VSS035

Vehicle Systems Integration (VSI) Research Laboratory at ORNL

… an integrated approach to advanced transportation technologies

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U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

OVERVIEW

Timeline	**Barriers***
• Project start date: Oct. 2010 • Project end date: Mar. 2012 • 10% complete	• Risk aversion • Cost • Lack of standardized test protocols **from 2011-2015 VTP MYPP*
Budget	**Partners**
• New project, no FY10 funding • FY11 (current) funding: $1500k • FY12 (projected) funding: $500k	• Oak Ridge National Laboratory

OBJECTIVE: A new research facility to address the complex interactions of advanced prototype technologies for maximum efficiency with lowest possible emissions

The "WHY"

- **An integrated approach is critical to the expeditious development and implementation of advanced transportation technologies.**
- **Significant improvements in *vehicle efficiency AND emissions* will require an in depth understanding of the interaction of advanced transportation technologies *in situ* under real-world conditions.**

The "HOW"

The ORNL Vehicle Systems Integration (VSI) research laboratory will

1. **Enable system-level research that integrates the best of advanced combustion, electric drive, controls, and fuels within applicable emissions constraints. ORNL has made numerous contributions within all these individual technology areas.**
2. **Establish a dedicated LD and HD propulsion dynamometer laboratory to support prototype component and subsystems integration R&D.**

Essential for proper development, evaluation, and validation of emerging high risk, long term advanced transportation technologies.

OBJECTIVE: The Vision of VSI

- **Dedicated systems integration facility to fully support DOE Vehicle Technologies Program**
  - Fosters **DOE VTP cross-cutting** activities in core areas such as Vehicle Systems, Advanced Combustion and Emissions, Fuels Technologies, and Advanced Power Electronics and Electric Machinery.
  - Leverages DOE R&D investments in light-duty vehicles to medium- and heavy-duty vehicles.
  - Research to focus on ***systems interactions*** subjected to "real world" conditions with focus on **emissions** and **thermal transients**.
- **Unique capabilities/features**
  - Exploits existing co-location of core competencies at ORNL to allow for thorough technology characterizations and for deeper understanding of technology merits.
  - Data collection activities fully support DOE VTP modeling/simulation efforts with detailed model development/verification.
  - **Full heavy duty capability** to support research in emerging medium and heavy duty advanced powertrain systems.
  - Modular design with propulsion dynamometer and HIL component emulation minimizes downtime to reconfigure drive systems and supporting technologies.
  - Allows better understanding of synergies and/or operational issues for **optimal efficiency AND lowest emissions**.

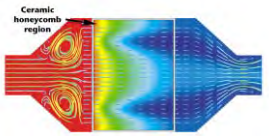
Engines

Components

Data

Unique Diagnostics

Modeling



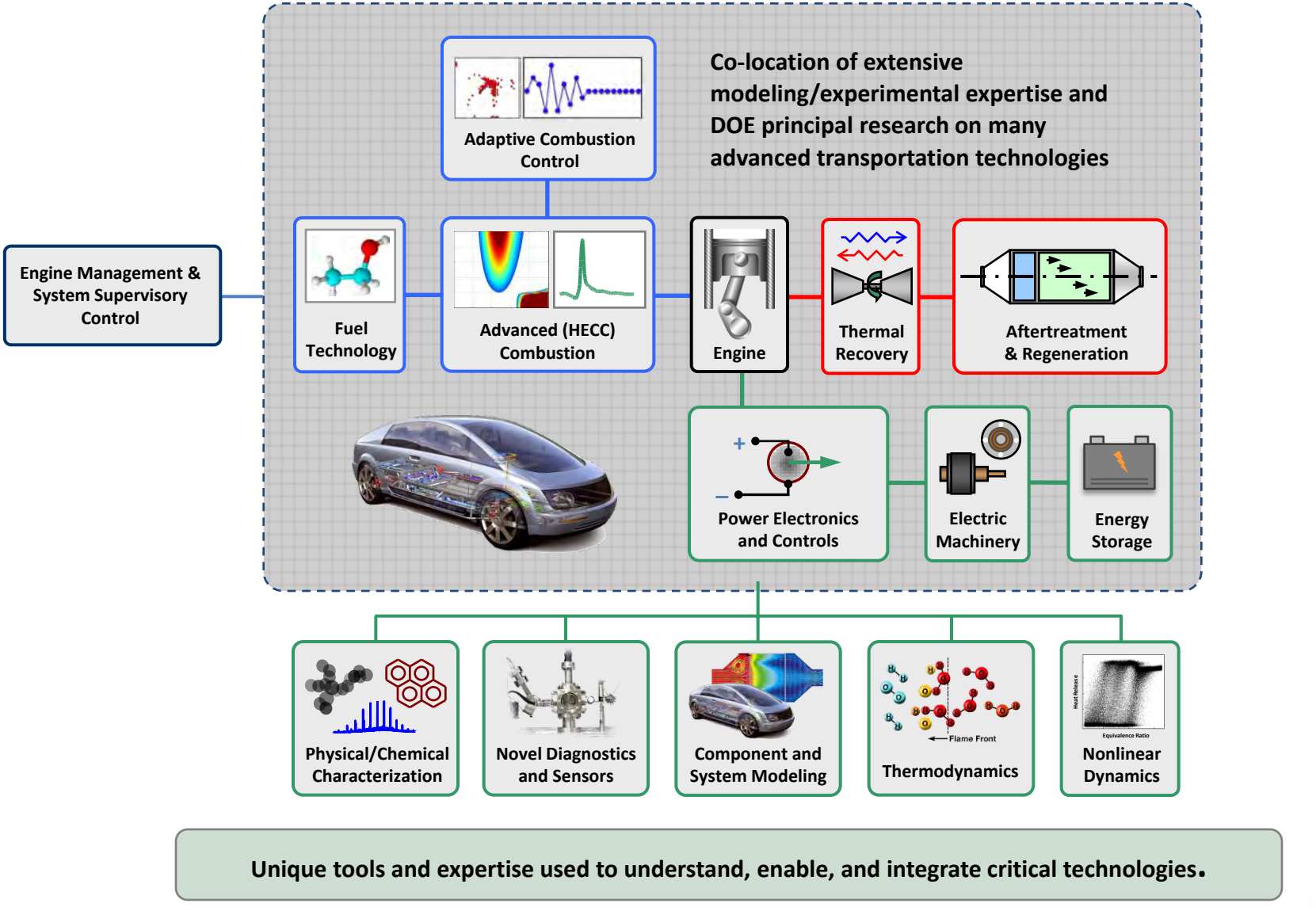
RELEVANCE

- **VSI supports the following VTP Multi-Year Program Plan Goals for VSST:**
  - Demonstrate market readiness for grid-connected vehicle technologies by 2015.
  - Address codes and standards needed to enable wide-spread adoption of electric-drive transportation technologies
  - Expand activities to develop and integrate technologies that address aerodynamic load reduction, hybridization, auxiliary load reduction, and idle reduction to greatly improve commercial vehicle efficiency.
  - Validate, in a systems context, performance targets for deliverables from the Power Electronics and Energy Storage Technology R&D activities.
- **VSI addresses the following VSST Barriers:**
  - **Risk aversion**: Provides a resource to develop and verify new vehicle component and/or powertrain technologies from a systems perspective through integration of both model-based design and hardware-in-the-loop principles.
  - **Cost**: Co-location of facilities and core technical expertise creates an environment for timely evaluation of advanced vehicle components and powertrain configurations.
  - **Lack of standardized test protocols**: VSI supports creation of standardized test protocols through practical evaluation of candidates standards, such as “powerpack testing” for medium and heavy duty advanced powertrains (SAE J2711).

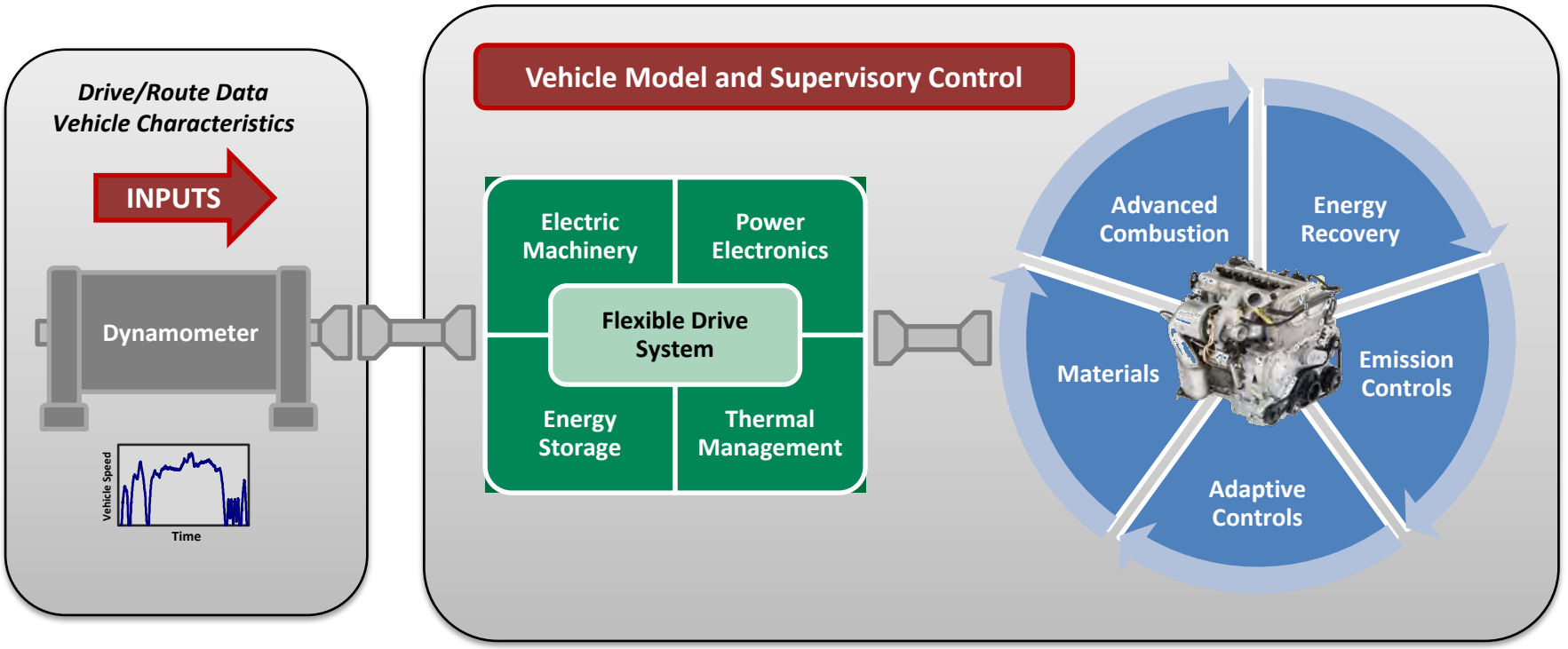
MILESTONE

- **Milestone: Complete baseline laboratory installation and commissioning (September 30, 2011).**
  - Establish a dedicated light and heavy duty powertrain integration research laboratory to support DOE VT Hybrid Electric Systems. The facility would be located at the National Transportation Research Center (NTRC) and consist of a powertrain-in-the-loop based integration facility suited to characterize component behaviors exposed to real-world operating conditions in a vehicle systems context, or subsystem interactions based on various advanced powertrain architectures.

APPROACH: VSI unites the diverse DOE VTP research portfolio at ORNL to enable new innovations in vehicle system efficiencies

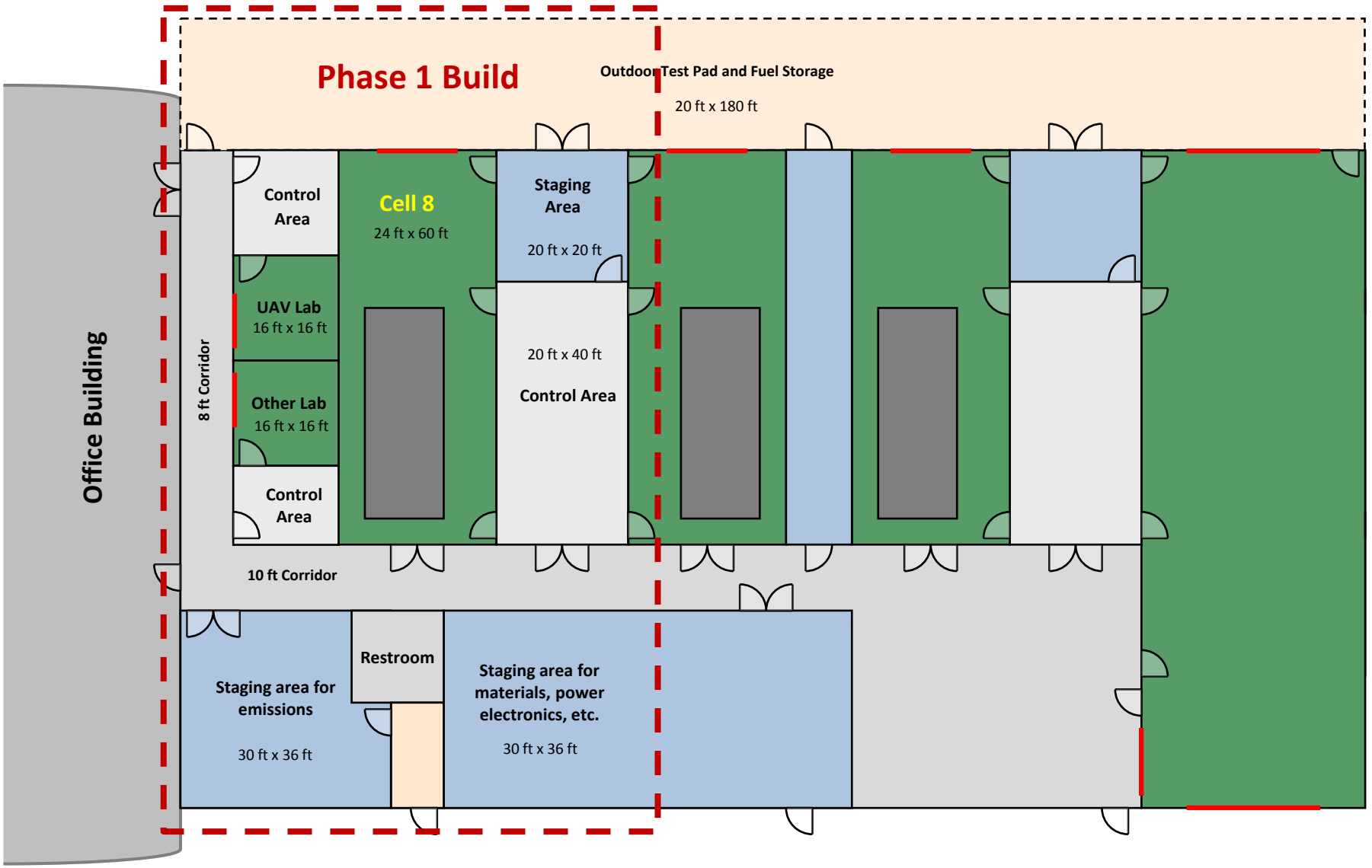


APPROACH: Schematic representation of VSI laboratory shows integration of engine, advanced high voltage traction drive system, and modeling/simulation



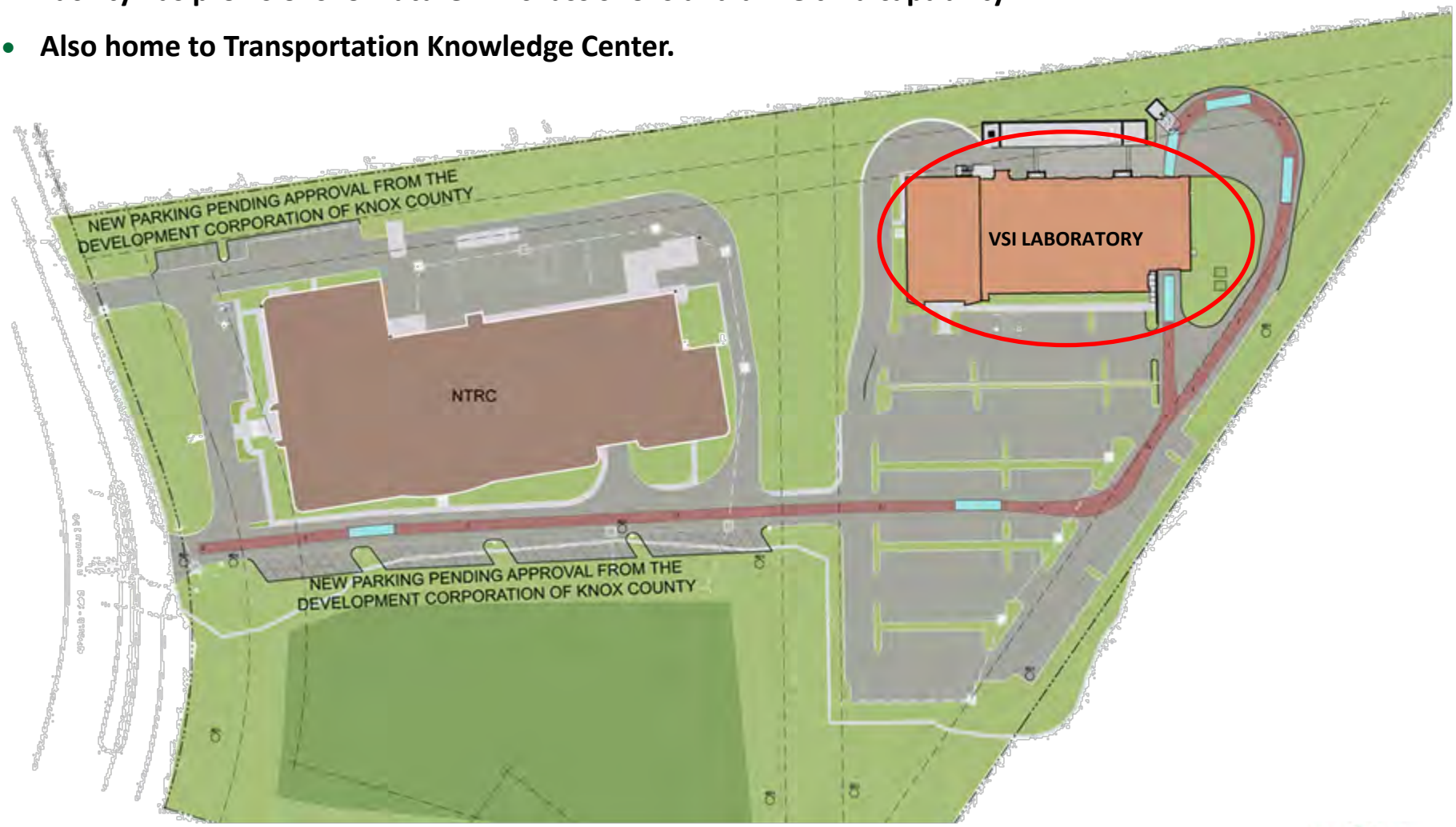
Model + Experiment to Simulate Passenger and HD Truck Vehicles

APPROACH: Phase 1 of laboratory space is in progress



ACCOMPLISHMENT: New facility has received approval from DOE real estate and construction is underway at NTRC site

- **Approximately 18,000 ft^2 available for new laboratory space.**
- **Facility has provisions for future HD chassis rolls and drive thru capability.**
- **Also home to Transportation Knowledge Center.**



ACCOMPLISHMENT: Occupancy schedule and funding

- **Occupancy Schedule:**
  - Office portion expected end of CY 2010.
  - Phase 1 of new laboratory end of FY 2011.
- **Building funded by ORNL ($6M).**
- **Phase 1 laboratory infrastructure and hardware support from multiple sources.**
  - ORNL 2010: $750k for dynamometer cell hardware.
  - ORNL 2011: $750k + TBD for additional infrastructure.
  - DOE 2011 (Advanced Vehicle Systems): $1,500k for dynamometer cell hardware and limited infrastructure.

*VSI laboratory construction status as of **2/11/2011***

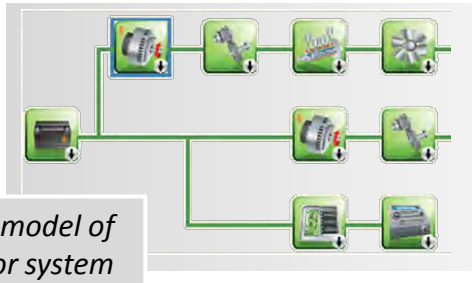
COLLABORATION AND COORDINATION

- **ArvinMeritor (1st project industry collaboration)**
  - Development and delivery of Dual Mode Hybrid Powertrain, including prototyped electric machines, transmission, and respective control systems
  - Modification and delivery of full Class 8 test vehicle with prototype DMHP
- **Oak Ridge National Laboratory (inherent cross-cutting collaboration with core research groups)**
  - Fuels, Engines, and Emissions Research Center (FEERC)
  - Power Electronics and Electric Machines Research Center (PEEMRC)
  - Center for Transportation Analysis (CTA)
- **Coordination with other DOE national laboratories**
  - Instrumentation and measurement for data sharing of components/systems for use in modeling and simulation activities
  - Joint collaborations on integration of advanced vehicle technologies at the system level

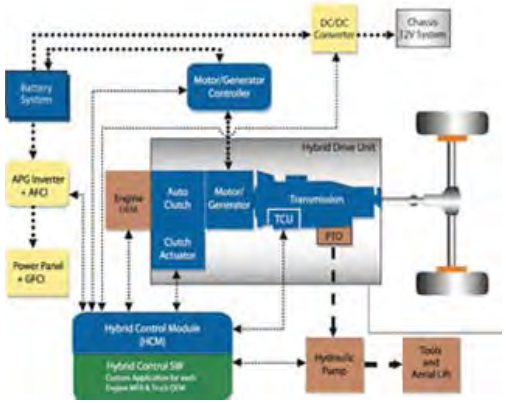
COLLABORATION: ArvinMeritor makes use of VSI laboratory to bridge simulation to full vehicle (Ref. VSS062)

Simulation

- Detailed vehicle and control system modeling and design optimization.
- Integration of detailed 1-D engine model for risk benefit analysis of advanced combustion and emissions effects.



Autonomie model of ArvinMeritor system



VSI Experiments

- Evaluation of engine only AND complete Dual Mode Hybrid Powertrain (DMHP).
- Characterization of merits of advanced controls, advanced combustion, and hybridization in a transient environment.
- Deep understanding of component interfacial issues, transient phenomena, thermal considerations.

Full Chassis Experiments

- ArvinMeritor will build and supply a complete Class 8 tractor equipped with DMHP for on road evaluation.
- Tractor will have limited service in Wal-Mart fleet with ORNL installed data acquisition system to generate usage/duty cycle data as well as component operating ranges.

ArvinMeritor

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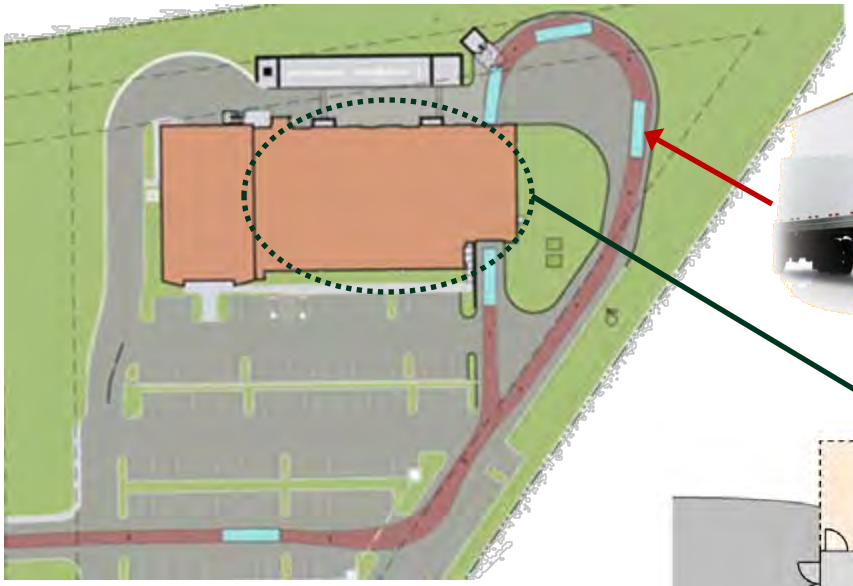
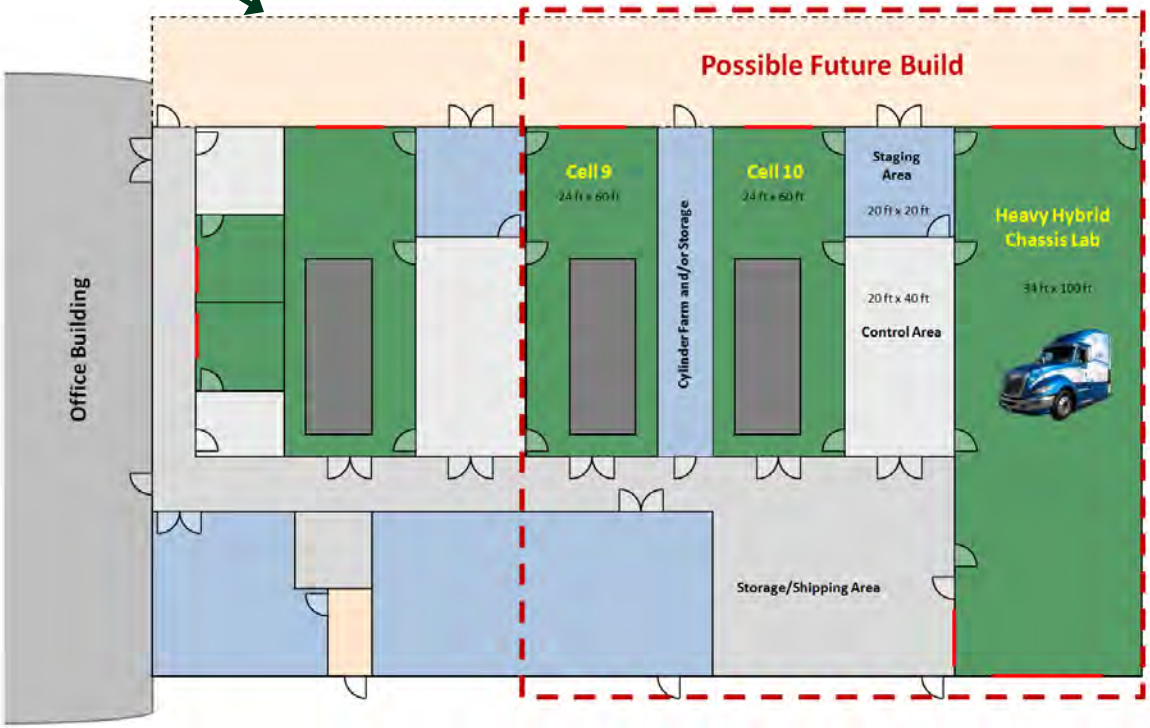
PROPOSED FUTURE WORK: Future Plans include development of additional VSI laboratories and HD chassis dynamometer



- **Building was designed to accommodate a Heavy Duty Chassis Dynamometer with drive-thru access for up to Class 8 vehicles.**
- **Potential for inter-agency collaborations including EPA, DOT, DOD, etc.**

NTRC is located just a few miles from Interstate I-40/I-75 Technology Corridor and just west of the termination of I-81, one of the busiest trucking corridors in the Eastern US. Many of the partners for previous MD and HD Duty Cycle data and analysis tasks are located in the area.



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SUMMARY: The ORNL VSI laboratory provides a mechanism for addressing critical challenges to the next generation of advanced vehicle systems

- **Integration of advanced technologies for maximum efficiency and lowest possible emissions.**
  - Development and evaluation of supervisory control and advanced propulsion strategies.
  - Exposure of full prototype system to transient and thermal conditions consistent with real world drive cycles.
  - Better understanding of component-to-component interactions.
  - Direct emissions measurements of full system necessary due to low-confidence level in predictive emissions modeling.
- **Enhancement of existing analytical models and the development of new advanced technology sub-models.**
  - New insight into transient and thermal behavior of advanced technologies.
  - Evaluation of component interfacial issues.
  - Source of transient data for component and full system validation.
- **Component development, characterization, and commercialization.**
  - Pathway to rapid development and commercialization of high efficiency vehicle technologies.
  - Characterization of advanced components after fleet evaluation to ascertain operational deterioration and effectiveness.
- **Support of recent EPA-NHTSA rule with coupled experiments and simulation to asses fuel consumption of heavy duty vehicles.**

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