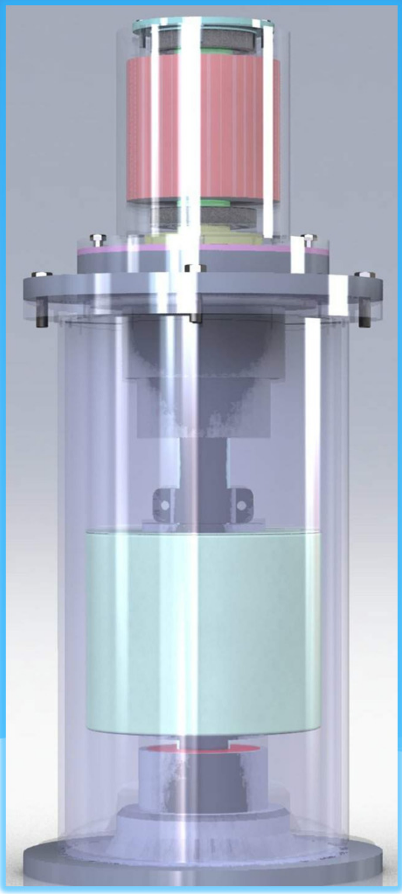
The Concept Design of a Kinetic Energy Storage Device



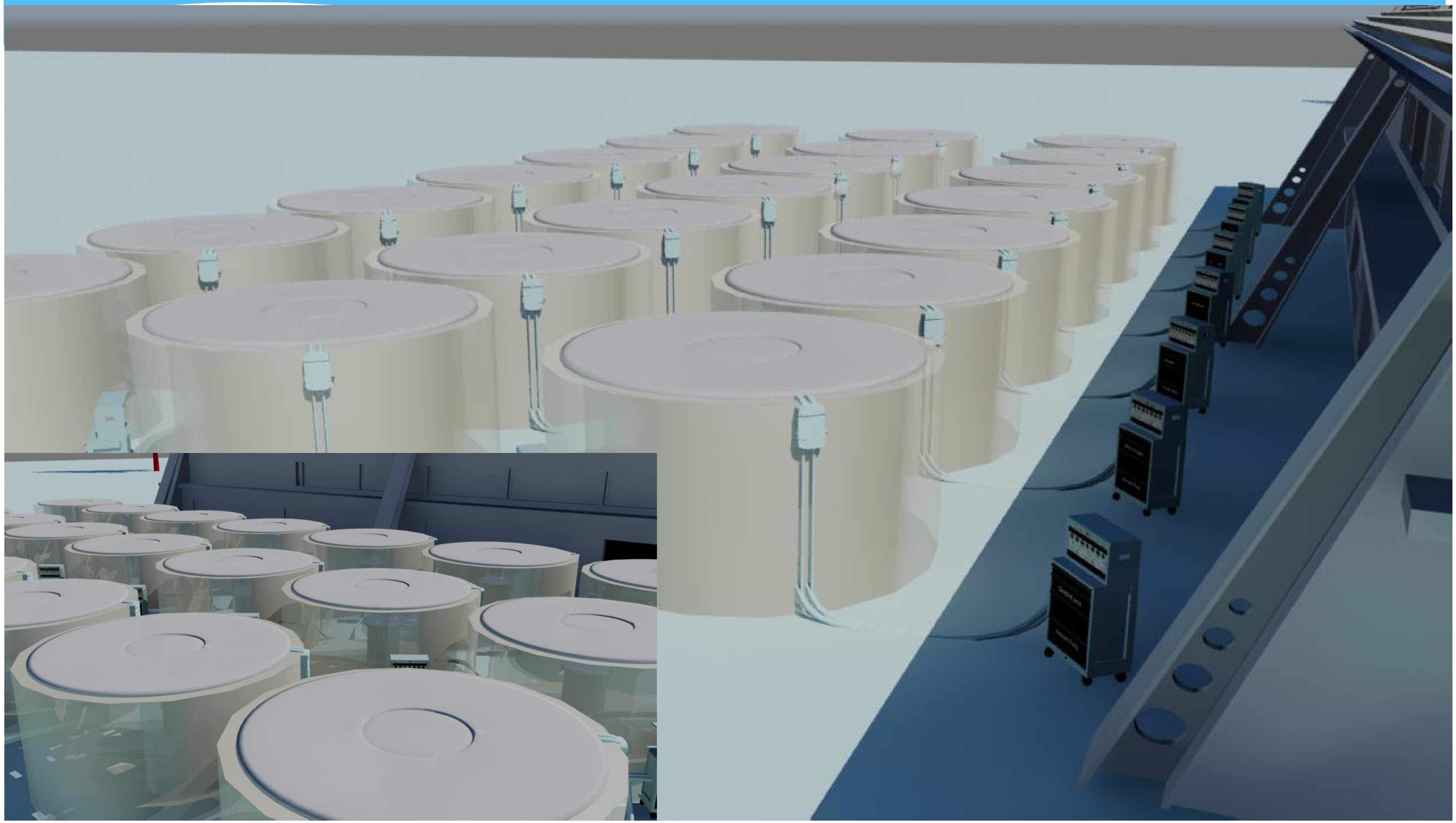
Ertu Unver

Anthony Johnson

Visualisation of the

Kinetic Energy Storage Device

Kinetic Energy Storage Device
Industrial Application



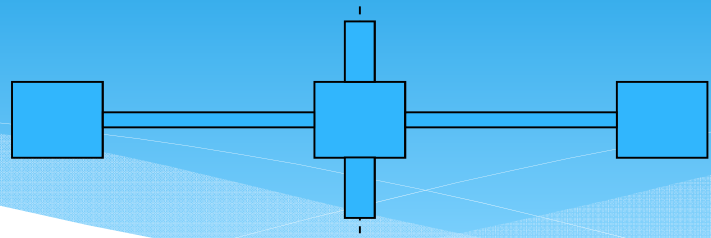
Target Design Specification

Envelope size:	$1m^3$ approx
Power rating:	20 to 50kWh
Efficiency:	> 75%
Power degradation over 24hrs:	< 10%
Calendar life:	10 years
Max sound power level:	63dBA
Low speed:	approx 20k rev/min

Flywheel Design Exploration

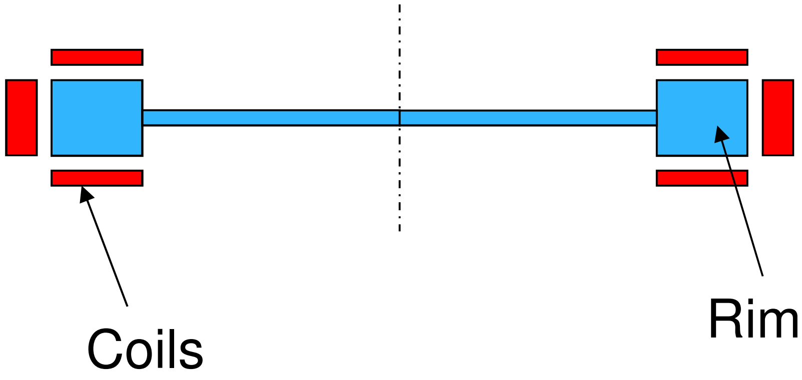
Flywheel Styles

1. Rim Type



2. Rim Type: Toroidal rotor with mag-lev bearings and motor/generator on outer rim.

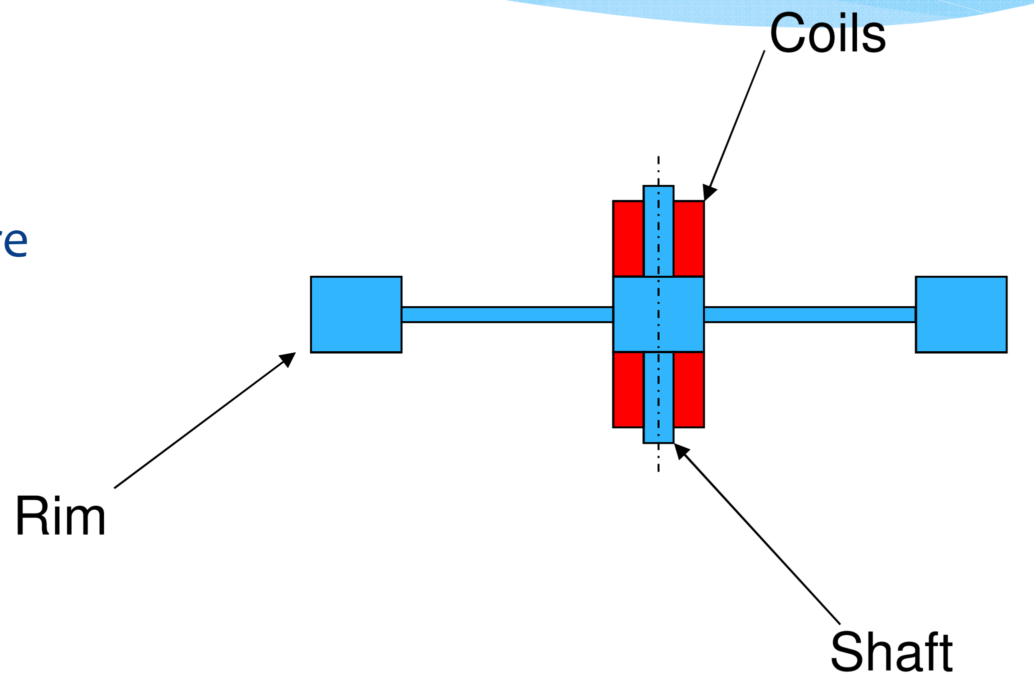
- Uses Eddy currents
- 70% efficient
- Large diameter coils
- Difficult to control
- Surface speeds at coils awkward to handle



Flywheel Design Exploration

3. Rim Type: with magnetic levitation bearings and motor/gen set on shaft.

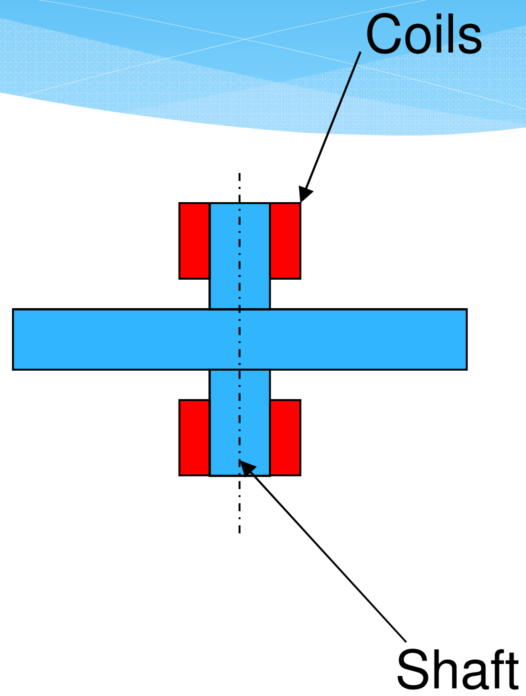
- Uses Stator and Rotor Technology
- 90% efficient
- Small diameter coils
- Easy to control
- Coils easy to manufacture
- Surface speed at shaft within workable bounds



Flywheel Design Exploration

Disc Type: with magnetic levitation bearings and motor/gen set on shaft.

* Uses Stator and Rotor Technology
* 90% efficient
* Small diameter coils
* Easy to control
* Coils easy to manufacture
* Surface speed at shaft within workable bounds



Design Approach Overview

* Standard mechanical engineering techniques
* Use known technology approach where possible
* Use standard materials where possible
* Keep development to a minimum

Design Approach: Practical

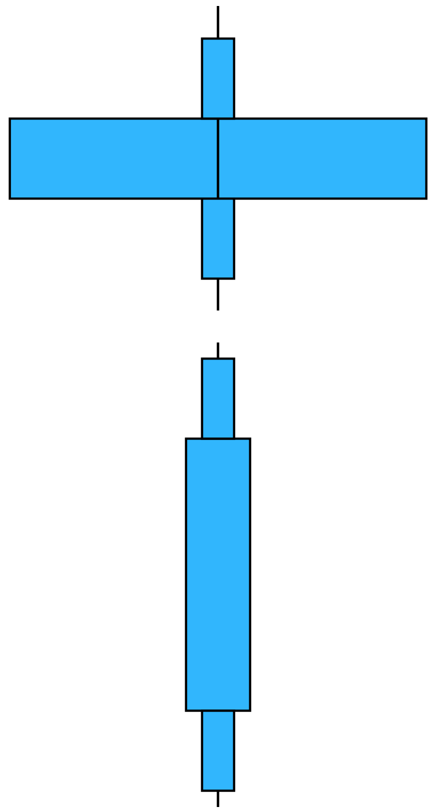
Options

- Small – High Speed
- Large Low Speed

Disc Type

- Large diameter – axially thin

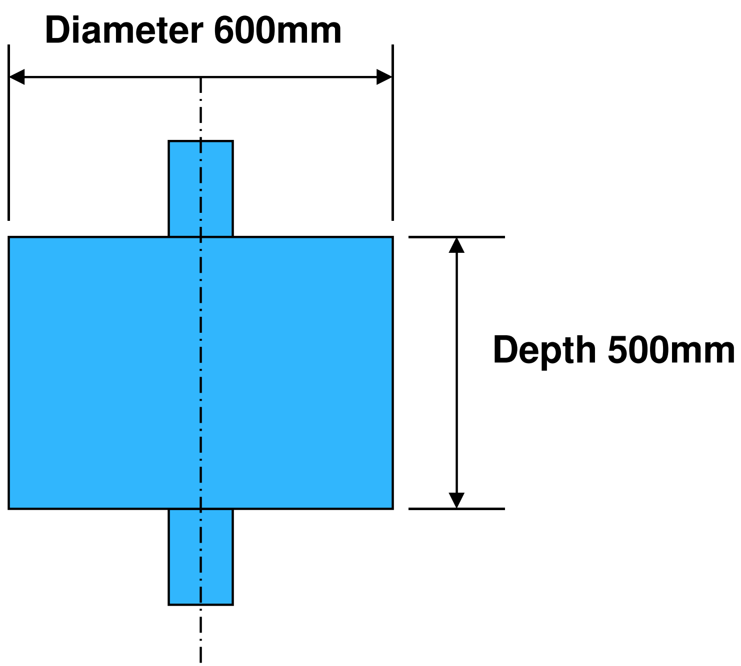
- Small diameter – axially long



Design Approach Disc Type Flywheel

Typical parameters were manipulated and iterated to reveal the **optimum solution** shown below:

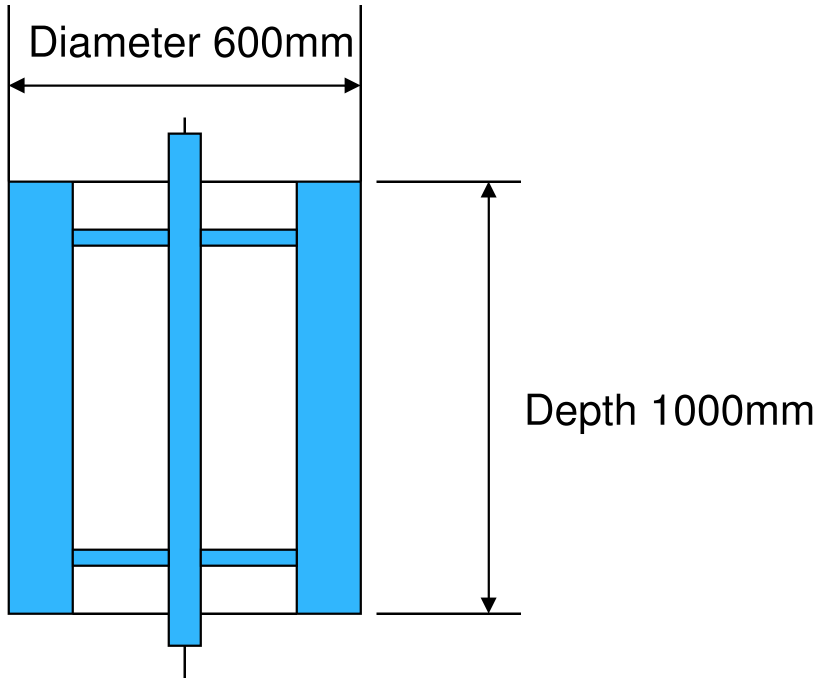
Dia	Depth	mass	Ang Vel	Surface	KE	KE	Power	1 tonne	Rim
m	m	kg	RPM	Speed	MJ	KWh	KW	Mass lift	Stress
				M/s				m	MN/m^2
0.60	0.50	1060	18000	566	318	24	6.6	8151	13



Design Approach Rim Type Flywheel

Typical parameters were manipulated and iterated to reveal the **optimum solution** shown below:

Outer Dia (m)	Inner Dia (m)	Depth (m)	mass (kg)	Ang Vel (Rev/min)	Surface Speed (m/s)	Energy (MJ)	KE (KWh)	Power (KW)	1 tonne Mass Lift (m)	Rim Stress (MN/m^2)
0.6	0.45	1	928	18000	566	74.2	20.6	5.7	8151	13.1

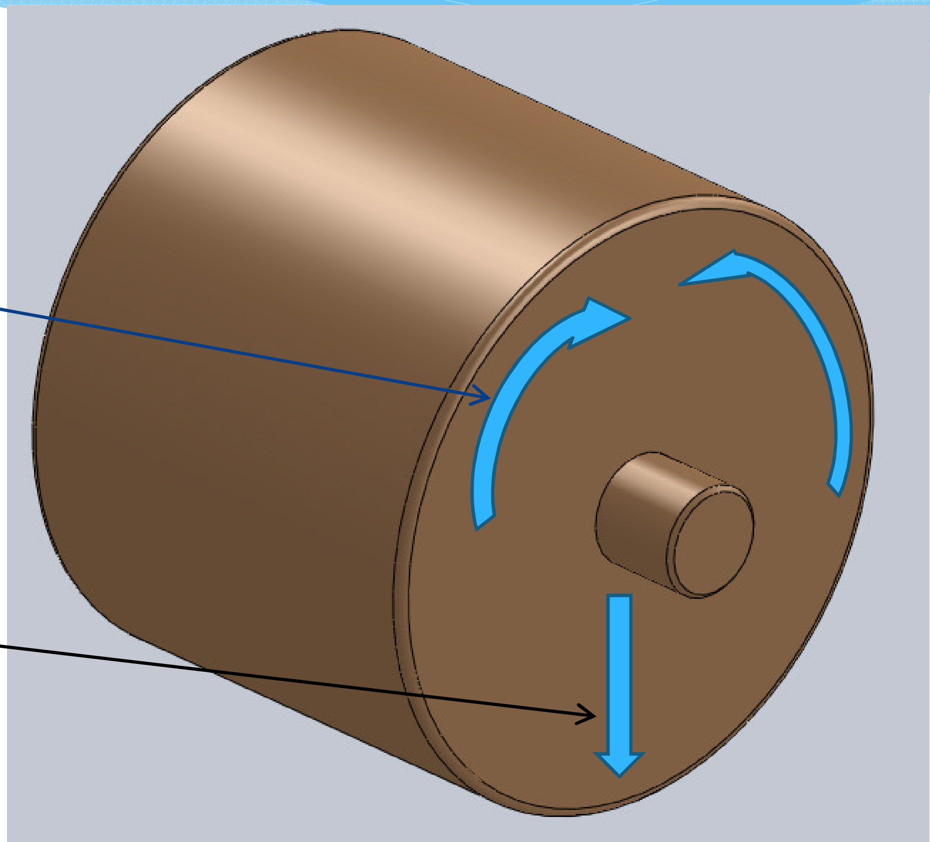


Design Elements and Decisions

Disc-Type Flywheel (Solid)

Careful analysis required to account for

* Radial Stresses
* Hoop tresses



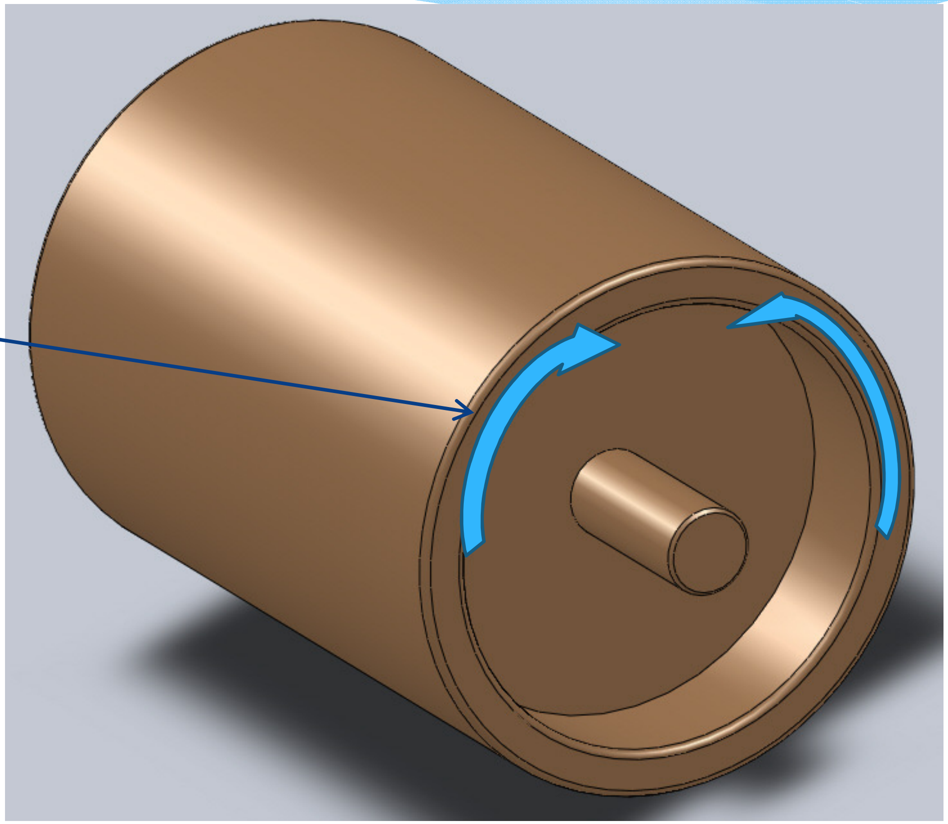
Design Elements and Decisions

Rim-Type Flywheel (Cylindrical)

Careful analysis required to account for

* Hoop tresses

HOOP STRESSES



Design Elements and Decisions

* **Surface speed 566m/s:** 1.6 x speed of sound
  Reduction of air turbulence drag and noise generation achieved by installing the rotor in a **Vacuum Chamber**

* **Reduction of frictional resistance:**
  Apply Magnetic Levitation Bearings
  * Axial Bearings
  * Radial

SKF Magnetic
Levitation Bearing

Design Elements and Decisions

Back-up Bearings

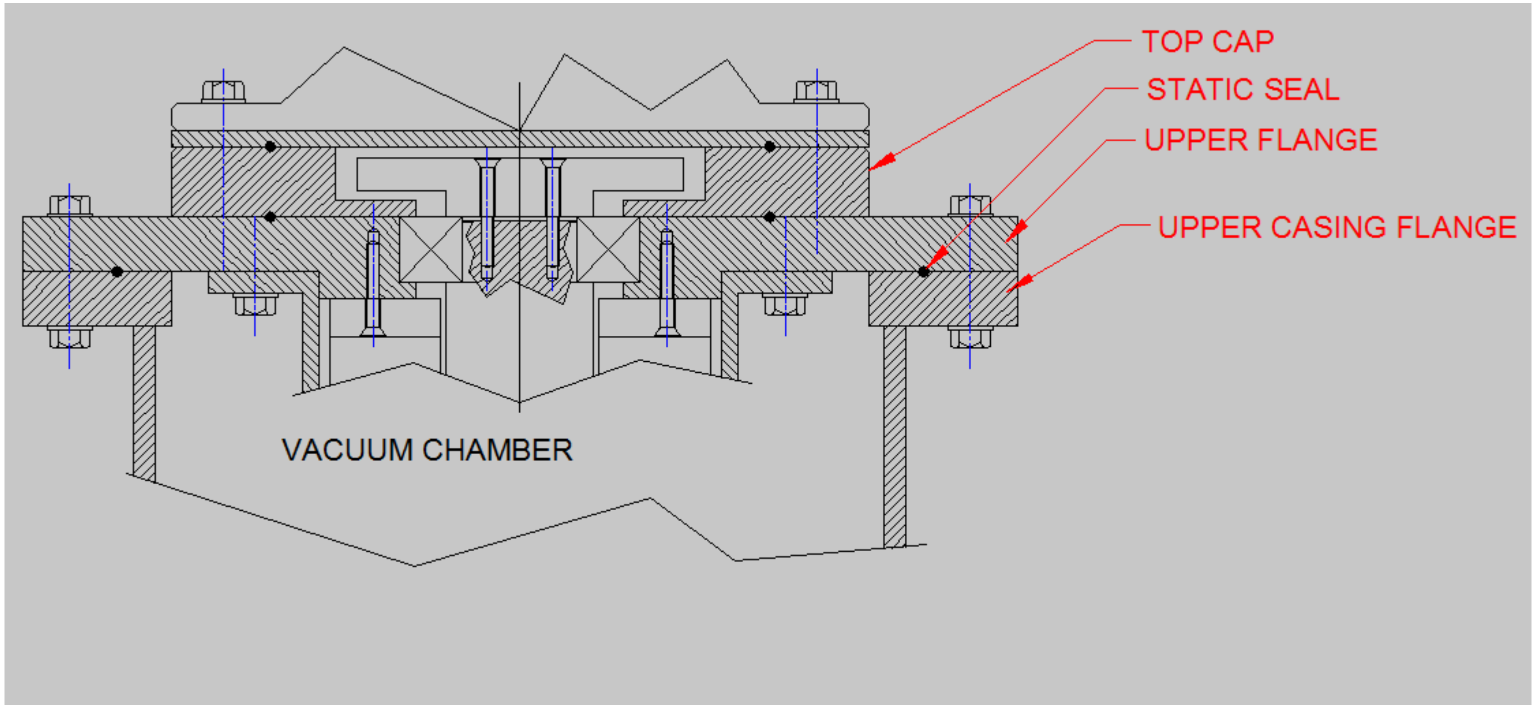
Should power fail to the magnetic levitation bearings a back-up set of **Rolling Element Bearings** will be applied.

Specialist Ceramic Bearings
Supplied by SKF

Design Elements and Decisions

Vacuum Chamber

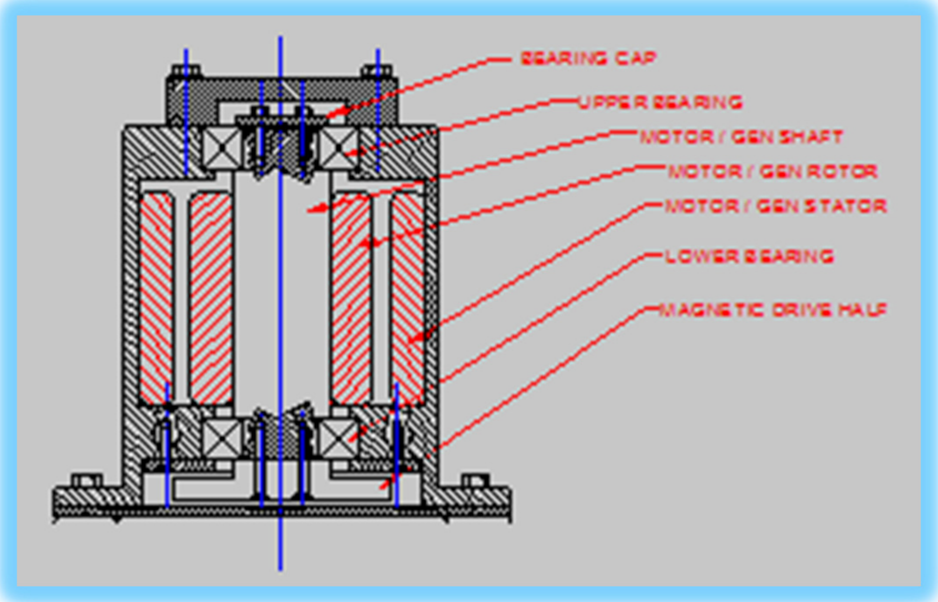
* Encloses the flywheel rotor
* Contains the vacuum
* Uses only static seals (reduces frictional resistance)

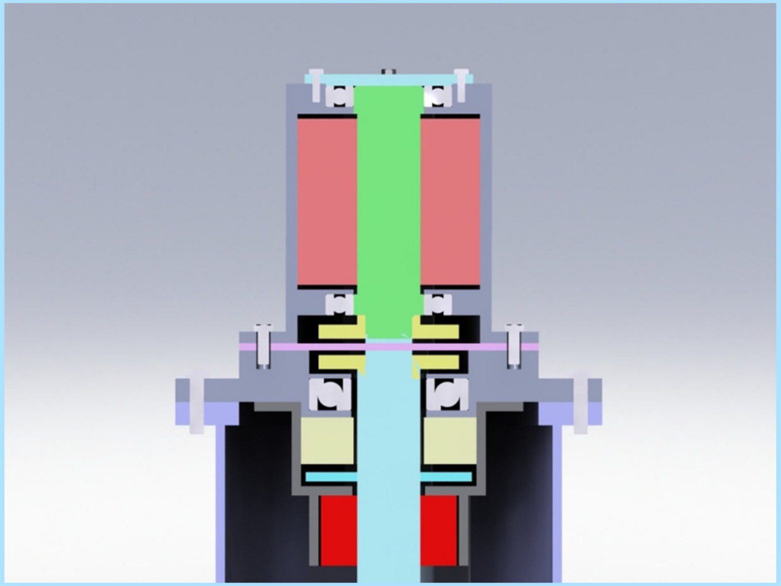


Design Elements and Decisions

Motor / Generator

* External to main flywheel and vacuum chamber
* Modular unit can be changed easily

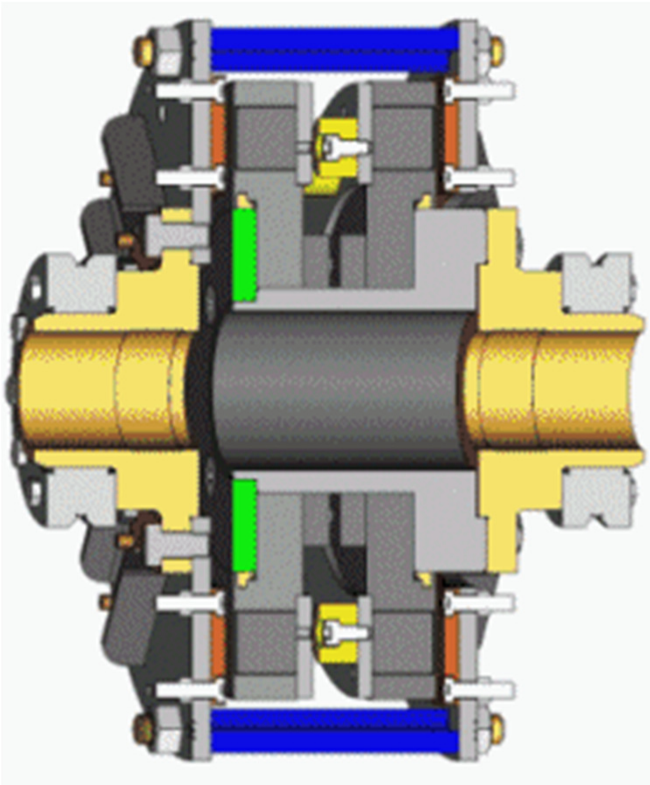




Design Elements and Decisions

Flywheel / Motor-Gen Coupling

* Flywheel Housing separate to Motor–Gen Housing
* Drive system needs to function across the sealed membrane.
* Apply magnetic coupling



Magna Drive Magnetic Coupling

Design Elements and Decisions

Containment Considerations

- Energy enough to lift a 1 tonne mass 8km vertically
- Dangers of burst are very real
  - 85MJ equivalent energy to 18kg (40 Lbs) of TNT

<u>Two Containment Options</u>:

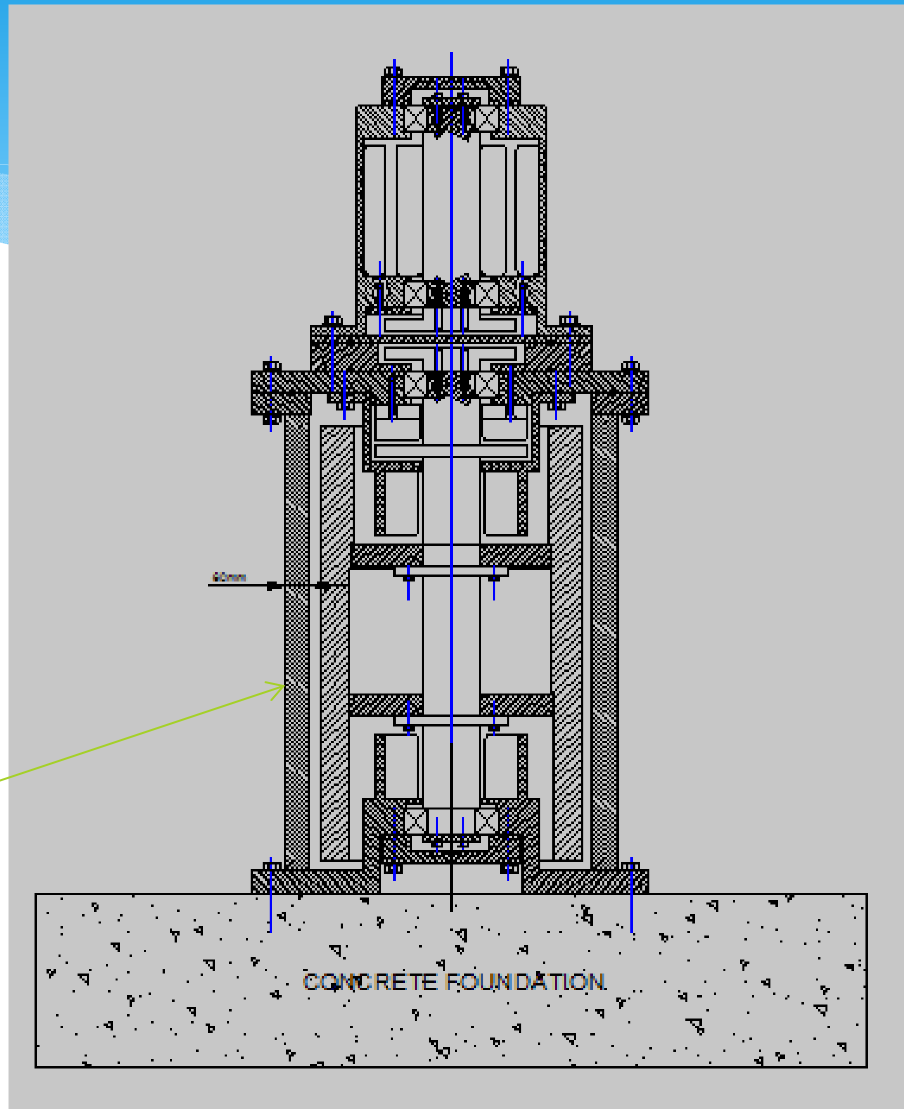
- Heavy containment cylinder on a heavy foundation
- Light weight vacuum chamber encased in a concrete casing.

Design Elements and Decisions

Containment Option One

- Heavy Steel Containment
- Heavy Concrete Foundation

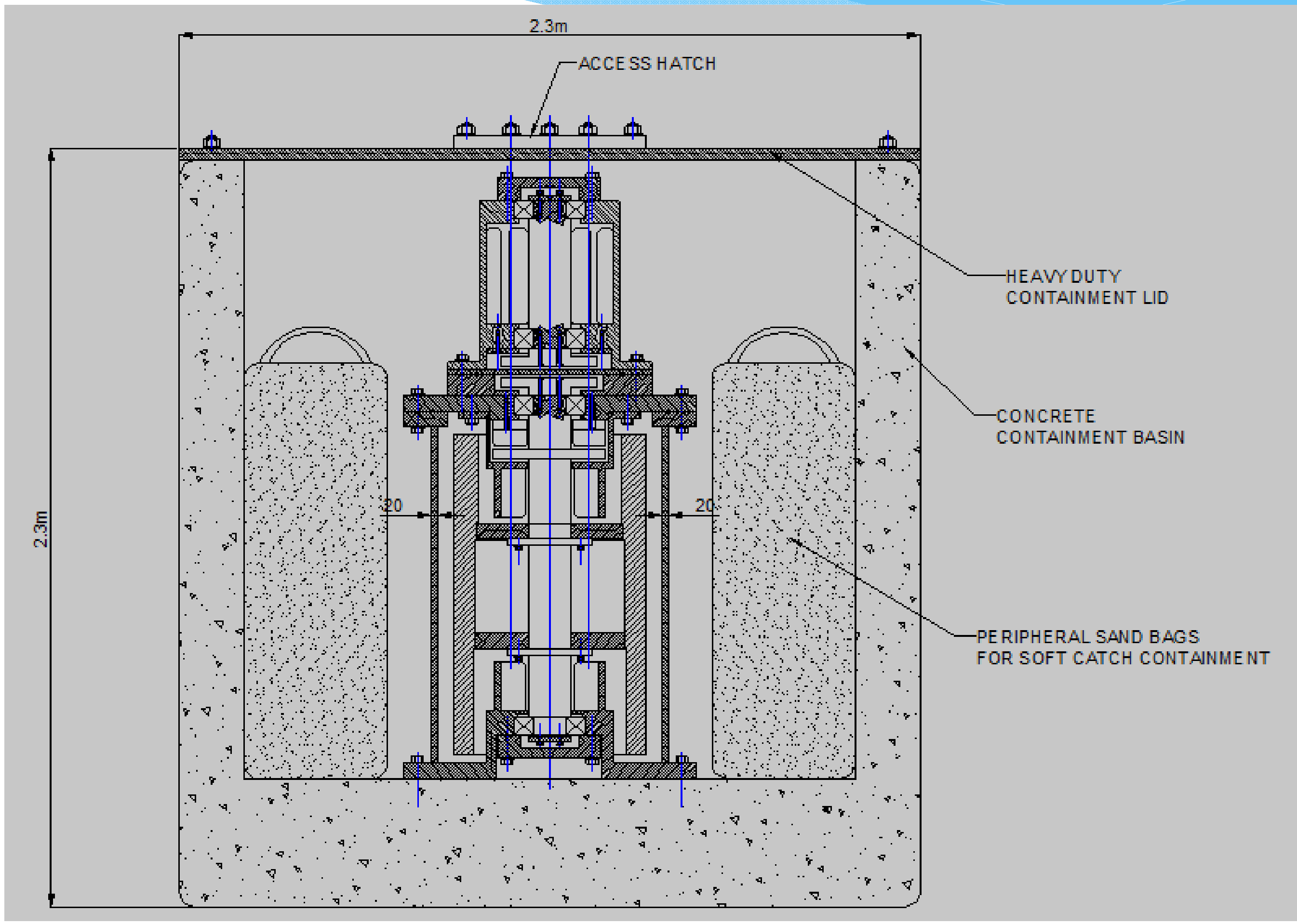
Heavy
Casing



Design Elements and Decisions

Containment Option Two:

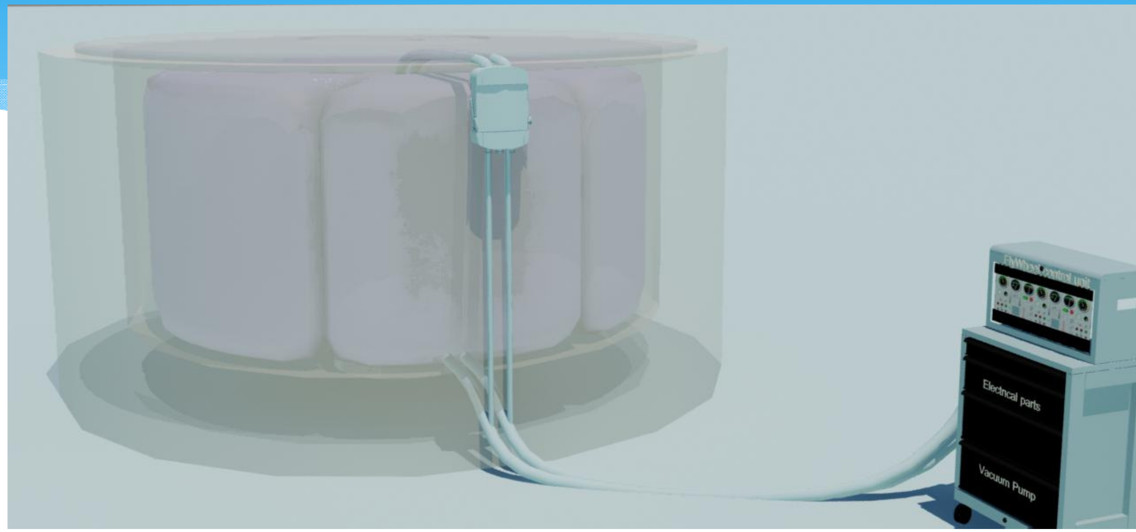
- Lightweight vacuum chamber encased in a concrete casing
- Includes sand bags radially mounted to act as a soft catch

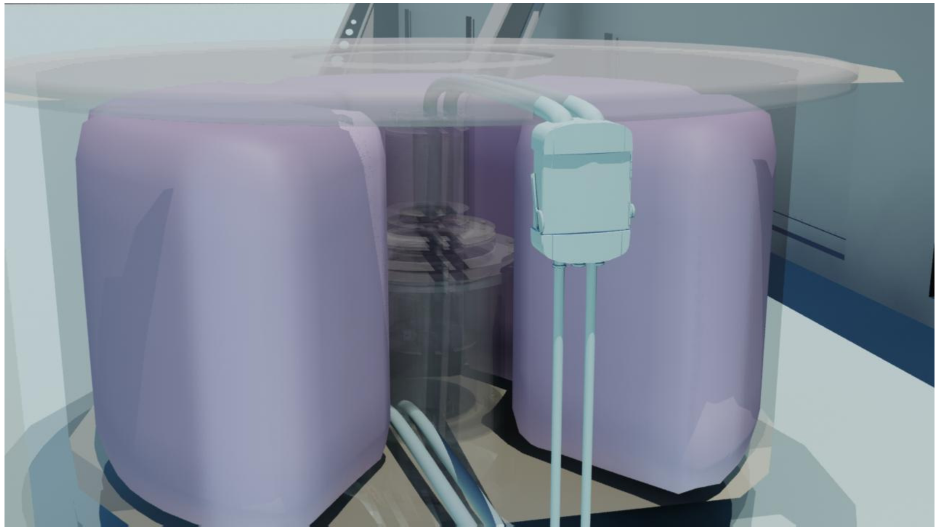


Design Elements and Decisions

Containment Option Two: Concrete Basin with Sand Bag Soft-Catch

Containment with sand bag segments





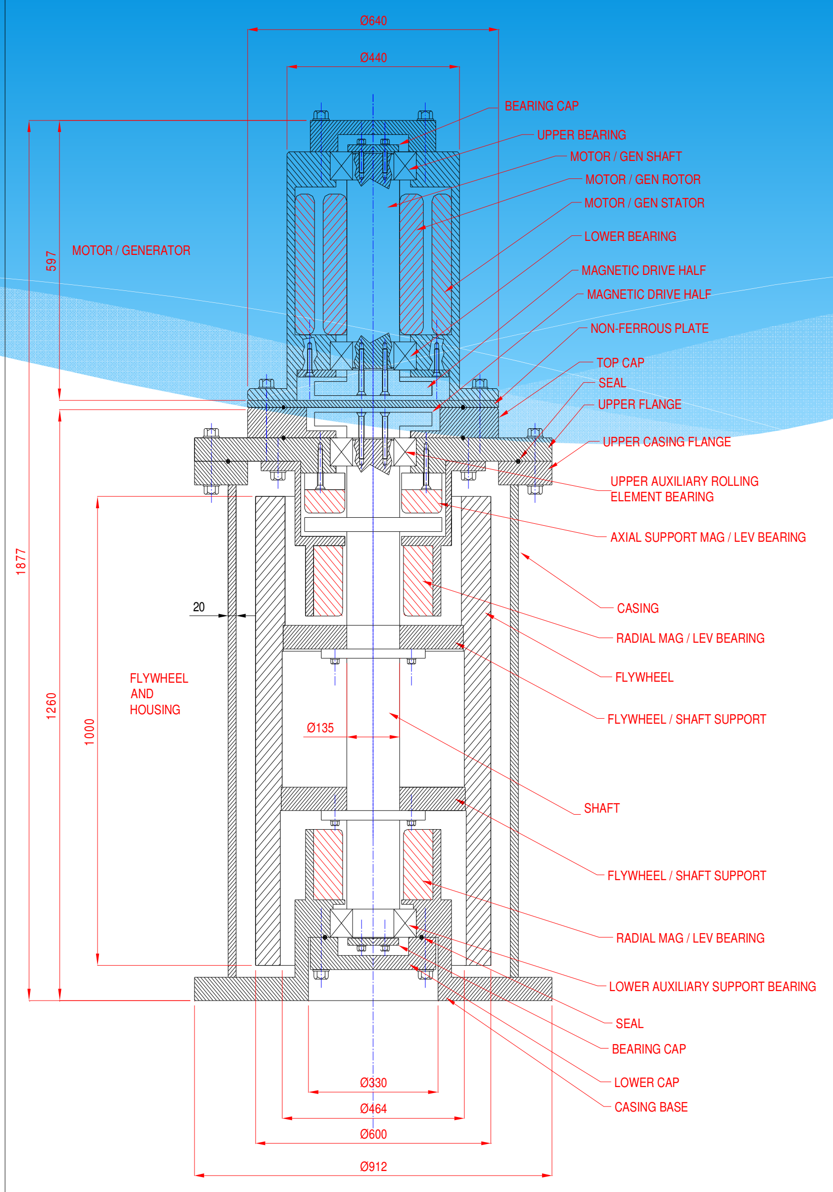
Containment with sand bag segments showing internal arrangement

Concept Outlines

Concept One

Rim Type Flywheel

- Takes the form of a cylinder
- Diameter 600mm
- Length 1000mm
- Mass 930kg



HOLLOW ROTOR FLYWHEEL SYSTEM

Concept Outlines

Rim Type Flywheel

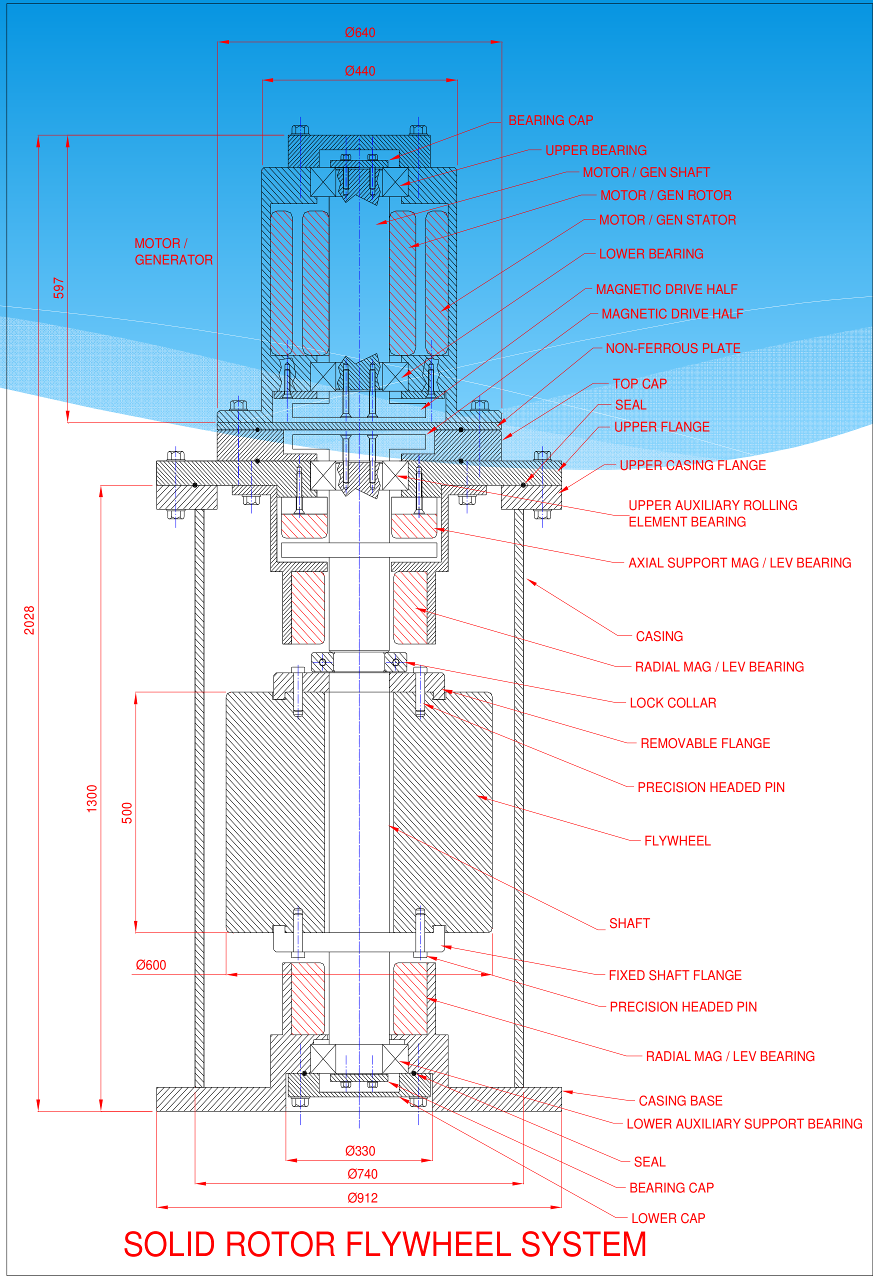
Style	Hollow cylinder
Outer diameter (mm)	600
Inner diameter (mm)	450
Rotor depth (mm)	1000
Material	steel
Density (kg/m^3)	7500
Rotor mass (kg)	930
Angular velocity (Rev/min)	18000
Surface speed (m/s)	565
Energy (Joules)	74,200,000
Energy (kWh)	20.61
Power (kW)	5.73
1 Tonne mass lift (m)	8150
Containment (Primary)	Steel casing
Containment (Secondary)	Concrete lined Pit
Bearing system radial	Magnetic Levitation
Bearing System (secondary)	Rolling element Brgs
Motor-Generator Drive Coupling	Magnetic
Chamber Type	Vacuum

Concept Outlines

Concept Two

Disc-Type Flywheel

- Takes the form of a solid rotor
- Diameter 600mm
- Length 500mm
- Mass 1060kg



Concept Outlines

Disc Type Rotor

Style	Solid cylinder
Outer Diameter (mm)	600
Inner diameter (mm)	n/a
Rotor depth (mm)	500
Material	Steel
Density (kg/m^3)	7500
Rotor mass (kg)	1060
Angular velocity (Rev/min)	18000
Surface speed (m/s)	565
Energy (Joules)	84,800,000
Energy (KWh)	23.55
Power (KW)	6.54
1 Tonne mass lift (m)	8,152
Containment (Primary)	Steel casing
Containment (Secondary)	Concrete lined Pit
Bearing system radial	Magnetic Levitation
Bearing System (secondary)	Rolling element Brgs
Motor Generator Drive coupling	Magnetic
Chamber Type	Vacuum

Selection of Concept

Rim Type

- Lower mass 930kg
- Height overall 1877mm
- Energy 20.61 kWh
- Power 5.73 kW
- Stresses in rim only
  (Less prone to burst)

Disc Type

- Higher mass 1060kg
- Overall height 2028mm
- Energy 23.55 kWh
- Power 6.54 kW
- Radial and Hoop stresses present

* Design and manufacturing will present a similar level of difficulty
* Balancing relatively easier with the rim-type flywheel
* Cost implications will be similar for each type

Overall Concept

Modular construction allows:

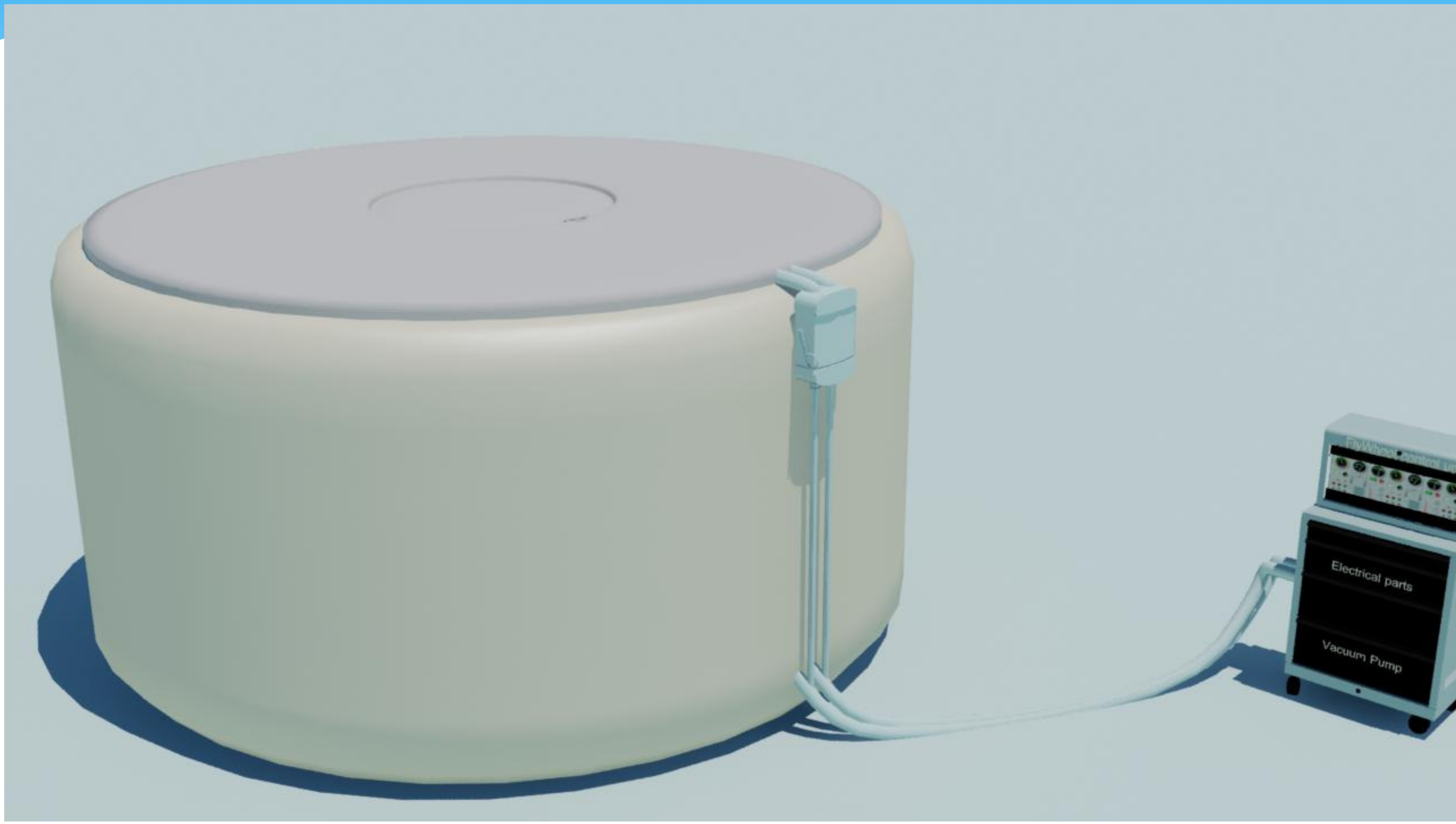
- Ease of Maintenance
- Ease of Assembly
- Standardised Components

Concrete containment can be:

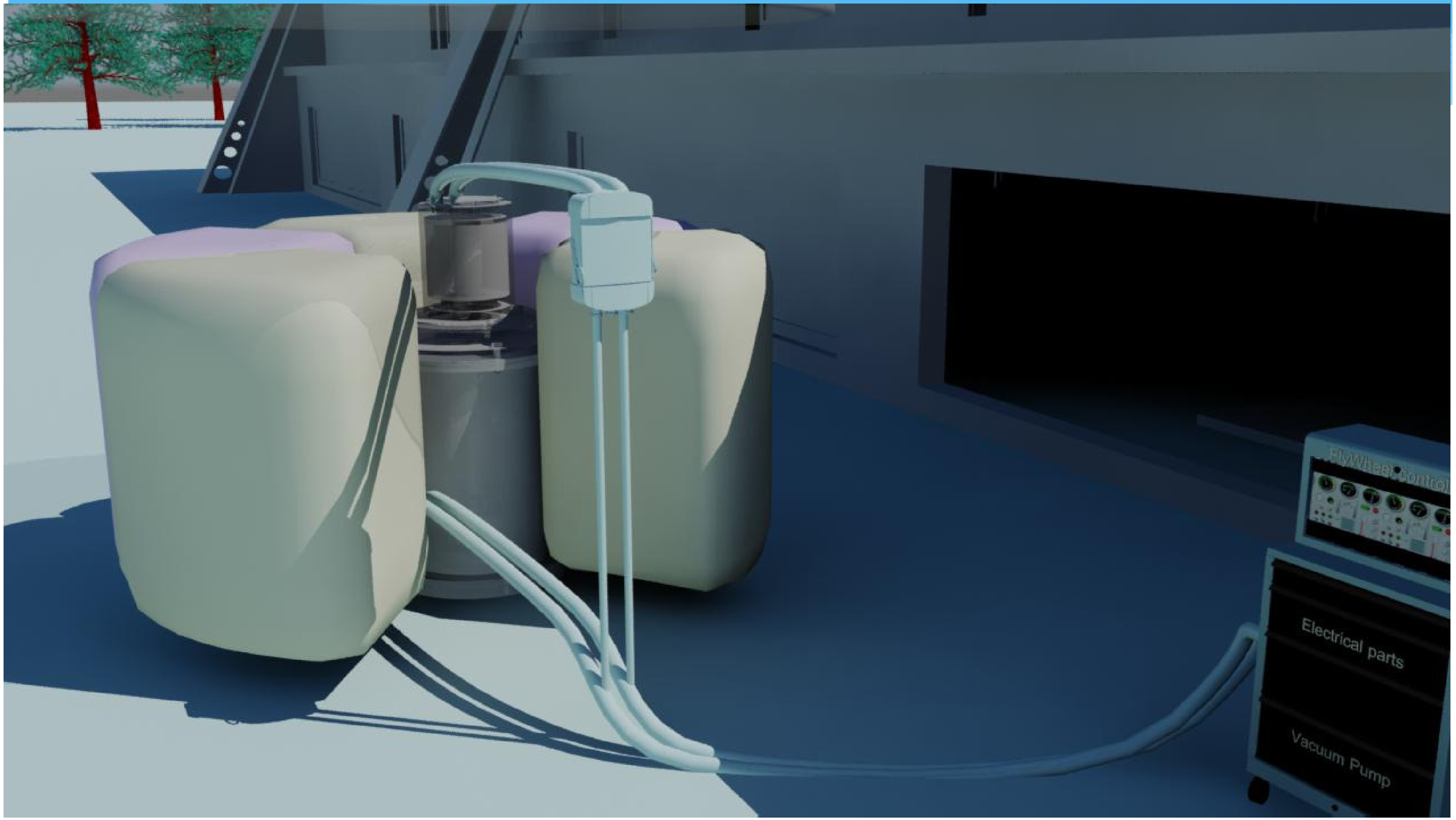
- Free Standing
- Buried

Overall Concept

Single Concrete Containment Basing showing Lid and Control System



6 x sand bags in case of failure



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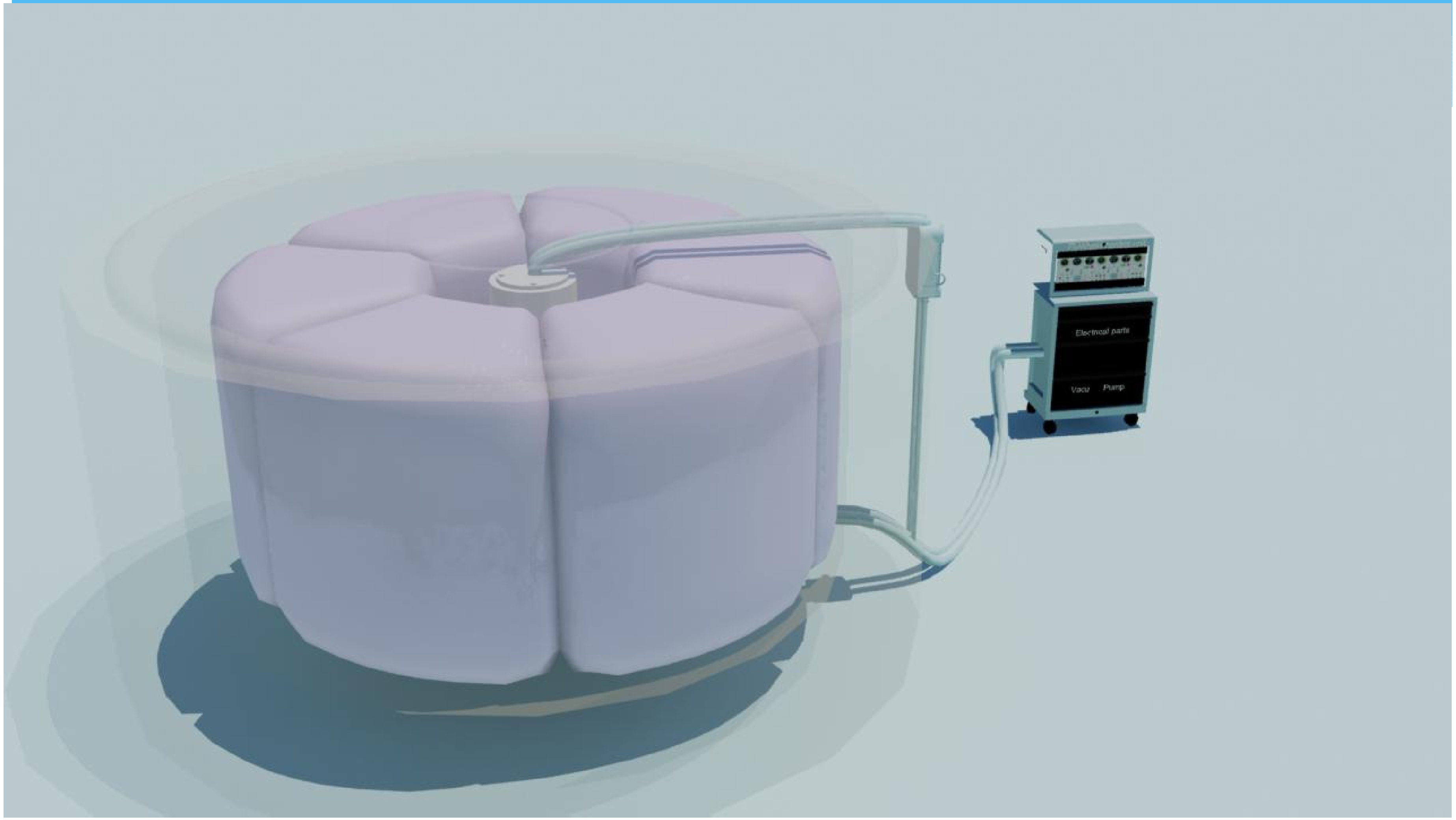
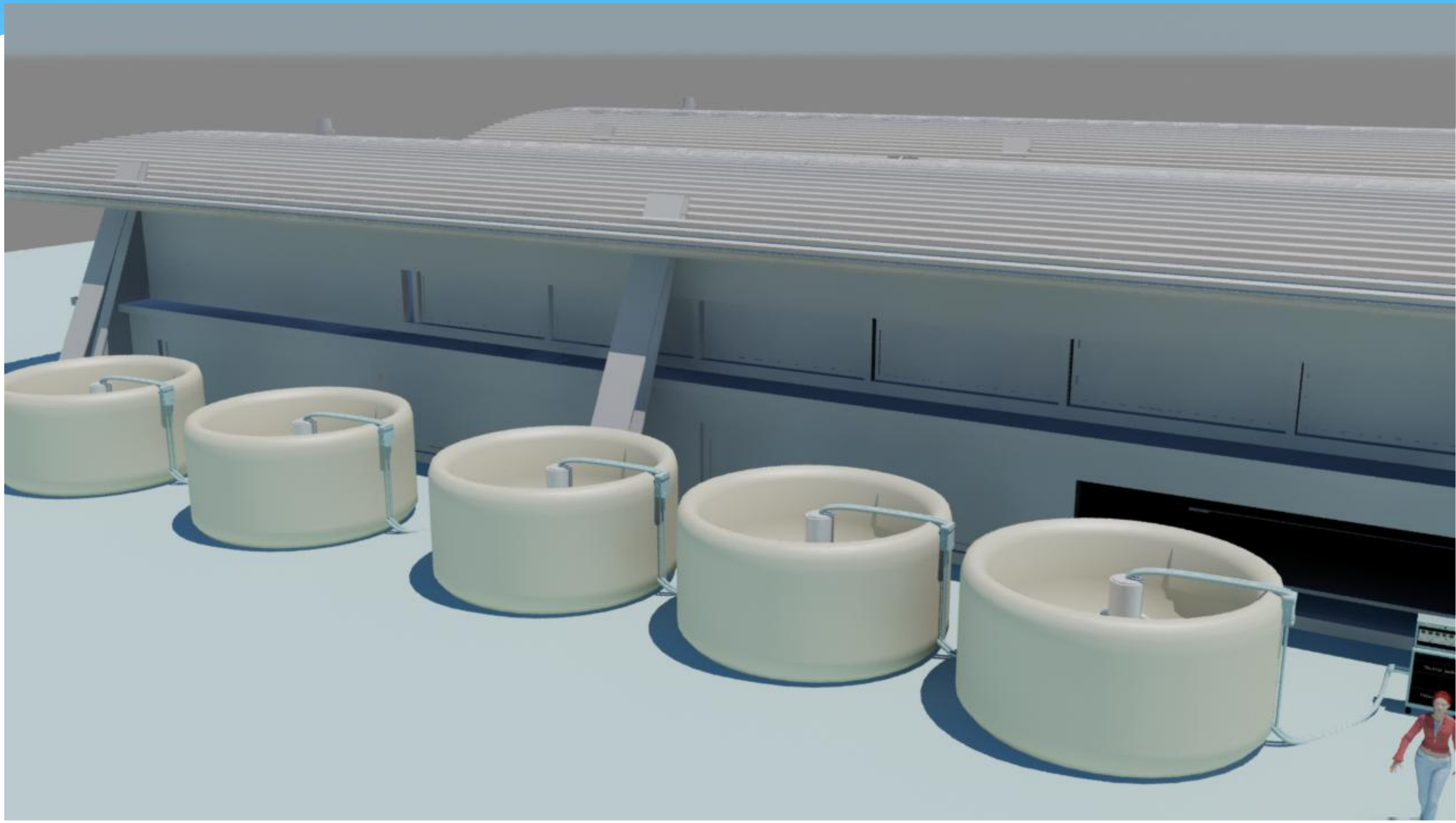


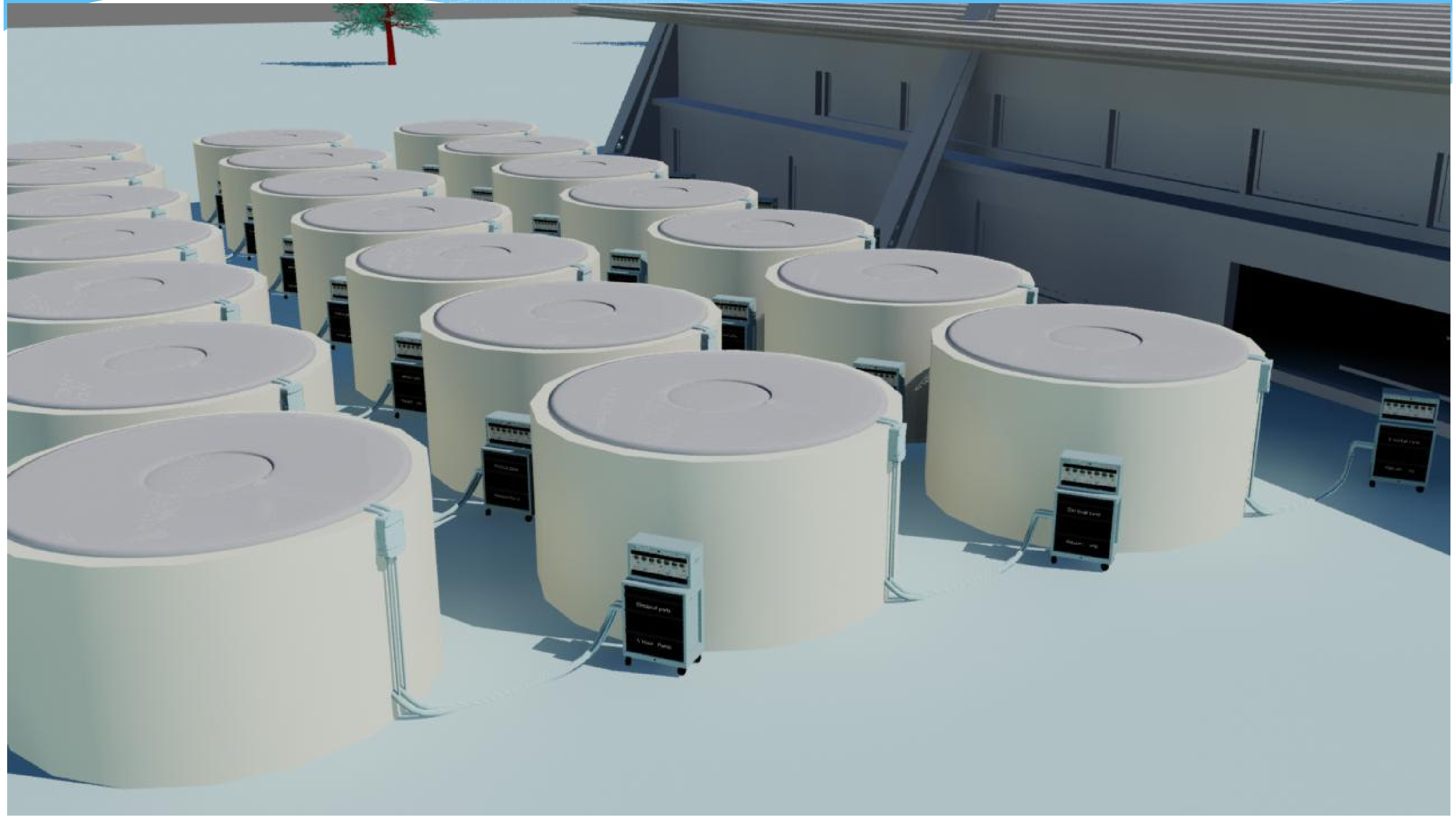
Overall Concept

Envisaged Industrial Application (lead removed)



Overall Concept

Envisaged Industrial Application (lead removed)



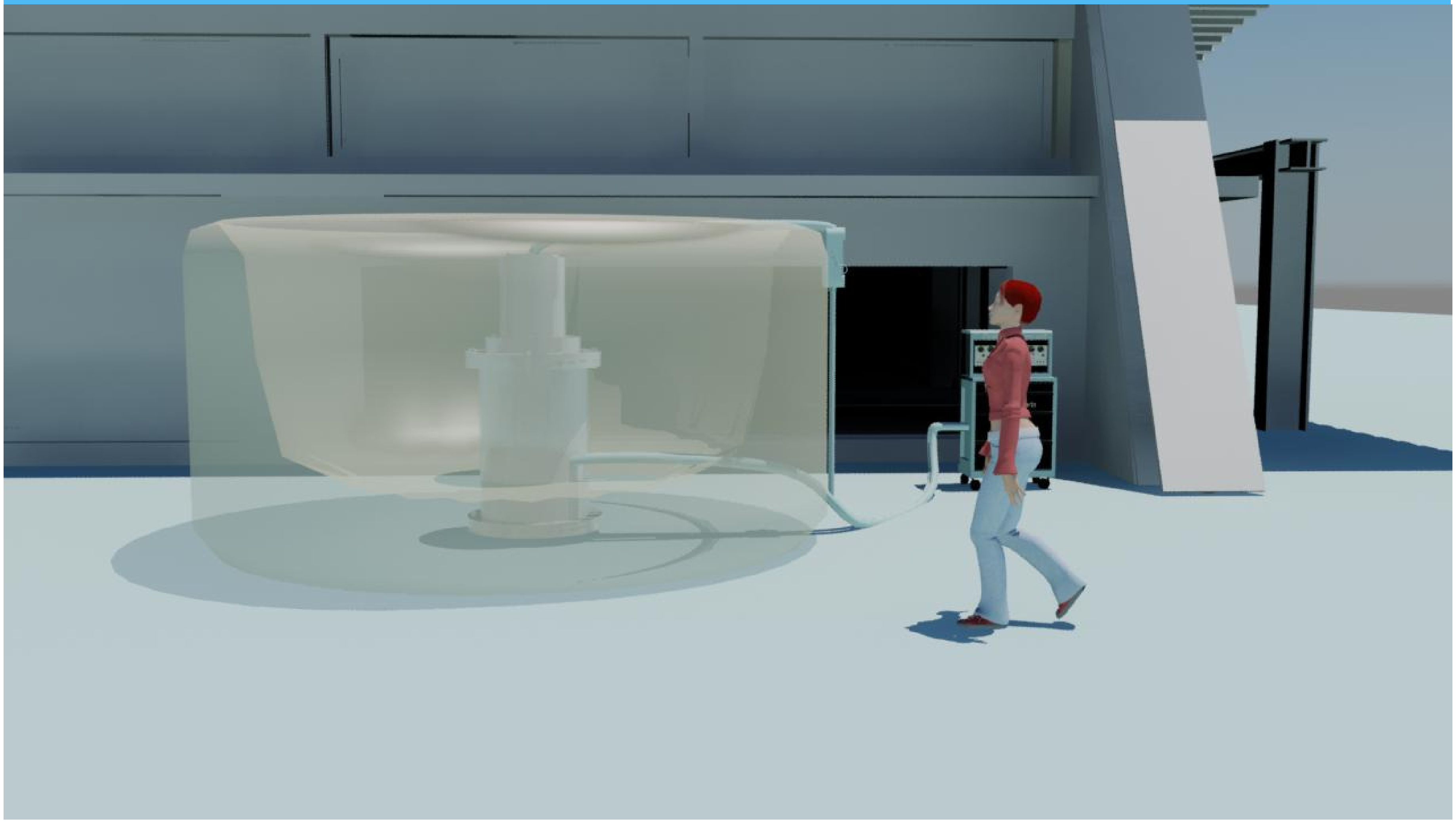
Overall Concept

Envisaged Industrial Application (lead removed)

Overall Concept

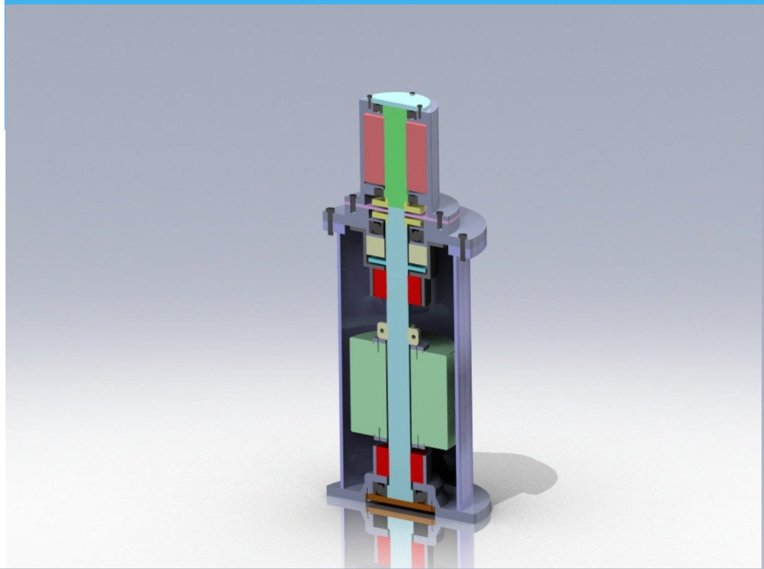
General Scale Visualisation

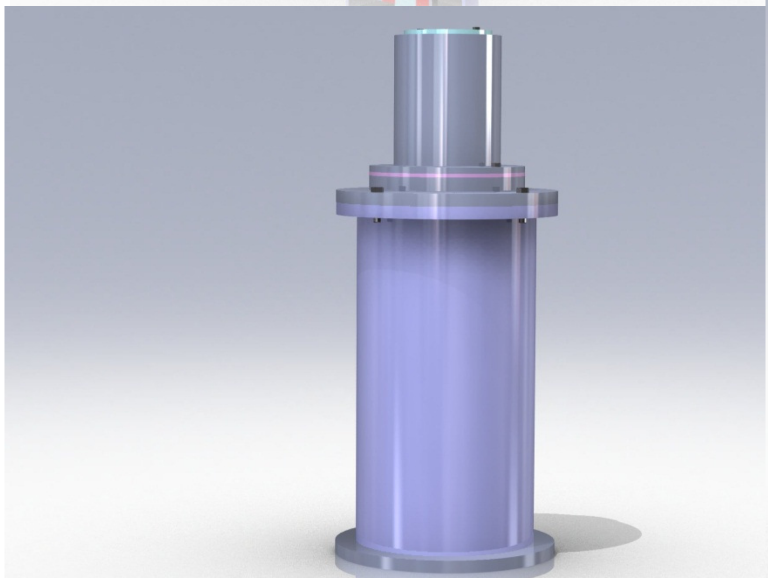
Overall Concept: Industrial

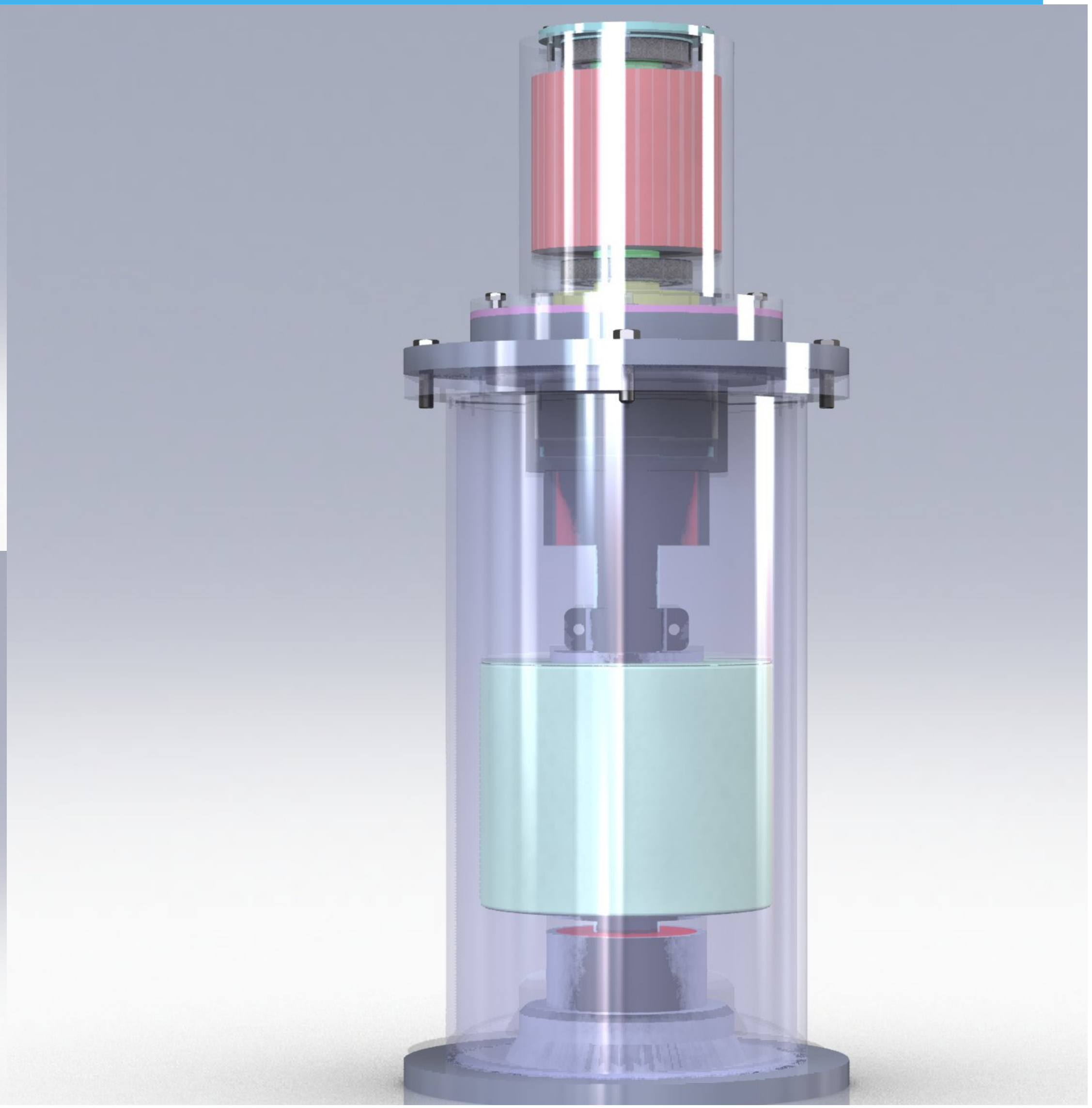


Overall Concept – Solid

Visualisation of the Kinetic Energy Storage Device

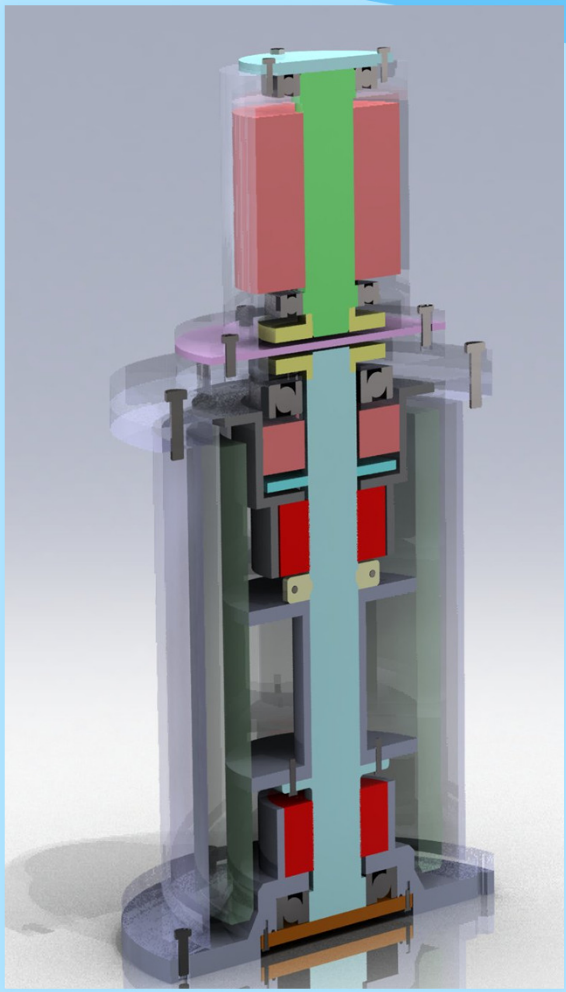






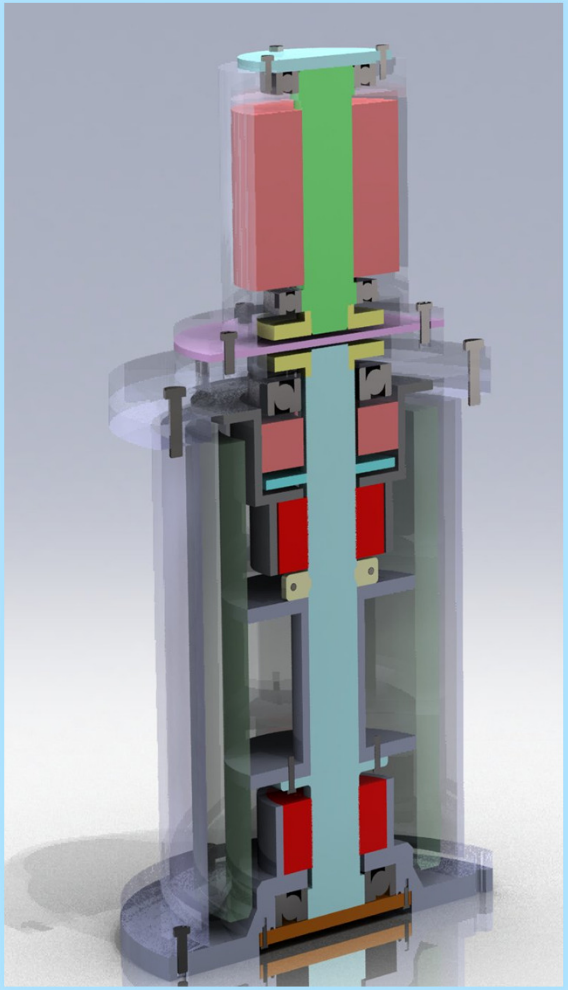
Overall Concept - Hollow

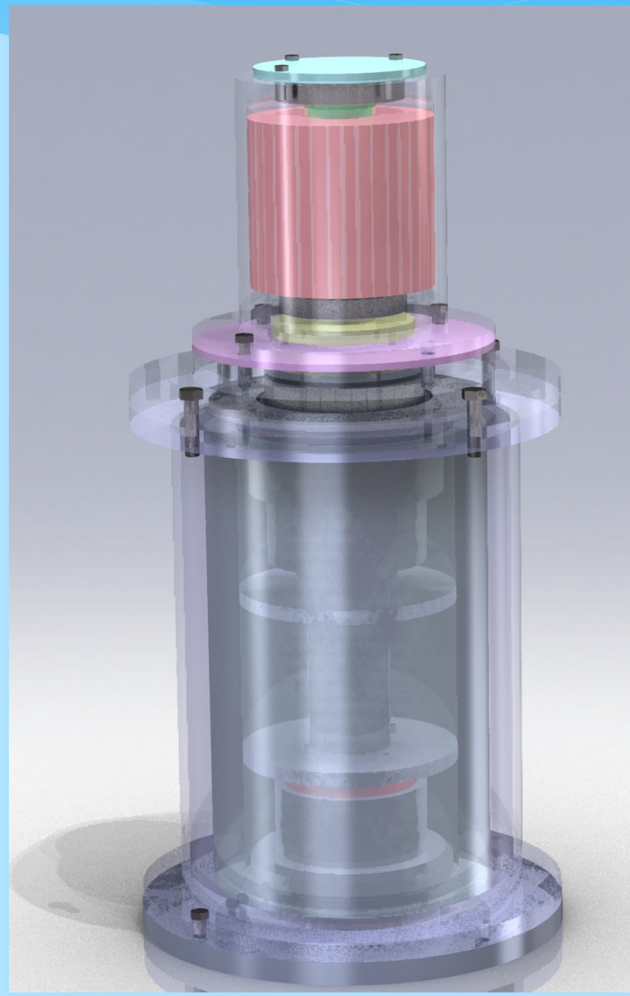
Visualisation of the Kinetic Energy Storage Device



Overall Concept

Visualisation of the Kinetic Energy Storage Device





Work Required to Progress the Project

* Finite element stress analysis vacuum chamber
* Mag/Lev radial bearing design
* Mag/Lev axial bearing design
* Control system for magnetic levitation bearings
* Machine monitoring system
* Design and manufacture of motor / generator set
* Control system for the motor / generator set
* Stress analysis of rotors for burst limitation
* Fluid flow analysis within the chamber
* Vacuum pump and equipment selection
* Rolling element bearing design and selection
* Vacuum casing design
* Explosion containment system design
* Foundations design
* Selection of materials

Questions?