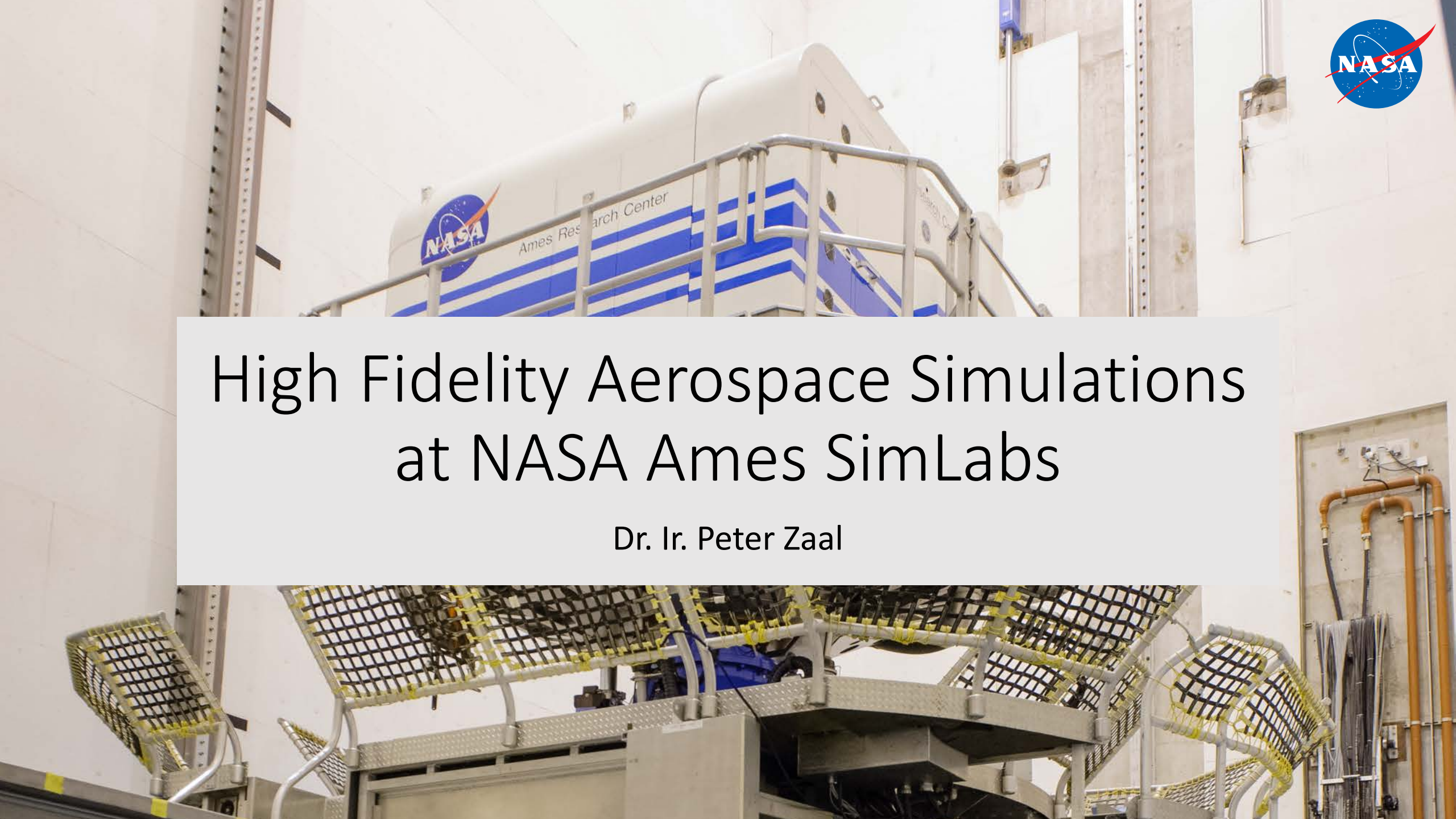


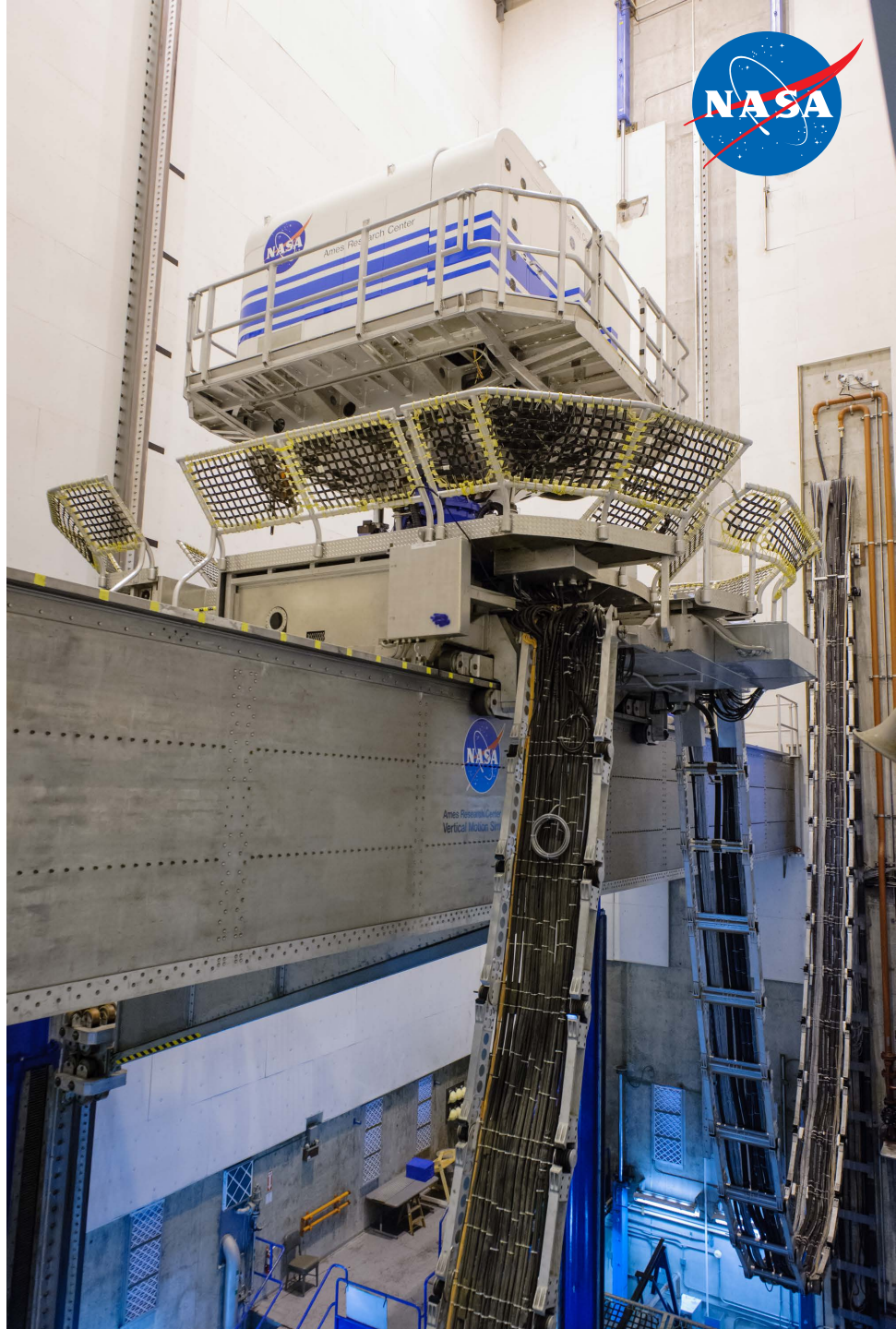
High Fidelity Aerospace Simulations at NASA Ames SimLabs

Dr. Ir. Peter Zaal

Outline

- SimLabs Facilities
- Vertical Motion Simulator
- Research and Training Overview
- Future Visual System and AR/VR

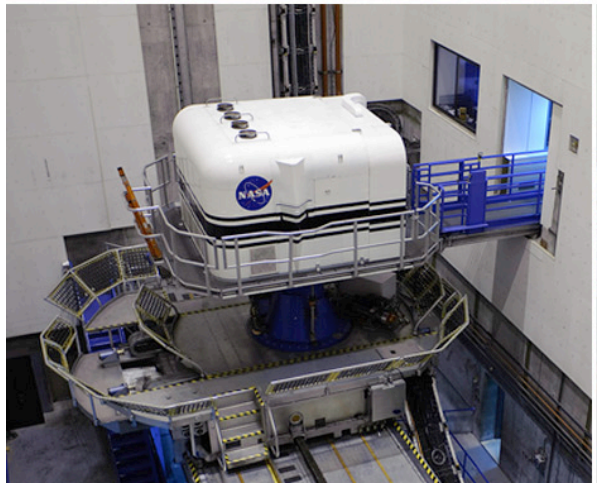
www.nasa.gov/simlabs



SimLabs Facilities

Unique high-fidelity simulation facilities capable of a wide range of aerospace systems research

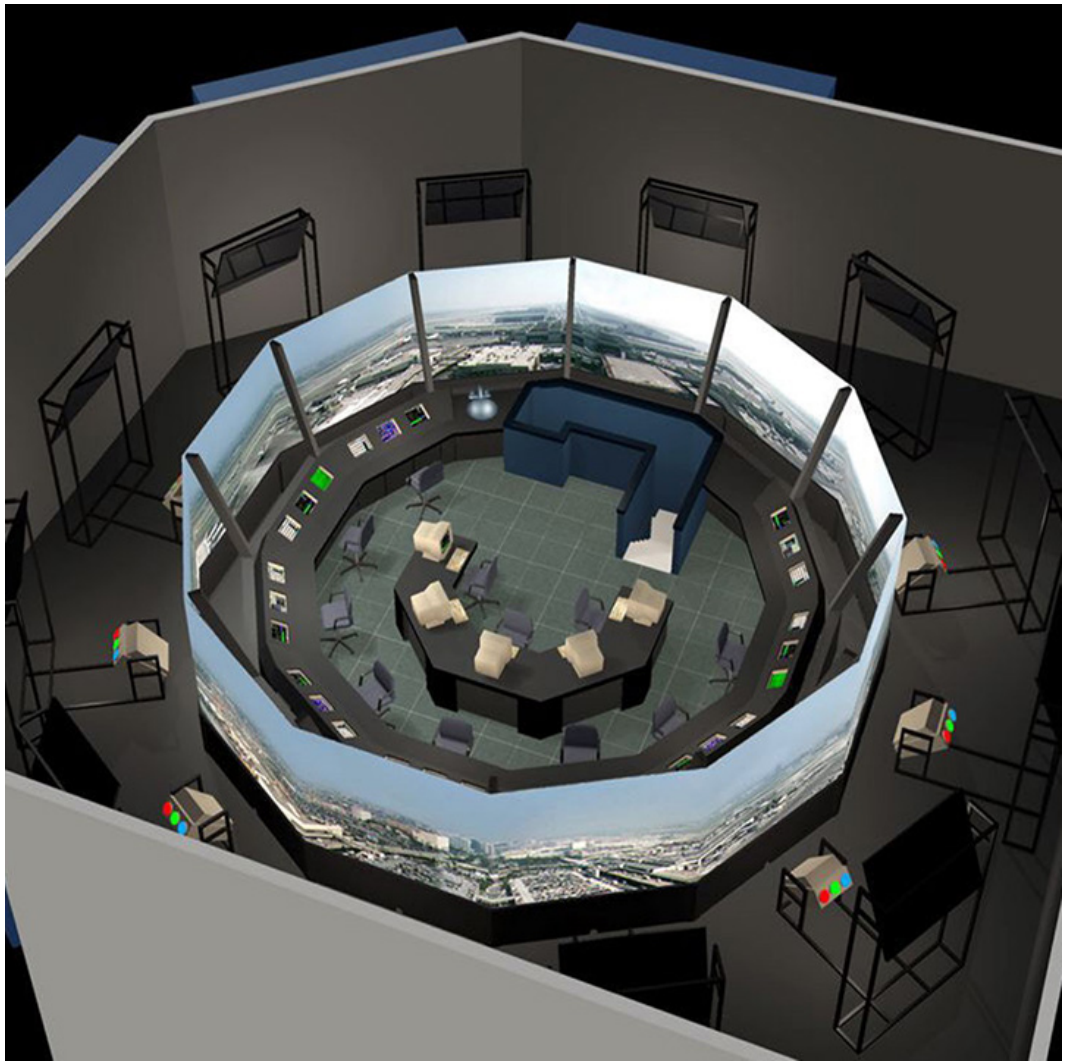
Vertical Motion Simulator



Future Flight Central

Crew-Vehicle Systems Research Facility

Future Flight Central



Crew-Vehicle Systems Research Facility

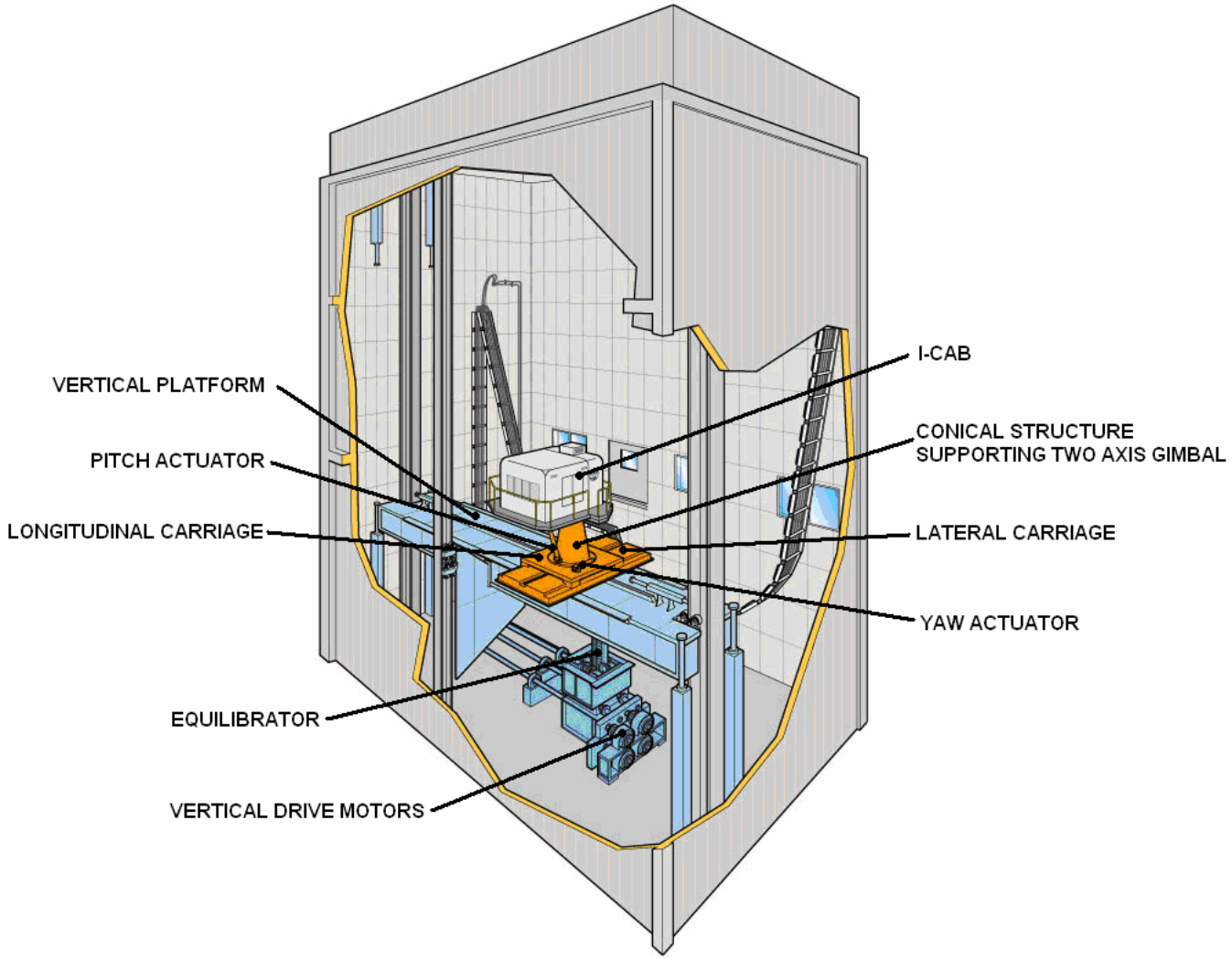
Vertical Motion Simulator

VMS was commissioned in 1979

- Originally designed to support Vertical Take-Off and Landing (VTOL) and Short Take-Off and Landing (STOL) research
- First simulation study was in 1980, investigating the Space Shuttle Pilot-Induced Oscillation (PIO) issue

325+ simulation studies conducted, primarily for research in:

- Handling Qualities of Aircraft and Spacecraft
- Flight Controls and Displays
- Simulation Fidelity

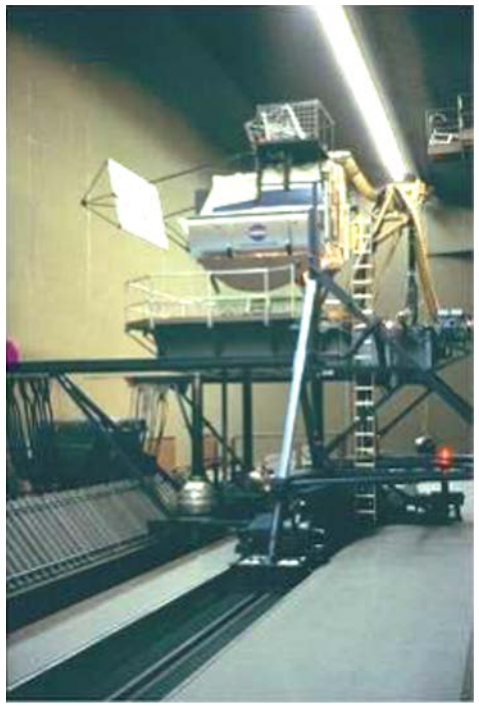


Designing the VMS for Realistic Motion Cueing

Height Control Test Apparatus (HiConTA)

Vertical displacement required for realistic sink-rate cues

Flight Simulator for Advanced Aircraft (FSAA)



Lateral/longitudinal displacement required for realistic horizontal translational cues

Six DoF Motion Simulator

Equilibrator design and engineering

VMS Motion Characteristics

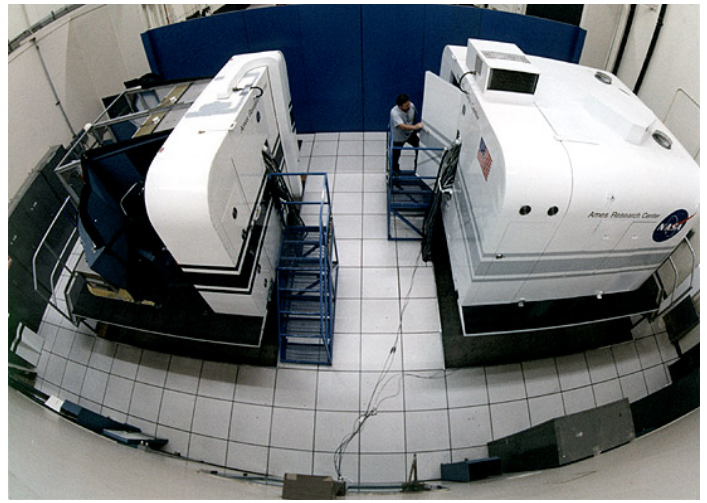
Largest motion travel of any ground-based flight simulator

- Six independent degrees-of-freedom
- Combination of electric and hydraulic drives
- 60 ft vertical travel, 40 ft lateral travel

VMS Nominal Motion Limits			
Axis	**Displacement (ft)**	**Velocity (ft/s)**	**Acceleration (ft/s^2)**
Vertical	**± 30**	**16**	**24 (0.75 g)**
Lateral	**± 20**	**8**	**16 (0.5 g)**
Longitudinal	**± 4**	**4**	**10 (0.3 g)**
	(deg)	**(deg/s)**	**(deg/s^2)**
Roll	**± 18**	**40**	**115**
Pitch	**± 18**	**40**	**115**
Yaw	**± 24**	**46**	**115**

VMS Features

- Interchangeable cabs
  - Five cabs with varying visual fields-of-view and cockpit layouts
  - Two fixed-base labs for simulation development
  - Programmable multi-function displays
  - Programmable force-feel systems with a variety of inceptors
- High-fidelity visual systems
  - Wide-angle collimated display optics for improved depth perception
  - Customizable visual databases
- Flexible simulation architecture
  - Tailored to research applications
  - Accepts user software and hardware modules
  - Conduct multiple simulations concurrently
  - Can be used in larger distributed simulations



Use of Head-Mounted Displays (HMDs) and Head-Up Displays (HUDs) in the VMS

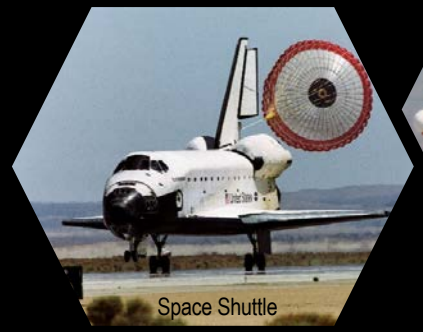
Use of head-mounted displays and head-up displays in the VMS has been based on vehicle and handling quality requirements:

- Integrated Helmet and Display Sighting System for the Apache Helicopter
- HUD for the Space Shuttle and civil tilt-rotor

HMDs were never considered for the OTW visuals due to the much higher fidelity of projection-based systems and physical cockpits

Vertical Motion Simulator - 40 Years of Innovation


UH-60


Space Shuttle


NT-33


USAir 427


Crew Exp. Vehicle


Lunar Surf. Acc. Module


X-Wing/RSRA


National Driving Sim


Piasecki VTCAD


RASCAL

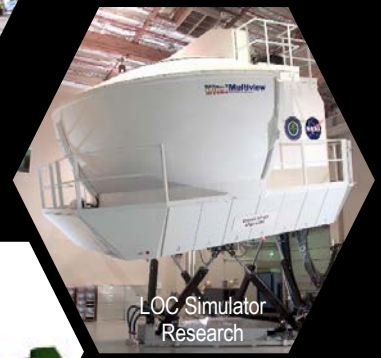

JMR Demonstrator

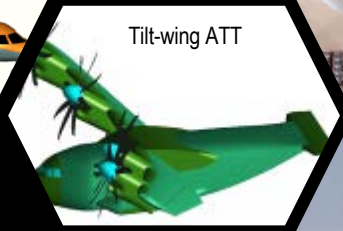

AH-64


YAV-8B/VSRA


C-17


VDTR


LOC Simulator Research


Tilt-wing ATT


XV-15


RAH-66


ASTOVL Concept


High Speed Civil Transport


CH-47


X-35B


X-32B


LCTR

Airship

1980

1990

2000

2010

2020

Vertical Motion Simulator in Action

https://www.nasa.gov/lunar-simulation

Space Shuttle Program

- VMS has supported the Shuttle program with research and training for its entire 30-year operational lifetime

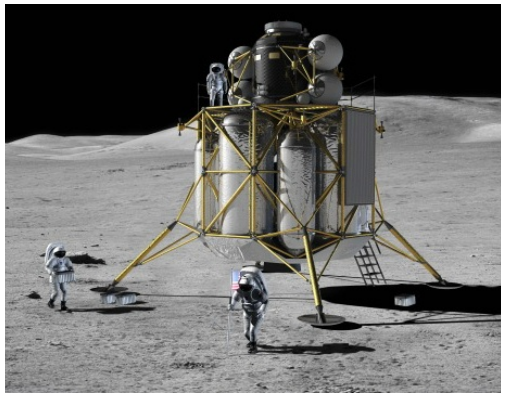
- All Shuttle pilot astronauts have trained on the VMS
  - Typical approach, landing, and rollout simulations (KSC, Dryden, White Sands)
  - Abort-on-Ascent simulations (21 landing sites)
  - Simulation of expanded off-nominal conditions (e.g., tire/brake failure, HUD misalignment)
  - Over 10,000 training runs performed

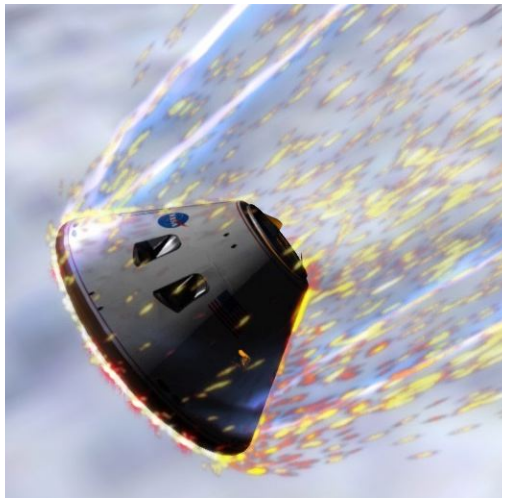
- VMS has been used as a platform for numerous Shuttle engineering studies
  - Quickly test new concepts at a high level and determine if they merit further investigation
  - 85 Shuttle engineering studies performed that led to 20+ flight rule changes

Lunar Landing Simulations

- Multiple studies were conducted in 2007-2010 with Apollo Lunar Module and Space Shuttle pilots
  - Precision Lunar Landing
  - Proximity Operations and Docking
  - Atmospheric Entry

- Possible VMS Uses in the Human Landing System (HLS) Program
  - Handling qualities studies to support vehicle configuration development and evaluation
  - Engineering studies for modifications after HLS enters service
  - Crew training





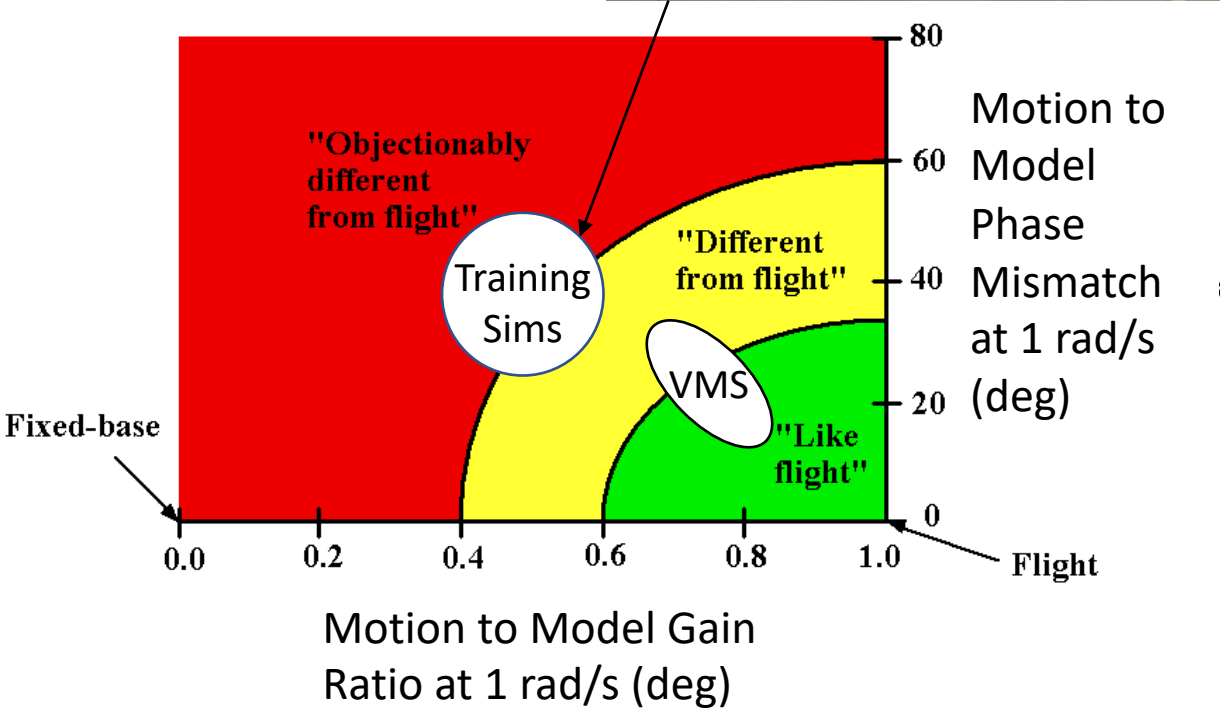
Rotorcraft and Advanced Air Mobility (AAM) Research

- The VMS was critical to:
  - Developing a valid rotorcraft handling qualities database
  - Development and continued improvement of the Rotorcraft Handling Qualities Specification (ADS-33)
- Future AAM research will focus on:
  - Vehicle handling qualities
  - Vehicle ride qualities
- Future Flight Central and ATM simulation support:
  - Vertiport operations
  - AAM integration into the National Airspace System

Simulation Fidelity and Cueing

The VMS has been instrumental in setting simulator fidelity and motion standards for pilot training

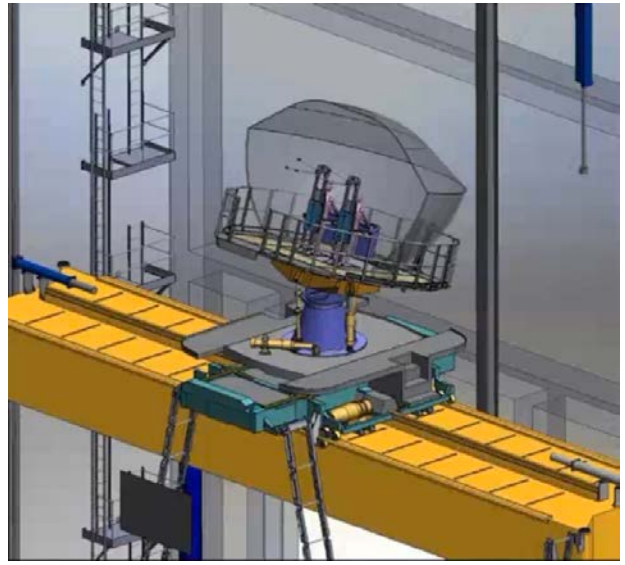
- Development and validation of Sinacori fidelity criteria
- Development of Objective Motion Cueing Test Criteria for the FAA
- Simulator motion algorithm development for stall recovery training

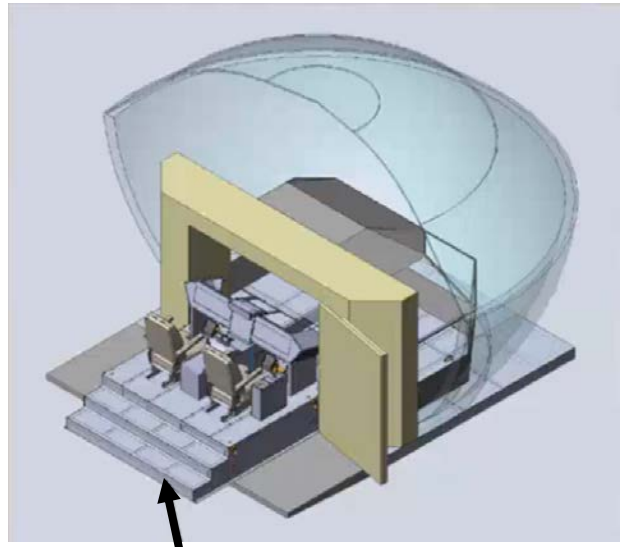


VMS Visual System Upgrade

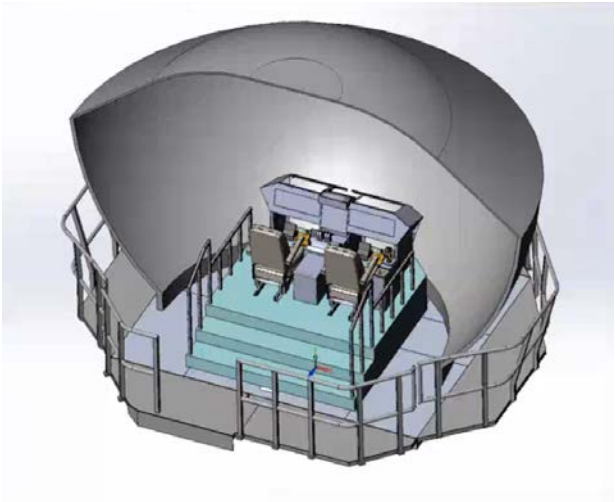
Replacement of the existing Wide-Angle-Collimated (WAC) display system with a wide projection display system

- 10-foot spherical dome (200x50 deg)
- Large aperture glass collimating mirror
- Three projectors
- Interchangeable flight deck
- One dome fixed to the motion base
- Two domes for fixed-base simulations





interchangeable flight deck



Using AR/VR Headsets for Training

- NASA has been using VR to train astronauts for decades
  - Mostly stationary tasks or tasks with little visual motion

- Both inside and outside of NASA, there is a potential need for VR training of vehicle manual control skills
  - Current technical specs are a limiting factor (mainly resolution and FOV)
  - Cybersickness/motion sickness is an issue
  - VR needs to be benchmarked against reality and other means of training

VR Training in the International Space Station

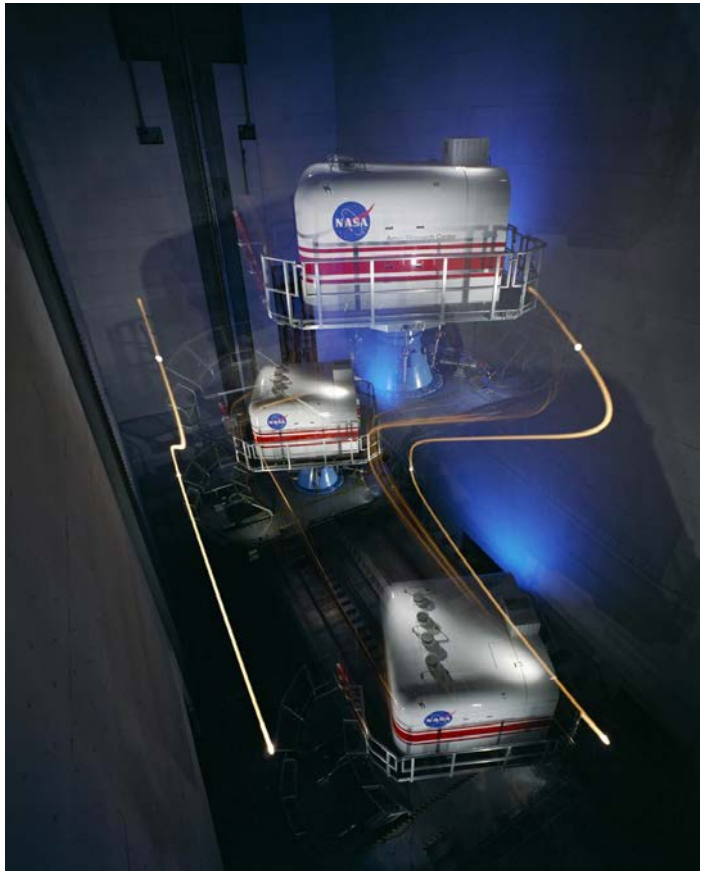
Possible Future Use of HMDs in the VMS

- Applications:
  - VR as a tool for experiment design
  - VR to simulate large OTW views (e.g. in advanced air mobility vehicles)
  - AR/VR for rapidly reconfigurable cockpits

- Research:
  - Cybersickness
    (Terenzi and Zaal, 2020, AIAA-2020-0171)
  - Benchmarking VR for training
    (Terenzi and Zaal, 2020, AIAA-2020-0170)

Summary

- The VMS is an excellent platform for aerospace vehicle research and training
  - Realistic human cueing environment approximates flight
  - Cost-effective and safe compared with flight test
- VMS has made significant contributions to:
  - Aircraft and spacecraft handling qualities
  - Setting simulation fidelity standards
  - Risk reduction for aircraft programs
  - Prototyping and evaluating pilot-vehicle interface concepts
- VMS has a bright future:
  - Significant hardware and software upgrades
  - Helping NASA and commercial partners getting back to the moon
  - Exploring technologies like AR and VR



Questions?

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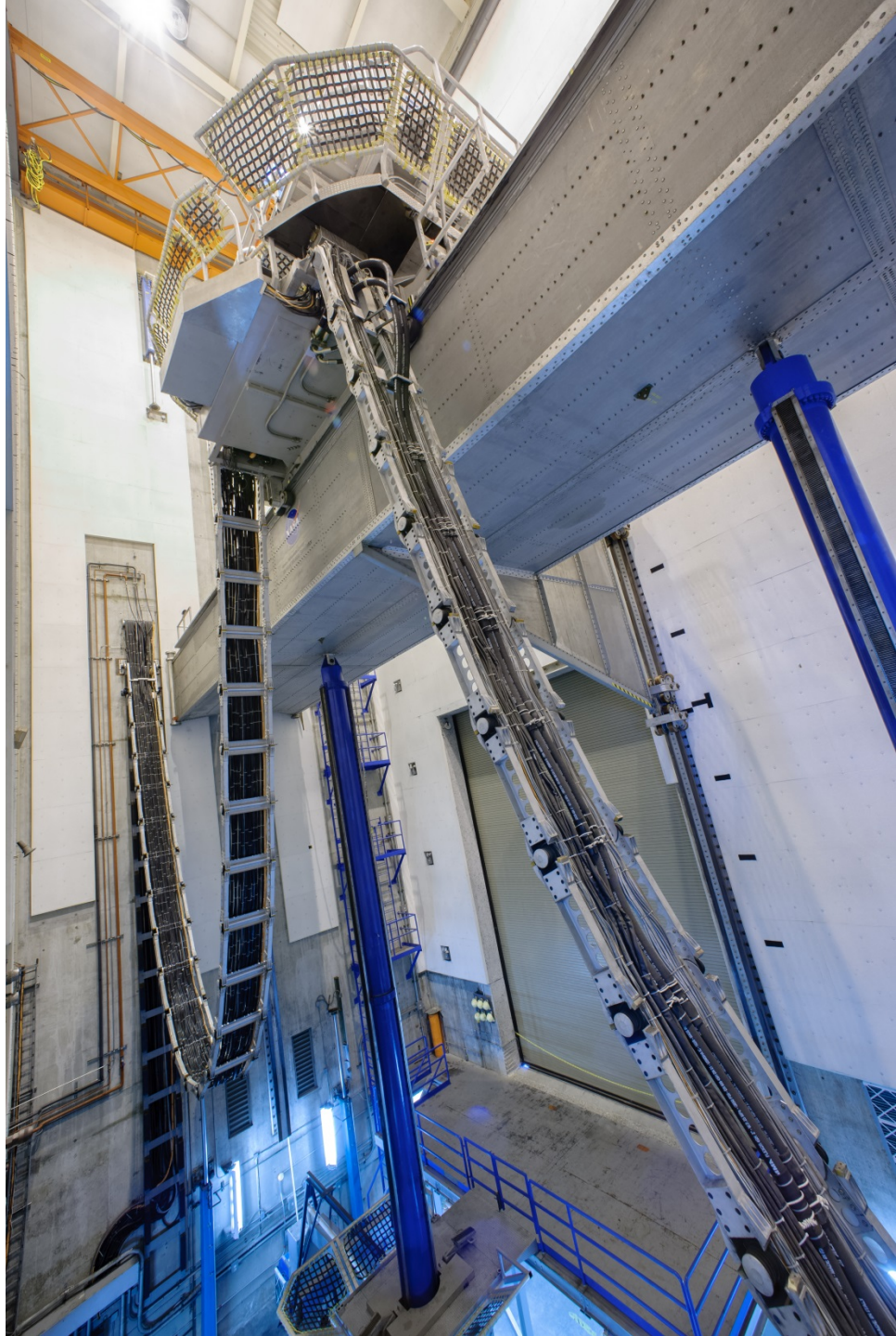

Bibliography

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