Pacific Northwest
NATIONAL LABORATORY

Deflagration Prevention for GSL Facility Design

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GSL Vision as a National Capability

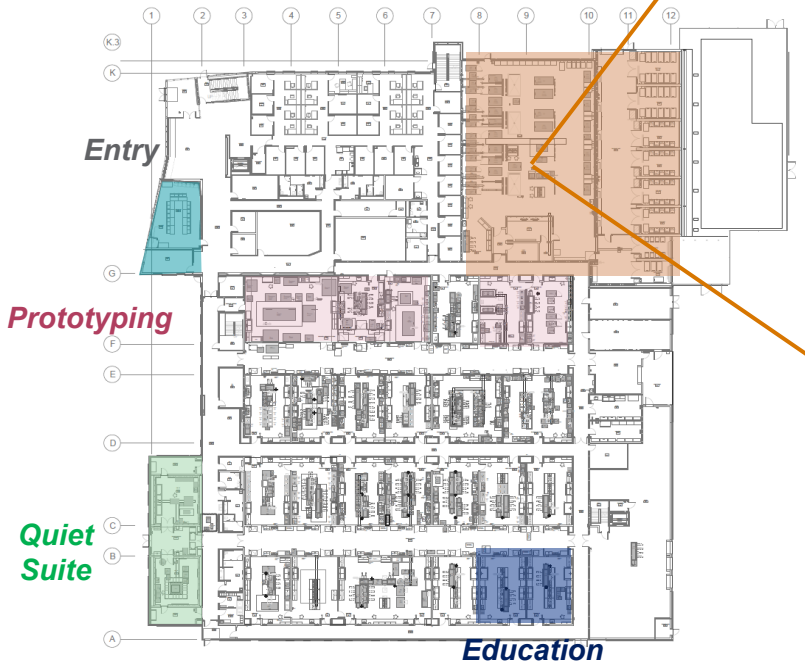
- Provide systematic and independent validation of new grid storage technologies from basic materials and components, through prototyping under grid operating conditions
- Test grid-scale battery systems (100kW)
- Enable the U.S. to maintain leadership in the next generation of grid energy storage technologies.

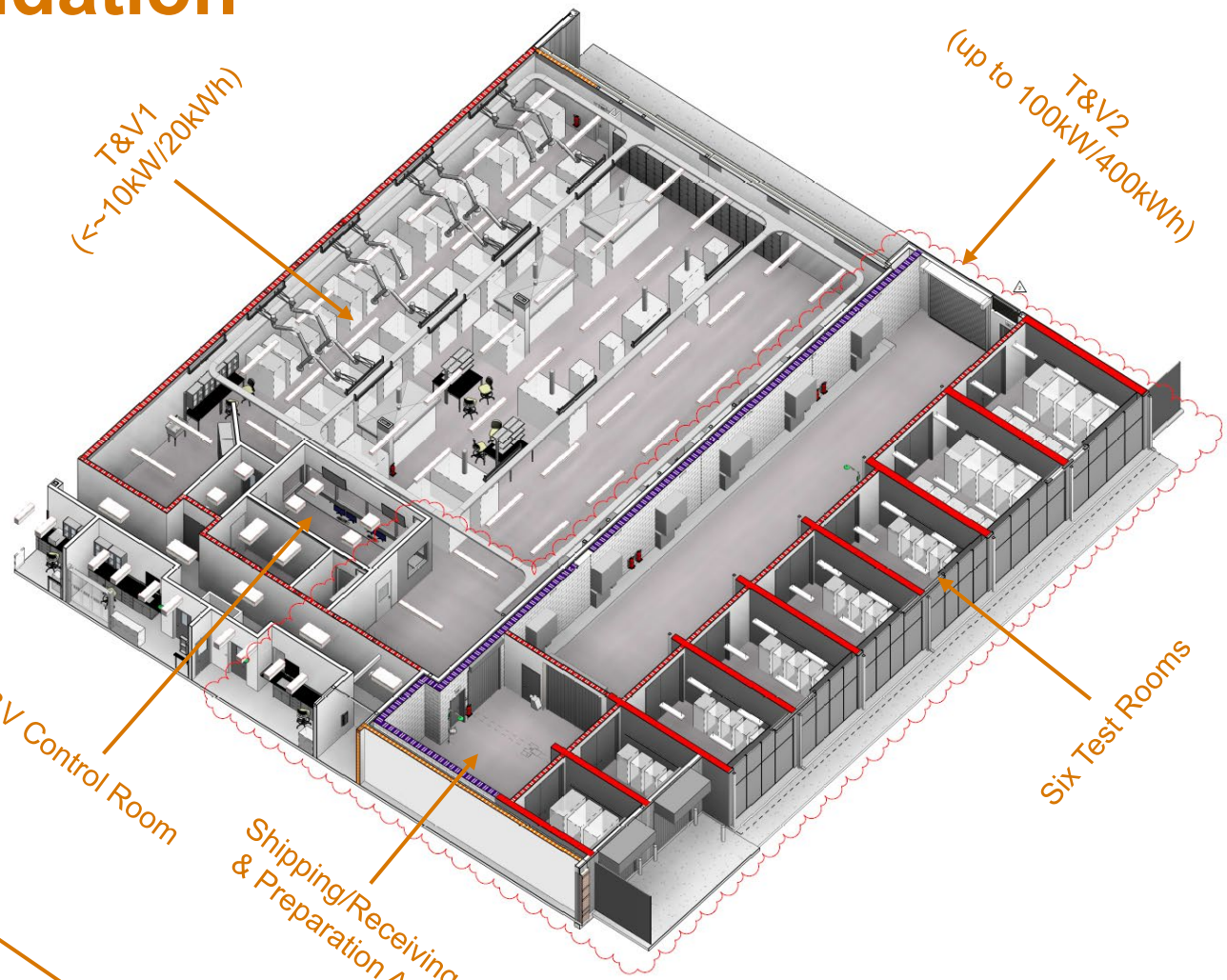
$77M
TOTAL ESTIMATED FACILITYCOST

100+ WORKSTATIONS

30+ LAB MODULES

GSL Test and Validation





Initial T&V2 Capabilities & Design Basis for Deflagration Prevention

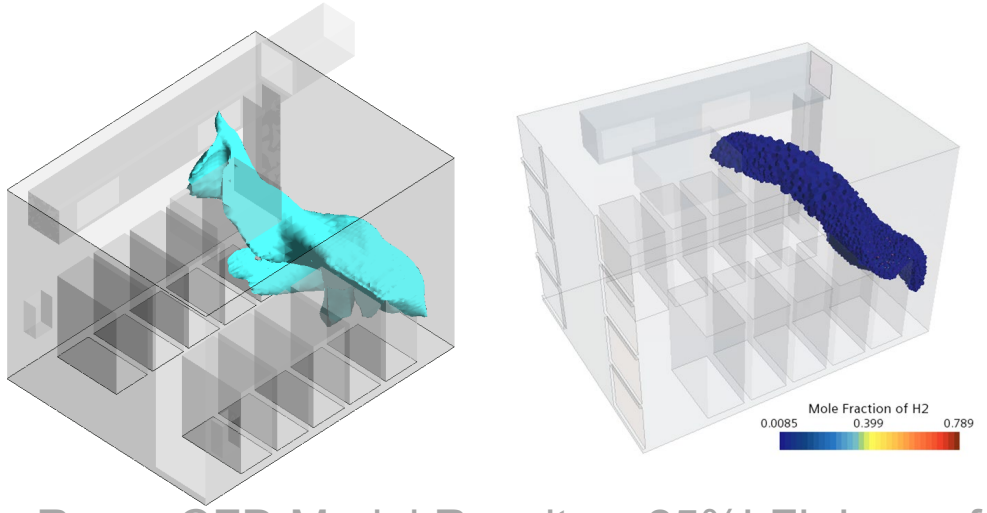
- Up to 100kW/400kWh Battery Energy Storage Systems
  - Closed Cell, Organic-based (Li-ion, Na-ion)
  - Aqueous Chemistry (lead acid, Zn-Ni)
  - Redox Flow
  - Molten Salt/metal (Na-metal hydride)

- NFPA 855, *Standard for the Installation of Stationary Energy Storage*
  - GSL reference design standard (not directly applicable to R&D activities)
  - NFPA 855 → NFPA 69 → ANSI/ISA 84.00.01 (IEC 61511)
    - ✓ NPFA 855: "Explosion prevention systems designed, installed, operated, maintained, and tested in accordance with NFPA 69"
    - ✓ NFPA 69: Chapter 8, "Deflagration Prevention by Combustible Concentration Reduction"
      - Explosion prevention system controls installed after November 5, 2021, shall be implemented as a SIS…to achieve safety integrity level 2 (SIL-2) or greater in accordance with ANSI/ISA 84.00.01"

Deflagration Prevention Design Process

- Flammable gas production evaluation
  - Challenge
    - ✓ Design for a wide range of current & future technologies
    - ✓ Unknown system configurations
  - Solution
    - ✓ Evaluate current/known systems
    - ✓ Application of safety factors to bound wide range of unknowns and future research

- Define required ventilation rate
  - HVAC standards
  - Safety factors
  - Confirmatory CFD models



Large Room CFD Model Results – 25%LFL Isosurface

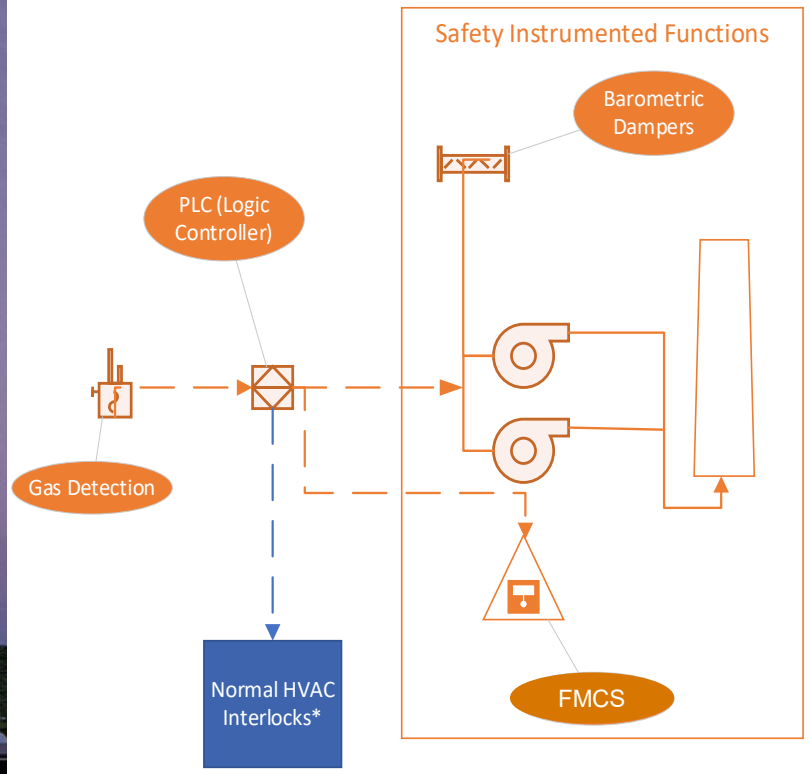
SIS SIL-2 Design Process

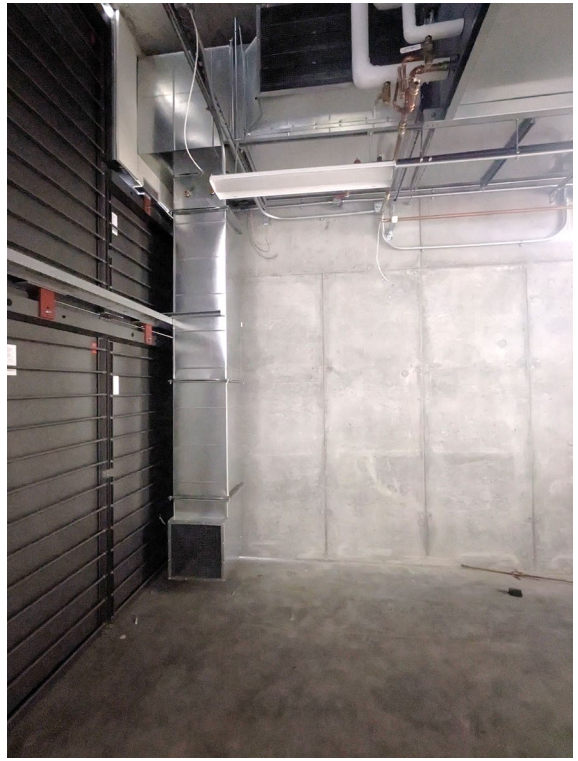
- Control system design
  - Definition of safety instrumented function (SIF)
  - Sensors, logic solver (PLC), final element(s)
  - System logic design

- Reliability analysis
  - Probability of failure on demand (PFD): SIL-2 target 10^{-3} - 10^{-2}
    - ✓ Considers all system components
    - ✓ Most systems contain a mix of SIL-certified and general service equipment
    - ✓ Likely to drive redundancy and selection of certified (expensive) equipment

- SIL verification planning
  - Factory acceptance testing
  - Site acceptance testing
  - Periodic proof testing

GSL Deflagration Prevention System Design





Operations Impact and Long-Term Considerations

- Protection of deflagration prevention system design basis
  - BESS proposal and acceptance process
    - ✓ Evaluation of system bounding flammable gas production rate
- System engineering and configuration management
- Maintenance of SIL rating / system operability
  - Regular equipment maintenance
  - Annual SIL proof testing
  - Change management / reverification of SIL rating

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Thank you