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Skytrak – Low Carbon Vertical Transportation Systems for the 21st Century

presented by

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Overview

Background, Changing Requirements, Needs and Wants

New Geometries, New Building Communities, New Opportunities

History of Elevators, Going Back in History

Lenz's Law of Electrodynamics

Skytrak Design Considerations, Some Basic Physics

Skytrak – Three "Prime Movers" / Five Inventions

Linear Motor, Claw Type Double Sided

Triple Function Retarder Design

Applications of the Retarder

EGRESS, Synchrorail, Skytrak Aerial Ropeway, Skytrak Circular and Vertical

Low & High Speed Drives and Novel Transfer "Switch"

Visual Simulation

Background

- Density of occupancy of all buildings is increasing
- Land becomes ever scarcer and more valuable
- Buildings have to get more efficient
- Elevator systems have to work harder!

Besides.....

- Architects want a new degree of freedom for vertical transportation systems i.e. passenger cabins that move outside the vertical plane
- New energy efficient “green” self-contained communities need to be established where people can live, work and play
- Multiple cabins need to travel in one shaft to reduce the number of lift shafts deployed in buildings to save space
- Passenger cabins need to move people within and between buildings and facilities to remove day to day use of cars

Requirements are Changing! Why?

- Building geometry is becoming more complex
- Steel, glass and other materials can be custom cut
- Architects want unique shapes of buildings
- Transit between buildings and complexes is required
- Need to move people from major transportation hubs
- Building in city centres very constrained
- New integrated transportation solutions required

My building is curved why can't my Vertical Transportation be!?

Vertical Transportation needs to respond to the architect's wants!

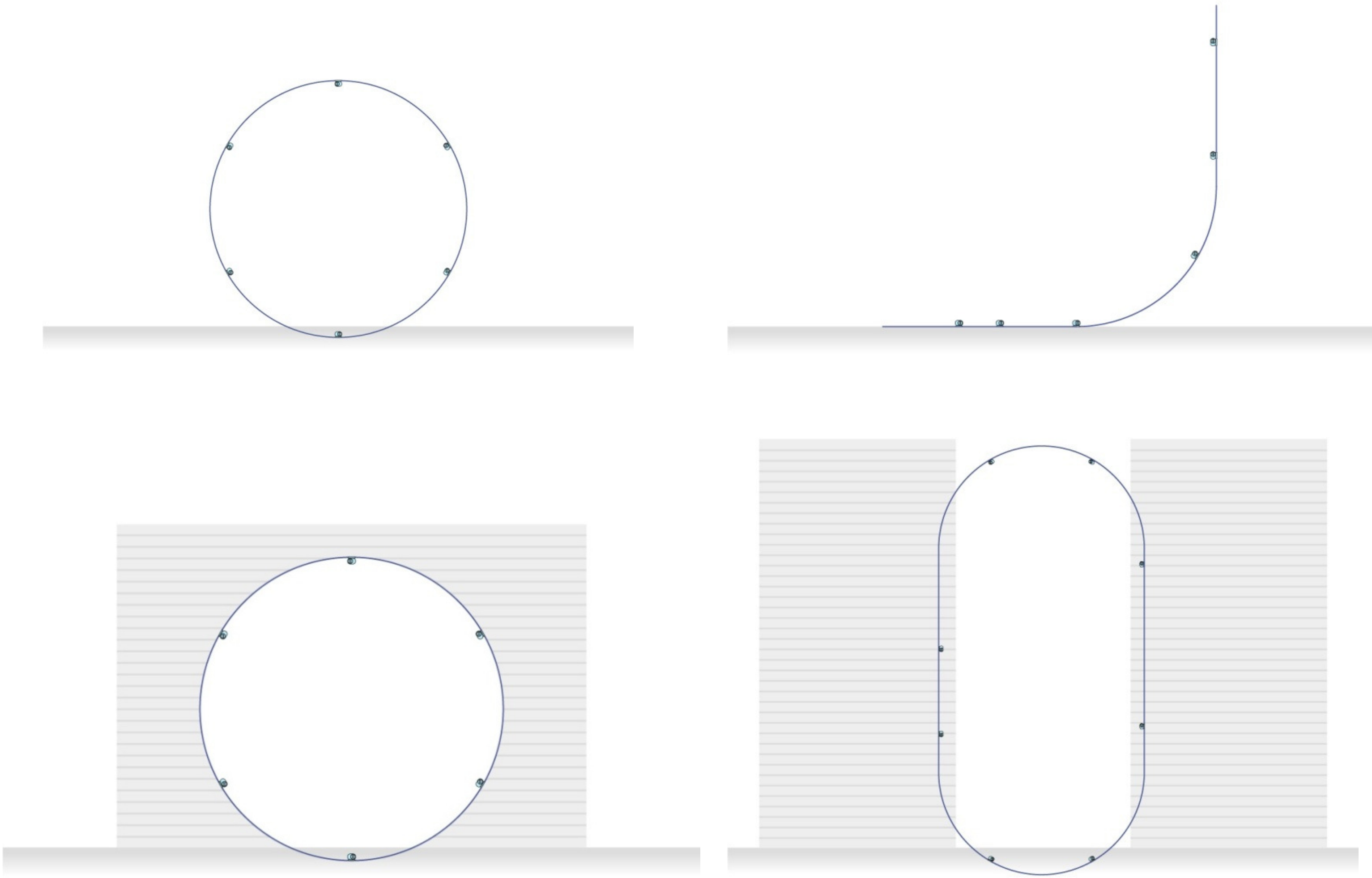
July 2010

Beijing CBD

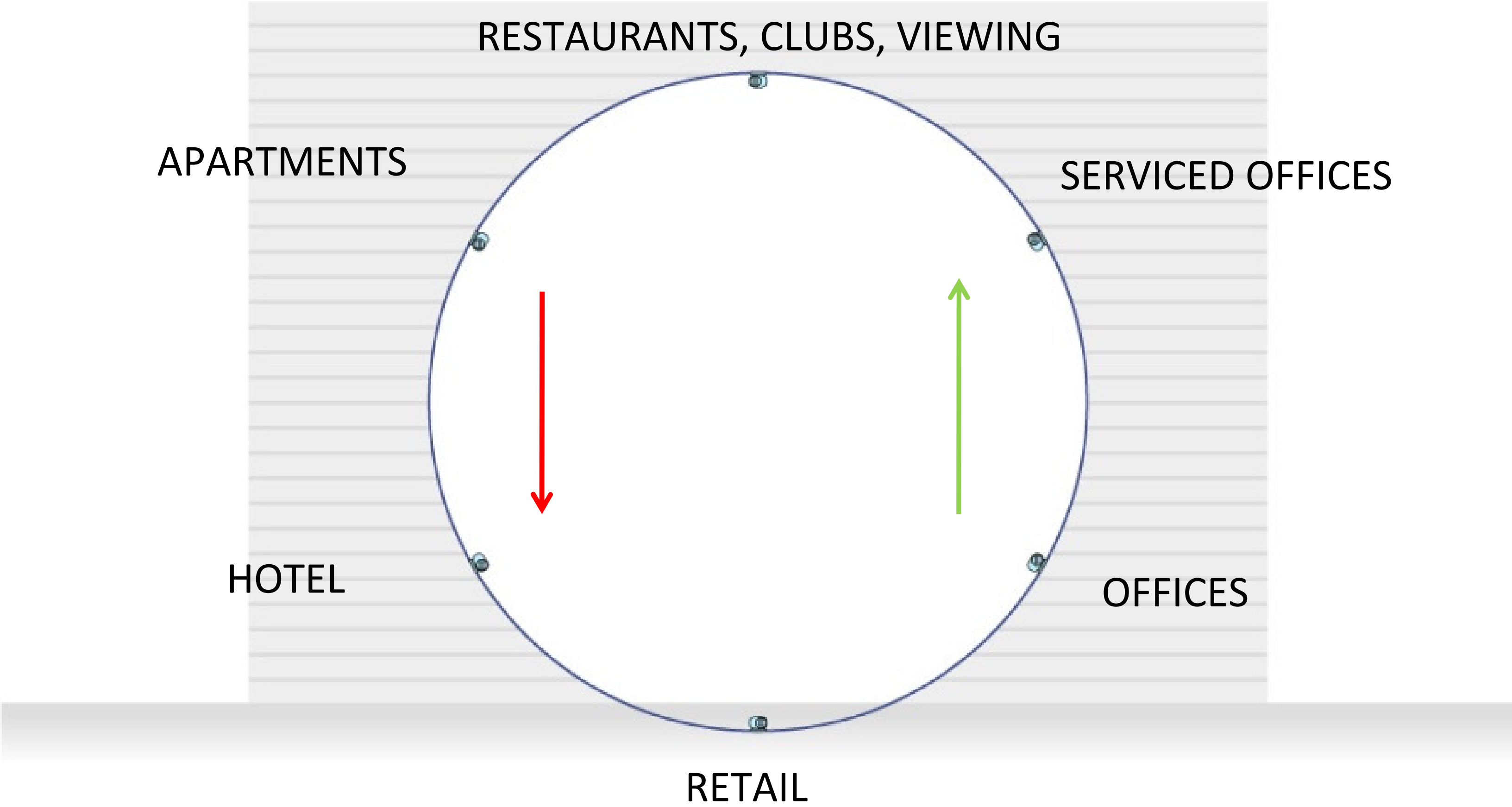
Competition

Entry

New Building Geometries ....



New Building Communities ...



You are just one journey away from anything and everything in the building!

History of Elevators

- The safety gear was publicly displayed by Elisha Graves Otis in 1853 at the Crystal Palace fair in New York
- It’s now over 150 years since this landmark invention and the uttering of the words “all safe gentlemen, all safe”
- Just think how far the aviation industry has moved since the Wright brothers took off in 1903!
- Today we want to prove that a new era for vertical transportation is about to unfold with the necessary inventions and technology now, at last, in place to enable the lift industry to finally take off!

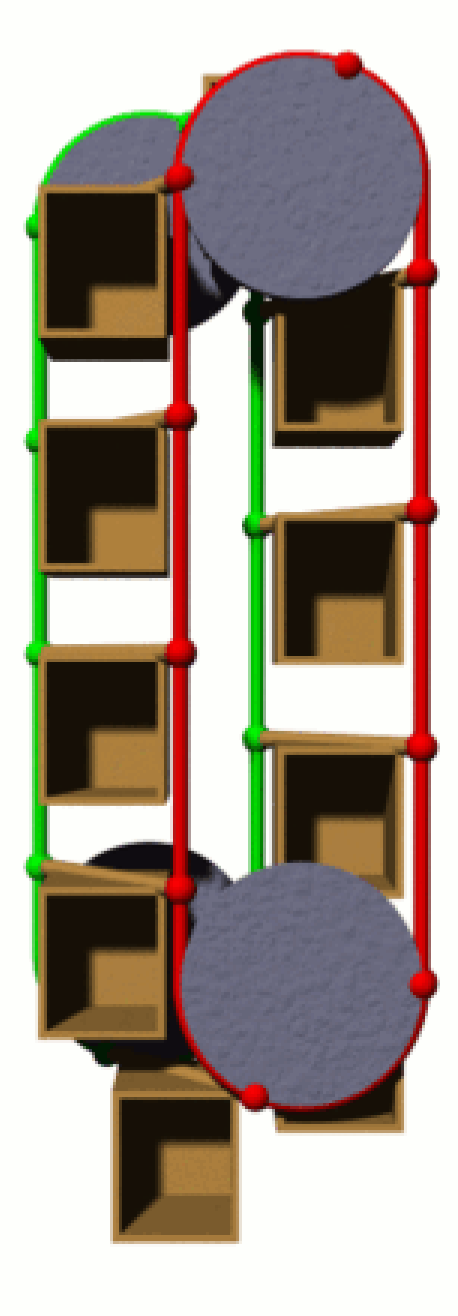
Going Back in History....

A **paternoster** or **paternoster lift** is a passenger elevator which consists of a chain of open compartments (each usually designed for two persons) that move slowly in a loop up and down inside a building without stopping. Passengers can step on or off at any floor they like. Courtesy Wikipedia

First built in 1884 by Londoner J. E. Hall as the **Cyclic Elevator**, the name *paternoster* ("Our Father", the first two words of the Lord's Prayer in Latin) was originally applied to the device because the elevator is in the form of a loop and is thus similar to rosary beads used as an aid in reciting prayers.[1]

Paternosters were popular throughout the first half of the 20th century as they could carry more passengers than ordinary elevators. They were most common in continental Europe, They are rather slow elevators, typically travelling at about 0.3 metres per second, thus improving the chances of jumping on and off successfully.

Today, in many countries the construction of new paternosters is no longer allowed because of the high danger of accidents (people tripping or falling over when trying to enter or alight). Five people were killed by paternosters from 1970 to 1993.



Lenz’s Law of Electrodynamics

- How can a law of electrodynamics established 20 years before the invention of the safety gear in 1853 hold out the prospect of safety for passenger cabins travelling without suspension ropes and a balance weight in the 21st century?

Lenz showed how electromagnetic circuits must always obey Newton’s third law. Lenz's law says:

"An induced current is always in such a direction as to oppose the motion or change causing it“

Skytrak Design Considerations

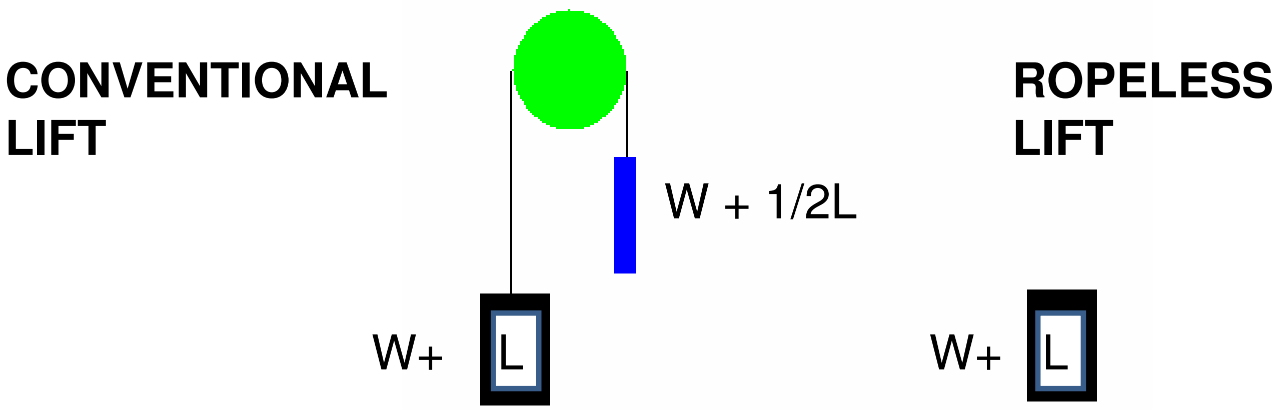
Some basic considerations concerning the practical design of a multicar ropeless lift system.

- Simple, efficient and quick mechanism for moving lift cabins from UP to DN and DN to UP at terminals
- Secure wireless communication to transfer commands from main control to moving lift cabins
- Satisfactory means of dealing with trapped passengers in an emergency
- Failsafe brakes must now be carried on board
- Increased structural loads will be applied to support track
- Keep cars “on” a track at all times

Skytrak Design Considerations (contd.)

- Light weight materials to be used throughout
- Cabins to be kept vertical when on curved trajectory
- Ride quality like today's best passenger lifts
- Lightest drive motor with the right characteristics
- Satisfactory control of deceleration in the UP direction when emergency stopping occurs
- Speed consistent with meeting ATTD criteria
- Safety is paramount - all ESHR's must be met
- Minimise overall system cost

Some Basic Physics ......



W = 1600kg	W = 1600kg
L=1600kg	L = 1600kg
Net Load = 800kg	Net Load = 3200kg
800kg @ 2.5m/s	3200kg @ 2.5m/s
800 * 9.81 * 2.5 = **19.6 kW**	3200 * 9.81 * 2.5 = **78.5kW**

Probable power requirement four times conventional lift!

Countermeasures to Power Input to achieve Low Carbon Alternative

1. Arrange for a common d.c. power bus to feed both UP and DN travelling lift cabins. Energy from DN cars is fed back into the bus to feed UP travelling cars

2. Maximum use of light weight components, composites and alloys

3. Run system at lowest speed consistent with acceptable time to destination

4. Ensure losses minimised, efficiency 96% plus

Skytrak – Three Types of “Prime Mover”

1. Controlled descent using a “gravity” drive
2. Low speed (up to 2.5 m/s) rotational linear motor drive
3. High speed (up to 6.0 m/s) linear motor drive

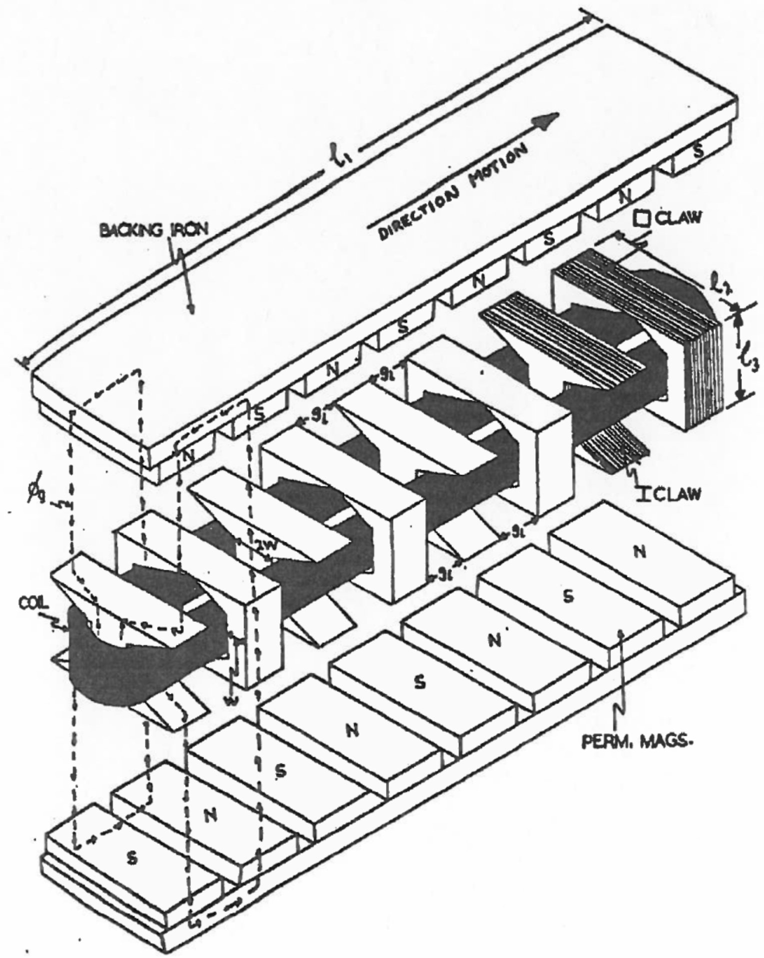
Skytrak – Five Important Inventions *

1. Use of “retarder” to allow safe descent under gravity
2. Passenger transportation on aerial ropeway
3. Emergency “up stopping” solution for high speed
4. Gearless lantern pinion drive using rotational linear motor
5. Terminal Switching of cars from “up” to “down” shafts

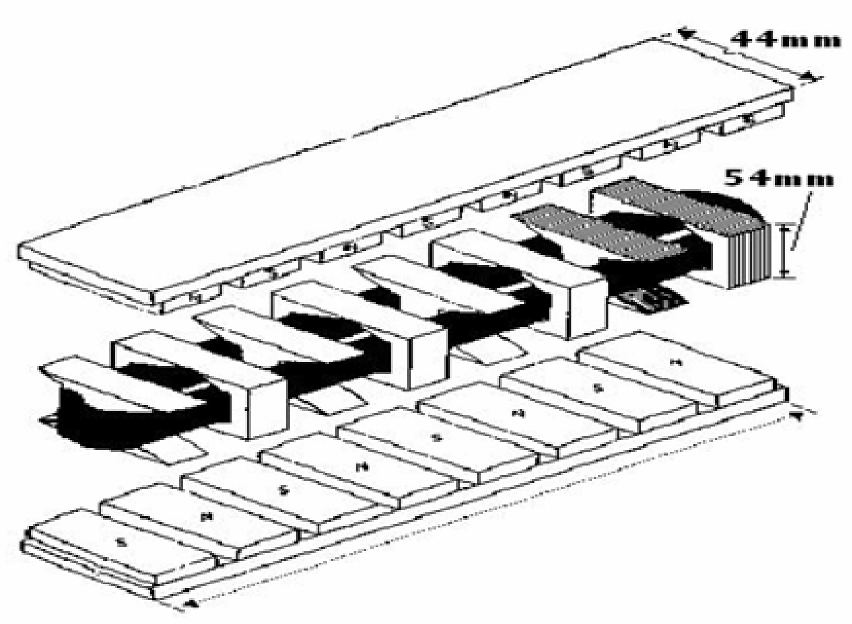
*** Patents Pending**

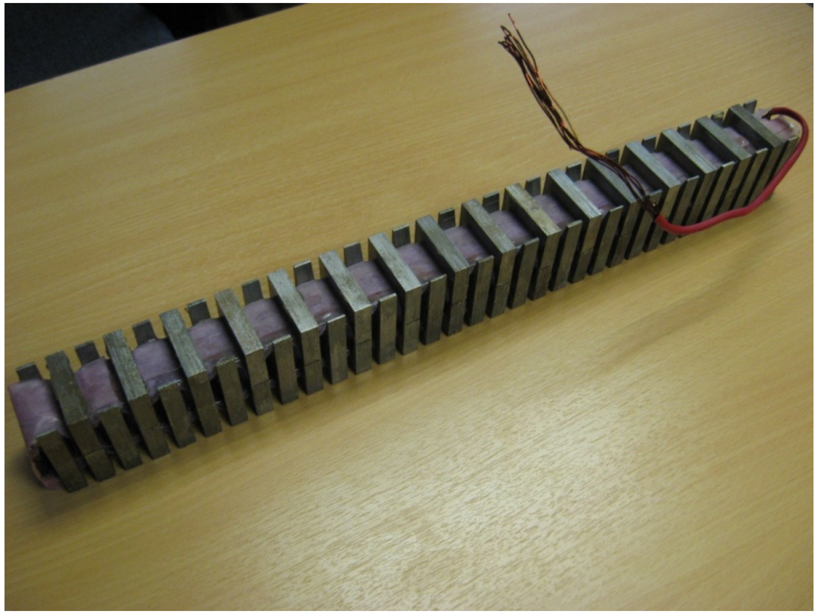
Linear Motor

- Simple construction
- Double sided to maximise output
- Single winding embraces large number of poles
- Moving magnet weight 30kg per metre
- Stacked as three phase
- Force output 5000 Newtons per metre for three phases



Linear Motor (contd.)

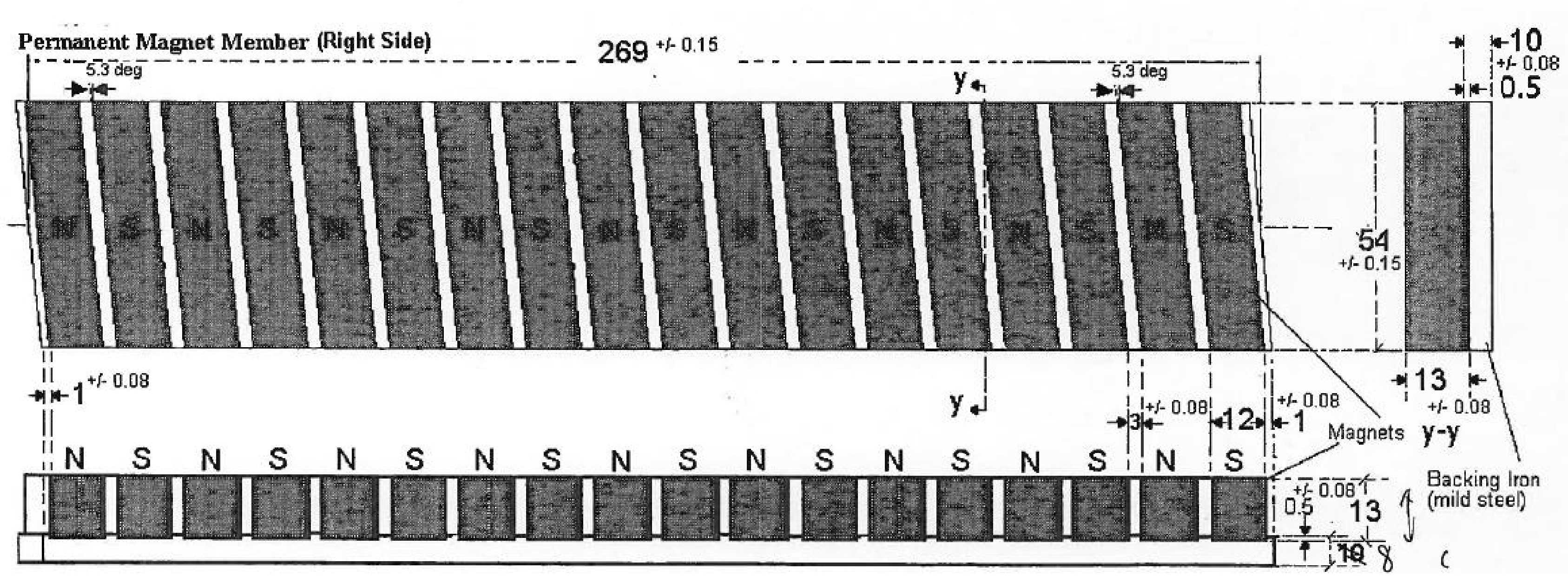




A one metre unit length of linear motor with stator cross sectional dimensions as shown can produce 1800 Newtons of thrust

Linear Motor (contd.)

Permanent magnet arrangement with backing iron

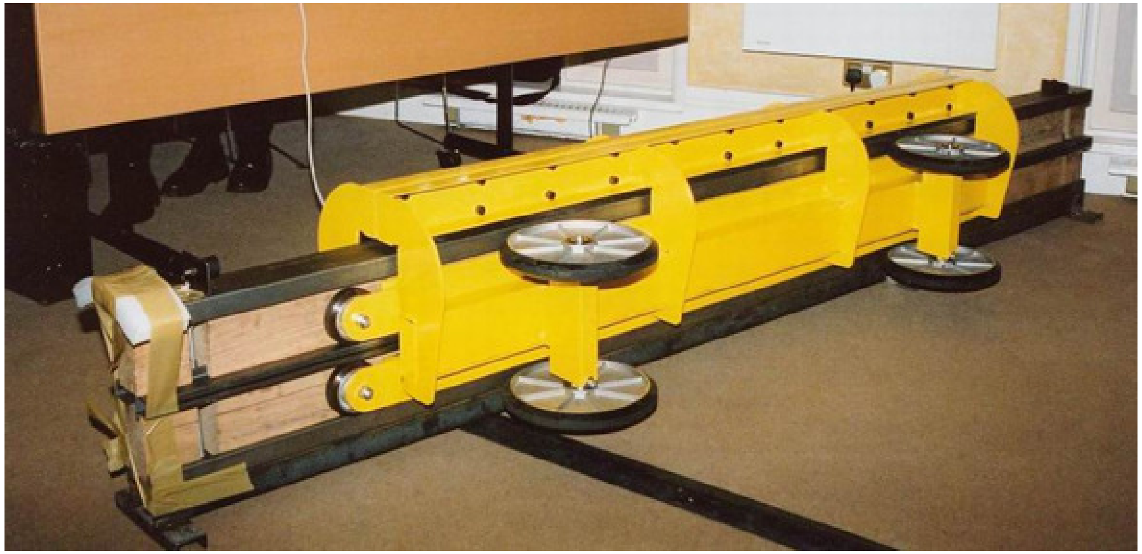


Linear Motor (contd.)

PROTOTYPE TESTING

With a 3.5m long moving magnet section reacting with a continuous stator section comprising 3 stacked claw motor elements the thrust from this combination would not be less than 20kN

Three of these motors in parallel would provide enough thrust to drive a lift of gross weight 4.5 tonnes



TEST ING OF MOTOR DRIVE OUTPUT

Linear Motor (contd.)

- Single winding permits the shaping of the poles to fit a circular construction for low speed version (discussed later)
- Labour used in manufacture is less than conventional motor
- Automated production possible with consequent reduction in cost per metre

Available Product

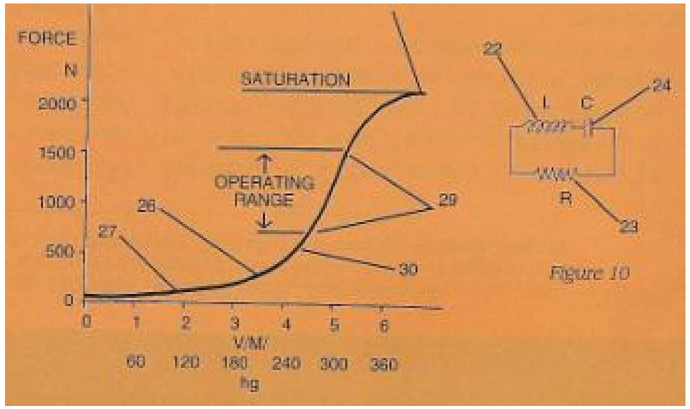
Can be manufactured by e.g. Phasemotion, China

Retarder (Under Test)

Triple Function

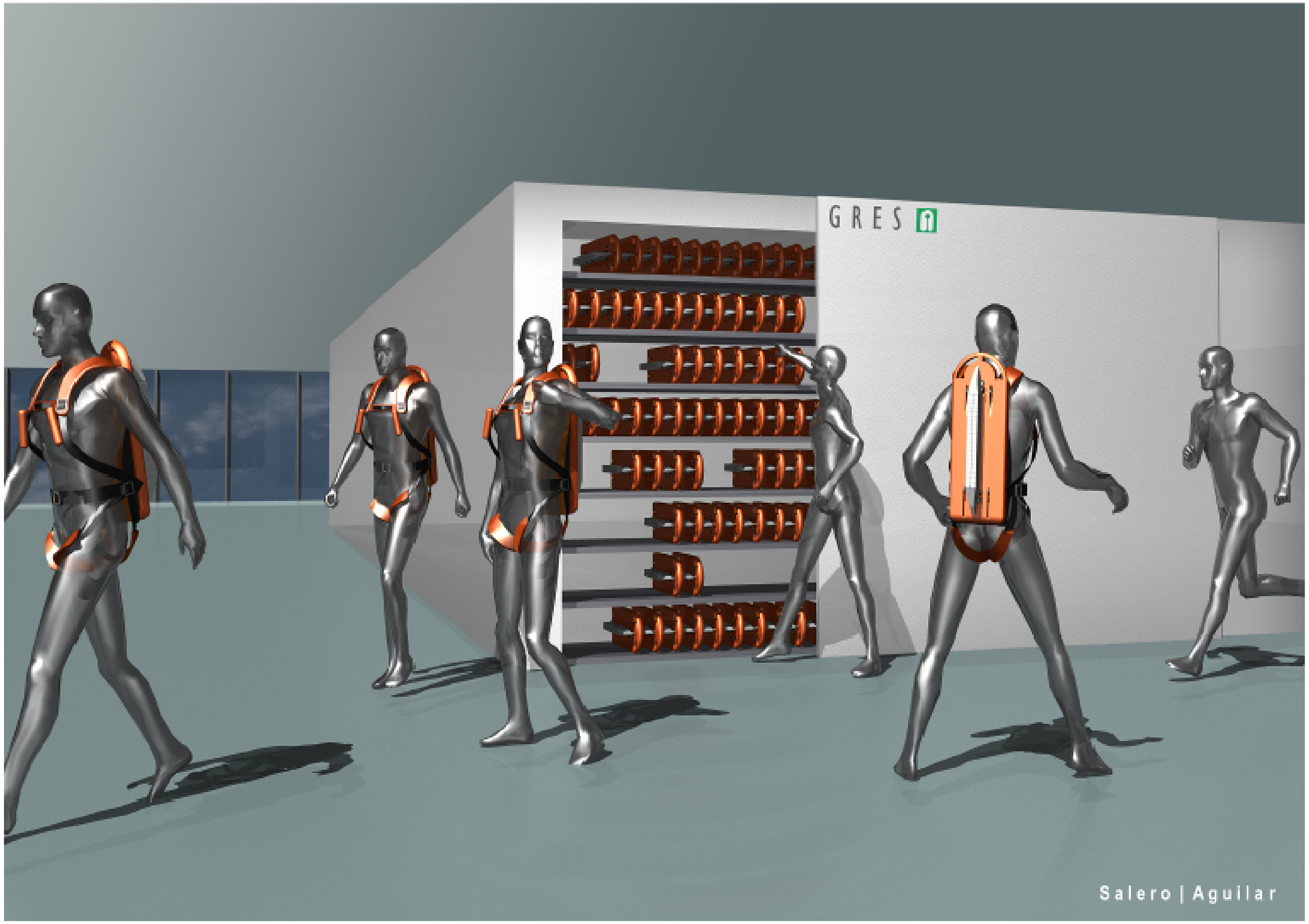
1. Act as a generator when moving to ensure the battery pack is continuously recharged
2. Act as a motor with sufficient force output such that when emergency up stopping occurs it will provide satisfactory deceleration of the lift cabin in conjunction with its power invertors and super capacitor pack
3. Act as a retarder capable of supporting the gross weight of the lift cabin and controlling its descent at a slow speed < 1.0 m/s enabling the lift cabin to return safely to floor level and discharge its passengers

A prototype of the "tuned generator" retarder under test is shown here

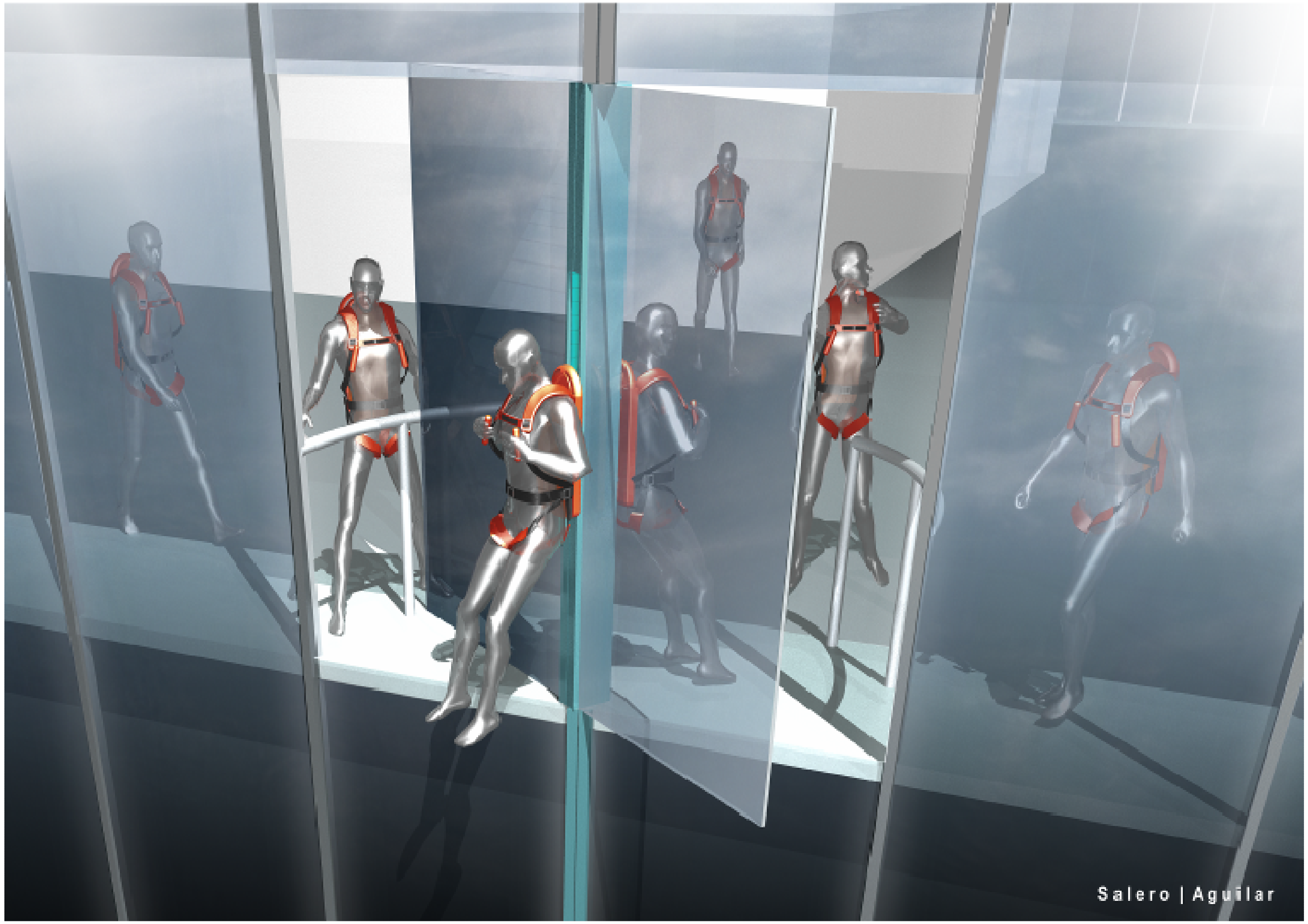


Applications of the “Retarder” Replacing the Conventional Safety Gear

- EGRESS Personal Rapid Escape Device
- SYNCHRORAIL Horizontal Transportation
- SKYTRAK Multi-Car Aerial Ropeway System
- SKYTRAK Multi-Car Circular Transportation System
- SKYTRAK Multi-Car Vertical Transportation System



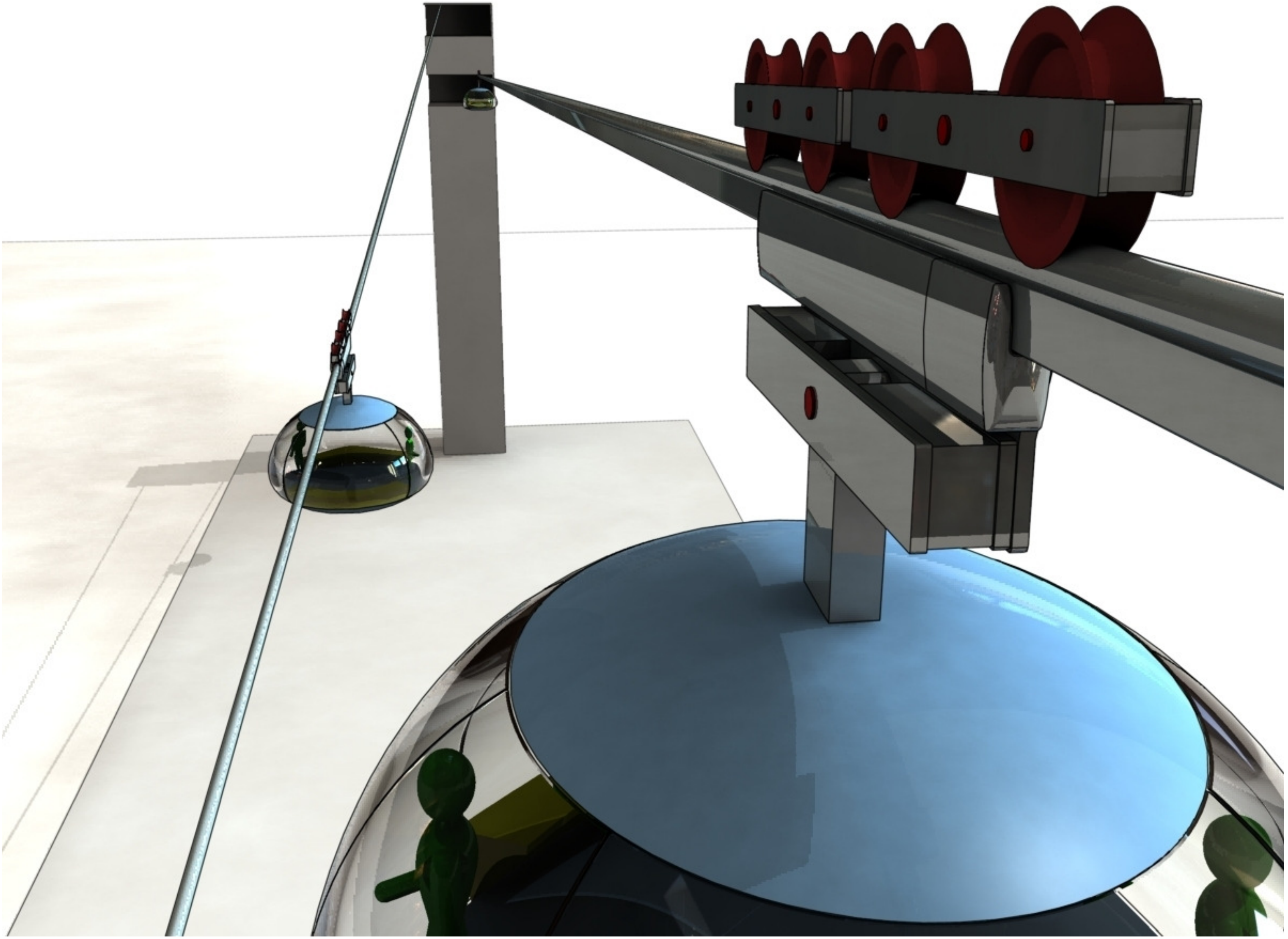
Building users take life jackets



Mullions in building cladding system contain magnet tracks

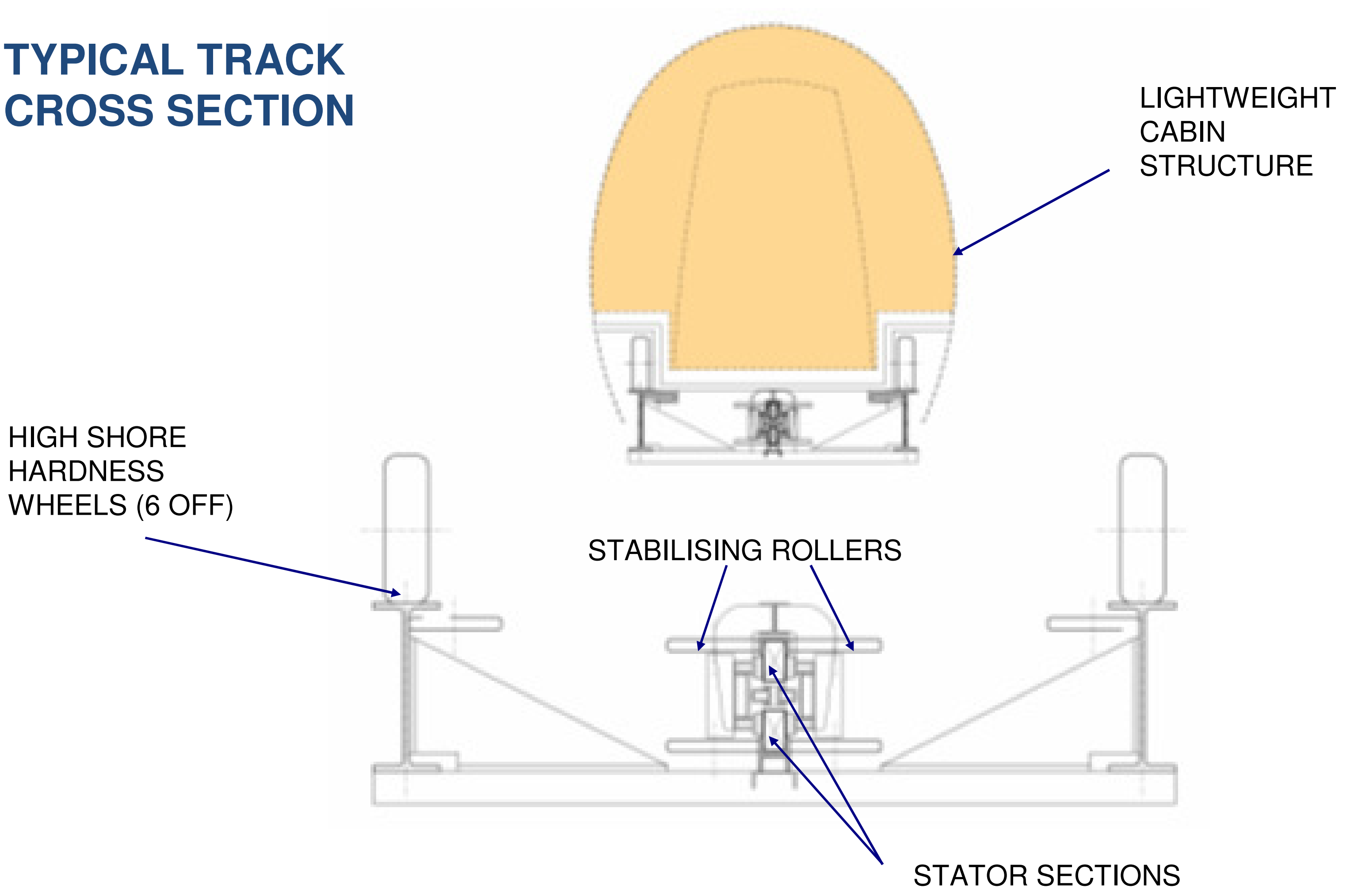
Occupants descend at constant speed to aircraft chute at base

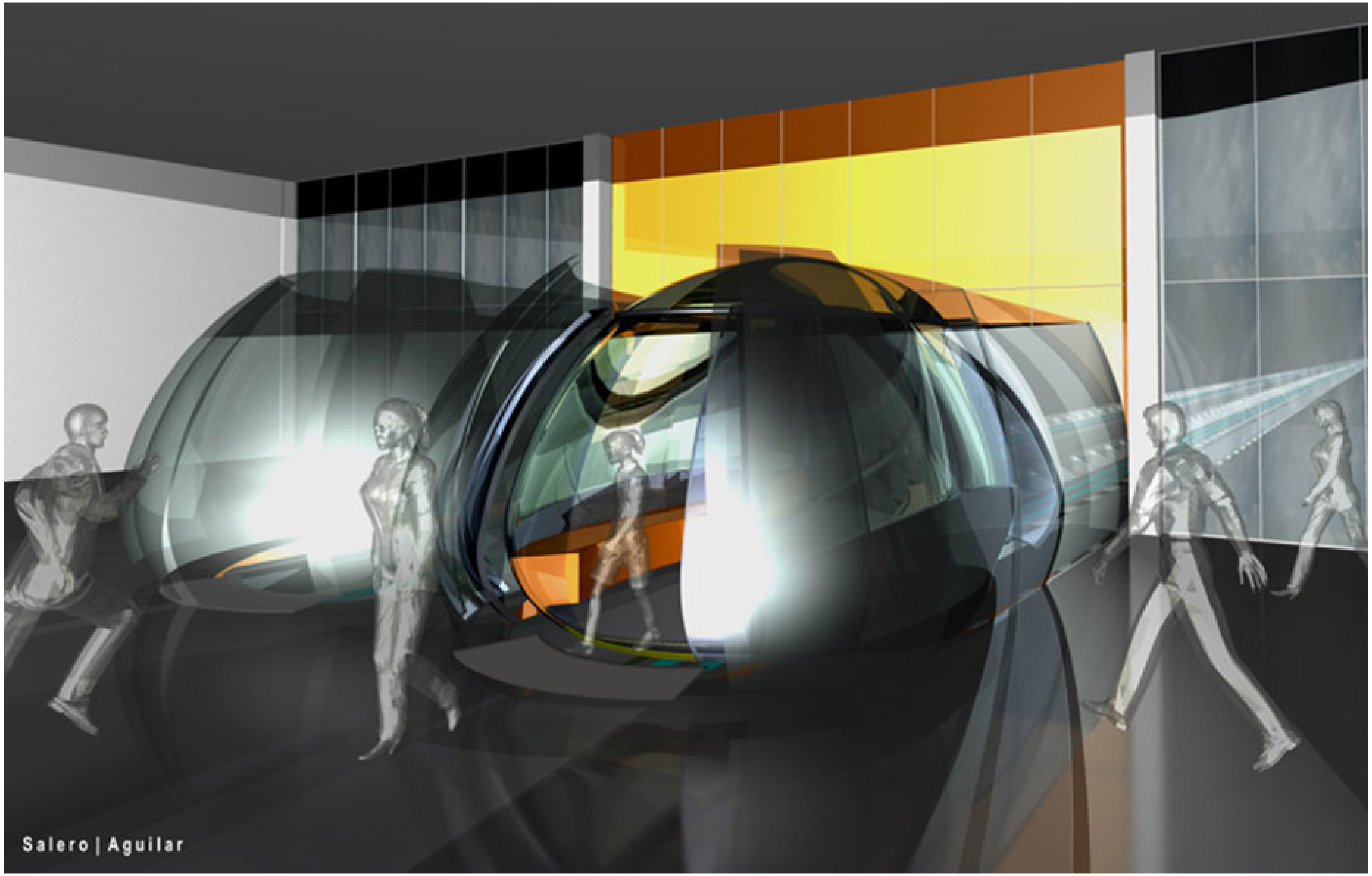
Passenger cabins travel down a simple hanging rope under gravity using the retarder invention



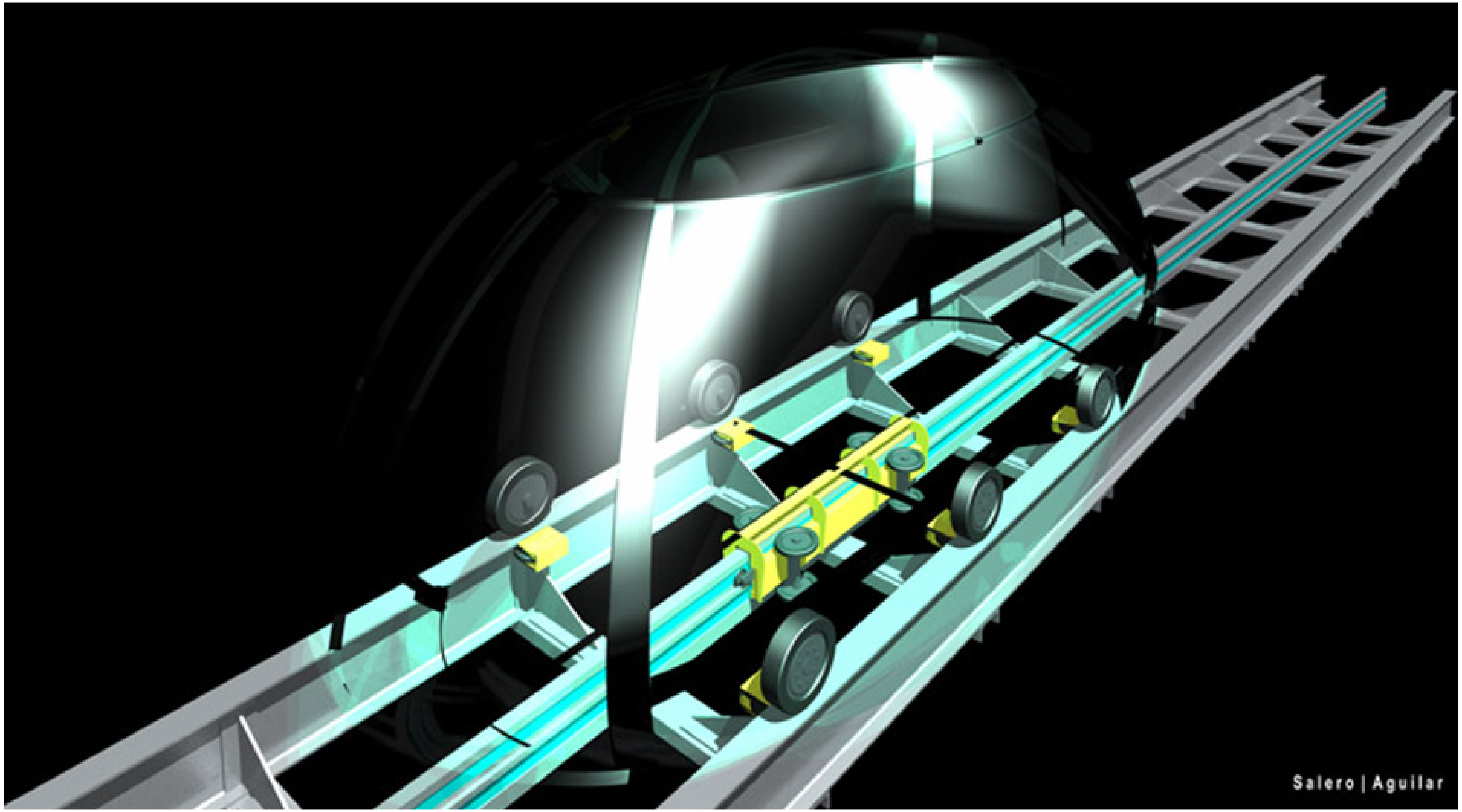
A simple steel rope has extruded steel sections threaded on to it that contain the permanent magnets and the upper running surface for the suspension rollers

TYPICAL TRACK CROSS SECTION

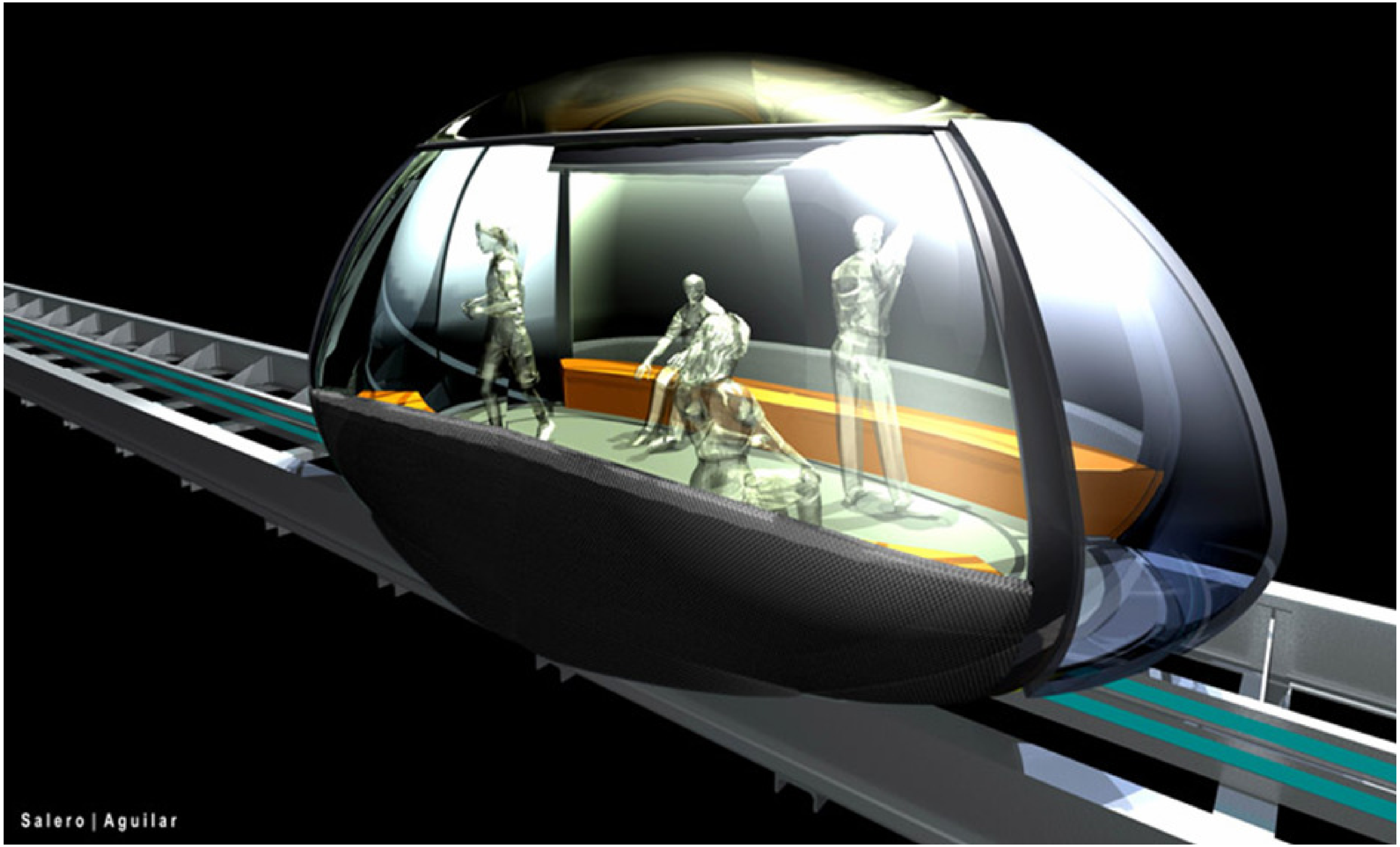




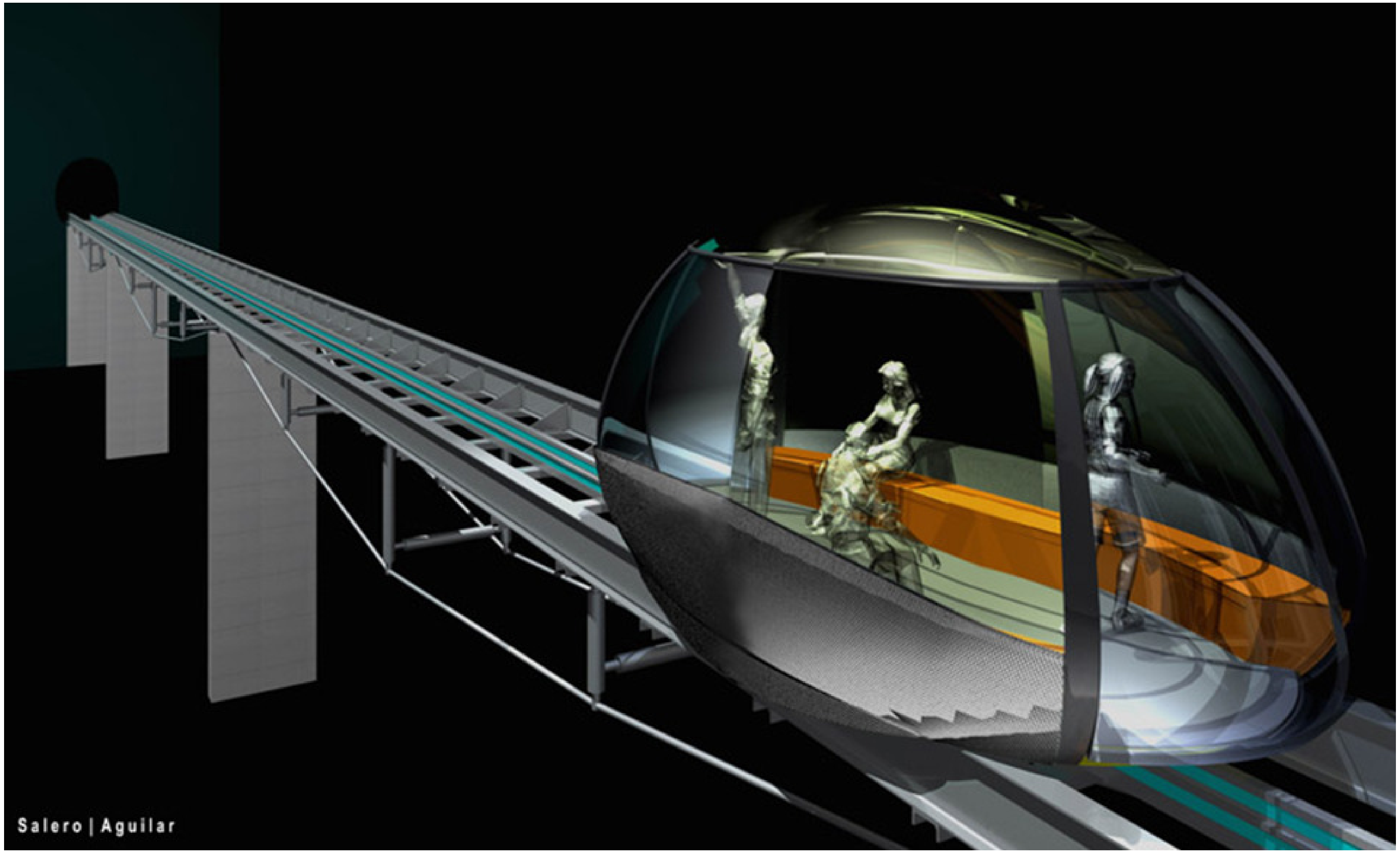
From the passenger viewpoint, entry and exit, ride quality and transit time is very similar to that of a high quality shuttle elevator



Shuttles are lightweight and have minimum moving parts providing high reliability, ease of maintenance and very low maintenance costs

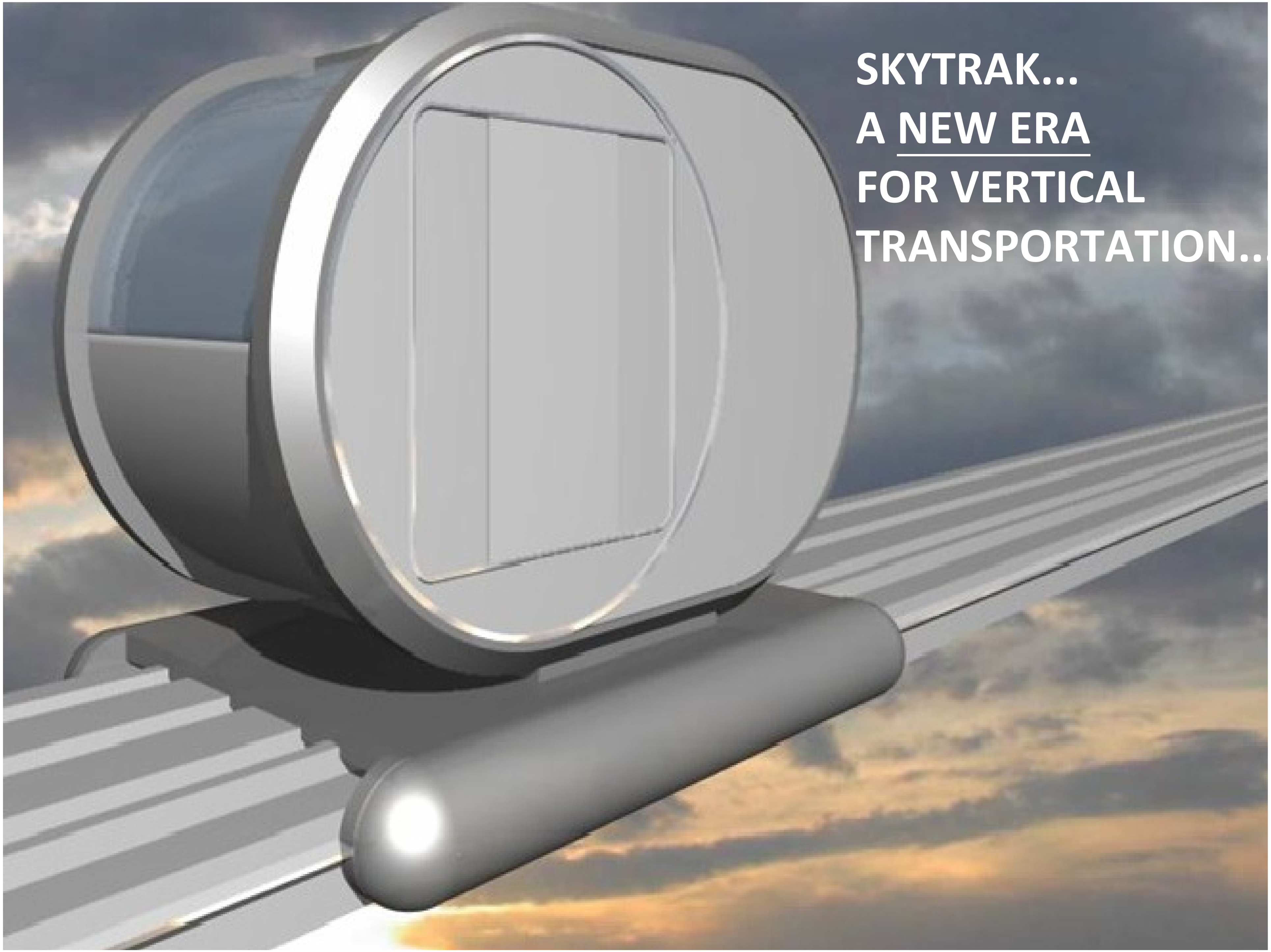


The entire system can be weather proofed and can comply with all handicapped access requirements



Simple truss sections can be used to support the track sections at high level

Skytrak Circular Transportation

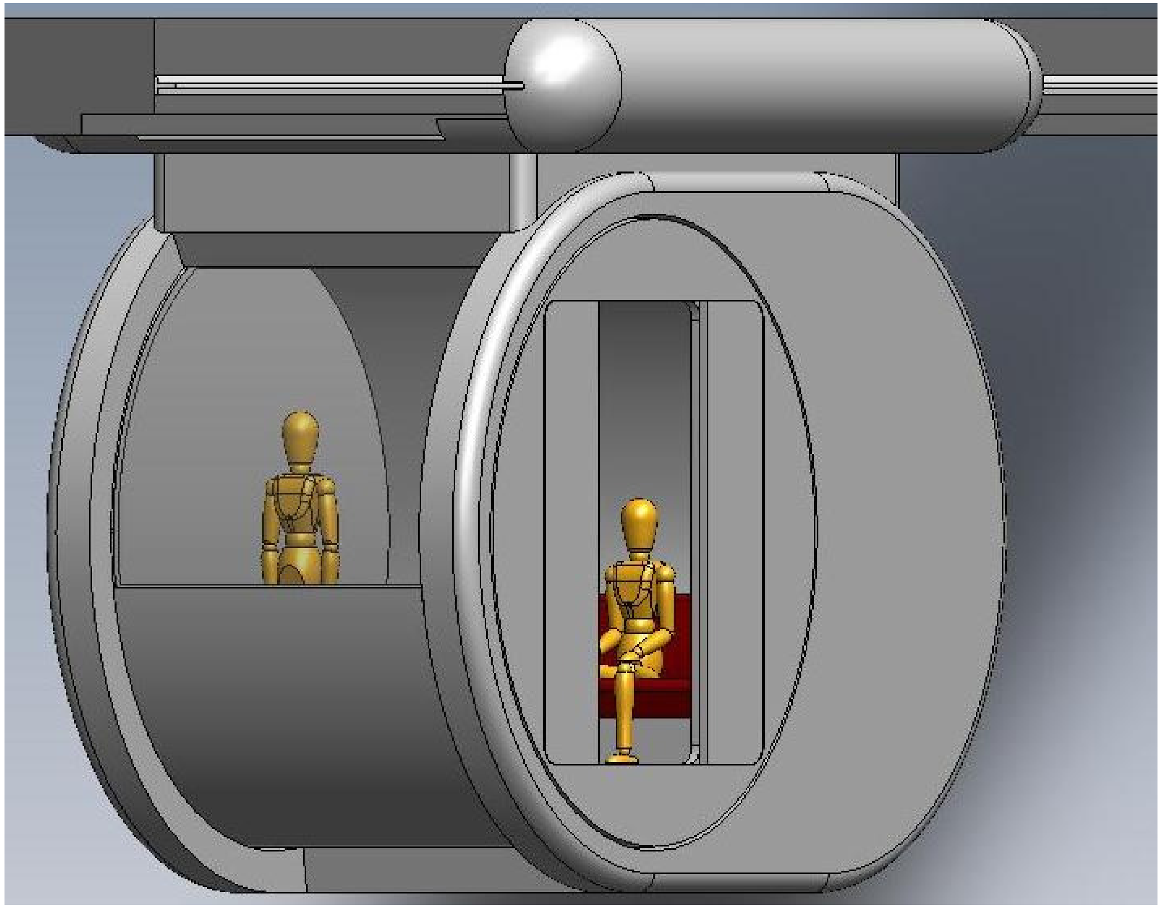

SKYTRAK...
A NEW ERA
FOR VERTICAL
TRANSPORTATION...

Prototype Test Track for Vertical and Circular Versions

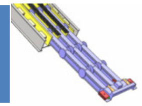
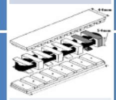
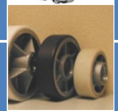
Cabin Assembly

Design (Total weight with rated load to be < 3200kg)

- Composite materials
- Seating, standing
- Battery pack
- Capacitor pack
- Overspeed monitoring
- Inertia switch
- Tilt switch
- TEC air conditioning
- Slewing and slip rings
- Secure wi-fi data
- Door operator
- Load switch
- Slip ring
- Brakes
- Cabin rotational drive with particle coupling



Skytrak – Cabin Weight Analysis 1597kg

Cabin Main Chassis 200kg		Sub Frame Assembly 50kg	
Car, Doors, Floor, Seating etc 150kg		Cabin External Enclosure 50kg	
Motor 523kg		Retarder 132kg	
Slewing Ring 30kg		Slip Ring 10kg	
Brakes 140kg		Logic Controller 10kg	
Guide Wheels 100kg		Door Operator 20kg	
Wireless Communication 5kg		Battery 60kg	
Inertia Switch 1kg		Lift Position Information 1kg	
Capacitor Pack & “Tuning” 85kg		Normally Closed Contactors 15kg	
Load Switch 5kg		Up Stopping Drive 10kg	

Emergency Up-Stopping Invention

Design

- Controlled deceleration when emergency stop occurs in the up direction

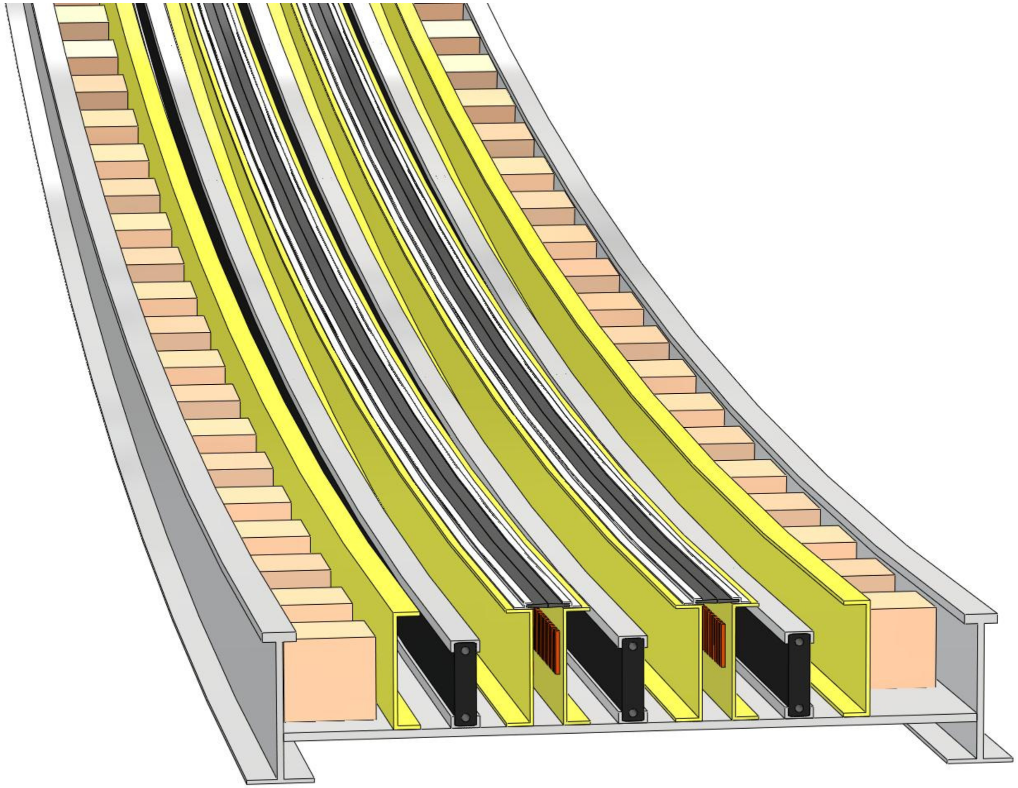
- Sufficient energy must be stored ”on board” and available at the instant that any emergency stop in the up direction occurs

- The lift cabin must separate from the failsafe brake chassis in order to allow the cabin to continue upwards decelerating at approximately 2 to 3m/s/s

- The storage element consists of a super capacitor module containing sufficient energy to drive a 3200 kg car in the up direction for several seconds depending on the speed

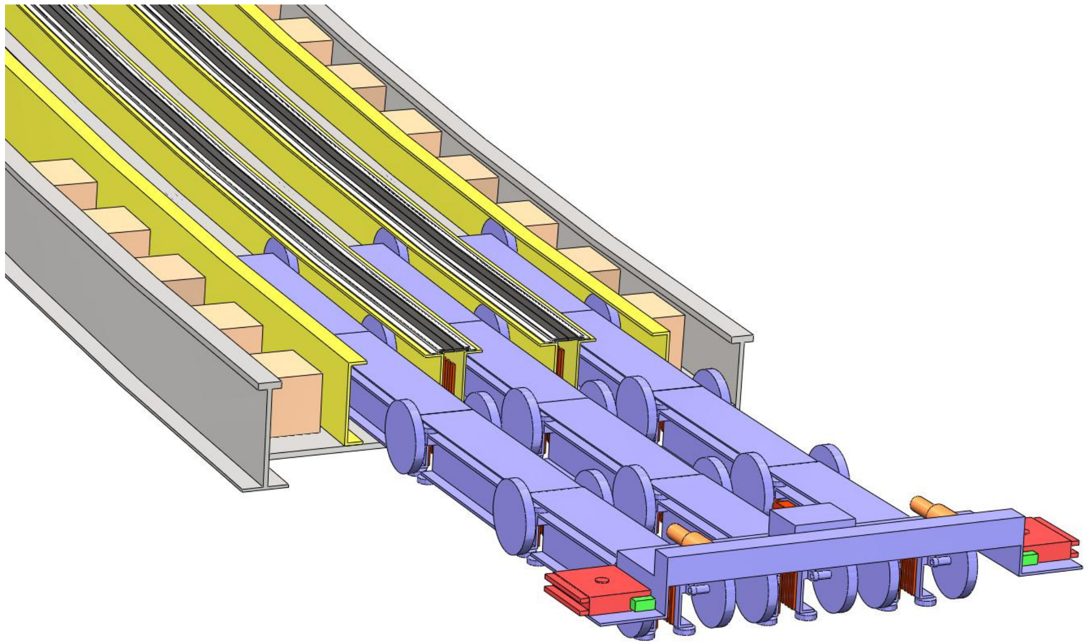
- This energy to be delivered to the “on board” retarder elements operating as a motor using a light weight power electronic drive for a short time interval

Emergency Up-Stopping Principle



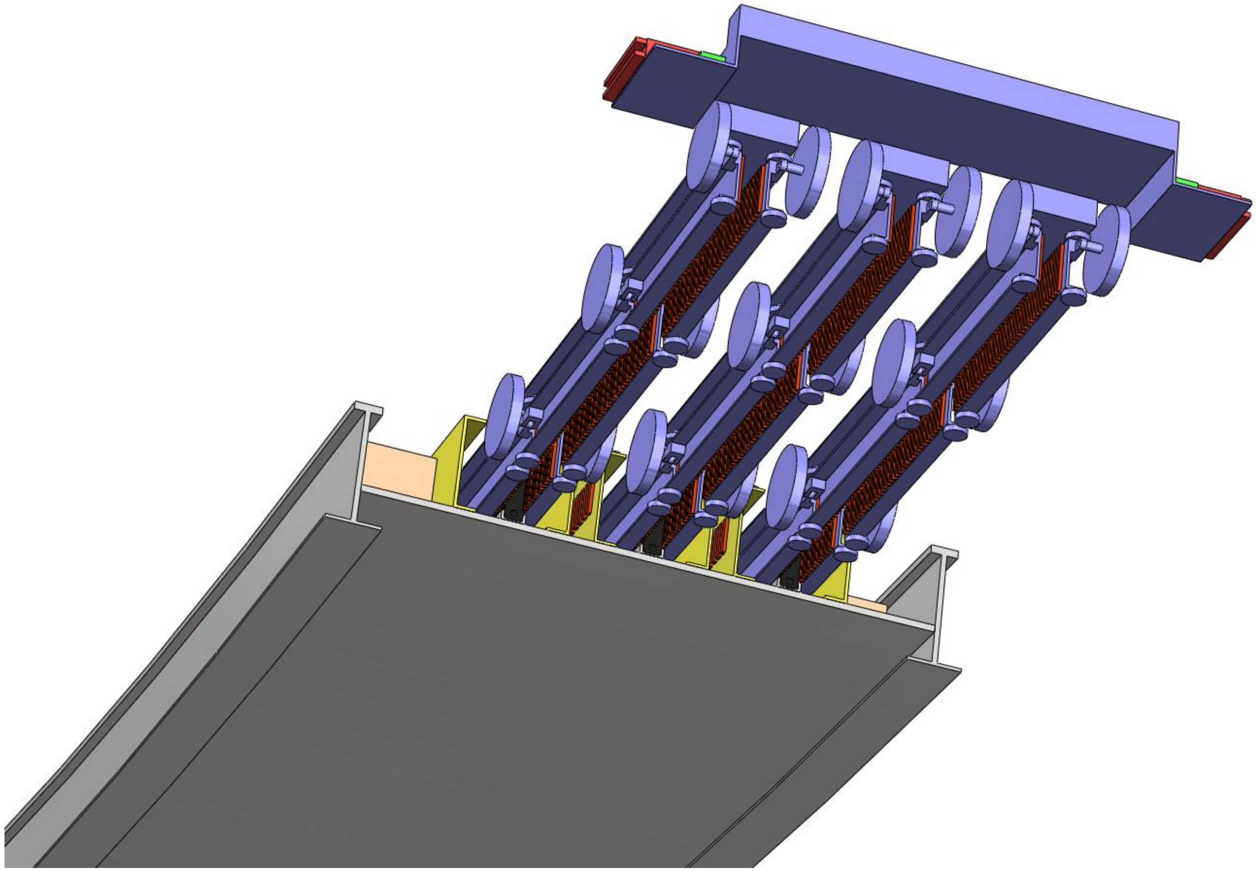
TRACK AND MAIN DRIVE

Emergency Up-Stopping Principle



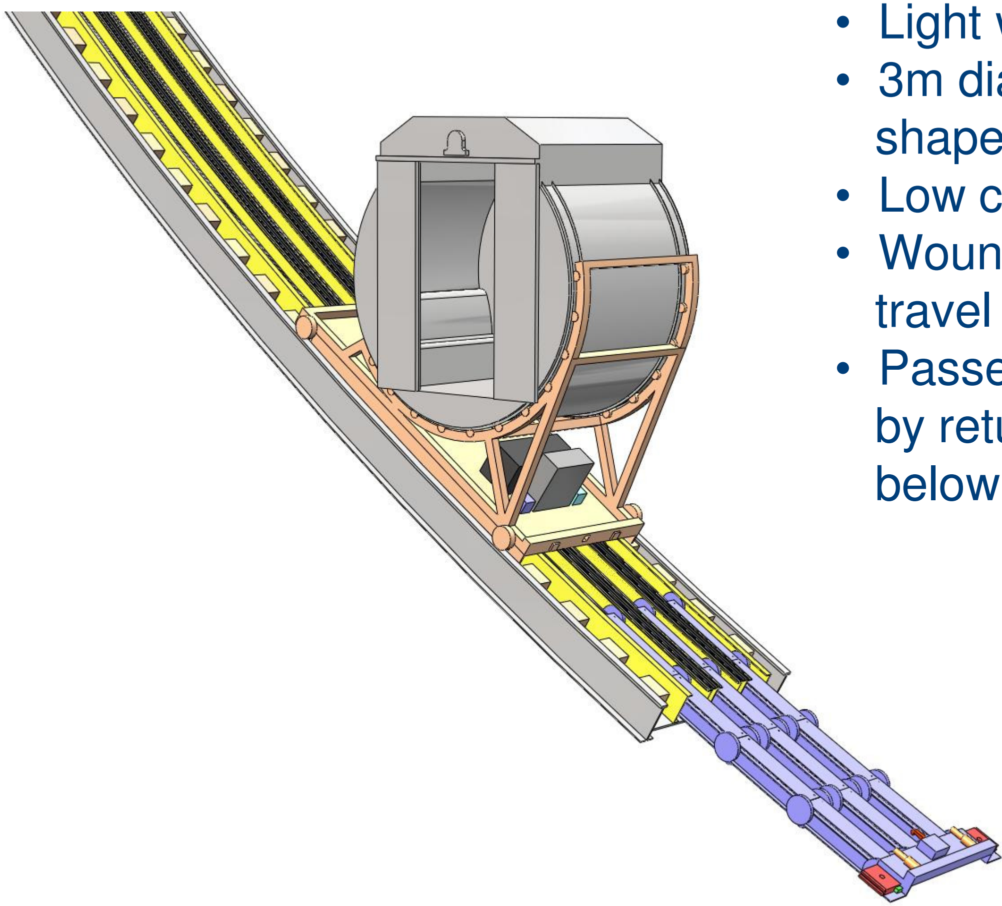
TRACK AND SUB FRAME ASSEMBLY

Emergency Up-Stopping Principle



UNDERSIDE OF SUB FRAME ASSEMBLY

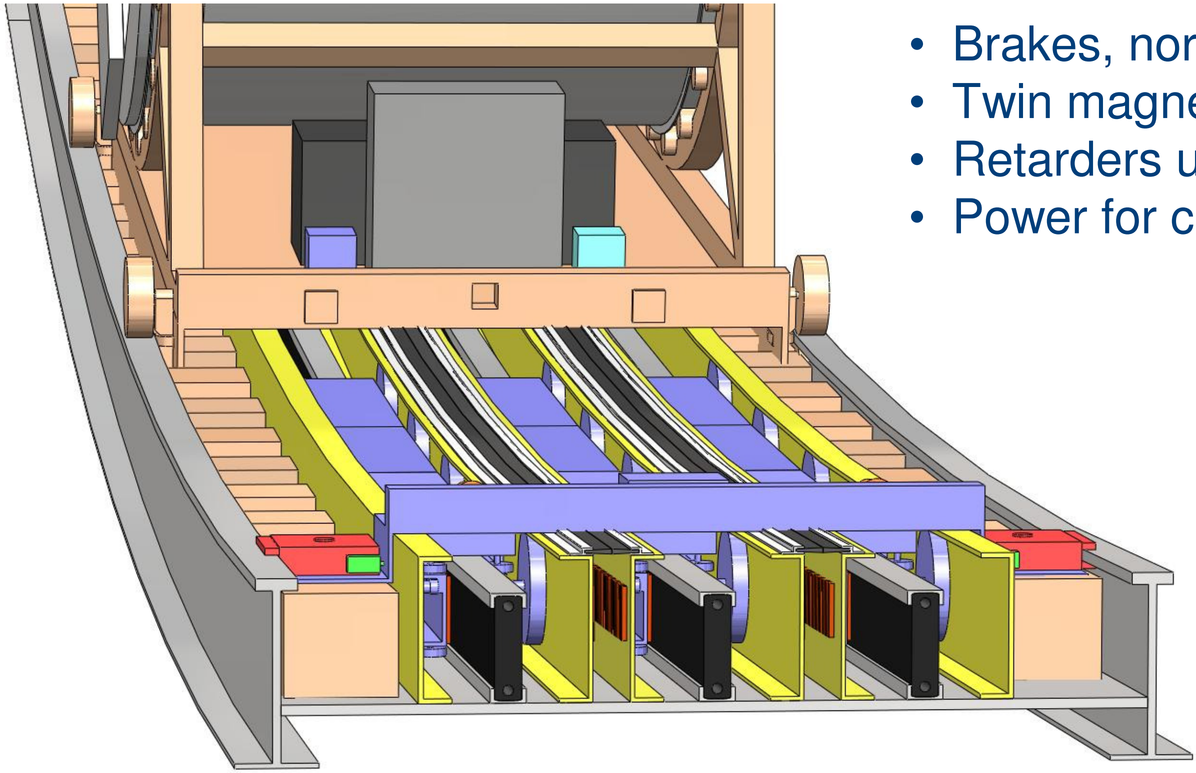
Emergency Up-Stopping Principle



- Light weight structure
- 3m diameter drum – shaped cabin
- Low centre of gravity
- Wound “retarder” stator sections travel with car
- Passenger entrapment negated by returning car to nearest floor below

MAIN CHASSIS AND SUB FRAME ASSEMBLY

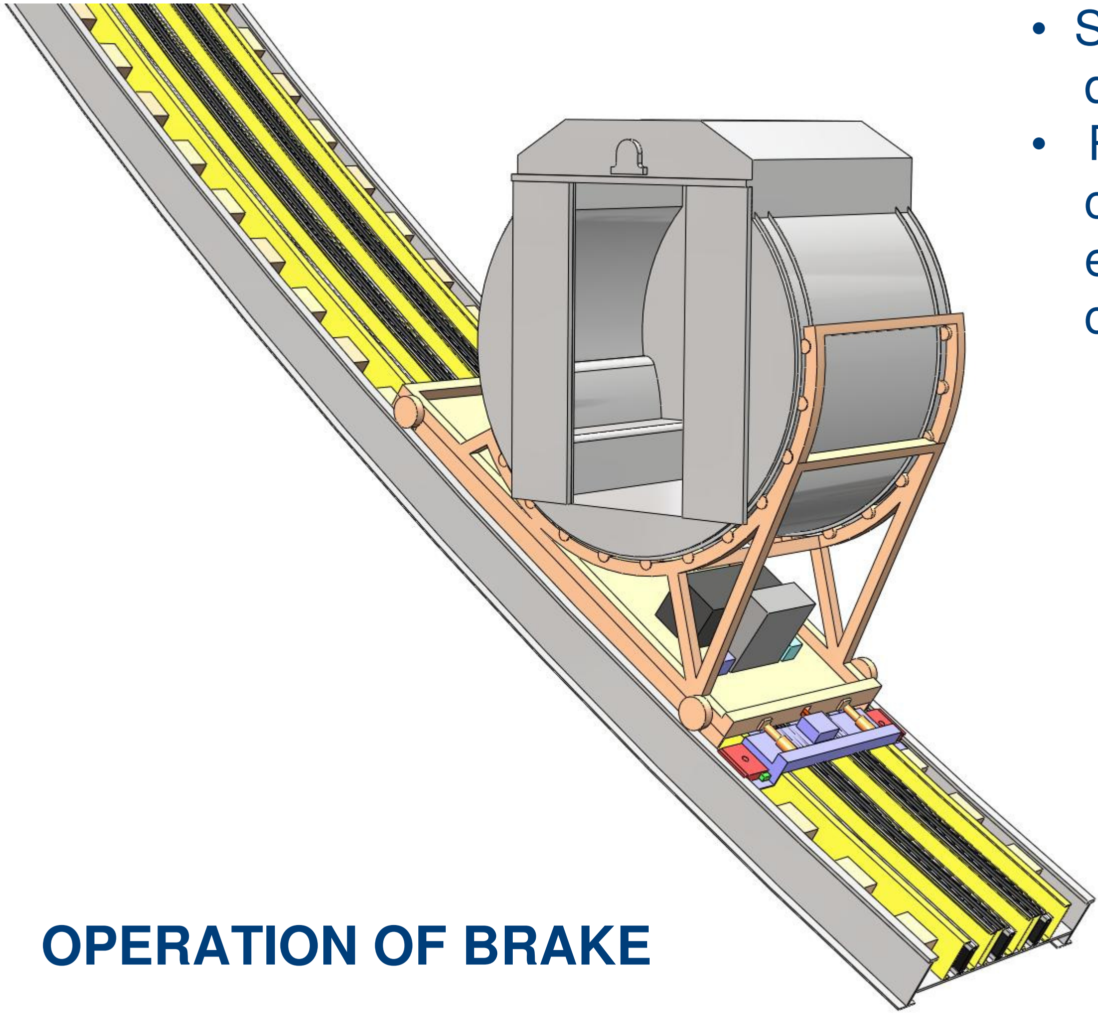
Emergency Up-Stopping Principle



- Brakes, normal stop
- Twin magnet tracks
- Retarders under car
- Power for car

TRACK, SUB FRAME ASSEMBLY AND BRAKES

Emergency Up-Stopping Principle

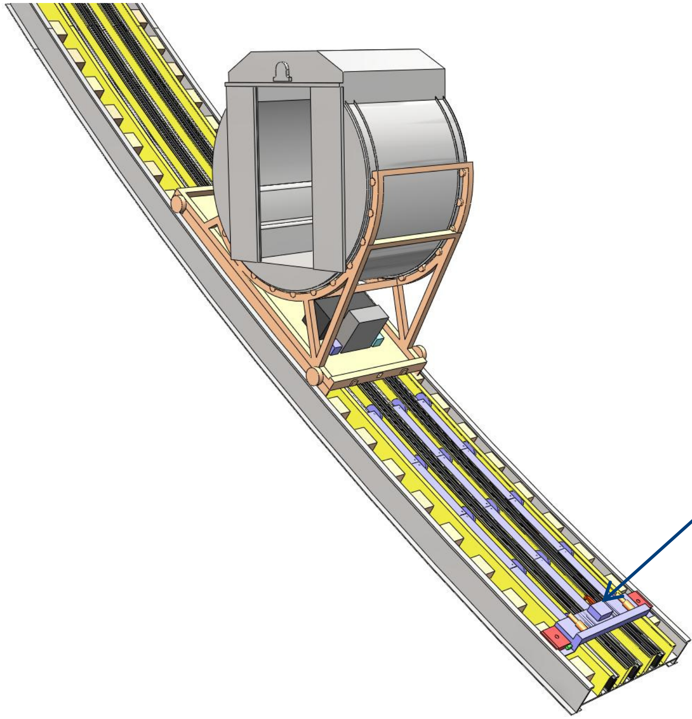


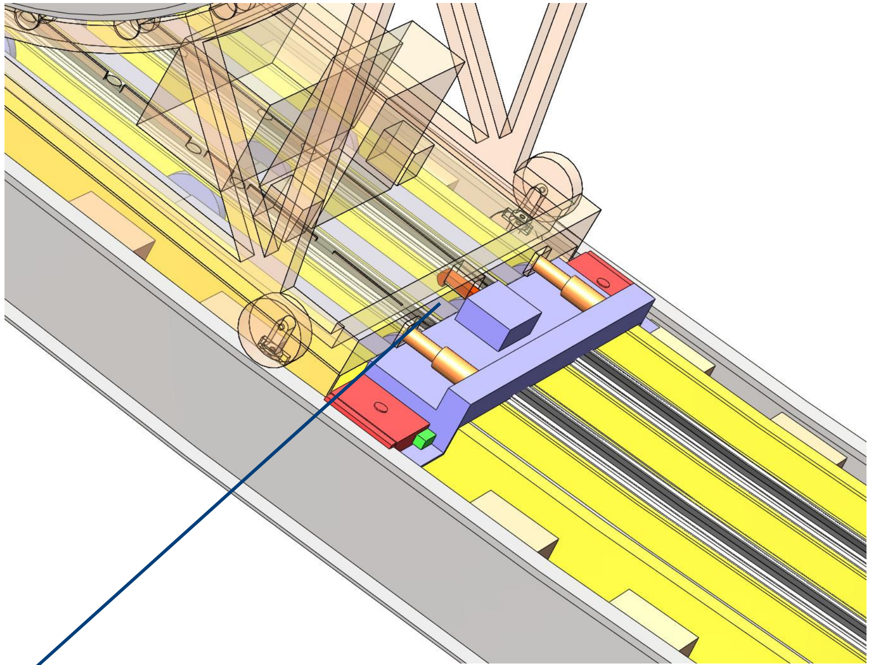
- Stopping in down direction
- Retarders underneath car negate passenger entrapment by returning car to low level

OPERATION OF BRAKE

Emergency Up-Stopping Principle

- Stopping in up direction
- Unlatching of car
- Stored energy gives 3s run on for controlled deceleration





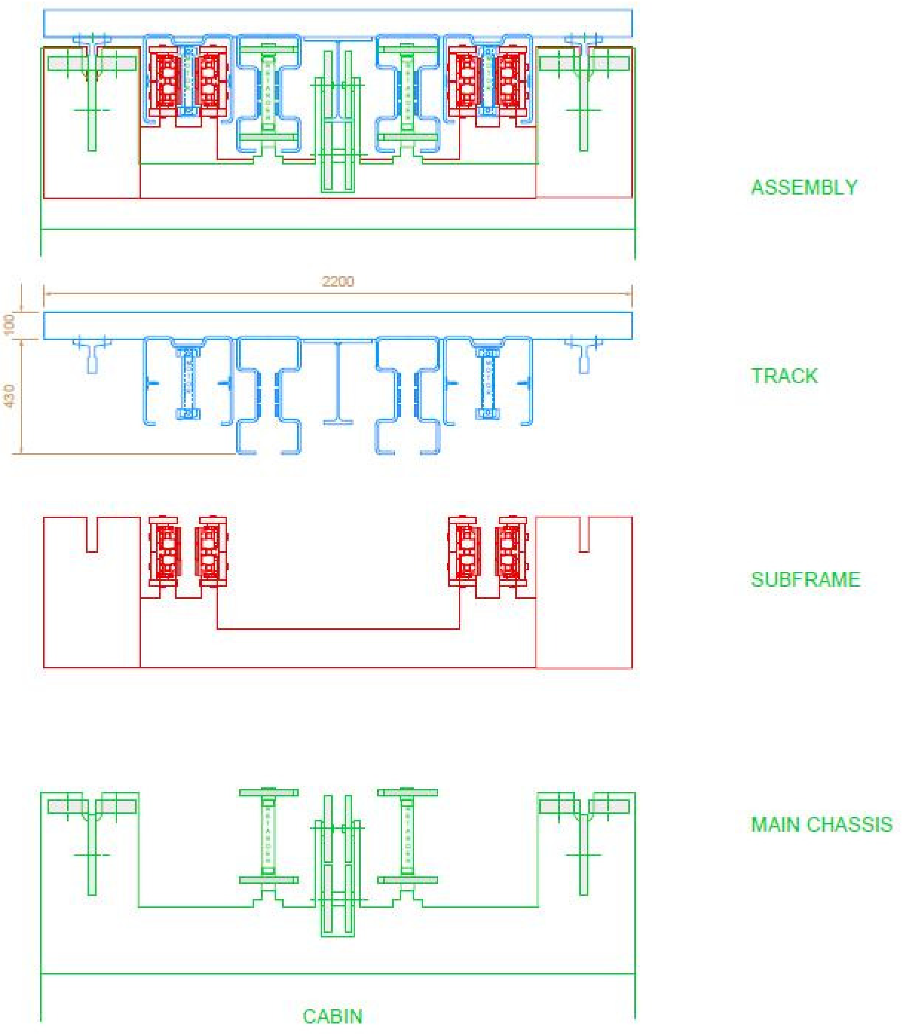
- Retarders control descent back to main drive assembly
- Car can then return to nearest floor

OPERATION OF BRAKE IN UPWARD DIRECTION

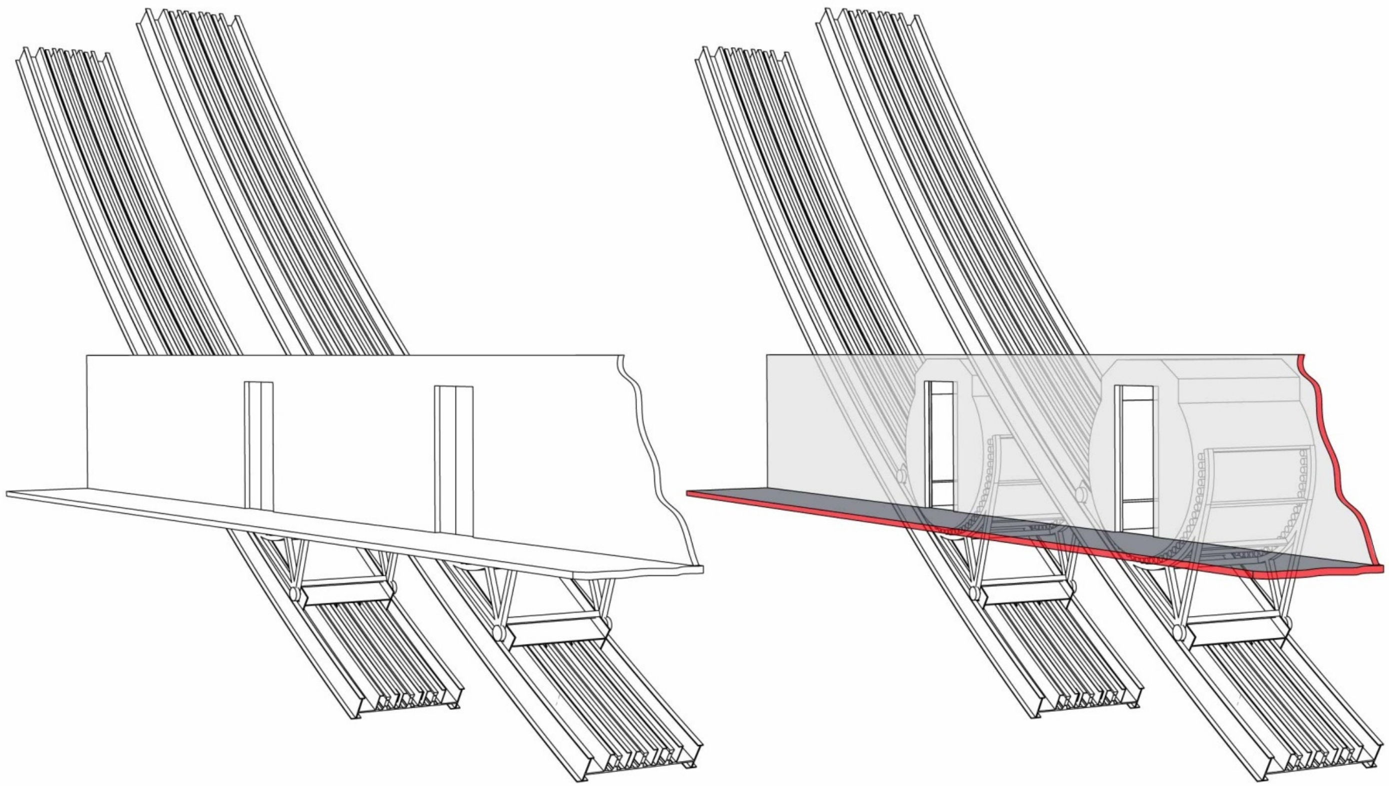
Track

Design

- Early high speed track proposal
- Ride quality to acceptable standard
- Same track for low speed and high speed
- Capable of being curved
- Use of composite materials
- Moulded to fit linear motors/retarders



Landing Entrances

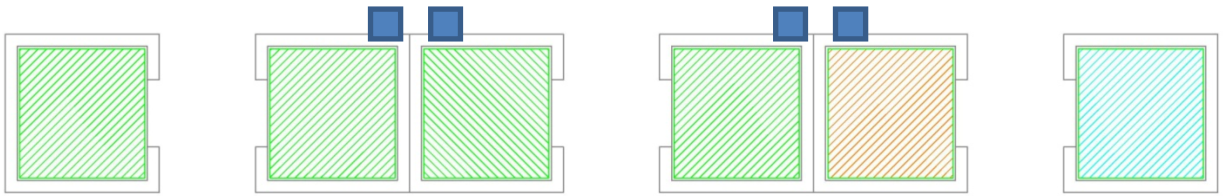


CONVENTIONAL FIRE RATED LIFT ENTRANCES

Traffic Control and Lobby Arrangements

Design

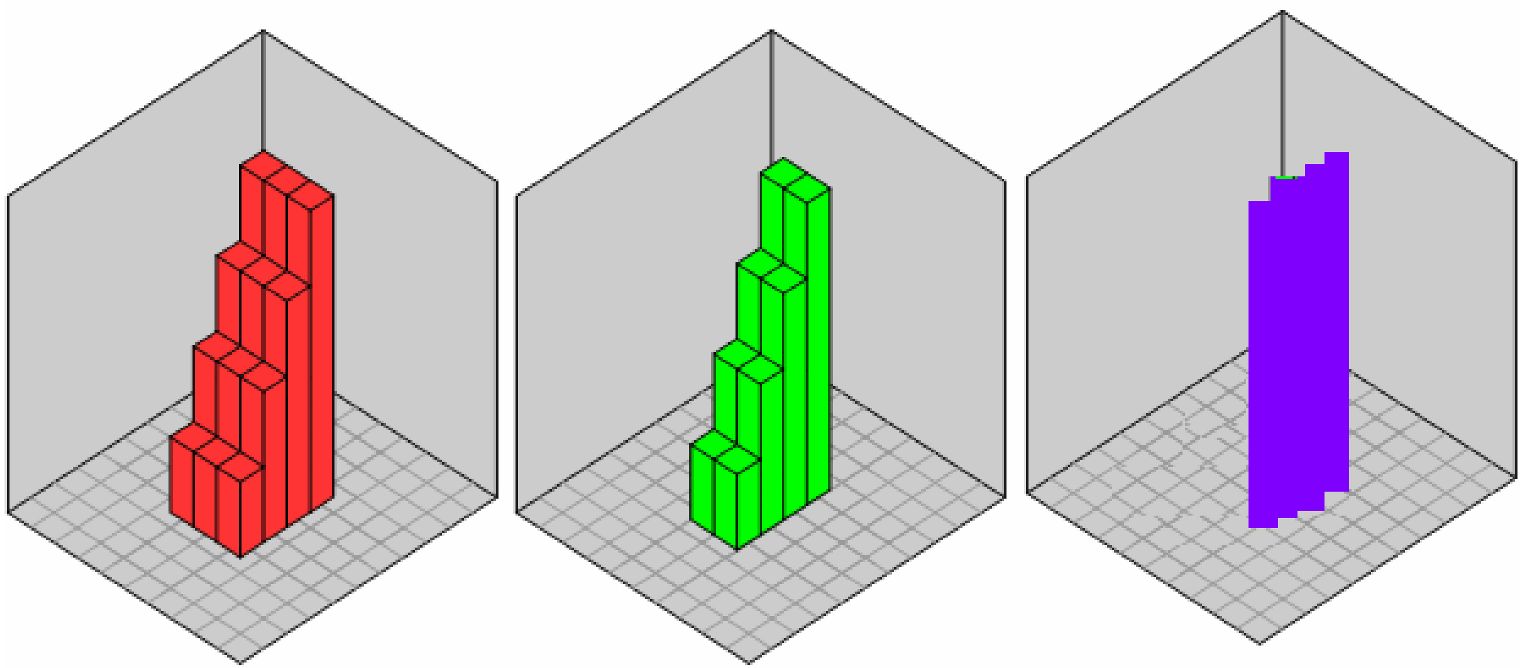
- Destination Hall Call Control
- Passenger journeys planned ahead and optimised
- Car speeds modulated to control headway
- “Up” cars balanced with “Down” cars
- Back to back redundant group control
- Curved or circular tracks/shafts are parallel with typical layout shown below



Reductions of Core Space with Skytrak Multi-Car Vertical Transportation System

Comparison of Core Space Take (30-story plus building)

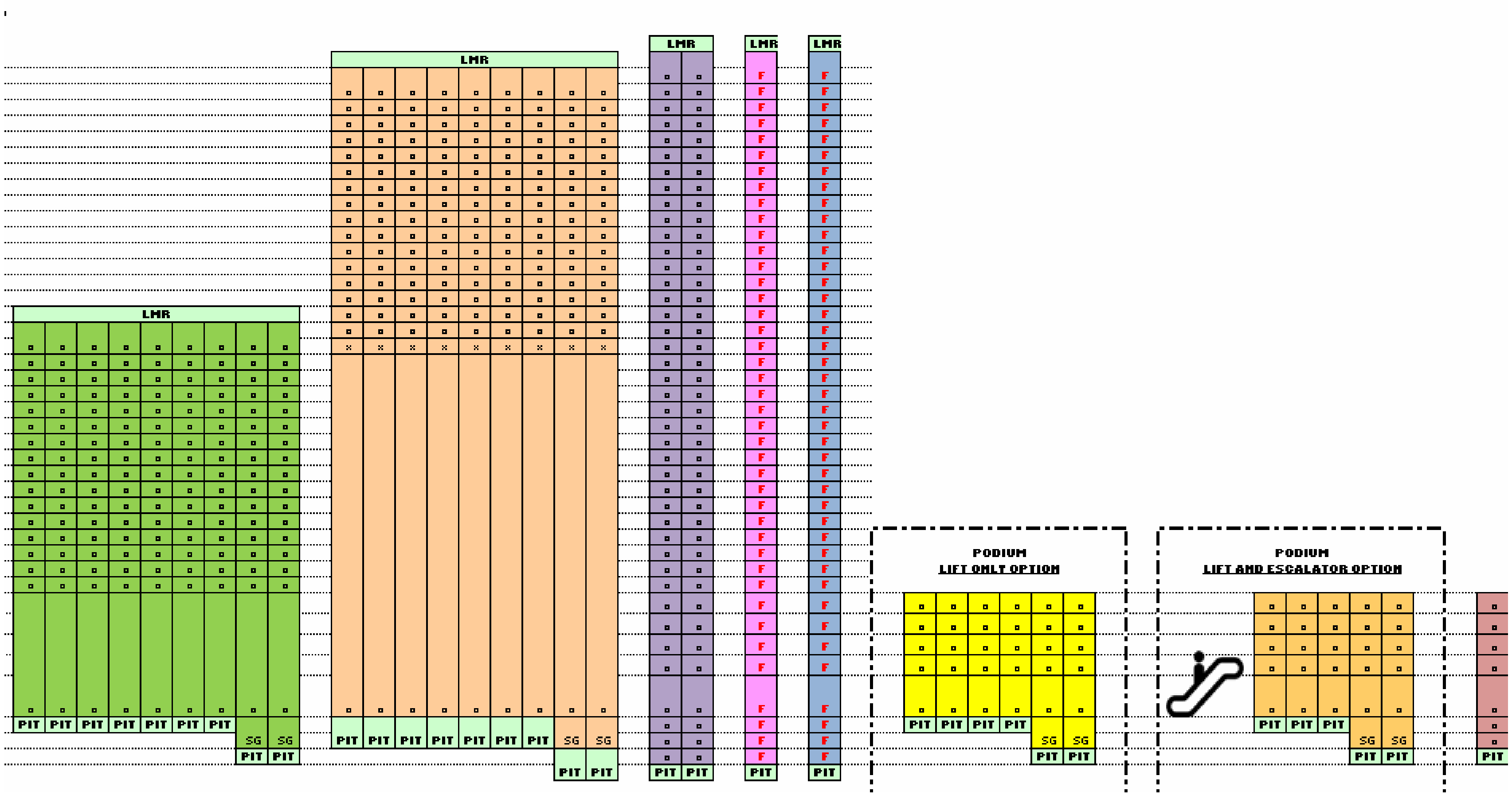
100 : 66 : 40



Single Deck | **Double Deck** | **Skytrak**

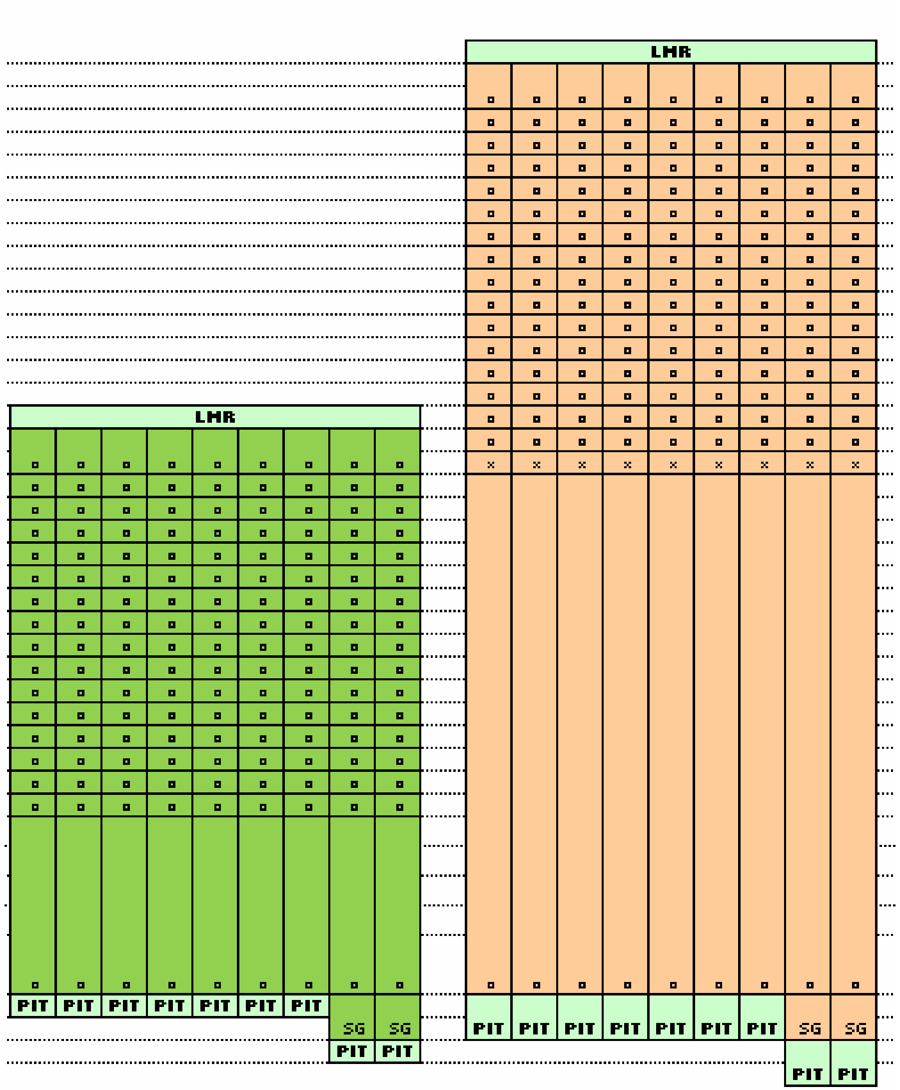
Business Case – Office Tower

- 36 floors, 7500 occupants, 4 trading floors, 27 lifts



Business Case – Office Tower

- One lift core serves all occupied floors
- Easy to travel around the building as no need to transfer between lift groups
- Additional entrances required in the low rise portion of the high rise zone

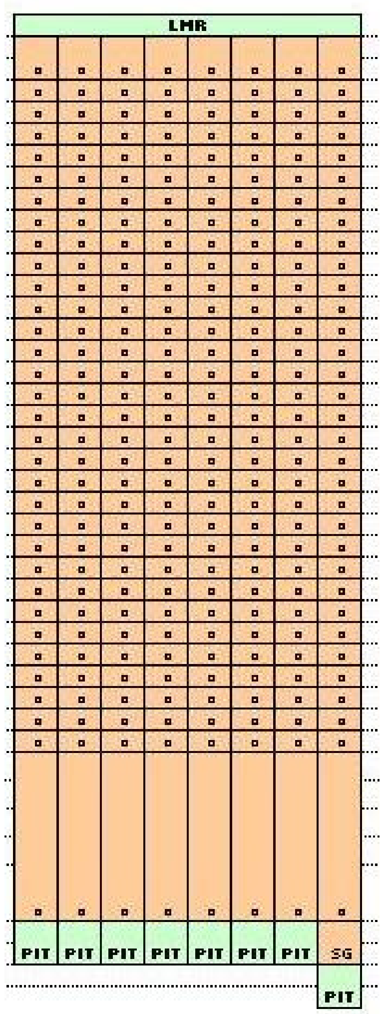


Business Case – Office Tower

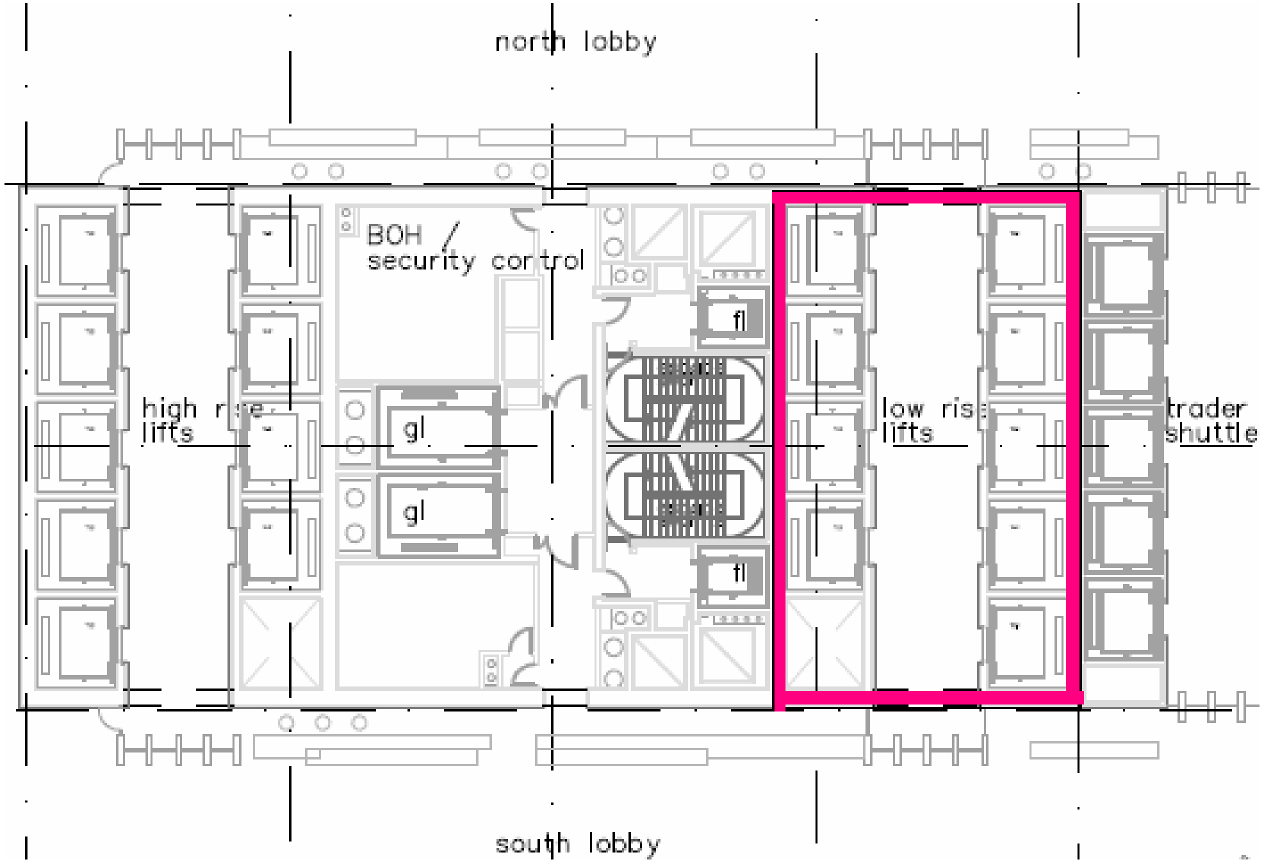
Proposed Design has eight lift shafts serving the entire building.

Floors served are levels 5 to 36 i.e. 32 levels

Building Population for purposes of traffic calculations is 12.5 sq m per person. The revised design adds back 3,680 sq m giving a roughly uniform floor plate with 159 persons per floor, total 5,088 persons



Business Case – Office Tower

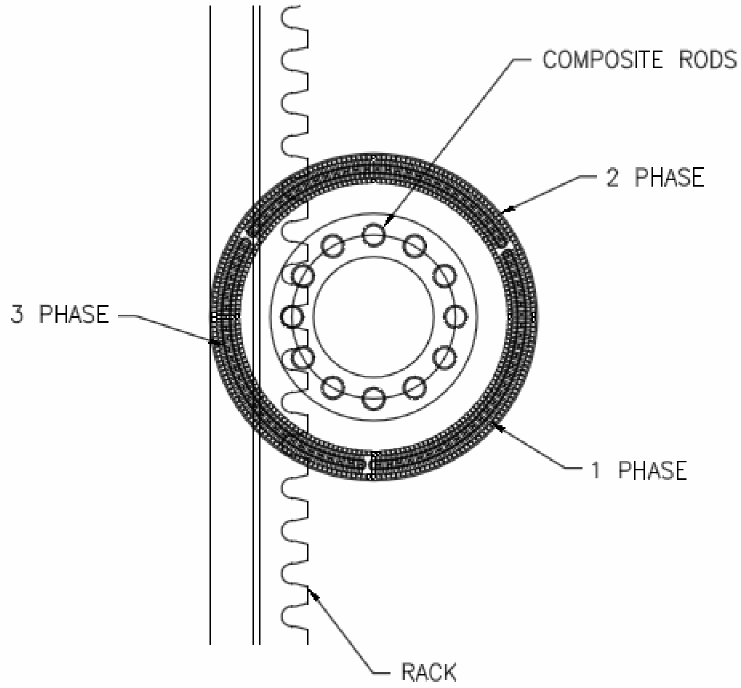


Summary of Business Case

- Additional Value of Space £36m
- Savings Generated £6m
- Eight high rise lifts @ £500k = £4m
- Take savings generated by not constructing the low rise lifts and place into high rise vertical transportation solution
- £6m plus £4m = £10m (£2.5m per up/down system)
- If the new vertical transportation solution costs no more than two and a half times the cost of the high rise lifts then the developer gets the £36m value “for free” !

Circular Linear Motor & Lantern Pinion Slow Speed Drive (<2.5m/s)

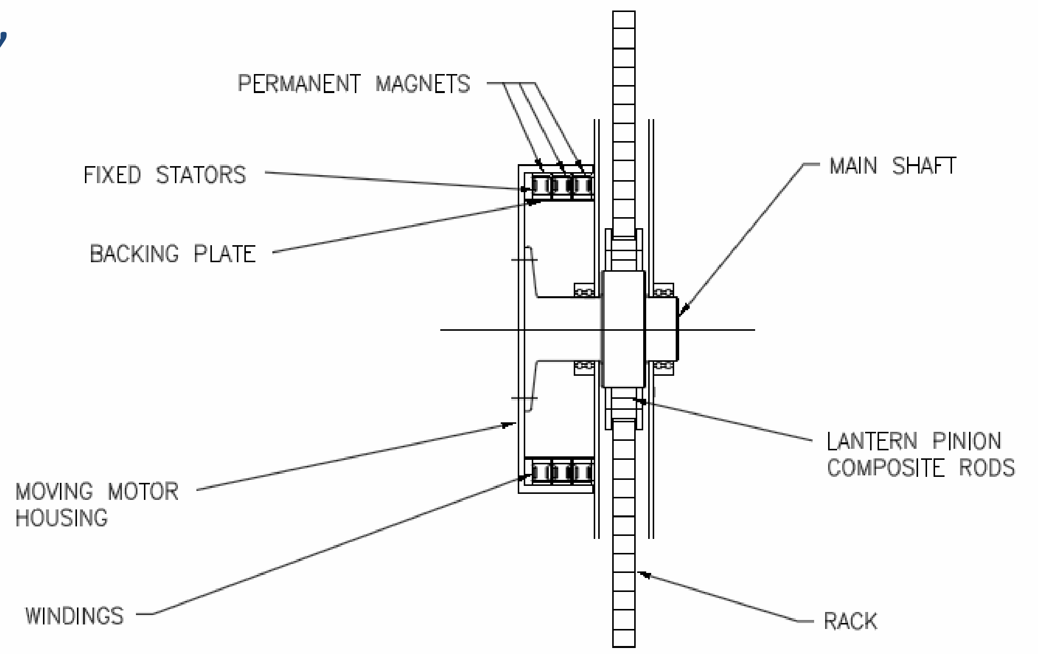
- Three single phase linear motor sections within a 1m diameter circle
- Direct motor drive to lantern pinion at less than 100 RPM for 2.5 m/s
- Avoids noisy gearing
- Lightweight alloy housing
- Pinion rods or track made of composite materials, low wear and noise
- Two motors used to avoid any backlash
- Combined force output on track 40000 Newtons



Patent Pending

Circular Linear Motor & Lantern Pinion Slow Speed Drive (<2.5m/s)

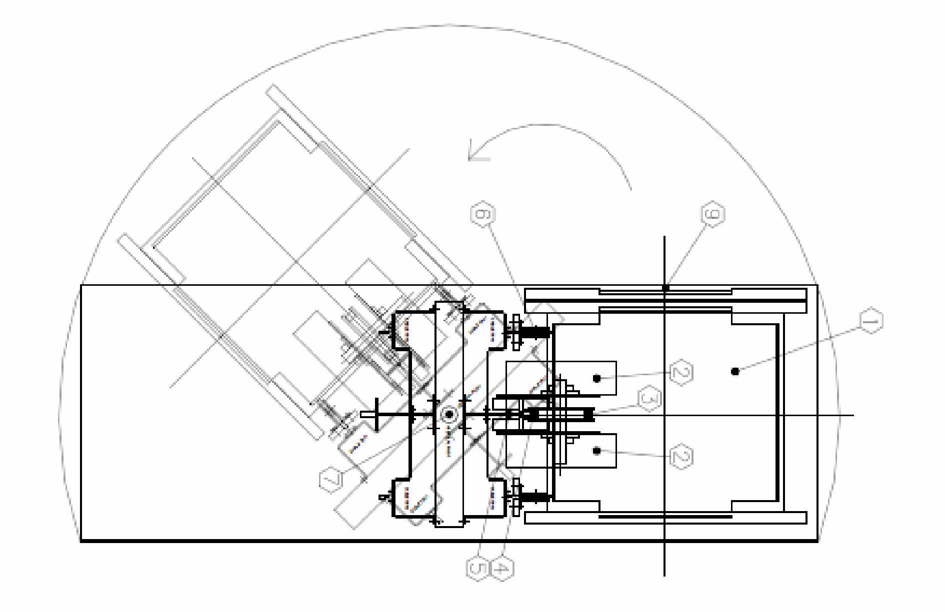
- Low speed motor magnetic design by CEDRAT, PIAK
- Low speed motor manufactured by PHASEMOTION, KEB
- Power electronic drives manufactured by TRIPHASE, PIAK, ETEL SENSITRON
- Lantern pinion materials to be refined



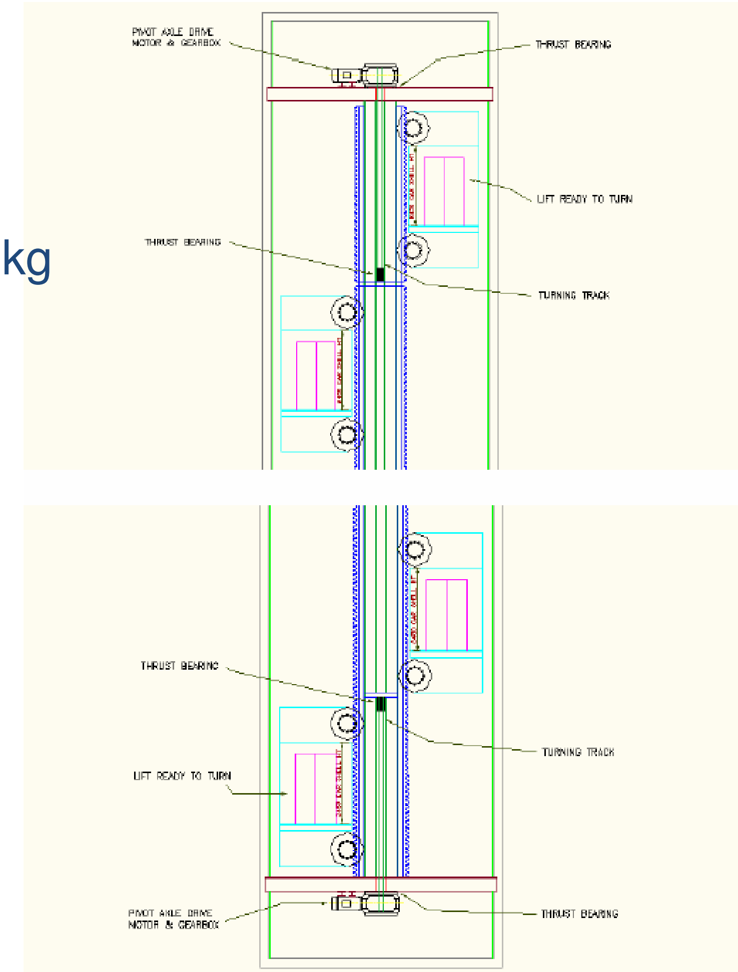
Patent Pending

Skytrak – Terminal "Switches"

- Minimum horizontal movement
- Minimum transfer time
- Cars remain "on" track
- Simple pivot drive arrangement
- Plan space of shafts = conventional 1600kg capacity lifts with side counterweight
- "Through" car design utilised



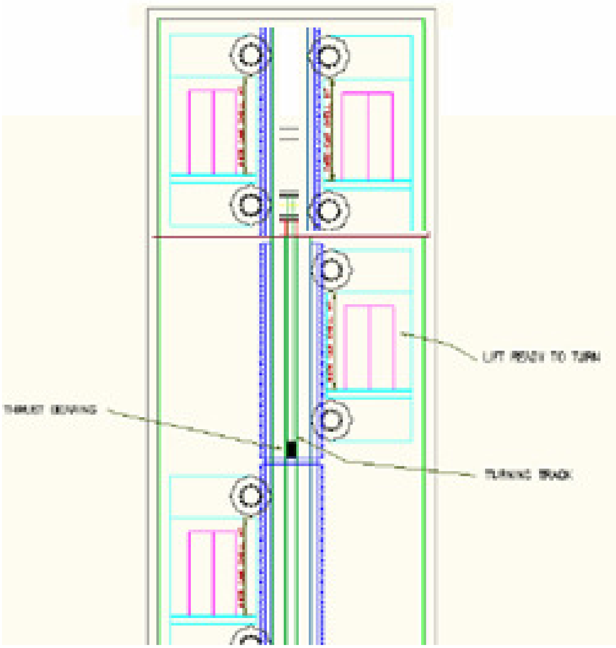
PLAN VIEW



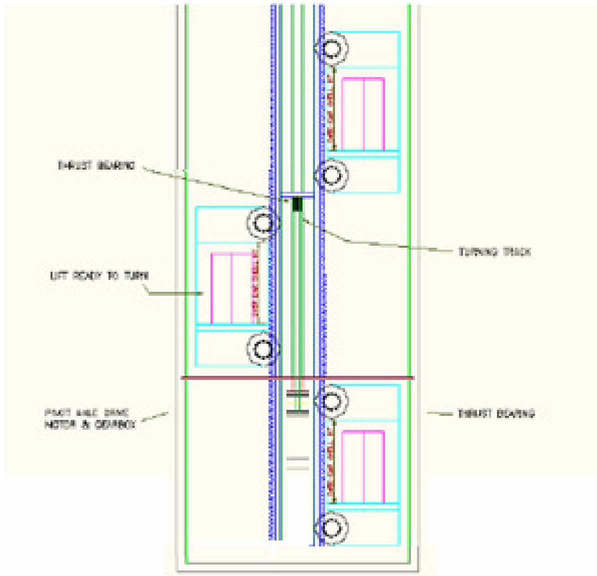
Patent Pending

SECTION VIEW

Skytrak – Terminal Parking and/or Servicing Areas



SECTION AT MACHINE ROOM LEVEL



SECTION AT PIT LEVEL

Patent Pending

“Low Speed” Skytrak – Traffic Simulation