



## ***“Engines of Change”***<sup>SM</sup> Low-Emissions “Gen-Set” Switching Locomotives for Los Angeles Rail Yards

Michael Iden, P.E. ~ Union Pacific Railroad  
Faster Freight Cleaner Air 2006 conference  
Long Beach, California  
January 30 - February 1, 2006

BUILDING AMERICA<sup>SM</sup>



## UP AND THE ENVIRONMENT

*“Union Pacific Railroad is committed to protecting the environment, for our customers, our employees and the communities in which we operate. Beyond compliance with laws and regulations, Union Pacific is committed to the development and use of new technologies to preserve the environment for future generations. Environmental protection is a primary management responsibility, as well as the responsibility of every Union Pacific employee.”*

*— Union Pacific Chairman, Dick Davidson*

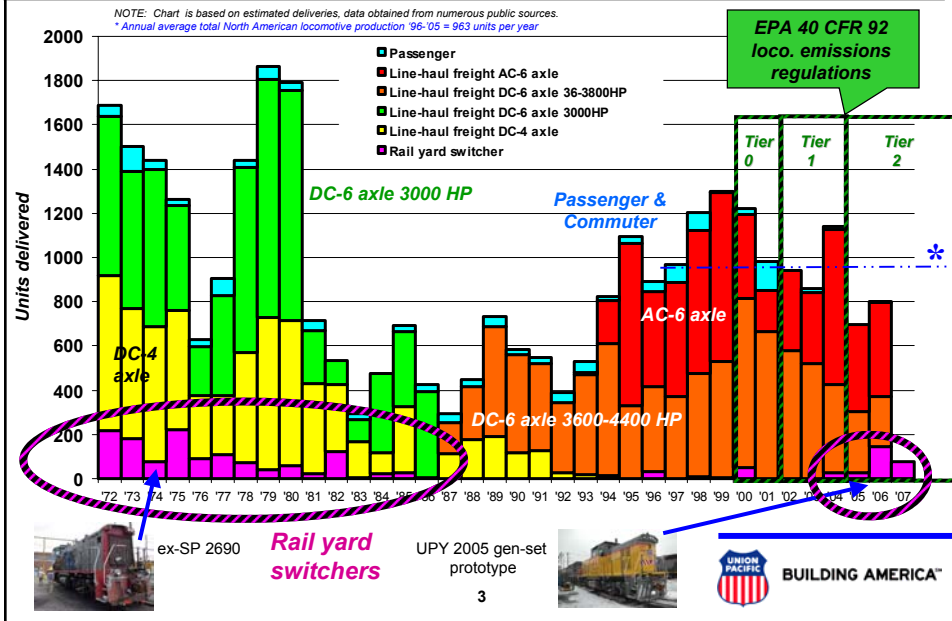


Go to: [http://www.uprr.com/she/emg/attachments/whitepaper\\_0905.pdf](http://www.uprr.com/she/emg/attachments/whitepaper_0905.pdf)



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# Rail yard switcher market: then & now



# Why did switcher market go dormant?

- ➔ US rail industry deregulated Oct. 1980
- ➔ Massive restructuring
  - ✓ Many small rail yards closed
  - ✓ Operations restructured and consolidated
- ➔ Existing fleet of switchers built 1970-1980 became surplus to the new demand
- ➔ EMD did not abandon the switcher market ... *the market simply disappeared*

## Shaking the “switcher market”

- ➔ Everyone knows a rail yard switch locomotive must be powered by one large locomotive engine. **WRONG**
- ➔ The multi-engine Gen-Set switcher is a **disruptive innovation**, the application of a technology which is usually too small (i.e., truck-type engines) for an historic application (i.e., locomotives).

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A **disruptive technology** is a **new technological innovation**, product, or service that eventually overturns the existing dominant technology in the market, despite the fact that the disruptive technology is both radically different from the leading technology and that it often initially performs worse than the leading technology according to existing measures of performance. A disruptive technology comes to dominate an existing market by either filling a role in a new market that the **older technology** could not fill (as more expensive, lower capacity but smaller-sized **hard disks** did for newly developed notebook computers in the 1980s) or by successively moving up-market through performance improvements until finally displacing the market incumbents (as **digital photography** has come to replace film photography).

By contrast, **sustaining technology** refers to the successive incremental improvements to performance that market incumbents incorporate into their existing product.

The term *disruptive technology* was coined by **Clayton M. Christensen** and described in his 1997 book *The Innovator's Dilemma*. In his sequel, *The Innovator's Solution*, Christensen replaced the term with the term *disruptive innovation* because he recognized that few technologies are intrinsically disruptive or sustaining in character. It is strategy that creates the disruptive impact.

Source: [http://en.wikipedia.org/wiki/Disruptive\\_technology](http://en.wikipedia.org/wiki/Disruptive_technology)

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**Multi-engine (Gen-Set) switching locomotives**

**Historic rail yard switch locomotives with large locomotive engines**

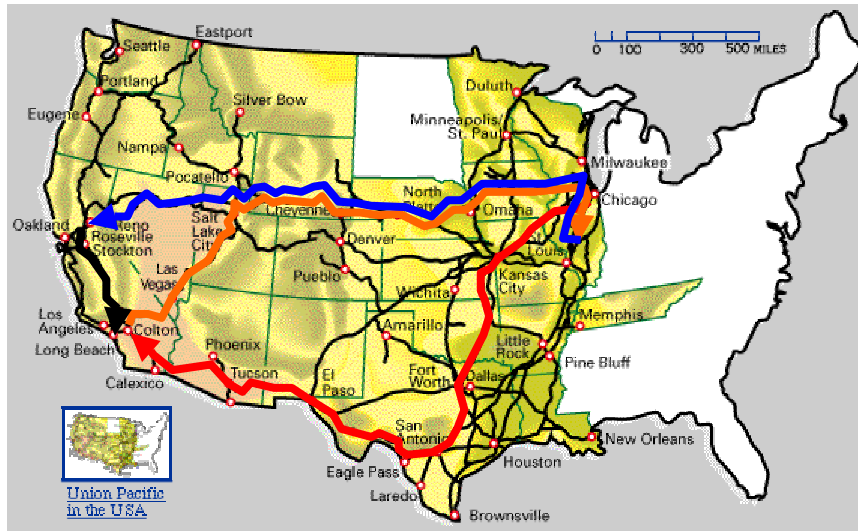
**Line-haul locomotives requiring one large locomotive engine for large amounts of power**



## UPY 2005 Gen-Set timeline

- ➔ February 2002 ... initial UP discussions
- ➔ 2002-03 ... UP investigates various engine configurations with NRE
- ➔ June 2004 ... UP expenditure approved ...  
July 2004 ... SP 2690 (1974) switcher moved from West Colton to Illinois for conversion
- ➔ April-November 2005 ... UPY 2005 built
- ➔ December 8, 2005 ... Testing began near Chicago
- ➔ *January 19, 2006 ... arrived in LA*

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- February 1974:** SP 2690 delivered by EMD (IL), starts work at W. Colton
- June 2004:** SP 2690 shipped to Chicago and then Mt. Vernon IL
- December 2005:** UPY 2005 delivered by NRE to Proviso, moves to Roseville
- January 2006:** UPY 2005 arrives Roseville January 4th, LA January 19th

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## Gen-Set funding

- ➔ UP funded construction of prototype with internal funds (no public grants applied for)
- ➔ Without UP funding of prototype, a “gen-set marketplace” likely would never have existed
  - ✓ UP action stimulated great interest by locomotive and diesel engine supply communities
  - ✓ Demonstrated feasibility of the technology
  - ✓ Showed UP commitment to developing low-emissions alternatives to older rail yard switching locomotives

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## What is a “Gen-Set”?

### ➔ Generator Set

- ✓ A self-contained modular factory-assembled electrical power generating package
  - ⇒ Engine
  - ⇒ Electrical generator
  - ⇒ Cooling system with antifreeze
- ✓ An EPA-certified nonroad diesel engine derived from state-of-the-art highway truck designs
- ✓ Typically used as stationary power sources
  - ⇒ Emergency back-up gensets (hospitals, etc.)
  - ⇒ Power generation in remote areas away from the grid

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## \*Locomotive engines v gen-sets

### ➔ (1) Locomotive diesel engine

- ✓ Non-turbocharged version of larger road loco. engine, large-bore, medium-speed engine (900 RPM), 1500-2000 HP
- ✓ EMD (now Electro-Motive Diesel, Inc.), not manufactured since early-1980s

### ➔ (2-to-3) Gen-Set diesel packages

- ✓ Nonroad derivative of highway truck engines, small-bore, high-speed engines (2100 RPM), 700 HP
- ✓ NRE: Cummins Engine Co. (various other firms compete)
- ✓ Latest engine and emissions technology, EPA nonroad Tier 3 certified

\* Conventional rail yard switching locomotives

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## California's 1st Gen-Set switcher



**SP 2690 1500 HP "MP15DC"**

Electro-Motive Div. of GM ("EMD")\*\*  
 Built in January 1974  
 30+ years at W. Colton Yard '74-'04  
 (1) EPA pre-Tier 0 diesel engine  
 Pre-EPA Tier 0 locomotive

\*\* EMD is now Electro-Motive Diesel, Inc., one of two manufacturers of EPA Tier 2 line-haul locomotives



**UPY 2005 1400 HP "GS14B"**

National Railway Equipment Co. ("NRE")  
 Built April-November 2005  
 Arrived in LA January 19, 2006  
 (2) EPA Tier 3 nonroad diesel engines  
 EPA Tier 2 locomotive certified  
 CARB "ULEL" \* status

\* Ultra-Low Emitting Locomotive, due to NOx certification at-or-below 4.0 grams/brake HP-hour

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**1974-vintage EMD 12-cylinder pre-EPA yard switcher engine formerly in SP 2690**

- 1500 horsepower
- 9-1/16" bore x 10" stroke (645 cu. in./cylinder)
- 25,380 pounds weight
- 905 RPM max. engine speed
- non-turbocharged, mechanical fuel injection
- hydraulic engine governor

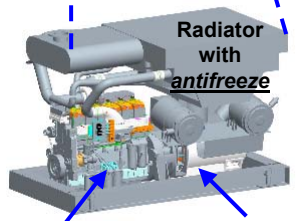
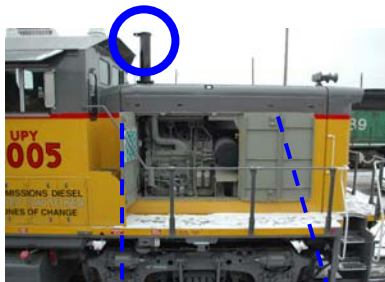


**2005 Cummins EPA Tier 3 nonroad diesel engine, one of two now in UPY 2005**

- 700 horsepower (2 engines = 1400 HP)
- 6-1/4" bore x 6-1/4" stroke (193 cu. in./cylinder)
- 4,235 pounds weight
- 2100 RPM max. engine speed
- turbocharged, common rail fuel injection
- programmable electronic engine control



**Note exhaust stack "cap" was closed ... engine had been automatically shut down.**



Cummins QSK19G engine      Electrical alternator

**December 8, 2005 ... UPY 2005 arrives at UP's Proviso Yard, Melrose Park, IL (near O'Hare Airport) to begin its working career as the US's first Gen-Set switching locomotive ... another cold windy Chicago winter day ... 25 degrees F ambient temperature and snow was falling.**



# Novel application: *clean gen-set power*



**Constant-speed engine operation (maintain 60 hertz power)**



Hospital emergency generator



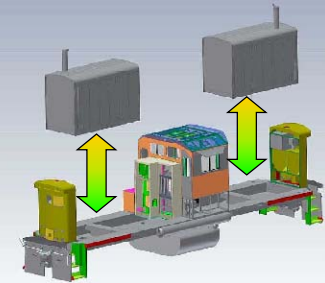
Remote communications center generator



uses multiple EPA low-emissions Tier 3 nonroad diesel gen-sets (*variable throttle*) ...



Unique "building block" approach ...



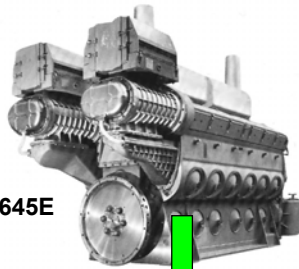
applied to rail yard switching locomotives



## 1500 HP switch locomotive

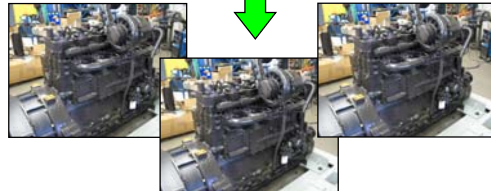
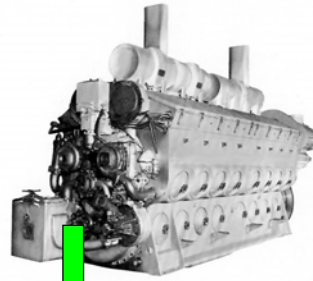
## 2000 HP switch locomotive

EMD 12-645E engine



(2) 700 HP Cummins QSK19 engines in gen-sets = 1400 HP

EMD 16-645E engine



(3) 700 HP Cummins QSK19G engines in gen-sets = 2100 HP

**1500-2000 HP gen-set switch locomotives**



## Paradigm shift in engine maintenance

### ➔ One large locomotive engine

- ✓ Typ. remains in locomotive carbody, up-to-30 years
- ✓ Replace large power assemblies as they wear out, periodic fuel injector changes, etc.

### ➔ Multiple Gen-Set engines

- ✓ Smaller size & modularity enables complete replacement instead of incremental replacement of power assemblies.
- ✓ Truck-derivative emissions improvements and enhancements are driven by massive highway truck engine market and ... federal R&D funding (as much as \$70 million in tax \$s per year!) *This project allows Union Pacific to “tap into” those emissions improvements.*

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## Rail yard switcher emissions

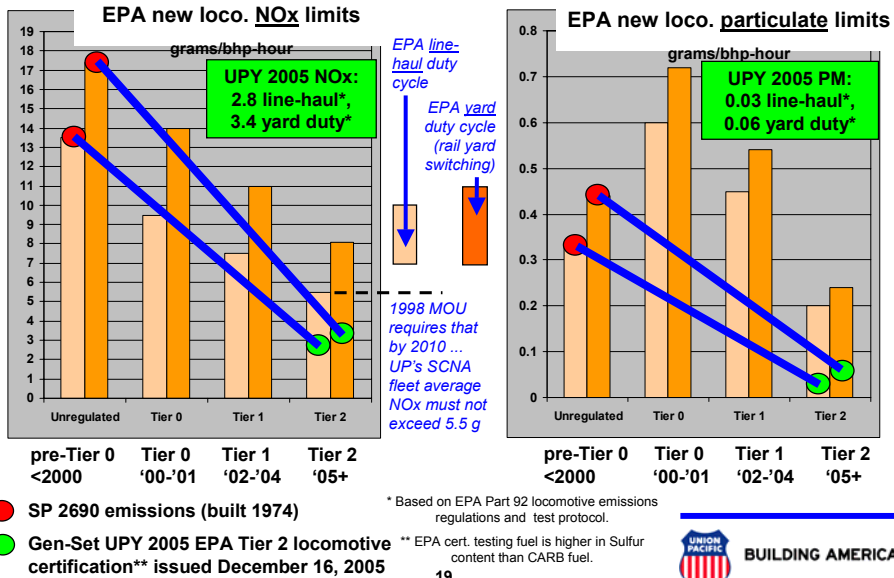
### ➔ Relatively low horsepower demand of a typical rail yard switcher enables use of multiple lower-HP gen-set engines in place of one large locomotive engine

- ✓ (1) 1500 HP loco. engine replaced by (2) 700 HP gen-sets
- ✓ (1) 2000 HP loco. engine replaced by (3) 700 HP gen-sets
- ✓ ... multiple gen-set replacements are *not practical* \* for large line-haul locomotives of 4000-4400 HP
- ✓ \* Smaller gen-set diesel engines produce lower levels of emissions than large locomotive engines *in rail yard applications*

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# Gen-Set emissions, EPA reg's, '98 MOU



# UP's LNG & Gen-Set switcher R&D

## LNG: 1995

2000 HP diesel engine required to obtain 1200 HP using LNG fuel



UP operated two (2) LNG-fueled 1200 HP switchers at Commerce Yard, 1995-1998. The locomotives were built pre-EPA loco. emissions regulations and test protocol, but LNG emissions data was gathered.





Two 700 HP EPA Tier 3 nonroad diesel Gen-Sets for 1400 HP

Diesel Gen-Set: 2005

Gen-Set prototype UPY 2005 is being operated under similar conditions. Emissions data was gathered (and certified) under EPA locomotive Tier 2 protocol.

# Diesel "Gen-Set" compared to LNG

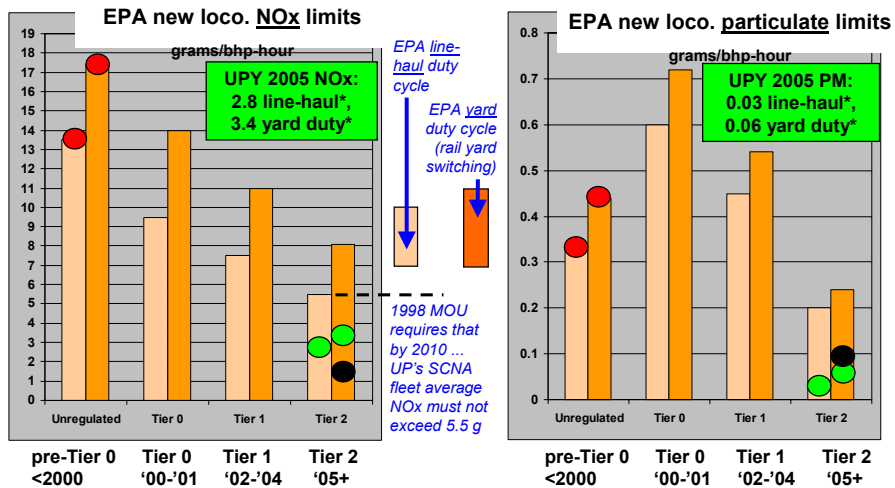
- Best available LNG switcher emissions data is from MK Locomotive MK1200G LNG switcher test data from 1993, adjusted to EPA protocol\*
- UPY 2005 has been tested in accordance with, and certified under, U.S. EPA Tier 2 locomotive emissions regulation\*\*.
- In EPA yard duty mode (grams/brake hp-hour):

	NOx	PM	CO	Unburnt HC (NMHC for LNG)
 MK1200G LNG*	1.4	0.09	2.2	3.3
 Gen-Set diesel**	3.4	0.06	1.51	0.036

**Smog precursors**



# Gen-Set v LNG switcher emissions



- SP 2690 emissions (built 1974)
- Gen-Set UPY 2005 EPA certification
- LNG switcher

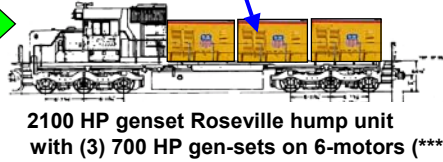
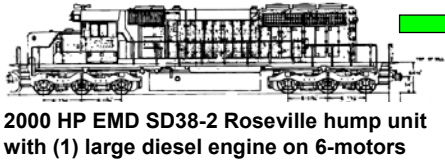
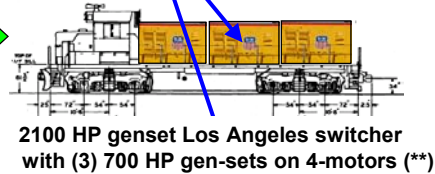
\* Based on EPA Part 92 locomotive emissions regulations and test protocol.

\*\* EPA cert. testing fuel is higher in Sulfur content than CARB fuel.



# Where gen-sets are headed

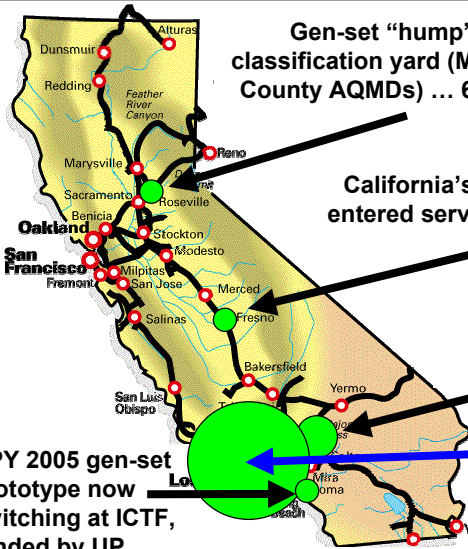
1400 HP gen-set prototype unit UPY 2005 (\*) ...  
 (2) 700 HP Tier 3 nonroad gensets in modular packages



(\*) UP funded construction of the gen-set prototype UPY 2005.  
 (\*\*) UP is reviewing bids to acquire (60) of these units for service in the Los Angeles area.  
 (\*\*\*) Sacramento and Placer County AQMDs have filed for a Moyer program grant to assist UP in building this prototype locomotive.



# CA's low-emissions ULEL yard fleet



Gen-set "hump" unit under design for Roseville classification yard (Moyer grant thru Sacramento & Placer County AQMDs) ... 6-axle version of UPY 2005 prototype

California's 1st diesel-battery hybrid, UPY 2004, entered service in Fresno on April 8, 2005 (Moyer grant thru SJV APCD)

Two Green Goat™ hybrids switching Mira Loma auto center (8 more due soon, purchased by UP)

*Bids now being considered for 60 gen-set switchers for Los Angeles rail yards, UP to fund*

UPY 2005 gen-set prototype now switching at ICTF, funded by UP

**All are (or to be) certified as Ultra-Low Emitting Locomotives!**



## UP Gen-Set diesel switcher summary

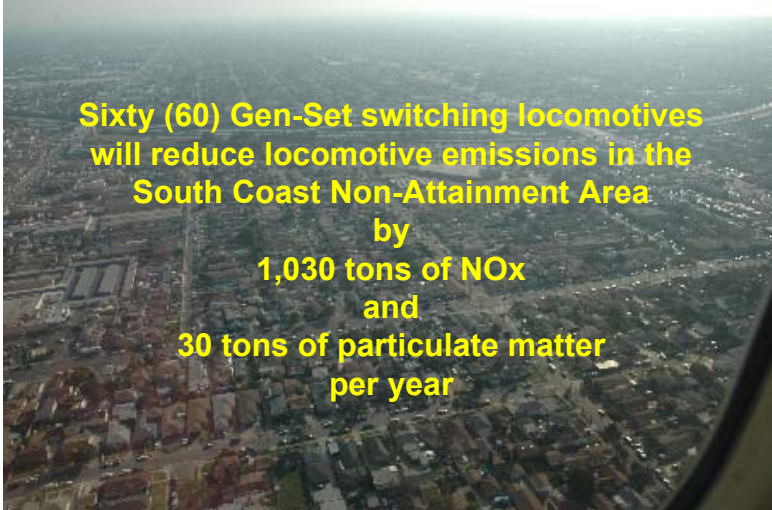
➔ *Compared to older switchers now in service in Los Angeles area rail yards:*

- ✓ 40% reduction in diesel fuel usage
- ✓ 80% less NOx and 90% less particulate matter
- ✓ Lower emissions than LNG
- ✓ Quieter operation, less line-side engine noise
- ✓ UP considering bids for acquisition of 60 units for service in Los Angeles area rail yards

✓ ***“Engines of Change”***



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An aerial photograph of a city, likely Los Angeles, with a text overlay in yellow. The text reads: "Sixty (60) Gen-Set switching locomotives will reduce locomotive emissions in the South Coast Non-Attainment Area by 1,030 tons of NOx and 30 tons of particulate matter per year".

**Sixty (60) Gen-Set switching locomotives will reduce locomotive emissions in the South Coast Non-Attainment Area by 1,030 tons of NOx and 30 tons of particulate matter per year**



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## Questions & Comments



**See the Gen-Set locomotive at  
UP'S Intermodal Contain Transfer Facility  
on Wednesday February 1, 2006  
(van tours depart at 2:00PM and 3:15PM)**