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SERAPHIM - A MAGNETIC PROPULSION SCHEME FOR FAST TRAINS

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We are attempting to develop and demonstrate a new type of linear synchronous induction motor capable of propelling a vehicle at high speed. The technology, based on a passive guideway containing sequential aluminum plates, was developed in Sandia's electromagnetic launch program. As such, it was called a "re-connection gun" and launched an aluminum plate from between pairs of pancake coils. In the proposed propulsion scheme, the plates are fixed and the coils move. Pairs of closely spaced pancake coils on the vehicle straddle vertically mounted aluminum plates in the roadbed as illustrated in figure 1. The current in the coils is turned on when the plate is fully covered, peaks at some optimal time, and decreases to zero before separation as shown in figure 2. This induces currents in the plate which interact with the coil current to produce repulsive forces. In essence, the pulsed coils push off the edge of the plate because at the high frequency of operation, the current has insufficient time to fully penetrate. Since no embedded flux is required, the efficiency actually increases with speed. This concept has been named SERAPHIM, for SEgmented RAil PHased Induction Motor. Figure 3 shows an artist's conception of what such a train might look like. Notice that the aluminum rail is actually composed of a solid structure with rectangular holes. The "plates" are the solid portions between the holes.

Figure 4 illustrates where and why various surface transportation methods fail, and provides a rationale for SERAPHIM. The speed limit on conventional trains is slightly over 100 mph because of limitations on the existing roadbeds. High speed trains on special tracks can do well over 200 mph but ultimately fail due to loss of traction between the powered wheels and the track. The SERAPHIM concept and the proposed magnetically levitated (MAGLEV) concepts can both achieve over 300 mph because the propulsion is contactless. Above these speeds, the power required to overcome air drag at sea level, which rises as the velocity cubed, becomes prohibitive. To achieve higher speed, the vehicle must either fly at 35000 feet or be in an evacuated tunnel.

The positive and negative aspects of this technology for high speed propulsion are as follows. The speed and grade climbing capability of trains with conventional powered steel wheels are limited by, among other factors, the loss of traction at high speed, especially when climbing a grade. The SERAPHIM method requires no contact for propulsion; all wheels are passive. Since no torque is transferred through the wheels, their design and size could be optimized for other considerations, such as noise reduction and comfort. We have taken 100 m/s (224 mph) as a target speed at which this technology becomes particularly useful. Since the SERAPHIM train runs on standard gauge rails, it could function on existing track with auxiliary propulsion such as small wheel mounted motors on some cars. Conversely, the aluminum rail could be side mounted to allow use of the track by conventional trains.

The main drawback to the SERAPHIM concept is that power must be provided either by a fueled

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generator on board or from high voltage lines along the track. We favor the former because drawing significant electric power from an external source at high speed is challenging and requires unsightly structures. Either way adds weight to vehicle.

The principal proposed methods of propulsion for MAGLEV trains involve powered coils in the guideway interacting with on-board superconducting magnets. This requires switching and power handling distributed along the entire roadbed. The passive SERAPHIM roadbed should be able to be built and maintained at much less expense. At moderately high speed, wheels still work! Magnetic levitation using superconducting magnets may not be necessary until much higher speeds are required.

Computer simulations using a three dimensional finite difference code for the vector potential indicate that good efficiency at high speed can be achieved. Because high frequency pulses are necessary for the SERAPHIM motor to work, the efficiency at low speed is poor. To gain practical experience and to validate the code, giving credence to predicted high speed performance, a full size, though not full speed, demonstration of the concept is being built. It will consist of five sequential coil pairs through which an end-supported aluminum plate is accelerated, as shown in figure 5. The coil and plate dimensions are given in figure 1. Each coil has two windings of 51 turns of 0.040 x 0.500 inch kapton-dacron insulated copper strip. Each stage has its own pulse generator which discharges a pair of 568 microfarad capacitors charged to 14 kilovolt and switched by a single ignitron without a crowbar. The coils are triggered by a fiber optic sensing system. The energy per stage will be kept below 14 kilojoules to limit mechanical stress on the coils. The two capacitors can be configured in series or parallel, or one unit can be used alone. The four windings of each stage can also be configured in series, parallel, or some combination. This gives flexibility in the pulsewidth, which will be nominally around 6 milliseconds.

Figure captions:

Figure 1. Schematic drawing of the pancake coils and aluminum plate. Dimensions are in meters.

Figure 2. Firing sequence as the plate passes between a coil pair

Figure 3. Velocity limits on high speed rail concepts.

Figure 4. The SERAPHIM train.

Figure 5. Laboratory demonstration of the SERAPHIM concept.

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Area of interest: EML Applications

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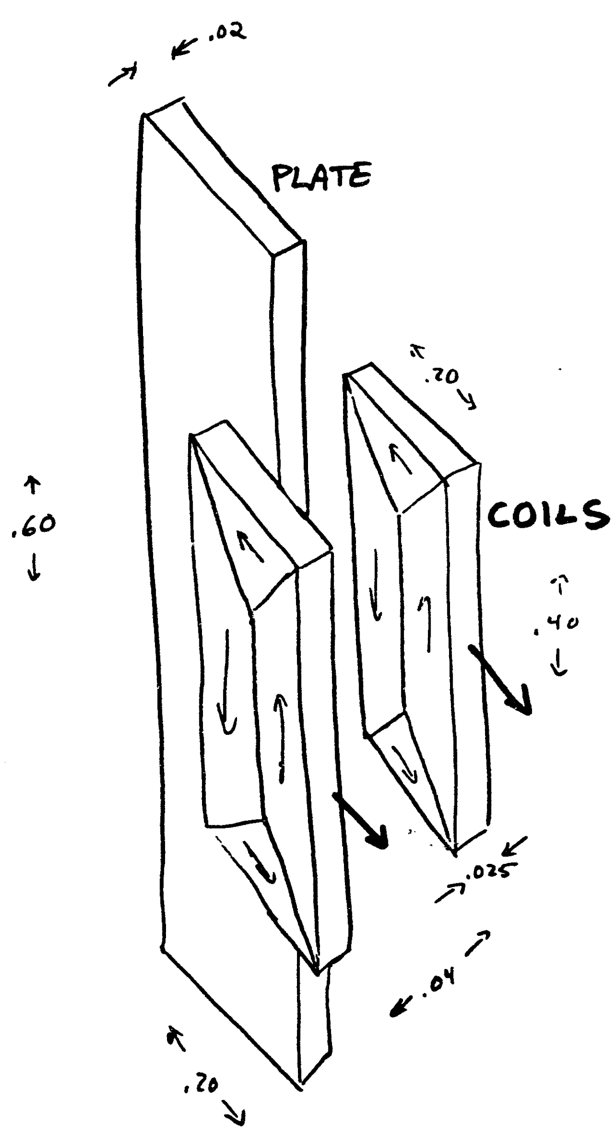


FIG 1

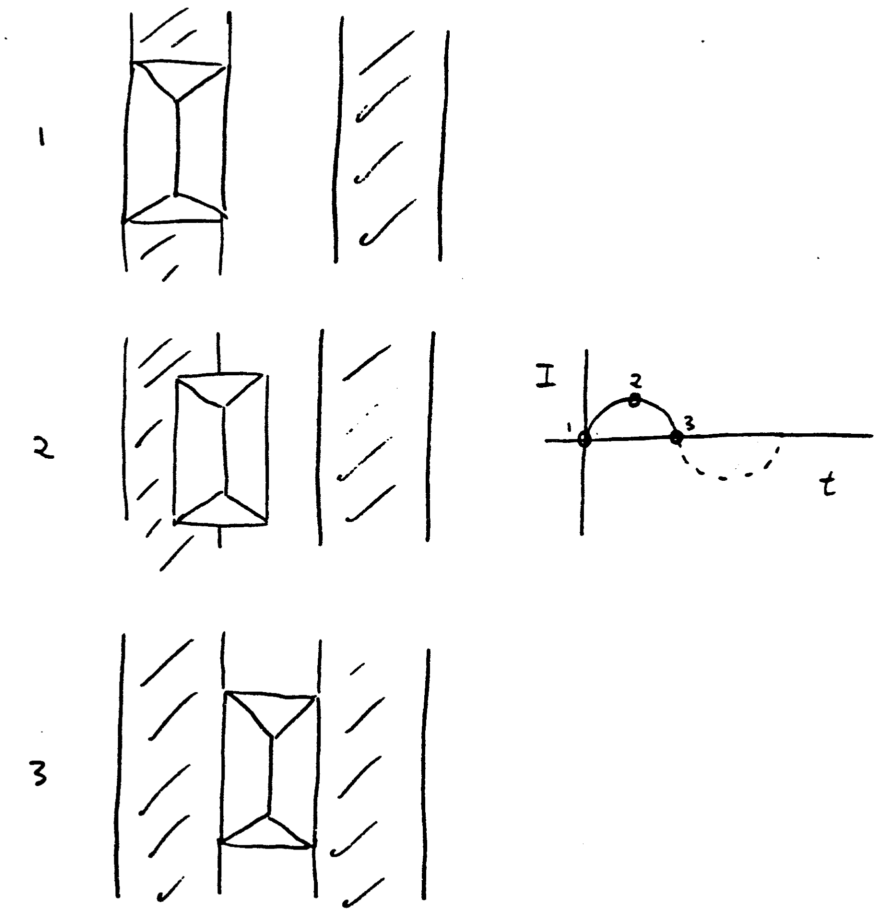


FIG 2

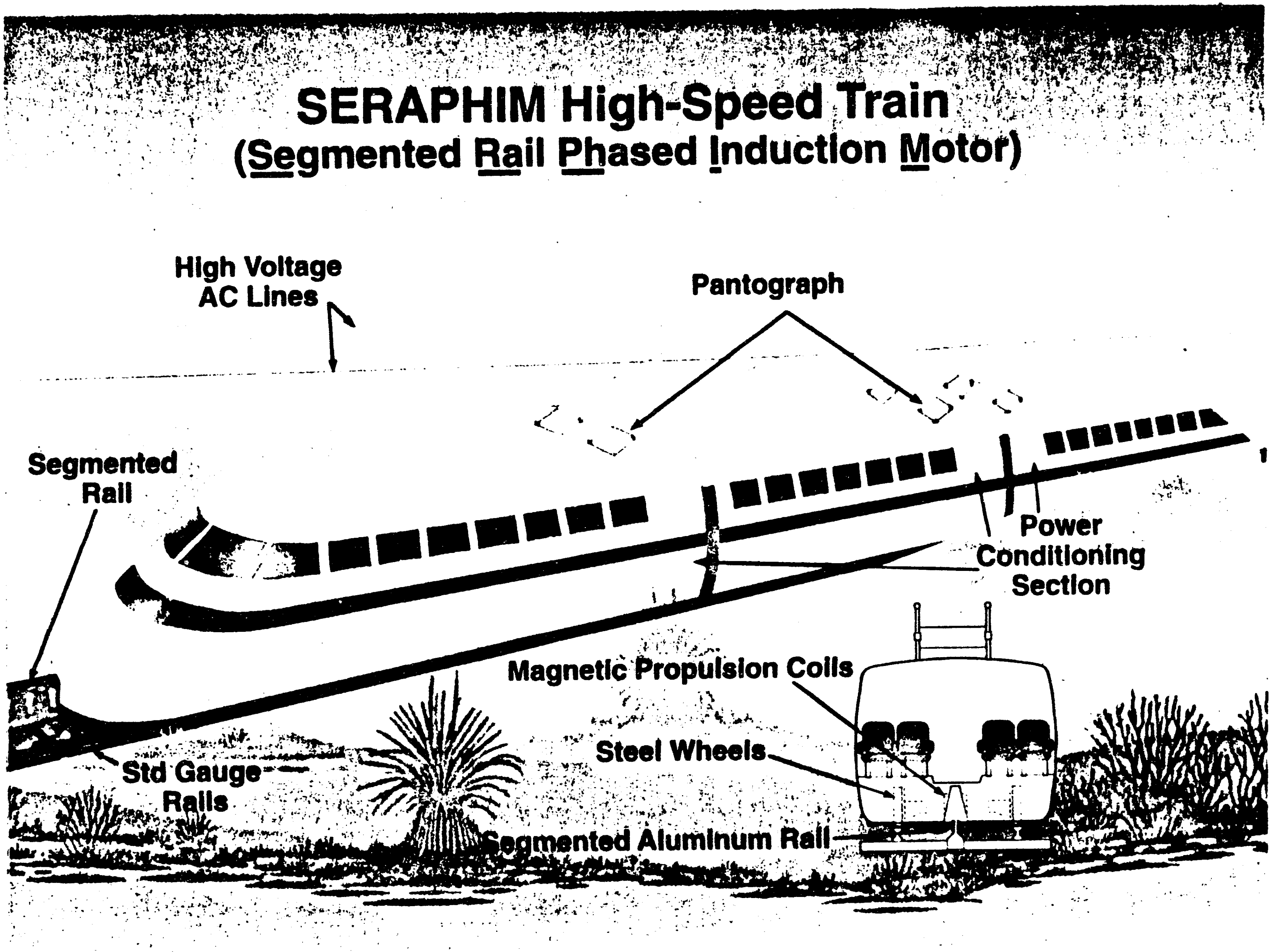
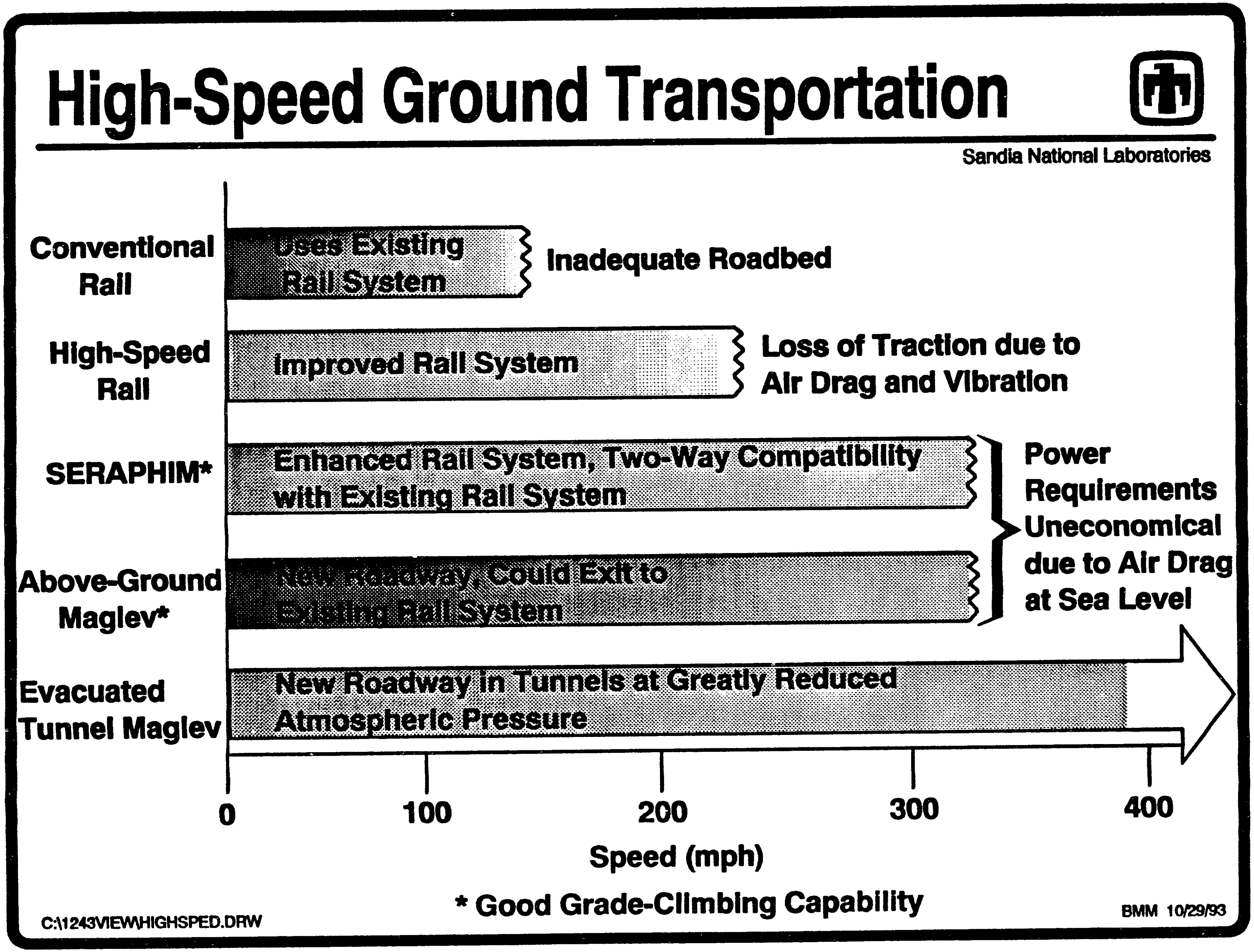

SERAPHIM High-Speed Train
(Segmented Rail Phased Induction Motor)
High Voltage AC Lines
Pantograph
Segmented Rail
Power Conditioning Section
Magnetic Propulsion Coils
Steel Wheels
Std Gauge Rails
Segmented Aluminum Rail

FIG 3


High-Speed Ground Transportation
Sandia National Laboratories
Conventional Rail
Uses Existing Rail System
Inadequate Roadbed
High-Speed Rail
Improved Rail System
Loss of Traction due to Air Drag and Vibration
SERAPHIM*
Enhanced Rail System, Two-Way Compatibility with Existing Rail System
Above-Ground Maglev*
New Roadway, Could Exit to Existing Rail System
Power Requirements Uneconomical due to Air Drag at Sea Level
Evacuated Tunnel Maglev
New Roadway in Tunnels at Greatly Reduced Atmospheric Pressure
0
100
200
300
400
Speed (mph)
* Good Grade-Climbing Capability
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BMM 10/29/93

FIG 4

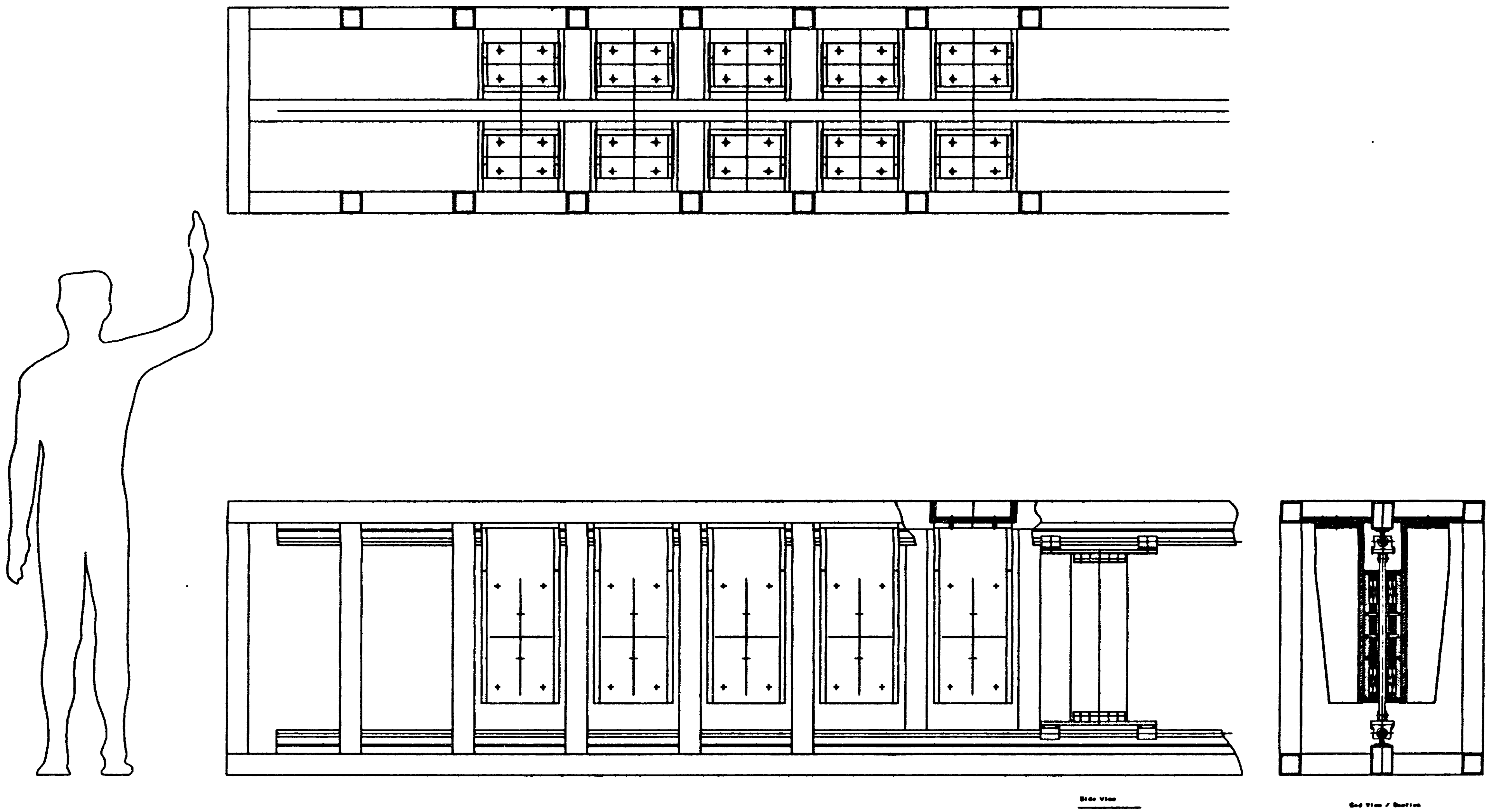

FIG 5

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