

**Acronym:** Spinal Elongation

**Title:** Spinal Elongation and its Effects on Seated Height in a Microgravity Environment

**Principal Investigator(s):**

Sudhakar Rajulu, Ph.D., Johnson Space Center, Houston, TX

**Contact(s):**

PI - [Sudhakar Rajulu](#), (281) 483-3725

Primary - [Jamian Lattin-Sims](#), (281) 483-7440

Secondary - [Lauran Kidd](#), (281) 218-3305

**Mailing Address(es):**

Dr. Sudhakar Rajulu  
Johnson Space Center  
National Aeronautics and Space Administration  
2101 NASA Parkway  
Mail Code: SF3  
Houston, TX 77058

**Developer(s):** Johnson Space Center, Human Research Program, Houston, TX

**Sponsoring Agency:** National Aeronautics and Space Administration (NASA)

**Increment(s) Assigned:** 20, 21, 22

**Mission(s):** STS-128/17A; STS-129/ULF3; STS-130/20A, STS-131/19A

**Brief Research Summary (PAO):** The purpose of the Spinal Elongation and its Effects on Seated Height in a Microgravity Environment (Spinal Elongation) study is to provide quantitative data as to the amount of change that occurs in the seated height due to spinal elongation in microgravity.

**Research Summary:**

- Spinal elongation due to microgravity is an important consideration for the seated height dimension. Past research has demonstrated that crewmembers tend to increase in stature by up to 3 percent, which has driven current requirements to allow for such growth in dimensions such as stature and seated height.
- The Spinal Elongation and its Effects on Seated Height in a Microgravity Environment (Spinal Elongation) study will provide Crew Exploration Vehicle (CEV) designers the accurate anthropometry (measurement of the size and proportions of the human body) data needed in order to ensure that the vehicle accommodates the full range of crewmembers. Seated height measurements are of particular interest due to the nature of seat layout within the vehicle.
- The criticality of this measurement is such that changes in seated height on the order of magnitude of inches have significant impacts on the level of crew accommodation available.

**Detailed Research Description:** The Spinal Elongation and its Effects on Seated Height in a Microgravity Environment (Spinal Elongation) investigation provides quantitative data about the amount of change that occurs in the seated height due to spinal elongation in space. Spinal elongation has been observed to occur in crewmembers during space flight, but has only previously been recorded in the standing position. The seated height data in microgravity is considered necessary to correctly identify the seated height projections of the crew in the Orion configuration. The projections of seated height will provide data on the proper positioning of the seats within the vehicle, adequate clearance for seat stroke

in high acceleration impacts, fit in seats, correct placements of seats with respect to each other and the vehicle and the proper orientation to displays and controls. Additionally, data concerning the effects of spinal elongation on seated height would aid in the design of suit components, habitation requirements and tool specifications of future long-duration space expeditions.

Changes in seated height due to spinal growth will be assessed based on measurement with an anthropometer (instrument for measuring the human trunk and limbs) as well as scaling of objects of known sizes in photographs of seated crewmembers. These methodologies, which have been tested in the laboratory and the Space Shuttle cockpit trainer, were selected as the most accurate means available during flight. Measurements will be taken at pre-defined intervals during flight for each crewmember.

The process will involve manual measurements as well as setting up a camera mount according to instructions. For each set of measurements, the crewmember will restrain him/herself into the commander seat while another crewmember assists by measuring the distance from the top of the seat to the top of the subject's head and taking a photograph using pre-defined camera settings.

**Project Type:** Payload

**Images and Captions:**



Operational sketch of Spinal elongation operations.

**Operations Location:** Sortie

**Brief Research Operations:**

- During the flight, the commander seat will be placed in entry configuration. Camera settings will be configured according to a set of provided instructions. The test operator will position the camera using a multi-bracket assembly installed on a camera shoe near the pilot seat.
- The test operator will retrieve and assemble the anthropometer. The subject, will be seated in the commander seat and gaze directly ahead at a reference object; the test operator will assist the subject in adjusting the lap belt to ensure that positive contact is made between the subject and the seat pan.
- The anthropometer will be used to measure the distance from the top of the seat to the top of the subject's head, the measurement will be recorded in the procedure log, and a photograph will be taken of the subject.

**Operational Requirements:** This study requires twenty-three subjects from both long-duration International Space Station subjects and short-duration Space Shuttle subjects. One preflight baseline data collection session will take place at any time after informed consent is obtained from the subject. At least one measurement is to be taken on orbit after the subject has been in orbit for 48 hours. Measurements taken later in the mission are highly desired. More than one session per subject is also highly desired to improve the science data. These measurements consist of photographs and data from the anthropometer. A postflight baseline data collection session will take place at any point within thirty days of landing.

**Operational Protocols:** During the flight, the commander seat will be placed in entry configuration, and the test operator will remove the seat pan cushion, parachute, and head rest from the seat. Camera settings will be configured according to a set of provided instructions, standardizing settings such as aperture and focus. The test operator will position the camera using a multi-bracket assembly installed on a camera shoe near the pilot seat. The camera position will be adjusted such that it is orthogonal to the commander seat by adjusting the multi-use bracket and using the pilot seat as a reference point, also ensuring that the subject's entire profile is captured in the frame. The pilot seat's seatback, set at the same angle as the commander seat's seatback, may be used as a guide to position the camera orthogonal to the subject. The test operator will retrieve and assemble the anthropometer, affixing the base to the top of the commander seat. The base will ensure that the anthropometer is in the proper standard location, extending along the line of the seatback upward and behind the subject's head. The position will be consistent between trials due to the design of the anthropometer's base. The subject, wearing light-weight clothing, will be seated in the commander seat. The test operator will assist the subject in adjusting the lap belt to ensure that positive contact is made between the subject and the seat pan. The subject will sit with his/her back and neck straight, with the shoulders resting against the seat back, and gaze directly ahead at a reference object. Training before flights should assist with consistency for this posture. The anthropometer will be used to measure the distance from the top of the seat to the top of the subject's head, the measurement will be recorded in the procedure log, and a photograph will be taken of the subject. The crewmember will exit the seat, and will repeat to gather the second set of data points. Each session involves two values recorded in procedure log and two photographs taken.

**Review Cycle Status:** PI Reviewed

**Category:** Human Research and Countermeasure Development for Exploration

**Sub-Category:** Bone and Muscle Physiology

**Space Applications:** This seated height data in microgravity is considered necessary to correctly identify the seated height projections of the crew in the Orion configuration. Correct projections of seated height should lead to proper positioning of the seats within the vehicle; adequate clearance for seat stroke in high acceleration impacts; providing proper fit in seats; proper placement of seats with respect to each other and the vehicle; and proper orientation to displays and controls. Additionally, data concerning the effects of spinal elongation on seated height would aid in the design of suit components, habitation requirements and tool specifications.

**Earth Applications:** This study will provide information on spinal elongation and compression for people who suffer from back pain on Earth.

**Manifest Status:** Continuing

**Supporting Organization:** Exploration Systems Mission Directorate (ESMD)

**Previous Missions:** This is the first mission for the Spinal Elongation investigation.

**Web Sites:**

[My How You've Grown](#)

**Last Update:** 01/23/2009

# **Spinal Elongation and its Effects on Seated Height in a Microgravity Environment**

**Principal Investigator Team:**

**Sudhakar Rajulu, PhD.  
Karen Young**

**NASA Experiment Manager**

**Jamian Lattin-Sims**

**Project Manager**

**Lauran Kidd**

**Experiment Support Team**

**Laura Sarmiento  
Scott Humbert  
Tessa Kuykendall**

# Objectives

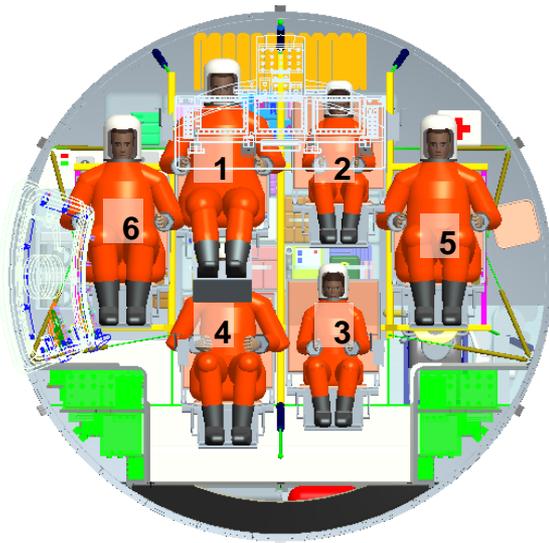
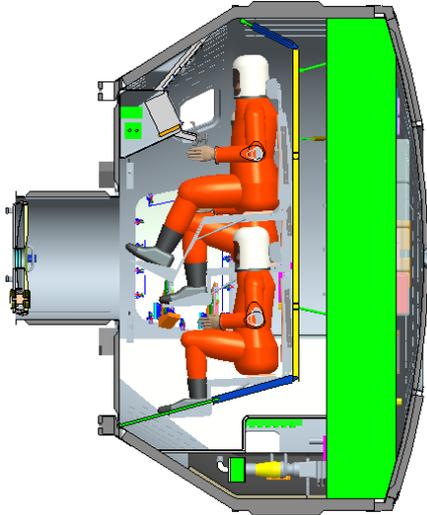
1. To collect spinal elongation induced seated height data for subjects exposed to microgravity environments.
2. To provide information relating to the seated height rate of change over time for astronauts subjected to microgravity.

We will collect:

- Seated Height measurement (ground & flight)
- Digital still photograph (**ground and flight**)

# Background

- Seated measurements are of critical interest to the Constellation program based on the layout of the Crew Exploration Vehicle (CEV)
- CEV's seat configuration
  - crewmember with a tall seated height in Seat 1 limits the clearance for the crewmember in Seat 4
- These conflicts exist for both the Lunar and International Space Station (ISS) configurations



**Figure 1: Seat layout of CEV as seen from above in ISS configuration and from the left of crewmembers in Lunar configuration.**

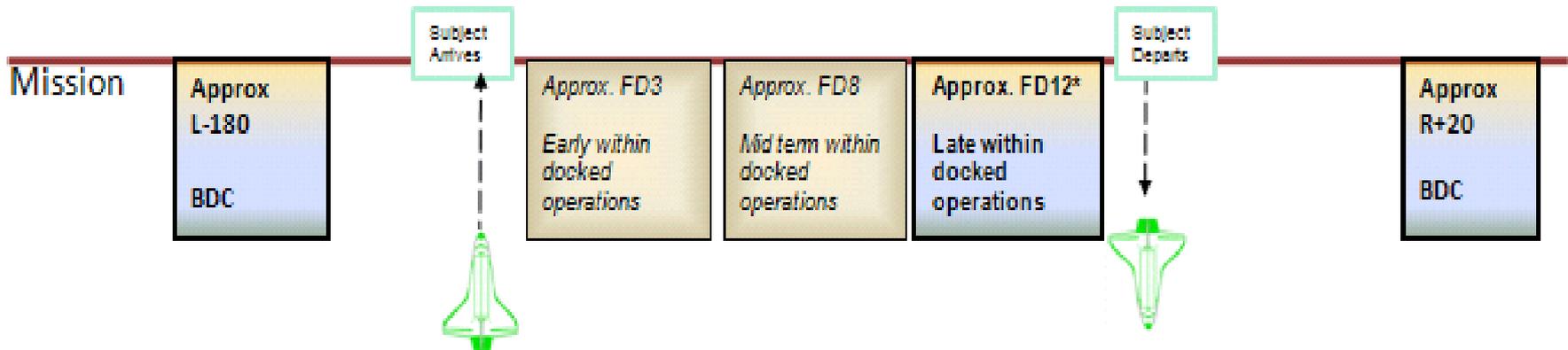
# Background

- Previous research
  - Skylab 4
    - Only stature collected
    - Small sample size  $n = 3$
    - Crewmembers' stature increased by 3%
    - Data only collected while crewmember was standing
    - Drives current requirements to allow for effects of such growth in dimensions such as seated height
  - Spinal elongation data has not been collected for subjects in a seated posture

# Background

- Spinal elongation is due to the straightening of the spinal curve and the expansion of inter-vertebral discs
- Human-Systems Integration Requirements (HSIR), **currently** states that designers should add 3% of stature to dimensions that include the length of the spine
  - Impacts dimensions such as stature, seated height, and eye height.
  - **Designers are not confident in the current stipulation, need data regarding seated height data in micro-g to fully assess the impact of spinal growth on CEV design considerations.**

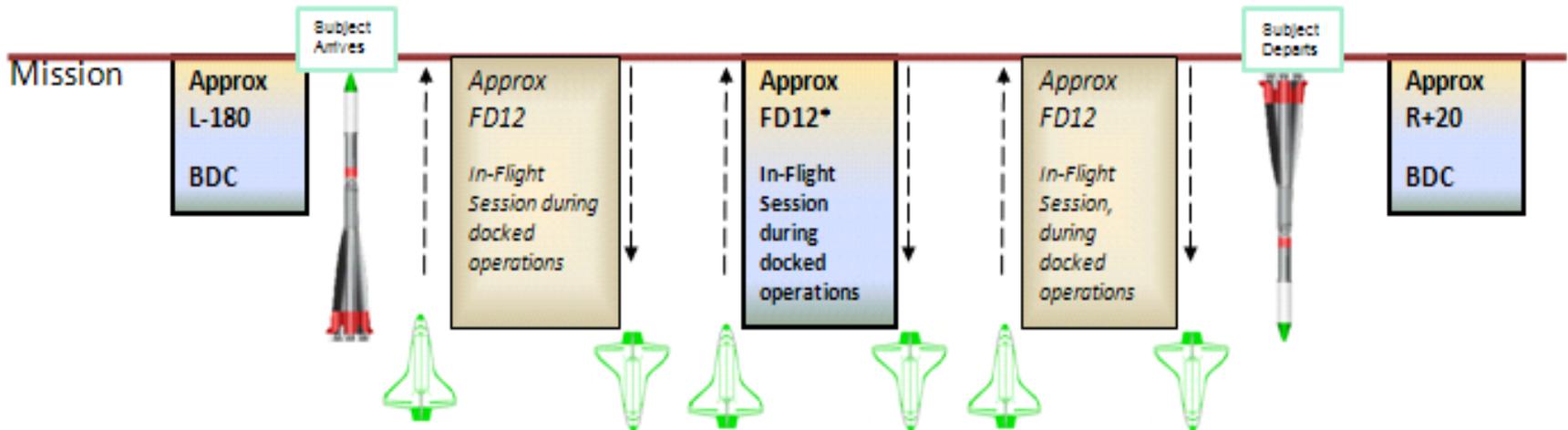
## Experiment Overview – Shuttle Subjects



\*If only one session of Spinal can be scheduled, then a session as late as possible in the mission will provide the best science. One measurement is all that is required to count as a subject for this experiment, however multiple sessions will enhance science.



## Experiment Overview – ISS Subjects



\*If only one session of Spinal can be scheduled, then a session as late as possible in the mission will provide the best science. However, for an ISS subject, from an implementation perspective we will be trying to take a measurement on the first overlapping Shuttle flight given the risk of Shuttle slips causing less Shuttle overlap opportunities.



**Spinal Elongation and its Effects on Seated Height in a Microgravity Environment**

**Informed Consent Briefing**

**Sudhakar Rajulu, PhD**

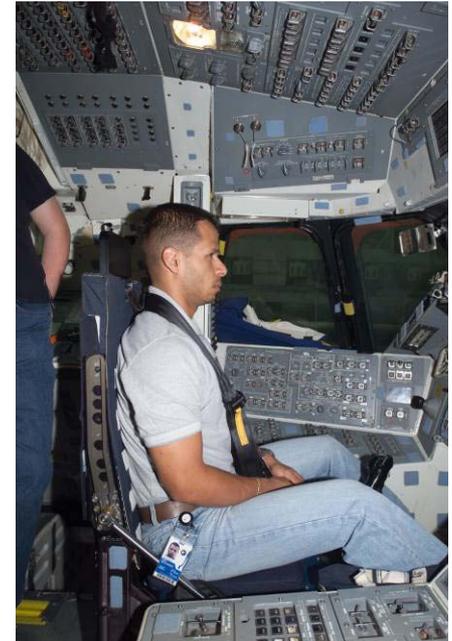
**Experiment Overview- different type of participants**

	<b>Pre-Flight</b>	<b>In-Flight</b>	<b>Post-Flight</b>
<b>Shuttle Subject Only</b>	~L-6 months –Overview and preflight BDC session (30 min)	~FD3 - In- flight Data Collection session (15 min) ~FD8 - In- flight Data Collection session ~FD12 – In- flight Data Collection session	~R+20 – post-flight BDC session (30 min)
<b>ISS Subject Only</b>	~L-6 months –Overview and preflight BDC session (30 min)	FD12 of First overlapping Shuttle mission– In- flight Data Collection session ~FD12 of Second overlapping Shuttle mission– In- flight Data Collection session ~FD12 of Third overlapping Shuttle mission– In- flight Data Collection session	~R+20 – post-flight BDC session (30 min)
<b>Operator Only</b>	~ L-6 months – Operator’s Training (60 min)	~FD12 – (assuming 1 session for 4 subjects) Hardware Setup Data Collection for 1st subject Data Collection for 2nd subject Data Collection for 3rd subject Data Collection for 4 <sup>th</sup> subject	None
<b>Both Operator &amp; Subject</b>	~L- 6 months – Operator’s Training and preflight BDC session (90 min)	~FD12 – (assuming 1 session for 4 subjects) Hardware Setup Data Collection for 1st subject Data Collection for 2nd subject Data Collection for 3rd subject, who is also an operator. Switch Operators Data Collection for 4th subject, who is an operator	~R+20 – post-flight BDC session (30 min)

# Preflight/Postflight BDC Session

## Baseline Data Collection (BDC) (30 minutes)

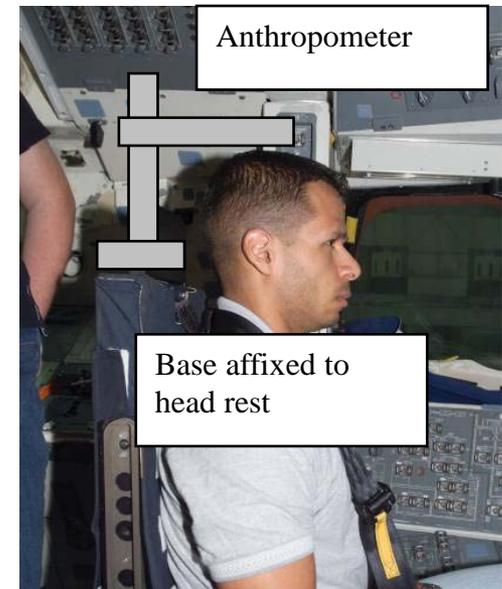
- Will take place at the Crew Compartment Trainer at JSC
- Session Flow:
  - Introduction and Overview
  - First sitting, adjustments
  - Data collection (photograph and anthropometric measurement)
  - Exit seat, stretch
  - Second sitting, adjustments
  - Data collection (photograph and anthropometric measurement)
  - Conclusion
  - Tips for best science collection for in orbit
- The Spinal BDC session occurs once preflight at any time after consent is obtained and once post-flight within 30 days of landing.



# In-Flight Session

In-Flight Data Collection (15 minutes **per subject**)

- Will take place on the Shuttle Flight deck, using the Commander seat
- Session Flow:
  1. Operator unstows equipment from ISS
  2. Anthropometer assembly setup on CDR seat on Shuttle
  3. Camera setup and configure
  4. Take photograph and downlink to ground for verification of experiment setup
  5. Subject setup into seat
  6. Operator collects and records photograph & anthropometric value
  7. Subject exits seat, stretches
  8. Subject re-enters seat
  9. Operator collects and records photograph & anthropometric value
  10. Take down camera setup and reconfigure
  11. Take down anthropometer setup
  12. Stow equipment on ISS



## In-Flight Session, cont'd

- Two rotations into the seat constitute a full session. (15 min per subject, 120 min for operator –assuming 4 participating subjects.)
- If the operator is also a subject, the backup operator will switch positions with the prime operator to collect data on the prime operator.
- This session can be performed at any point after 48 hours after entry into orbit.
- Only one session is required per subject, but multiple trials are highly desired.
- **Constraints:**
  - Subject should wear light-weight clothing
  - Do not take nominal Spinal Elongation measurements within 1 hour after compression exercise, or countermeasures (Penguin Suit, EVA, weight lifting, ARED, IRED, TVIS, etc.).
  - Crew member must not wear a Penguin suit before in-flight measurements are taken per this session.

Multi-use  
bracket assembly



Nikon D2XS camera

## Optional Science Sessions

-Seated height measurement after wearing a Penguin Suit or while wearing an Entry suit are also desired to show their effects but are not required. Performing such a session requires that an in-flight nominal session be performed first.

-Standing height measurements in the mid deck.

-For comparison to the seated height measure, to determine if standing height can be an indicator of spinal growth for seated height as well.

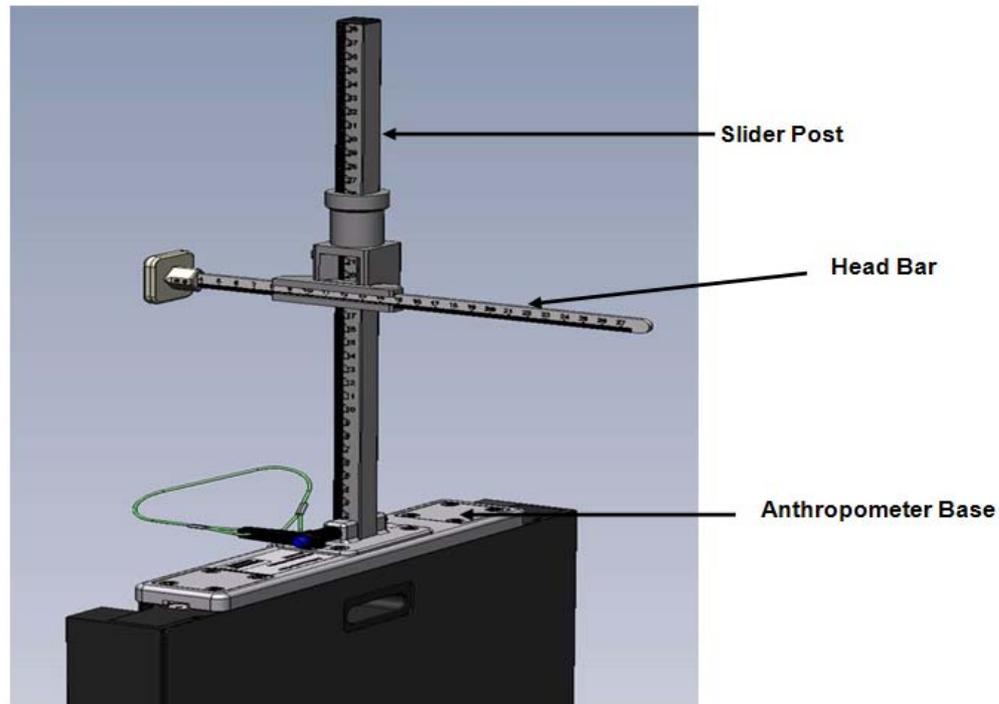
-Standing height is not yet validated as an acceptable means for judging seated height changes due to:

-the variation in each subject's torso and leg length.

-the lack of seated height and standing height measurement data in microgravity

# Spinal Hardware

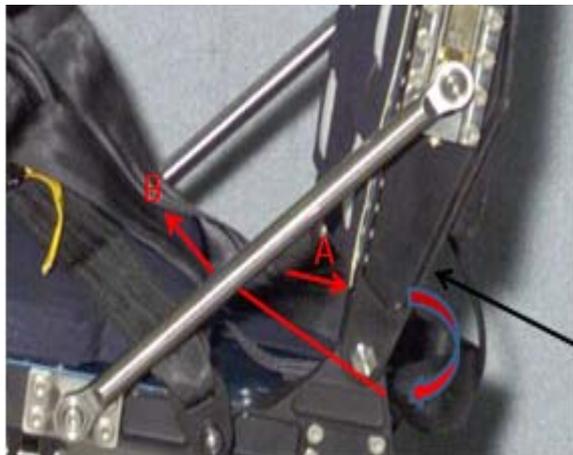
- Anthropometer
  - Scientifically calibrated device designed to take anthropometric measurements.
  - Previous studies utilized paper or other non-specific measurement methods that induce potential error into the reading.
  - The Spinal Anthropometer provides the ability to take data as consistently and as accurately as possible.



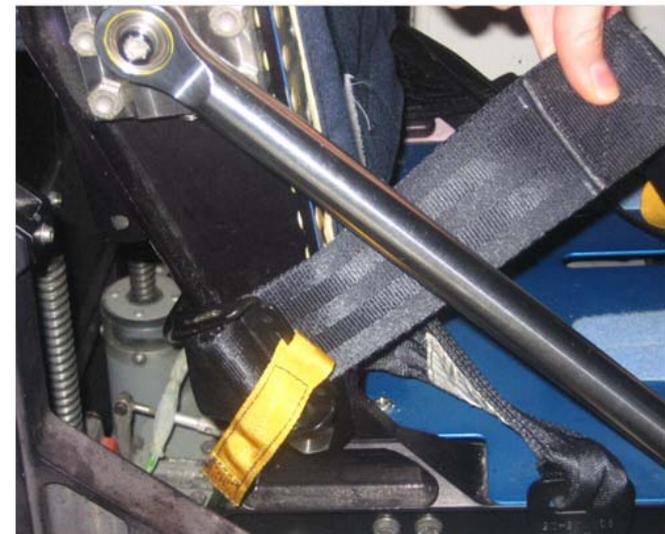
# Spinal Hardware

Restraint Method, modified use of the seat lap belt.

- Tested on Microgravity flights.
- Proven to minimize any error in height readings due to floatation.
- Additional restraint methods were investigated and were deemed unnecessary



Joint between seat  
and seat back (black  
metal frame)



# Experiment Training

<b>Session Title</b>	<b>Schedule</b>	<b>Duration</b>
Spinal Elongation Operator Task Training	~L-6 months	1.0 hours

**No training required for subjects only.**

# **Possible Risks or Discomforts**

## **Minimal/Reasonable Risk**

- The PI foresees only minimal risk and discomfort with these experimental protocols
- Some discomforts and risk will be a result of:
  - Adjustment to microgravity environment
  - Discomfort due to test setup
  - Care in placement of straight-edge and adjustment of lap restraints
- Protection to minimize risk: Ensure that the operator performs the measurement with caution, have subject position him/herself and provide feedback about the restraint comfort and anthropometer pressure against the top of his/her head.

# **Experiment Success**

The major mark of success for this experiment will be the collection of spinal elongation measurements to determine the percentage of spinal growth that occurs in microgravity for a seated posture. This data will then be used to update the Constellation Requirements Document (HSIR) and aid the CEV designers in the design of CEV and Constellation hardware.

## **Benefits**

- Additional data will allow HSIR (database of spinal length values) to be updated to reflect any changes as well as increase the level of confidence in the current requirement.
- Seated height data in microgravity is considered necessary to correctly identify the seated height projections of the crew in the Orion configuration.
- Correct projections of seated height should lead to
  - a) proper positioning of the seats within the vehicle;
  - b) maintaining adequate clearance for seat stroke in high acceleration impacts;
  - c) providing proper fit in seats;
  - d) proper placement of seats with respect to each other and the vehicle;
  - e) proper orientation to displays and controls.
- Additionally, data concerning the effects of spinal elongation on seated height would aid in the design of suit components, habitation requirements and tool specifications.

## **PI's Promise**

- The PI will control access to original data.
  - Secured-locked file storage
  - Password protected file storage on PC
- Anonymity of *all* crew members is ensured.
  - Data files will be immediately labeled with code known only to PI and Co-Investigators.
  - The PI will remove all names and references during coding that might permit attribution to a specific individual, crew, or ISS increment

**Thank You!**

**Sudhakar Rajulu, Ph.D**

Anthropometry and Biomechanics Facility

NASA, JSC

Office: 281-483-3725

Email: [Sudhakar.Rajulu-1@nasa.gov](mailto:Sudhakar.Rajulu-1@nasa.gov)