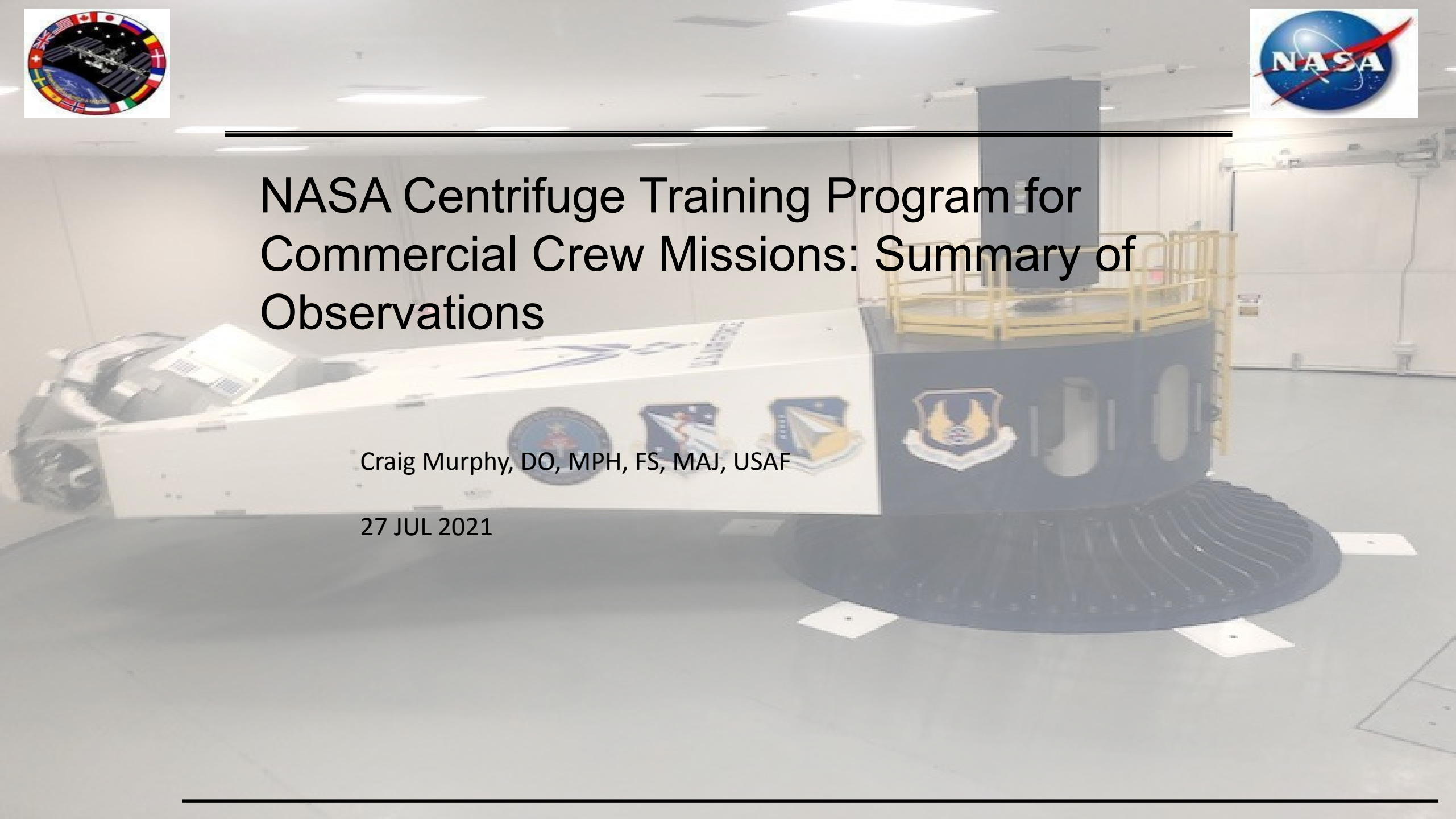

NASA Centrifuge Training Program for Commercial Crew Missions: Summary of Observations

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Introduction

- The development of new Commercial Crew space vehicles returns NASA to capsule configurations with ascent and entry accelerations comparable to those of Apollo, Gemini, and Soyuz spacecraft.

- The pivot away from the space shuttle configuration has necessitated new training updates to familiarize crewmembers, and most recently untrained commercial spaceflight participants (SFPs), with flight-like acceleration forces

- Testing profiles were developed at Johnson Space Center (JSC) and Kennedy Space Center (KSC) and carried out at Wright-Patterson Air Force Base (WPAFB)

Background

- Human spaceflight, particularly critical phases of flight including takeoffs, landings, and some special maneuvers, expose capsule occupants to levels of acceleration (g-forces) several times that experienced by most humans on a day-to-day basis

- The capsule configurations of current spacecraft, including the Soyuz and SpaceX Crew Dragon, expose occupants to primarily forces in the Gx, or chest-to-back, axis. Compared to Gz (head-to-toe) and Gy (side-to-side) humans tolerate Gx forces extremely well.

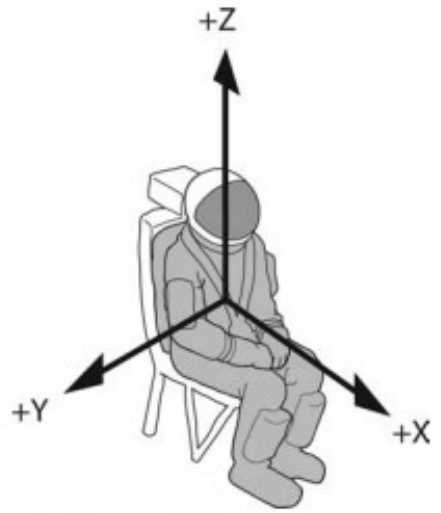

FIGURE 4-4 An axial diagram of the human coordinate system for linear motion. This convention is referred to as the *left-hand rule* because the placement of the axes mimic a left hand with the index finger pointed forward, the thumb pointed up, and the middle finger directed to the right (*Source:* John Martini, BRC).

Methods

- We developed a standardized centrifuge protocol with g-loads timed and sequenced to simulate the ascent, descent, and abort procedures, corresponding to peaks of roughly 3.5 and 4.5Gx, respectively

- Peak Gx periods were sustained for 120 seconds with 90-second rest periods between profiles.

- Touchscreen panels and flight similar hardware were mounted in appropriate positions to provide realistic manipulation challenges for participants as would be expected during an actual flight.

- Participants were evaluated and monitored by flight surgeons before, during, and after each spin to assess for adverse signs and symptoms. Results were collected using a standardized questionnaire and tabulated to identify any major risks or common findings

Results

- A total of 50 spins (n=50) were conducted. A handful of participants completed the protocols on multiple occasions over the course of the study, yielding a total of 40 unique participants.

Symptom	Frequency
Chest Pressure	28%
Breathing Effort	26%
Reaching Difficulty	26%
Felt Warm	22%
Throat Discomfort	20%
Dizziness	18%
Nausea	14%
Cough	10%
Chest Discomfort	8%
Paresthesia	8%
Pain	8%
Blurry Vision	6%

Results (post-spin)

Participant Reported

Symptom	Frequency
Dizziness	28%
Unsteady Gait	16%
Nausea	14%
Felt Warm	8%

Flight Surgeon Exam

Abnormal Finding	Frequency
Fall on Tandem Romberg	4%
Persistent Nystagmus	4%

Discussion

- Perhaps the most important takeaway from the data is the fact that there were no serious adverse effects, and those symptoms that did occur were quite transient.

- Humans, whether trained or untrained, can tolerate sustained Gx exposure well without much training and without any special maneuvers or provisions.

Discussion

- The most common reported symptom of **chest pressure** is unsurprising.
  - This is essentially part of the definition of Gx exposure, but for untrained SFPs it underscores the importance of good briefing materials, that address the top 3 observations, including **breathing** and **reach difficulty**

Discussion

- While the three most common observations could reasonably be considered normal experience in the centrifuge, the remaining symptoms should be acknowledged by the flight surgeon and prepared for.
  - Warmth
  - Throat discomfort
  - Dizziness
  - Nausea
  - Cough

Conclusions

- This data adds to prior centrifuge runs and confirms good human tolerance of capsule operations at accelerations up to 4.5Gx with minimal adverse effects with minimal vibratory input.

- Novel symptoms, including warmth, dizziness, nausea, numbness, pain, and throat discomfort with or without cough, occurred with frequencies in the 10-20% range

- Few symptoms persisted after completion of the centrifuge profile, and even these were quite transient

Strengths/Weaknesses

Strengths

- Centrifuge profiles were able to closely mimic the onset and termination of acceleration forces as they would be experienced in flight.
- Crewmembers were able to actuate controls as would be expected during a mission
- Participants included untrained individuals who tolerated the protocols as well as trained astronauts and pilots

Weaknesses

- Smaller cohort limits power of any observed associations.
- The standard form used to assess for signs and symptoms was changed midway through data collection to address changes in SpaceX mission profile. Although very similar, the two forms are not identical

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