National Aeronautics and Space Administration

Drop Tower and Aircraft Capabilities

31st American Society for Gravitational and Space Research

November 12, 2015

Alexandria, VA, USA

Background

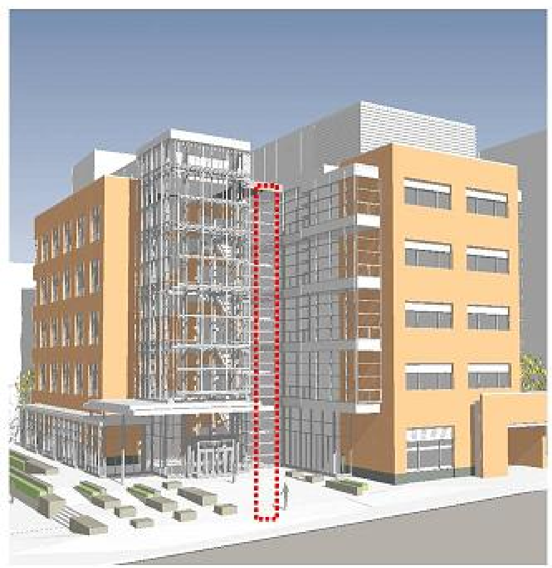
- **Current Drop Tower capability is little changed in decades despite major technology growth**
  - exceptions
    - Bremen ---- launch capability
    - Portland State University – rapid turnaround
- **Planetary exploration plans raise new research needs in partial gravity that cannot be satisfied on aircraft alone**
- **Partial gravity research largely ignored despite substantial technical importance**

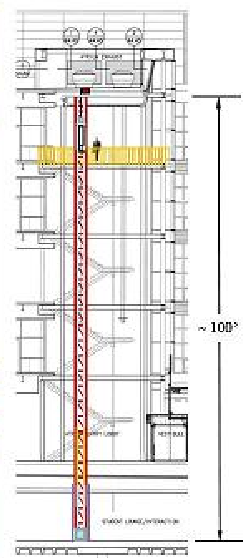
Operational Drop towers (t > 1 s)—partial list

- NASA zero-g: 5.2 seconds, 10^{-5} g, 7 drops / week
- NASA 2-second: 2.2 seconds, 10^{-3} g, 15 drops / day
- Queensland University (Australia) 2. seconds, 10^{-4} g, 15 drops / day
- Portland State Univ.: 2.1 seconds, 10^{-3} g, 20+ drops / day
- Fallturm Bremen (Germany): 4.7 seconds, 10^{-5} g, 9 seconds with catapult
- Purdue University: 2 seconds
- Hokkaido University (Japan): 3 seconds, 10^{-3} g
- Others?

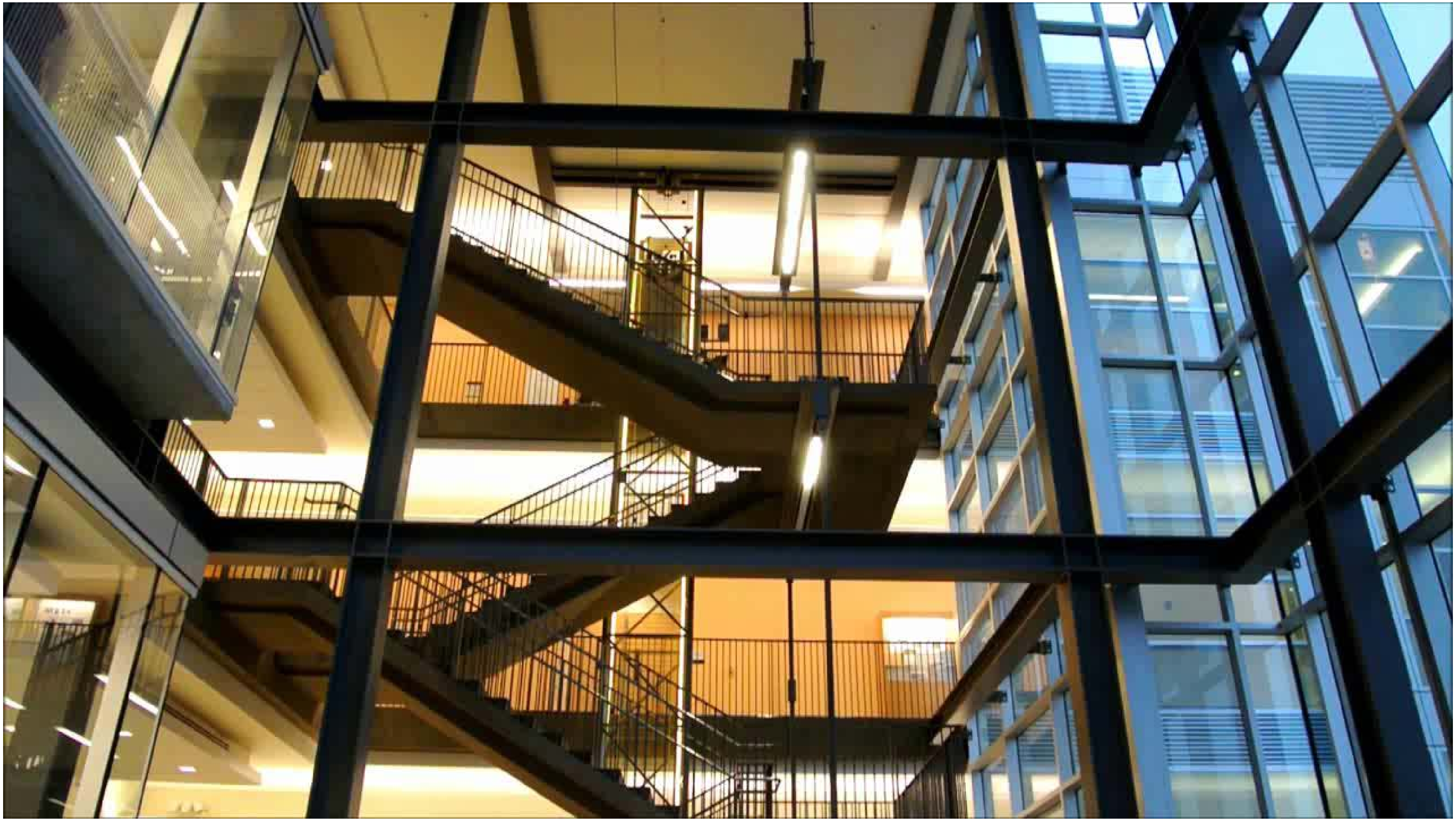
PSU Dryden Drop Tower

- **Tower height: 31.1m (102ft)**
- **Free fall distance: 22.2m (73ft)**
- **Low-g time: 2.13 sec.**
- **g-level: $< 10^{-3} g_o$**
- **Deceleration distance: ~ 3.5m**
- **Drag Shield mass: 115kg**
- **Experiment mass: < 50kg**
- **Peak deceleration: $15 g_o$**
- **Average deceleration: $8.5 g_o$**
- **Automated Retrieval: 5 min.**



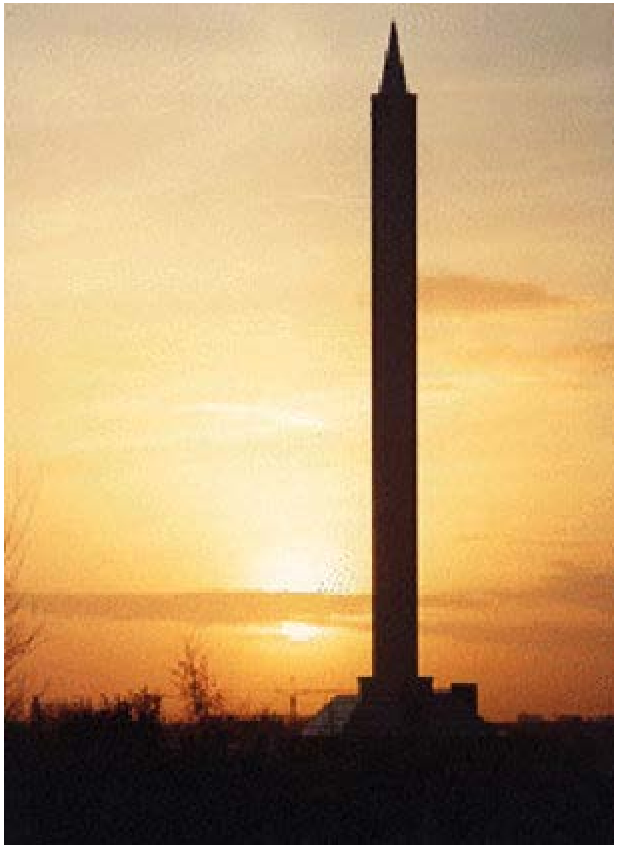


PSU Dryden Drop Tower



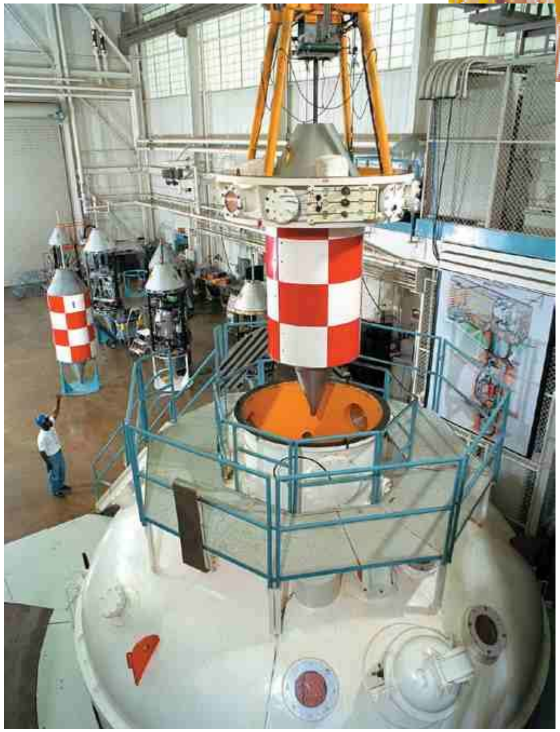
Bremen

- Free fall distance: 110 m
- Low-g time: 4.5 sec.
- g-level: < 10^{-6} g_o
- Deceleration distance: ~ 3.5m
- Deceleration: 50 g_o



NASA Zero-g facility

- **Microgravity Duration: 5.18 seconds**
- **Free Fall Distance: 432 feet (132 m)**
- **Gravitational Acceleration: <0.00001 g**
- **Peak Deceleration: 65 g**
- **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)**

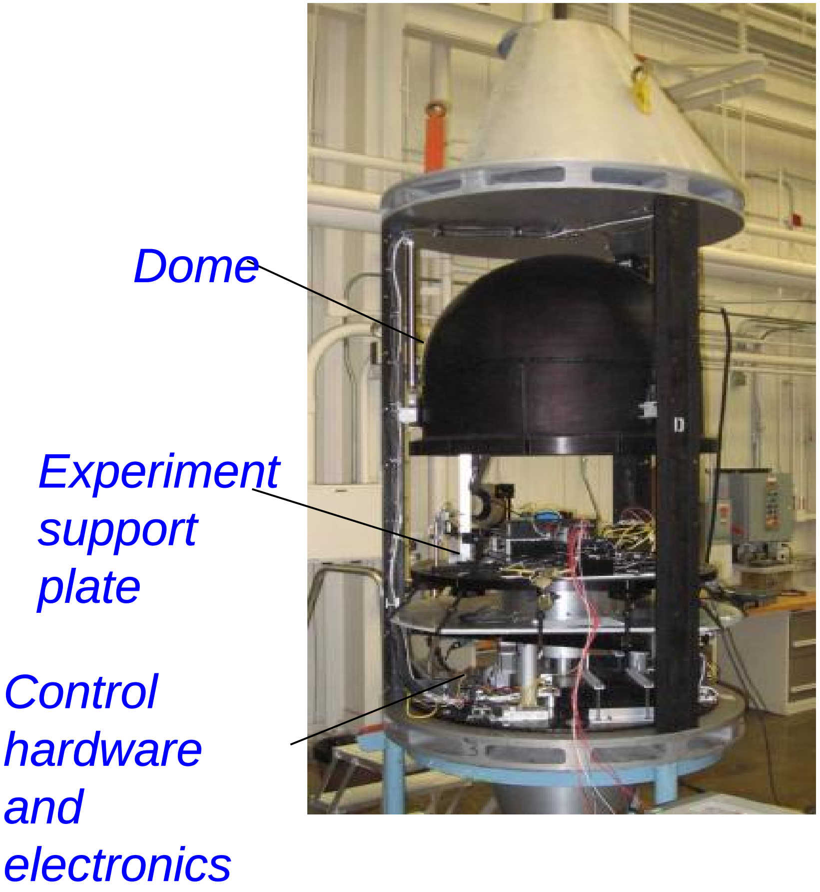


Hokkaido Drop Tower

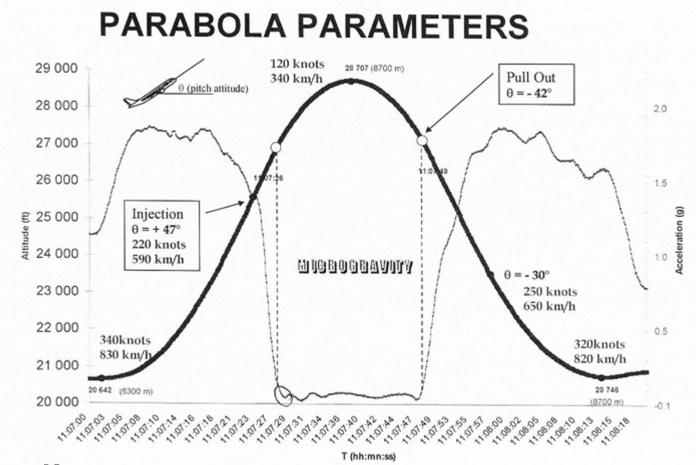
- micro-g time: 3 s
- Drop Height: 50 m
- micro-g quality: 10^{-3} G
- Payload Size: 0.5 m Diam x 0.8 m
- Total Weight: 400kg

Partial Gravity: Centrifuge in NASA Zero-g facility

Recent work using a centrifuge in the drop tower demonstrated real promise for exploring partial gravity conditions.



Zero-g aircraft

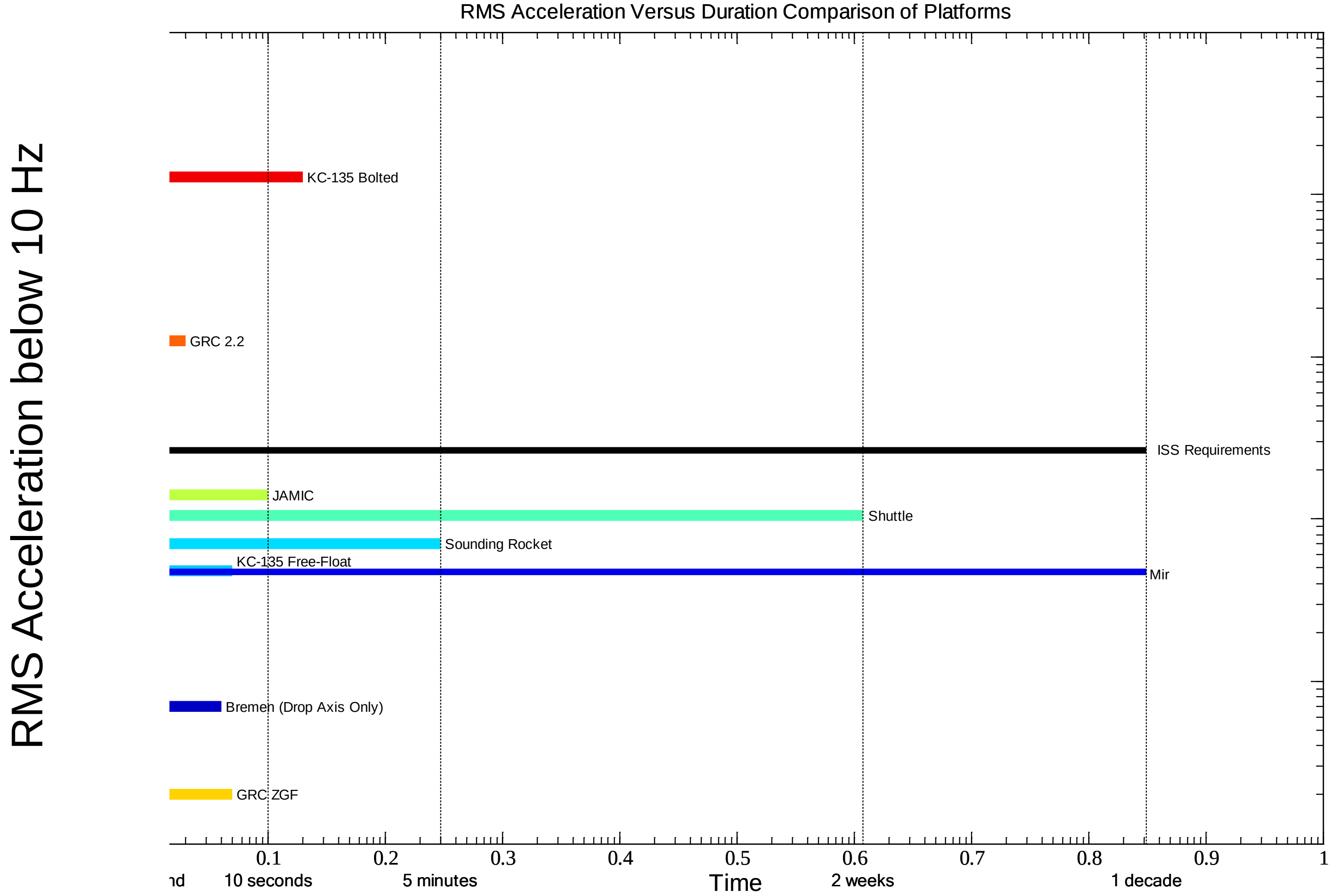


- Partial-g flights on aircraft have been flown repeatedly
- G-jitter typically ~ 0.1 to 0.02 g has less impact on partial-g tests than zero-g tests but is still substantial
- Reproducibility of g-levels difficult
- Cost is on the high side
- Schedule opportunities and number of tests are limited

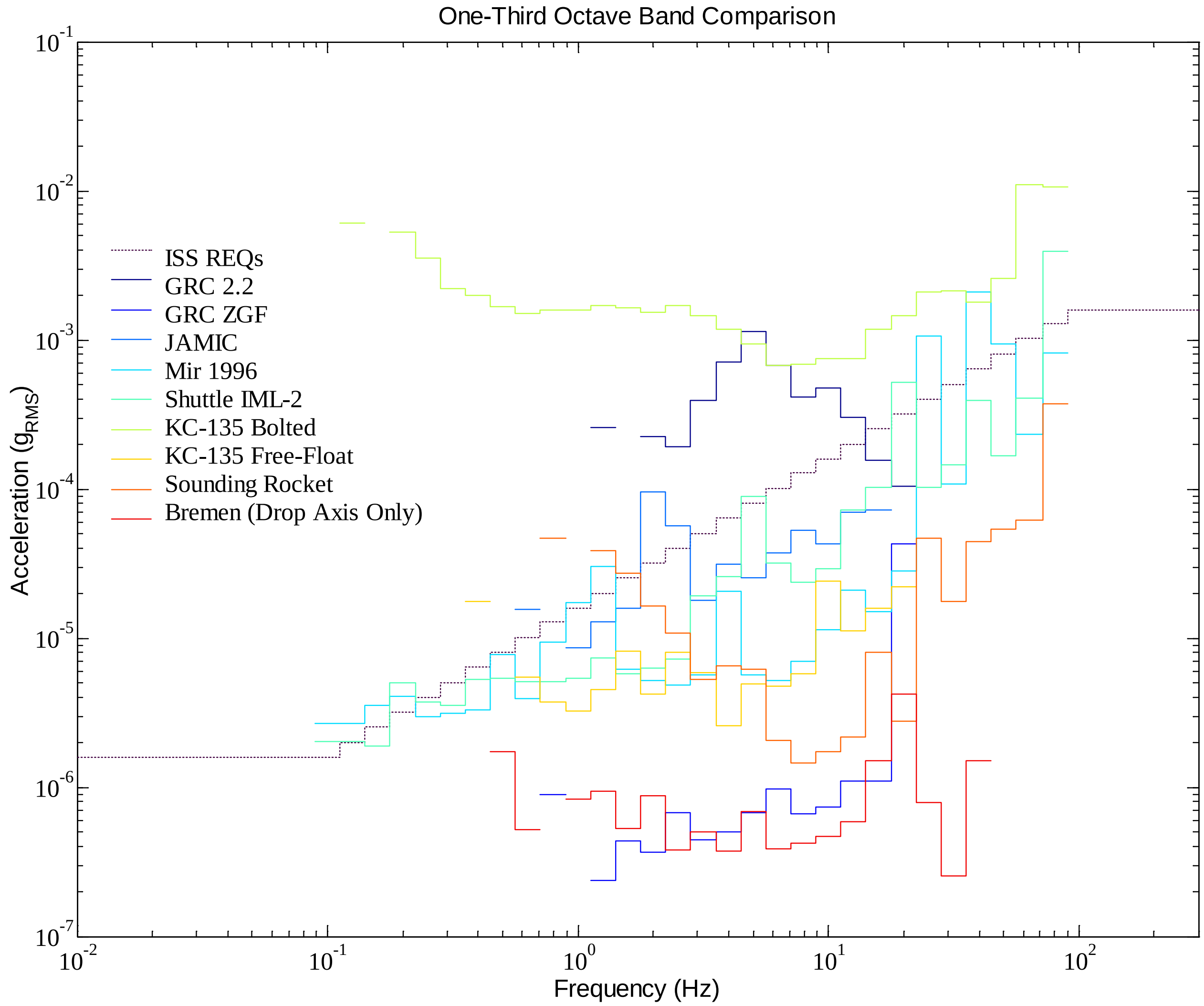
Incomplete list of providers:

- Integrated Spaceflight Services, (Swiss Space Systems) Airbus 340
- Zero-G B-727
- Novespace A-300 (serves ESA, DLR, CNES, JAXA)
- NASA aircraft DC-9 (uncertain future)

g-level comparison



g-level comparison



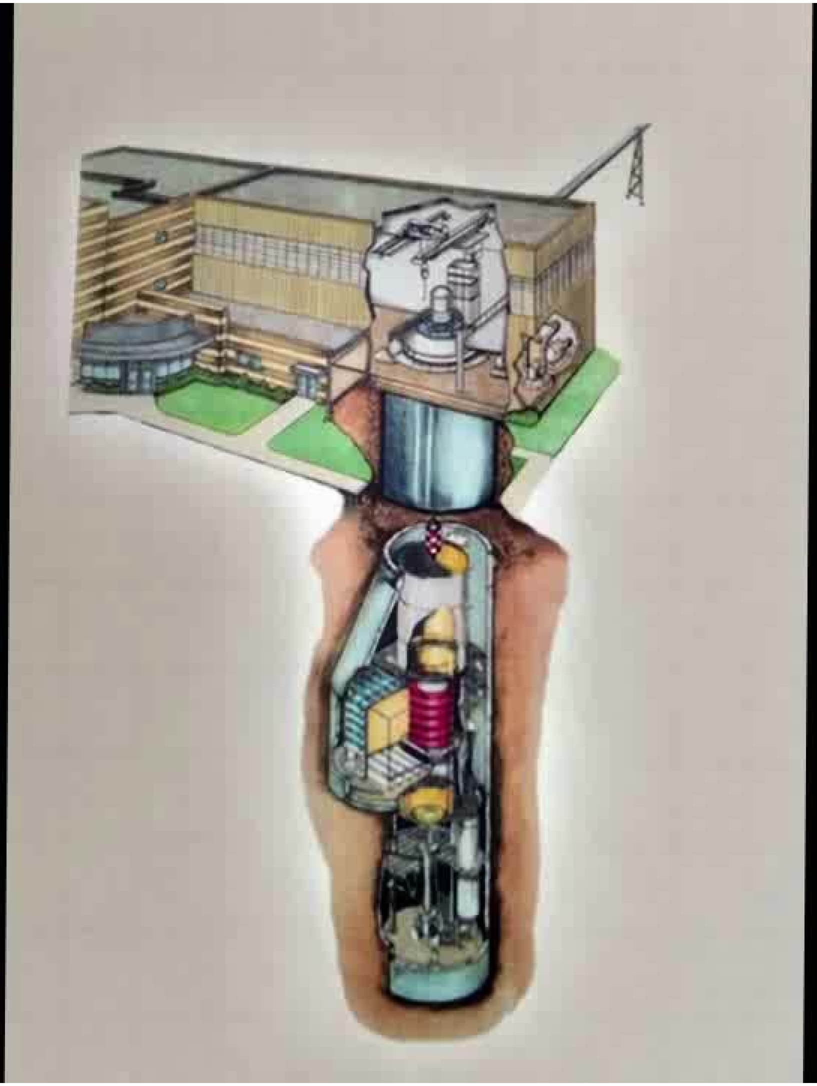
Future capabilities

NASA GRC Maglev Concept

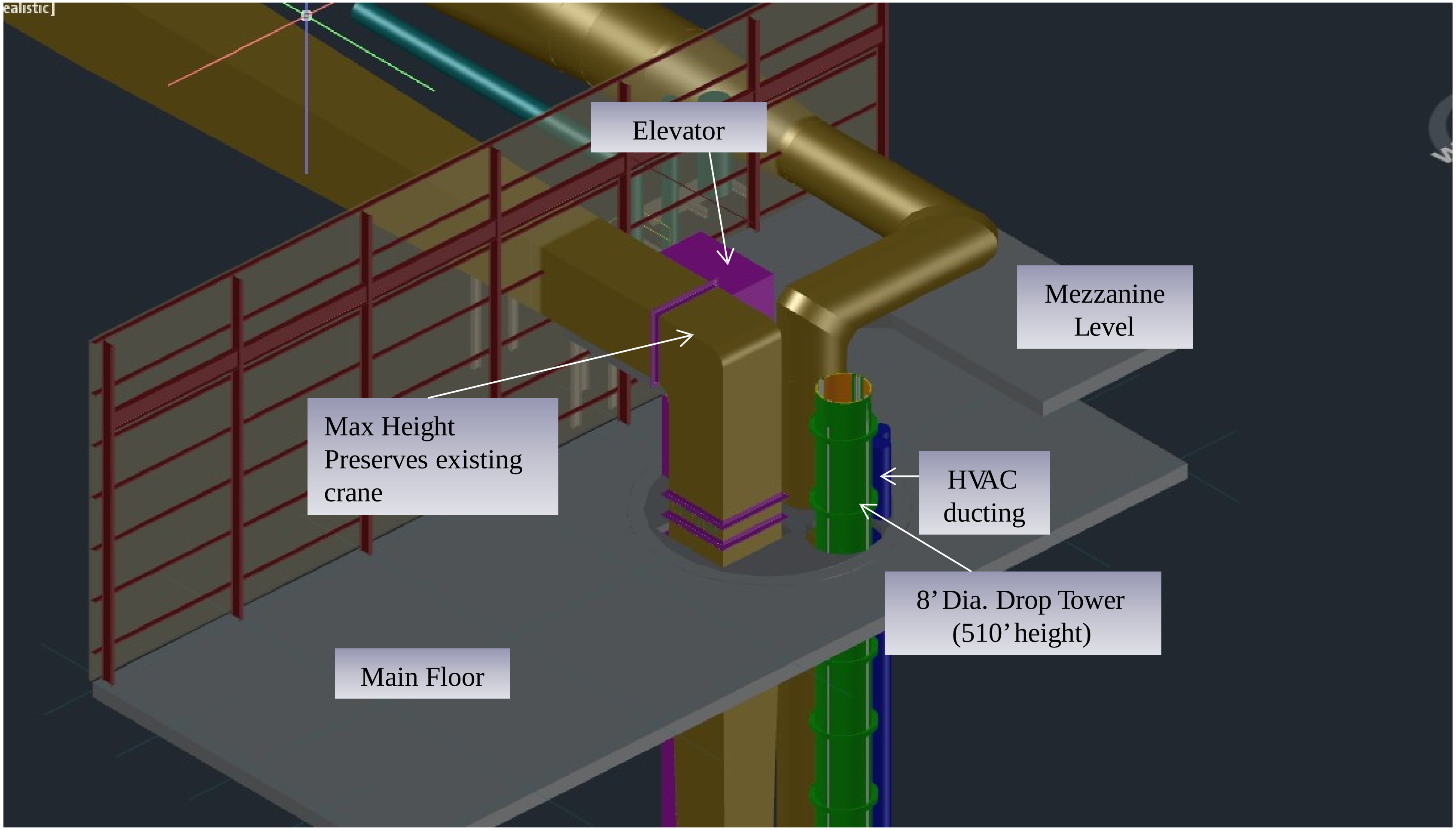
- Weight of entire payload 2,000 to 2,500kg including LIM (or LSM)
  - Configuration – Concept is based on a vertical LIM
  - Power requirements
    - Tradeoffs 4g vs 15g acceleration levels

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

Animation

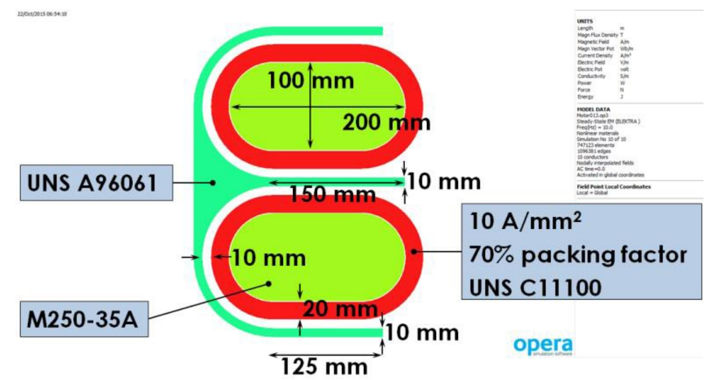


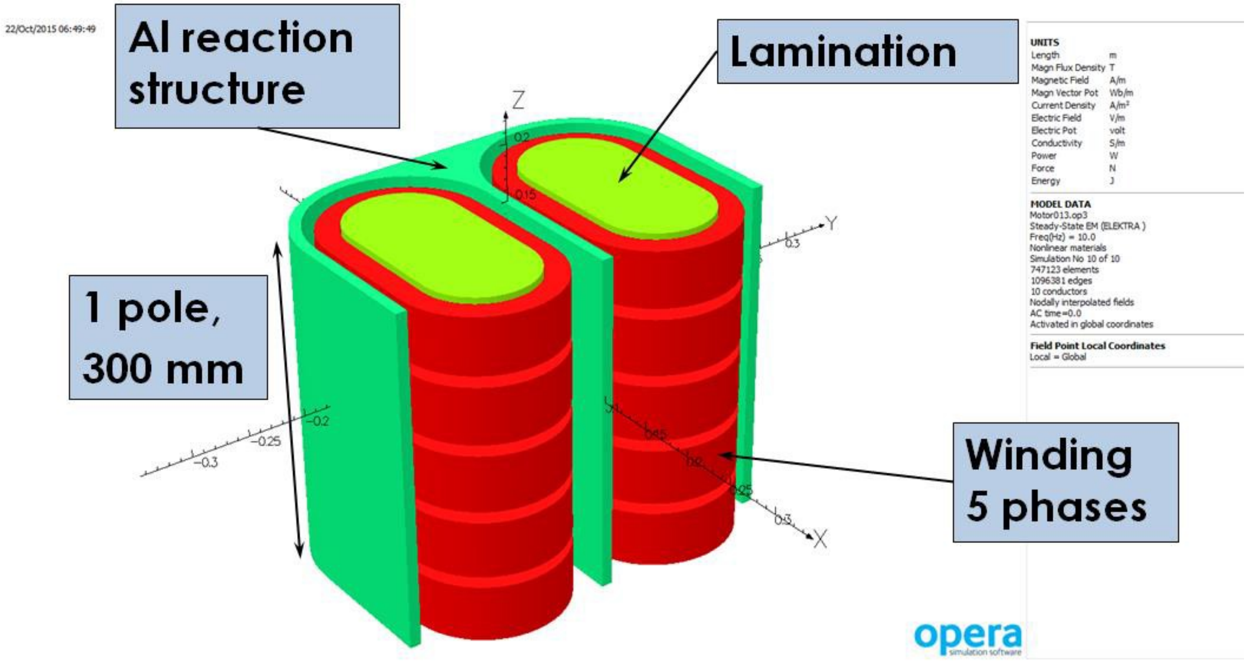
Airline Concept



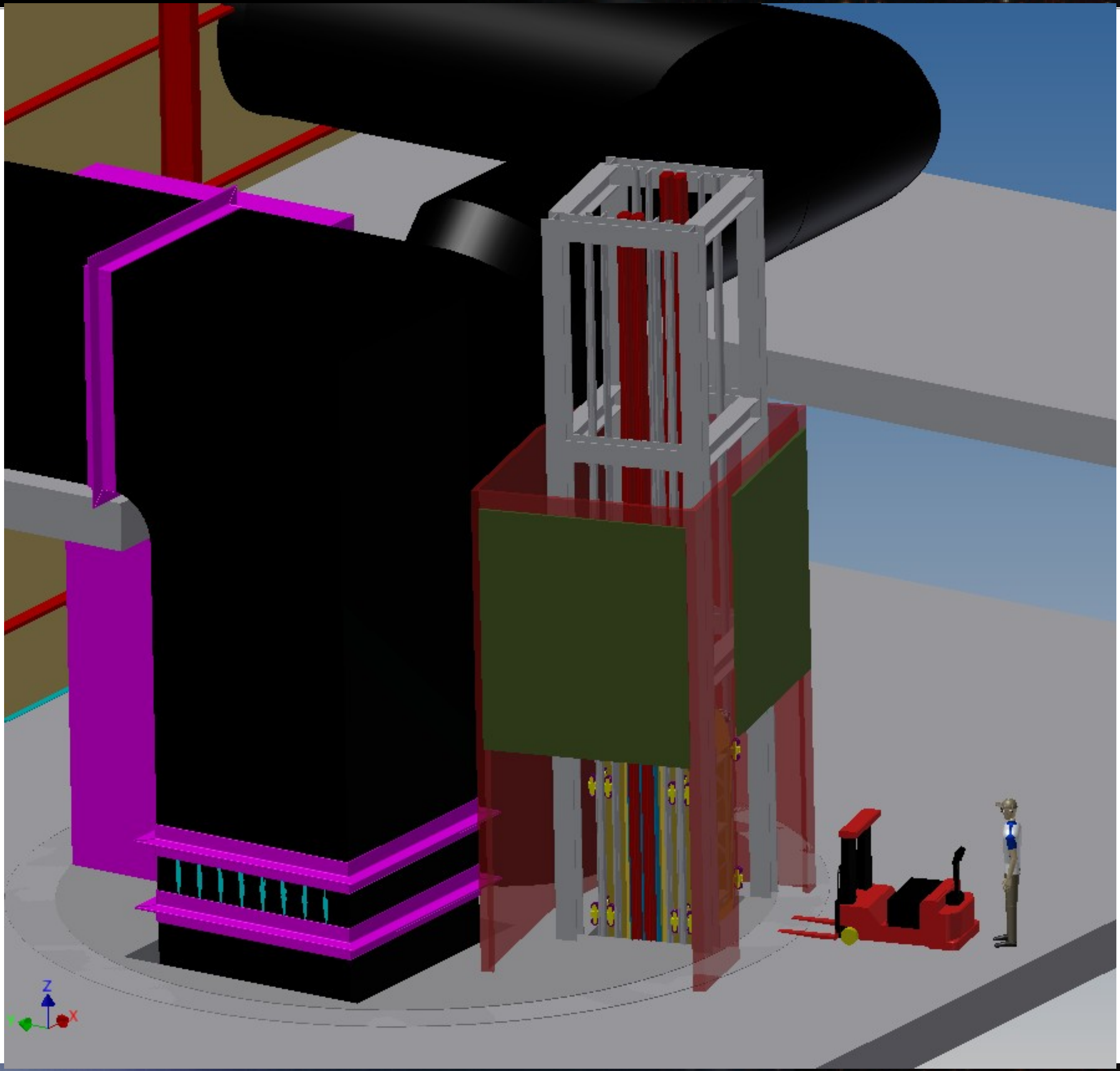
Maglev Concept

- 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





Maglev Concept



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Conclusions

- **Recent improvements in drop tower systems/technology raise the potential for enhanced capability:**
  - Increased duration
  - Increased throughput
  - Reduced cost
  - Partial Gravity
  - Variable Gravity
- **Comparable capabilities at extended durations but noiser g-levels exist on aircraft**
- **Both platforms are adaptable to user needs.**
- **Input is sought for NASA drop tower modification concept.**