



Computational Modeling and Machine Learning Projects Supporting the Human Research Program at NASA

Mona Matar

NASA Glenn Research Center - Ohio

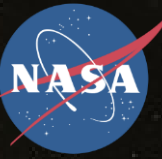
Data Science Seminar - Arizona State University

Feb 5th, 2024



My Background





Education



Aug 2004

B.S. in Electrical and Electronics Engineering
focusing on Telecommunications and Computer Science
The Lebanese University



Aug 2014

Master in Applied Mathematics

The University of Akron

Thesis Title: Atomistic-To-Continuum Modeling Of The Detachment Of A Graphene Sheet



Aug 2019

Ph.D. in Applied Mathematics

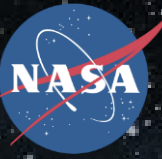
Kent State University

Dissertation Title: Node and Edge Importance in Networks via the Matrix Exponential



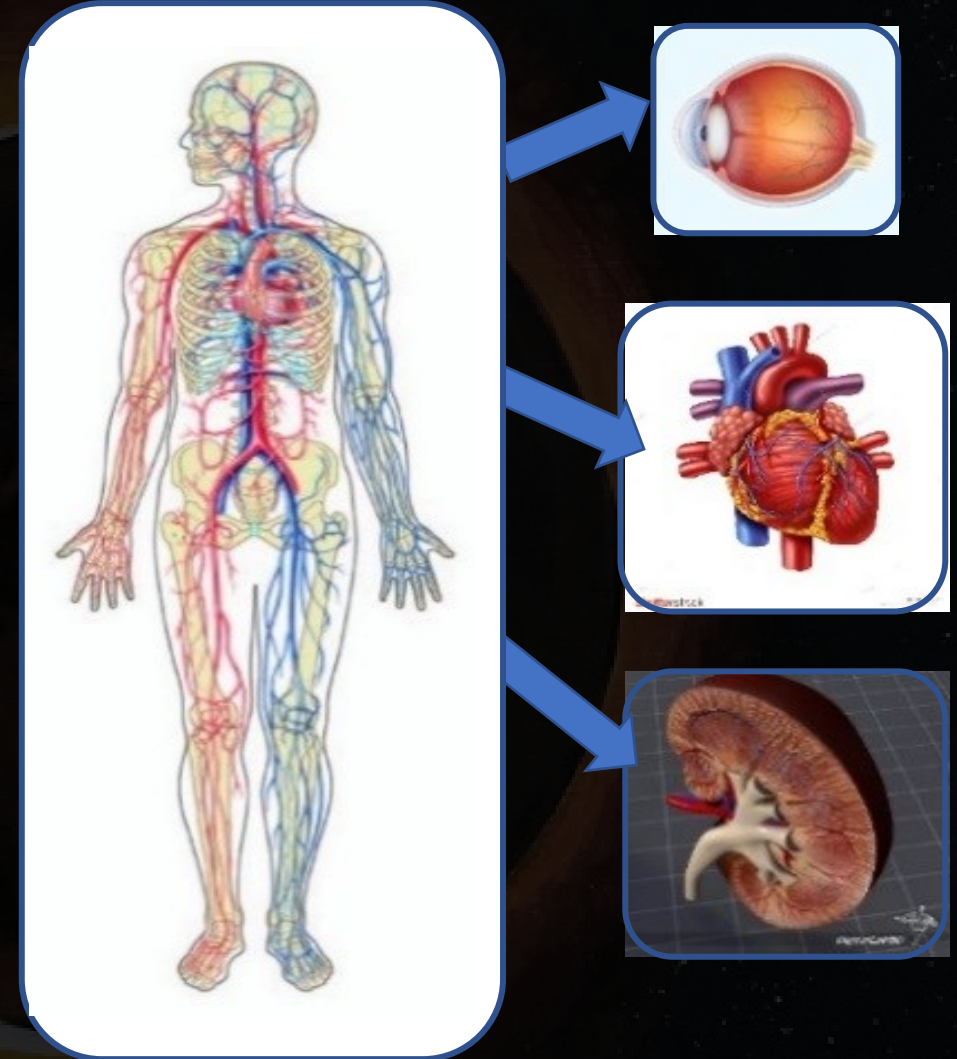
Projects at Glenn Research Center

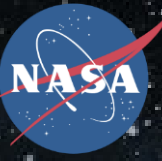




Projects for the Human Research Program

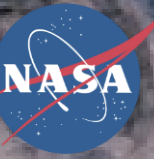
- Crew Health and Performance – Probabilistic Risk Assessment (CHP-PRA)
- Spaceflight Associated Neuro-ocular Syndrome (SANS)
- Renal stones
- Operational Volume Data and Habitat Design





Tools and Models

- Simple regression (Data driven, curve fits)
- Multifactorial regressions (Data driven, Gaussian Process Regression, Neural Networks)
- Probabilistic inference (Bayesian networks)
- Event tree structure
- Deterministic model
- Probabilistic model
- Hybrid models



Possible Data Sources

Ground studies

Animal



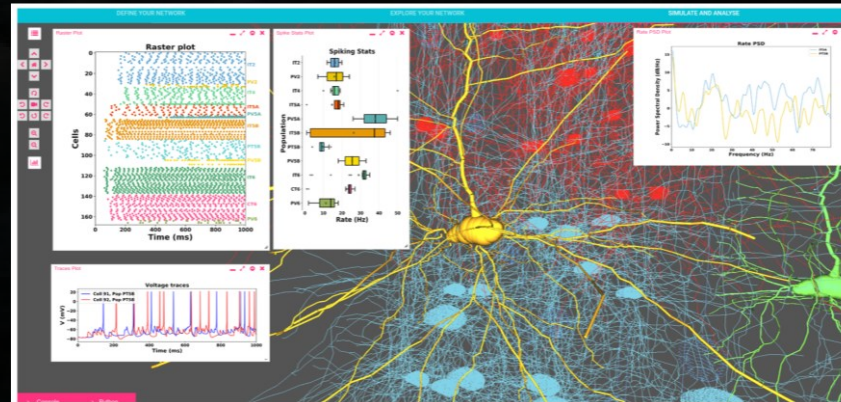
Human



Astronaut data

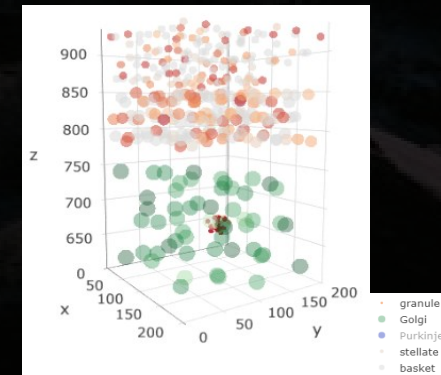


NetPyNE GUI



Courtesy: <http://www.neurosimlab.com/netpyne/overview.html>

Cerebellum microcircuit





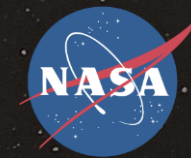
CBS Project

Alien Brain Study





CBS Project



Radiation exposure

Galactic Cosmic Rays (GCR)



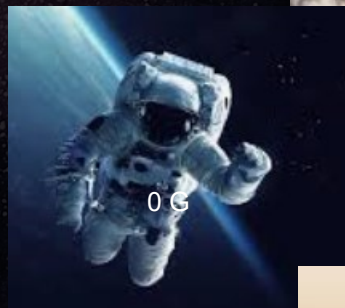
Solar Particle Events (SPE)



Approximate size of Earth

Altered gravity

1 G to 0 G



0 G

0 G to 3.7 G on Mars

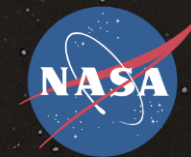


Isolation / confinement





CBS Project

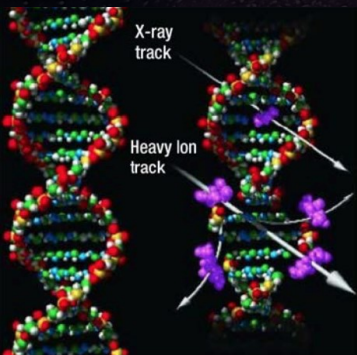


Central nervous system

Altered cognitive function



DNA molecule can break



Behavioral medicine

Depression
Fatigue
Circadian rhythm
Monotony
Boredom
Hallucination
Anxiety



Sensorimotor



Spatial orientation
Space motion sickness
Difficulty walking



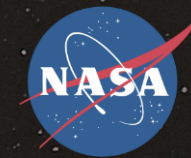
Tools and Models



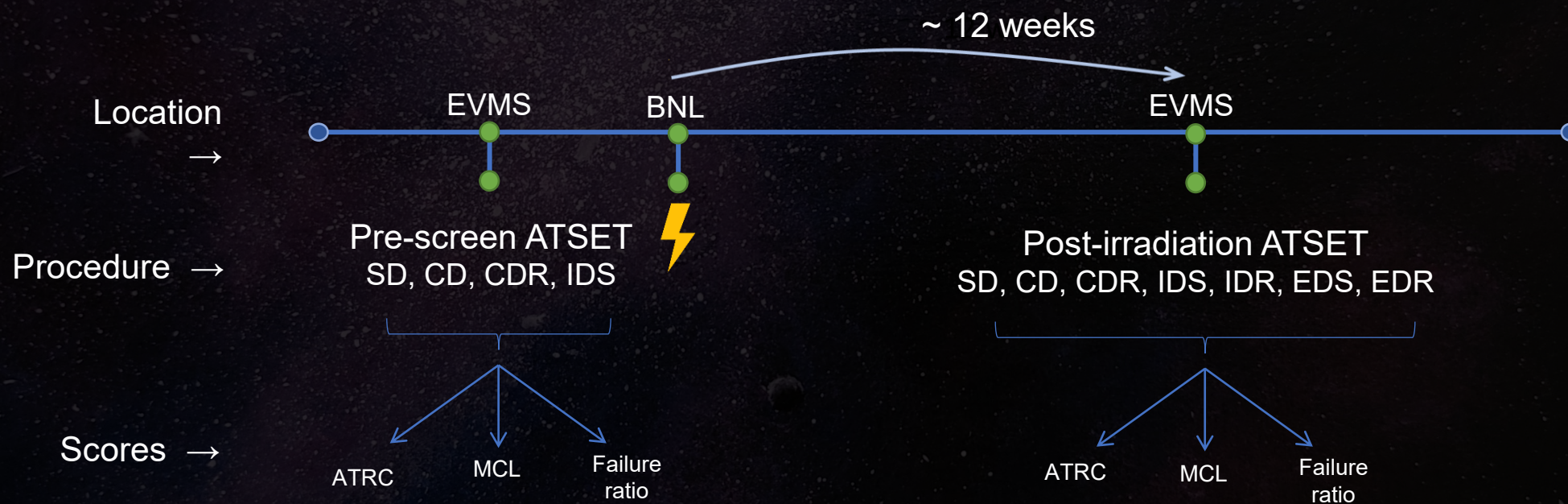
- Subjects are Wistar rats
- ATtentional SET shifting test
- Cognitive flexibility performance
- Series of 7 stages: SD, CD, CDR, IDS, IDR, EDS, EDR
- Different relevant/irrelevant cues in each stage
- Criterion to pass: 6 consecutive successful attempts
- Experiment by Dr. R. Britten's lab (Jewell et al., 2018; Britten et al., 2020; Burket et al., 2021)



ATSET: ATtentional SET shifting test
SD: Simple Discrimination
CD: Compound Discrimination
CDR: Compound Discrimination Reversal
IDS: Intra-Dimensional Shifting
IDR: Intra-Dimensional Shifting Reversal
EDS: Extra-Dimensional Shifting
EDR: Extra-Dimensional Shifting Reversal

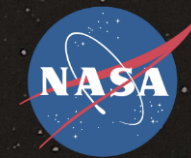


Experiment Timeline and Data





Objective

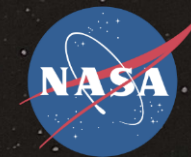


Predict cognitive impairment:

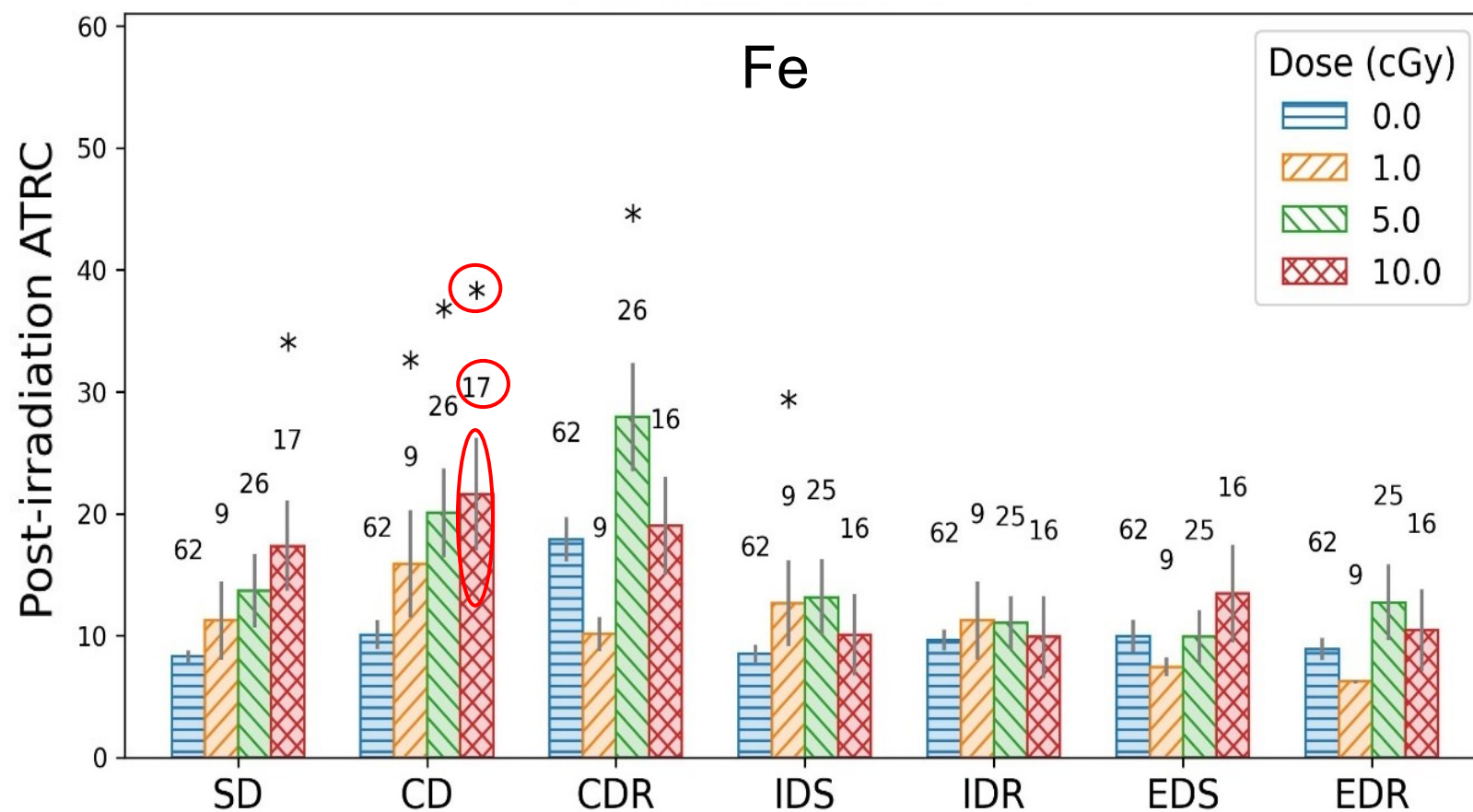
- at subject level
- based on prescreen scores

Implication for astronauts:

- probability of failing a task for each individual
- before spaceflight

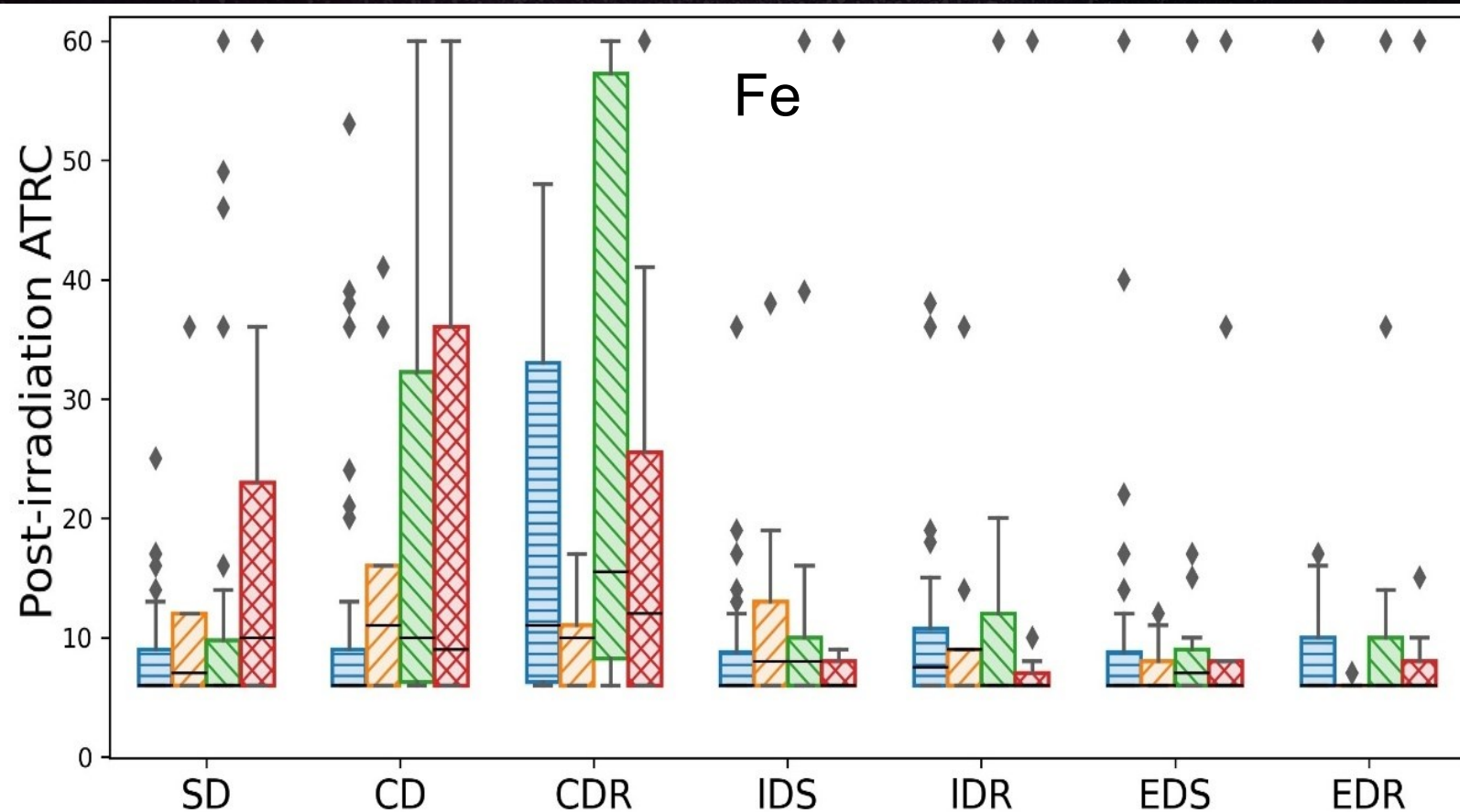


Basic Statistics

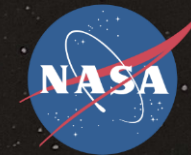


- “*” statistically different from control
- Group size above the bar
- Large SEM
- Δ in the number of rodents

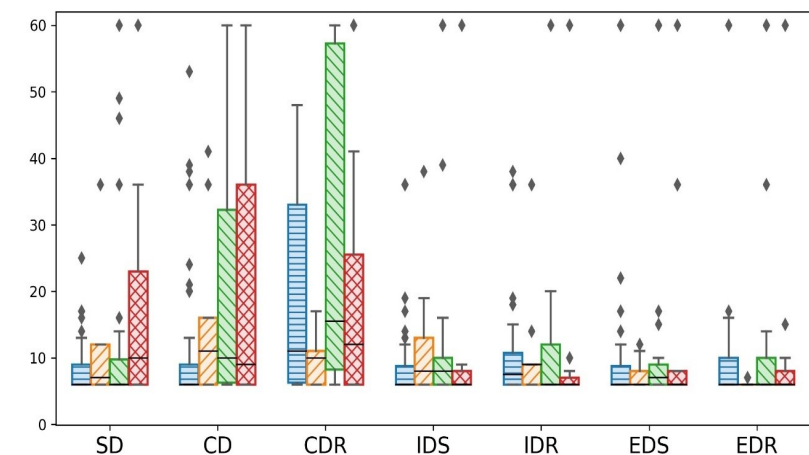
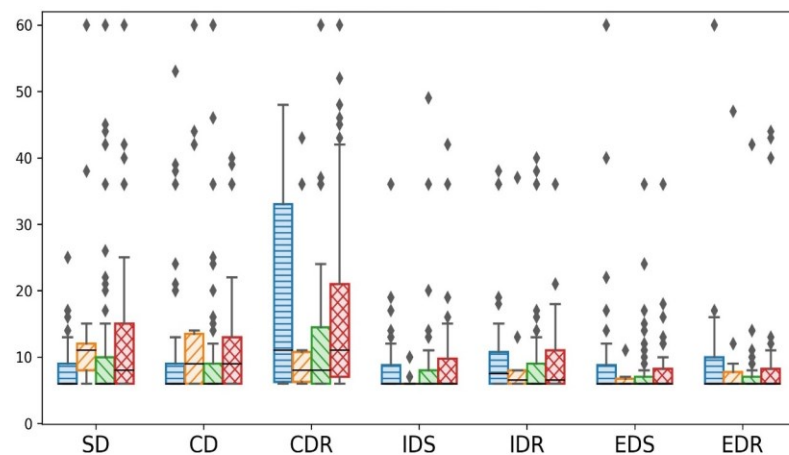
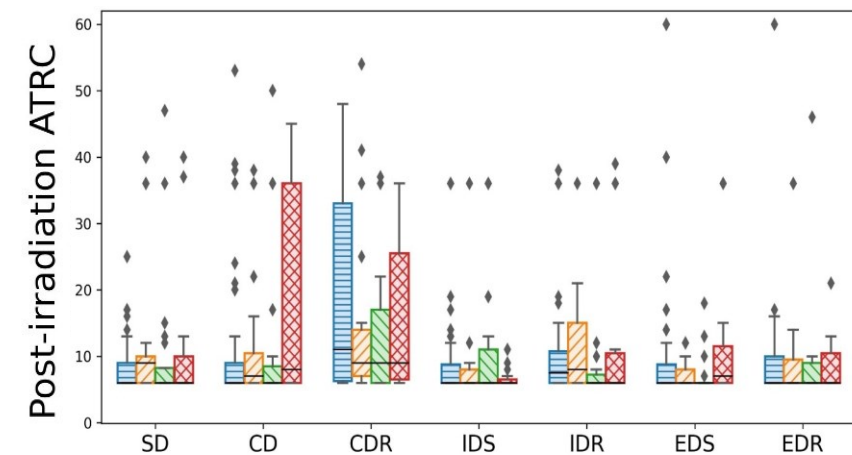
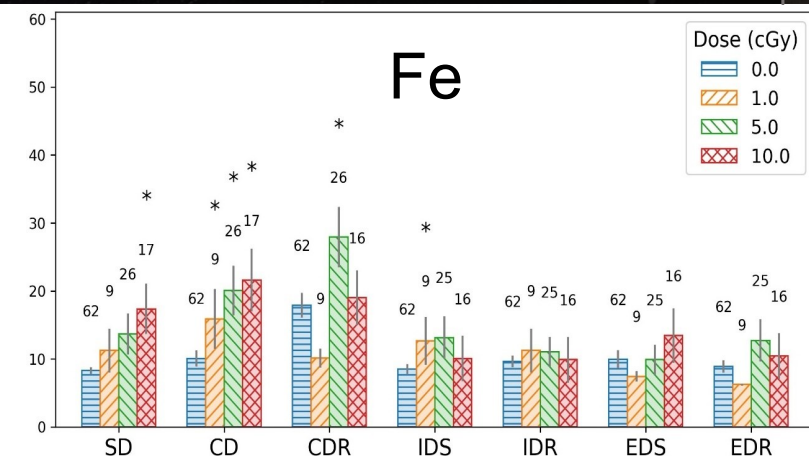
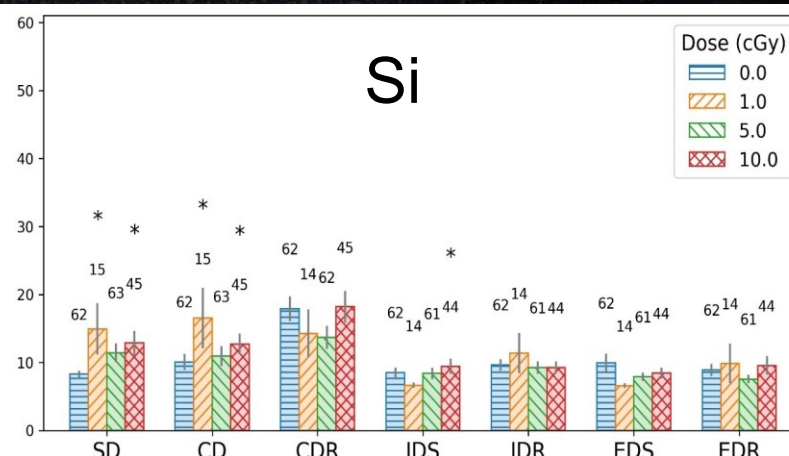
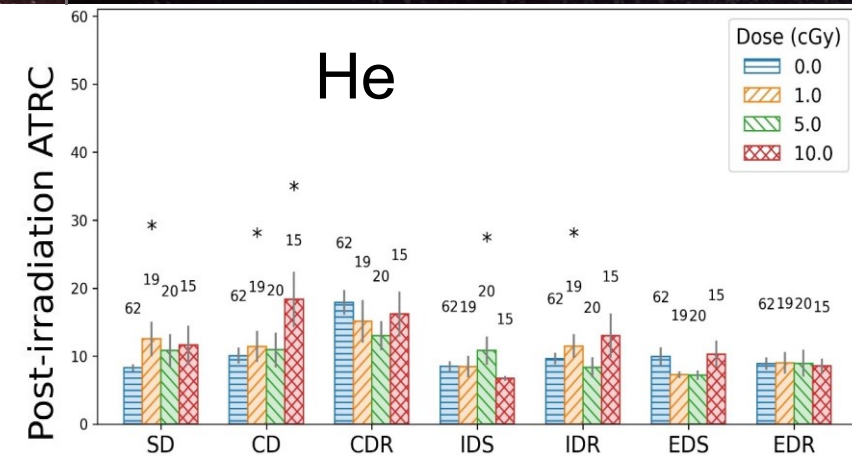
Basic Statistics



- Mean and SEM not representative of the distribution
- Many outliers shift the mean
- Data bimodal

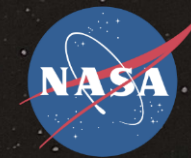


Basic Statistics

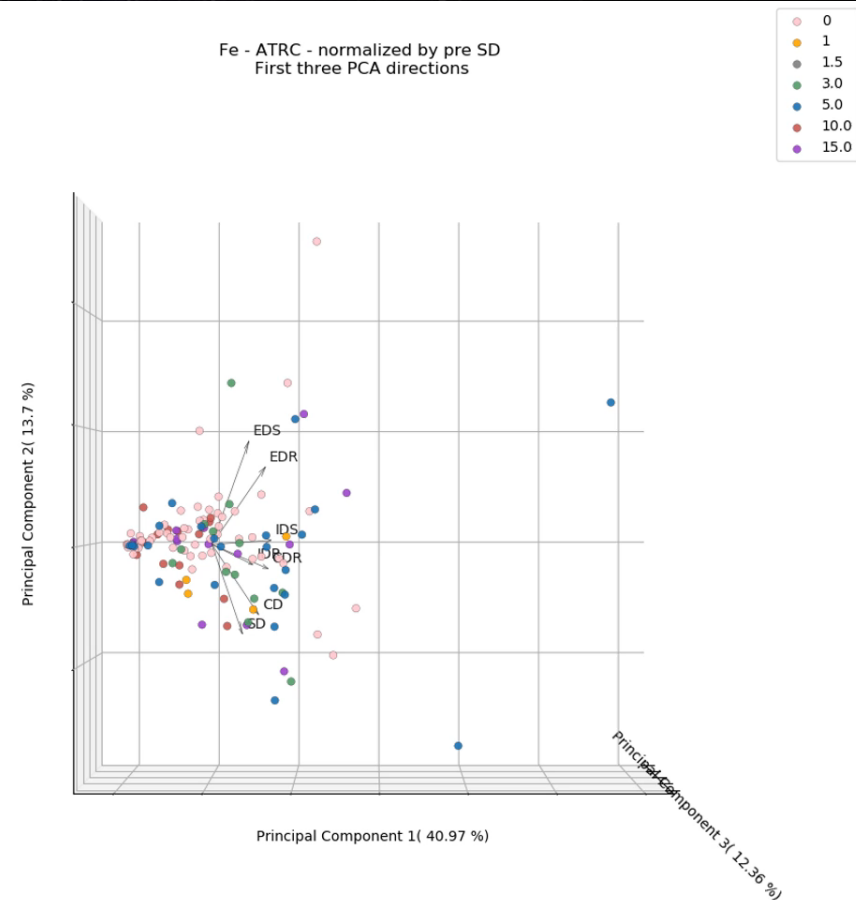




PCA Analysis

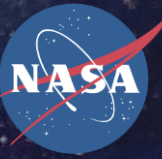


- PCA to reduce the dimension of the dataset and visualize the data
- Create a new coordinate system with orthogonal bases
- Projection of the data has greatest variance on the first component, then second, ...
- Reduce the dimension by selecting the first few principal components



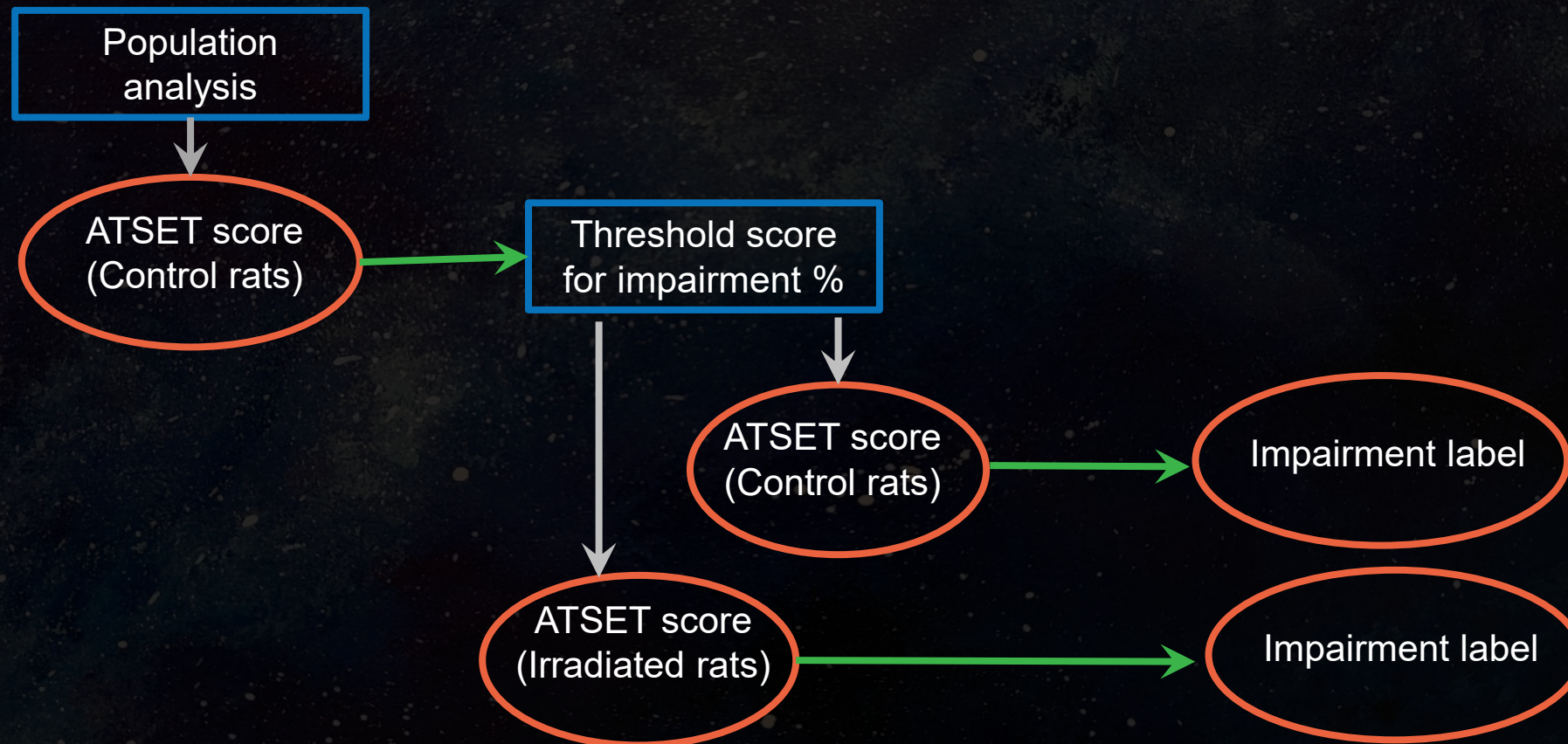


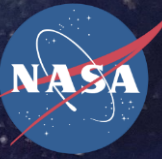
Supervised Machine Learning



Formulation of the Supervised ML Problem

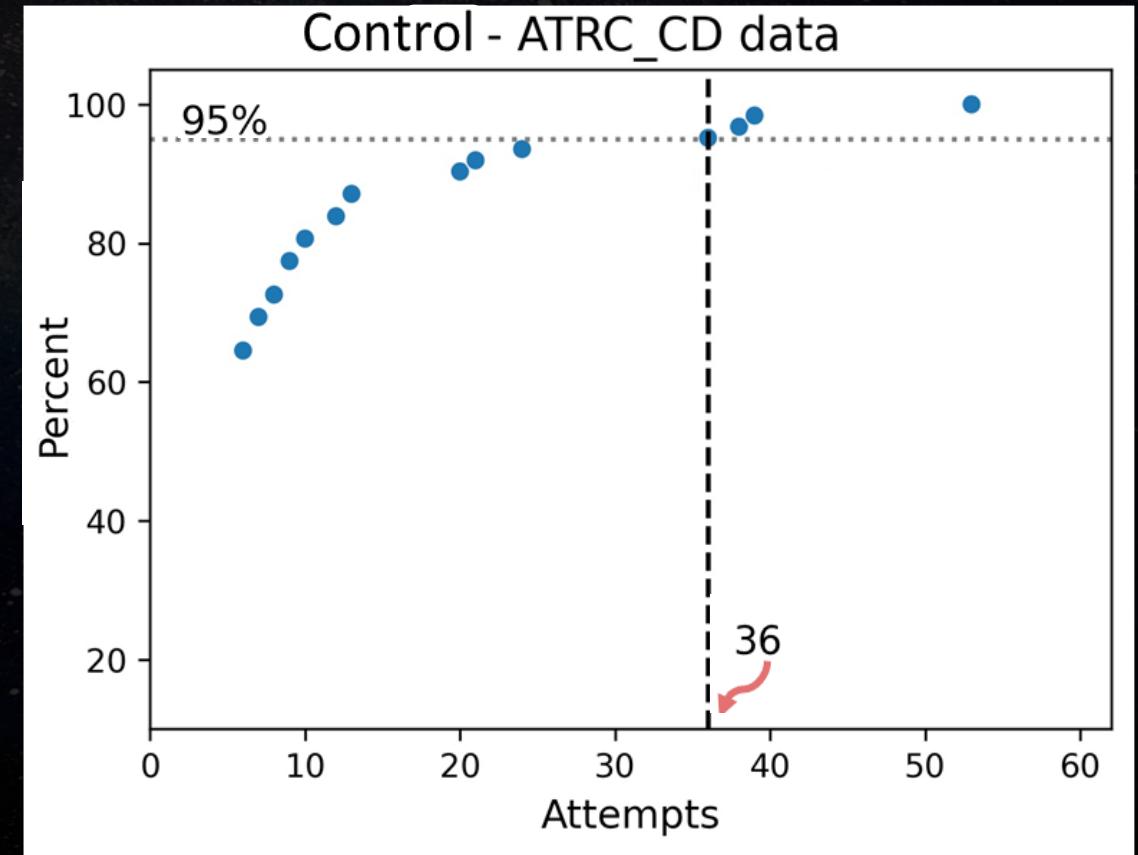
Step 1: Label rats **impaired/not impaired**

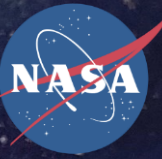




95% Threshold in CD

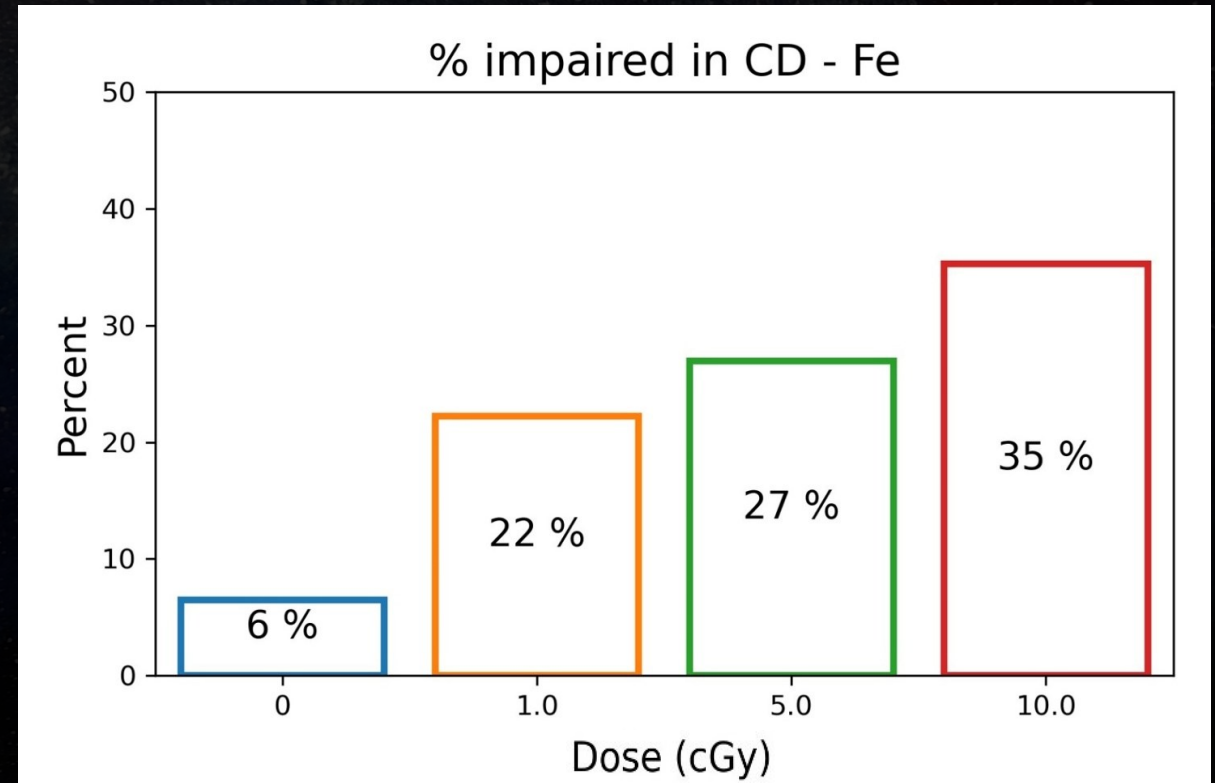
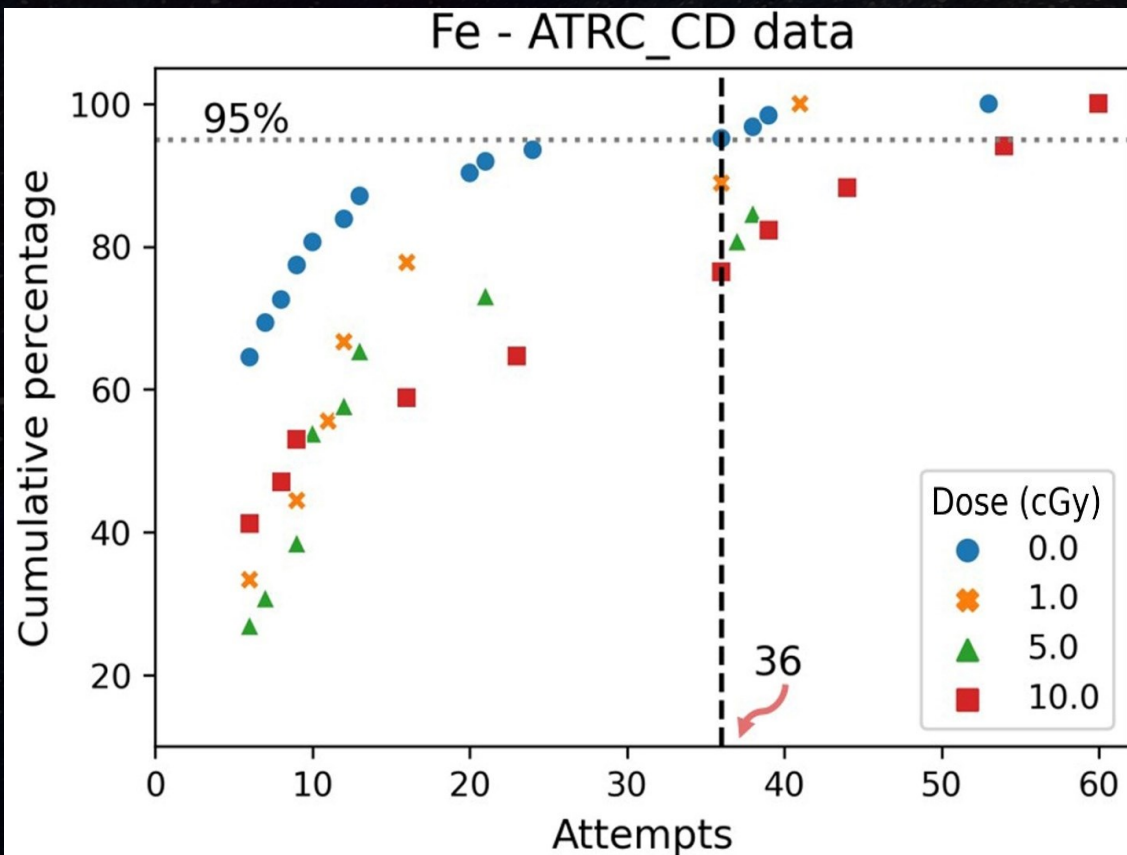
- Plot cumulative percentage for the control group
- Cumulative percentage at $x = 100 \frac{\# \text{ rats with score} \leq x}{\text{total} \# \text{ rats}}$
- A 95% threshold corresponds to a y-value of 95
- Corresponding x-value is the impairment threshold

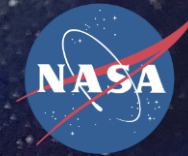




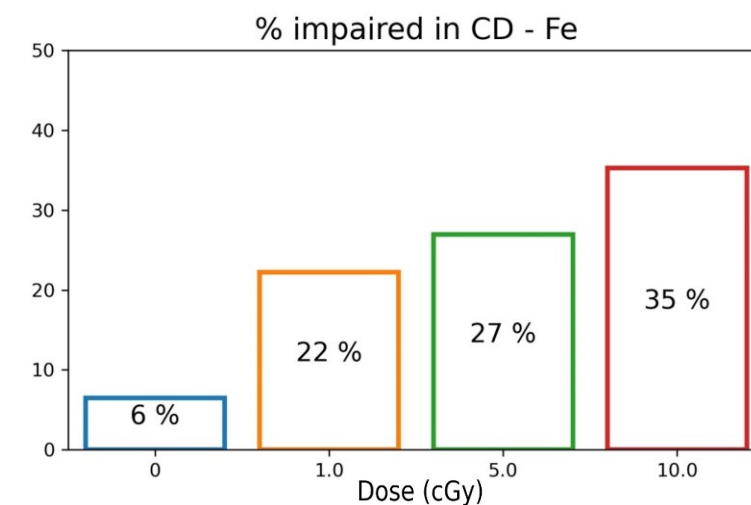
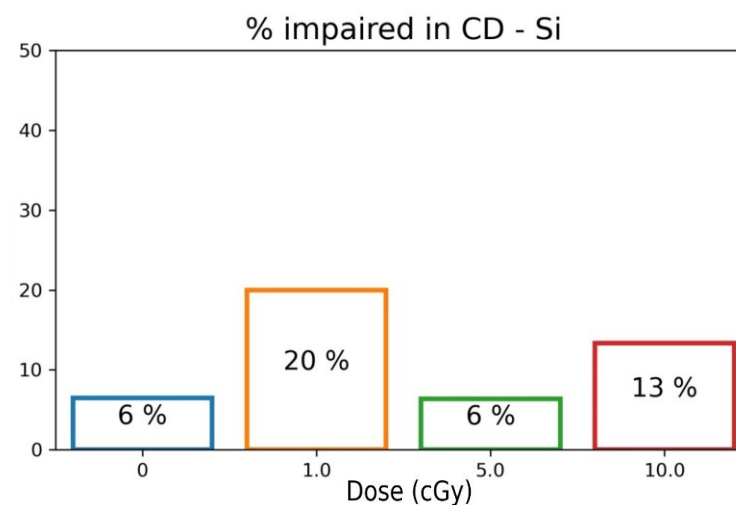
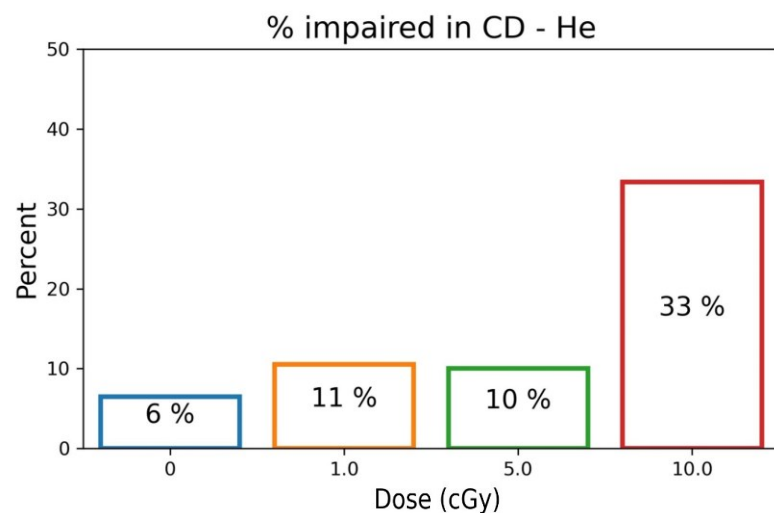
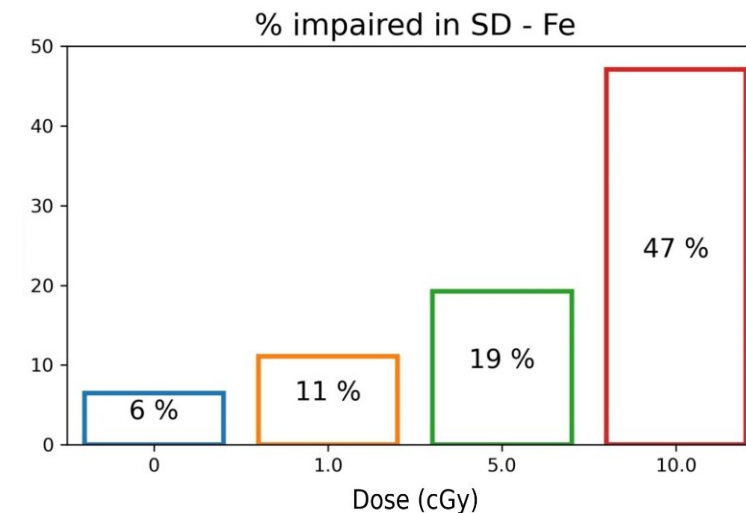
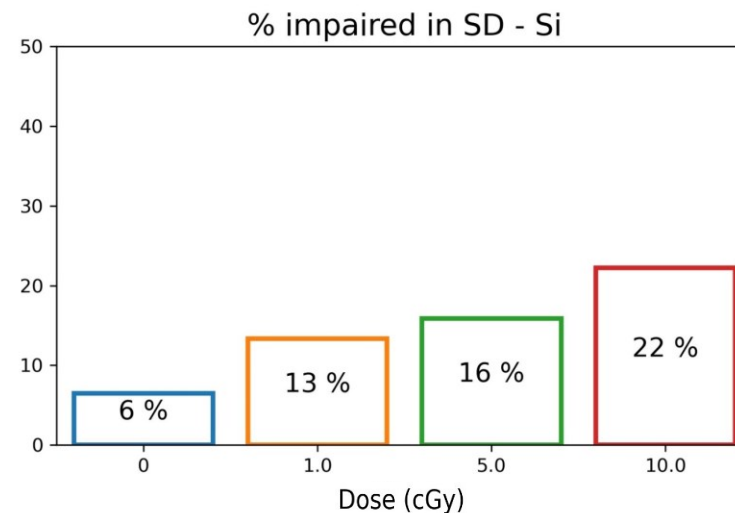
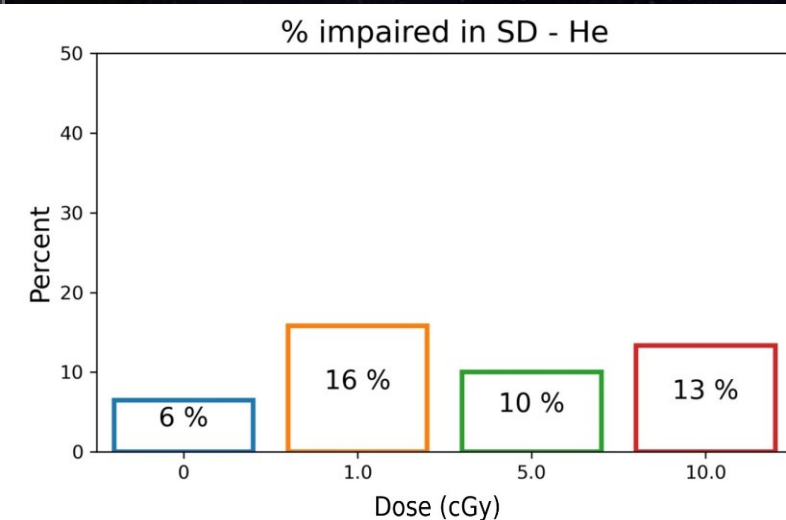
Rats' Impairment Labeling

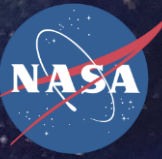
- Impaired rat: if score at or above the threshold
- Non-impaired rat: if score below the threshold





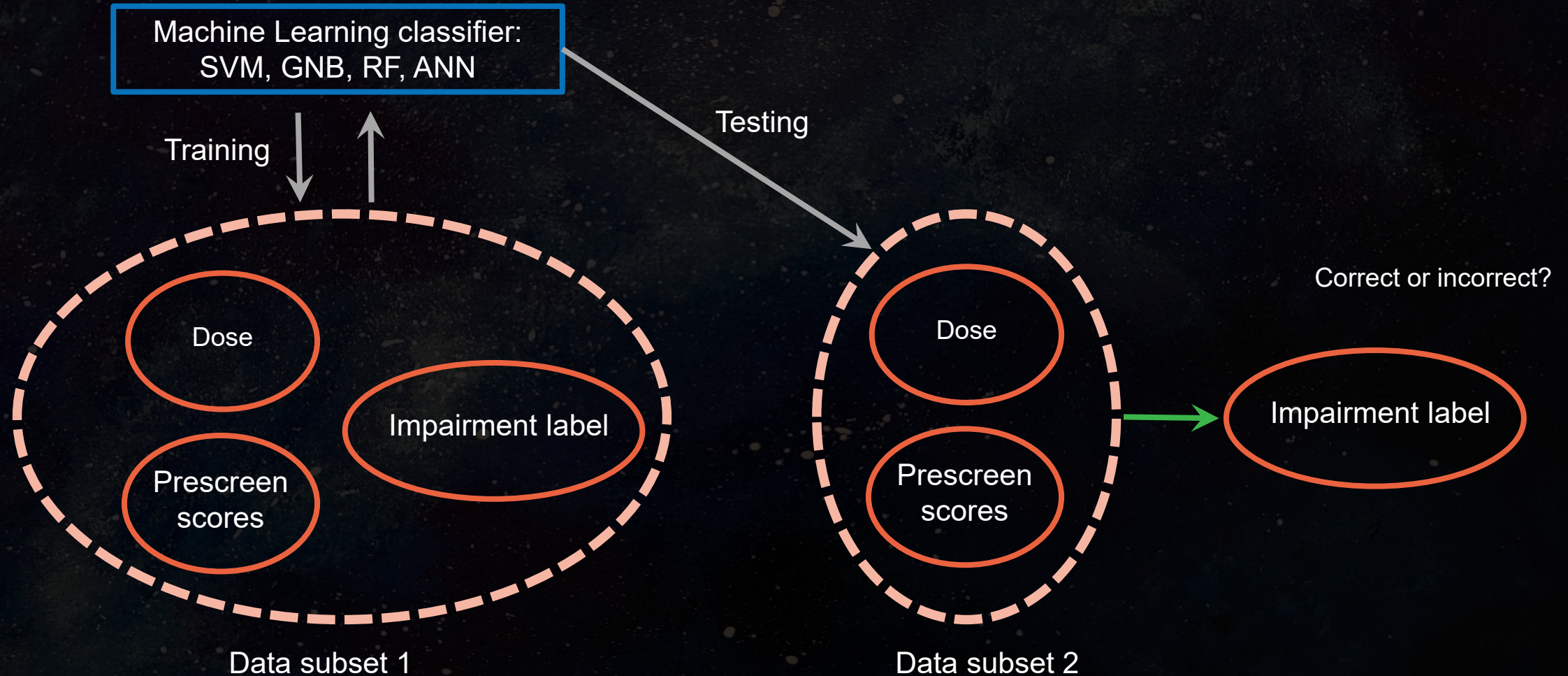
Percentage of Impaired Rats

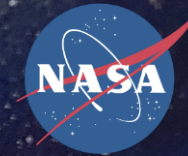




Formulation of the Supervised ML Problem

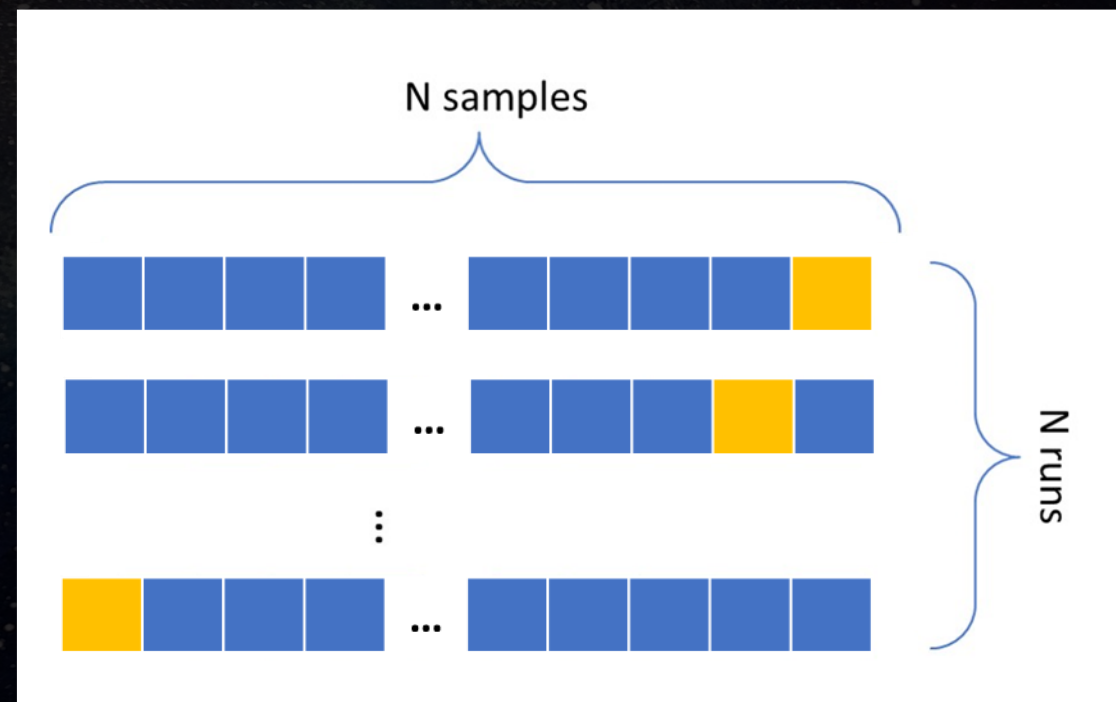
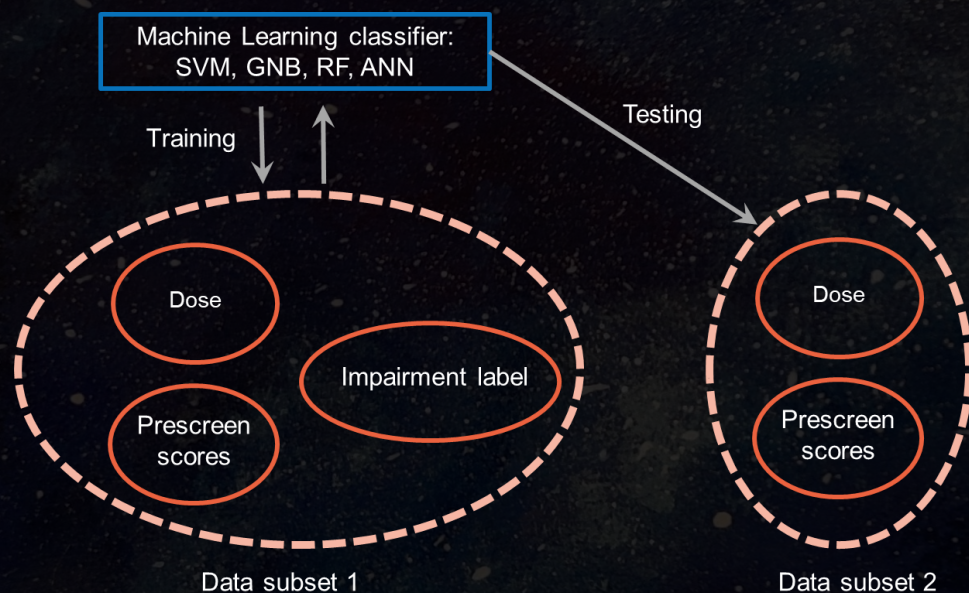
Step 2: **Predict** impairment at a given dose





Leave-one-out Cross Validation

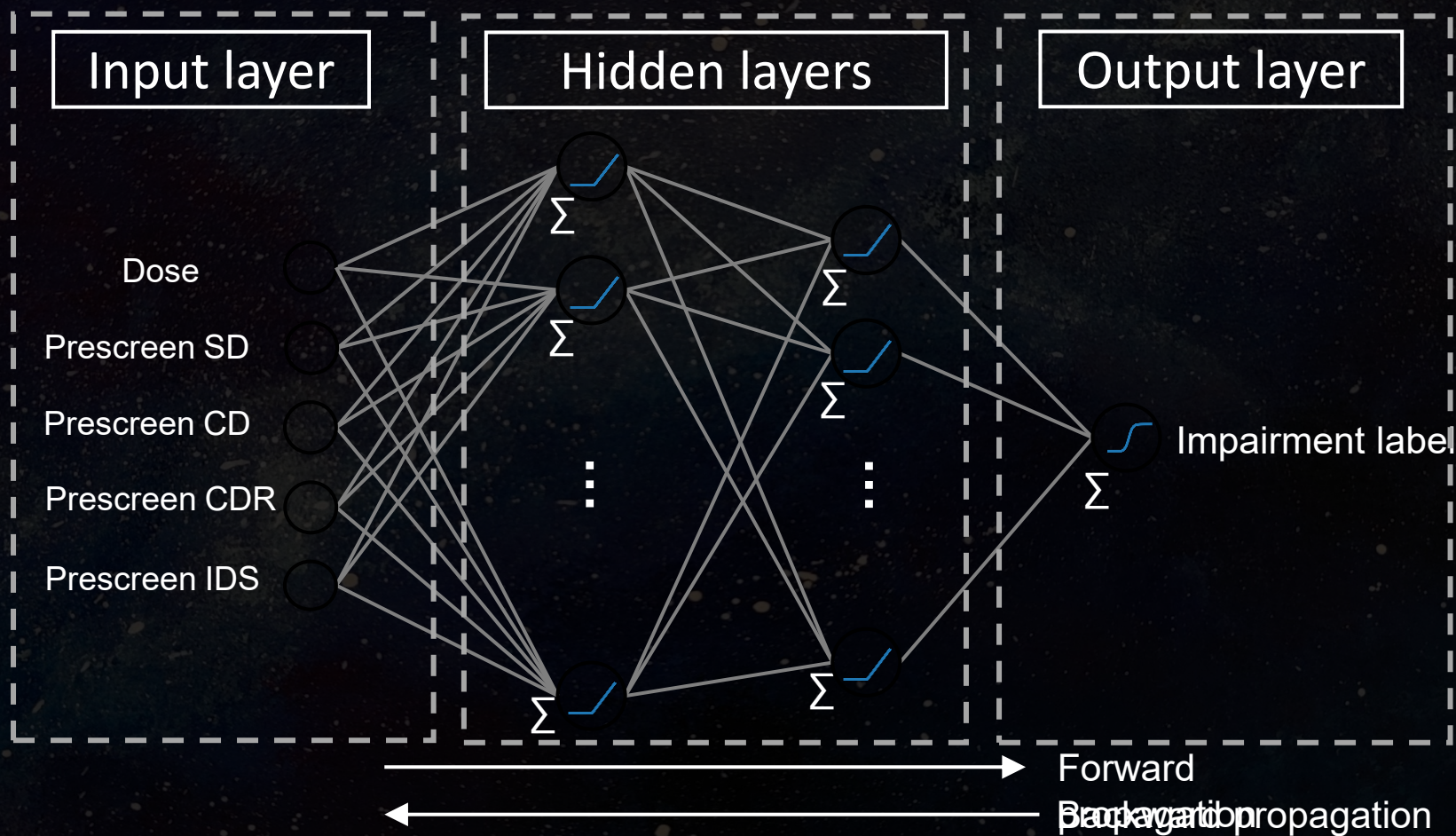
Step 2: Predict impairment at a given dose



- Data subset 1
- Data subset 2

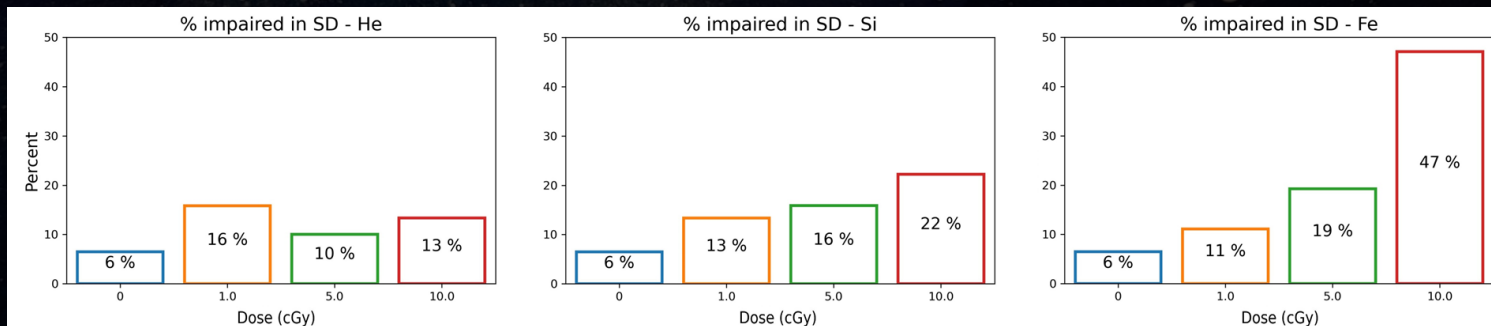
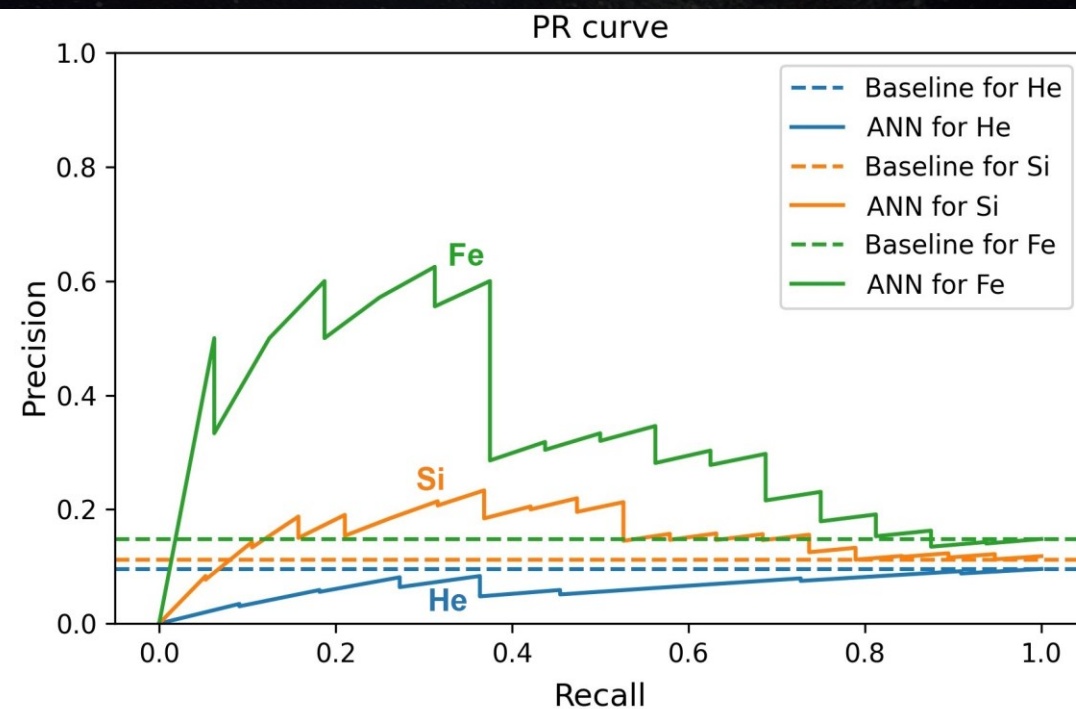
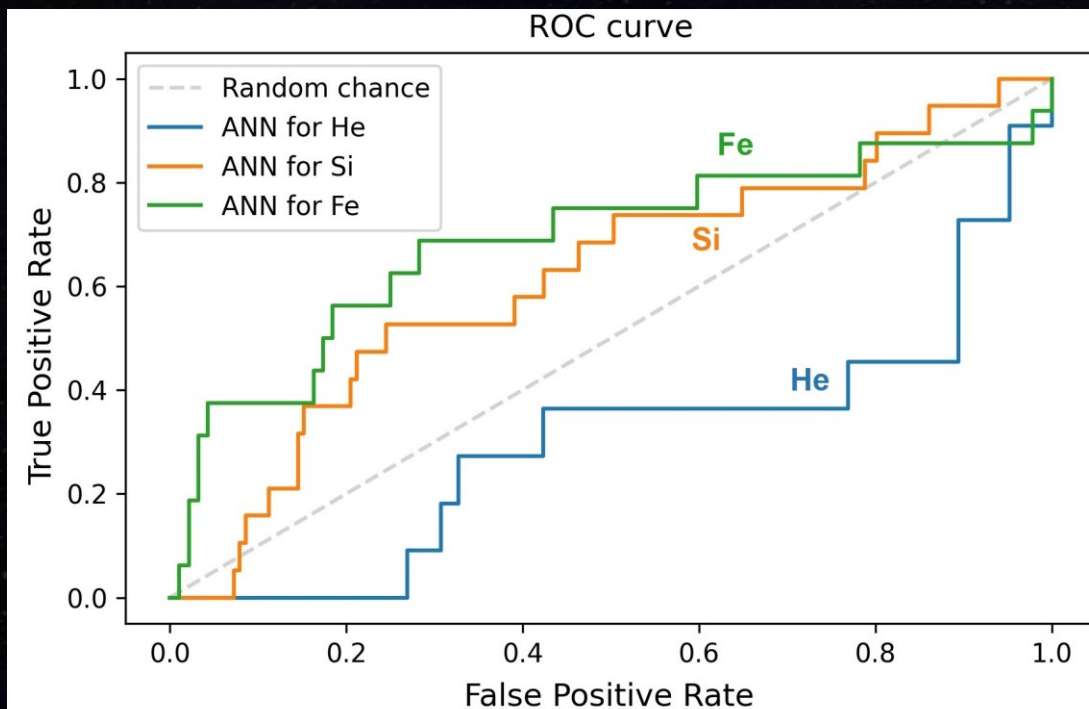


Artificial Neural Network (ANN)





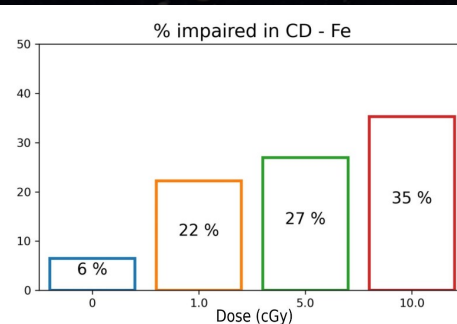
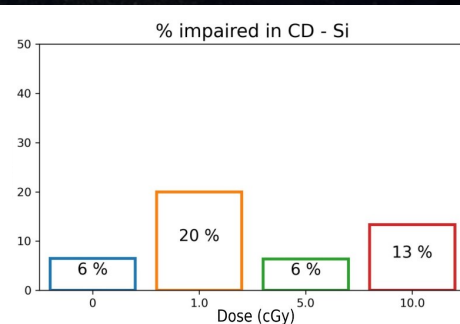
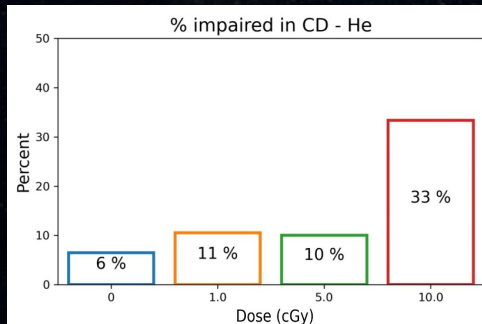
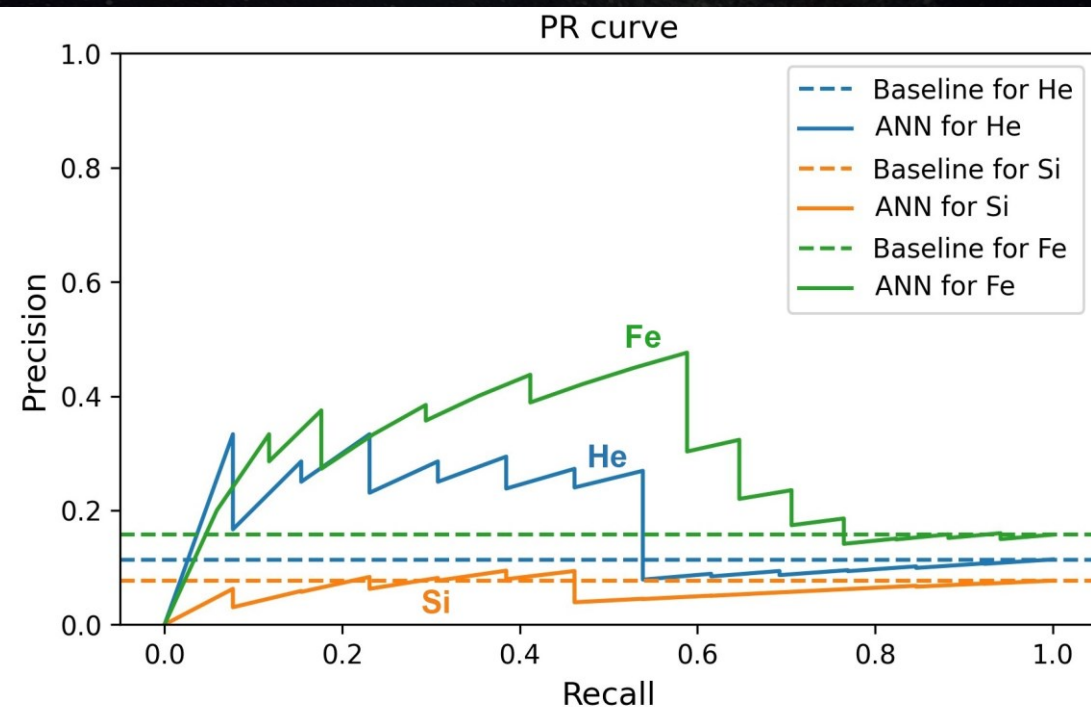
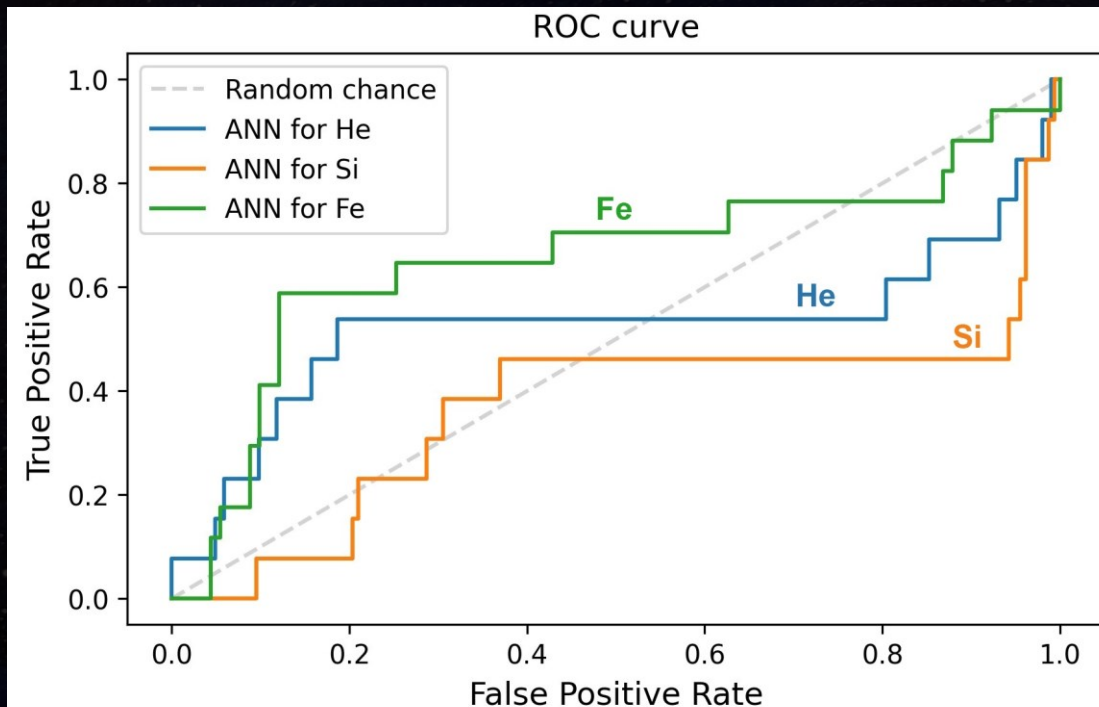
ANN Performance for SD



Matar M, Gokoglu SA, Prelich MT, Gallo CA, Iqbal AK, Britten RA, Prabhu RK and Myers JG Jr (2021) Machine Learning Models to Predict Cognitive Impairment of Rodents Subjected to Space Radiation. Front. Syst. Neurosci. 15:713131.



ANN Performance for CD



Matar M, Gokoglu SA, Prelich MT, Gallo CA, Iqbal AK, Britten RA, Prabhu RK and Myers JG Jr (2021) Machine Learning Models to Predict Cognitive Impairment of Rodents Subjected to Space Radiation. Front. Syst. Neurosci. 15:713131.



Conclusions

- Traditional population-based analyses show the presence of cognitive deficits as a trend at a group level
- Percent impaired values suggest deleterious dose-effect of ^{56}Fe in both SD and CD and ^{28}Si in SD
- Impairment due to ^4He in CD at 10 cGy
- Machine Learning models such as ANNs can pinpoint to the individuals at a higher risk of impairment
- Predictions are based on expected dose and pre-exposure scores



Limitations and Outlook

- More behavioral tests and biomarkers should be investigated on the same subjects
- With the availability of multi-ion and/or multi-stressor data, ANNs can be trained to attempt to predict the combined effect from single ions and single stressors
- Inter- and intra-variabilities in behavioral tests always present
- More work needed for the translatability of results to human subjects



For More Information



Matar, Mona, Suleyman A. Gokoglu, Matthew T. Prelich, Christopher A. Gallo, Asad K. Iqbal, Richard A. Britten, R. K. Prabhu, and Jerry G. Myers Jr. "Machine learning models to predict cognitive impairment of rodents subjected to space radiation." *Frontiers in systems neuroscience* 15 (2021).



Some Publications

- The effect of the Katz parameter on node ranking, with a medical application
H Rehm, M Matar, P Rombach, L McIntyre, Social Network Analysis and Mining 13 (1), 132
- Biological research and self-driving labs in deep space supported by artificial intelligence
LM Sanders, RT Scott, et al., Nature Machine Intelligence 5 (3), 208-219
- Machine Learning Models to Predict Cognitive Impairment of Rodents Subject to Space Radiation Exposure
M Matar, SA Gokoglu, et al., Frontiers in Systems Neuroscience 15, 102
- Predicting space radiation single ion exposure in rodents: A machine learning approach
MT Prelich, M Matar, et al., Frontiers in Systems Neuroscience 15, 715433
- Exposure to low (≤ 10 cGy) doses of ^4He particles leads to increased social withdrawal and loss of executive function performance
JA Burket, M Matar, et al., Radiation Research 196 (4), 345-354



Internships and Jobs





My Internships Experience



Spring 2018
Data Science intern
NASA Glenn Research Center
Graphics and Visualization Lab



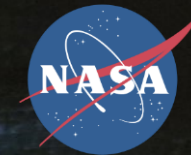
Summer 2018
Data Science intern
The J.M. Smucker Company
Coffee roasting with R&D team



Fall 2018
Pathways Trainee
NASA Glenn Research Center
Modeling team for the Human
Research Program



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Internship

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NASA'S INTERNSHIP PROGRAMS
NASA Office of STEM Engagement

NOTICES AND UPDATES

INTERN

NASA Office of STEM Engagement (OSTEM) paid [internships](#) allow high school and college-level students to contribute to agency projects under the guidance of a NASA mentor.

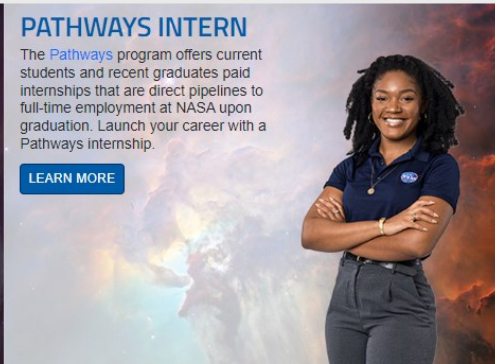
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PATHWAYS INTERN

The [Pathways](#) program offers current students and recent graduates paid internships that are direct pipelines to full-time employment at NASA upon graduation. Launch your career with a Pathways internship.

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FELLOW

NASA Fellowships allow graduate-level students to pursue research projects in response to the agency's current research priorities.

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INTERNATIONAL INTERN

University students from participating countries may intern through the agency's International Internships Project. Students work with other interns under the guidance of a NASA mentor.

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National Aeronautics and Space Administration

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Viewing 1 - 10 of 86 jobs

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NASA Pathways Intern - Student Trainee (Engineering)

Langley Research Center
National Aeronautics and Space Administration
Hampton, Virginia

Open 10/01/2019 to 12/02/2019

Starting at \$47,264 (GS 7)
Internships • Part-Time

Supervisory Research AST, Earth Sciences Remote Sensing

Goddard Space Flight Center
National Aeronautics and Space Administration

Starting at \$137,849 (GS 15)
Permanent • Full-Time

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Hiring path

Select all

- ☐ Open to the public (26)
- Federal employees (71)**
 - ☐ Competitive service (10)
 - ☐ Excepted service (2)
 - ☐ Internal to an agency (40)
 - ☐ Career transition (CTAP, ICTAP, RPL) (11)

The image is a painting of an astronaut's helmet, viewed from the front. The helmet is white with a thick, textured rim. Inside the helmet's visor, a vibrant sunset scene is depicted. The sun is a bright yellow circle on the horizon, casting a long, shimmering reflection across a deep blue ocean. The sky transitions from a bright orange near the horizon to a clear blue at the top, with a few wispy clouds. A sandy beach is visible at the bottom of the visor. In the center of the visor, there is a black rectangular box containing the text "Thank You" in a large, white, sans-serif font, followed by a white smiley face emoji. Below this, the word "Questions?" is written in a smaller, white, sans-serif font.

Thank You 😊

Questions?