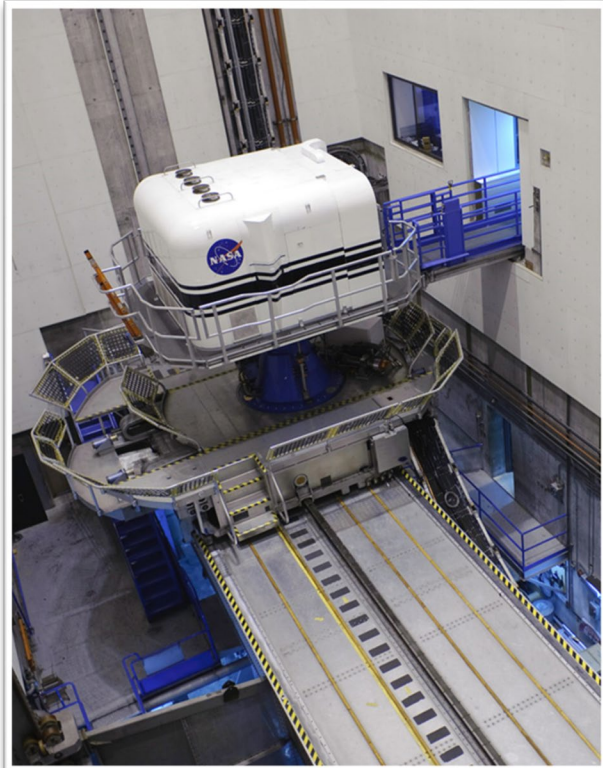




# Vertical Motion Simulator

## A Unique Facility for Piloted GNC Research

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**NASA Ames Research Center**

NESC GNC TDT Annual Meeting

22 July 2020

# VMS History

- VMS was commissioned in 1979
- Originally designed to support Vertical/Short Take-Off and Landing (V/STOL) research
- First simulation study was in 1980, investigating the Shuttle Pilot-Induced Oscillation (PIO) issue
- 325+ simulation studies have been conducted, primarily for research in:
  - Handling Qualities of Aircraft (fixed-wing and rotorcraft) and Spacecraft
  - Flight Controls and Displays
  - Simulation Fidelity



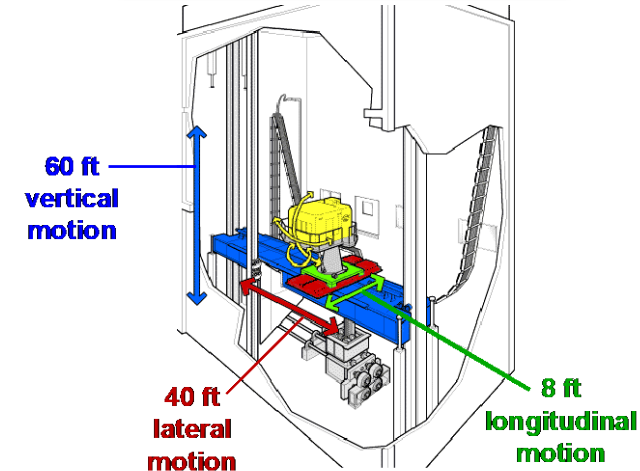
# VMS Motion Characteristics

Largest motion travel of any ground-based flight simulator

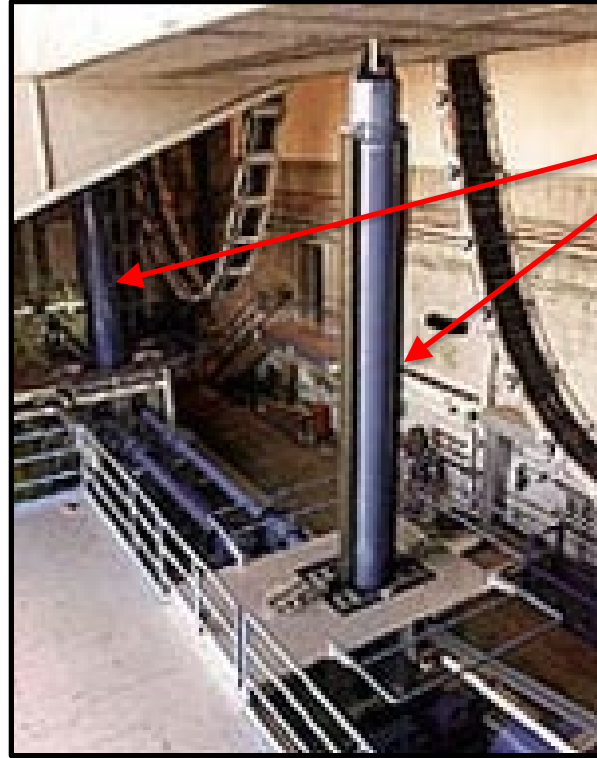
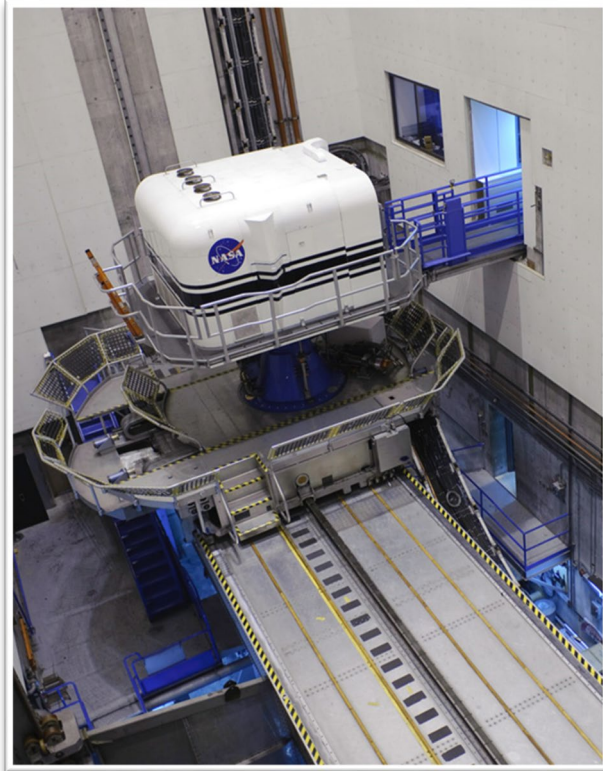
- Six independent degrees-of-freedom
- Rotational and translational motion drivers are independent of each other (unlike hexapod simulators)



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



# VMS Hardware



- Equilibrator system pressurizes two supporting columns with nitrogen gas, neutralizing the 70-ton load
- Columns move in 75 ft deep shafts
- Electric motors provide vertical acceleration up to  $\sim 0.75\text{ g}$

# 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
  - Can be used as an element in large distributed simulations



# VMS in Motion

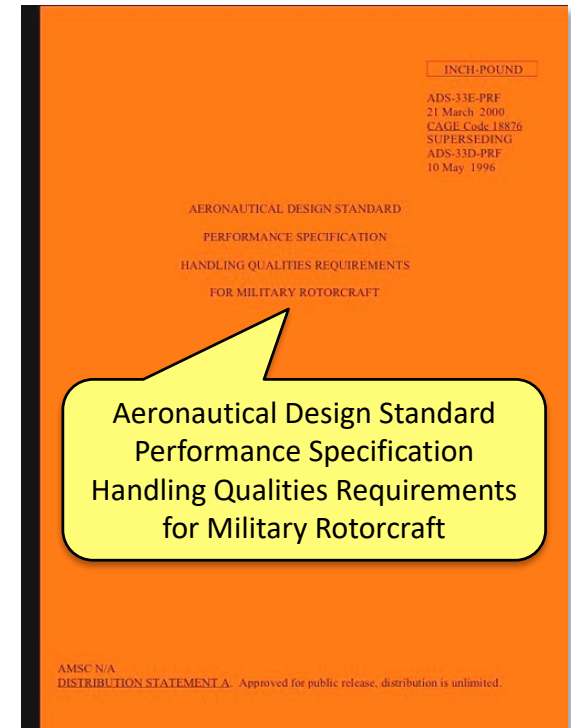


# Vertical Motion Simulator - 40 Years of Innovation



# Rotorcraft Research

- Army Aeronautical Design Standard (ADS-33)
  - Handling qualities requirements for military rotorcraft
  - First released in 1987; periodic updates
- The VMS played a critical role in:
  - Developing a valid handling qualities database
  - Development and continued improvement of the ADS-33 design standard
- ADS-33 is now a widely accepted standard for piloted GNC aspects of rotorcraft design
  - Used by the Army and Navy for procurement



# Shuttle Landing Simulations

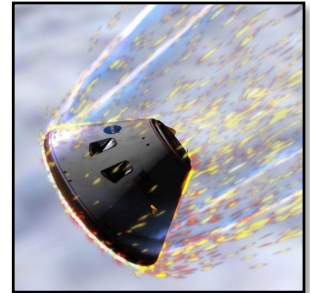
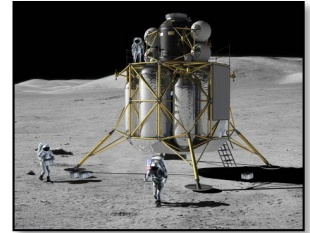
- VMS has supported the Shuttle program for its entire 30-year operational lifetime
  - Crew training for all STS missions
  - Typical approach, landing, rollout simulations (KSC, Edwards, White Sands)
  - Abort-on-Ascent simulations (21 landing sites)
  - Simulation of expanded off-nominal conditions (e.g., tire/brake failure, HUD misalignment)
  - Over 65,000 training/engineering 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



# Constellation Vehicle Studies

- Six studies of spacecraft handling qualities conducted, 2007–10
- Flying tasks studied
  - Precision Lunar Landing (Altair)
  - Proximity Operations and Docking (Orion)
  - Atmospheric Entry (Orion)
- Handling qualities evaluated by:
  - 4 Apollo Lunar Module pilots
  - 29 Space Shuttle pilots
  - 5 NASA / Army test pilots

Findings from these studies are now being used to guide handling qualities aspects of Artemis vehicle designs



# Potential VMS Use for Human Landing System

- Handling qualities studies to support HLS vehicle configuration development
- Support the development of an in-flight HLS simulator
- Platform for verification of HLS handling qualities requirements
- Crew training for flight operations in HLS missions
- Engineering studies for modifications/enhancements after HLS enters service



# Altair Lunar Lander Simulation in the VMS



Vice President Mike Pence and NASA Administrator Jim Bridenstine

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# Questions?

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# Bibliography

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