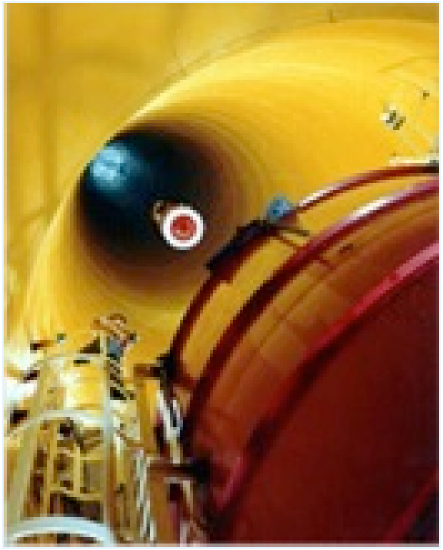
Modification Plans For The NASA 5.2 Second Drop Tower

David Urban



Purpose of this presentation

- Introduce a proposed one-year design study for a CoF action to upgrade the current 5.2 second Zero-g facility at GRC to:
  - Increased the capabilities and reduce the operational costs of the Zero-g facility
  - Include a new capability for a Supercooled Large Droplet (SLD) Icing Facility.

Project goals

- Enhance NASA's capability to perform micro/partial gravity experiments
  - Optimize space flight research (basic and applied)
  - Be prepared to maximize science and technology development for exploration and planetary science in the post-ISS era.
  - Expand the ground-based program by providing inexpensive access to reduced-gravity
  - Reduce operational costs and increase utilization rates

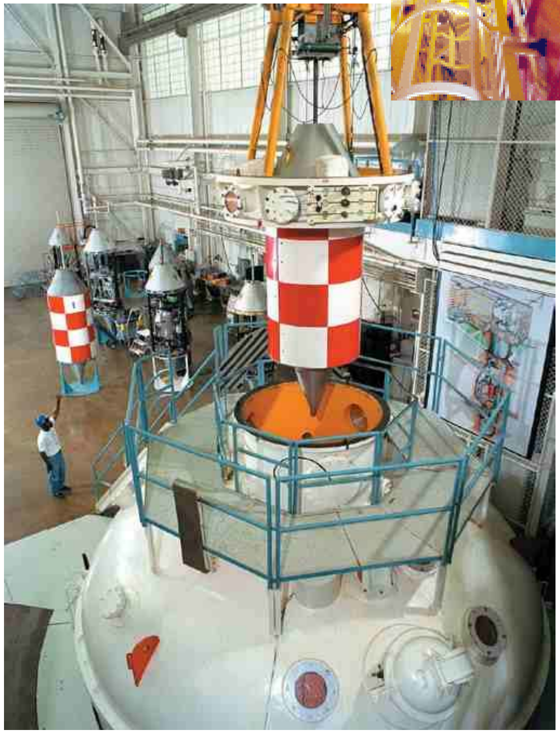
- Create a unique capability for SLD icing research
  - Simulation of the entire range of in-flight icing conditions (i.e. conventional icing, freezing drizzle, and freezing rain)
  - Provide the icing community with tools for means of compliance with new regulations
  - Enhance NASA research in SLD icing physics
  - Create publicly available databases for evaluation of SLD capable computational tools
  - Provide the capability for development and evaluation of ice protection/detection systems to be used in SLD conditions

Agenda

- Drop Tower Expansion Background
  - Current Facility
  - Currently operating drop towers (partial list) and other ground-based facilities
- Research Areas Enabled By This Proposal
- Supercooled Large Droplets (SLD)
  - Capability Needs
  - Design Issues
- Integrated Concept
- Proposed Plan / Status

NASA Zero-g Facility

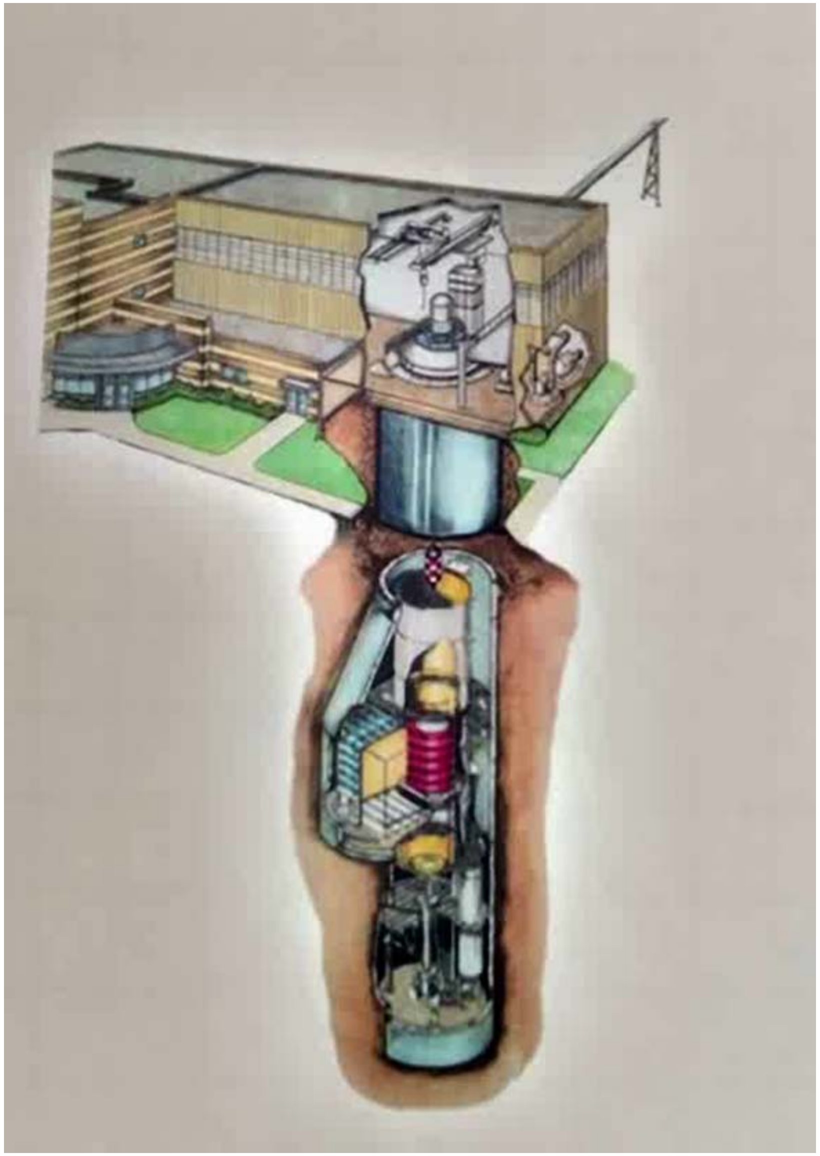
- GRC Zero-g Facility became operational in 1966
- No major mods since then
- Over 4900 drops
- Utilization rate: 2 drops/day
- Operational cost: $5.8 K/drop; 74 labor hrs/drop
- Microgravity Duration: 5.18 s
- Free Fall Distance: 432 ft (132 m)
- Gravitational Acceleration: <0.000,01 g
- Deceleration: 35/65 g mean / peak
- Payload - Cylindrical, 42 in. (1 m) diameter by 13 ft. (4 m) tall
- Gross Vehicle Weight: 2500 lbs. (1130 kg)
- Experimental Payload Weight: up to 1000 lbs. (455 kg)

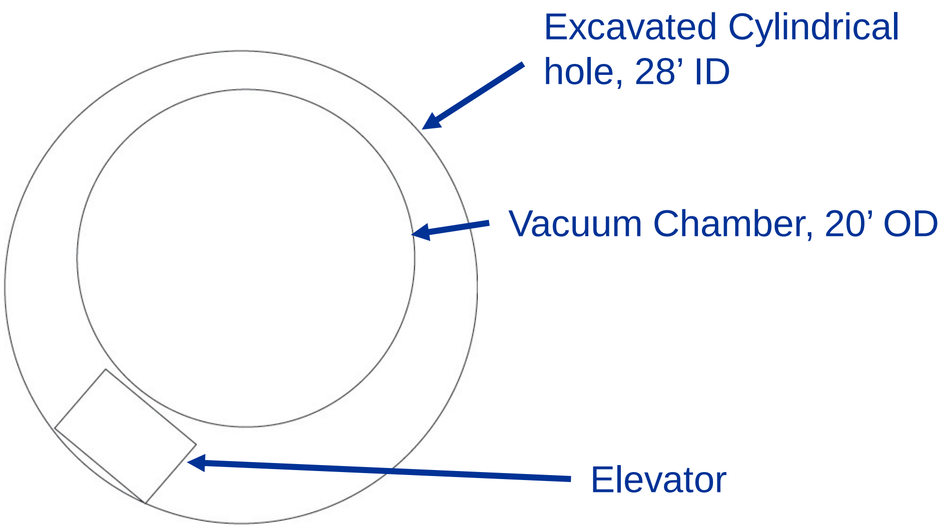


Zero-g Facilities Background

- Current world-wide Drop Tower capability is little changed in decades despite major technology growth
- Exceptions
    - ZARM-Bremen -- launch capability provides 10 seconds of micro-g
    - Portland State University -- rapid drop turnaround provides 2 seconds of micro-g with increased productivity and innovation
- Planetary exploration plans raise new research needs in partial gravity that cannot be satisfied on low-g aircraft alone (NASA terminated support in 2015)
- Partial gravity research largely ignored despite substantial technical importance for both fundamental science and exploration needs

Current Layout





Research Areas Enabled By This Proposal

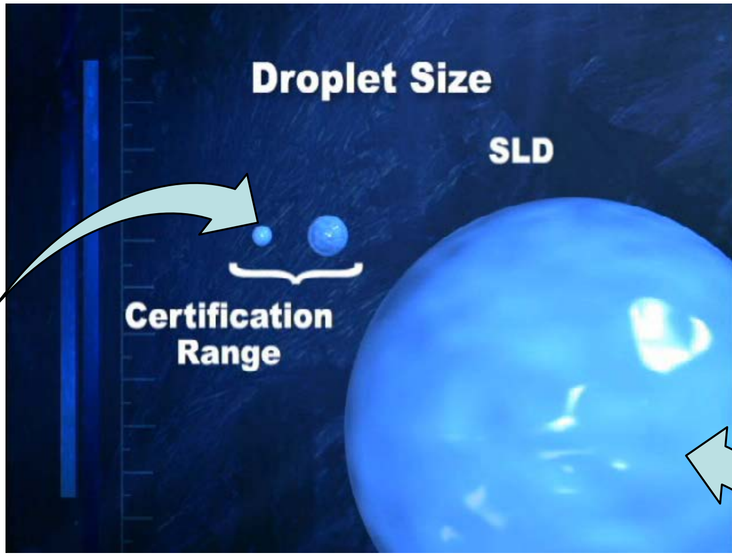
- Combustion Science (high pressure engine research)
- Spacecraft Fire Safety (exploration atmospheres flammability)
- Extra Terrestrial habitat fire safety
- In-situ Resource Utilization (reactor design, regolith behavior)
- Interfacial Phenomena (fluid control on spacecraft and E.T.)
- Fluid Physics (life support systems)
- Materials
- Fundamental Physics
- Plant Biology
- Aeronautics (Supercooled large Droplet Icing)

Supercooled Large Droplet Facility Concept

Capability Needs

- The certification envelope for flight in icing conditions has recently been expanded to include larger droplet conditions than have been previously considered
  - Freezing drizzle ($100\mu m \leq d_{max} \leq 500\mu m$)
  - Freezing rain ($d_{max} > 500\mu m$)
- No current icing test facility can adequately reproduce SLD icing conditions for the entire range
- Experimental and computational tools are needed to evaluate the impact of SLD on aircraft and aircraft sub-systems
  - Facility for direct simulation of exposure to SLD
  - Data for development and validation of computational simulation tools
  - Assess impact of SLD on current and future aircraft configurations
    - Current commercial transports and rotorcraft
    - Assessment of future configurations (N+2/3 aircraft)
    - UAV

Airframe Ice
(Super-Cooled Liquid Droplets)



Conventional Icing (FAA Appendix C)

- Supercooled Liquid Droplet < 100 micron

Supercooled Large Droplets (SLD)

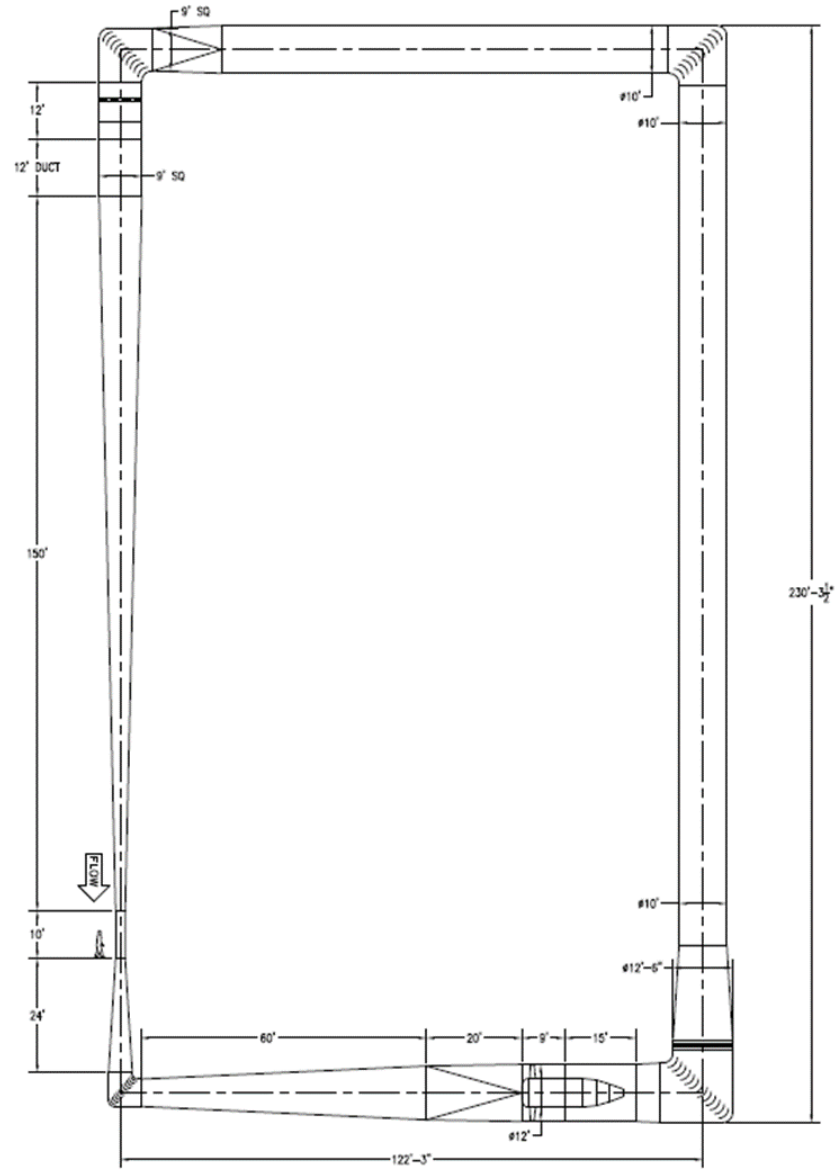
- Freezing Drizzle (100-500 micron)-FAA Appendix O in 2014/2015 (Limited Low Droplet Drizzle Range IRT Icing Data Available)
- Freezing Rain (>500 micron- FAA Appendix O)-FAA Appendix O in 2014/2015 (No Icing Data Available)

Facility Issues

- Cloud Uniformity
  - Stratification due to gravity for horizontal tunnels
  - Inertial effects due to passage through a contraction section
- Thermal Equilibrium
  - Distance from spray bars to test section
- Dynamic Equilibrium
  - Distance from spray bars to test section
- Drop Breakup
  - Shear forces on the drops in short contraction sections
- Facility Parameters
  - Drop size
  - Cloud drop distribution
  - Cloud liquid water content
  - Velocity range
  - Temperature range

Icing in the Zero-G Facility

A recent study identified the characteristics of an icing wind tunnel capable of generating icing conditions that would encompass the full range of the SLD environment. This study concluded that such a facility would be a vertical flow icing wind tunnel with a 150ft section between the spray bars and the test section. This study also estimated the cost for such a facility as being approximately $60-70M. This current technology development study would investigate use of the Zero-G facility as a more affordable alternative to a stand-alone vertical flow icing tunnel.

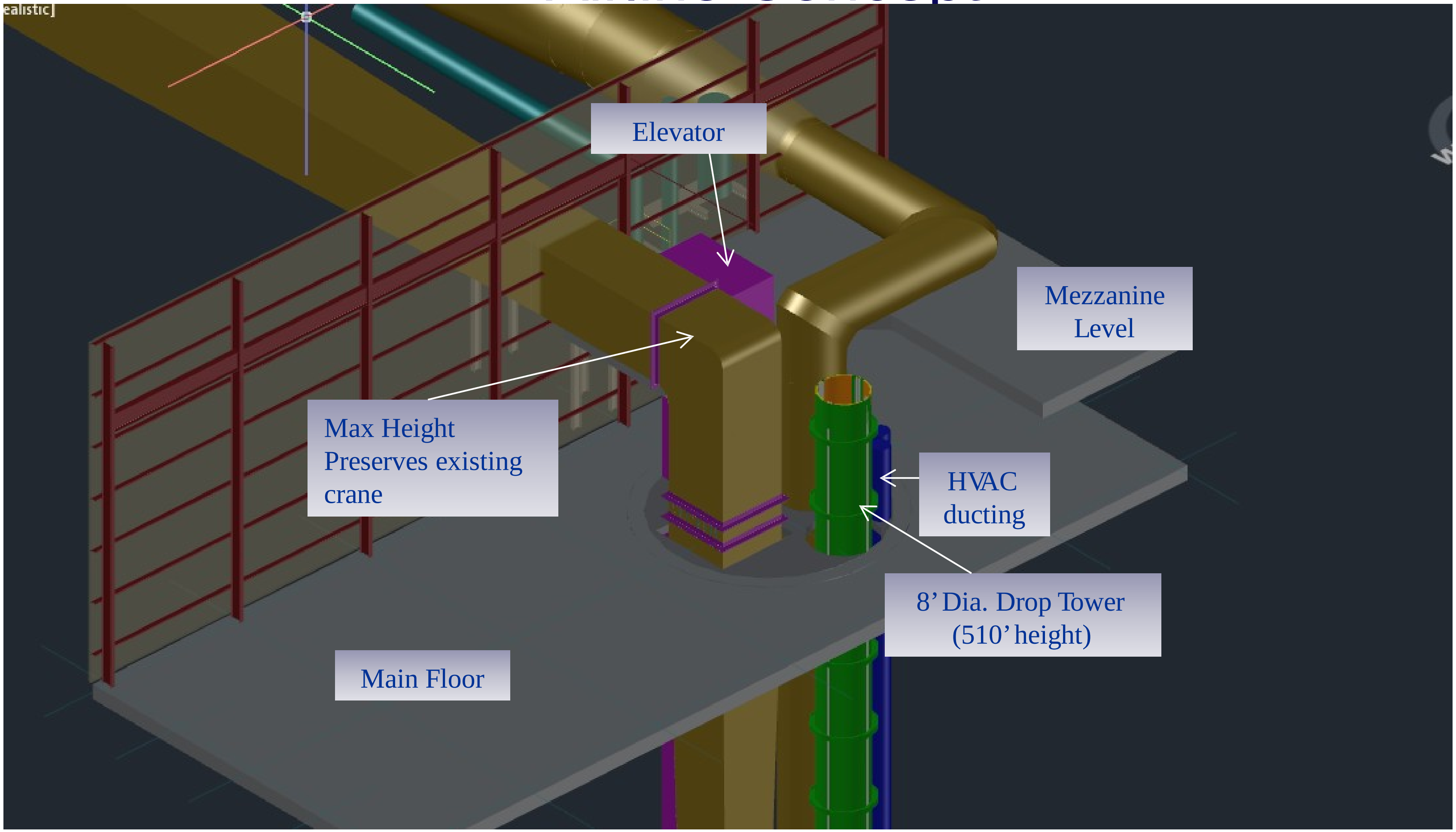


Integrated Concept

Integrated Concept

- Potentially Preserve vacuum drop capability
  - Peerless micro-g facility
  - Would use new smaller tube to provide more room
- Install Mag-lev drop tower adjacent to vacuum vessel
  - Use full depth plus mezzanine, ~520 ft
  - Throw packages from the bottom for increased time
  - Reduced deceleration levels, ~15 g
  - Fail-safe, crane-less operation
  - 30 drops/day
- Install Supercooled Large Droplet Facility
  - ~200 feet
  - Requirements TBD
- This redesign would render the 2.2 s tower (Bldg 45) superfluous (opportunity for footprint reduction)

Airline Concept



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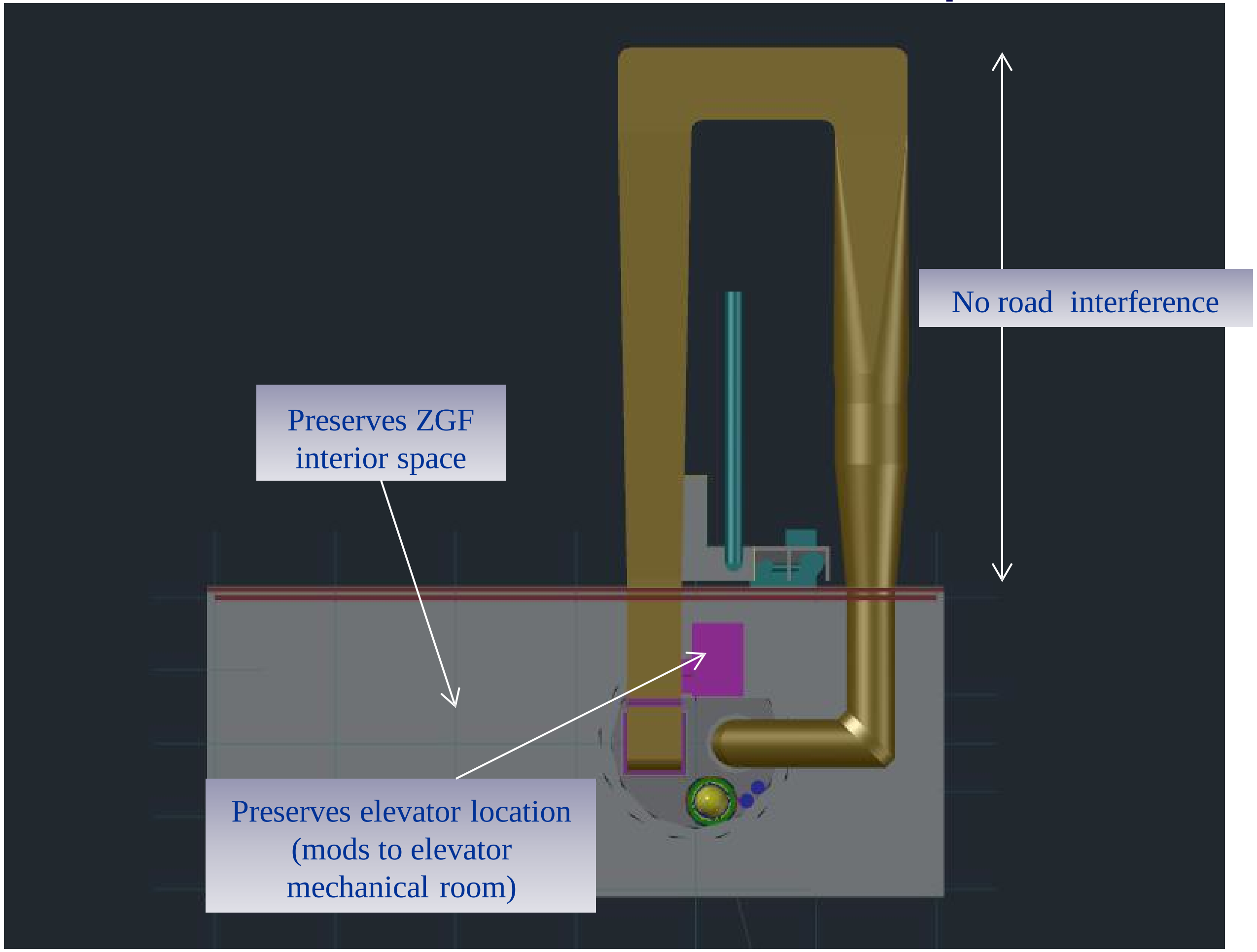
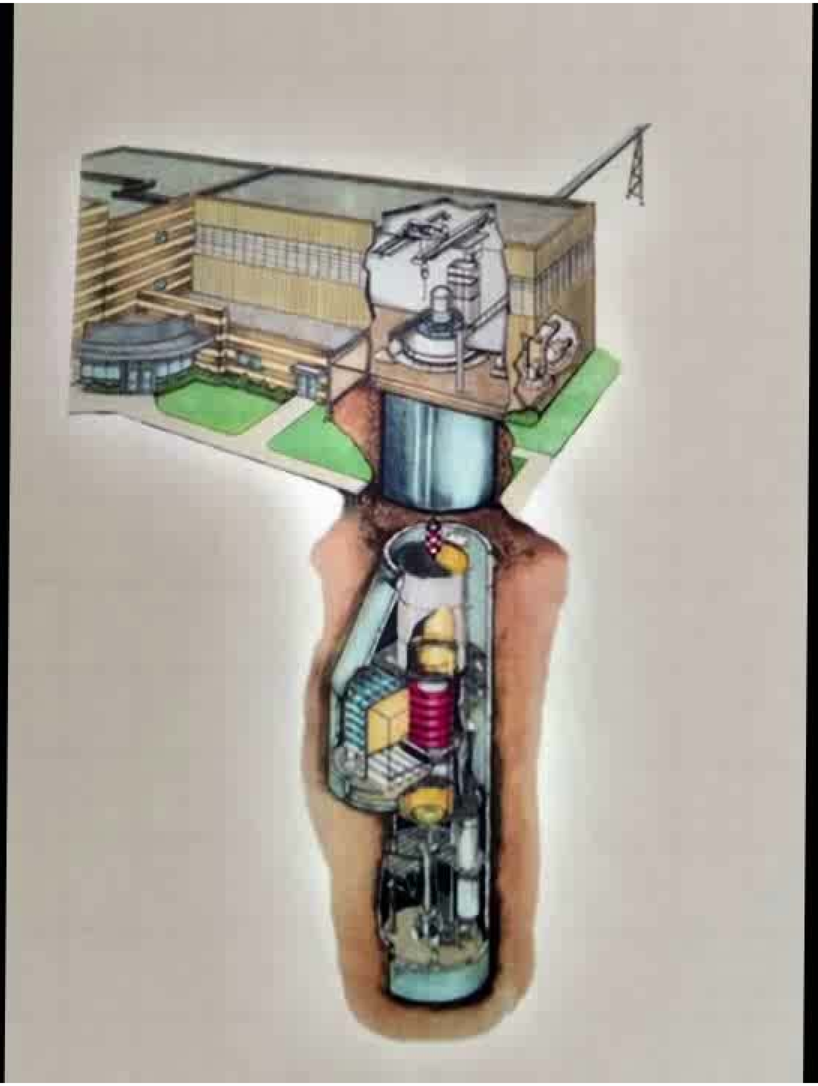


Animation



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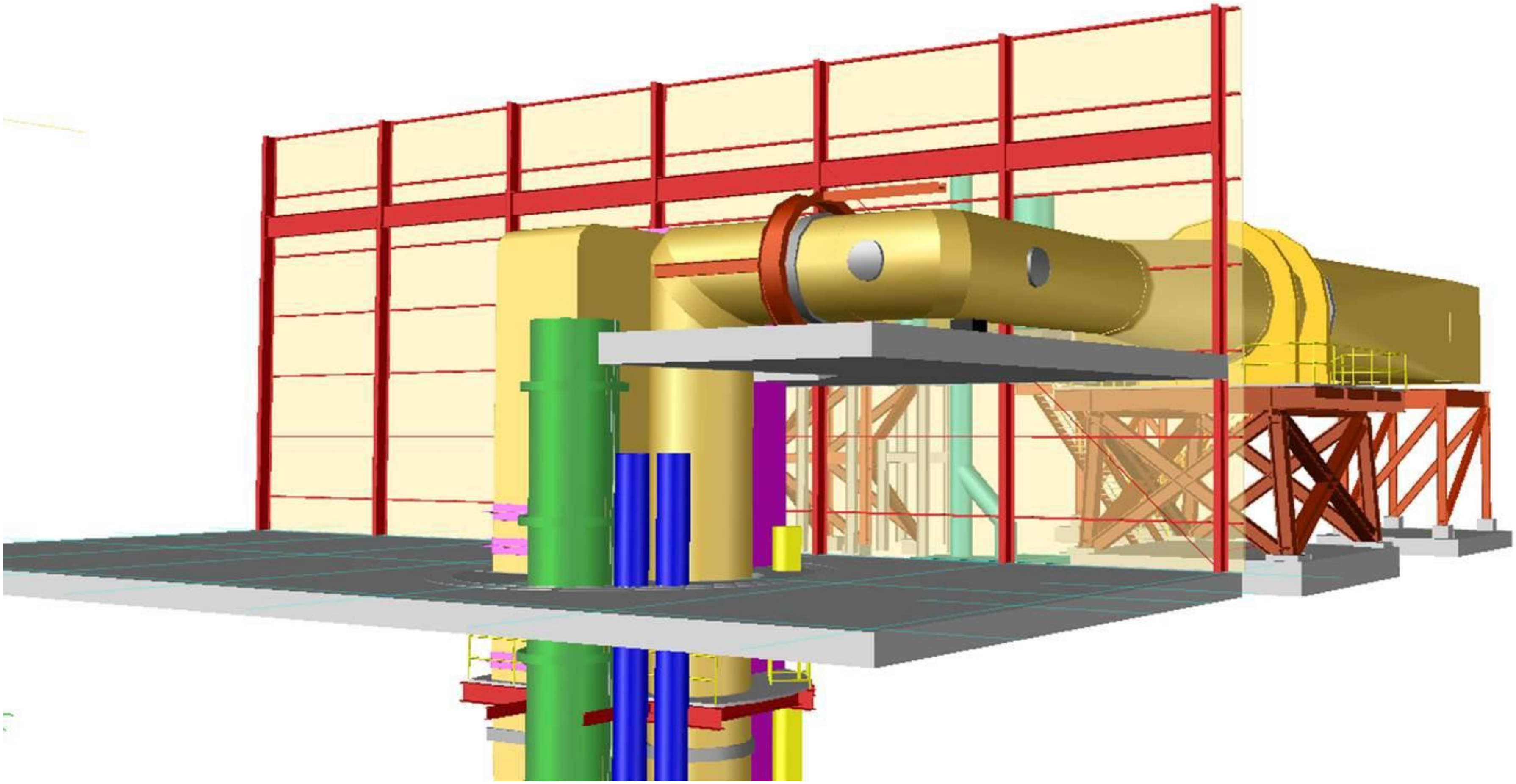

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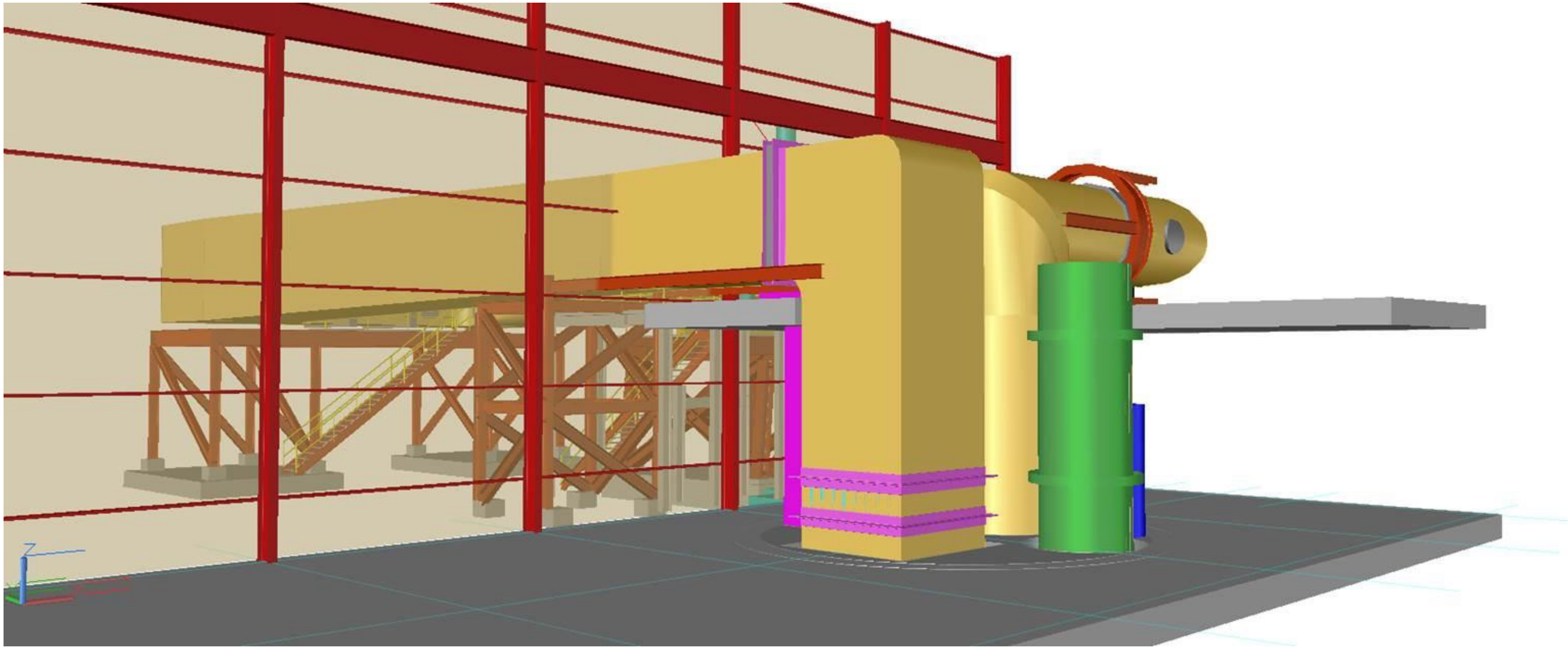


Maglev Concept

- ❑ Ongoing discussions with General Atomics and InTraSys

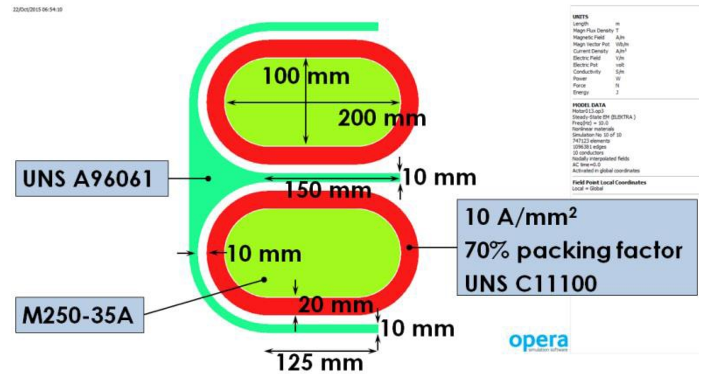
<u>Primary discussion points</u>

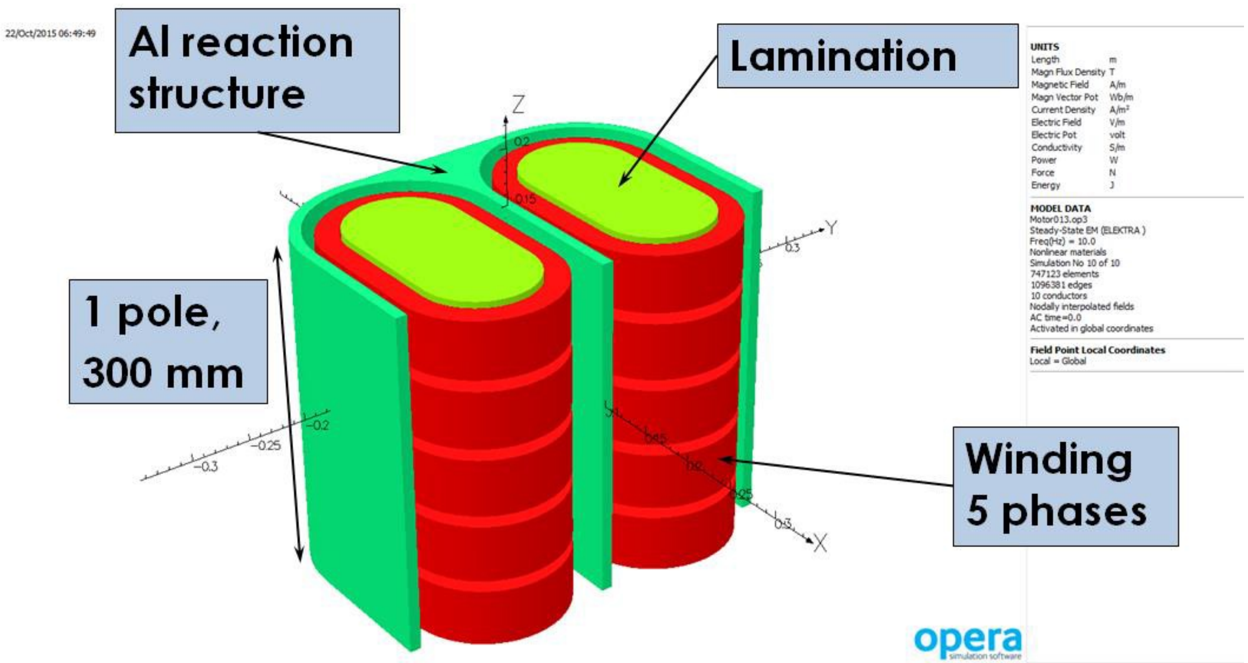
- Weight of entire payload 2,000 to 2,500kg including LIM (or LSM)
- Ability to achieve 10-5 g vibration levels during test
  - GA does not believe this LIM configuration alone will provide the required low frequencies (10^{-5} g). It may be a few orders of magnitude greater. A second suspension system (internal to the payload module) may be required to dampen the payload to the required g-loading.
- Configuration – Concept is based on a vertical LIM
- Power requirements
  - Tradeoffs 4g vs 15g acceleration levels

Summary @ 2,000kg Package, quality level = 1E-6g	Time		Power	
Total thrown time 15g/15g	10.83	s	1.6E+07	watt
Total thrown time 4g/15g	10.42	s		watt
Total thrown time 4g/4g	10.00	s	3.86E+06	watt
Total thrown time 1.5g/4g	9.33	s		watt
Total thrown time 1.5g/1.5g	8.66	s	1.25E+06	watt
Perspective: 7 MW is approx. mechanical power output of a Top Fuel dragster (Source: Wiki)				

Maglev Concept

- Linear induction motor
  - Keep dropped mass as small as possible
- Gramme winding
  - Very small force ripple
- Axial length of reaction structure
  - Must be integer number of wavelengths of the LIM
  - Reason: force ripple





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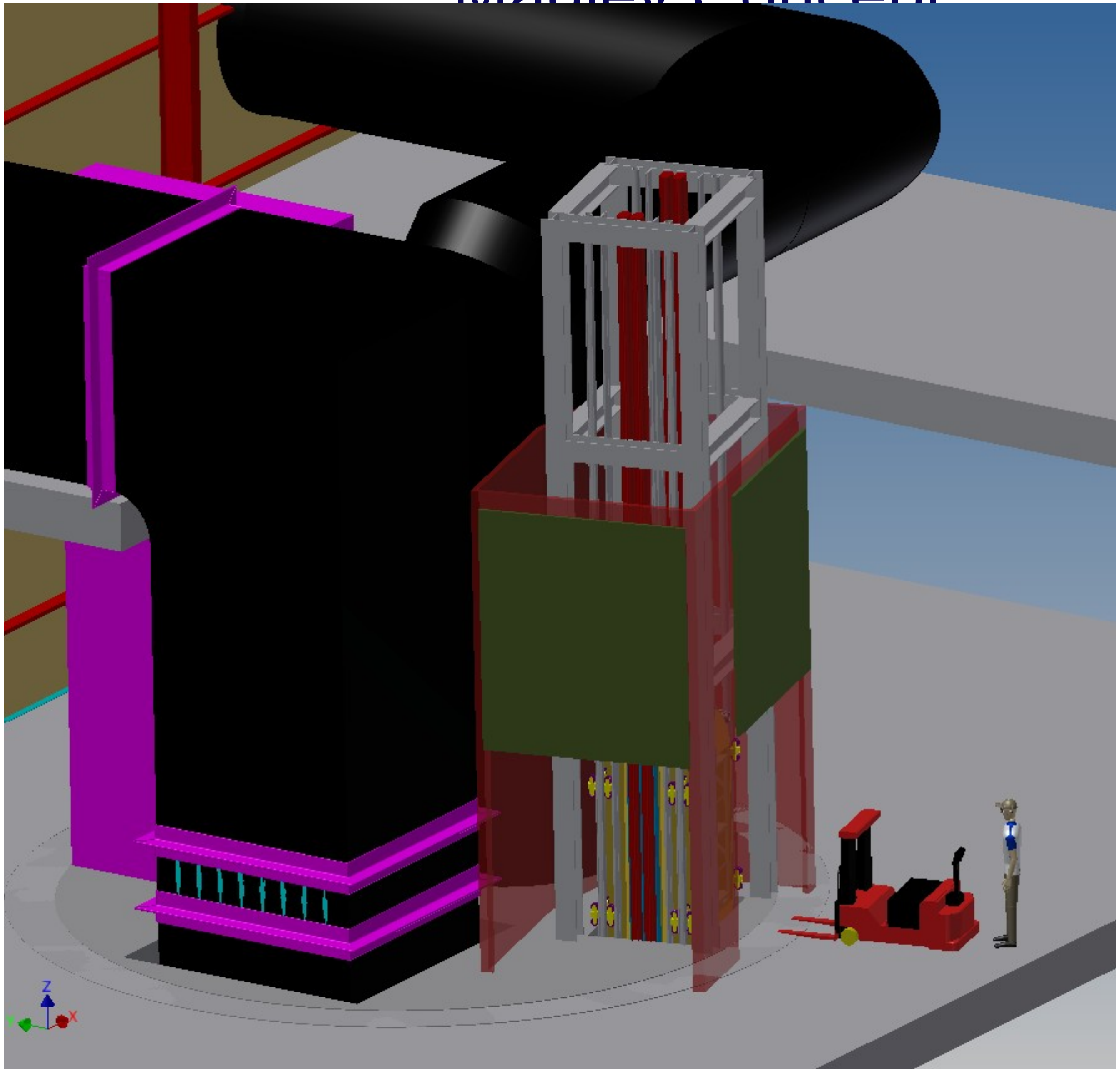

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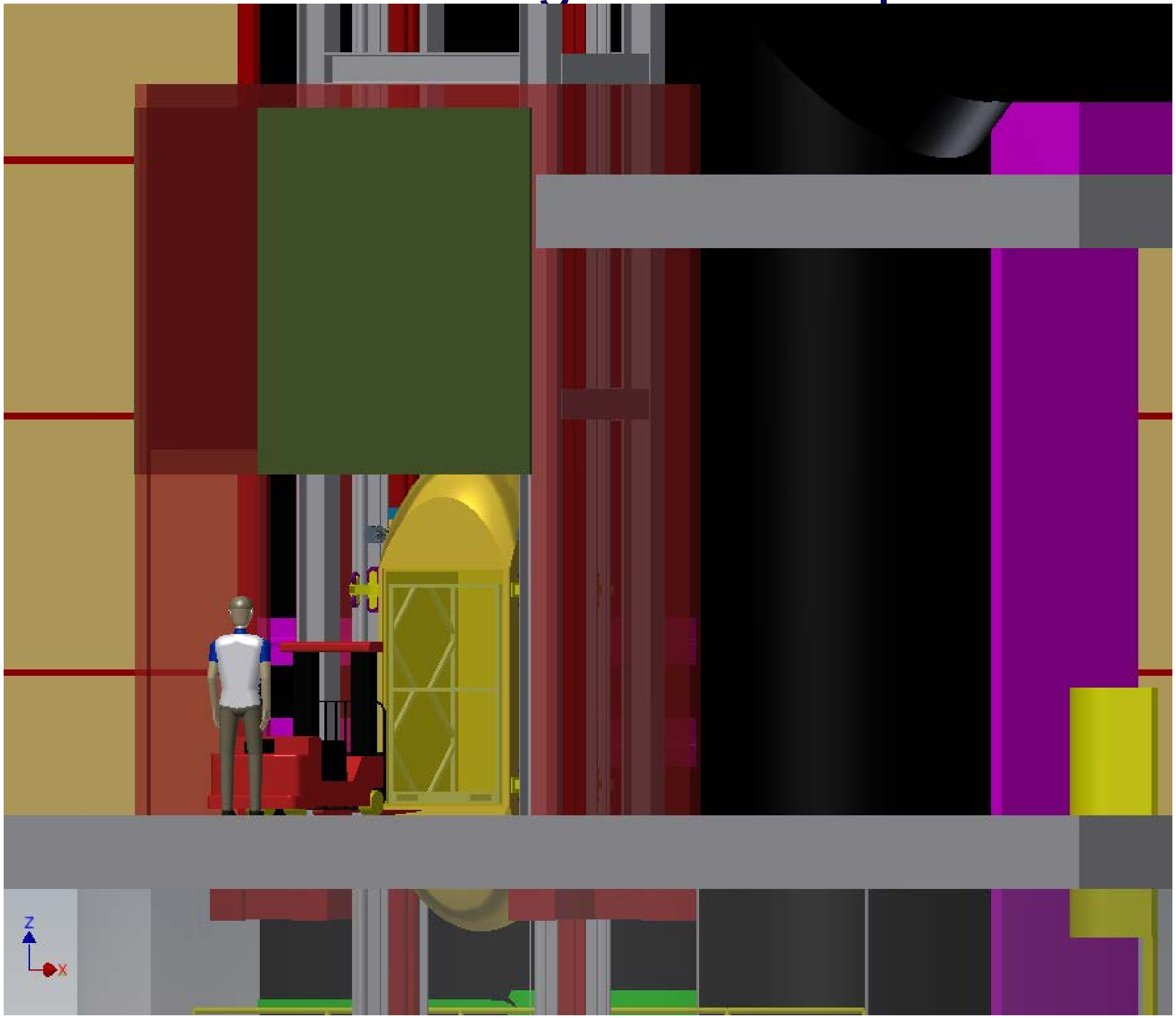
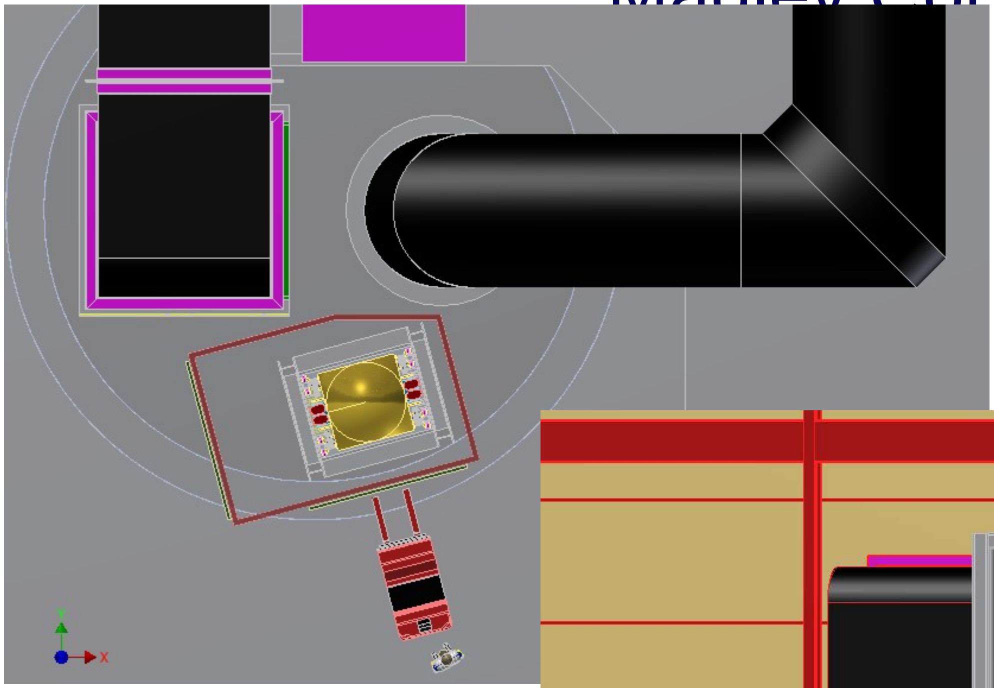


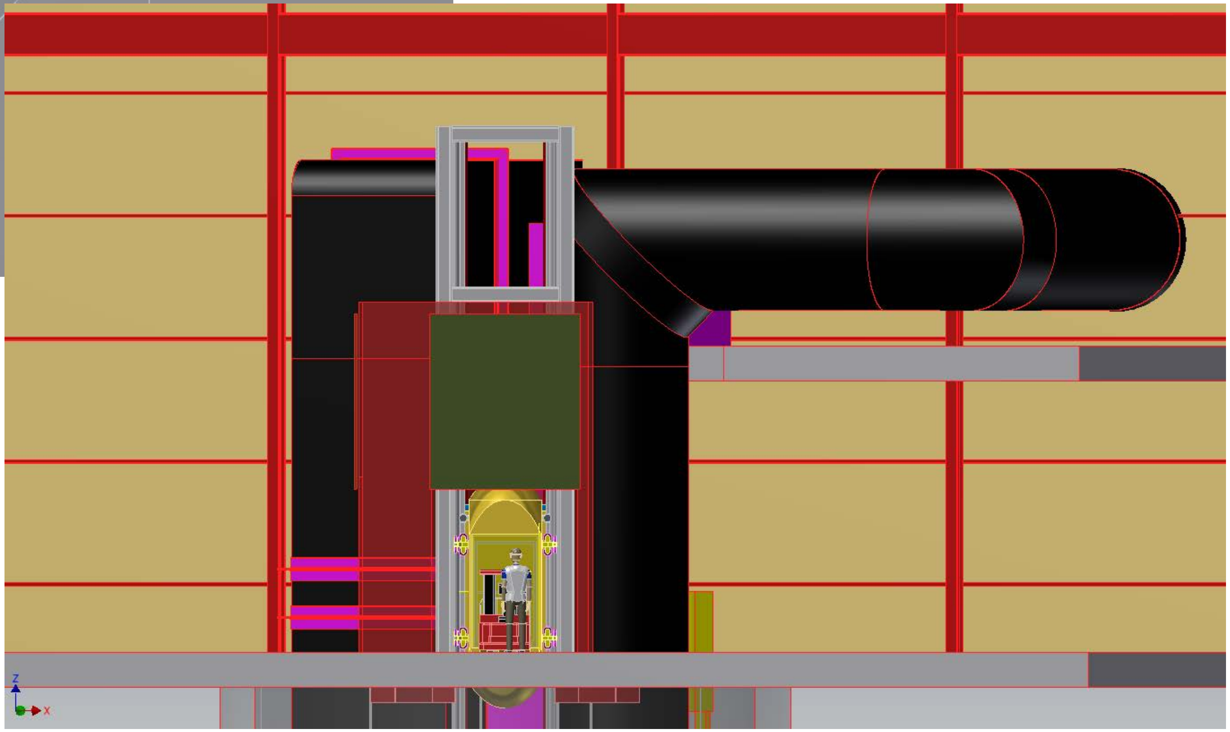
ISO 2

Maglev Concept

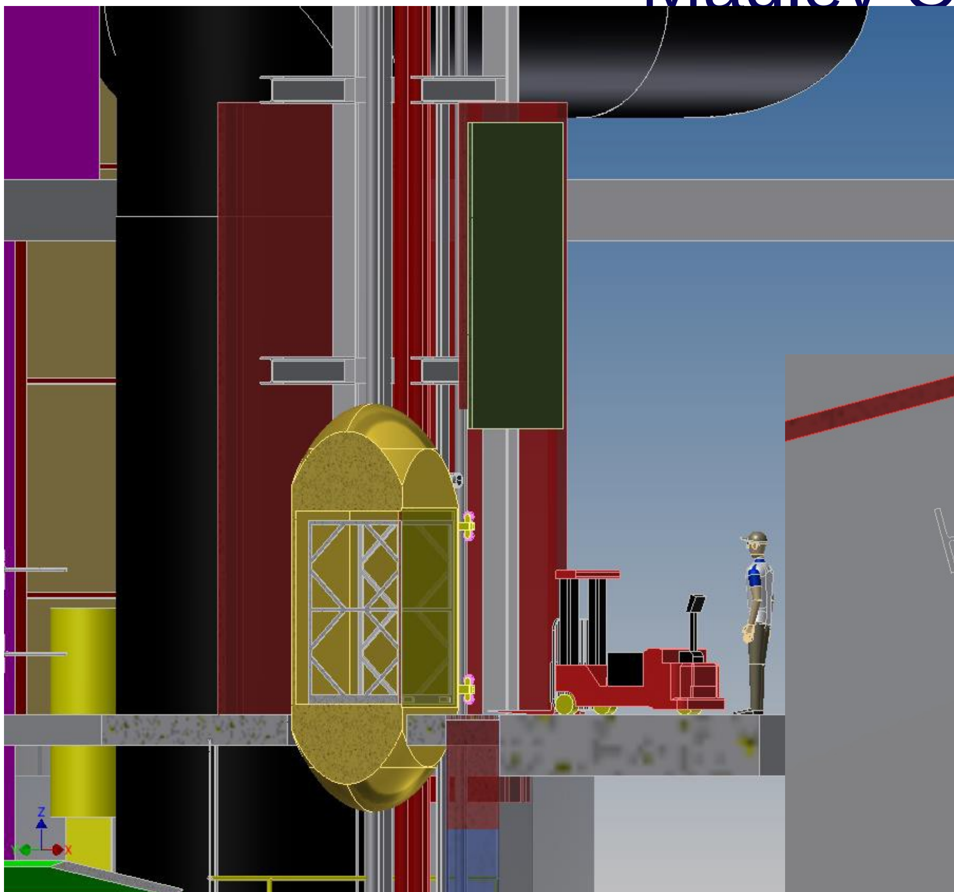


PLAN

ELEV

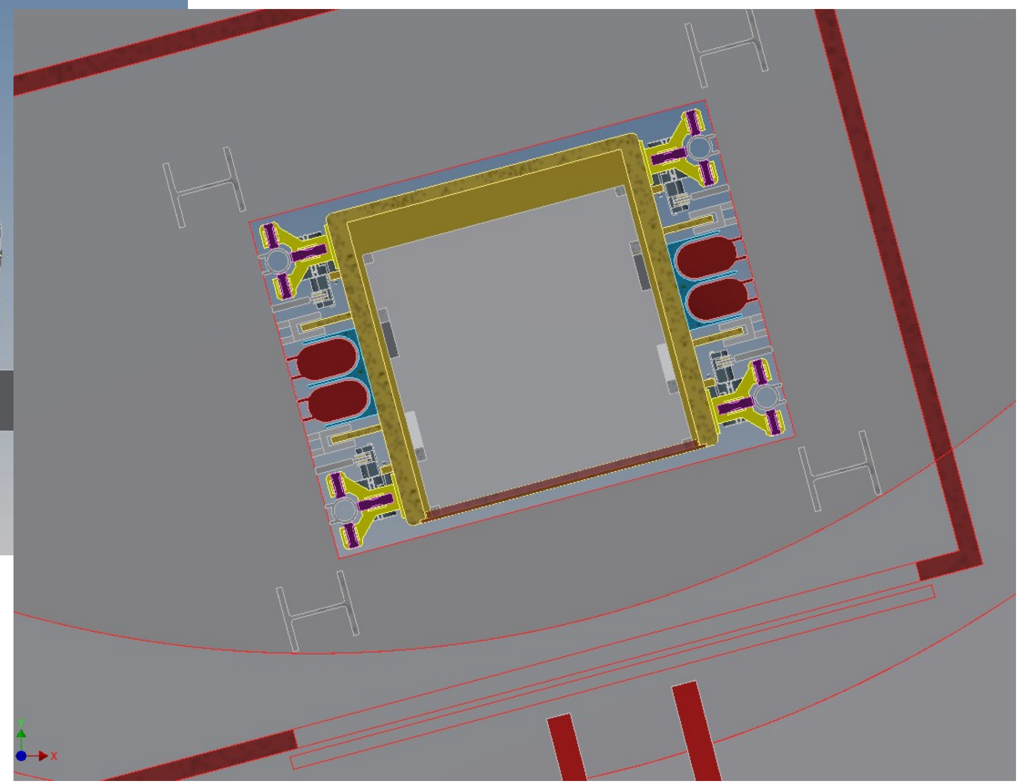


Maglev Concept

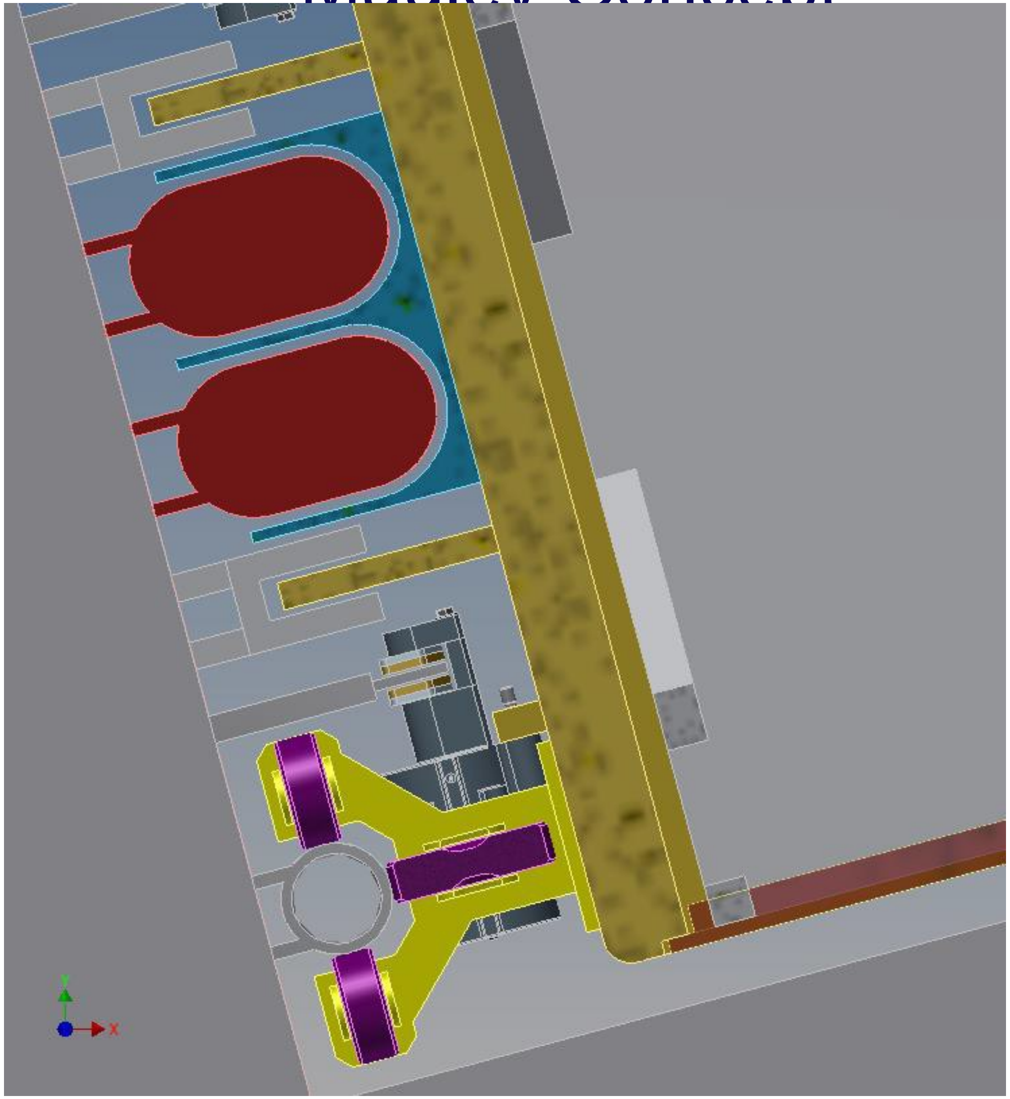


SECTION VIEW 1

SECTION VIEW 2

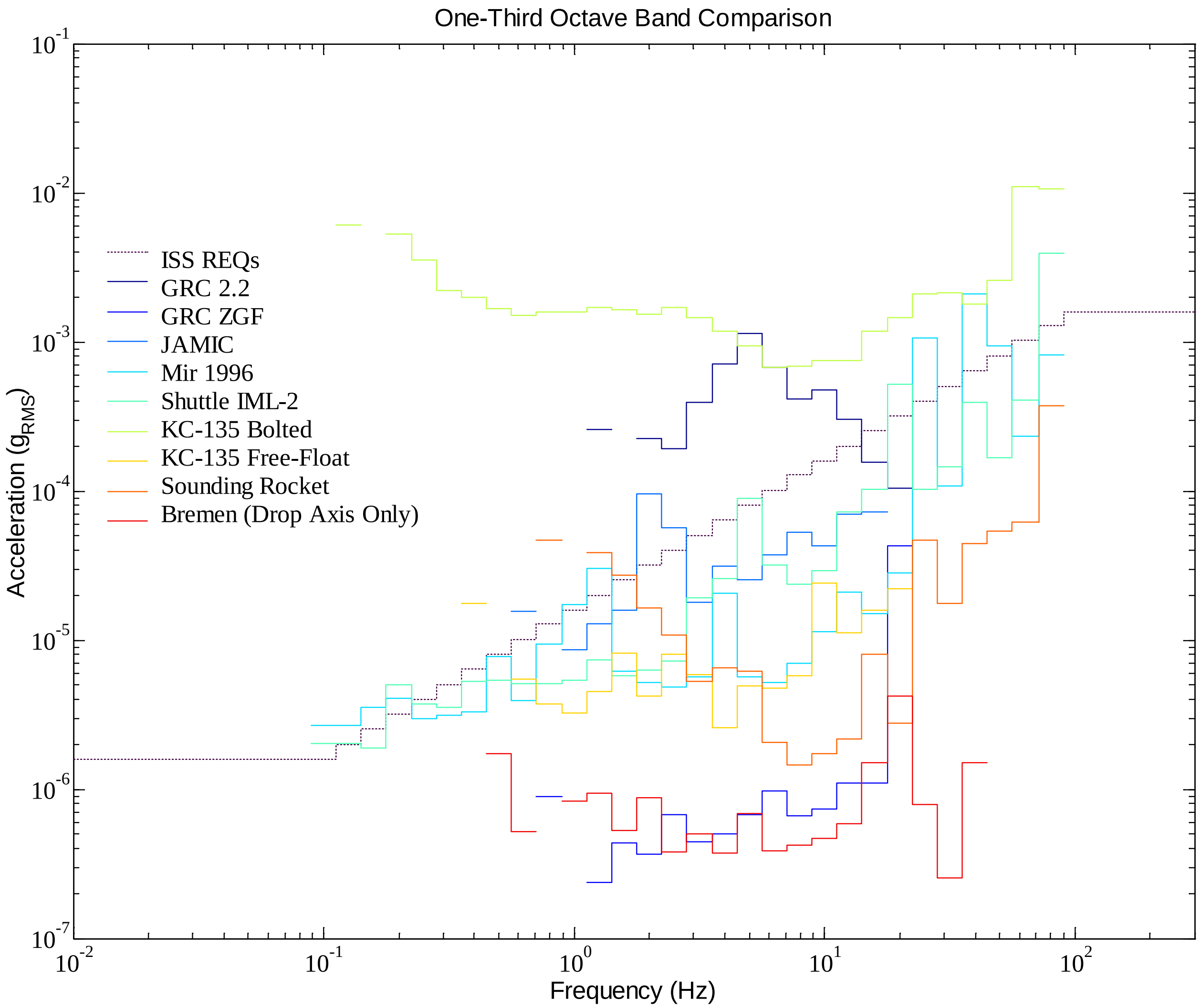


Maglev Concept



SECTION VIEW 3

Backup: g-level comparison



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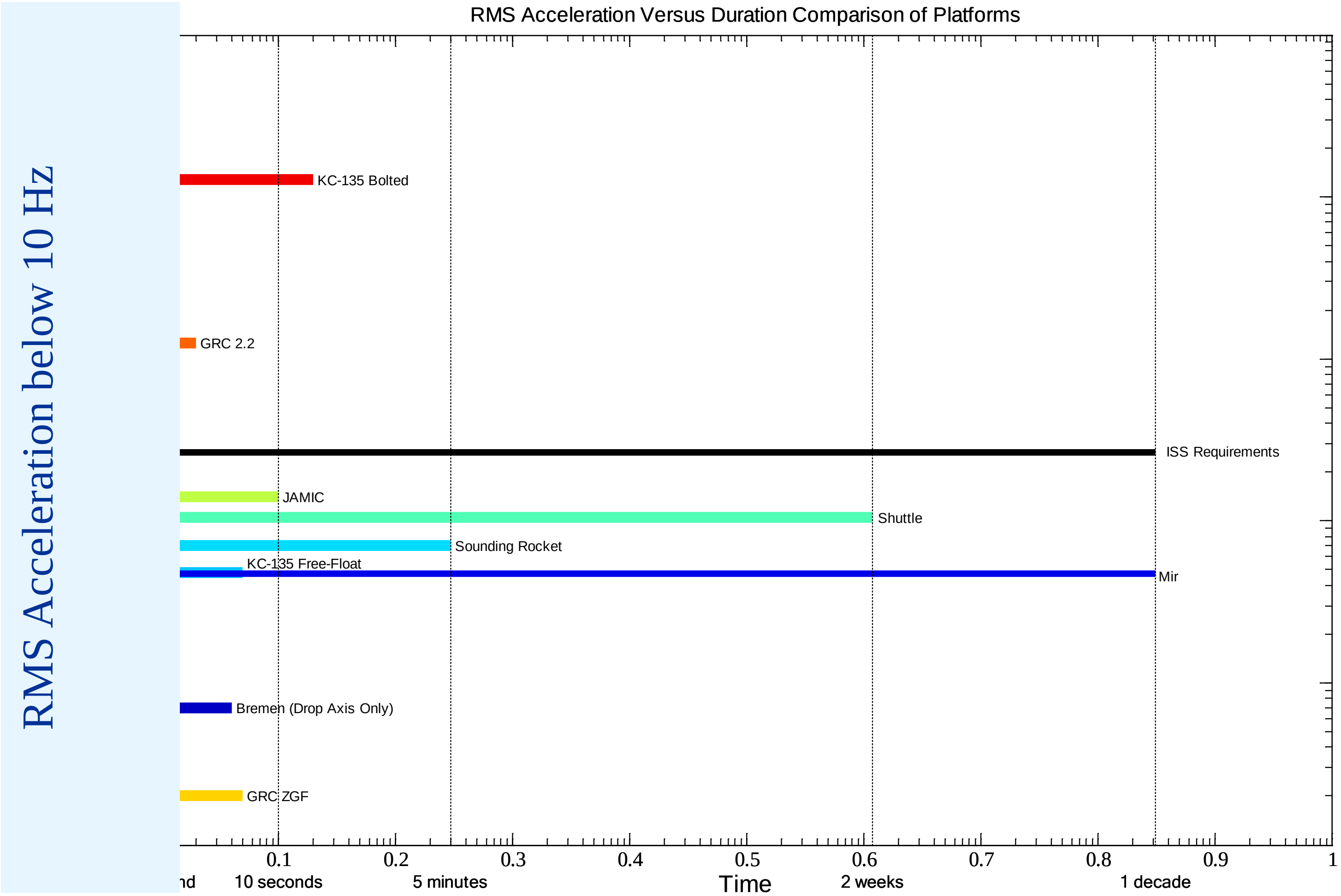

Proposed Plan

- Initiate one-year engineering design study funded through GRC facilities contract
- Participants:
  - HEOMD:SLPS (Space Life & Physical Sciences)
  - HEOMD:AES (Advanced Exploration Systems)
  - ARMD: Aircraft Icing
- Study Milestones
  - Phase 1 Kickoff ~August 1, 2015 (20 weeks)
  - Phase 1 Final Report NET Dec 21 2015
  - Down select
  - Initiate Phase 2 study February 1 2016
  - Design out-brief July 2016, go-no go decision
- Further develop business case in FY15
- Pursue complete design FY17
- Construction FY18/19
- First drops (and droplets) FY20

Conclusion

- Are there any other details for g-level quality required or facility capability or test duration that we should include in the requirements?