Sex and Gender in Spaceflight: How Far We Have Come in Research

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Focus on Human Health & Performance Risks

Research to Reduce Risk through Better Knowledge, Standards and Technologies

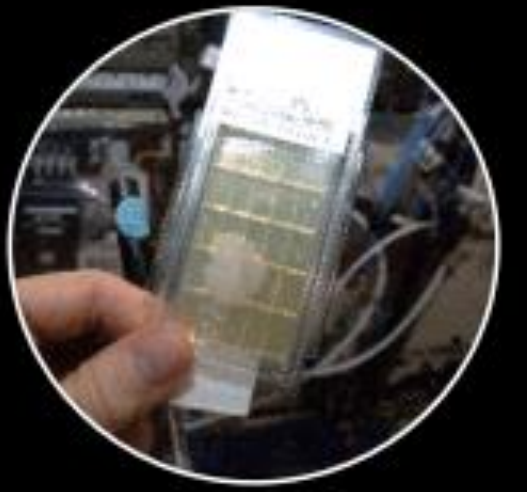
Radiation

Isolation & Confinement

Distance from Earth

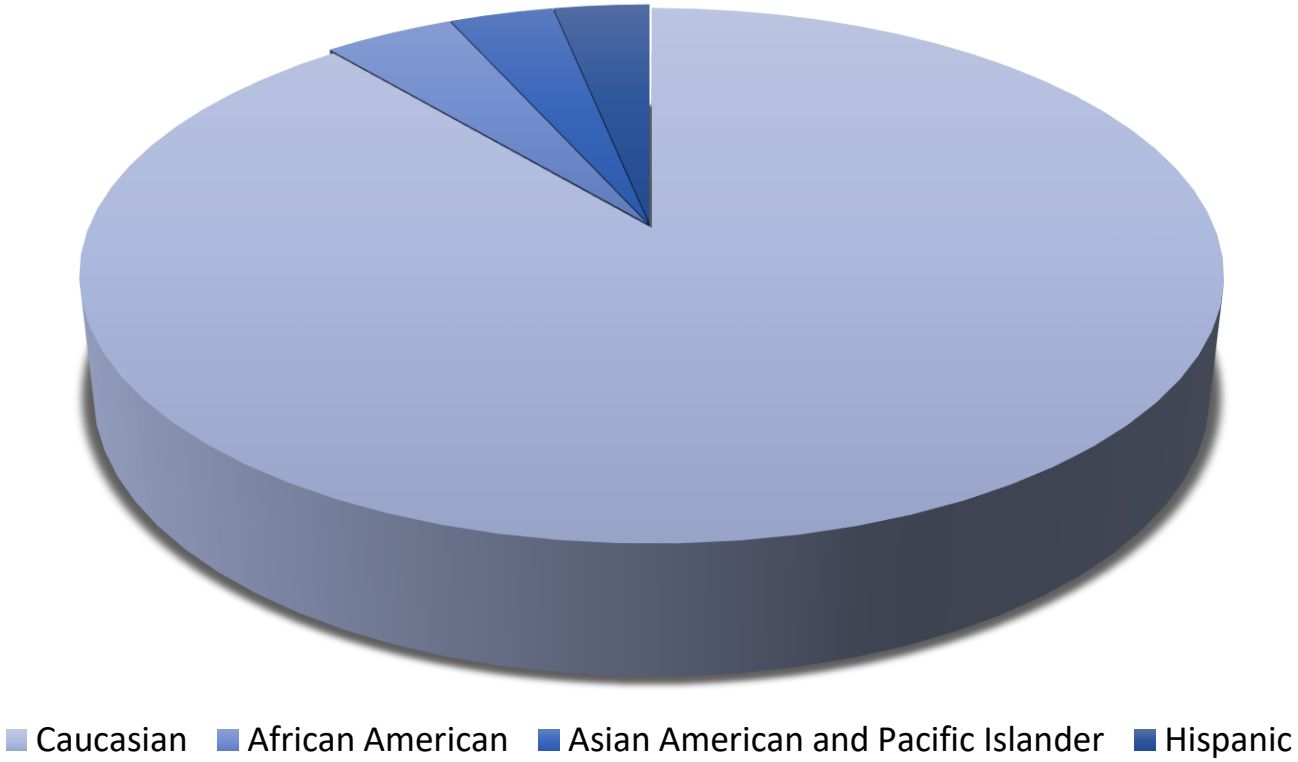
Gravity fields

Environments



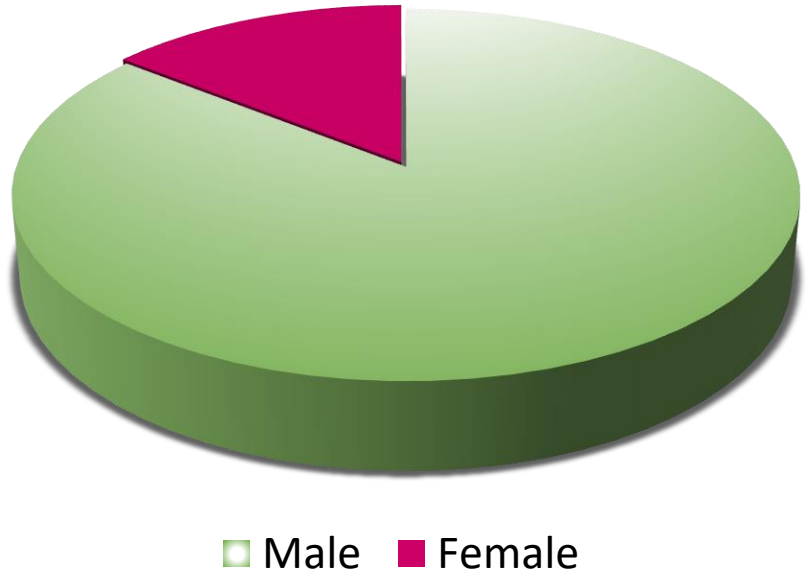
Phased Research

Who We're Sending to Space



Total	342
Caucasian	304
African American	15
Asian American and Pacific Islander	12
Hispanic	11

Total	342
Male	293
Female	49



The Effects of Space Flight on the Human Body

Human Space & Ground Analog Research Subjects

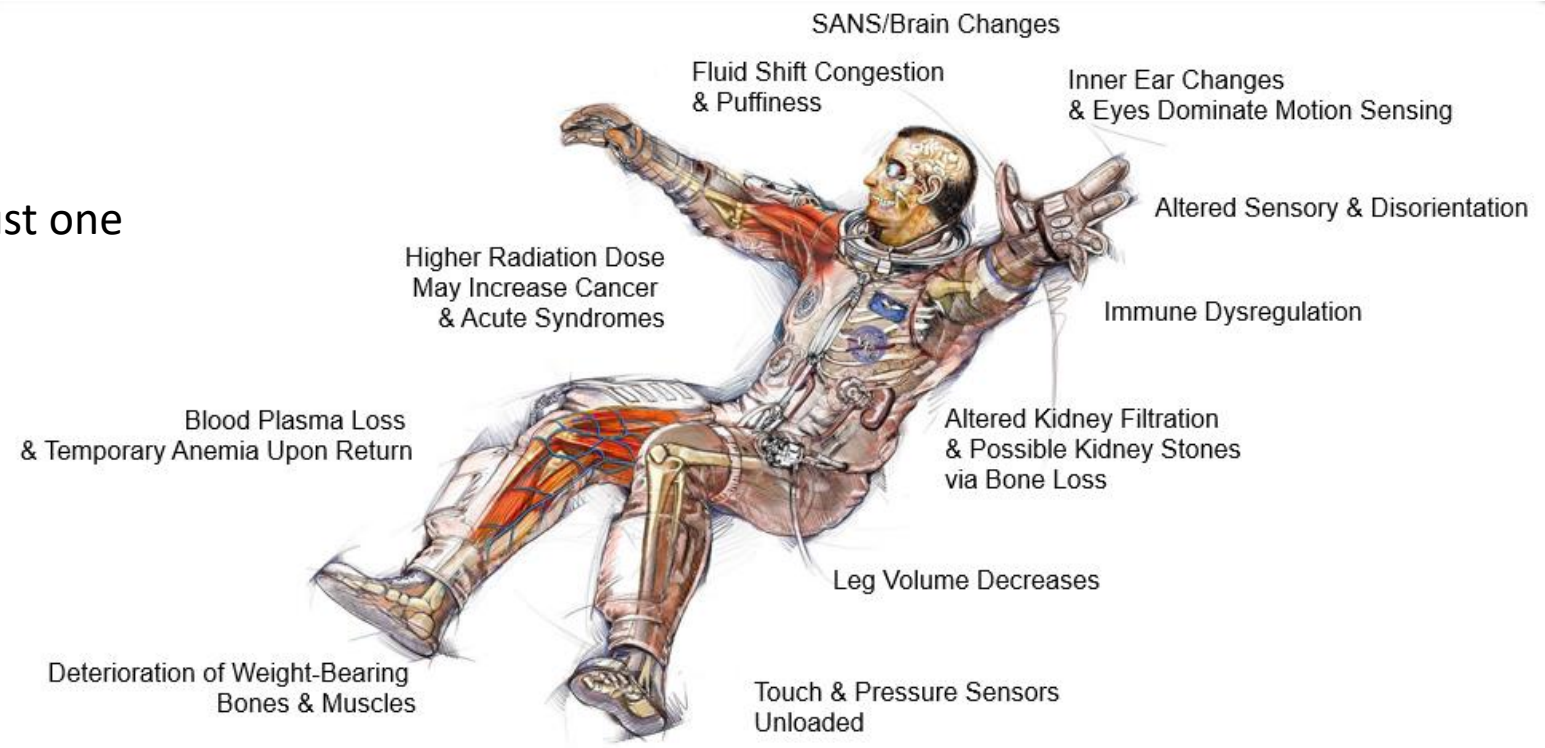
- Good Progress Towards Equal Male: Female
- Numbers Accumulate Slowly

Can Be Hard to Draw Conclusions

- Multiple Variables to Consider - Sex is just one
- Evolve As More Subjects
- Goal To Focus On "Individual"

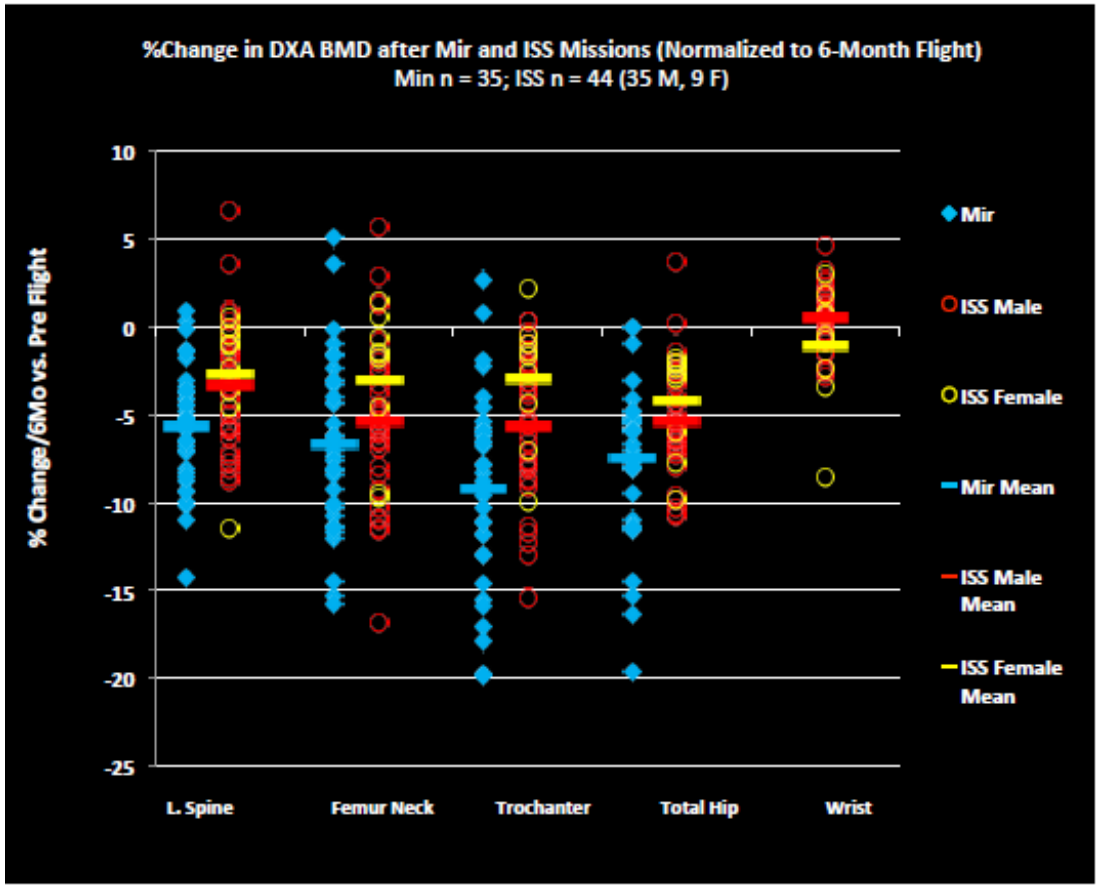
Exploring Role of Sex in Multiple Systems & Outcomes

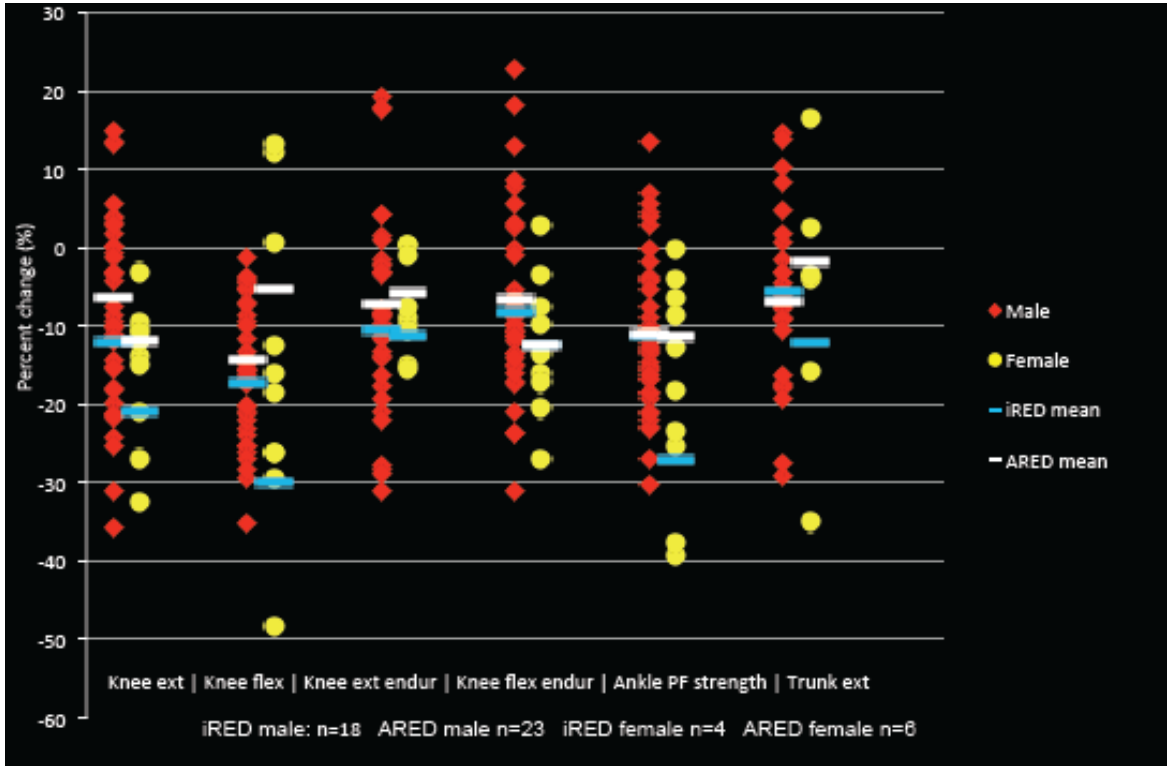
- Bone and Muscle
- Immune
- SANS
- Sensorimotor
- Cardiovascular & Orthostatic Intolerance
- Countermeasures



Bone and Muscle Changes in Space

HUGE Individual Variability In Bone & Muscle Change in Space
No Clear "Sex" Differences





Data courtesy NASA JSC Bone Lab, Exercise Physiology and Countermeasures Lab, and LSAH

Sex Differences in Immune Responses

Biological Sex Differences on Earth

- Women more robust immune system
- Great for fighting infection
- Increased risk autoimmune disorders

Antarctic Winter Over Studies

- Isolation and Confinement Space Analog
- No profound changes

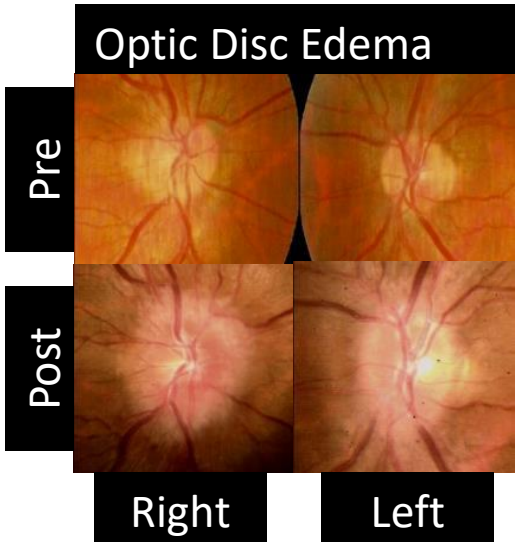
Spaceflight

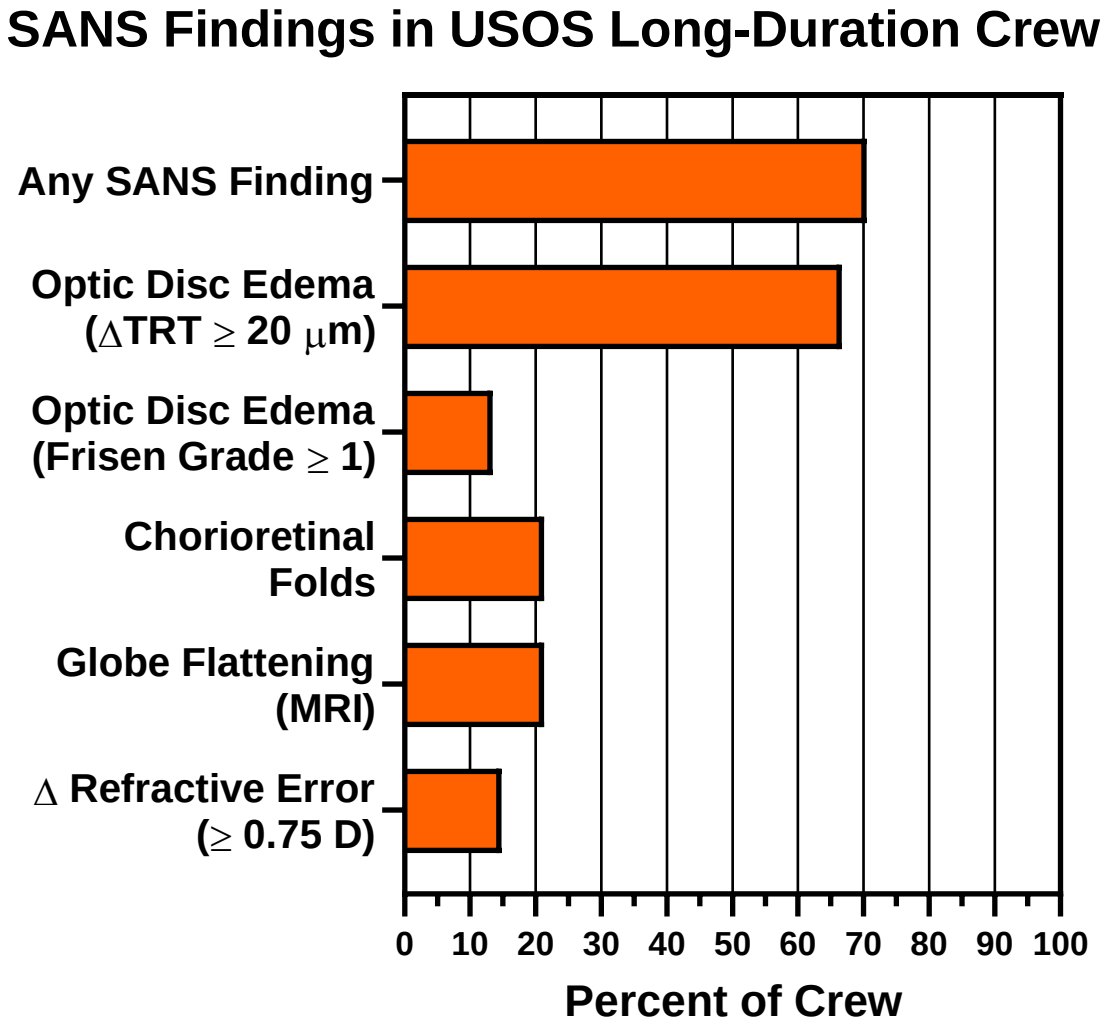
- Not enough women flown to make conclusions
- Upcoming: Data from Functional Immune space investigation

Spaceflight Associated Neuro-ocular Syndrome (SANS)

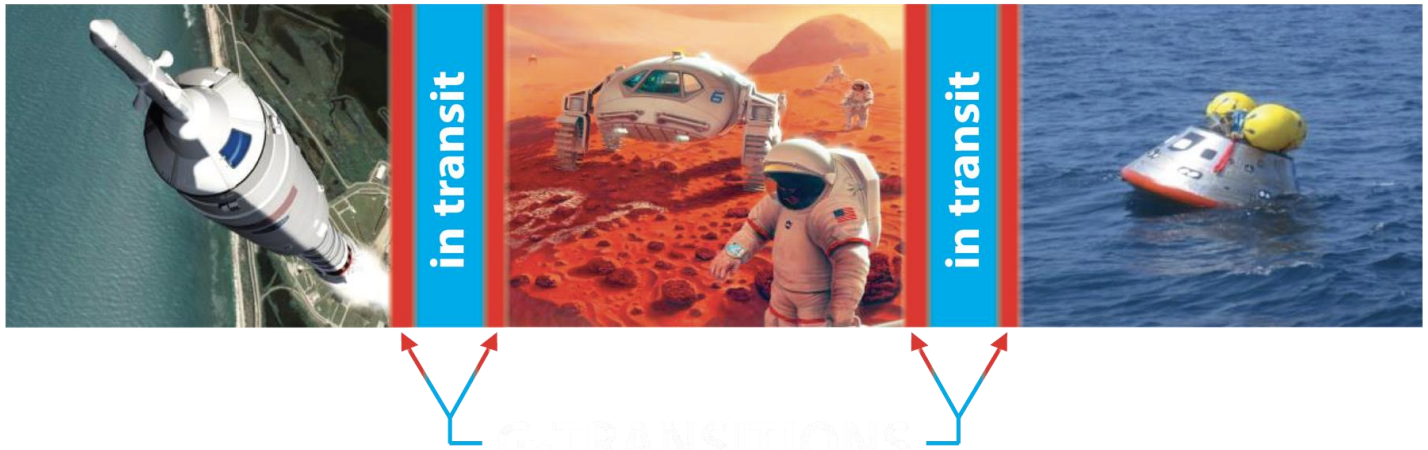
Objective Quantification of Optic Disc Edema

- Developed in both eyes and both sexes
- Women get SANS as severely as men





Sensorimotor Disturbances Caused by G-transitions



Human Health Issues

- Postural and gait instability
- Visual performance changes
- Manual control disruptions
- Spatial disorientation
- Motion sickness

Operational Impact

- Vehicle control
- Vehicle egress
- Planetary EVAs

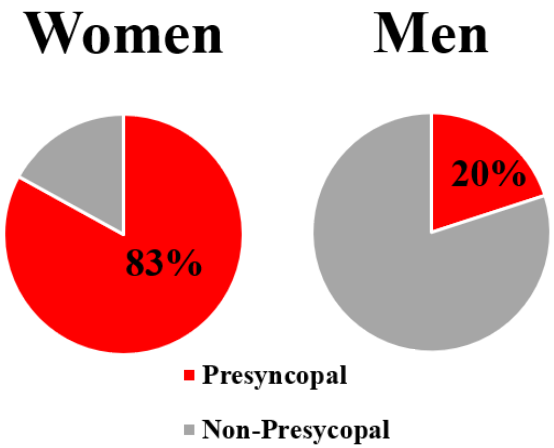
Postflight R+0 – Tandem Walk

Objective measures of symptoms show no consistent sex difference in peak score

Orthostatic Intolerance

Large % astronauts have Orthostatic Intolerance upon return to Earth's gravity

Women more affected than men



- **Compression garments:**
  - Mitigate in male astronauts
  - Fewer female astronauts studied
- **Artemis (Moon mission) crewmembers:**
  - Will also experience some G_z loads during ascent from the lunar surface
  - May pose an additional risk
- **Research planned:**
  - Assess sex differences at varying G-levels expected for crews
  - Determine if compression garments are effective in both sexes

Source: SpaceX

Source: NASA

Source: Stenger et al. 2013. Aviat Space Environ Med.

Countermeasures Development

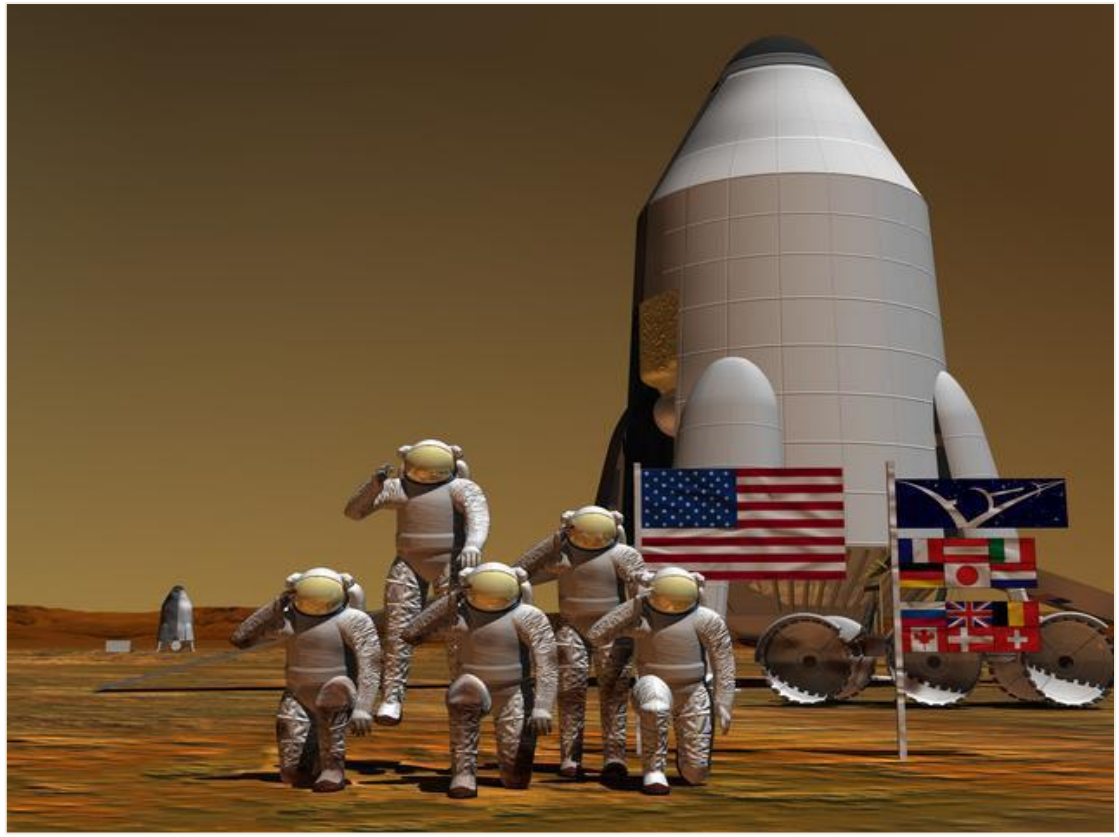
Lower Body Negative Pressure

Exercise

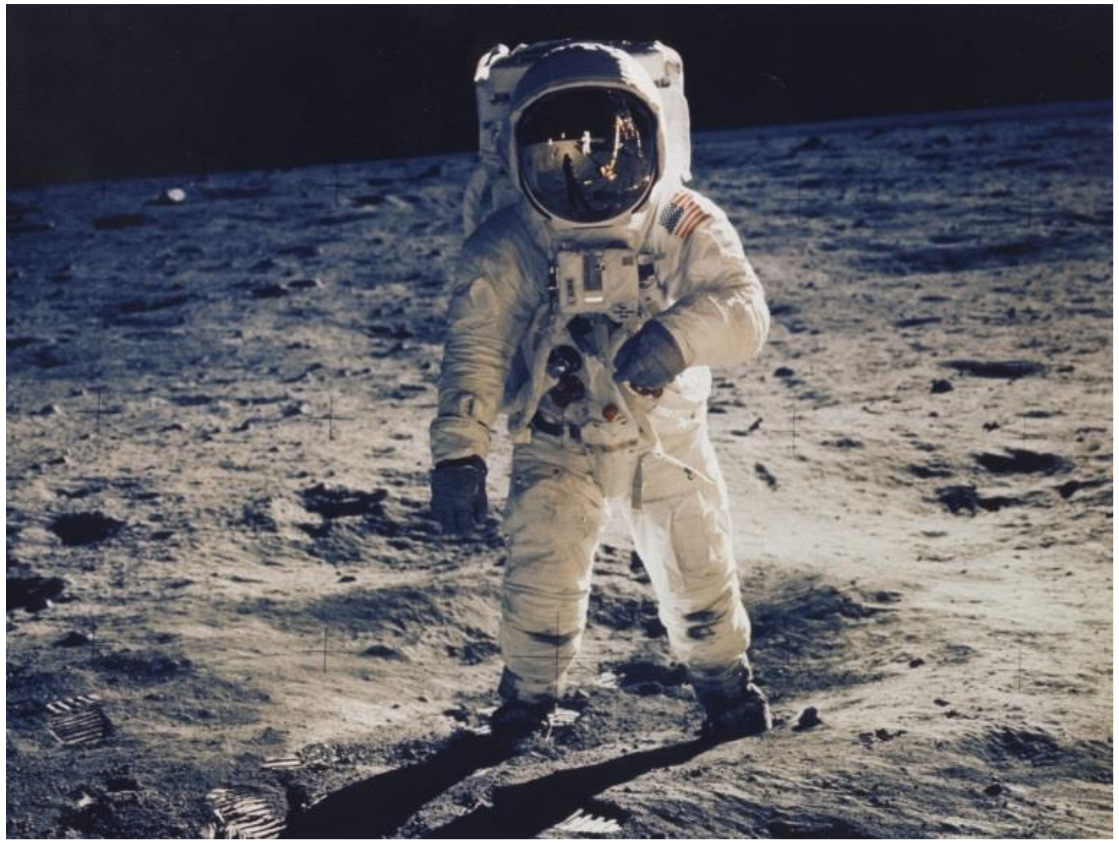
Nutrition/Behavioral Health

Informing Engineering & Operational Solutions

A Habitable Habitat



A Suitable Suit



Space Radiation

Different Levels, Energy & Type in Space

- Galactic Cosmic Radiation
- Trapped Radiation
- Solar Energetic Particles

Major HRP Risk Focus – Biological Sex Research as Current Work

- Carcinogenesis
- Cardiovascular
- CNS

Other Past & Current Topics Related to Sex

- Long term fertility – Other factors currently greater issue
- Radiation Standard Change – One for all
- Underlying DNA Susceptibility – Individual susceptibility high priority research

Earth Independence: Autonomous Medical Systems

- **No Real Time Communications**
- **No Consumables Resupply**
- **No Evacuation Capability**

Medical Incidences Model

- Individual Risk Factors
- Includes tracking sex-related issues
- Potentially Identify unexpected sex differences

Informs Operations

- Pharmaceuticals & Other Personal & Medical Kit Items
- Equipment & Training
- Precision health approach

rHealthOne

Autonomous Medical Officer Support (Amos)

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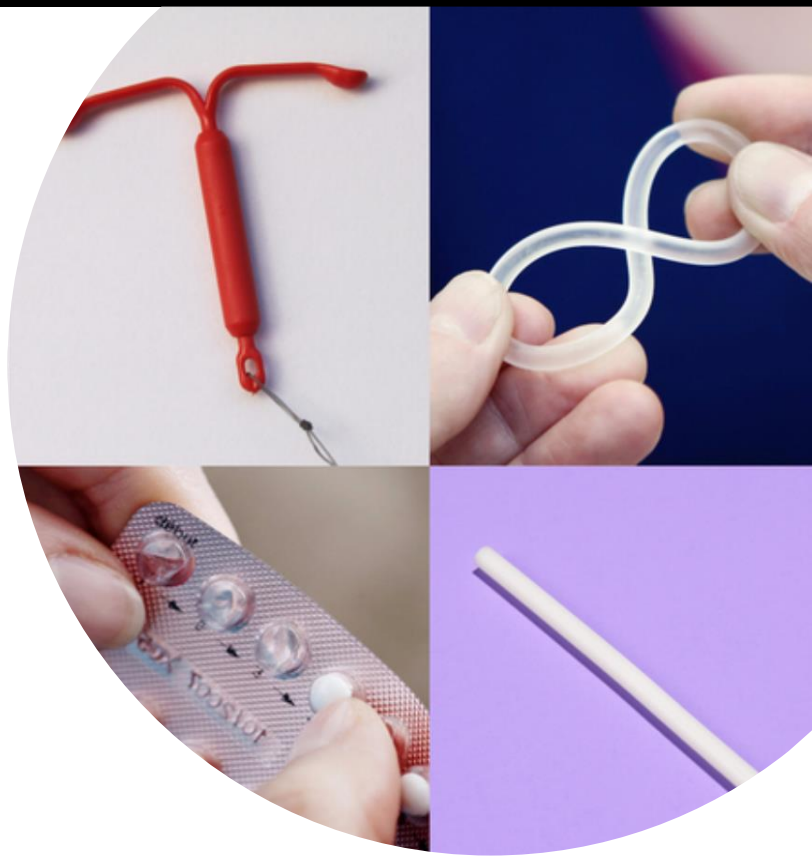
Fertility and Pregnancy



Preventing Pregnancy Inflight

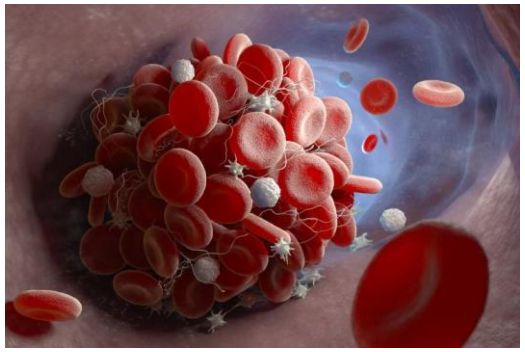
- Contraceptives, but risk of pregnancy inflight > 0%
- Routine pregnancy testing; final preflight pregnancy test ~10 days pre-flight
- Scant data from animals about pregnancy in space

Fertility & Development Concerns

- Pre-flight reproductive counseling/egg freezing
- Discerning spaceflight fertility risks vs. advanced maternal age
- Fertility outcomes not yet robustly studied post-flight
- Scant data from animals about development in space

Venous Thrombosis

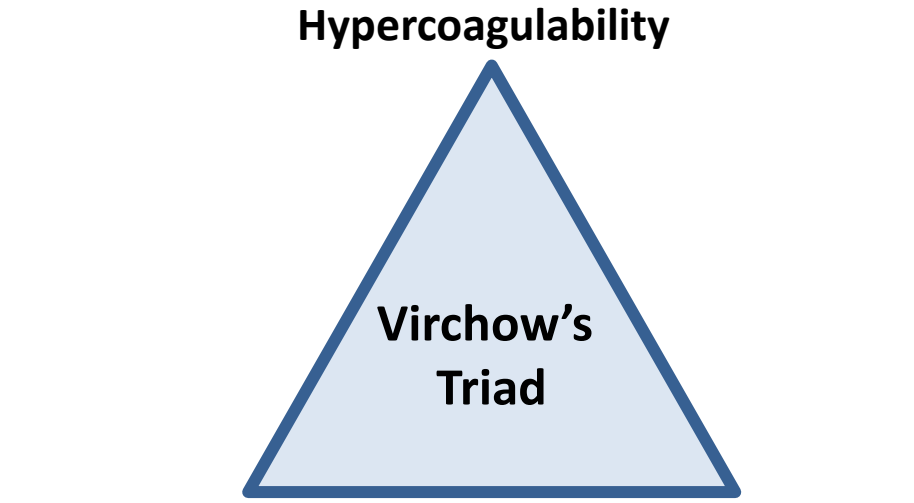
Source: NASA



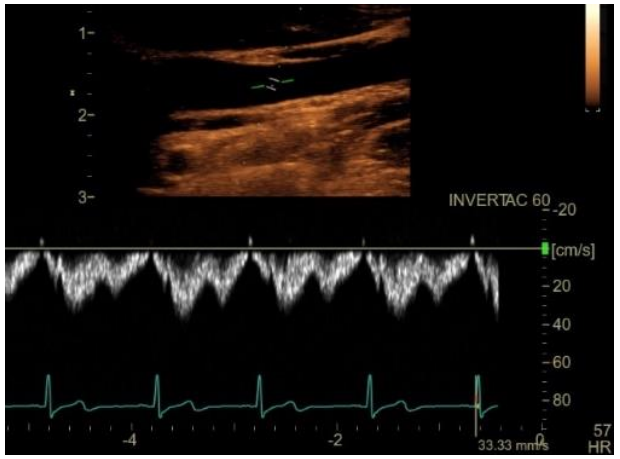
Source: NIH-NHLBI

Ultrasound imaging to detect venous thrombosis (blood clot)

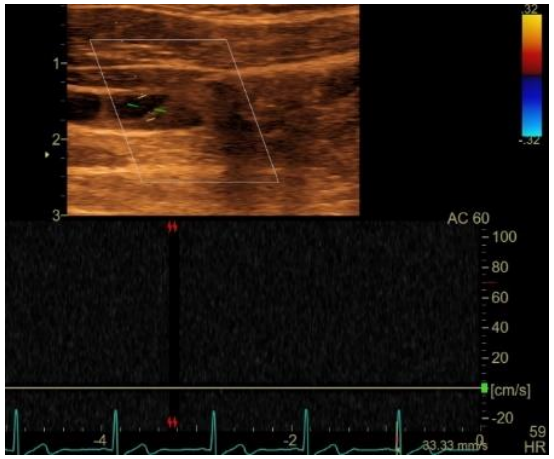
- First venous thrombosis during spaceflight detected recently left internal jugular vein (Marshall-Goebel et al., JAMA Ntwk, 2019)
- Key risk factors for development: hypercoagulability, flow stasis, and vessel injury
- Oral contraceptives historically used by female crew for menstrual suppression known to increase hypercoagulability and thus thrombosis* risk



Preflight



Inflight



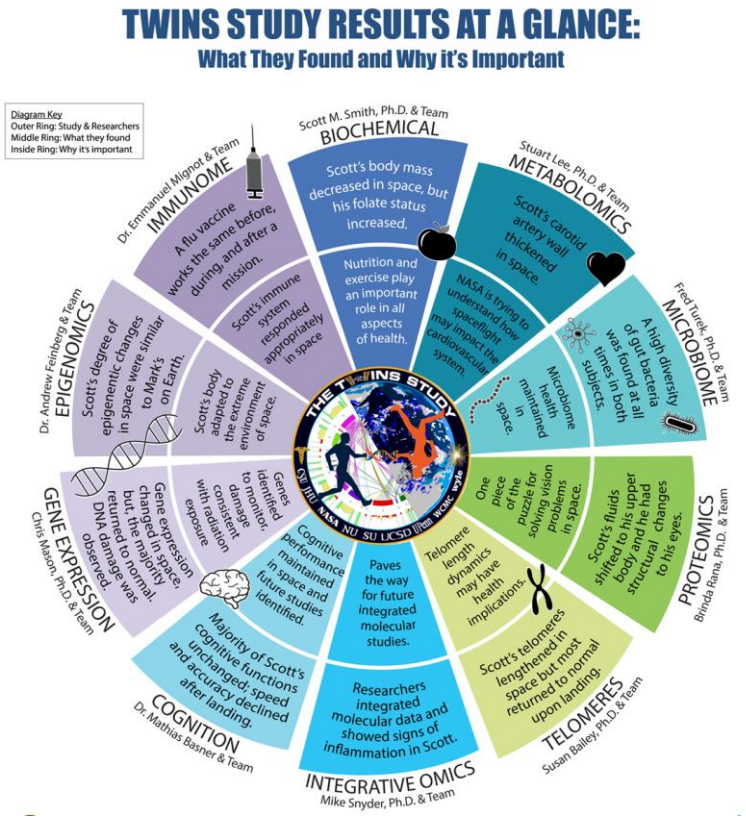
*Terrestrial risk on contraceptive hormonal therapy = 0.7-1.2% (4-6x increase from baseline)

Behavioral Health & Team Dynamics

- **Space, Antarctic and Ground Analogs Data**
- **Take Homes:**
  - Lack of data on women, but improving
  - Multiple factors beyond biological sex to consider
  - If different biologically, may not be relevant to performance outcome

- *Circadian Rhythms and Sleep*
- *Cognitive/Performance*
- *Stress, Anxiety, Depression*
- *Brain*
- *Team & Individual Behavior during Isolation and Confinement*
- *Crew Selection*
- *Family Issues*

Consistent Measures from ALL Participating Astronauts



Complement of Integrated Protocols for Human Exploration Research

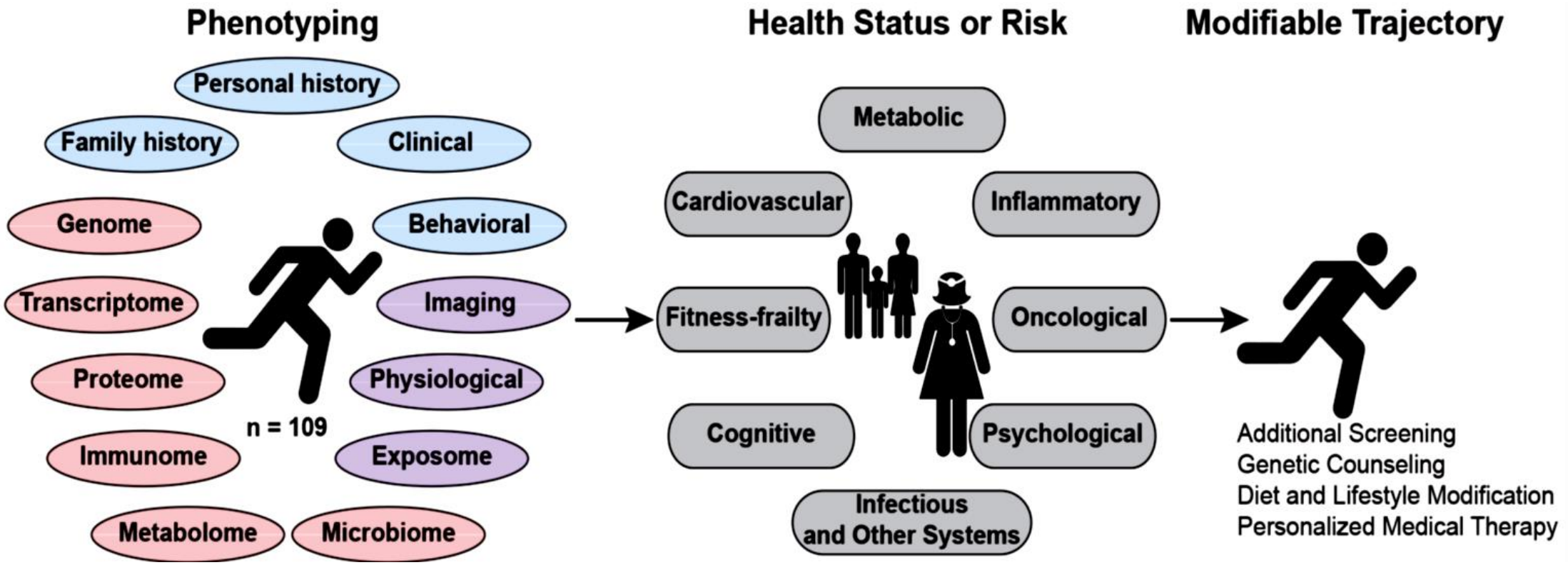
(CIPHER) Single Research Complement of Science Measures across disciplines for multiple times on ISS

6 weeks 6 months 1 year

Precision Health Initiative: Focus on Individuals

Detailed molecular, clinical and performance measures + integrated analyses →

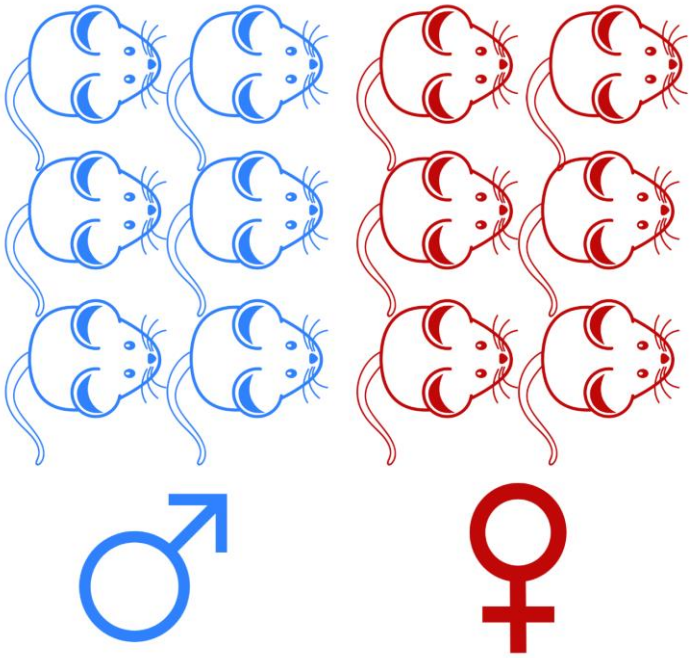
Draw conclusions about **individual's** response to environment, diet, medications, etc.



Rose, SM S-F, Contrepois, K, Moneghetti, KJ, et al. A Longitudinal Big Data Approach for Precision Health, **Nat Med.** 2019 May ; 25(5): 792–804. doi:10.1038/s41591-019-0414-6.

Sex and Gender Balance in Research & Language

Research 50:50 male : female

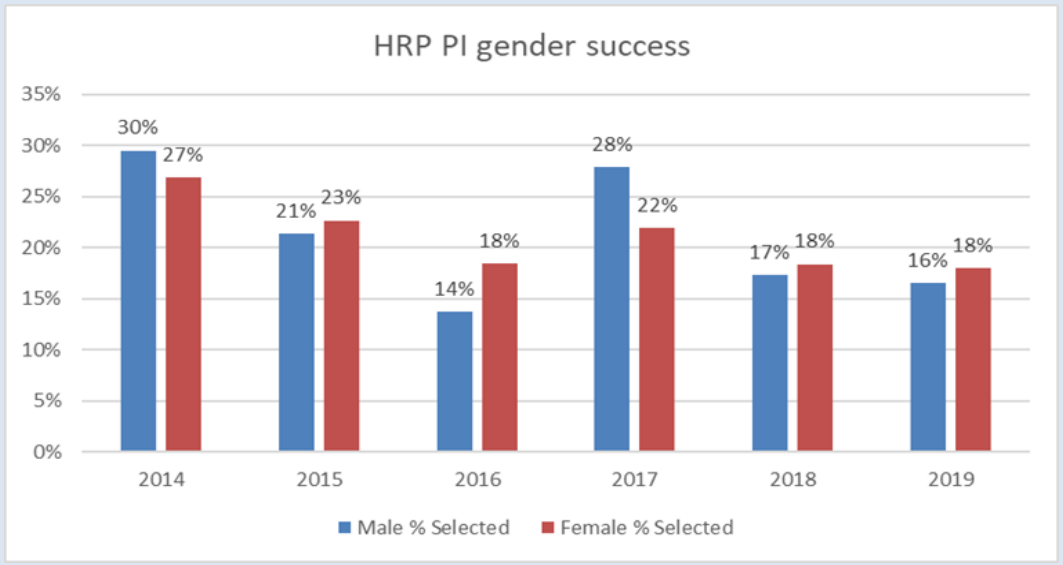


Research and document language “neutral”

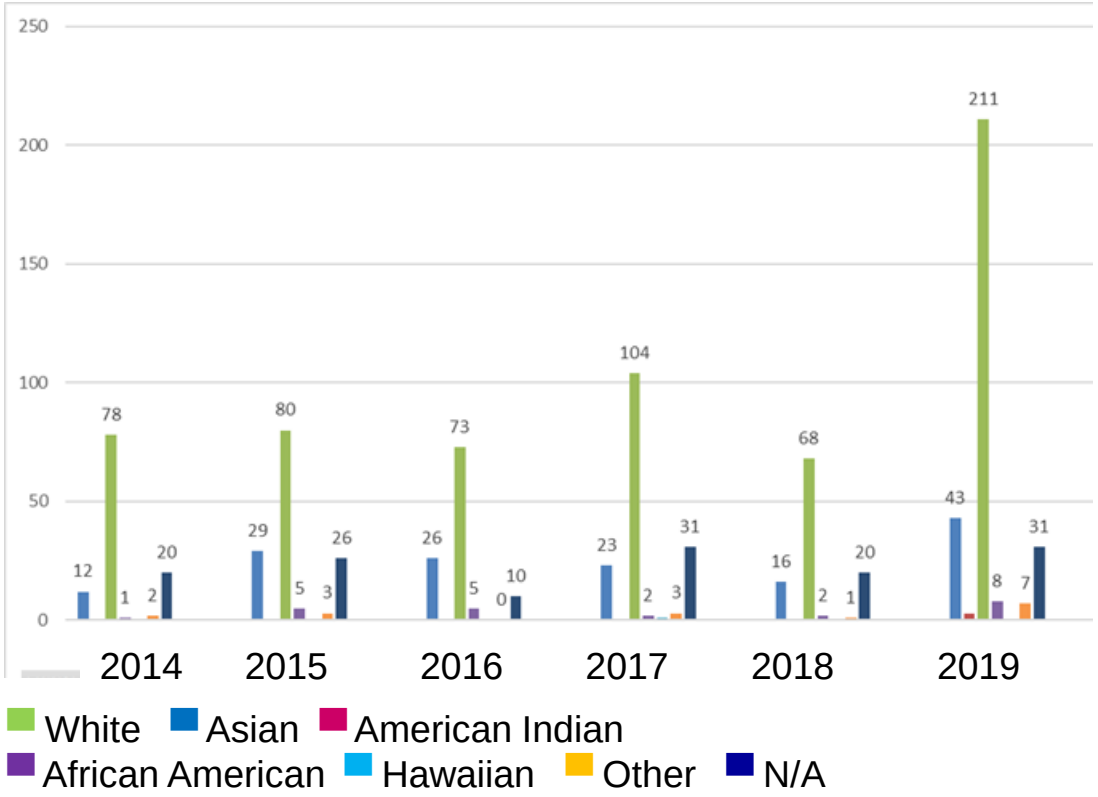
HRP Investigator Gender & Race

(Binary) PI Gender – Submitted Proposals

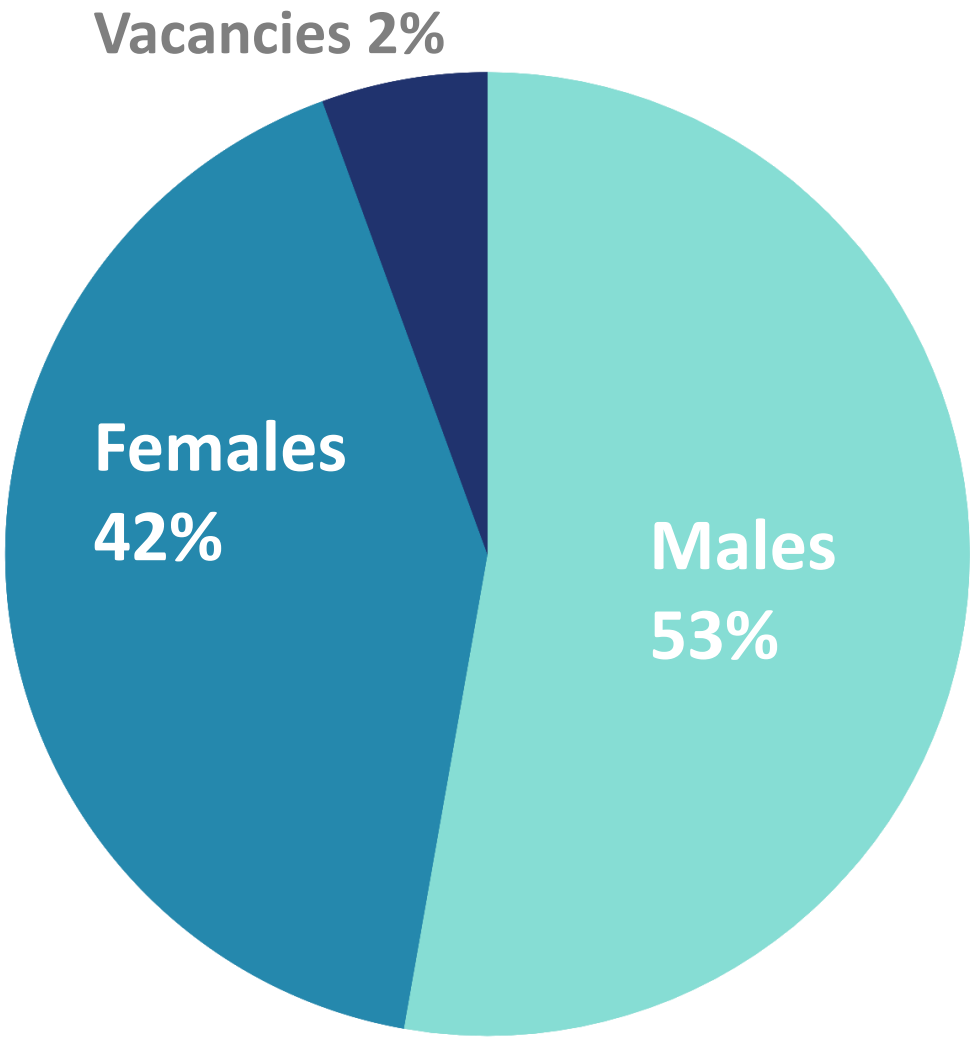
Proposal Success



HRP Investigator Race



HRP Leadership in 2021



36 positions = 15 women + 19 men + 2 vacancies

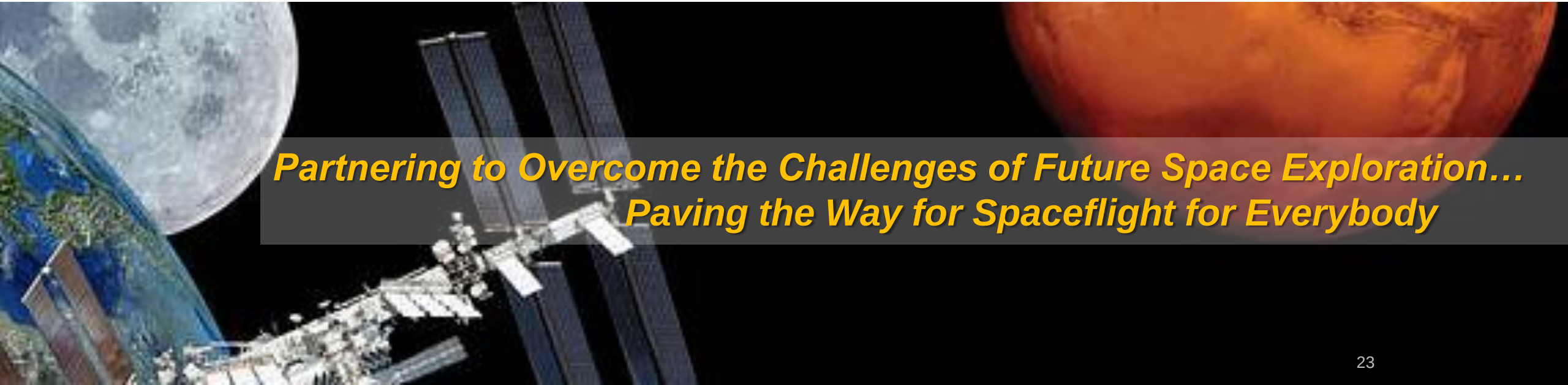
Concluding Remarks

Addressed 2014 Recommendations

- Equal sex representation
- Focus on individual health/performance issues
- Attended to multiple variables and small subject number prior to drawing conclusions
- Inclusive language

Future directions

- Experiments in progress to get more data on women
- More inclusion of women's health issues
- Enhanced diversity HRP leadership, investigators, advisors, and reviewers
- Collaboration with commercial space programs, with greater diverse populations and data collection
- Treating each astronaut as an individual, which includes all aspects of diversity



Partnering to Overcome the Challenges of Future Space Exploration…
Paving the Way for Spaceflight for Everybody

HRP Acknowledgements

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