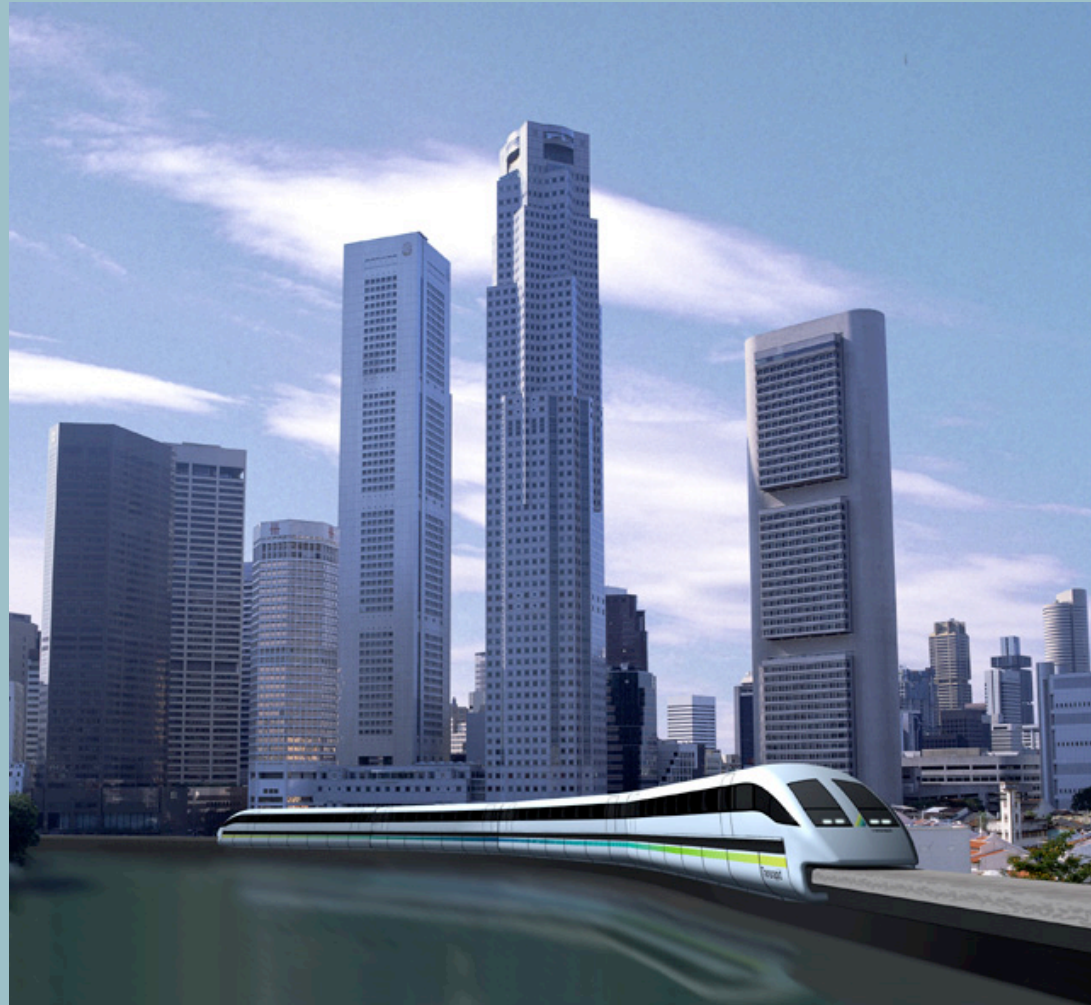


Maglev Technology

Fault Tolerance and Safety

**based on a
project by
Azarin
Jazayeri**



Presentation Outline

- History and Recent Developments
- Technology Background
- Fault Tolerance and Safety
- Comparison with Other Systems



Early Developments



- In 1750 Mitchell noted: different magnetic fields attract each other and similar magnetic fields repel each other. This scientific principle is critical for the train to float.
- In 1904 Goddard described a rail system using an electromagnetic rail bed to levitate a train in a tube.
- The first ideas for a modern Maglev train were thought up in the early 1960's.

Projects Around The World

- **United States** - investigated Maglev technology but decided it was too expensive
- Cost is \$10 m to \$30 m / mile to build Maglev train system in US
- **Japan** - planning on building a commercial train, test prototypes have been developed, extensive research into Maglev systems
- **Germany** - built Transrapid train, extensive research into Maglev systems
- First commercial Transrapid line completed in China, in public use by end of 2003

Current Research & Developments

- Only Germany and Japan working intensively on further developing this technology.
- Researcher are currently working on making the technology safer, more efficient, and cheaper.
- Shanghai Maglev line is first commercial Maglev line in the world
- 8min from City Center to Airport, 45min by car
- Cost for project was \$1.2 billion US
- Germany, China, Netherlands & US all considering additional Maglev lines

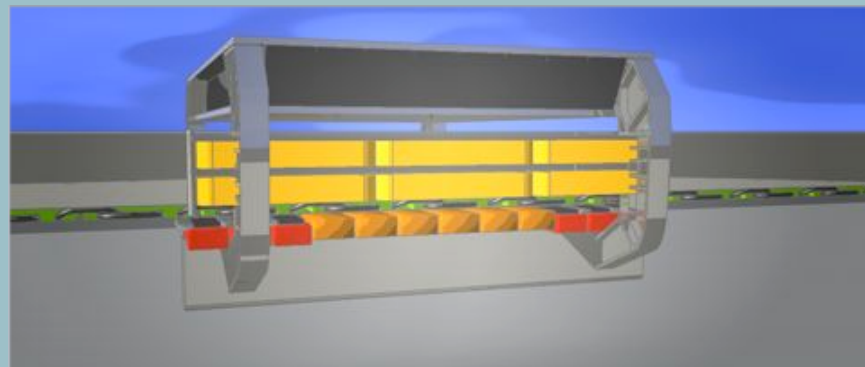
The Transrapid



- Maglev train designed in Germany
- First prototype developed in 1968, since then 8 different models have been built
- Most modern Transrapid has been tested over 60,000 miles
- Most tested Maglev system in the world.
- First Maglev system in commercial use

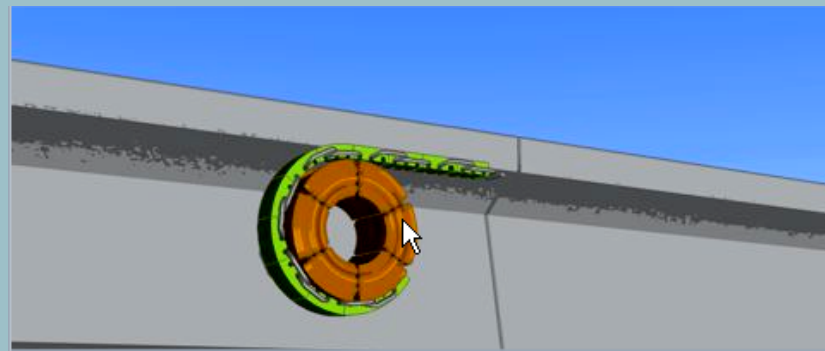
Vehicle Structure - Fault Tolerance

- Train is divided into separate sections
- Each section is placed on 4 bogies
- Bogies wrap around the track
- Each section has complete mechanical freedom
- Sections can respond individually to crosswind forces, radial forces and other forces



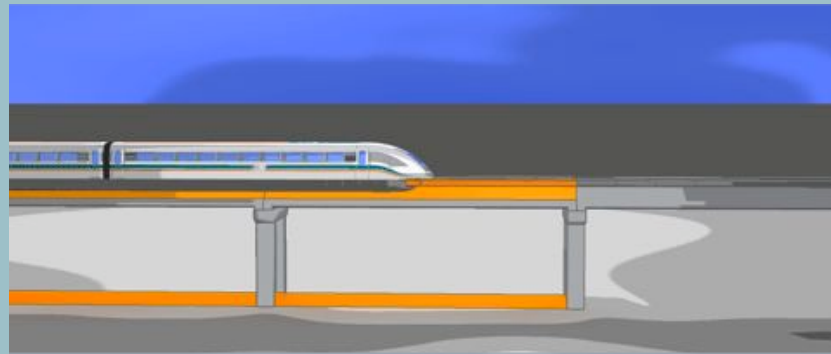
Propulsion System - Overview

- Like electric motor, except stator windings are underneath track.
- Generates a travelling magnetic field that pulls the support magnets and train along.



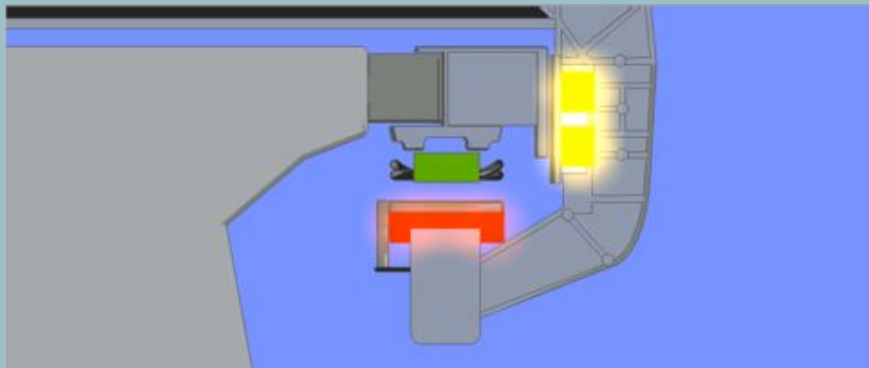
Propulsion System - Fault Tolerance

- Each section of the track is powered separately
- If power fails, train will be able to glide to next section where propulsion can resume
- Since track can only go one way at a time, collisions are near to impossible



Levitation System - Overview

- Support and Guidance magnets in a module
- When power turned on, train rises, when turned off, falls down.
- Power switched 100,000 times per second.

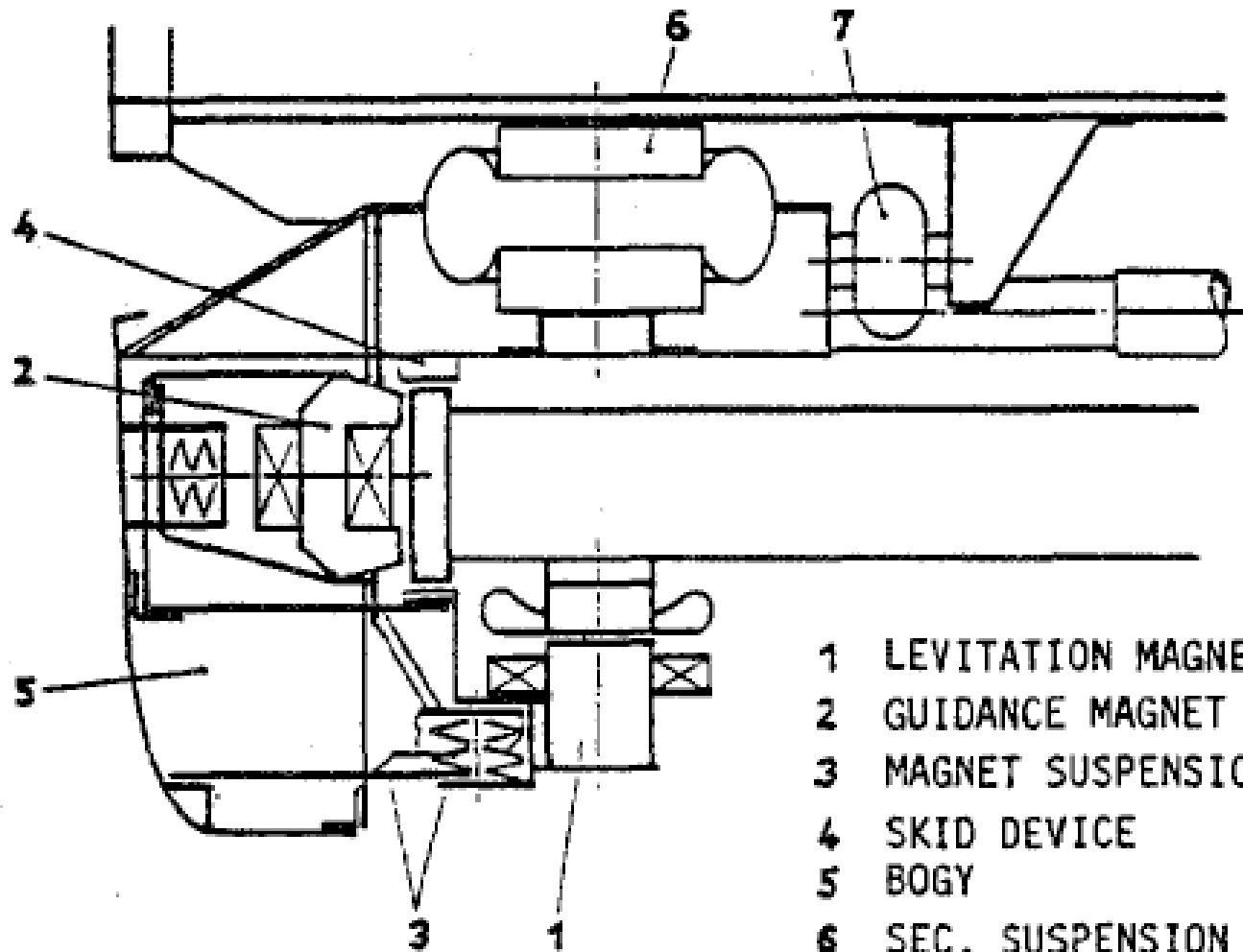


Levitation System - Fault Tolerance

- Magnets and electronics are called “magnetic wheels”
- 8 levitation wheels and 6-8 guidance wheels per boggy
- Wheels arranged in groups of 8
- 2 out of 8 wheels in every group can fail before entire system fails
- Failed levitation wheels are removed from system

Suspension System - Fault Tolerance

- Each boggy has its own vertical and horizontal suspension system
- Suspension is very soft
- If suspension on one boggy fails, other boggies still provide adequate suspension
- Horizontal suspension is reinforced with a hydraulic motor



- 1 LEVITATION MAGNET
- 2 GUIDANCE MAGNET
- 3 MAGNET SUSPENSION
- 4 SKID DEVICE
- 5 BOGY
- 6 SEC. SUSPENSION z
- 7 SEC. SUSPENSION y

Braking System - Fault Tolerance


- Triple redundancy
- Normal system uses magnets, emergency systems are mechanical
- Emergency systems act simultaneously if there is an emergency
- Each system controlled by separate component of on-board computer
- Emergency systems are independent on each boggy

Power System - Fault Tolerance

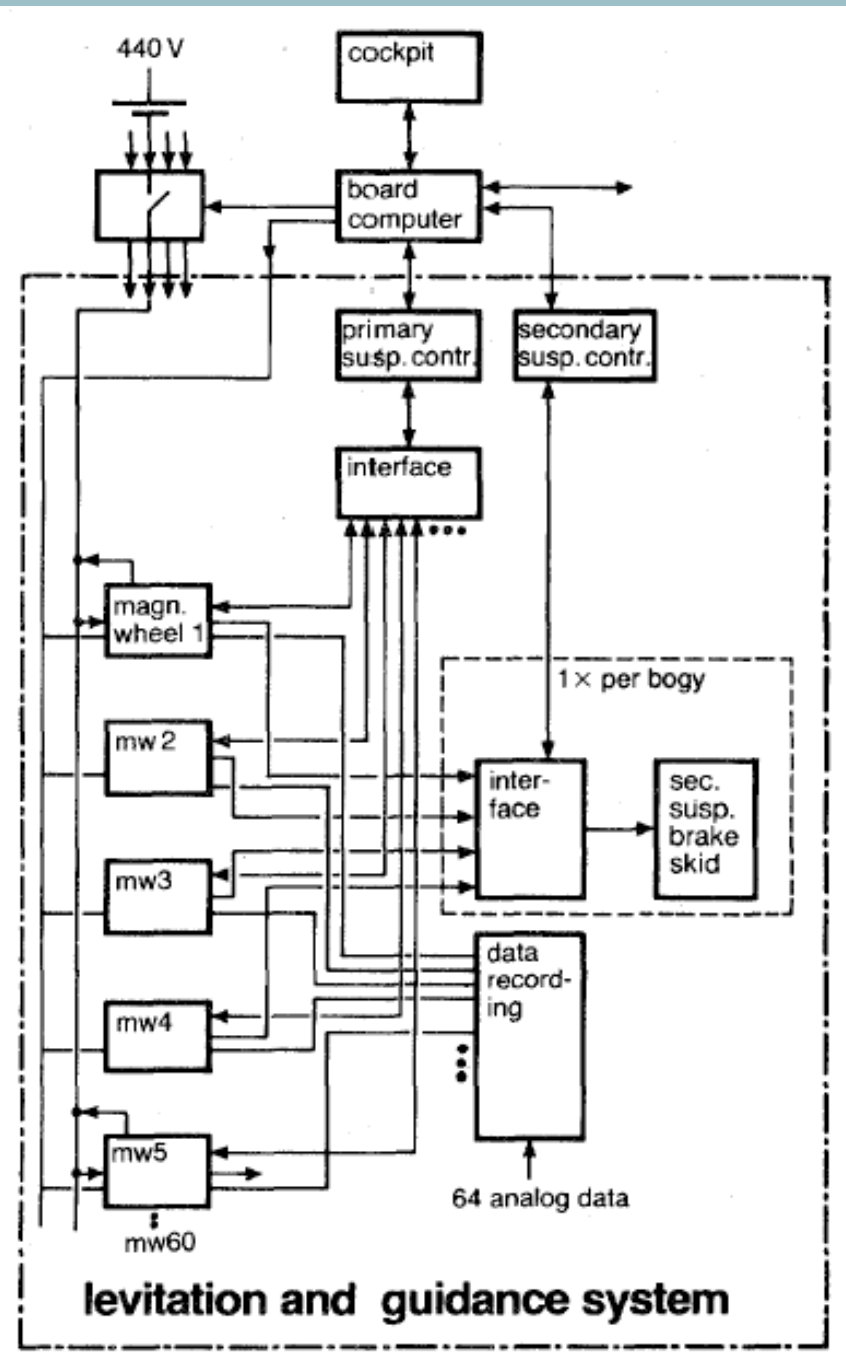


- Powered by four 440V batteries
- Each battery powers different set of magnetic wheels
- If one battery fails, controlled slowdown still possible

Control System - Fault Tolerance



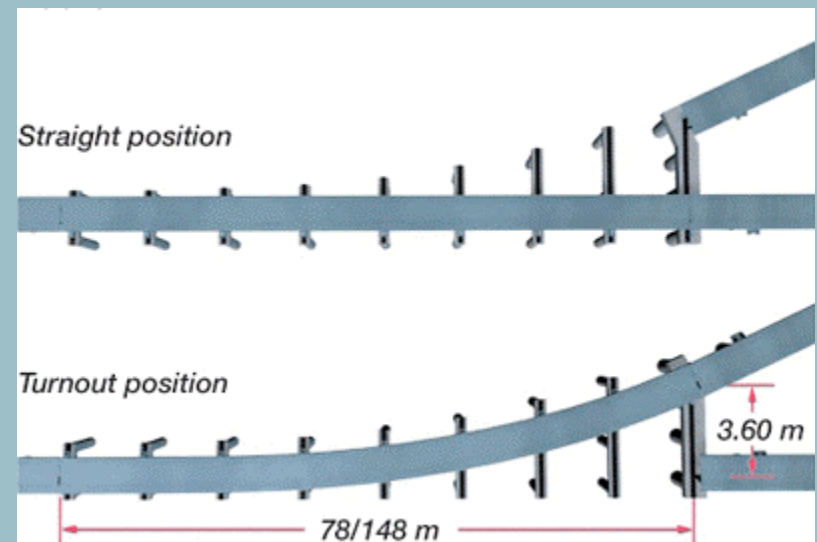
- Train fully computer controlled
- Three components
- Each component checks the others
- Each component controls at least one of the braking systems
- Even if two components fail, third component can safely stop train



levitation and guidance system

Track Switches - Overview

- To change guideways, large switches are elastically bent and then secured.
- Can travel at full speed for unbent switches, and 100km/h for 78m bent switch, 200km/h for 148m bent switch.



Comparison - Other Train Systems

- **Japanese Shinkansen (Bullet Train)**
- **French TGV**



Japanese Shinkansen - Overview



- Built in 1964
- The world's most advanced electrical and mechanical high speed train
- Speed = 300km/h, Passengers = 350,000/day & 130 million/year
- Automatic computer control for basic operation functions and human operator control for more complex functions

Japanese Shinkansen – Safety & Reliability

- No derailment or collision accidents
- No passenger or crew member fatalities
- Amazing Punctuality – average lateness per train in 1999 was 24 seconds



Japanese Shinkansen – Fault Tolerance

- **Scheduling and routing system**
 - displays the operation schedule on a single screen
 - allows the schedule to be revised by entering changes directly into the schedule diagram
- **Facility Monitoring System (FMS)**
 - when a failure occurs, the operator is alerted
 - monitors the "wind, snow, rain and rail temperature" environment data
- **Statistical Process Control & Proactive Failure Prevention**
 - meteorological & disaster information
 - appropriate speed limits and operating guidelines for safe train operation

French TGV – Overview


- Put into operation in 1981
- Combines high-speed performance with low environmental impact
- Speed record 370km/h in 1981 & 515km/h in 1990
- Operated in France, Belgium, Spain, Britain, Switzerland, Italy, and the Netherlands

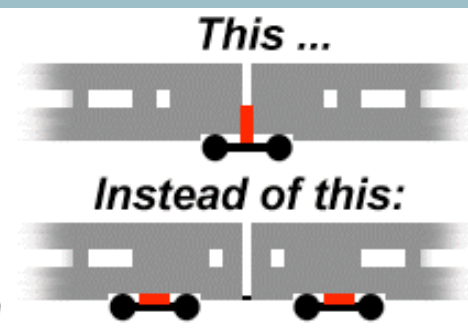


French TGV – Fault Tolerance & Safety

- **No passenger or crew member fatalities**
- **Constant monitoring system**
 - integrity of all the elements of the bogies, suspension and braking system
- **Special articulation**
 - maximize the stability of the train set in a derailment and minimize the risk of jack-knifing
- **Latest power systems & aerodynamic improvements**



 Red is Secondary Suspension



Benefits of Maglev

- High speed - 550km/h
- Very efficient - 30% less energy consumption than conventional trains
- Very comfortable
- No pollution, little impact on the environment
- Low maintenance, low operating costs
- Very safe and fault tolerant