The Lifetime Surveillance of Astronaut Health

NEWSLETTER

October 2022 | Vol 27 Issue 2

Editor's Note

BY **RONNIE RAFANAN**

We have a new look! In an effort to increase the online readability of the Lifetime Surveillance of Astronaut Health (LSAH) Newsletter, we've modified the format in which you view and access content. Please enjoy the new graphics and theme and be sure to let us know how you like the changes!

In this Issue...

SPACE MEDICINE OPERATIONS DIVISION

NASA JSC

Meet Dr. Jacqueline Charvat

BY **MARY WEAR, PhD**

LSAH would like to introduce you to our Senior Epidemiologist, Dr. Jacqueline (Jackie) Charvat. Jackie has been with the LSAH team for over ten years after moving to Houston from Ohio. Jackie earned a Bachelor of Science in Athletic Training with an emphasis in Exercise Physiology from Ohio University and a Master of Science as well as a PhD in Epidemiology from Case Western Reserve University. Before coming to NASA, Jackie managed several large research projects, including increasing exercise in adults with a history of cardiovascular disease and interventions for obesity and high blood pressure in youth.

As the LSAH Senior Epidemiologist, Jackie wears several hats. She is our subject matter expert for several disciplines, including cardiovascular disease, thromboembolism, and cancer. She conducts statistical analysis and represents the epidemiology perspective at various NASA boards. In addition to her subject matter expertise, Jackie is a strong mentor to other LSAH epidemiologists, which she finds to be one of the most rewarding parts of her job. (See full article on page 4)

What is Occupational Surveillance?

BY **RONNIE RAFANAN**

As defined by the National Institute for Occupational Safety and Health (NIOSH), "Occupational health surveillance can be viewed as the tracking of occupational injuries, illnesses, hazards, and exposures. Occupational surveillance data are used to guide efforts to improve worker safety and health, and to monitor trends and progress over time."

The Lifetime Surveillance of Astronaut Health (LSAH) collects, analyzes, and interprets medical, physiological, hazard exposure, and environmental data for the purpose of maintaining astronaut health and safety as well as preventing occupationally induced injuries or disease related to space flight or space flight training. It allows NASA to effectively understand and mitigate the long-term health risks of human spaceflight, as well as support the physical and mental well-being of astronauts during future exploration missions. (See full article on page 6)

Identifying
Comparable Cohorts, Building Relationships, & Understanding Astronaut Health

BY **JACQUELINE CHARVAT, PhD**

Lifetime Surveillance of Astronaut Health recently published work comparing the US Astronaut Corps to a non-astronaut cohort, the Cooper Center Longitudinal Study. This study focused on the risk of cardiovascular disease (CVD), such as heart attack and stroke, in astronauts across their lifespan. LSAH epidemiologists evaluated 10 different cohorts from across the US, with the Cooper Center Longitudinal Study (CCLS), housed at the Cooper Institute in Dallas, Texas, chosen as a comparator. Five CCLS participants were included for every astronaut who had completed a spaceflight by the end of the study period. Results of this study showed there was a slight increased risk of non-fatal CVD events in astronauts.

While this study was unable to tease apart whether specific spaceflight exposures impacted CVD risk, it is an initial step in helping us understand the lifetime risk to our crewmembers. (See full article on page 7)

Approaching the Question:

Is SANS Pathological or a Normal Adaptation to Spaceflight?

BY **TAYMA MACHKHAS, B.S.**

As NASA focuses on the Artemis program to return to the Moon and prepare for Mars, understanding conditions that could negatively impact crew during long-term missions is critical to mission success. One of these conditions, Space-Associated Neuro-Ocular Syndrome (SANS), is a constellation of findings that are not well understood. Two major questions are asked about SANS: 1) What is normal for spaceflight and 2) Which clinical SANS findings are true pathology compared to normal adaptation to spaceflight?

To begin the process of determining the pathological threshold of SANS, the LSAH occupational surveillance program began a review of neurological and vision terrestrial cohorts. Out of 358 cohorts, the systematic review yielded 35 potential studies of healthy populations with ocular outcomes obtained through testing similar to specialized SANS testing. Future work includes accessing and processing the data of promising neurological and vision cohorts. Results from these proposed comparison studies of terrestrial cohorts will enhance the understanding of the spectrum of findings that describe SANS. (See full article on page 9)

IMPALA's Body System Model Helps Address Health Risks in Spaceflight

BY **DEVAN PETERSEN, MPH**

As described in LSAH Newsletter Volume 27 Issue 1, the IMPALA team has successfully ingested data from 18 different sources into the IMPALA platform. Now the IMPALA team is focused on organizing the data into clean tables that are easily accessible and understandable by the user and creating dashboards to allow users to access and interact with data in IMPALA. The IMPALA platform is also utilized to help inform NASA's risk posture at the Human Systems Risk Board and helps to answer NASA's operational questions and any other data requests.

Overall, IMPALA allows users to have access to a common reservoir of transformed and organized data for exploration and analysis, helping the astronaut corps by supporting risk management and operational decisions. (See full article on page 11)

Unlocking How **HUMAN BODIES** Will React to Long Journeys Into **SPACE**

BY **NATHAN CRANFORD**

Active astronauts can now volunteer for a suite of experiments that aim to help scientists learn more about how extended missions impact the human body. Together, these experiments are called the Complement of Integrated Protocols for Human Exploration Research, or CIPHER. Through CIPHER, astronauts participate in an integrated set of 14 studies sponsored by NASA and international partner agencies. To get meaningful results, CIPHER scientists will target as many as 30 astronauts, evenly divided over short, standard, and extended missions.

In addition to answering research questions central to each study, CIPHER takes an integrated approach. All data from across CIPHER investigations will be pooled to identify patterns and gain a deeper understanding of how the body reacts to long durations in space. (See full article on page 14)

Meet
Dr. Jacqueline Charvat

BY **MARY WEAR, PhD**

LSAH would like to introduce you to our Senior Epidemiologist, Dr. Jacqueline (Jackie) Charvat. Jackie has been with the LSAH team for over ten years after moving to Houston from Ohio. Jackie earned a Bachelor of Science in Athletic Training with an emphasis in Exercise Physiology from Ohio University and a Master of Science as well as a PhD in Epidemiology from Case Western Reserve University. Before coming to NASA, Jackie managed several large research projects, including increasing exercise in adults with a history of cardiovascular disease and interventions for obesity and high blood pressure in youth. Jackie was attracted to epidemiology at NASA due to her lifelong interest in the space program. She said, "As a child every summer I wanted to go to space camp but never had the chance. Now, I get to go to space camp every day as part of my job!"

As the LSAH Senior Epidemiologist, Jackie wears several hats. She is our subject matter expert for several disciplines, including cardiovascular disease, thromboembolism, and cancer. She conducts statistical analysis and represents the epidemiology perspective at various NASA boards. She designed and conducted a study of cardiovascular disease in the US astronaut corps (1) that was recently published in the journal Mayo Clinic Proceedings and is being promoted on the Cooper Institute website (Out of This World: What Is the Long-Term Heart Health of NASA Astronauts? [cooperinstitute.org]). Jackie has also co-authored several scientific publications on occupational health in the astronaut corps (2,3,4).

As our cancer epidemiologist, Jackie created a NASA Cancer Registry to systematically collect information allowing for tracking of cancer cases and for understanding astronauts' unique risk factors for cancer, such as time spent in space and piloting. The NASA Cancer Registry enables easy analysis of cancer incidence and prevalence to understand the disease in our population. She also regularly provides briefings on the incidence of cancer morbidity and mortality in the NASA astronaut corps to various groups such as the Space Radiation Research and Clinical Advisory Panel (RCAP) and the National Academies of Sciences, Engineering and Medicine.

Jackie works closely with NASA pharmacists and pharmacologists to understand in-flight medication use onboard the International Space Station, specifically evaluating if medications are being prescribed in proper doses and frequency as well as the effectiveness of medication for the given indication. Jackie implemented IMPALA natural language processing to create an extensive database of medication use records. This is the first time medication use has been compiled from multiple sources to create a single database. Medication use is an important variable for understanding disease processes, so this database is frequently used to support operational and research questions. In addition to her subject matter expertise, Jackie is a strong mentor to other LSAH epidemiologists, which she finds to be one of the most rewarding parts of her job. "Seeing your colleagues excel

and knowing you played a part no matter how small always feels great." She frequently leads the epidemiology community of practice within the group as well as a writing group. She mentors participants in the Aerospace Medicine Clerkship, comprised of medical students and residents who want to learn more about aerospace medicine at NASA. She also mentors for the Space Life Sciences Summer Internship program, wherein college students spend their summer at JSC learning how humans change when they journey to space.

Jackie enjoys the art and science of occupational surveillance and medical research. "I look forward to learning more about the human after they venture to space and what life holds for them as they age."

ATTENTION!

Ongoing occupational surveillance and research benefits from the use of **YOUR DATA** in the LSAH/LSDA Repositories!

If you are attending the astronaut reunion and would like to meet with LSAH regarding participation in these repositories, please contact Ruth Reitzel (ruth.a.reitzel@nasa.gov).

To read more of Jackie's work

1. Charvat JM, Leonard D, Barlow CE, DeFina LF, Willis BL, Lee SMC, Stenger MB, Mercaldo SF, Van Baalen M. Long-term Cardiovascular Risk in Astronauts: Comparing NASA Mission Astronauts With a Healthy Cohort From the Cooper Center Longitudinal Study. Mayo Clin Proc. 2022 Jul;97(7):1237-1246. https://doi.org/10.1016/j.mayocp.2022.04.003. PMID: 35787853

2. Reid CR, Charvat JM, Mcfarland SM, Norcross JR, Benson E, England S, Rajulu S. Modeling Occupational Fingernail Onycholysis Disorders in the Population of US Astronauts Who Have Engaged in Extravehicular Activity. Hum Factors. 2021 Dec 27:187208211062299. https://doi.org/10.1177/00187208211062299. PMID: 34961336

3. Jain V, Ploutz-Snyder R, Young M, Charvat JM, Wotring VE. Potential Venous Thromboembolism Risk in Female Astronauts. Aerosp Med Hum Perform. 2020 May 1;91(5):432-439. https://doi.org/10.3357/AMHP.5458.2020. PMID: 32327017

4. Ade CJ, Broxterman RM, Charvat JM, Barstow TJ. Incidence Rate of Cardiovascular Disease End Points in the National Aeronautics and Space Administration Astronaut Corps. J Am Heart Assoc. 2017 Aug 7;6(8):e005564. https://doi.org/10.1161/JAHA.117.005564. PMID: 28784652

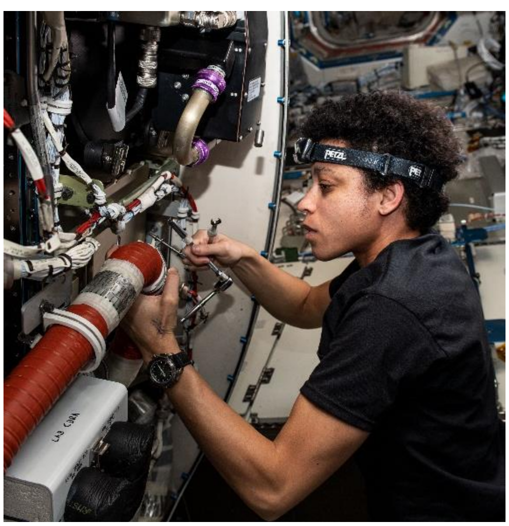
What is
Occupational Surveillance?

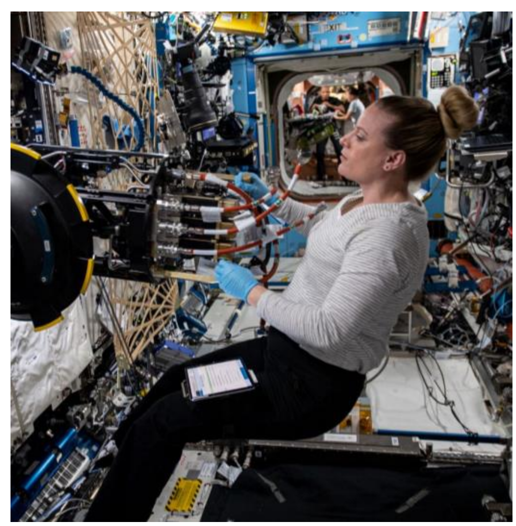
BY **RONNIE RAFANAN**

As defined by the National Institute for Occupational Safety and Health (NIOSH), "Occupational health surveillance can be viewed as the tracking of occupational injuries, illnesses, hazards, and exposures. Occupational surveillance data are used to guide efforts to improve worker safety and health, and to monitor trends and progress over time. Surveillance includes both population- or group-based activities and individual-based activities."

In accordance with the NASA Transition Authorization Act of 2017, the "To Research, Evaluate, Assess, and Treat (TREAT) Astronauts Act" authorizes NASA to monitor, diagnose, and treat conditions in astronauts associated with spaceflight. NASA's Occupational Surveillance program is conducted throughout an astronaut's life, beginning with the selection into the astronaut corps, throughout space flight, and into retirement. To maintain current and continued data on non-active and former astronauts, data collection is accomplished by means of invitational, periodic, physical examinations conducted at Johnson Space Center (JSC).

The Lifetime Surveillance of Astronaut Health (LSAH) collects, analyzes, and interprets medical, physiological, hazard exposure, and environmental data for the purpose of maintaining astronaut health and safety as well as preventing occupationally induced injuries or disease related to space flight or space flight training. It allows NASA to effectively understand and mitigate the long-term health risks of human spaceflight, as well as support the physical and mental well-being of astronauts during future exploration missions.





Identifying

Comparable Cohorts, Building Relationships, & Understanding Astronaut Health

BY **JACQUELINE CHARVAT, PhD**

In the first of its kind, LSAH recently published work comparing the US Astronaut Corps to an outside cohort, the Cooper Center Longitudinal Study. This study focused on the risk of cardiovascular disease (CVD), such as heart attack and stroke, in astronauts across their lifespan. The risk of CVD among astronauts may be high due to their stressful occupation and changes in sleep patterns over their lifetime, along with unique spaceflight exposures such as radiation.

Identifying comparable cohorts has been a quest for LSAH over the last several years. Most data collected by the US government through the National Health and Nutrition Examination Survey (NHANES) and the Surveillance, Epidemiology, and End Results Program (SEER) is representative of the general US population, people who are not necessarily representative of the astronauts. Astronauts are selected based on numerous health factors (or lack thereof), education status, and highly specific skills. Further, astronauts need to maintain exemplary physical health to complete their job and vice versa: doing their job (and receiving excellent health care) helps them stay healthy, a phenomenon known as the healthy worker effect. While the healthy worker effect is found in other occupations, it is definitely present in astronauts due to rigorous medical selection standards and the ongoing focus on maintaining physical health in order to perform strenuous training and spaceflight. With over 60 years of data on the first astronauts, it is necessary to find cohorts that also have data that dates back to ensure similarities in lifestyle and the practice of medicine. For instance, the use of statins for controlling cholesterol levels began in the early 2000s and changed the cardiovascular risk profile of many Americans, including astronauts.

LSAH epidemiologists evaluated 10 different cohorts from across the US, many coming from large research studies (e.g., Multiethnic Study of Atherosclerosis (MESA), the Prospective, Army Coronary Artery Calcium Study, Coronary Artery Risk Development in Young Adults Study (CARDIA)), as well as the military (e.g., the US Air Force and the

Millennium Cohort). Each possible cohort was evaluated for types of data collected, from whom the data was collected based on typical characteristics such as gender, age, and race and ethnicity, and the duration of data collection (when did data collection start and end). It was imperative to identify a cohort with none of the pre-existing cardiovascular disease or other major illnesses that astronauts were also screened for when selected for the corps.

Ultimately, the Cooper Center Longitudinal Study (CCLS), housed at the Cooper Institute in Dallas, Texas, was chosen as a comparator, and investigators from both NASA and CCLS met in Dallas to begin discussions on how best to execute the study. The groups worked together over several years to understand the privacy concerns of both groups, develop matching protocols, complete the statistical analysis, and write the final paper, which was published in the July 2022 issue of Mayo Clinic Proceedings.

NASA astronauts were matched to participants of the CCLS based on age at entrance into the study, year of birth, gender, and level of fitness at entrance into the study. Five CCLS participants were included for every astronaut who had completed a spaceflight by the end of the study period. Results of this study showed that both the CCLS and astronauts had lower than average rates of CVD and death during the 30 years of average follow up. There was no difference between the two groups in CVD related death; however, there was a slight increased risk of non-fatal CVD events in the astronauts. This finding wasn't worrisome to investigators as the number of events was low. While this study was unable to tease apart whether specific spaceflight exposures impacted CVD risk, it is an initial step in helping us understand the lifetime risk to our crewmembers. It will be important to repeat this type of study to help bolster our understanding, especially as astronauts complete longer missions further from Earth.

The Cooper Center Longitudinal Study was an appropriate cohort for studying CVD; however, it may not be the best cohort for studying spaceflight related disorders such as SANS or other illnesses of aging, such as cancer. Identification of the most appropriate cohorts will be of utmost importance as we learn more about the health effects of space on the human body, particularly across the entire lifespan.

Charvat Mayo Clin Proc. 2022;97(7): 1237-1246

Josephson Mayo Clin Proc. 2022;97(7): 1222-1223

www.cooperinstitute.org

APPROACHING THE QUESTION:

Is **SANS** Pathological or a Normal Adaptation to Spaceflight?

BY **TAYMA MACHKHAS, B.S.**

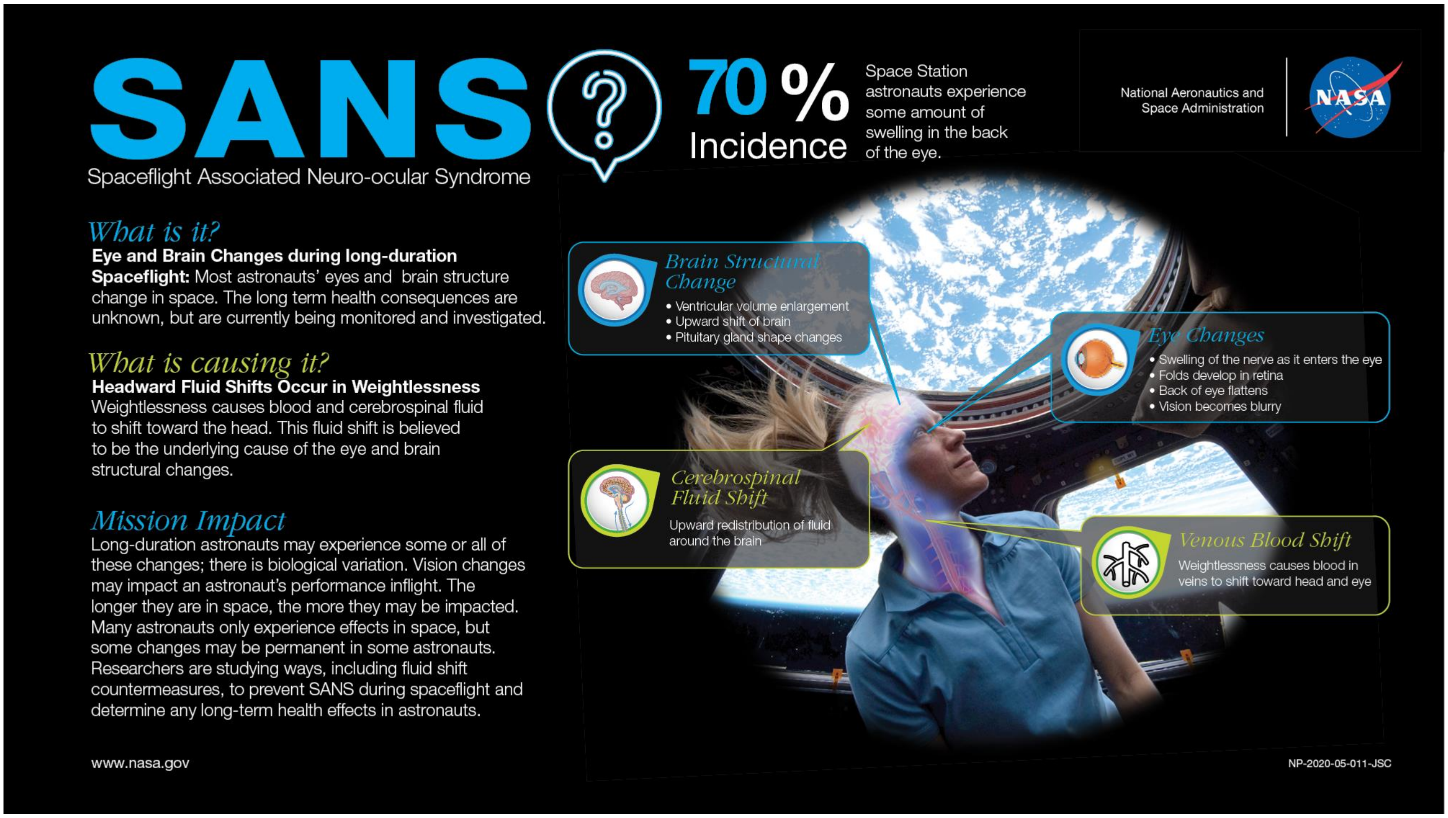


Figure 1: *Background on Spaceflight Associated Neuro-Ocular Syndrome (SANS)*
SANS: Spaceflight Associated Neuro-ocular Syndrome (nasa.gov)

As NASA focuses on the Artemis program and returning to the Moon and on to Mars, understanding conditions that could negatively impact crew during long-term missions is high priority. One of these conditions, Space-Associated Neuro-Ocular Syndrome (SANS), is a constellation of findings that are not well understood. SANS can manifest like some terrestrial disease analogs; however, it typically differs in presentation, making it difficult to truly understand and mitigate pathological risk to the astronaut. As a result, two major questions are asked about SANS: 1) What is normal for spaceflight and 2) Which clinical SANS findings are true pathology compared to normal adaptation to spaceflight?

As seen in Dr. Jacqueline M. Charvat's work with the Cooper Clinic, identifying a comparison cohort to the astronaut population can help determine long-term risk by ensuring that baseline health profiles are similar among both populations. However, given the highly specialized and unique nature of the astronaut corps, finding a comparison cohort can be difficult, and the process may be different for each health risk. With SANS, it involved assessing studies with specific ophthalmological and brain imaging exams typically only used for clinical diagnosis in diseased populations, such as traumatic brain injury, idiopathic intracranial hypertension, glaucoma, or multiple sclerosis. The goal was to identify populations where the specialized testing used for SANS was conducted in healthy individuals.

To begin the process of determining the pathological threshold of SANS, the LSAH occupational surveillance program reviewed neurological and vision terrestrial cohorts. From June to September 2021, cohorts were identified in international registries, systematic reviews, as well as in a large PubMed query. The exclusion criteria were as follows: studies that only recruited a diseased population, studies that were based solely on surveys or questionnaires (due to the lack of SANS-specific testing), studies that included subjects < 18 years of age, and studies with no vision outcome data. Once a list of promising cohorts was established, demographic and health data, as well as study design characteristics, were extracted. Out of 358 cohorts, the systematic review yielded 35 potential studies of healthy populations with ocular outcomes obtained through testing similar to specialized SANS testing, including an optical coherence tomography scan (OCT), visual acuity assessment, ocular biometry, and intraocular pressure.

Optical Coherence Tomography	Indirect/Direct Ophthalmoscopy	Visual Acuity Assessment	Ocular Biometry	Automated Refraction	Contrast Sensitivity	Intraocular pressure
15	26	22	7	13	3	18

Figure 2: *Frequency of SANS-specific tests and measures performed in the 35 studies found*

Future work includes accessing and processing promising neurological and vision cohort data. Results from these proposed comparison studies of terrestrial cohorts will enhance the understanding of the spectrum of findings that describe SANS. Additionally, LSAH epidemiologists will be able to use this thorough and standardized documentation of the tools and processes in future surveillance activities as they seek to identify comparison cohorts for other health outcomes.

IMPALA'S
Body System Model Helps Address
Health Risks
in Spaceflight

BY **DEVAN PETERSEN, MPH**

ORGANIZATION OF DATA IN IMPALA

As described in LSAH Newsletter Volume 27 Issue 1, the IMPALA team has successfully ingested data from 18 different sources into the IMPALA platform. Now the IMPALA team is focused on organizing the data into tables that are easily accessible and understandable by the user. These tables are referred to as "Domain Data Models," data sets based on 15 body systems, including:

- Bone and Musculoskeletal
- Cancer
- Cardiovascular
- Dental
- Endocrine
- Ear, Nose, Throat, and Neurovestibular
- Eye/Vision/Spaceflight Acquired Neuro-ocular Syndrome (SANS)
- Gastrointestinal
- Decompression Illness
- Genitourinary/Reproductive
- Head and Neurological
- Immune
- Nutrition
- Pulmonary
- Skin

By organizing the data into Domain Data Models, the IMPALA team can combine, clean, and restructure the content, allowing users to search lists of common information without requiring complicated searches by the user.

Within each of these Domain Data Models, there are six sub-systems called Facets

- **Diagnoses:** occurrences of medical outcomes/events including symptoms, conditions, disorders, diseases, injuries, *e.g., stroke, brain cancer, renal stone formation, sprain, etc.*
- **Exposures:** potentially harmful/protective elements that may lead to or prevent a health outcome—measured at person level or environmental level, *e.g., Celestial dust, EVAs, pilot experience, radiation*
- **Labs and Vitals:** results of laboratory test on blood, urine, etc., plus common vital signs, *e.g., alkaline phosphatase, Vitamin D, total cholesterol, Hba1c, blood pressure, heart rate*
- **Medications:** pharmaceuticals prescribed and recorded with key information such as frequency, dose, timeframe, class/category, drug name, etc., *e.g., beta blockers, Tylenol, Ibuprofen, hydrocortisone cream*
- **Procedures:** occurrences of medical procedures, especially of a screening, diagnostic, and treatment variety, *e.g., surgery, colonoscopy, chemotherapy, endarterectomy, dermatological screen*
- **Risk Factors:** factors that may influence the development of a health outcome, often in the form of socio-demographic characteristics or lifestyle behaviors, *e.g., family history, routine diet/ fitness, tobacco use, vaccination(s)*

Image 1 is a visual representation of the organizational structure of medical data within IMPALA, referred to as the IMPALA Blueprint. The 15 body systems of the Domain Data Models appear in the left-most column and are ordered alphabetically from "Bone/MSK" to "Skin." Each row is then split into the six facets, labeled in the top row, starting with "Diagnoses" and ending with "Risk Factors". The IMPALA team has prioritized the work based on interest within the Agency, projects currently underway, and logical progression.

Image 1: *IMPALA Blueprint – Medical Data*

As of 8/30/2022

6 FACETS

15 DOMAIN DATA MODELS

	Diagnoses	Exposures	Labs & Vitals	Medications	Procedures	Risk Factors
Bone/MSK	FY21	FY21	FY20	FY20	FY21	FY24
Cancer	FY20	FY21	FY20	FY20	FY20	FY24
Cardiovascular	FY23	FY21	FY20	FY20	FY23	FY24
Dental	FY24	FY21	N/A	FY20	FY24	N/A
Endocrine	FY24	FY21	FY20	FY20	FY24	FY24
ENT & Neurovestibular	FY22	FY21	FY20	FY20	FY22	FY24
Eye/Vision/SANS	FY21	FY21	FY20	FY20	FY21	FY24
Gastrointestinal	FY23	FY23	FY20	FY20	FY23	FY24
Decompression Illness	FY22	FY21	FY20	FY20	FY22	FY24
Genitourinary/Reproductive	FY24	FY21	FY20	FY20	FY24	FY24
Nervous System	FY22	FY21	FY20	FY20	FY22	FY24
Immune	FY23	FY23	FY20	FY20	FY23	FY24
Nutrition	TBD	TBD	FY20	FY20	N/A	FY24
Pulmonary	FY23	FY21	FY20	FY20	FY23	FY24
Skin	FY23	FY21	FY20	FY20	FY23	FY24

COMPLETE IN WORK NOT STARTED NOT APPLICABLE

The IMPALA platform can support NASA in multiple ways. Examples include providing views of disease prevalence, informing assessment of risk posture at the HSRB, and supporting operational decisions.

CREATING & INTERACTING WITH DASHBOARDS

One method users can access and interact with data in IMPALA is through dashboards. Image 2 is a screenshot of the Fractures Metric Dashboard. Each metric dashboard is organized with four filtering options, a legend, four tables or graphs, and present population data in summary format.

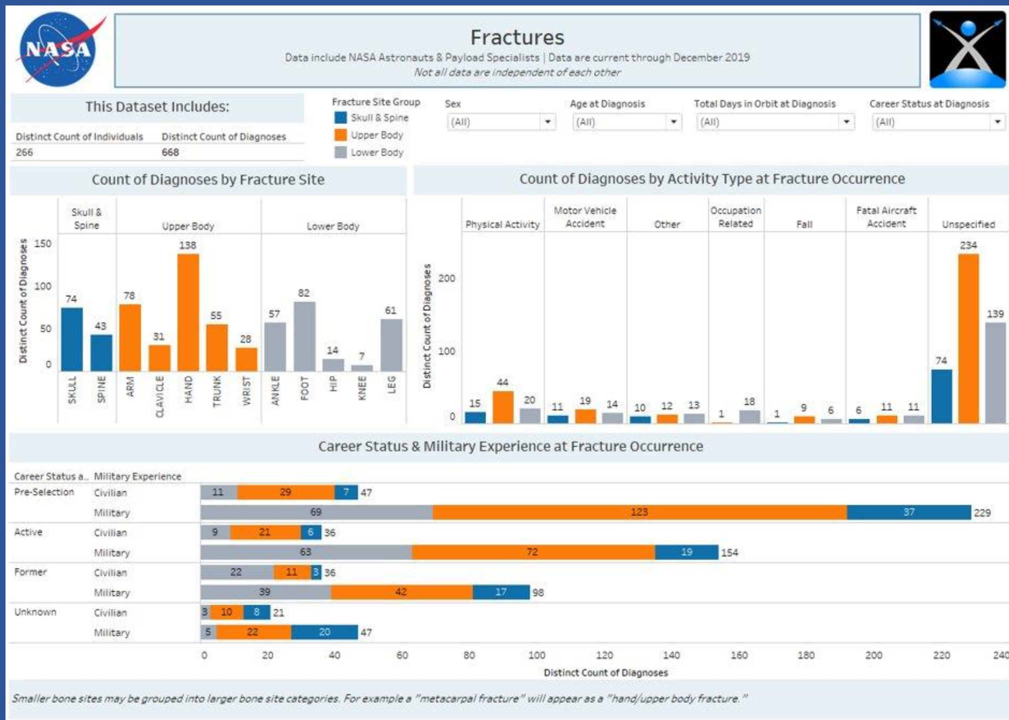
Like the other metric dashboards, this Fractures Metric Dashboard quickly conveys a variety of information to a broad audience including

- Number of individuals and fracture diagnoses included in the dataset
- Number of fracture diagnoses by body site
- Number of fracture diagnoses by activity type
- Career status and military experience at the time of the fracture

Additional data details can be viewed by applying different filters to the Fractures metric dashboard, such as

- Sex
- Age at Diagnosis
- Career Status at Diagnosis
- Total Days in Orbit at Diagnosis

Image 2: *Fractures Metric Dashboard*



HELPING TO INFORM NASA'S RISK POSTURE

The IMPALA platform is also utilized to help inform NASA's risk posture at the Human Systems Risk Board. LSAH Epidemiologists serve on every Risk Custodian team and support the team by exploring and analyzing astronaut health and medical data in IMPALA. These data, in turn, serve as a part of the evidence base that is considered to identify useful metrics for risk postures. The data within the IMPALA platform have been transformed into more useable formats, allowing the LSAH Epidemiologists to quickly find and extract the appropriate data. This efficient interaction with the data housed in IMPALA allows the LSAH Epidemiologists and other key users to spend more time analyzing data (instead of finding and processing it!).

ANSWERING NASA'S OPERATIONAL QUESTIONS

The IMPALA platform is also utilized to answer NASA's operational questions and other data requests.

A recent internal Agency request asked for an anonymous dataset that included the most recent body weight measurements of all active astronauts. The requestor was attempting to understand the spectrum of weights for developing vehicle requirements and needed these data compiled quickly. The IMPALA platform was queried, and data were extracted and delivered to the requestor in about 2.5 hours.

If these data had not been housed in IMPALA, the data request would have taken approximately 10–12 hours to complete, as each individual record would have been accessed one by one, solidifying IMPALA as a crucial asset in responding to these requests.

CONCLUSION

The IMPALA platform is a data repository for astronaut health data and related career exposures. The data within the IMPALA platform are ingested, organized, and protected, allowing users to facilitate quick and easy access encouraging exploration and analyses. By providing users with this easy-to-navigate common reservoir of data for astronaut health and related career exposures, IMPALA is an invaluable tool for supporting risk management and operational decisions.

Unlocking how HUMAN BODIES will react to long journeys into SPACE

BY **NATHAN CRANFORD**

Through Artemis, NASA astronauts are returning to the Moon then proceeding on to Mars. To better prepare astronauts for these long journeys, scientists need to know: How do extended durations in space change the human body?

Active astronauts can now volunteer for a suite of experiments that aim to help scientists learn more. Together, these experiments are called the Complement of Integrated Protocols for Human Exploration Research, or CIPHER.

"CIPHER is the first study to integrate multiple physiological and psychological measures and gives us a chance to assess the whole human response to time spent in space," CIPHER project scientist Dr. Cherie Oubre explains. "As more astronauts head to space through Artemis and other programs, we hope to learn more about how the various systems of the body, such as the heart, muscles, bones, and eyes, adapt to long-term spaceflight."

Through CIPHER, astronauts participate in an integrated set of 14 studies sponsored by NASA and international partner agencies. To get meaningful results, CIPHER scientists will study up to 30 astronauts, evenly divided over three mission-length categories:

- Short (less than 3.5 months in space)
- Standard (between 3.5 and 8 months in space)
- Extended (more than 8 months in space)

These research studies will monitor the health of astronauts before, during, and after their missions, and together address the following themes:

Bone and Joint Health – Studies show that astronauts lose bone density and muscle quality faster in space than on Earth. Calcium lost from bone ends up in their blood and urine.

Astronauts will:

- Undergo scans to measure bone density, skeletal health, and muscle quality surrounding bones and joints
- Collect blood and urine periodically before, during, and after their missions

Scientists will:

- Examine whether the rate of bone and muscle loss stays constant, slows down, or even stops beyond six-month missions
- Determine what sort of health risks, if any, this poses

Brain and Behavior – Fluids in the brain shift due to low gravity in space, and long-duration spaceflight may slightly alter brain structure, which could affect how the brain processes spatial information and, in turn, impact crew performance.

Astronauts will:

- Complete cognitive tests
- Use a computer to simulate movement of a robotic arm
- Undergo MRI scans while doing cognitive tests

Scientists will:

- Examine how brain activity before missions differs from brain activity after missions
- Pinpoint patterns dependent on mission duration

Cardiovascular – Long-duration spaceflight may lead to stiffer arteries and may increase the risk of heart disease.

Astronauts will:

- Complete CT, MRI, and ultrasound imaging of the heart, surrounding organs and muscles, and blood vessels
- Wear a shirt that measures heart rate and respiration across 2 days
- Take periodic blood pressure measurements

Scientists will:

- Tease out patterns across mission durations to provide objective indicators of heart health
- Examine whether the removal of gravity affects organs, muscles, and vessels near the heart

Exercise – Exercise can counter bone and muscle loss in space, but scientists want to understand whether exercise is an effective strategy for maintaining astronaut health in long-duration spaceflight.

Astronauts will:

- Test muscle strength and endurance throughout their missions using the station's exercise equipment
- Track their nutrition and sleep habits
- Navigate through an obstacle course after they land back on Earth, while at times wearing space suits off-loaded to Martian gravity

Scientists will:

- Evaluate crews' abilities to carry out specific exercises over time
- Evaluate how soon and how well crews can perform critical tasks in new gravities

Vision – Because low gravity conditions shift the body's fluids toward the head, spaceflight can alter the structure and function of the eyes and the brain.

Astronauts will:

- Participate in MRI and eye imaging scans
- Perform vision tests
- Assess eye pressure and how the retina responds to light

Scientists will:

- Evaluate eye changes for each mission duration
- See how the structure of astronauts' brains change after their missions, and how such changes affect vision

Sensorimotor – Many astronauts experience dizziness and disorientation aboard the station and when they return to Earth, and scientists want to understand factors that may influence how long these symptoms last.

Astronauts will:

- Record their eye, head, and body movements using specialized techniques
- Fill out surveys on how they perceive motion

Scientists will:

- See whether mission duration influences how long it takes to adapt to new gravity
- Investigate the reasons behind changes in balance and the ability to adapt to new gravities

Biomarkers – Scientists are curious: Do any changes to the human body induced by long-duration space travel come with indicators that can be detected in blood and urine?

Astronauts will:

- Provide blood and urine samples before, during, and after spaceflight
- Complete questionnaires regarding health and exercise habits

Scientists will:

- Examine blood and urine for potential indicators of changes to cartilage health, inflammation and immune function, kidney health, brain structure and function, spatial cognition, performance of operational tasks, risk of cardiovascular disease, and more
- Investigate the interplay between mission length, DNA damage responses, and post-mission recovery of telomeres—the caps at the ends of chromosomes that shorten as we age but may lengthen in space before rebalancing themselves back on Earth

CIPHER also includes a long-running study called Spaceflight Standard Measures, which collects a core set of information on as many crew members as possible. This core set includes metrics about the crew member's sleep, cognition, biomarkers, immune function, microbiome, and more.

In addition to answering research questions central to each study, CIPHER takes an integrated approach. Data across CIPHER investigations will be evaluated to identify patterns and gain a deeper understanding of how the human body reacts to long durations in space.

"CIPHER is an all-encompassing, total-body approach to learning how humans adapt to spaceflight," says Oubre. "Insights gained through CIPHER may well be key to enabling humans to remain healthy while exploring the Moon, Mars, and beyond."

PUBLICATION CORNER 2022

Attached are publications related to LSAH data requests and other papers that may be of interest. For your convenience, each publication has a link to take you directly to the abstract or publication online. For papers not available via open source, the corresponding author may be able to provide you with a copy.

Antonsen, E. L., Myers, J. G., Boley, L., Arellano, J., Kerstman, E., Kadwa, B., . . . Van Baalen, M. (2022). Estimating medical risk in human spaceflight. *NPJ Microgravity, 8*(1), 8. https://doi.org/10.1038/s41526-022-00193-9

Barisano, G., Sepehrband, F., Collins, H. R., Jillings, S., Jeurissen, B., Taylor, J. A., . . . Wuyts, F. L. (2022). The effect of prolonged spaceflight on cerebrospinal fluid and perivascular spaces of astronauts and cosmonauts. *Proc Natl Acad Sci U S A, 119*(17), e2120439119. https://doi.org/10.1073/pnas.2120439119

Bisserier, M., Saffran, N., Brojakowska, A., Sebastian, A., Evans, A. C., Coleman, M. A., . . . Goukassian, D. A. (2021). Emerging Role of Exosomal Long Non-coding RNAs in Spaceflight-Associated Risks in Astronauts. *Front Genet, 12*, 812188. https://doi.org/10.3389/fgene.2021.812188

Bloomfield, S. A. (2022). Developing an international database on long-term health effects of spaceflight. *Acta Astronautica*. https://doi.org/10.1016/j.actaastro.2022.06.006

Buckey, J. C., Lan, M., Phillips, S. D., Archambault-Leger, V., & Fellows, A. M. (2022). A theory for why the spaceflight-associated neuro-ocular syndrome develops. *J Appl Physiol (1985), 132*(5), 1201-1203. https://doi.org/10.1152/japplphysiol.00854.2021

Charvat, J. M., Leonard, D., Barlow, C. E., DeFina, L. F., Willis, B. L., Lee, S. M. C., . . . Van Baalen, M. (2022). Long-term Cardiovascular Risk in Astronauts: Comparing NASA Mission Astronauts With a Healthy Cohort From the Cooper Center Longitudinal Study. *Mayo Clin Proc, 97*(7), 1237-1246. https://doi.org/10.1016/j.mayocp.2022.04.003

Goodenow-Messman, D. A., Gokoglu, S. A., Kassemi, M., & Myers, J. G., Jr. (2022). Numerical characterization of astronaut CaOx renal stone incidence rates to quantify in-flight and post-flight relative risk. *NPJ Microgravity, 8*(1), 2. https://doi.org/10.1038/s41526-021-00187-z

Greene, K. A., Tooze, J. A., Lenchik, L., & Weaver, A. A. (2022). Change in Lumbar Muscle Size and Composition on MRI with Long-Duration Spaceflight. *Ann Biomed Eng, 50*(7), 816-824. https://doi.org/10.1007/s10439-022-02968-3

Huff, J. L., Plante, I., Blattnig, S. R., Norman, R. B., Little, M. P., Khera, A., . . . Patel, Z. S. (2022). Cardiovascular Disease Risk Modeling for Astronauts: Making the Leap From Earth to Space. *Front Cardiovasc Med, 9*, 873597. https://doi.org/10.3389/fcvm.2022.873597

Hupfeld, K. E., Richmond, S. B., McGregor, H. R., Schwartz, D. L., Luther, M. N., Beltran, N. E., . . . Piantino, J. (2022). Longitudinal MRI-visible perivascular space (PVS) changes with long-duration spaceflight. *Sci Rep, 12*(1), 7238. https://doi.org/10.1038/s41598-022-11593-y

Josephson, R. A., & Gillombardo, C. B. (2022). The Right Stuff. *Mayo Clin Proc, 97*(7), 1222-1223. https://doi.org/10.1016/j.mayocp.2022.05.026

Koller, D. P., Kasanin, V., Flynn-Evans, E. E., Sullivan, J. P., Dijk, D. J., Czeisler, C. A., & Barger, L. K. (2021). Altered sleep spindles and slow waves during space shuttle missions. *NPJ Microgravity, 7*(1), 48. https://doi.org/10.1038/s41526-021-00177-1

Koppelmans, V., Mulavara, A. P., Seidler, R. D., De Dios, Y. E., Bloomberg, J. J., & Wood, S. J. (2022). Cortical thickness of primary motor and vestibular brain regions predicts recovery from fall and balance directly after spaceflight. *Brain Struct Funct, 227*(6), 2073-2086. https://doi.org/10.1007/s00429-022-02492-z

Lagatuz, M., Vyas, R. J., Predovic, M., Lim, S., Jacobs, N., Martinho, M., Valizadegan, H., Kao, D., Oza, N., Theriot, C. A., Zanello, S. B., Taibbi, G., Vizzeri, G., Dupont, M., Grant, M. B., Lindner, D. J., Reinecker, H. C., Pinhas, A., Chui, T. Y., Rosen, R. B., ... Parsons-Wingerter, P. (2021). Vascular Patterning as Integrative Readout of Complex Molecular and Physiological Signaling by VESsel GENeration Analysis. *Journal of vascular research*, *58*(4), 207–230. https://doi.org/10.1159/000514211

Marshall-Goebel, K., Kramer, L. A., & Macias, B. R. (2022). The Importance of the Intracranial Compartment in the Development of Spaceflight-Associated Neuro-ocular Syndrome-Reply. *JAMA Ophthalmol, 140*(1), 99-100. https://doi.org/10.1001/jamaophthalmol.2021.4863

Mehta, S. K., Szpara, M. L., Rooney, B. V., Diak, D. M., Shipley, M. M., Renner, D. W., . . . Crucian, B. E. (2022). Dermatitis during Spaceflight Associated with HSV-1 Reactivation. *Viruses, 14*(4). https://doi.org/10.3390/v14040789

Ong, J., Tavakkoli, A., Strangman, G., Zaman, N., Kamran, S. A., Zhang, Q., . . . Lee, A. G. (2022). Neuro-ophthalmic imaging and visual assessment technology for spaceflight associated neuro-ocular syndrome (SANS). *Surv Ophthalmol, 67*(5), 1443-1466. https://doi.org/10.1016/j.survophthal.2022.04.004

Pardon, L. P., Macias, B. R., Ferguson, C. R., Greenwald, S. H., Ploutz-Snyder, R., Alferova, I. V., . . . Laurie, S. S. (2022). Changes in Optic Nerve Head and Retinal Morphology During Spaceflight and Acute Fluid Shift Reversal. *JAMA Ophthalmol*. https://doi.org/10.1001/jamaophthalmol.2022.1946

Pavela, J., Sargsyan, A., Bedi, D., Everson, A., Charvat, J., Mason, S., . . . Moll, S. (2022). Surveillance for jugular venous thrombosis in astronauts. *Vasc Med, 27*(4), 365-372. https://doi.org/10.1177/1358863X221086619

Reid, C. R. (2021). Modeling Occupational Fingernail Onycholysis Disorders in the Population of US Astronauts Who Have Engaged in Extravehicular Activity. *The Journal of Human Factors and Ergonomics Society*. https://doi.org/10.1177%2F00187208211062299

Reyes, D. P., Masterova, K. S., Walton, M., Kerstman, E. L., & Antonsen, E. L. (2022). Assessment of Sex-Dependent Medical Outcomes During Spaceflight. *J Womens Health (Larchmt)*. https://doi.org/10.1089/jwh.2021.0636

Roberts, D. R., Collins, H. R., & Al Kasab, S. (2022). The Importance of the Intracranial Compartment in the Development of Spaceflight-Associated Neuro-ocular Syndrome. *JAMA Ophthalmol, 140*(1), 98-99. https://doi.org/10.1001/jamaophthalmol.2021.4860

Roma, P. G., Schneiderman, J. S., Schorn, J. M., Whiting, S. E., Landon, L. B., & Williams, T. J. (2021). Assessment of Spaceflight Medical Conditions' and Treatments' Potential Impacts on Behavioral Health and Performance. *Life Sci Space Res (Amst), 30*, 72-81. https://doi.org/10.1016/j.lssr.2021.05.006

Rosenberg, M. J., Coker, M. A., Taylor, J. A., Yazdani, M., Matheus, M. G., Blouin, C. K., . . . Roberts, D. R. (2021). Comparison of Dural Venous Sinus Volumes Before and After Flight in Astronauts With and Without Spaceflight-Associated Neuro-Ocular Syndrome. *JAMA Netw Open, 4*(10), e2131465. https://doi.org/10.1001/jamanetworkopen.2021.31465

Salazar, A. P., McGregor, H. R., Hupfeld, K. E., Beltran, N. E., Kofman, I. S., De Dios, Y. E., . . . Seidler, R. (2022). Changes in working memory brain activity and task-based connectivity after long-duration spaceflight. *Cereb Cortex*. https://doi.org/10.1093/cercor/bhac232

Taibbi, G., Young, M., Vyas, R. J., Murray, M. C., Lim, S., Predovic, M., . . . Parsons-Wingerter, P. (2021). Opposite response of blood vessels in the retina to 6 degrees head-down tilt and long-duration microgravity. *NPJ Microgravity, 7*(1), 38. https://doi.org/10.1038/s41526-021-00165-5

Trudel, G., Shahin, N., Ramsay, T., Laneuville, O., & Louati, H. (2022). Hemolysis contributes to anemia during long-duration space flight. *Nat Med, 28*(1), 59-62. https://doi.org/10.1038/s41591-021-01637-7

Waisberg, E., Ong, J., Zaman, N., Kamran, S. A., Lee, A. G., & Tavakkoli, A. (2022). A non-invasive approach to monitor anemia during long-duration spaceflight with retinal fundus images and deep learning. *Life Sci Space Res (Amst), 33*, 69-71. https://doi.org/10.1016/j.lssr.2022.04.004

Wostyn, P., Gibson, C. R., & Mader, T. H. (2022). Optic Disc Edema in Astronauts from a Choroidal Point of View. *Aerosp Med Hum Perform, 93*(4), 396-398. https://doi.org/10.3357/AMHP.6010.2022

Zwart, S. R., Aunon-Chancellor, S. M., Heer, M., Melin, M. M., & Smith, S. M. (2022). Albumin, oral contraceptives, and venous thromboembolism risk in astronauts. *J Appl Physiol (1985), 132*(5), 1232-1239. https://doi.org/10.1152/japplphysiol.00024.2022

Did you move? New email address? Remember to update us so we can continue to send you the LSAH Newsletter, LSAH invitational physical exam letters, and any other news we may need to share with you. Contact Denise Patterson at 281-244-5195 or denise.a.patterson@nasa.gov.

You may also write us at

Lifetime Surveillance of Astronaut Health (LSAH)
Flight Medicine Clinic/SD3C
NASA Johnson Space Center
2101 NASA Parkway
Houston, TX 77058-3696
Or email us at Jsc-lsah@mail.nasa.gov

For past newsletters, please visit the LSAH website on the new NASA Life Sciences Portal

This newsletter is funded by **Crew Health and Safety/Space Operations Mission Directorate**.