes impact to power, space, cooling, environmentals, equipment selection
  - Detailed project plan (budget, resource-loaded schedule, deliverables, etc)

Scope of Activity – The Timeline

- What begins first: timeline for activities (Does this activity occur before or after hardware)?
  - Substantially before RFP.
  - Strategic Planning (capacities of space, electrical distribution, cooling)
  - Execution Plan
- Rolling annual update of the 5 year master Plan
  - Insert real life (year-end purchases, manufactured emergencies “your failure to plan does not constitute an emergency on my part”)

The Role of Early Hardware Access.

- What is the role of early hardware access (either locally or remotely) and prototype systems?
- Receipt of an early or test/development system helps validate the MUS values that were provided by the OEM/vendor.
  - Identify facility-related shortfalls that can still be corrected before the larger system arrives.
    - Secondary loop problems, (we want to receive the final product, not the initial engineering product).
    - Address early problems with safety standards, interlocks, etc.
    - Harmonics (Cray XT5 power supplies generate significant harmonics that were affecting transformers). Not identified until after installation.
    - *"Its better to retrofit at the factory than instead of on my floor"* –J. Broughton.
  - But don't fool yourself- the test system will not reveal the issues that will be seen at scale.

What is the role of vendor partnerships?

- Pre-delivery
  - Accurate engineering estimates for power and cooling demands
  - Accurate engineering estimates for rolling and point loads
  - Accurate engineering estimates for environmental controls, water chemistry, similar.
  - Timely Machine Unit Specifications from these engineering estimates that allow timely completion of site prep.
  - Support development of Commissioning Plan(There are elements of both Facilities Commissioning and System Commissioning)
  - (Best Practice) Visit the vendor. Packaging is critical. Make SURE that there are no surprises. Re-fit to accommodate these unnecessarily increases site prep cost.
- Post-delivery and Operation
  - Identification of variances from engineering specification/MUS
  - Assistance with execution of Commissioning Plan
  - Accurate FIT rate, power consumption data
  - Examining/considering/supporting allowable variations to operating conditions and tolerances that can improve Center efficiency without impacting system

The roles of R&D and engineering?

- What role can NRE play? Is there benefit?
  - As an example, consideration of 600V distribution instead of just 480V as the default.
  - Warm water (and hotter) cooling strategies
    - May support additional options for energy reuse that can lower total facility costs.
  - *"Cooling efficiencies allow higher densities, reduce investment in infrastructure, allow more dollars to be allocated to computing, not infrastructure."* – Steve Hammond
  - The packaging design for a system can take as long as the chip design: NRE can definitely provide value.
  - Potential to reduce the complexity of the interface between facilities and these large systems- "*plug and play*". We hand them the large power and cooling sources, and let the vendor take responsibility for its integration into their systems (an Option in CORAL)
  - Emergent technologies- how do we shift legacy air-cooled/208V systems (such as the file/storage systems) to more efficient packaging?
  - The coexistance of cold- and warm- air-cooled environments is difficult/challenging.

What resiliency activities are executed (for example, redundancy)

- Electrical (Inside)
  - Critical systems may need redundant, load sharing power.
- Mechanical
  - n+1 (or better) chillers, towers, pumps, heat exchangers
  - diverse routes (and valve/control systems) for delivery of chilled water
  - Best Practice – chilled water system must have some minimum pumping capacity on a redundant/diverse/UPS power source.
- Fuel Cells (external to the facility)
- Use of Renewables

Organization and management

- What is the structure of the integration and preparation teams?
  - Are these maintained as separate teams?
  - Are these maintained as matrixed teams?
  - Are these roles the responsibility of a single organization?
  - Are these roles the responsibility of multiple organizations?
  - Do you take advantage of subcontractor or third-party services? Which of these are effective? Which are not?
  - **Takeaways**
    - Operations teams are tightly coupled with the Facilities Teams
    - SMEs/skilled third party crafts can provide value
    - What skills do you need to maintain all the time as part of your “bench” and what skills can be outsourced? Cross-training of staff allows you to cover your base needs in the face of declining staff numbers/budgets
  - **Consider**
    - Physical and Cyber Access Control to Facility
    - Access Control Lists, Proper Training for Access to Machine Floor, PPE, Subcontractor Flow Downs of Safety Requirements, Lab Space Manager with responsibility to ensure that requirements are met.

Organization and management, cont.

- What are the necessary skills for the activity team?
  - What perspective is most useful? Facilities and Systems as separate functions, working together? Where should ownership lie?
    - The less integrated these teams, the more challenging. Inefficiencies, potential for miscommunication and errors. Tie this back to the best practice of an integrated project schedule.
    - Example – LLNL's Impact Meeting – Events that impact others make this Master schedule.
  - Skill sets-
    - Technicians, controls technicians, operators, facility knowledgeable computer scientists (facilitate Facility to Customer Communication, accurate interpretation of requirements), engineers, project manager, financial officer, subcontracts administrator

Experiences and lessons learned

- Programmatic
  - Strong Commissioning Plan
  - Capture Lessons Learned in a structured post mortem
  - Ensure that OEM contract includes specific clauses protecting customer from unexpected deviations from Machine Unit Specification (MUS) (weight, etc) and pushes responsibility for damages/reparations to OEM.
- Electrical Distribution/Systems
  - Load bank testing is mandatory
  - Maintenance
  - Configuration Management- the issue of power distribution, from the transformer to the equipment: one step beyond the 1-lines.
- Mechanical Distribution/Systems
  - Never undersize pipe. The cost is all in the labor, so go big.
  - Test makeup water to see what variations exist in supply water quality. Water quality varies over the course of the year, and may introduce operating issues with new systems.
- Environmental Controls
  - Water treatment controls to reduce/eliminate conditions affecting scale, etc.
  - Construction is dirty. Protect sensitive equipment (tape archives especially) with separate containment if possible. Supplement with HEPA filters, regular cleaning. Minimize debris (construction, manufacturing, packaging)

Experiences and lessons learned, cont.

- What were the most productive activities?
  - Integrating Facilities and Systems Integration Groups to ensure consistent lines of communication. Early involvement in procurement activities to eliminate/reduce impact from unforeseen issues.

  - Electrical Distribution Systems
    - Metering at no less than the rack level.
  - Mechanical Systems
    - Sub-metering
  - HPC
    - Press for SEMI F47-compliant or ITIC-compliant power supplies
    - Longer ride through, better tolerance to PQEs

Experiences and lessons learned, cont.

- What were the resiliency experiences?
  - Critical systems should have hardened, diverse, redundant electrical distribution/power systems. What is the tolerance to a CW outage? How long until equipment must EPO to prevent damage?
  - Example- chilled water pumps should have diverse/redundant/UPS feed to ensure that the physical asset is protected in the event of a loss of line-side/normal power to Central Energy Plant
  - How can Facility Maintenance be structured such that interruption to operations of the systems is minimized?
    - We need enough redundancy in the Electrical and Mechanical systems so that we can reduce impact to systems.
    - Understand that there may be a significant cost associated with some of these design features
  - How do you recover when something bad happens?
    - (example) No paint on pumps. Overspray on the impeller kills.
    - Contingency planning.
    - “I can’t make this stuff up” – AMB
    - Do not commission anything at Christmas

Experiences and lessons learned, cont.

- What was the highest risk? Was it a surprise or expected?
  - The “unknown unknown”. With every new project, facility change, system install, there are new issues.
  - Highest risk is that we do not meet the programmatic requirements … no float left in the schedule. No contingency remains. Impacts delivery to operation.
  - Large-cost items can remain at the end.
  - Risks that are accepted, as very low probability/high impact, and then occur (e.g. flooding in Thailand causes significant supply chain issues)

Most significant observation

- Provide a summary statement for the most significant observation
  - All sites have similar issues. Some surface at different times. Lessons learned should be leveraged among sites.
  - “Get the facilities people involved early, often, and always “- Kim

Effort estimate

- How big of an effort was this (facility prep for a new system)? Team size?
  - Estimate $1-1.5M/MW as a Project cost for an upfit to an existing facility (clean install)
  - Estimate that ~50% of project cost is labor (subcontractor, PM, etc.)
    - Significant fluctuations in labor and material costs based on supply chain issues, skilled labor demand, etc.
  - How many FTEs? Are these people already on-staff? Is this other-duties-as-assigned, or is there bench support for this work?
    - These are big efforts, with several ten's of people participating.
      - Planning and design effort.
      - Construction effort
      - Colocated activities? Parallel efforts in the same space can dramatically impact schedule, cost, risk.
      - System Installation and Integration effort.
      - In existing facilities, the conflict of managing existing operations while upfitting the existing facilities.

(Additional Topic) - Funding

- Is the activity funded as a separate project?
- Is the activity funded as part of the acquisition?
- Is the activity funded through external mechanisms, such as third party landlord, or other?
- Is the activity funded separately, through operations (not a separate project)?
- How are budgets for facilities improvements derived? (lab investment, program office line item, operations) and who does these- sow/engineering firm/architect?
- To what extent is the cost for the decommissioning of the system accounted for?
- What is the anticipated life time for the major components of an upgrade? Are the medium voltage improvements a 25-40 year item? Transformer and switchboard improvements a 20-year item? Chilled water loops- 10-15 years? Ancillary and secondary and step transformers- just 5 years?

(Additional Topic) -

- Are the same project management requirements in play? (earned value, resource loaded schedules, etc).
- Is the activity managed by existing staff, or is there some surge capacity or additional labor resource available? What stress does a new project have on existing operations?

Best Practices

- Future-proof your facility- make every effort to prepare the facility such that it is flexible for subsequent systems. Incremental upgrades at lower cost.
- Scaling facility infrastructure: the concept of “right time” improvements and upgrades.
  - Reduced cost, less rework, better integration with new systems.
  - And the corollary, don’t install infrastructure components (e.g. hard pipe) that cannot readily/easily meet future demand.

Best Practices

- RFPs that fully describe facility boundary conditions, requirements for ASHRAE standards (water quality, temperature ranges); integrated system planning that includes the system siting, as a requirement back to the vendor.
- Integrated Project Plan that includes the full Facility Procurement/Build (to Certificate of Occupancy), RFP, System Acquisition and Integration
  - Great example at LLNL that includes every system on a single timeline. Historical reference to present day.

Best Practices

- Visit the vendor and examine the actual operating conditions under which the proposed system is operating. Identify conflicts between your facility/infrastructure, and their expectations/anticipations.
  - Packaging is critical. Make SURE that there are no surprises. Re-fit to accommodate these unnecessarily increases site prep cost.
- (Facility Design/Operations) Chilled water system must have some minimum pumping capacity on a redundant/diverse/UPS power source.

Shotgun (or what to talk about at parties)

- Minimum freight elevator limitation of 10,000 pounds gross
- Minimum finished door heights of 9’ (10’+ preferred) from dock to machine room, and 12’+ from deck to deck
- Never build a raised floor to 125 pounds/ft2. 250 is a bare minimum. Consider slab-on-grade, dedicated plenum spaces, multi-level designs that can eliminate the need for raised floor.
- Fire detection and suppression
  - Debate: wet pipe vs. dry pipe
  - Use of VESDA, HSSD (High Sensitivity Smoke Detection)
  - Widespread use of zones
- Test your shunt trips and EPOs regularly

More shotgun (what Dave talks about at parties)

- Caution: Be aware of non-uniform interpretation and enforcement of fire protection/safety requirements by the FPE/AHJ (and worse, changing interpretation over time)
- Classify your space as a single story multi-level machine room to simplify the interpretation by the FPE/AHJ of the plenum spaces below and above
- Beware hot-aisle/waste heat containment strategies, as they may not meet the interpretation of the AHJ
  - When is a space a plenum? Not a plenum?

High Level Takeaways

"There is no perfect solution" – Susan Coghlan

- Mechanical systems are hard to change
  - Rigid infrastructure
  - Control sequence is a hard problem
- Electrical systems are costly to retrofit/expand
  - Evolving electrical codes
- Structural limitations are show stoppers
- *"The needs of the machines are evolving faster than the timeline for the facility investment"* – Jeff Broughton
- Challenge: Balancing the Programmatic Need and the Facility Benefit