BNSF's Alternative Fuels

H2@Rail Conference

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Overview

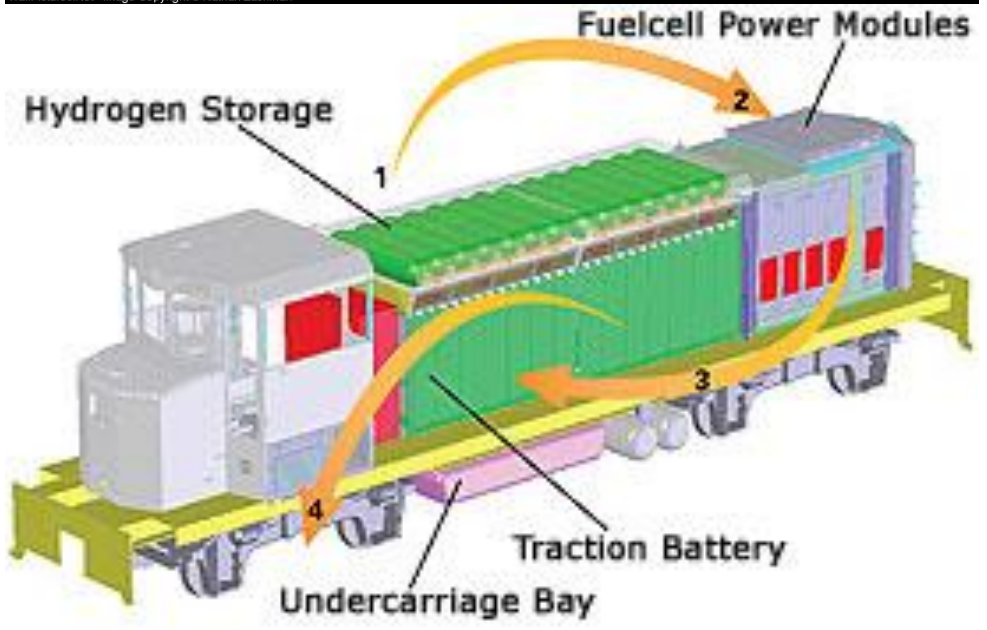
- BNSF Railway Overview
- Hydrogen Switcher
- Liquefied Natural Gas
- Battery Electric Equipment Development
  - Battery Electric Locomotive
- Key Hydrogen Challenges for Rail

BNSF Railway Overview

- **32,500** route miles in **28** states and **3** Canadian provinces
- **43,000+** employees
- Operates **~1,500** trains per day
- Serves over **40** ports and **25** intermodal facilities
- Over **10** million carloads shipped annually

Hydrogen Switcher

- Partnership between BNSF, Vehicle Projects, & US Army
- Built at BNSF's Topeka shops
- Tests run 2008 - 2009

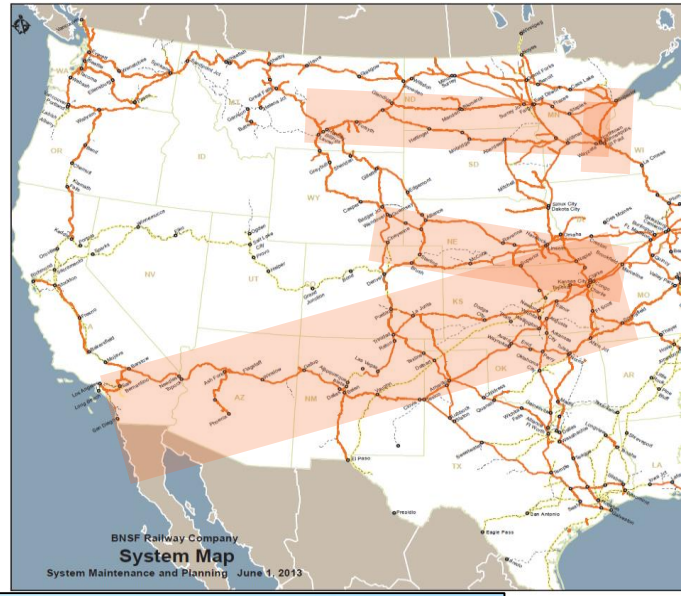


Liquefied Natural Gas

- BNSF evaluated natural gas as an alternative locomotive fuel in revenue service operations from 2013 to 2017

- Equipment:
  - 2 tank car style tenders
  - 4 total HHP locomotives
    - (2 EMD & 2 GE)

- Partnered with industry to develop AAR M-1004 tender standard



Battery Electric Equipment Development

Equipment Types:

- Battery electric locomotives
  - Line haul: hybrid battery electric consist
  - Switcher locomotives (concepts, previous projects & other roads)
- Intermodal equipment
  - Battery electric drayage truck
  - Hybrid rubber-tired gantry (RTG) cranes
  - Battery electric side loader
  - Battery electric hostler trucks

Grant: Zero- and Near Zero-Emission Freight Facilities (ZANZEFF)

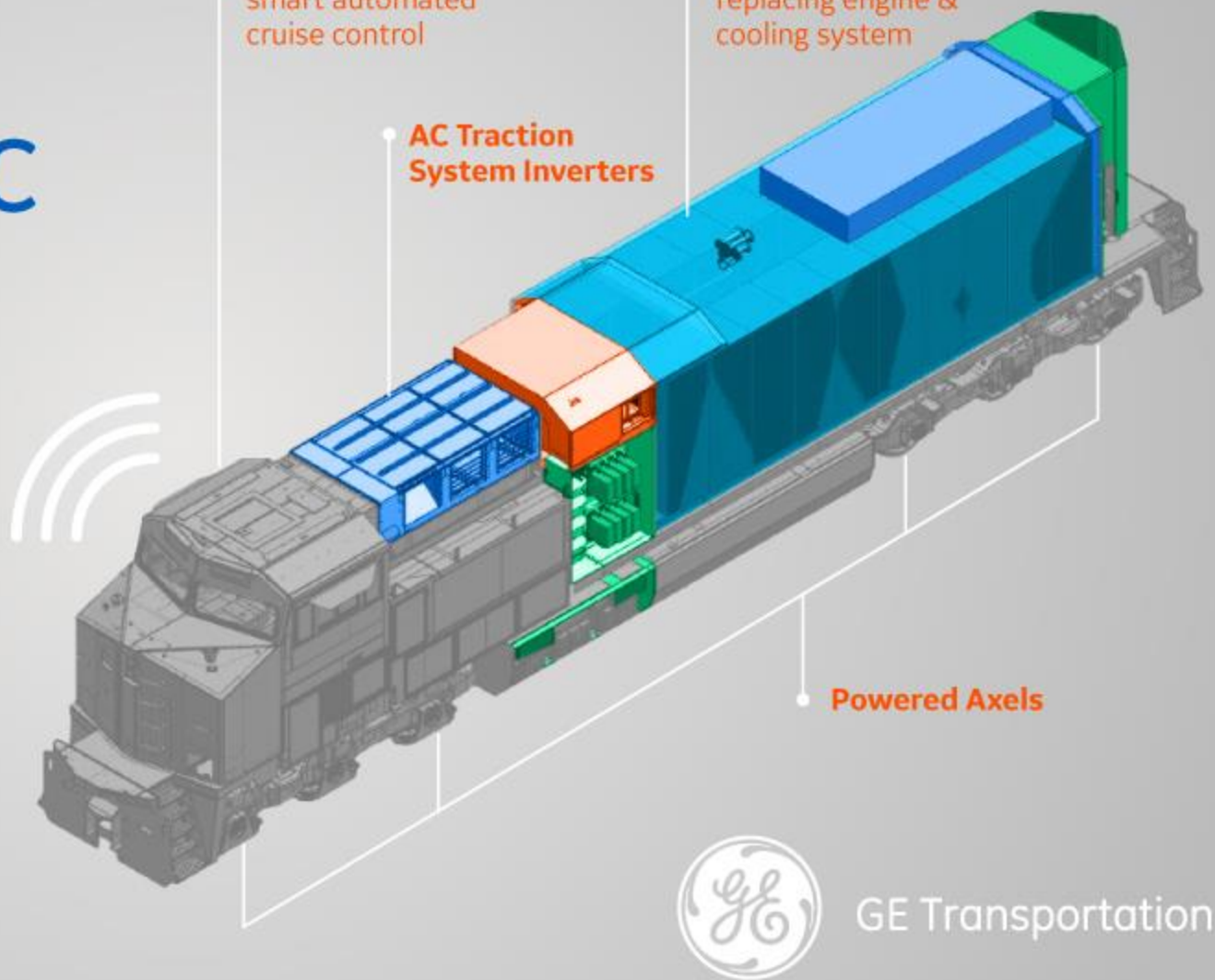
- CARB funding in partnership with SJVAPCD

GE Transportation's

Battery-Electric Locomotive

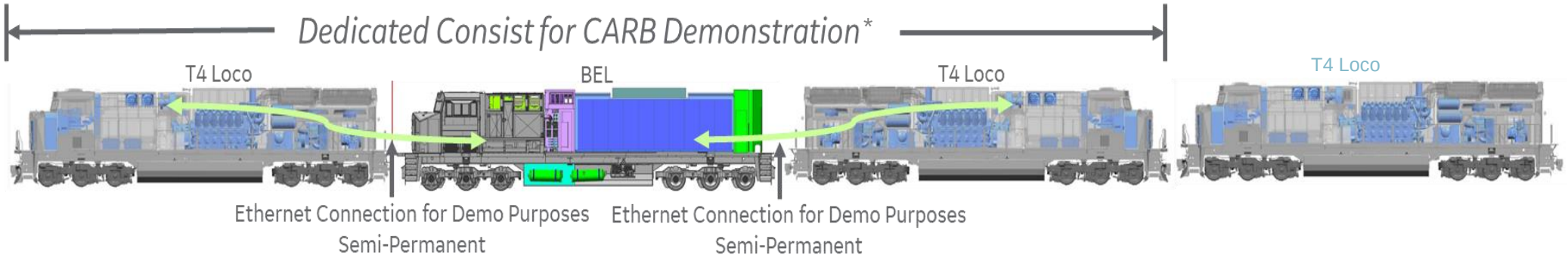
Massive **power generation capabilities** up to **2400** kWhrs

Huge **fuel savings** of at least **10-15** %



GE Transportation

Hybrid Consist Demonstration



Battery: ~2400 Kwh

Mainline Operating Mode

- Revenue service operation between Stockton and Barstow
- Hybrid consist mode
  - Regenerative braking for battery charging
  - Trip optimizer integration
- Targeted fuel and emissions reduction

Yard Operating Mode

- Within Stockton yard
- Yard consist and train arrival/departure movement powered by battery-electric locomotive only
- Near-zero emissions operation
- Diesel locomotives in consist will idle or shut down

Hybrid Consist Development Goals

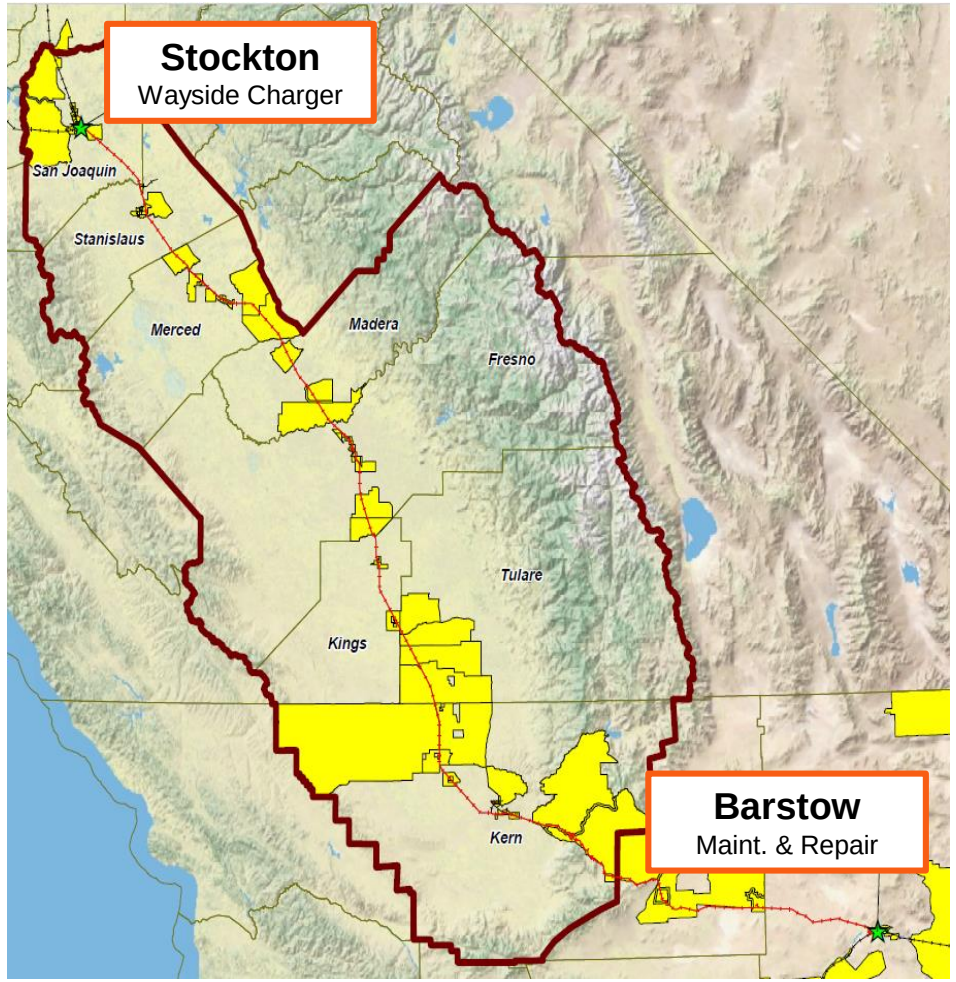
Develop system architecture and sub-components

- Hardware Development
  - Electrical system, battery integration, wayside charging, controls system, etc.
- Software Development
  - Intra-consist communication, Trip Optimizer integration, route optimization, etc.
- Operational Integration
  - Consist management, battery state of charge impact, locomotive utilization, train handling impact, maintenance and repair, etc.

Validate fuel savings and operational performance

- Pilot efforts allow for testing of differing locomotive services. Ideal services have heavy dynamic use
- Modeling and projections suggests performance to grow with technology advancement

Pilot Testing Route



Key Hydrogen Fuel Challenges for Rail

- **Safety**
  - Compressed or cryogenic fuel handling
  - Flammability of gaseous fuels
    - LFL 4% to UFL 75% mixture with air

- **Energy density**
  - Long distances require energy dense fuels
    - LA to Chicago Gulf to Pacific Northwest Unit train service
  - Mitigation requires additional/larger equipment

- **Infrastructure investment**
  - Large, decentralized physical foot print
    - Refueling facilities across network
  - Cryogenic liquid or compressed gas equipment is complex & costly
  - Onsite hydrogen generation adds equipment & cost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