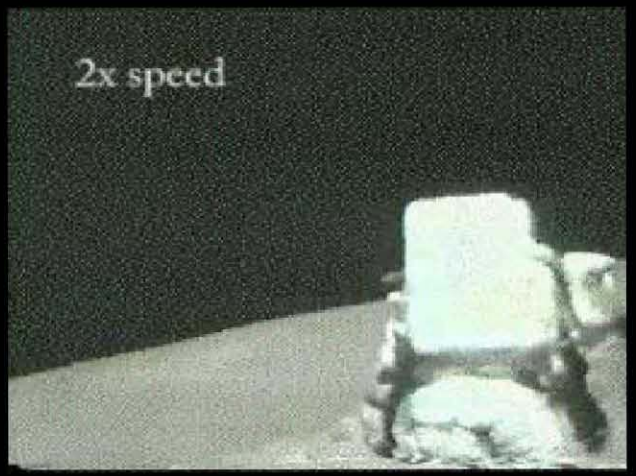
EFFECT OF CHANGING THE CENTER OF GRAVITY ON HUMAN PERFORMANCE IN SIMULATED LUNAR GRAVITY

[1]Steven P. Chappell, [1]Jason R. Norcross, [2]Michael L. Gernhardt.

[1]Wyle Integrated Science and Engineering Group, Houston, TX
[2]NASA Johnson Space Center, Houston, TX

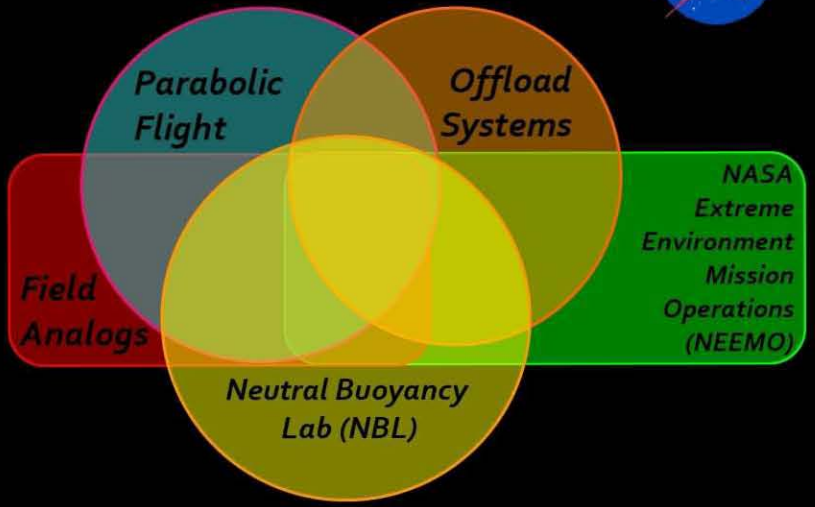
Moving Past Apollo

- Apollo was a remarkable human achievement, however fewer than 20 total program EVAs
- Limited mobility, dexterity, center of gravity and other features of the suit required significant crew compensation to accomplish the objectives
  - It would not be feasible to perform Exploration EVAs using Apollo vintage designs
- The vision is to develop an EVA system that is low overhead and results in close to (or better than) 1-g shirt sleeve performance i.e. " A suit that is a pleasure to work in, one that you would want to go out and explore in on your day off"
- Exploration EVA will be very different from Earth orbit EVA – a significant change in design and operational philosophies will be required to optimize suited human performance in lunar gravity
- Unlike Shuttle & ISS, all Exploration crewmembers must be able to perform EVA – and suits must be built to accommodate and optimize performance for all crew



Testing in Analog Environments

Tests are performed in multiple analogs, as each environment has limitations for simulating partial gravity and representing a realistic operational environment




Parabolic Flight


Offload Systems


NBL


Field Analogs


NEEMO

NEEMO/NBL CG Studies

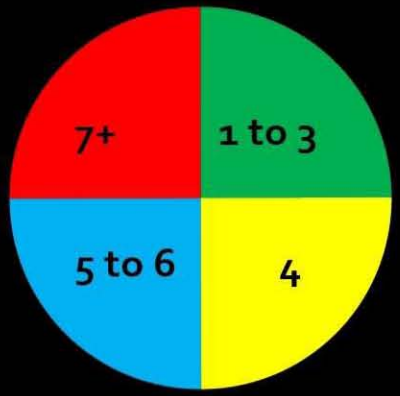
NEEMO

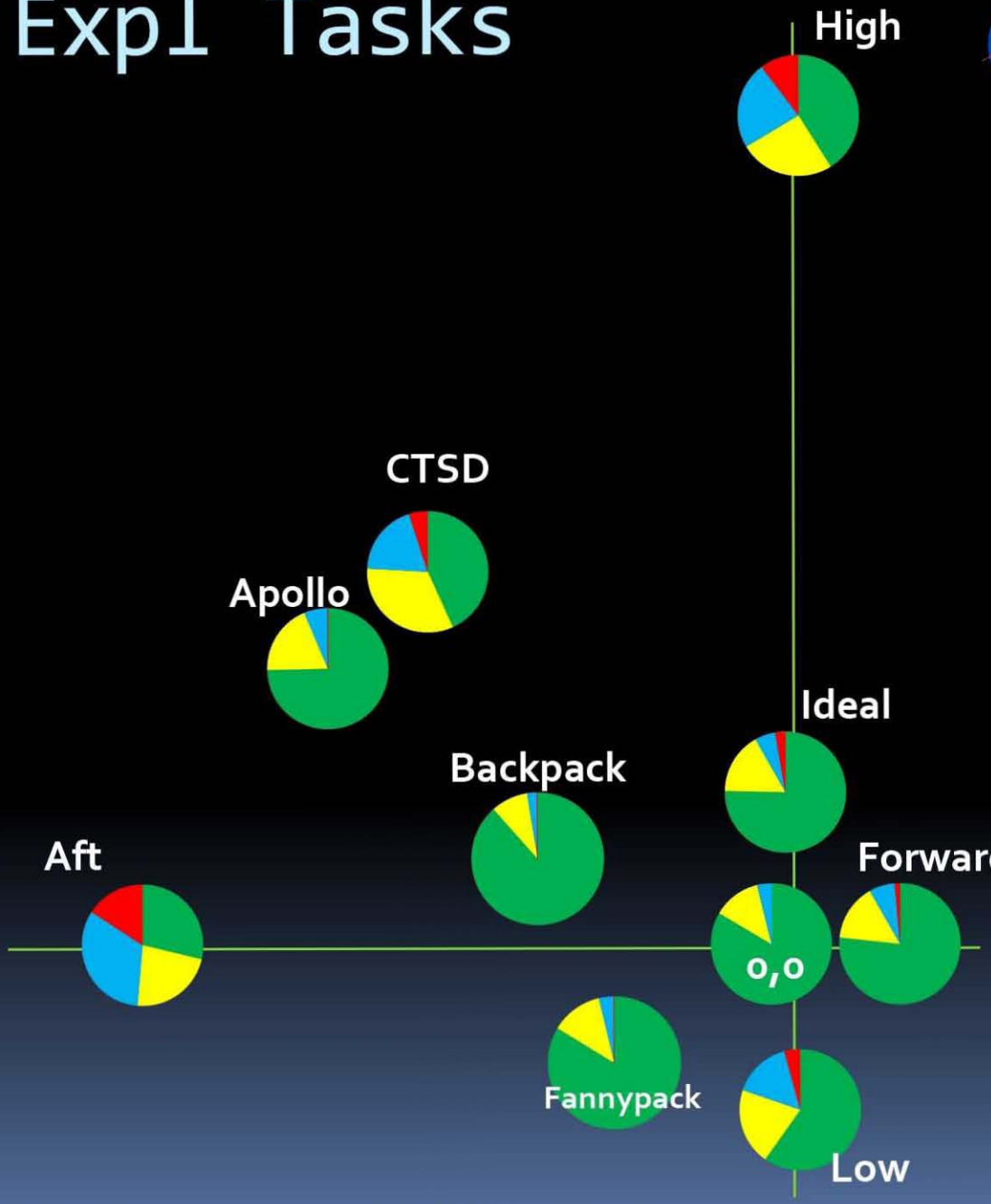
NBL

Gravity compensation and performance scale (GCPS) ratings and time to task completion were collected

- GCPS ratings are based on the level of operator compensation required in partial gravity compared to performing the same task, unsuited, in 1-g
- On this 10 point scale, a rating of 2 is equal to 1-g performance and larger numbers indicate perceived increases in the amount of subject compensation required to achieve desired performance

NEEMO/NBL Expl Tasks

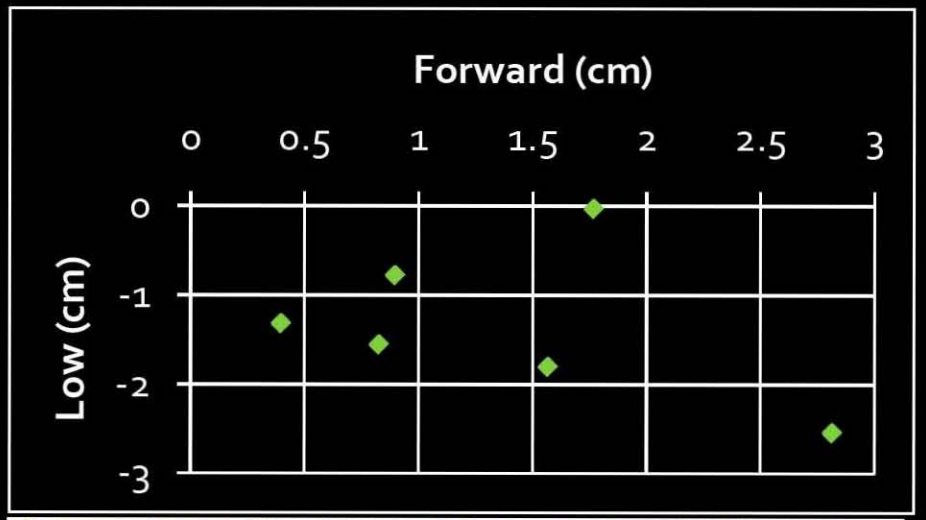




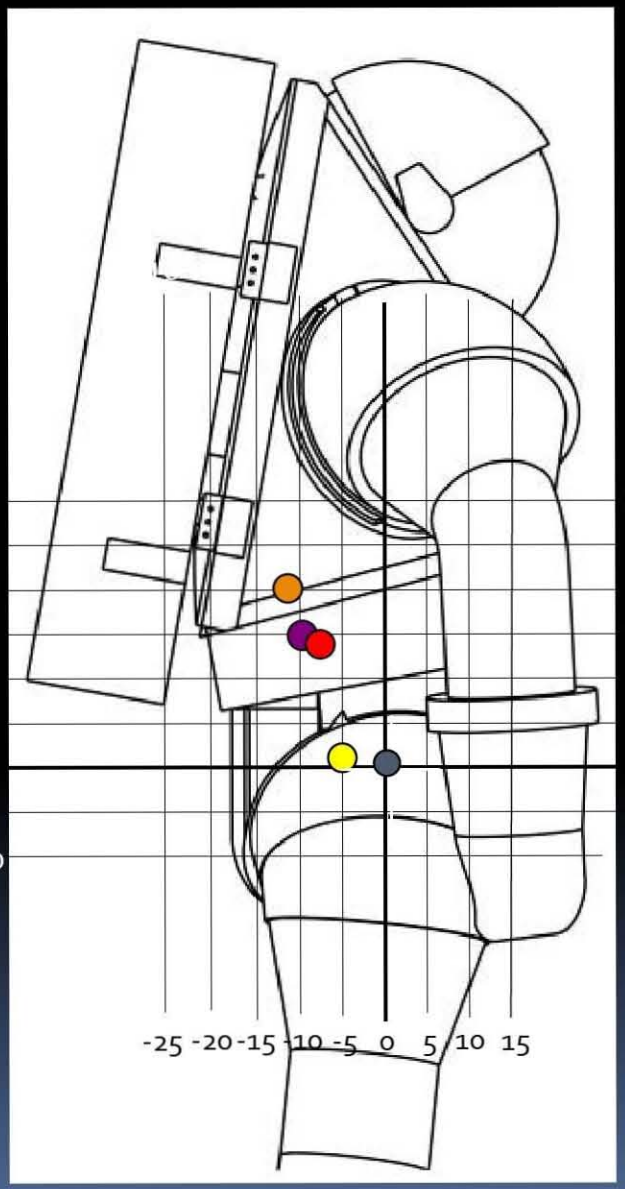
CG Initial Findings(POGO)

- Post test analysis indicated that the suited system CG was 11.2 cm (4.41") aft and 20.1 cm (7.93") high from the standard subject CG
- POGO requires system CG to line up with gimbal axes of rotation
  - Subject will line up system CG slightly forward and low of gimbal axes when allowed to choose

System CG Alignment with Gimbal Axes



Center of Gravity Test Design



IST-3 shirt-sleeve rig CG locations

Previously Tested Cases at NEEMO/NBL

2005 CTDSD Baseline	7.6 cm aft / 14.4 cm high
Flex Pack Backpack	4.8 cm aft / 1.0 cm high
0,0	0.0 cm aft / 0.0 cm high

Previously Tested Cases at EWT/IST-1/IST-2

Pogo System	11.2 cm aft / 20.1 cm high

Mk III w/ PLSS mockup, C9 CG rig, stowed arms, no lead weights	9.0 cm aft / 14.8 cm high

CG locations in a red box were assessed in parabolic flight tests

- CG coordinates are the difference between the subject's CG and the system CG

Methods

- Ratings of perceived exertion (RPE) and gravity compensation and performance scale (GCPS) ratings were collected
- Motion-capture cameras were used to capture kinematic data, and force plates were used to record ground reaction forces for all tasks except kneel/stand

Walking

Kneel/Stand

Shoveling

Rock Pickup

CG Suited Locations (C-9)

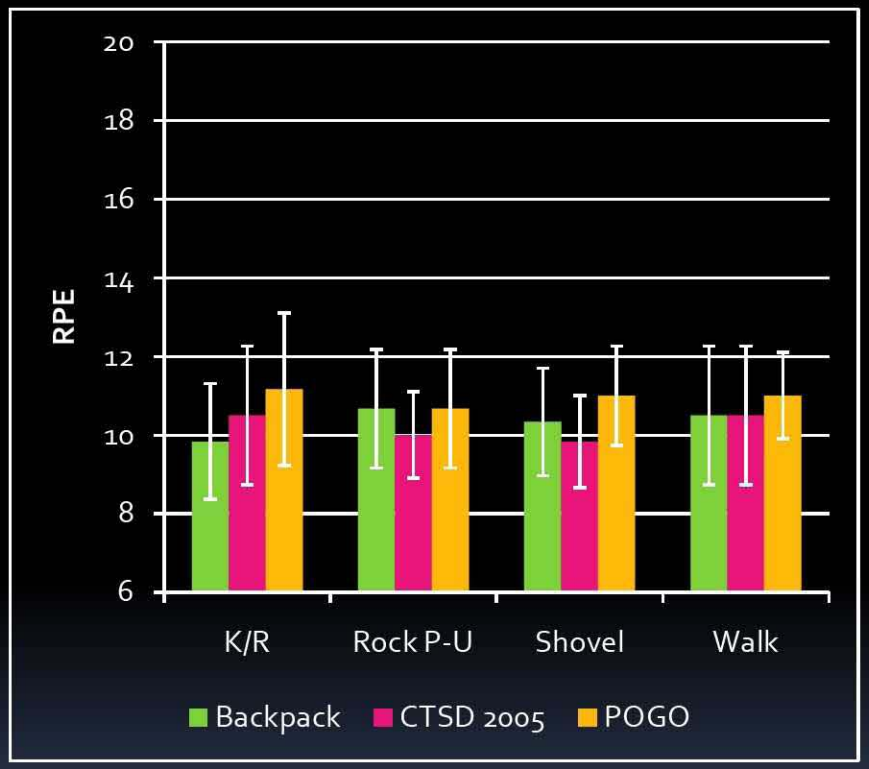
Backpack

CTSD 2005 Baseline

POGO

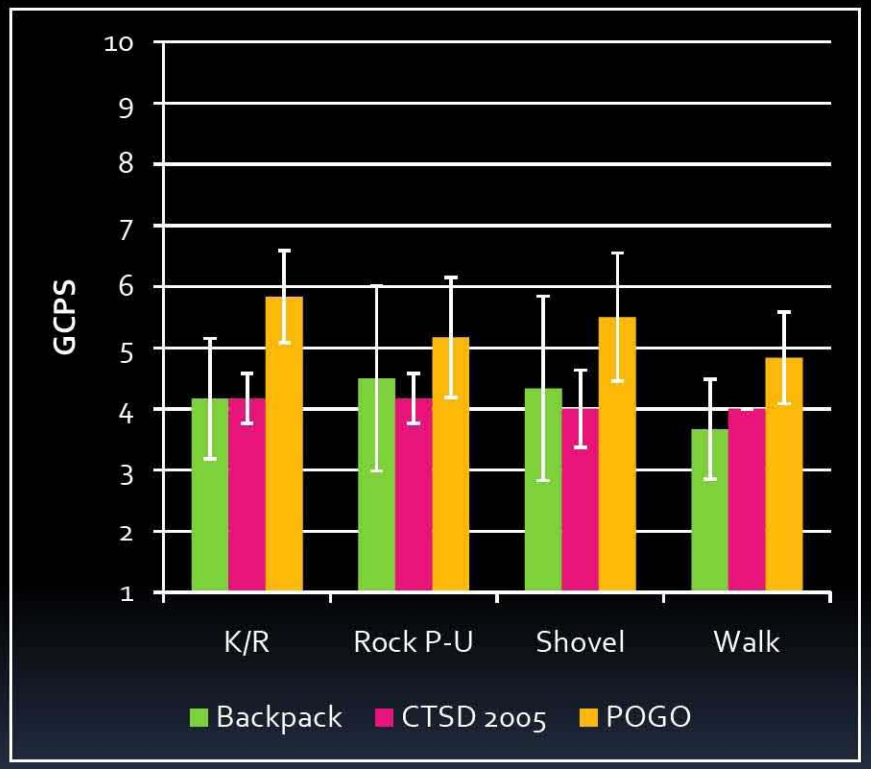
CG Results (C-9)

RPE



- RPE was not notably different between conditions
- Variation between subjects in the same task was as great as 8 to 13

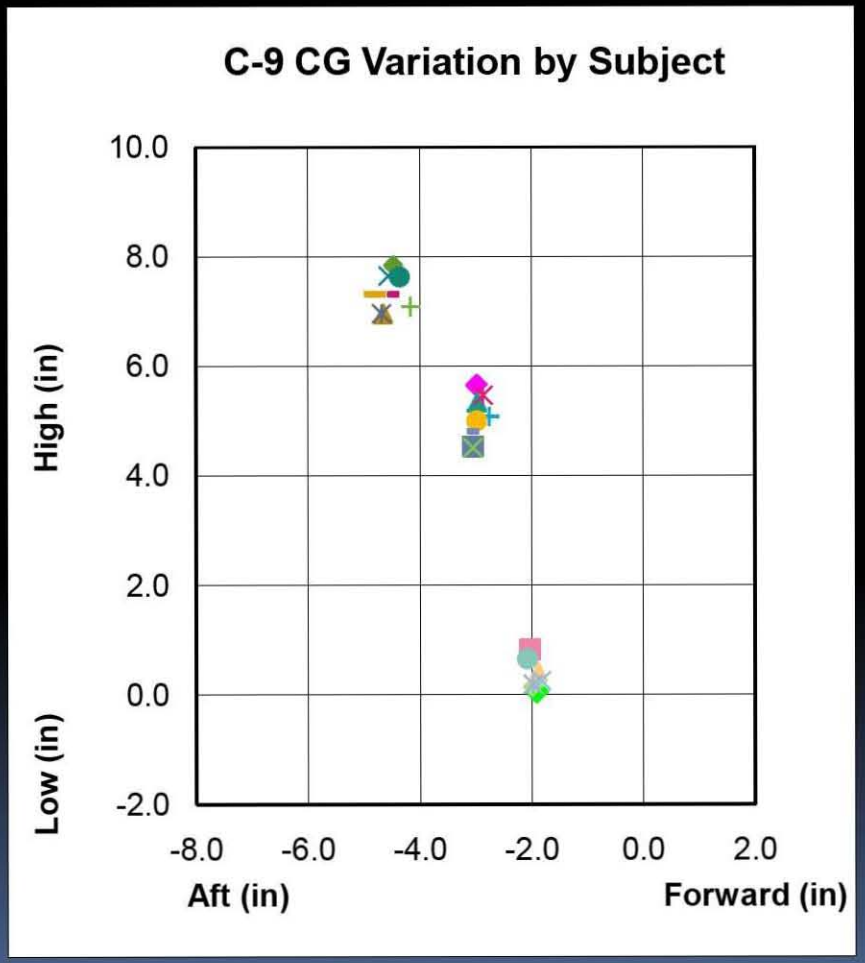
GCPS



- GCPS highest at POGO and most variable at Backpack
- Variation between subjects in the same task was as great as 3 to 7

CG Individual Considerations

- CG locations were based on a standard male subject
- Individual CG variation is expected depending on how different the subject is from the model



CG Shirt-Sleeve Locations (POGO)

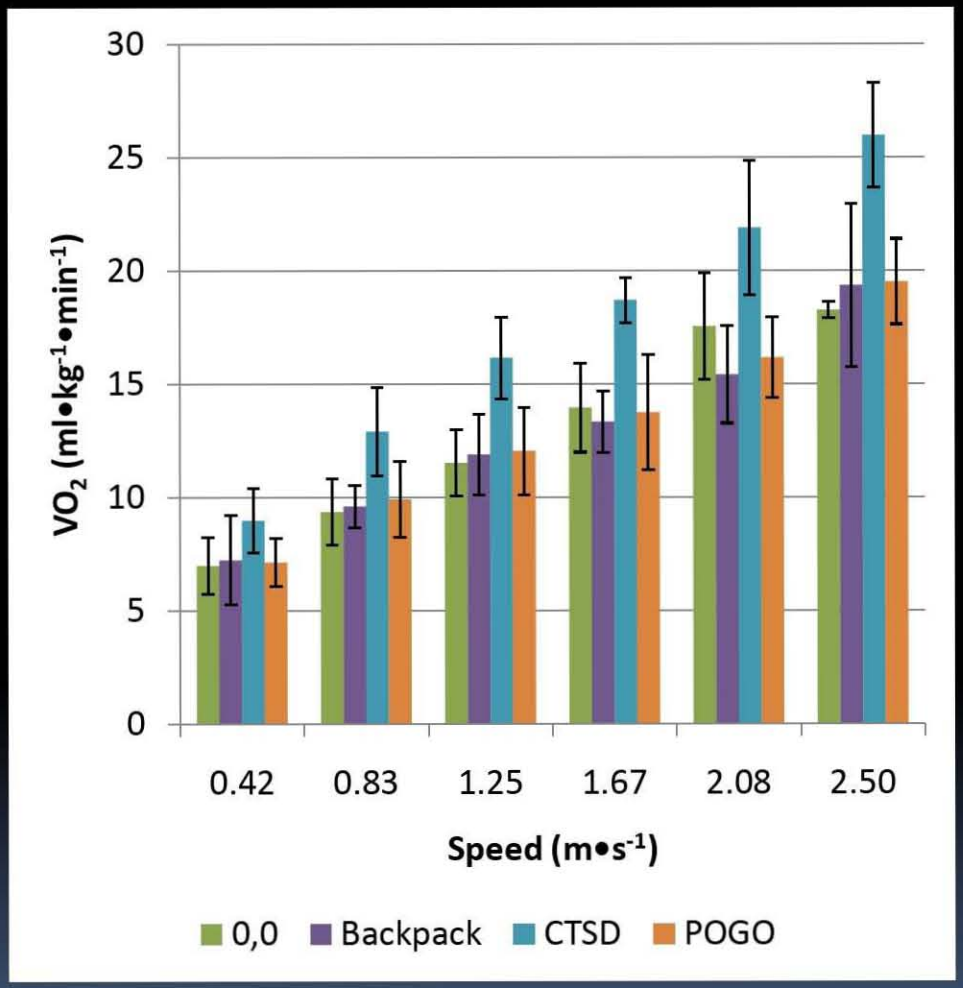
0,0

Backpack

CTSD 2005 Baseline

POGO

CG Results (POGO unsuited)

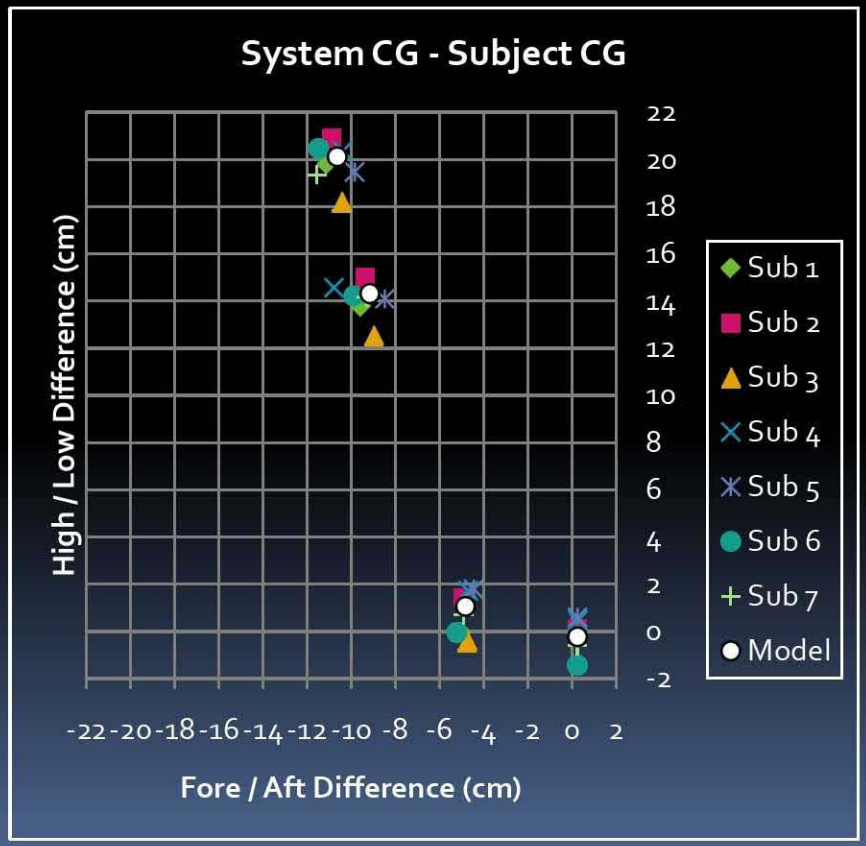


- (O,O), Backpack and POGO had similar results in metabolic rate, stability and subjective ratings
- Performance was worst with the CTSD 2005 Baseline CG
  - Unexpected - this was not seen with the other high/aft CG (POGO)
  - Possible reasons
    - Alignment with gimbal axes
    - Differences in model calculated CG location from actual subject's location
    - Could be a bad CG
- Biomechanics results were more variable – showed mixed results

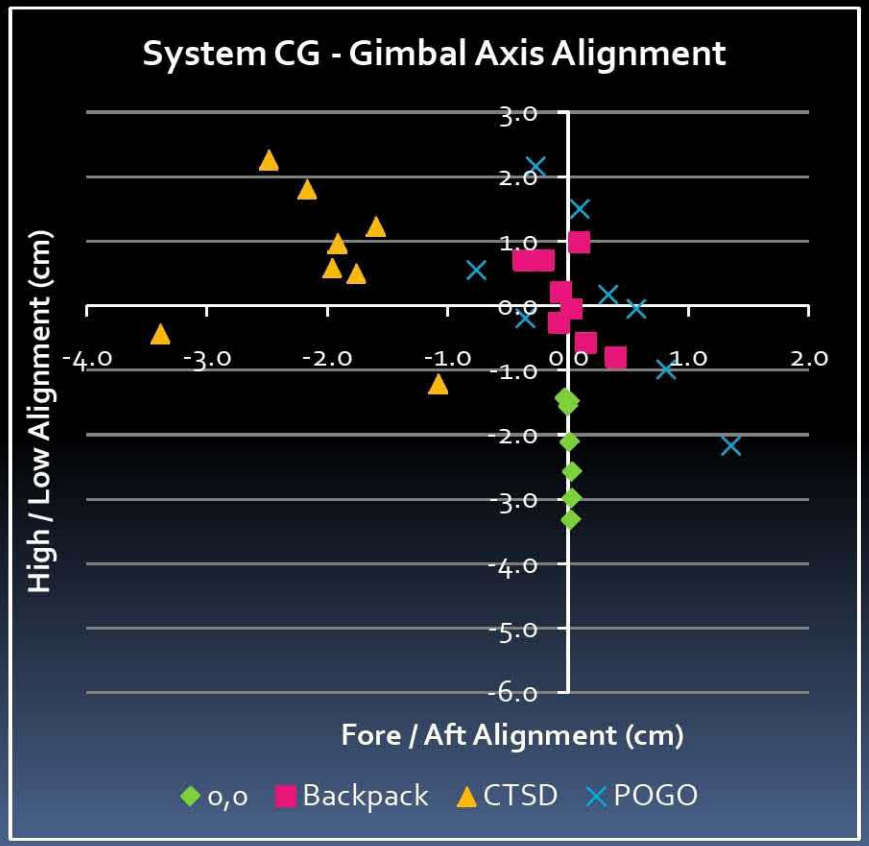
CG Results (POGO)

Individual CG Differences

System to Subject CG



System CG to Gimbal Axes (Specific to the POGO only)

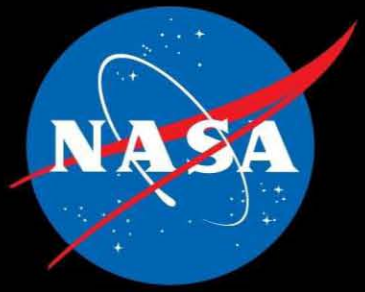


CG Results Summary

- CG can definitely affect performance, BUT
- Large variation exists between subjects
  - Need to explore interactions between CG, mass, gravity and subject strength, fitness and/or anthropometry
- CTSD CG led to worst performance on IST-3 unsuited testing, yet led to the best performance during parabolic flight
  - Unclear what causes the variance
    - Analog environment
    - Test set-up
    - Data collection scales
- CG testing on the POGO can be significantly affected if system CG is misaligned with gimbal axes

Thank You

- Questions?



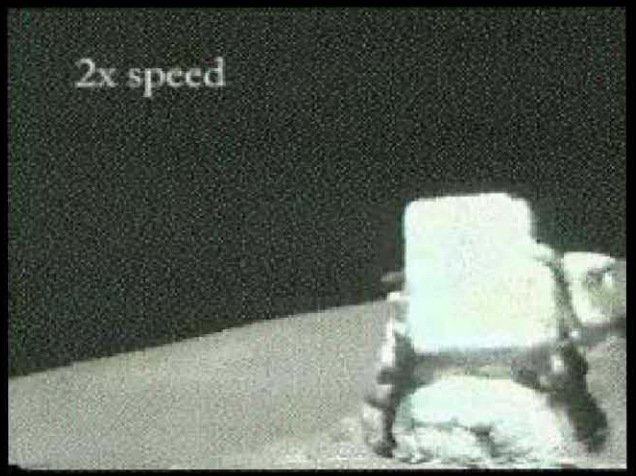
EFFECT OF CHANGING THE CENTER OF GRAVITY ON HUMAN PERFORMANCE IN SIMULATED LUNAR GRAVITY

[1]Steven P. Chappell, [1]Jason R. Norcross, [2]Michael L. Gernhardt.

[1]Wyle Integrated Science and Engineering Group, Houston, TX
[2]NASA Johnson Space Center, Houston, TX

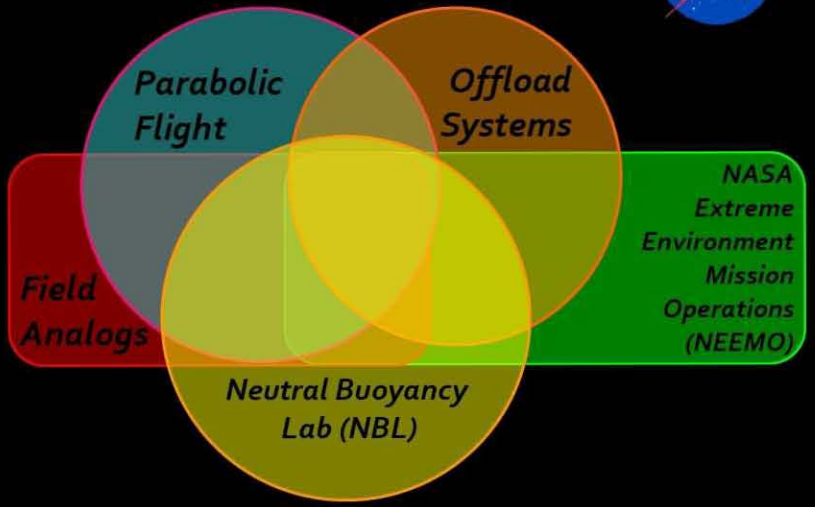
Moving Past Apollo

- Apollo was a remarkable human achievement, however fewer than 20 total program EVAs
- Limited mobility, dexterity, center of gravity and other features of the suit required significant crew compensation to accomplish the objectives
  - It would not be feasible to perform Exploration EVAs using Apollo vintage designs
- The vision is to develop an EVA system that is low overhead and results in close to (or better than) 1-g shirt sleeve performance i.e. " A suit that is a pleasure to work in, one that you would want to go out and explore in on your day off"
- Exploration EVA will be very different from Earth orbit EVA – a significant change in design and operational philosophies will be required to optimize suited human performance in lunar gravity
- Unlike Shuttle & ISS, all Exploration crewmembers must be able to perform EVA – and suits must be built to accommodate and optimize performance for all crew



Testing in Analog Environments

Tests are performed in multiple analogs, as each environment has limitations for simulating partial gravity and representing a realistic operational environment




Parabolic Flight


Offload Systems


NBL


Field Analogs


NEEMO

NEEMO/NBL CG Studies

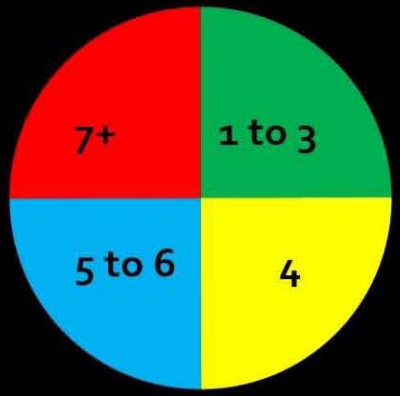
NEEMO

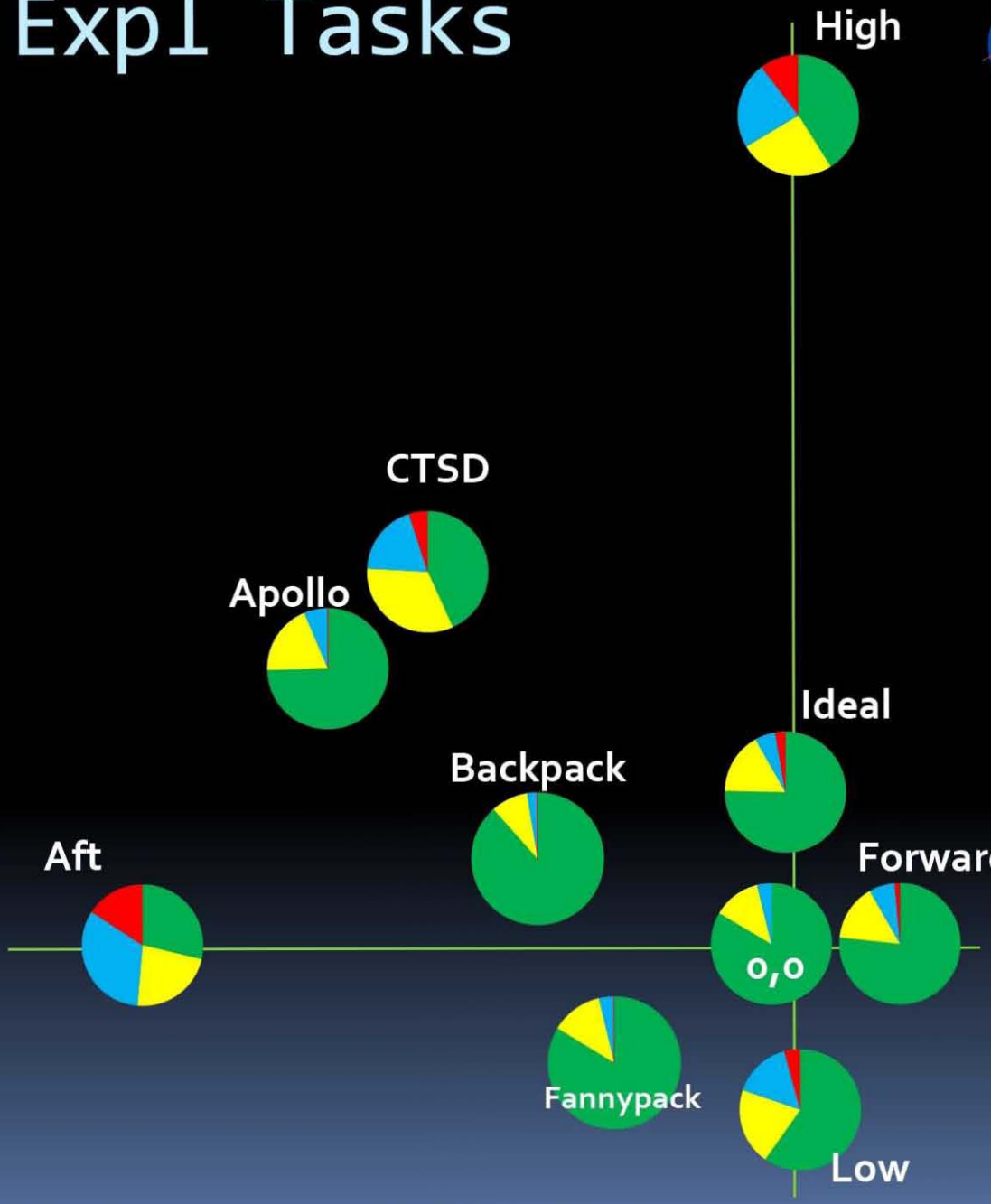
NBL

Gravity compensation and performance scale (GCPS) ratings and time to task completion were collected

- GCPS ratings are based on the level of operator compensation required in partial gravity compared to performing the same task, unsuited, in 1-g
- On this 10 point scale, a rating of 2 is equal to 1-g performance and larger numbers indicate perceived increases in the amount of subject compensation required to achieve desired performance

NEEMO/NBL Expl Tasks

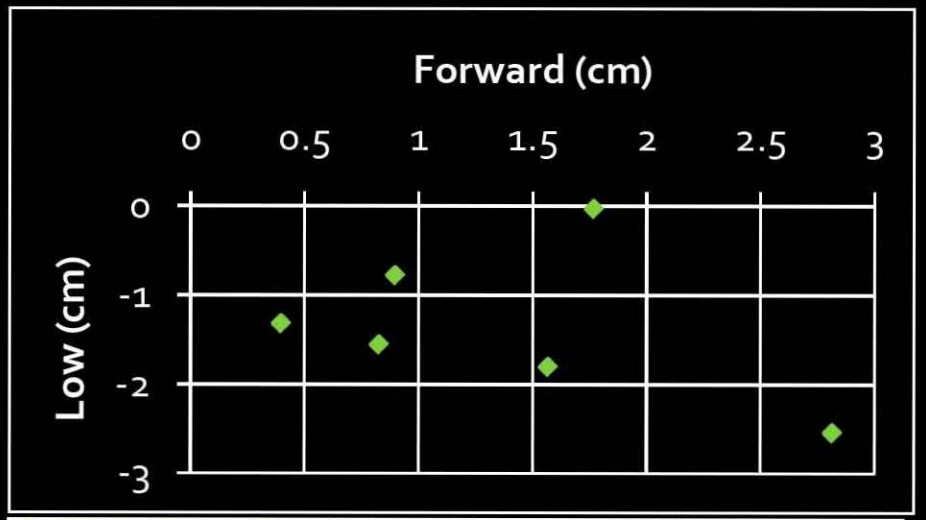




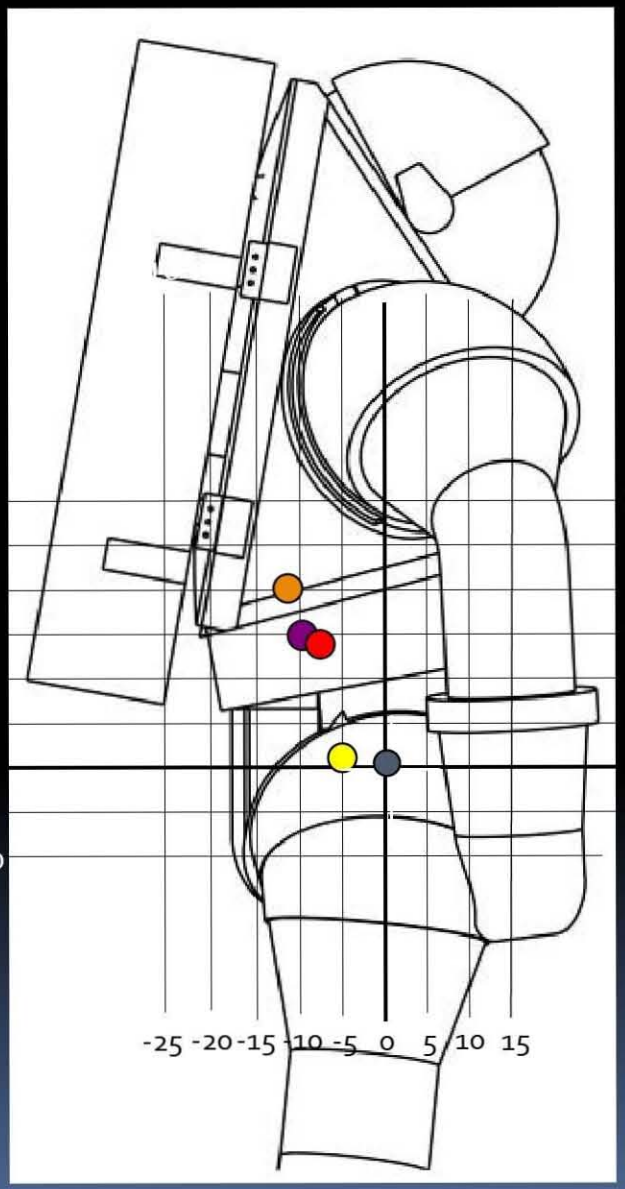
CG Initial Findings(POGO)

- Post test analysis indicated that the suited system CG was 11.2 cm (4.41") aft and 20.1 cm (7.93") high from the standard subject CG
- POGO requires system CG to line up with gimbal axes of rotation
  - Subject will line up system CG slightly forward and low of gimbal axes when allowed to choose

System CG Alignment with Gimbal Axes



Center of Gravity Test Design



IST-3 shirt-sleeve rig CG locations

Previously Tested Cases at NEEMO/NBL

2005 CTDSD Baseline	7.6 cm aft / 14.4 cm high
Flex Pack Backpack	4.8 cm aft / 1.0 cm high
0,0	0.0 cm aft / 0.0 cm high

Previously Tested Cases at EWT/IST-1/IST-2

Pogo System	11.2 cm aft / 20.1 cm high

Mk III w/ PLSS mockup, C9 CG rig, stowed arms, no lead weights	9.0 cm aft / 14.8 cm high

CG locations in a red box were assessed in parabolic flight tests

- CG coordinates are the difference between the subject's CG and the system CG

Methods

- Ratings of perceived exertion (RPE) and gravity compensation and performance scale (GCPS) ratings were collected
- Motion-capture cameras were used to capture kinematic data, and force plates were used to record ground reaction forces for all tasks except kneel/stand

Walking

Kneel/Stand

Shoveling

Rock Pickup

CG Suited Locations (C-9)

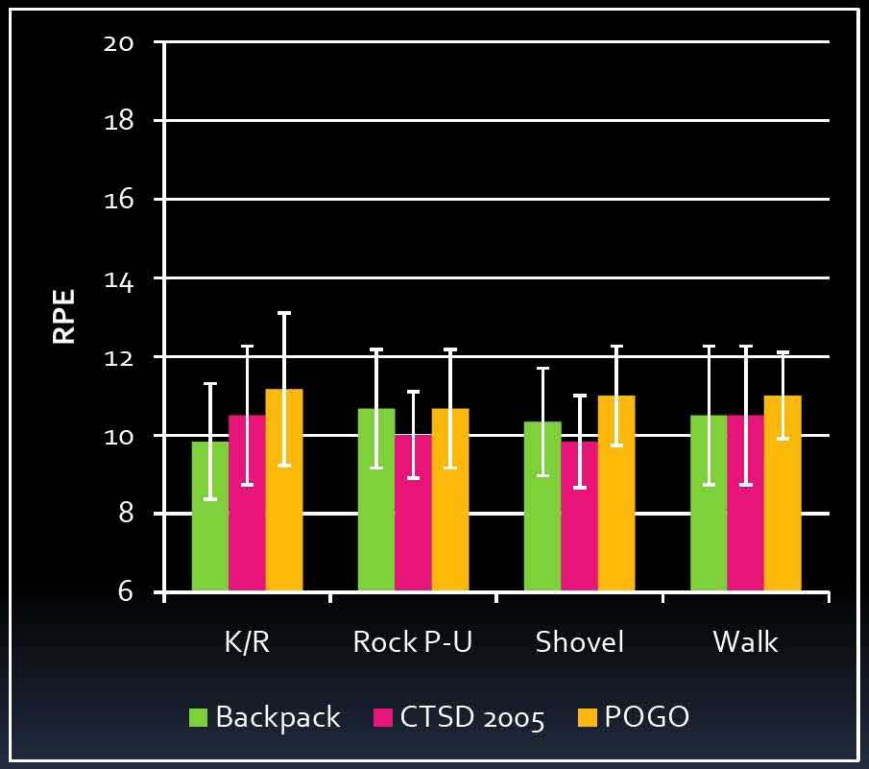
Backpack

CTSD 2005 Baseline

POGO

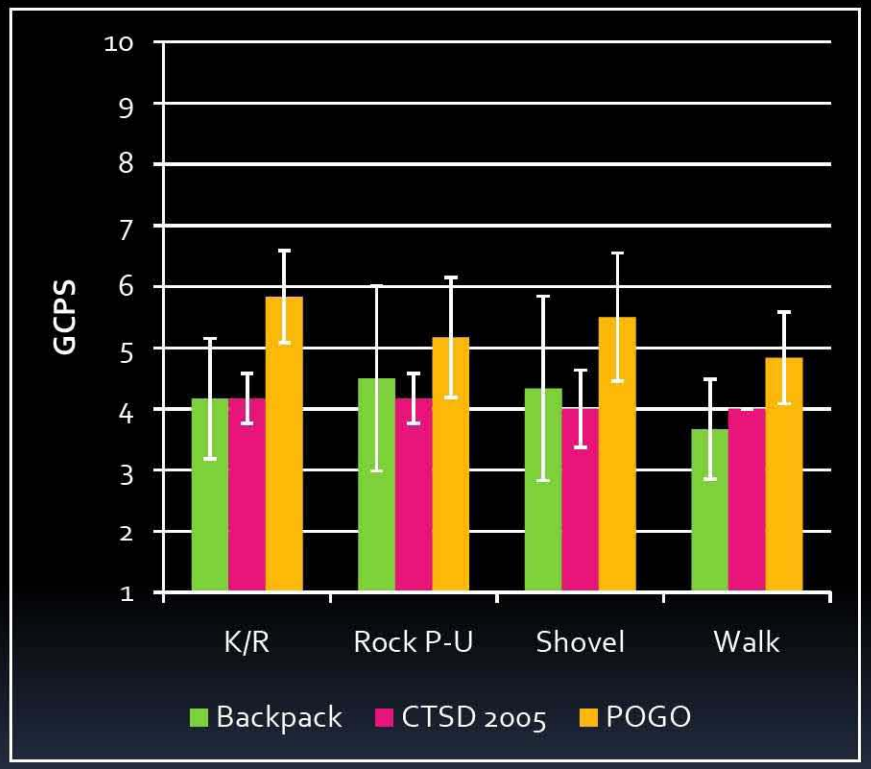
CG Results (C-9)

RPE



- RPE was not notably different between conditions
- Variation between subjects in the same task was as great as 8 to 13

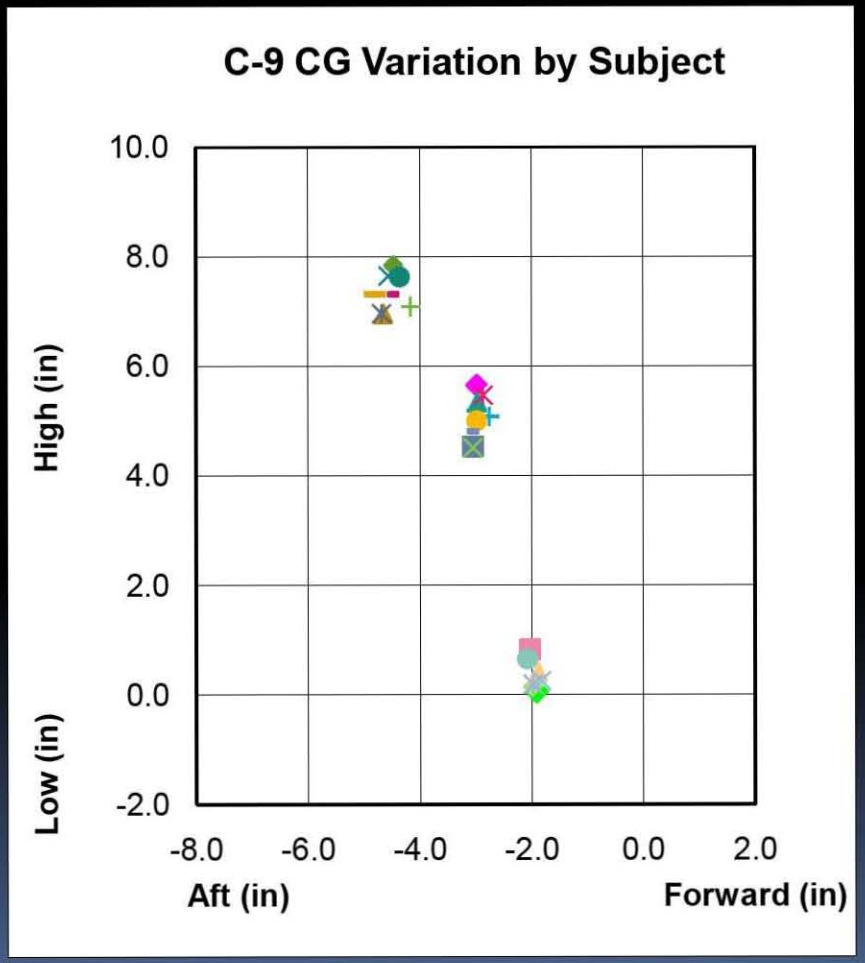
GCPS



- GCPS highest at POGO and most variable at Backpack
- Variation between subjects in the same task was as great as 3 to 7

CG Individual Considerations

- CG locations were based on a standard male subject
- Individual CG variation is expected depending on how different the subject is from the model



CG Shirt-Sleeve Locations (POGO)

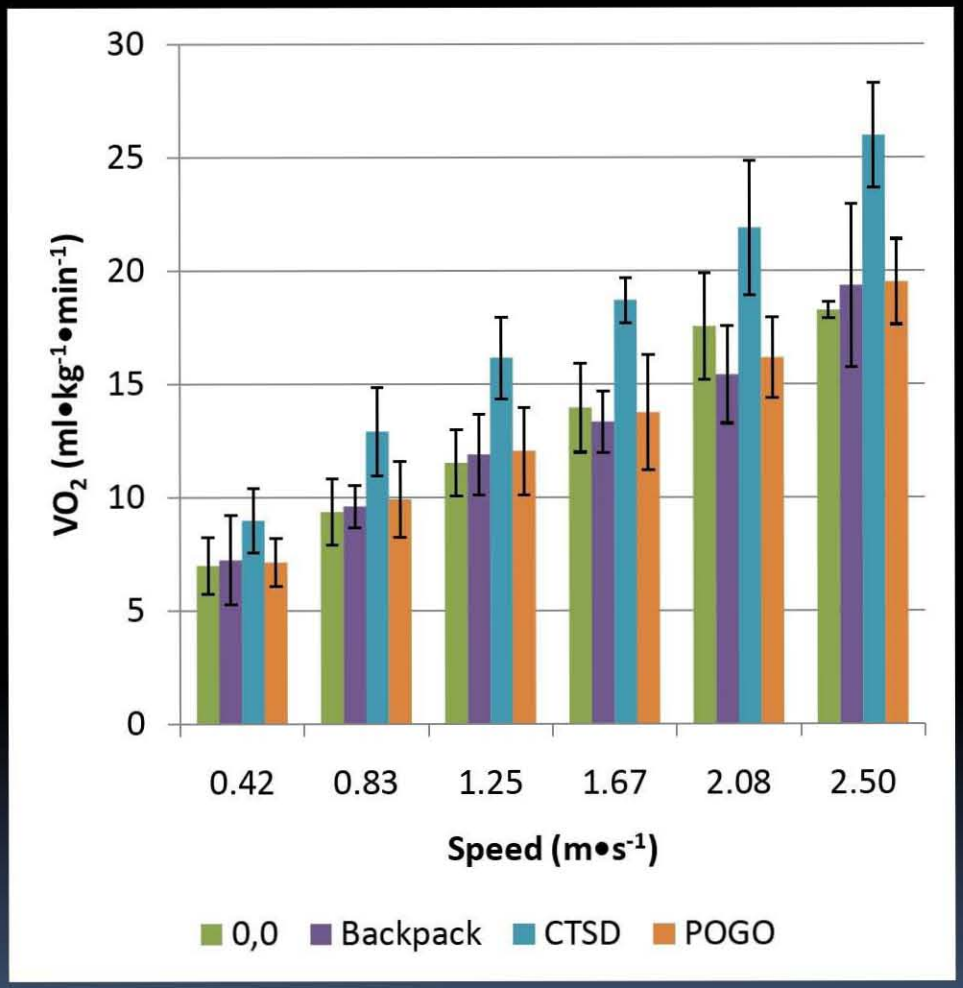
0,0

Backpack

CTSD 2005 Baseline

POGO

CG Results (POGO unsuited)

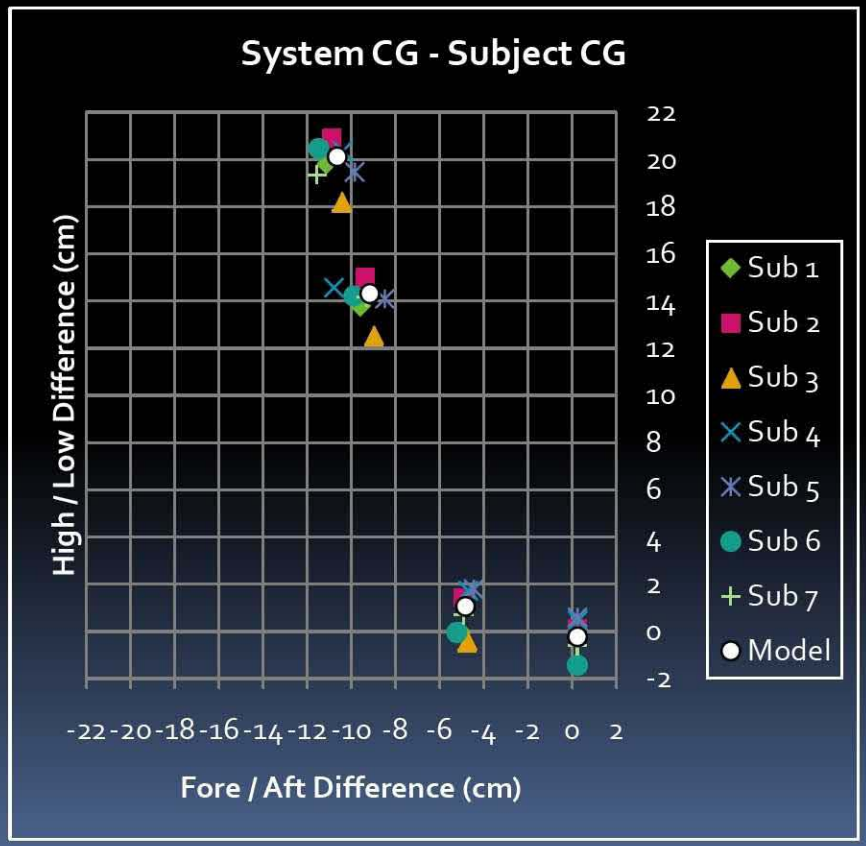


- (O,O), Backpack and POGO had similar results in metabolic rate, stability and subjective ratings
- Performance was worst with the CTSD 2005 Baseline CG
  - Unexpected - this was not seen with the other high/aft CG (POGO)
  - Possible reasons
    - Alignment with gimbal axes
    - Differences in model calculated CG location from actual subject's location
    - Could be a bad CG
- Biomechanics results were more variable – showed mixed results

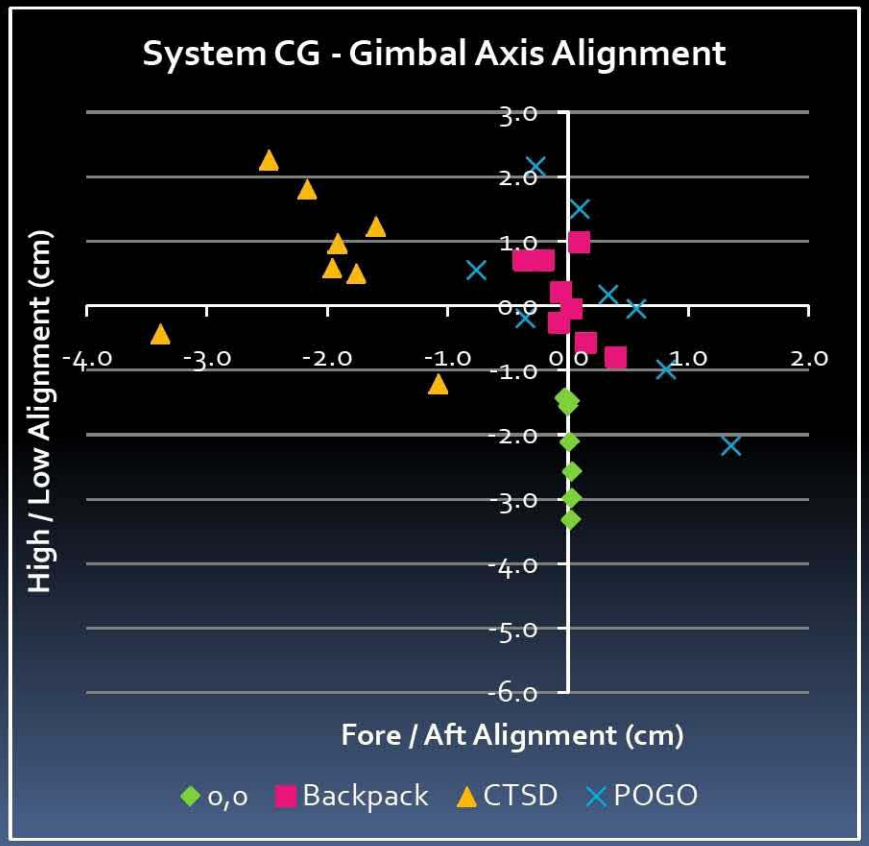
CG Results (POGO)

Individual CG Differences

System to Subject CG



System CG to Gimbal Axes (Specific to the POGO only)



CG Results Summary

- CG can definitely affect performance, BUT
- Large variation exists between subjects
  - Need to explore interactions between CG, mass, gravity and subject strength, fitness and/or anthropometry
- CTSD CG led to worst performance on IST-3 unsuited testing, yet led to the best performance during parabolic flight
  - Unclear what causes the variance
    - Analog environment
    - Test set-up
    - Data collection scales
- CG testing on the POGO can be significantly affected if system CG is misaligned with gimbal axes

Thank You

- Questions?