Space Health Impacts for the NASA Experience (SHINE)

2023 Space Radiation Didactic Curriculum

Welcome!

Sigrid Reinsch, Ph.D.
Director SHINE Program
NASA AMES Research Center

- Introductions
- What to Expect
- Space Radiation Element Overview
  - Human Research Program
  - Space Radiation Element
  - Useful Websites and Resources
  - Acronyms
- Questions?

Introductions

SHINE Training Program

- Provide important information about the relevant scientific elements of the Human Research Program (HRP)
  - Space Radiation is hopefully just the first to provide a curriculum

- Targets graduate students to potential new investigators with an emphasis on early career investigators

- Virtual program meant to improve inclusion

Didactic Space Radiation Curriculum

- Program objectives:
  - Provide an overview of the **fundamental scientific concepts** to understand the space radiation environment and how it impacts human health
  - Introduce participants to **NASA experts** to broaden scientific understanding and promote **collaboration and networking** opportunities
  - Educate participants on the Human Research Program **grant application process** and potential **funding opportunities**
  - Familiarize participants with **internal NASA processes** that impact radiation risk management and research
- Future years will include a seperate competitive practicum session to plan and conduct space radiation research at the NASA Space Radiation Laboratory (NSRL)

SHINE 2023 Participants

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Ph.D. Candidate, Weill Cornell Graduate School and Houston Methodist

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Coordinating Doctor/Flight Surgeon, International SOS/USAFR

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UTMB Galveston

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Research Scientist NASA Ames

Sneha Mehta
MPH Candidate, Columbia U.

Kathleen Miller, Ph.D.
Research Scientist, National l Institute of Aerospace

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SHINE 2023 Participants

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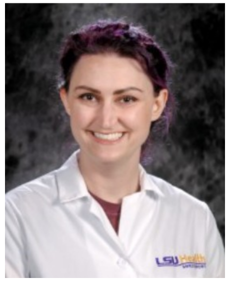
Research Scientist II, National Institute of Aerospace

Shirin Rahmanian
Research Scientist, National Institute of Aerospace



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Molika Sinha, M.S.
Research Scientist, Stanford University

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Space Radiation Element Team

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SR Element Scientist

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Cancer Discipline Lead

Jason Weeks
Element Manager

Ryan Norman
Acting Deputy Element Manager

Jordan Rhone
Science Integrator

Keli Woolery
Financial Analyst

Jennifer Lett
Scheduler

What to Expect

Weekly Activities

Tuesdays 10a-12p Central

- **Didactic Lectures/Seminars**
  - Invited speakers from NASA, academia, industry, etc.
  - 1-2 hours depending on content
- **Coffee Hours**
  - Informal interaction with an invited guests
  - Speaker may present ~10 minutes to stimulate conversation and questions
- **Office Hours**
  - Informal session to interact with Space Radiation Element (SRE) personnel
  - Answer questions about mock beam-time proposals or anything else!

Other Activities

- **Mock Beam-Time Proposal**
  - “Beam-time” to use of the NASA Space Radiation Laboratory (NSRL) is requested by submitting a proposal to the Brookhaven National Laboratory (BNL) Science Advisory Committee for Radiation Research (SACRR)
  - Proposal is in addition to that submitted to acquire funding
  - Participants will develop and present a “mock” beam-time proposal
- **Suggested Readings**
  - Foundational or important papers in the field collected from speakers
- **Surveys**
  - Gauge participants understanding and to improve sessions in the future

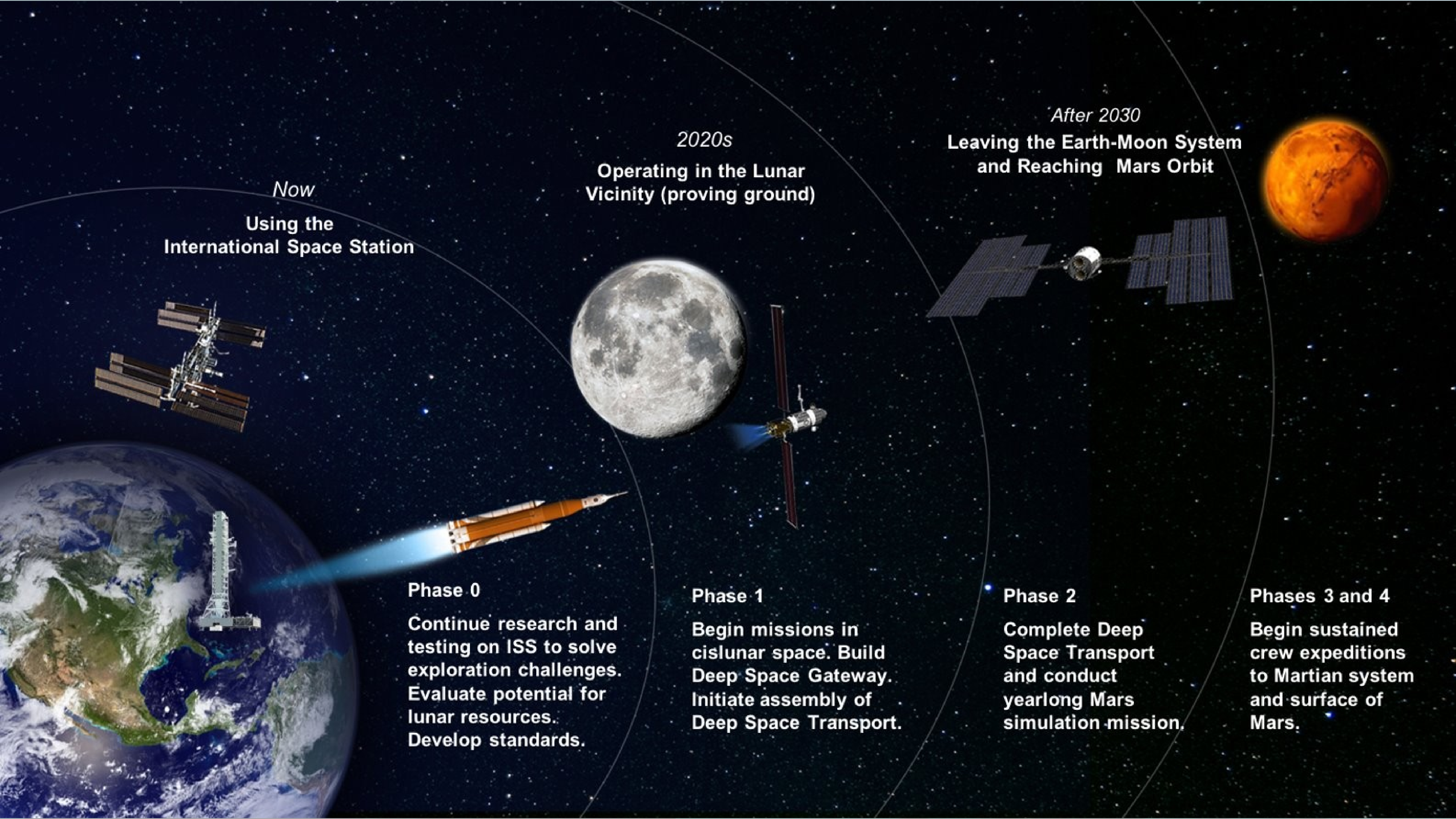
Course Outline

Month	Type	Topic
February 2023	Seminar	Space Radiation Element
March 2023	Seminar	Radiation Physics and Dosimetry
	Coffee Hour	*HRP/element*
	Seminar	Space Radiation Environment
	Coffee Hour	*Protons/Therapy*
	Seminar	Space Radiation Analogs
April 2023	*Coffee Hour*	*STAR/Space Biology*
	Seminar	Mechanism of Damage and Repair
	Office Hours	
	Seminar	Mechanism of Damage and Repair – Oxidative Stress

Month	Type	Topic
May 2023	*Coffee Hour*	*HSRB overview*
	Seminar	Biomarkers
	Office Hours	
	Seminar	Radioprotectants & Mitigation
	Coffee Hour	*NASA Open Science*
June 2023	Seminar	Experimental Models I
	Seminar	Experimental Models II
	Office Hours	
	Seminar	Radiation Epidemiology and Biostatistics
July 2023	Seminar	Bioinformatics & Data Modeling
	Coffee Hour	*Grants*
	Presentations	Mock Beam Time Proposals
August 2023	Seminar	Funding Opportunities

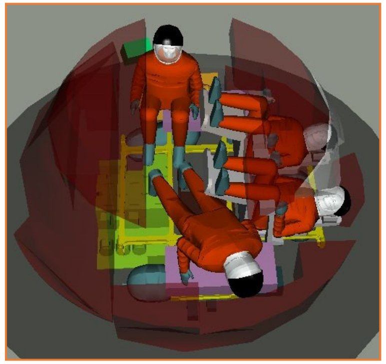
Space Radiation Element Overview

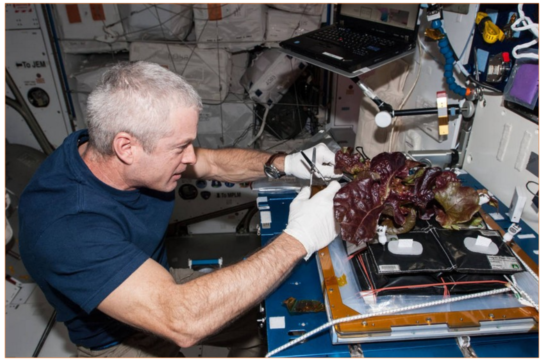
Human Research Program


Now
Using the International Space Station
2020s
Operating in the Lunar Vicinity (proving ground)
After 2030
Leaving the Earth-Moon System and Reaching Mars Orbit
Phase 0
Continue research and testing on ISS to solve exploration challenges. Evaluate potential for lunar resources. Develop standards.
Phase 1
Begin missions in cislunar space. Build Deep Space Gateway. Initiate assembly of Deep Space Transport.
Phase 2
Complete Deep Space Transport and conduct yearlong Mars simulation mission.
Phases 3 and 4
Begin sustained crew expeditions to Martian system and surface of Mars.

An **Applied** Research Program

- Scientific Goals
  - Understand and mitigate human health and performance risks due to the five known hazards of spaceflight
  - Enable development of human spaceflight medical and human performance standards
  - Develop and validate technologies that serve to characterize and reduce health risks associated with human spaceflight





Hazards of Human Spaceflight

1 Space Radiation

Invisible to the human eye, radiation increases cancer risk, damages the central nervous system, and can alter cognitive function, reduce motor function and prompt behavioral changes.

2 Isolation and Confinement

Sleep loss, circadian desynchronization, and work overload may lead to performance reductions, adverse health outcomes, and compromised mission objectives.

3 Distance from Earth

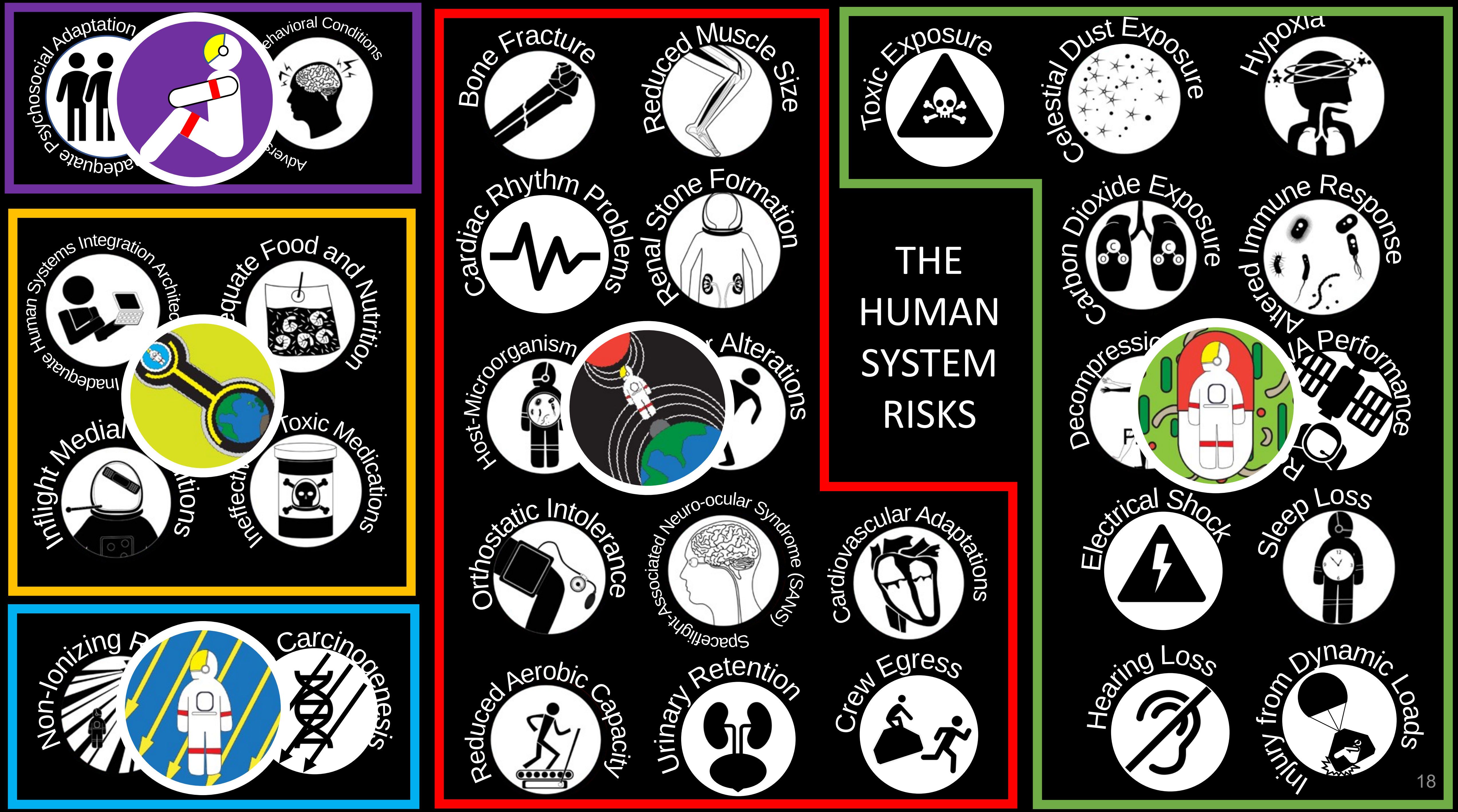
Planning and self-sufficiency are essential keys to a successful mission. Communication delays, the possibility of equipment failures and medical emergencies are some situations the astronauts must be capable of confronting.

4 Gravity (or lack thereof)

Astronauts encounter a variance of gravity during missions. On Mars, astronauts would need to live and work in three-eighths of Earth's gravitational pull for up to two years.

5 Hostile/Closed Environments

The ecosystem inside a vehicle plays a big role in everyday astronaut life. Important habitability factors include temperature, pressure, lighting, noise, and quantity of space. It's essential that astronauts stay healthy and happy in such an environment.



adequate Psychosocial Adaptation
ehavioral Conditions
Adver
Human Systems Integration Architec
Inadequate
equate Food and Nutrition
Inflight Medial
tions
Ineffecti
Toxic Medications
Non-Ionizing R
Carcinogenesis
Bone Fracture
Reduced Muscle Size
Cardiac Rhythm Problems
Renal Stone Formation
Host-Microorganism
r Alterations
Orthostatic Intolerance
Spaceflight-Associated Neuro-ocular Syndrome (SANS)
Cardiovascular Adaptations
Reduced Aerobic Capacity
Urinary Retention
Crew Egress
THE HUMAN SYSTEM RISKS
Toxic Exposure
Celestial Dust Exposure
Hypoxia
Carbon Dioxide Exposure
Altered Immune Response
Decompressio
A Performance
Electrical Shock
Sleep Loss
Hearing Loss
Injury from Dynamic Loads

Translating Basic Science to Applications (Example in Biomedicine)

Space Biology

Basic | **Translational Research** | **Applied**

Human Research

Basic Science

Study how life responds, adapts, develops, interacts and evolves in the space environment and across the gravitational continuum:

- Cell and Molecular Biology
- Microbiology
- Animal Biology
- Plant Biology
- Developmental & Reproductive Biology

Science Exploring the Unknown

Scientific data and findings that foster research and development across biological systems

- Animal Research
- Cells and tissues
- Immunology
- Wound healing and fracture repair
- Bone and muscle
- Radiation/micro-g interactions
- Microbiome of the built environment

Critical Link!

Identify, characterize and mitigate the risks to human health and performance in space:

- **Exercise Countermeasures**
- **Physiological Countermeasures**
- **Space Radiation Biology**
- **Behavioral Health and Performance**
- **Space Human Factors and Habitability**
- **Exploration Medical Capability**
- **Environmental Monitoring**

Science Addressing The Known Risks

Medical Operations

https://humanresearchroadmap.nasa.gov/

Addressing Health Risks

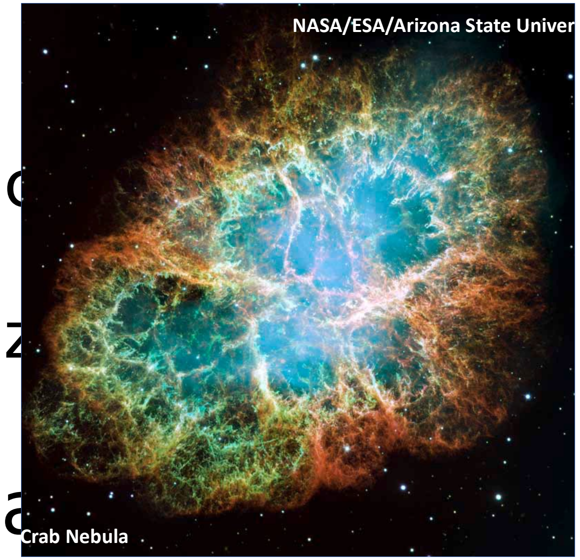
- Five HRP Elements and 23 active risks :
  - Exploration Medical Capability (ExMC)
    - Medical care for deep-space missions
  - Human Factors and Behavioral Performance (HFBP)
    - Interfaces between humans, vehicles, and habitats
    - Individual and interpersonal
  - Human Health Countermeasures (HHC)
    - Physiology
  - **Space Radiation (SR)**
    - **Biological effects of radiation exposure**
  - Research Operations and Integration (ROI)
    - Infrastructure for flight and analog experiments
- Funds Translational Research Institute for Space Health (TRISH) to pursue disruptive, breakthrough approaches that reduce risks to human health and performance
- Collaborates with NASA Space Biology program to understand causal cellular and other mechanisms that underlie adaptation to spaceflight in cells, microorganisms, plants, and animals

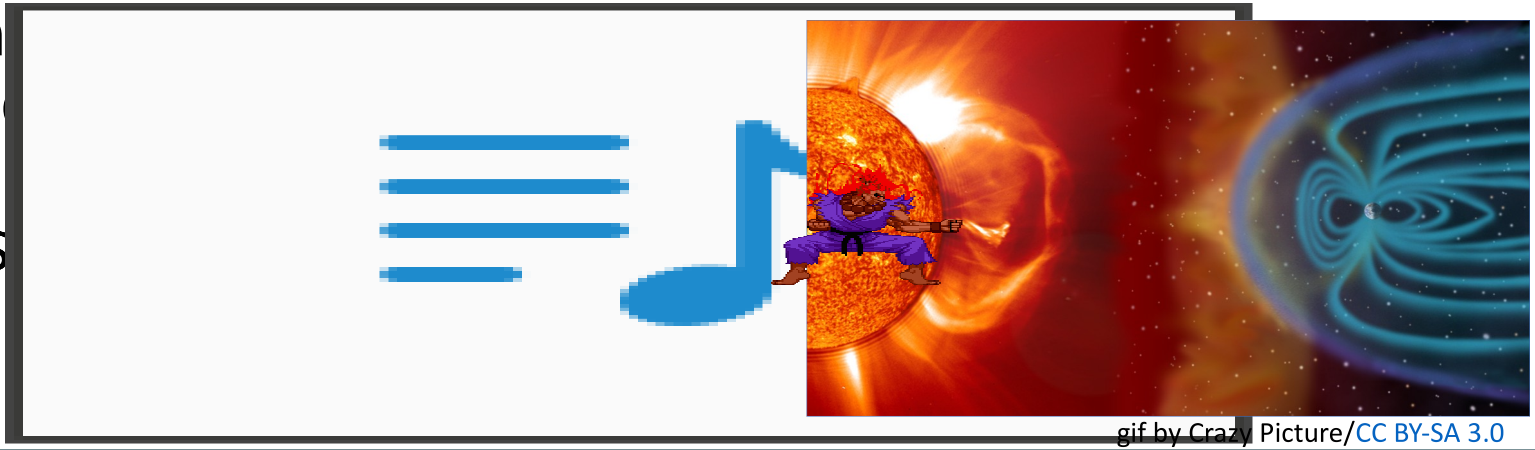
Space Radiation Element

Space Radiation

More on the Space Radiation Environment in Seminar #3!

- Why does NASA care about radiation?
  - Radiation can cause damage when it interacts with c components
  - Space is a "radiation environment" ⟹ Workplace haz
    - Astronauts are radiation workers
- Space radiation is different than terrestrial radia
  - Mainly high energy pa
    - Galactic Cosmic Rays (
    - Trapped Radiation
    - Solar Particle Events (S





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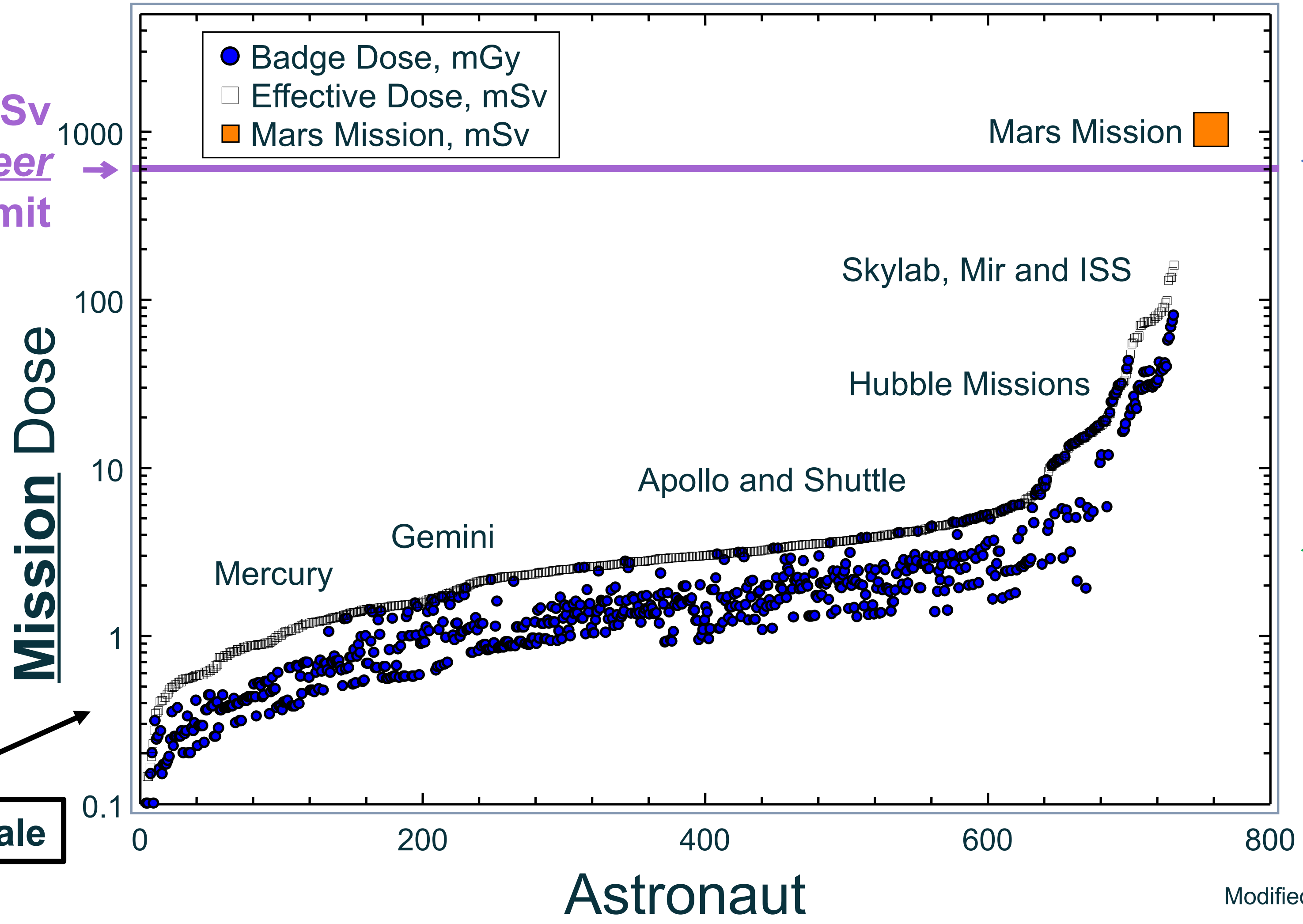
Historical NASA Crew Mission Doses

600 mSv
NASA *Career*
Radiation Limit



650 mSv
NCRP *Lifetime*
Radiation Worker
Guidance for 65yo

50 mSv/yr
Annual NRC Radiation
Worker Limit

3.6 mSv
Annual Average US
Background Dose

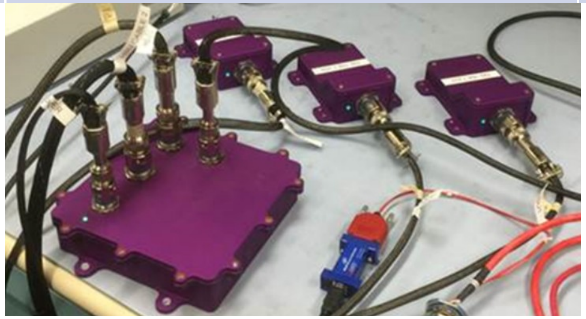
NOTE: Log Scale

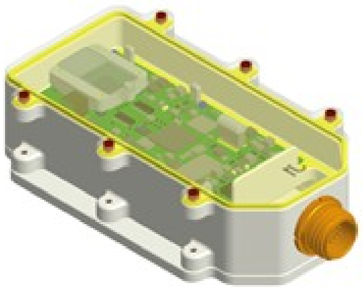
Modified from Cucinotta et al. Radiat Res (2008)

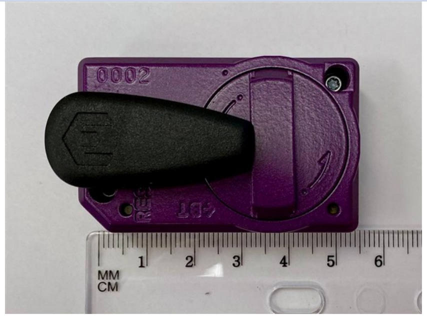
More on Dosimetry in Seminar #2!

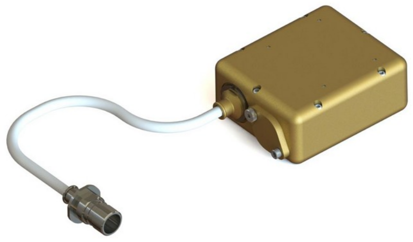
Instrument Suite for Crewed Artemis Missions

Function	HERA	ARES	CAD	ARD
Measurement	• Charged Particle Detector • Area monitoring of flux/species and dose		• Crew member dose rate/total dose	
Proposed mission(s)	• Orion/Artemis	• Gateway, Lander • (HERA heritage hardware)	• Personal dosimetry	
Use	• Real time radiation environmental monitoring • On-board alerting		• Real-time dose at crew • Worn by crew at all times **inside** crewed vehicles • Post mission crew risk assessment • Re-flight determination	• Real time dose at crew • EVA, integrated with xEMU • On-board alerting • Post mission crew risk assessment
Mass	• ~3kg	• <2kg	• 35g	• 430g
Dimensions	• HPU: 19.3 cm x 17.5 cm x 4.6 cm • HSU (2 each): 13.5 cm x 10.7 x 5.3 cm	• 9.9 cm x 17.8 cm x 4.6 cm	• 5.7 x 3.4 x 2.6 cm	• 7 cm x 6 cm x 3 cm









Space Radiation Health Risks

Mission Success

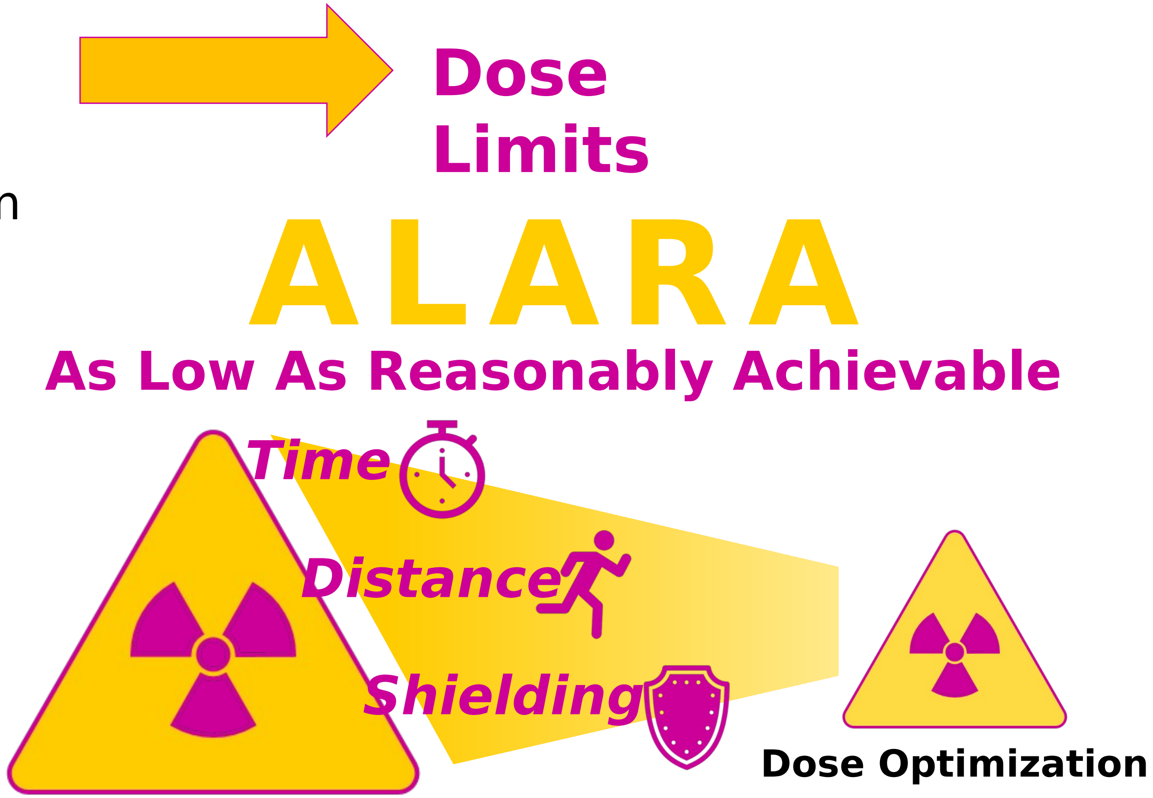
- Acute effects
  - Very large high-energy solar events
    - Estimate ~ 200 – 400 mSv (unsheltered) for 1972 Event
    - **MILD** symptoms IF they occur at all given doses
- Potential early neurological effects
  - Behavior or memory decrements
  - Observed only in animal models

Long Term Health

- Cancer
  - Space radiation may cause unique impacts
- Degenerative
  - Cardiovascular disease
  - Cataracts
  - Immune
- Potential late neurological decrements
  - Behavior or memory decrements
  - Neurodegenerative disease
  - Observed only in animal models

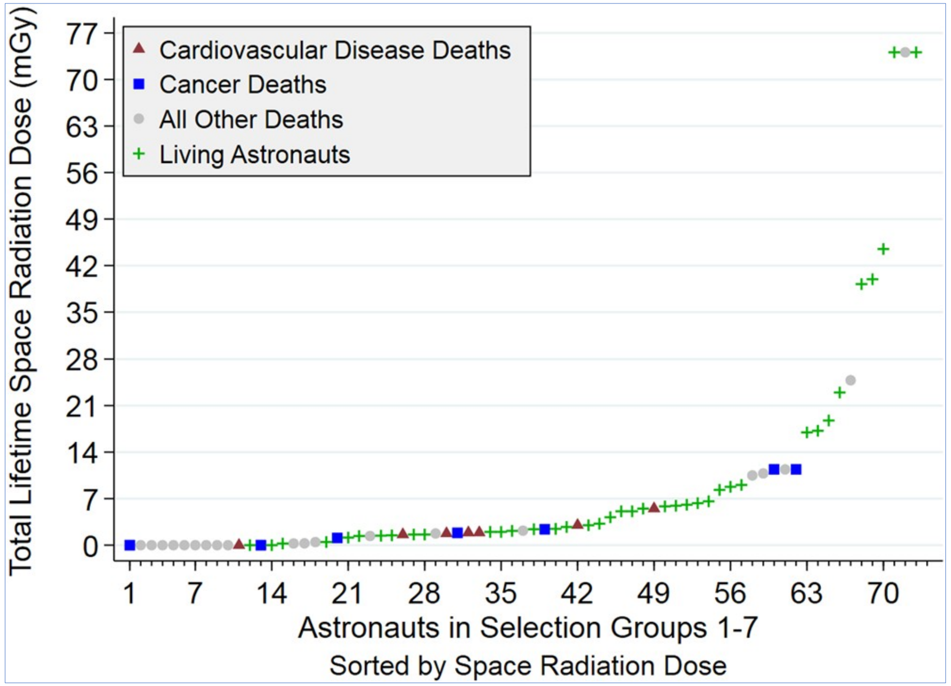
The Space Radiation Protection Challenge

- Traditional terrestrial protection strategies fall short in space:
  - **Time**
    - At some point you will always reach a limit
  - Distance
    - There is no point source to move away from
  - Shielding
    - Energetic particles are penetrating
      - Secondary particles
- NASA is exploring other protection strategies
  - Individualized risk characterization
  - Health surveillance including early disease detection
  - Compound-based countermeasures



Research Challenges

- Limited observed outcomes in astronauts
  - Small population
  - Low doses and dose rates
  - Common outcomes



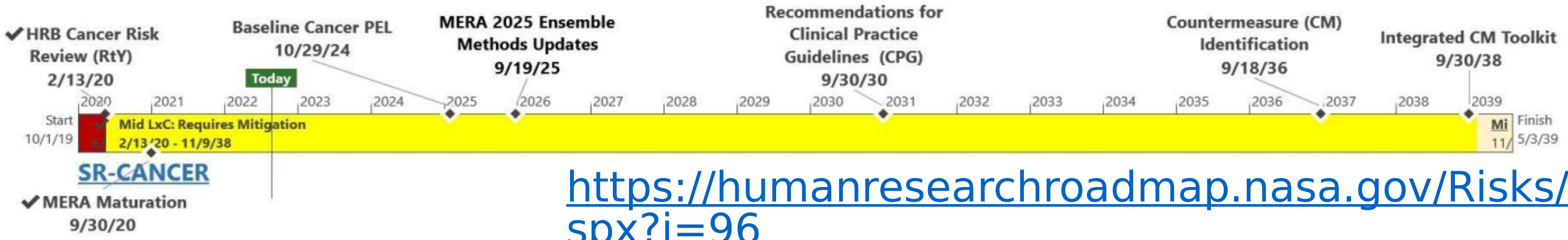
- Limited knowledge of biological effects of space radiation
  - Heavy reliance on animal studies
  - Space radiation is unique

Space Radiation Element Research

- Mission: Characterize and facilitate the management of the human health outcomes associated with space radiation exposure to protect astronaut health and wellbeing to enable human spaceflight
  - Carcinogenesis
  - Cardiovascular and Immune
  - Central Nervous System

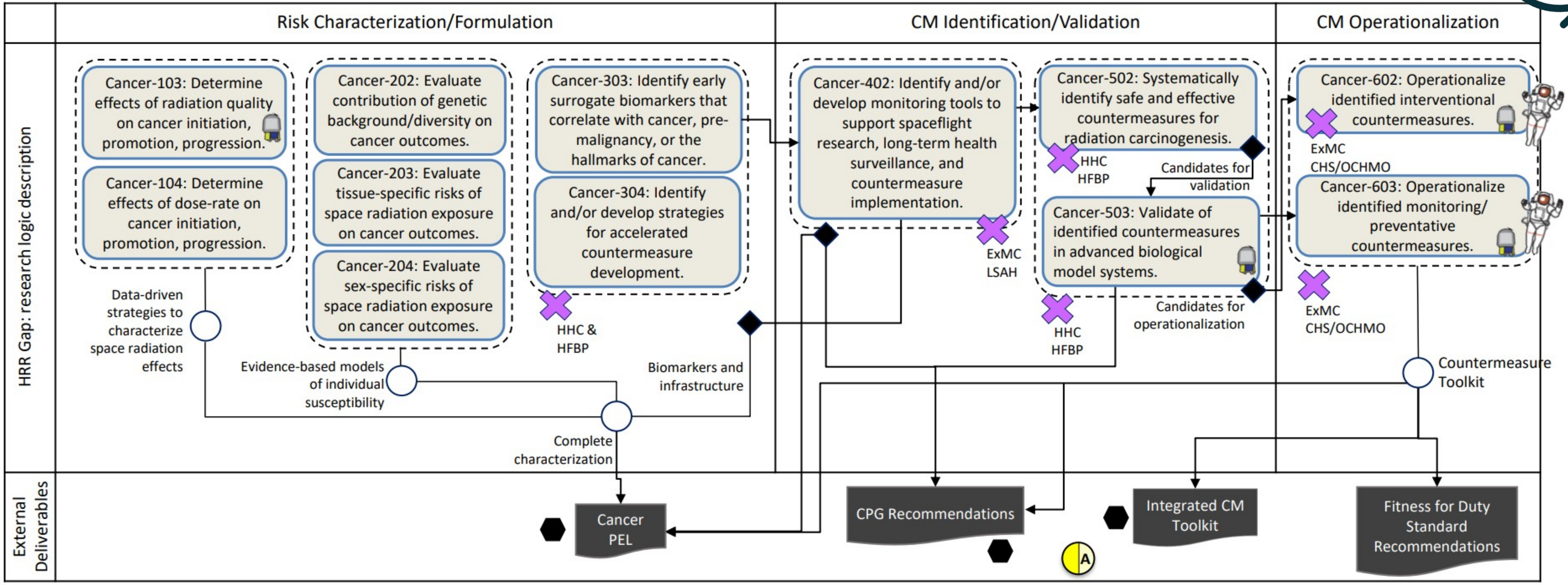
Characterization	⟷	Mitigation
Dose and Dose Rate Effects	Biomarkers	Countermeasure Identification
Radiation Quality	Individual Susceptibility	Countermeasure Validation
Cross-Species Translation	Combined Stressors	

Cancer Risk Approach Plan



https://humanresearchroadmap.nasa.gov/Risks/risk.aspx?i=96

Cancer risk



Note: Decision Points (◆), Element Milestone (○) and Gap Closures (⬢) are Program reviews with defined entry/exit criteria.

Legend: Analog | Flight environment | Cross Element Integration | Anticipated PRR Color Change

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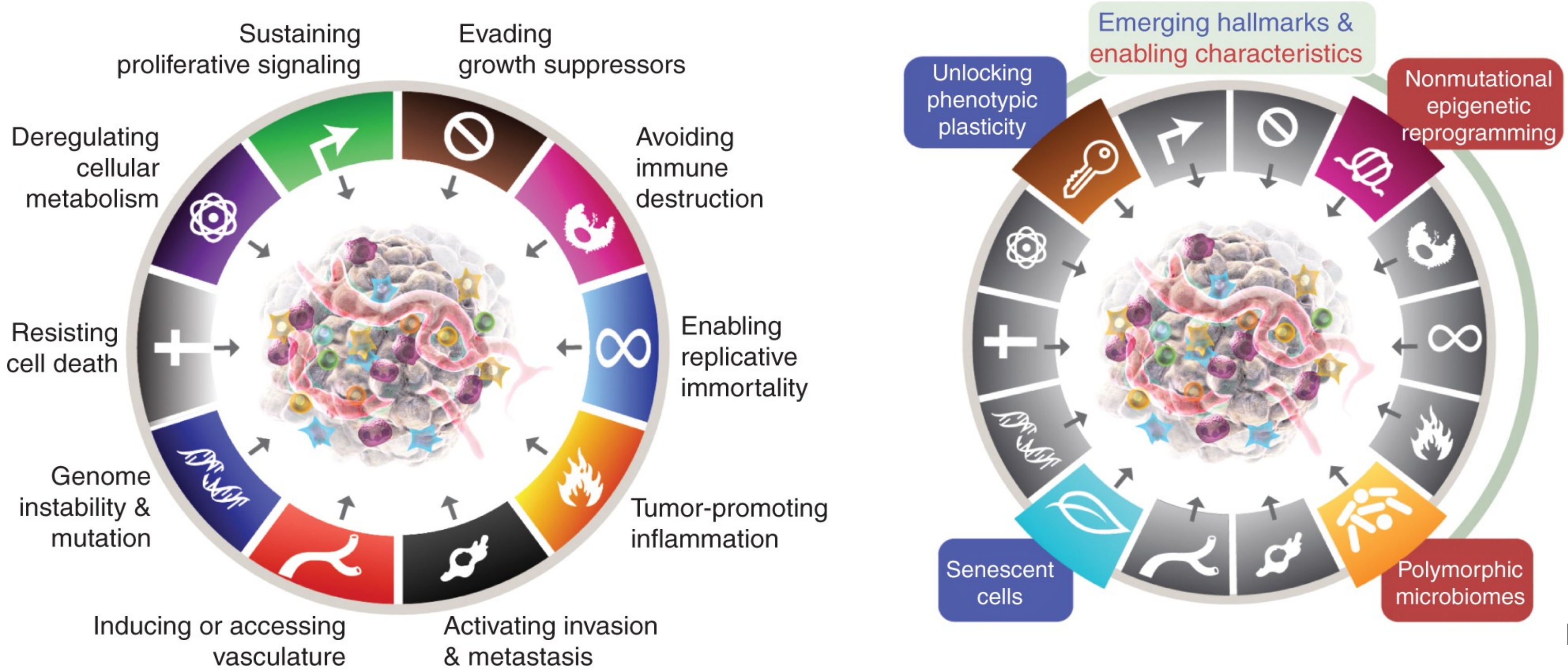
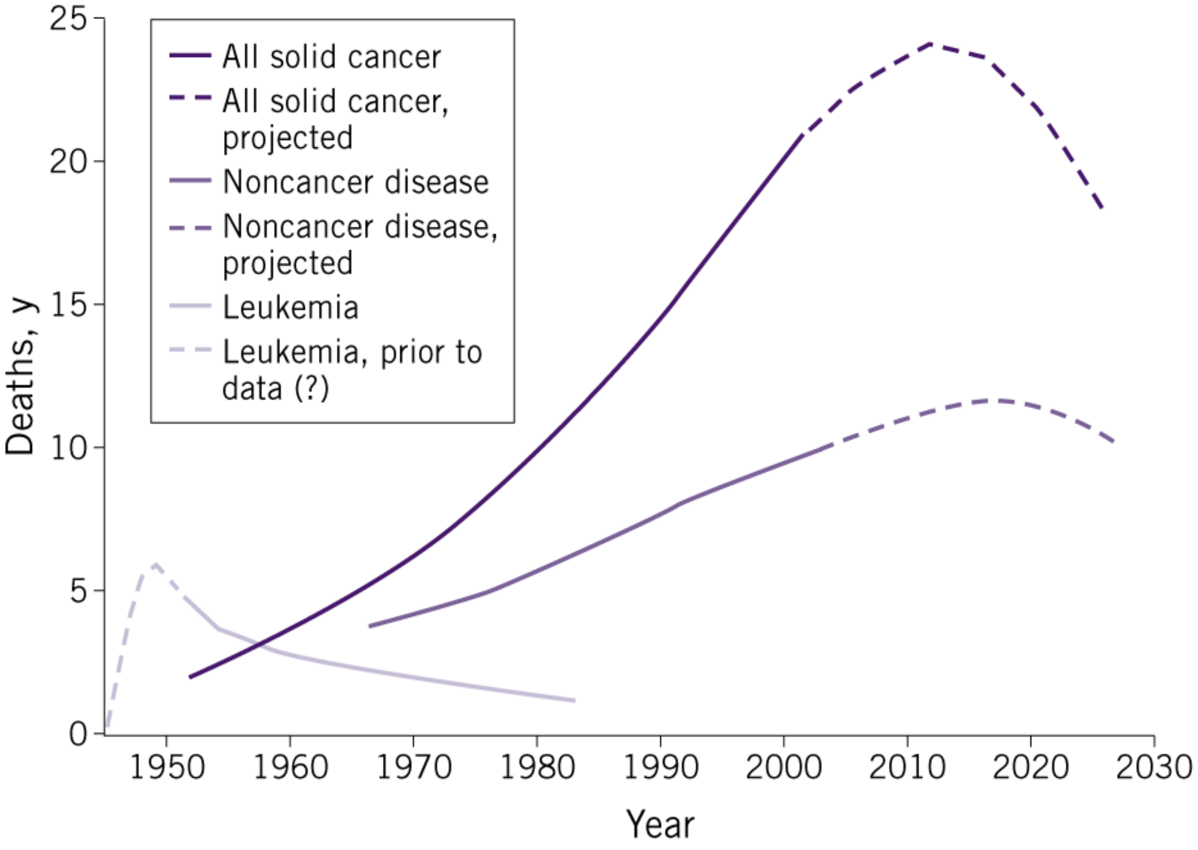
What is Cancer?

- Cancer is defined as a cluster of diseases characterized by the uncontrolled proliferation of cells that spread to other



Hanahan 2022 (Cancer Discovery)

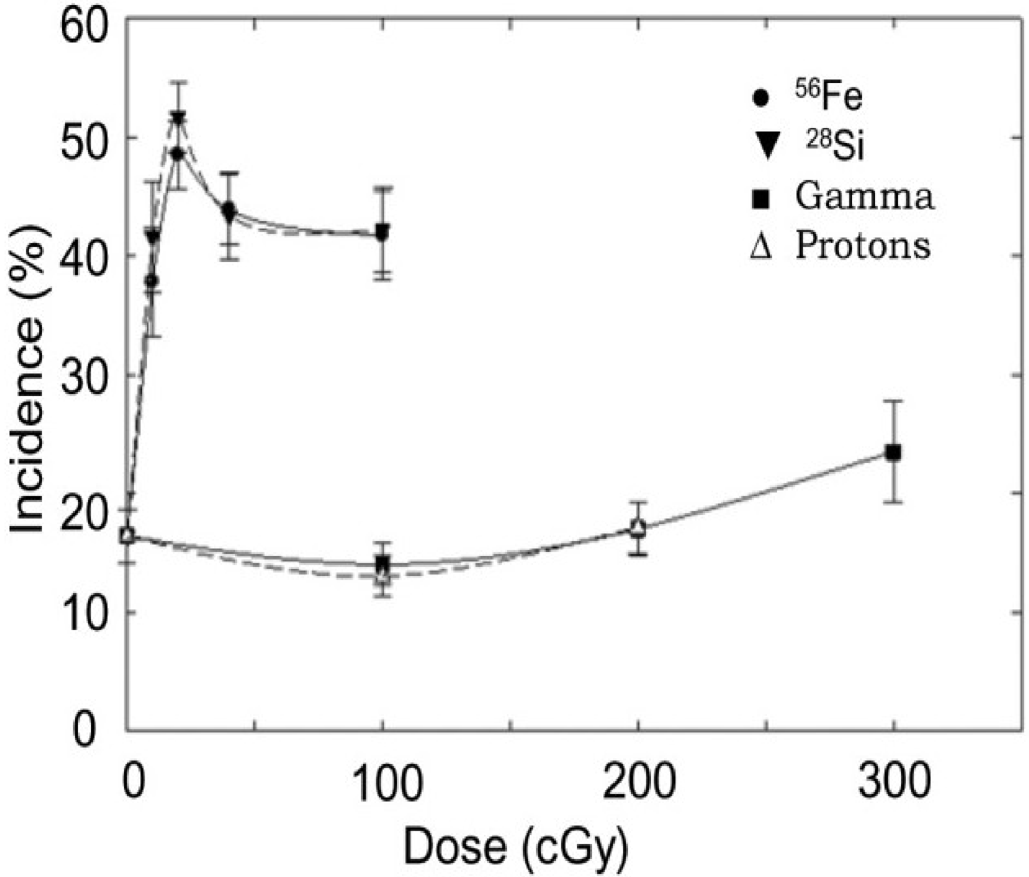
Why Does NASA Study Carcinogenesis?

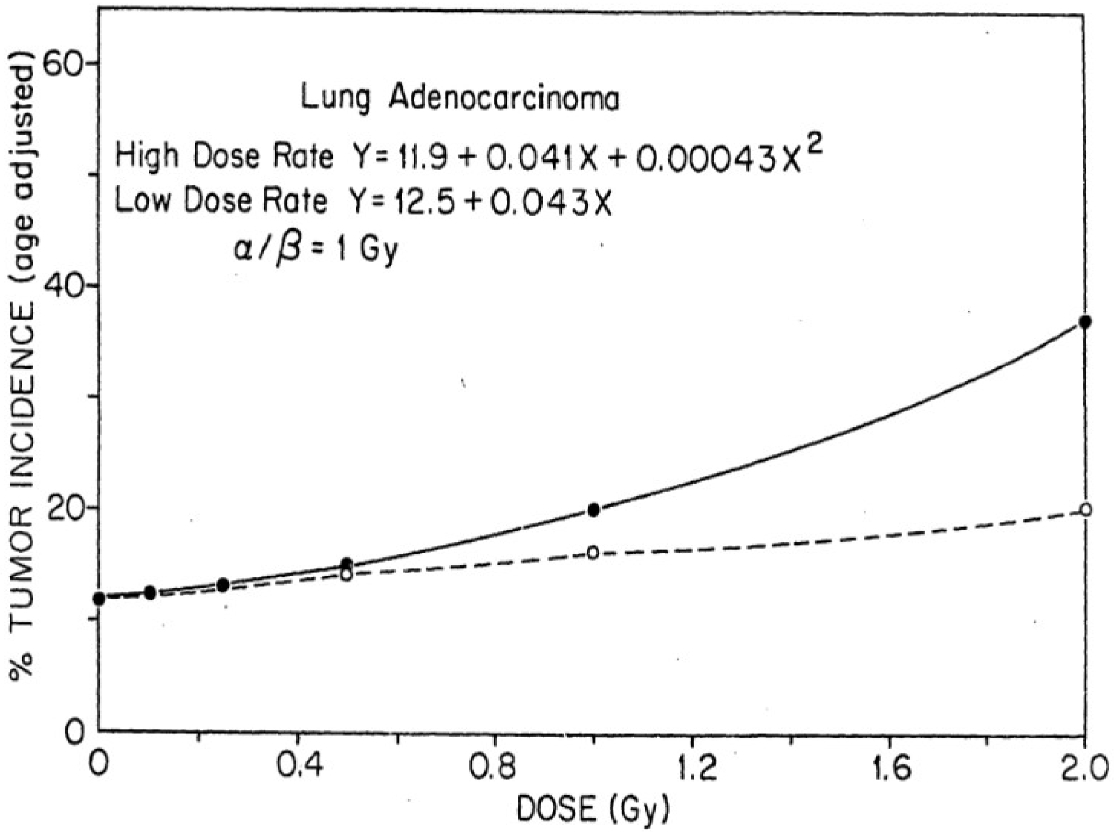


Douple et. al. (2013, Disaster Medicine and Public Health Readiness)

- Epidemiological studies of human populations exposed to ionizing radiation (IR) indicate an increased lifetime risk of cancer dependent on dose received.
- The tumor spectrum produced by IR is not necessarily different than those tumors that occur spontaneously.

Radiation Quality and Dose Rate Effects

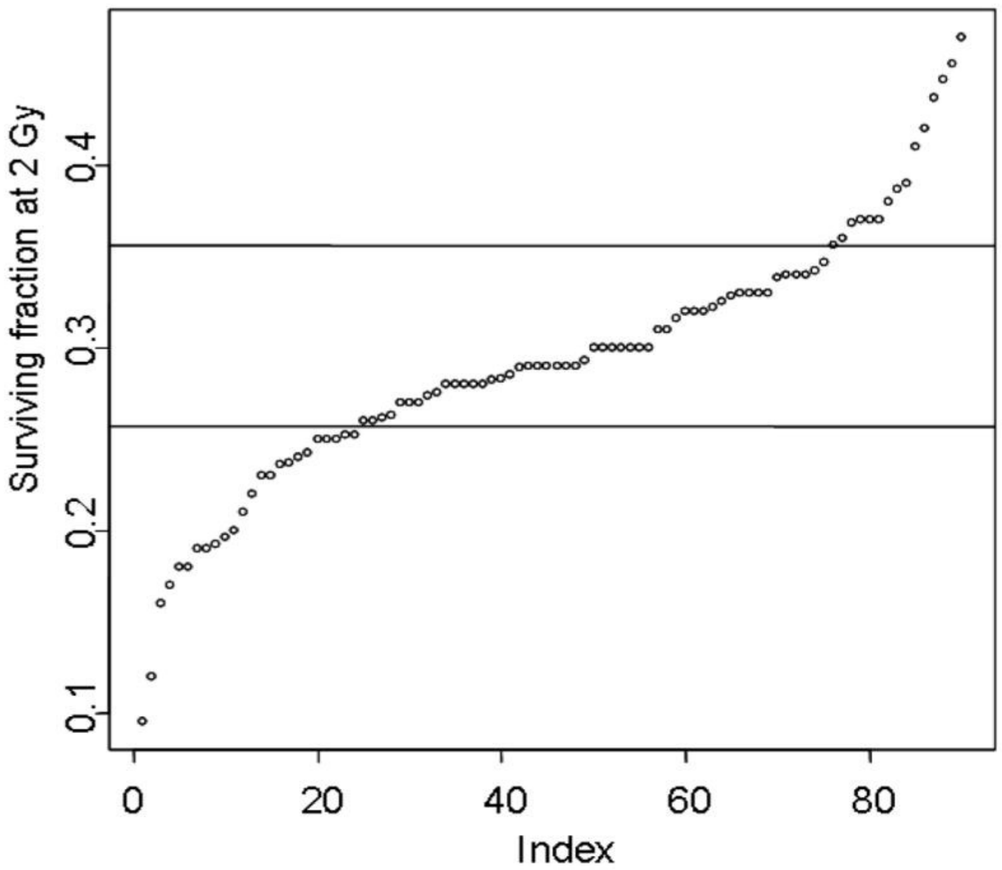




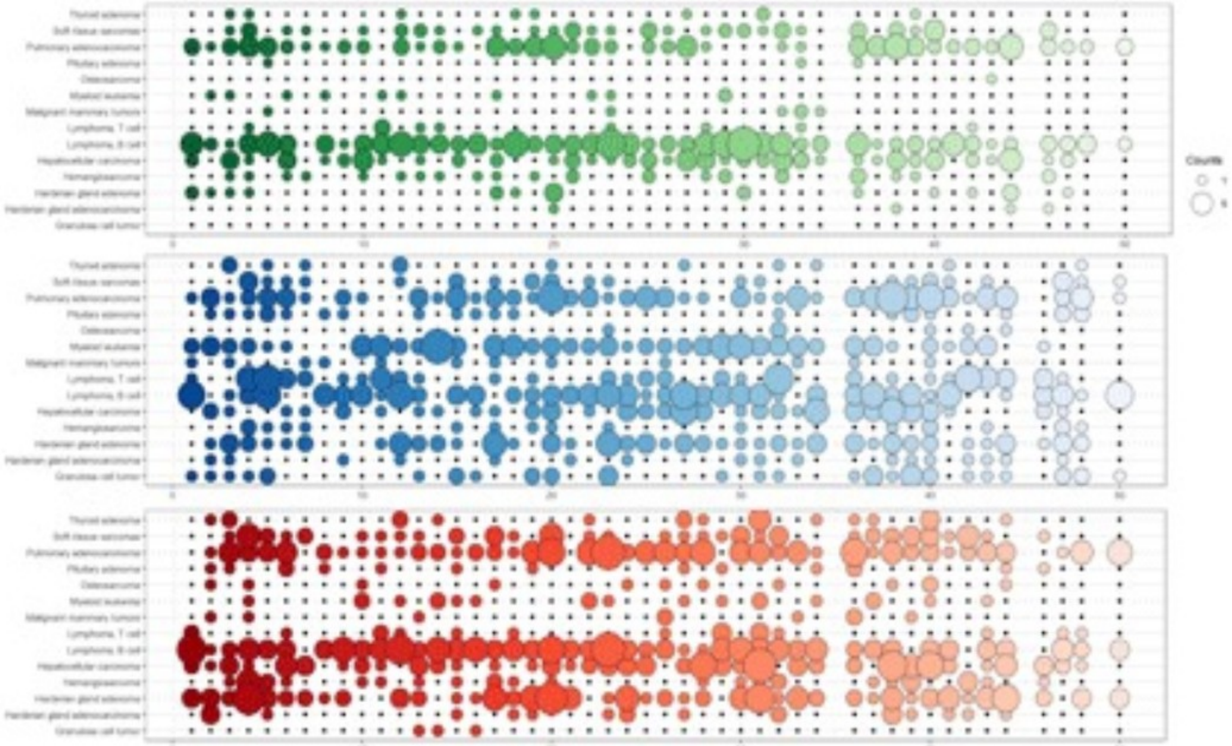
Weil et. al. (2014, PLOS One)

Ullrich (1986, Oakridge National Lab Annual Report)

Individual Sensitivity

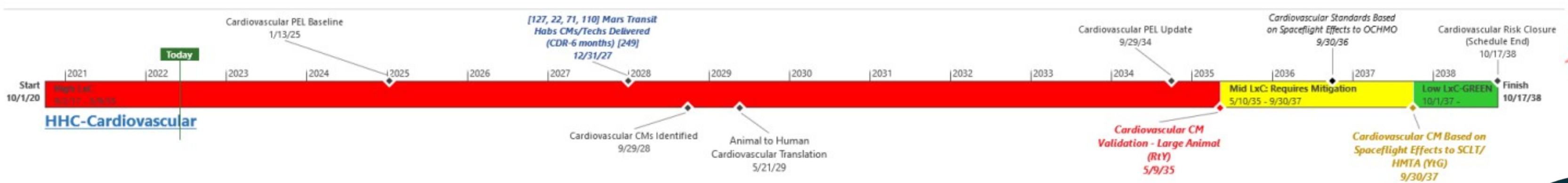


Story, M.D., et al, (2012, Health Physics)



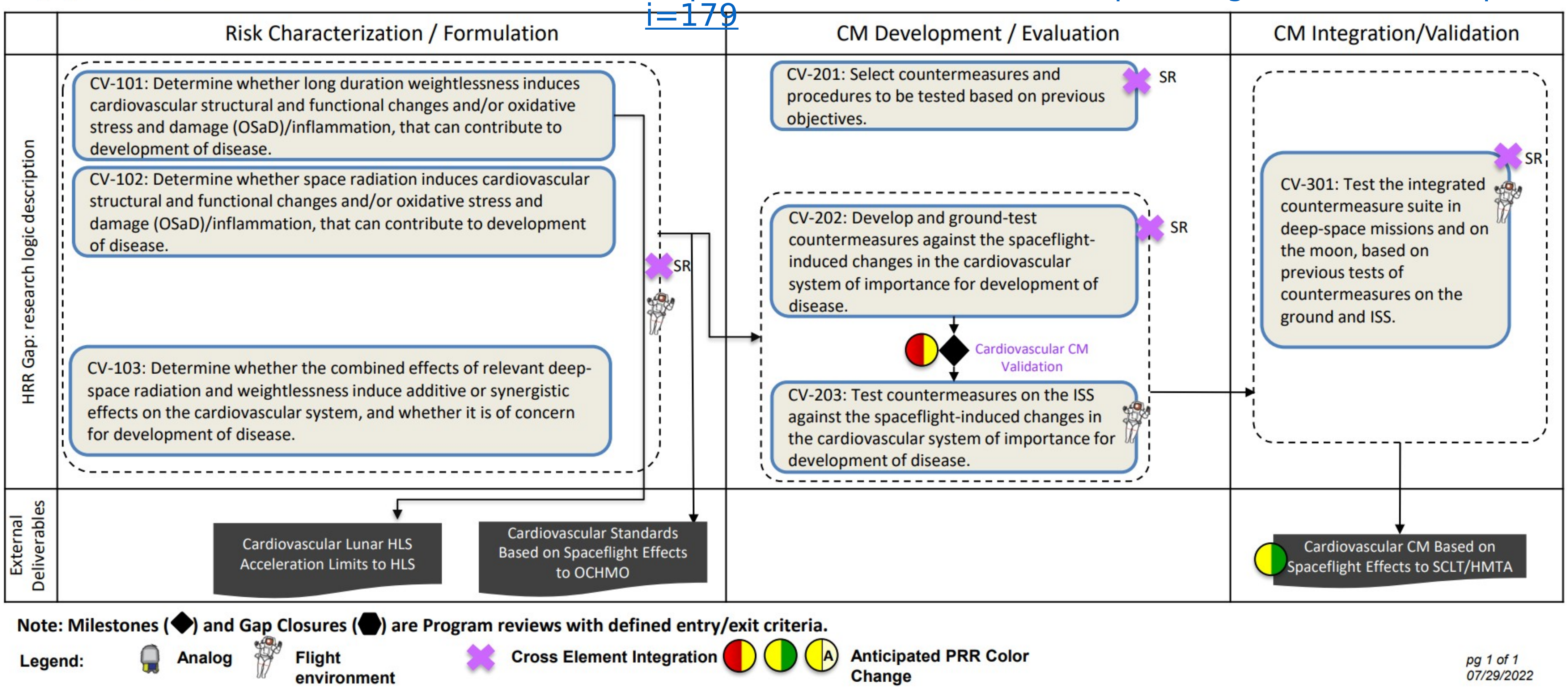
Edmonson et. al. (2020, Science Advances)

CV Risk Approach Plan



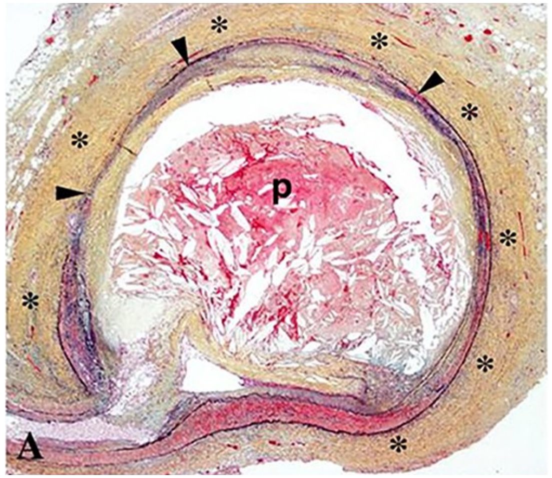
https://humanresearchroadmap.nasa.gov/Risks/risk.aspx?i=179

Cardiovascular risk



Risk of Cardiovascular Disease (CVD) from Radiation Exposure

- Cardiovascular disease, like cancer, has been associated with radiation exposure at high doses.
  - Ionizing radiation at high doses as used for radiotherapy produces direct damage to the heart and major arteries and increases the risk of cardiovascular diseases.
- In contrast, the evidence for a causal relationship between long-term risk of cardiovascular diseases after moderate doses (0.5–5 Gy) is suggestive, and weak after low doses (<0.5 Gy).
- Meta-analyses of epidemiologic studies show a small but statistically significant increase in CVD mortality risk with increasing radiation exposure at low doses.
  - ERR/Sv values in the Table.
- Since epidemiological findings for low and moderate doses are suggestive and not persuasive, their use in dose risk assessment is limited.



67-year-old patient with severe adventitial fibrosis (*) with intimal plaque (p) causing 75% luminal narrowing of coronary artery, 7 years post RT.

Yang EH et al. (2021)
Front. Cardiovasc. Med. 8:652761.
doi: 10.3389/fcvm.2021.652761

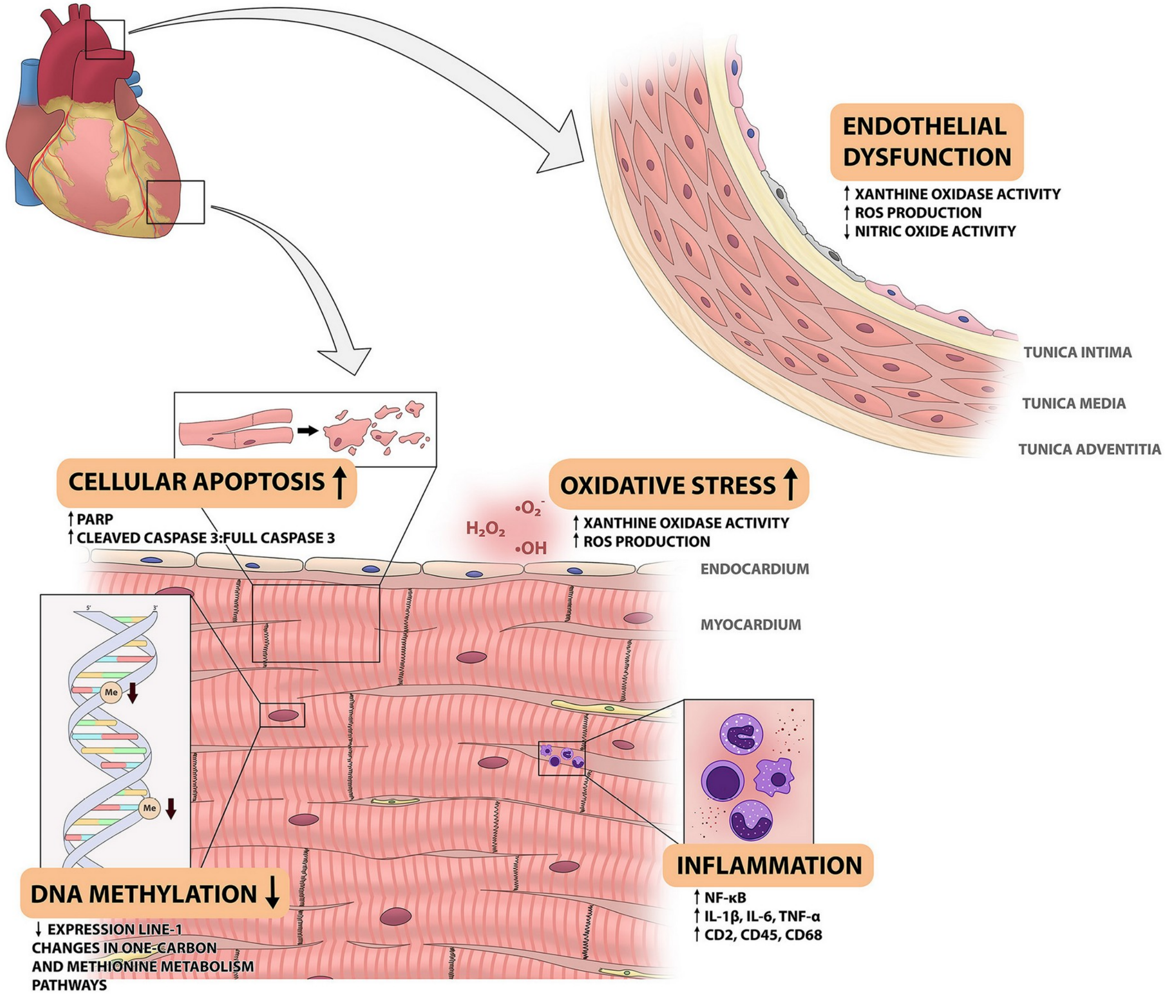
Cardiovascular Risk from Low Dose Radiation Exposure Review and Scientific Appraisal of the Literature

Circulatory Disease Category	ERR/Sv	95% CI:
CVD Mortality		
Japanese Atomic Bomb Survivors – LSS	0.11	0.050, 0.170
Mayak Production Association Workers	0.05	0.000, 0.110
U.S. Peptic Ulcer Study	0.082	0.031, 0.140
French Uranium Miners	0.60	-1.80, 3.5
INWORKS (note 90% CI)	0.22	0.08, 0.37
Canadian + Mass. TB-Fluoroscopy study < 0.5 Gy (50 rads)	0.246	0.036, 0.469
U.S. Power Reactor Workers	8.32	2.3, 18.2
U.S. Nuclear Power Plant Workers	0.06	-0.50, 0.40
U.S. Industrial Radiographers	0.02	-0.03, 0.08
U.S. Mound Workers	-0.40	-3.9, 3.2

Electric Power Research Institute. Technical Report 2020

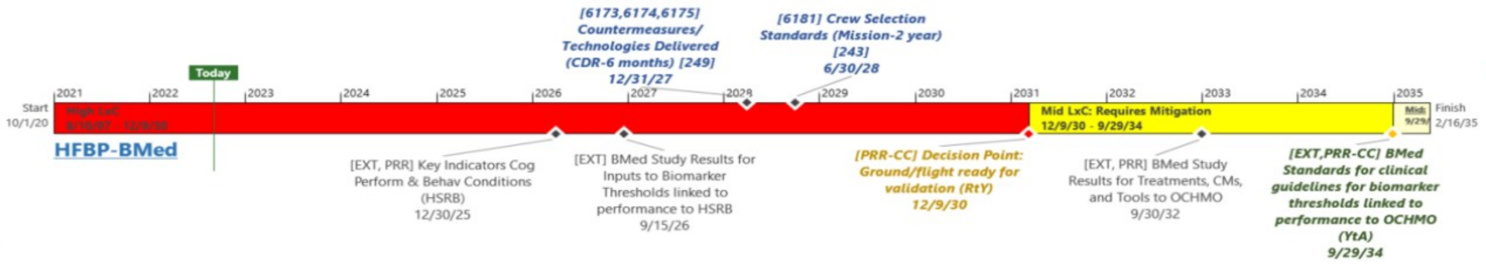
Putative Mechanisms of CVD induction after IR Exposure

- Knowledge gaps exist in mechanistic understanding of radiation-induced CVD, including underlying molecular and biological mechanisms.
- Characterizing CV risk from low dose radiation exposure is complicated by confounders such as diet, smoking, lifestyle and/or genetic risk factors.

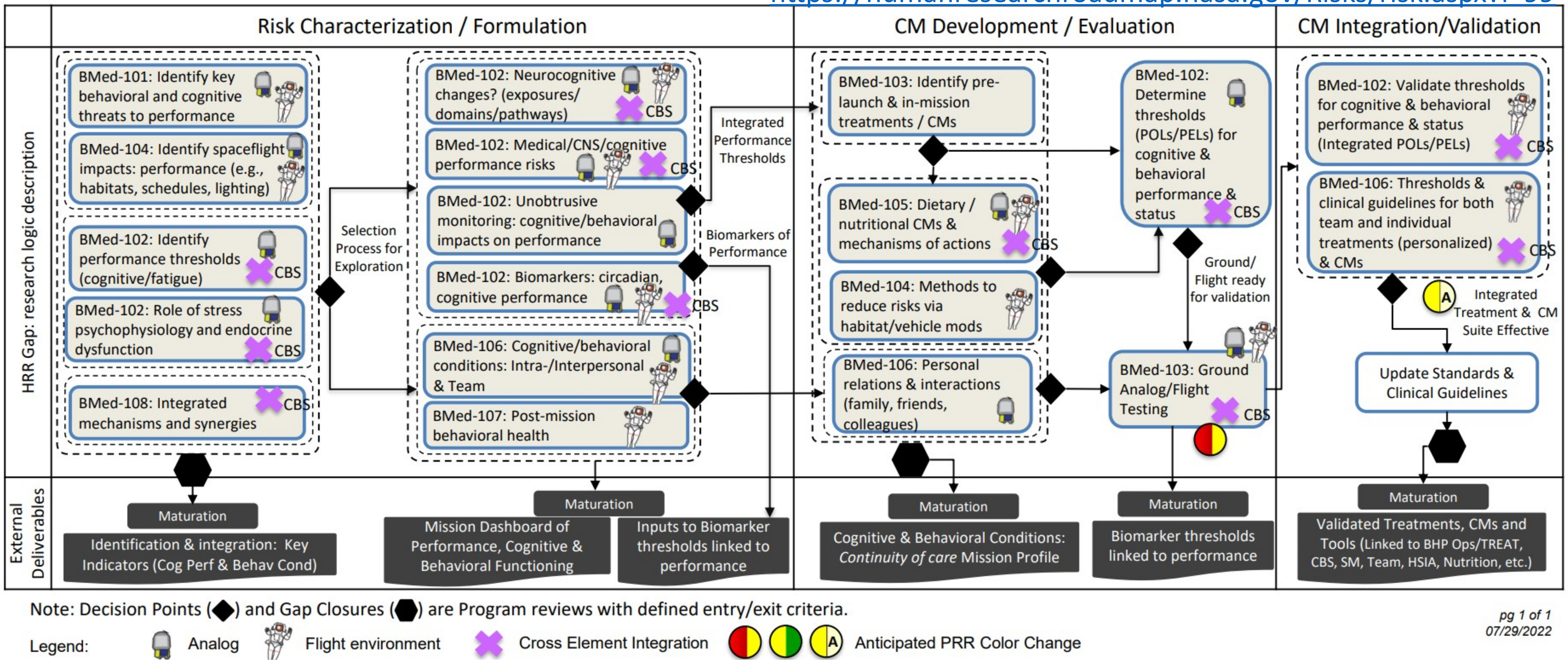


Meerman M, et al. (2021) Front. Cardiovasc. Med. 8:631985.doi: 10.3389/fcvm.2021.631985

BMed Risk Approach Plan



https://humanresearchroadmap.nasa.gov/Risks/risk.aspx?i=99



Behavioral Medicine risk

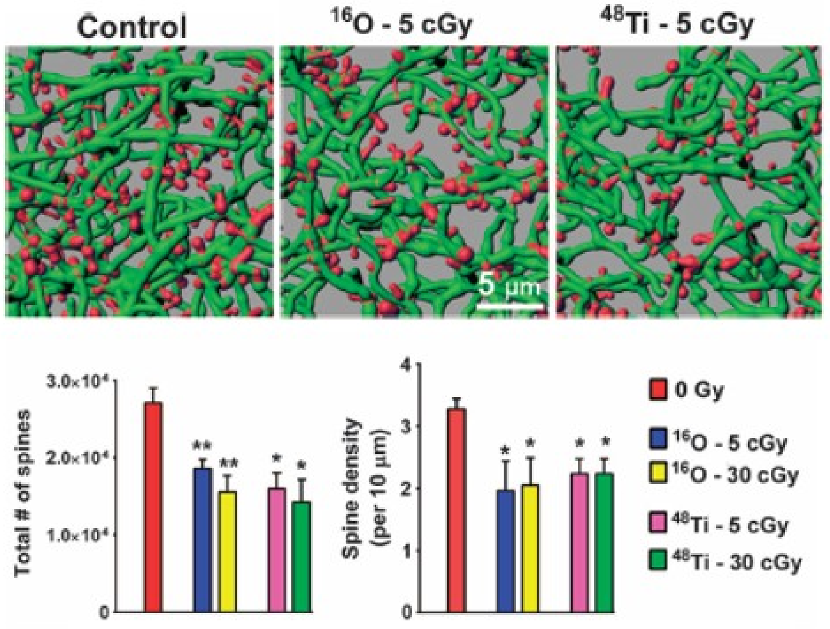
Changes to the Central Nervous System after Space-Like Radiation Exposure

- Reduction in neuron arborization and synapse number (dendritic spines)
  - Persistent reductions for > 1 year after doses of high Linear Energy Transfer (LET) nuclei below 5 cGy
- Significantly reduced production of new neurons in brain
- Increased activation of microglia (signaling neuroinflammation)
- Deficits in neurocognitive performance for several mouse and rat behavioral paradigms
  - High-LET nuclei at low doses (<10 cGy, with 1 cGy sensitivity reported in one study)
- Dose threshold for performance deficits following exposure to high-LET nuclei depends on
  - Physical particle characteristics, strain, sex, age at exposure, and evaluation time after exposure
  - Male mice appear to be more radiosensitive than female mice in several studies

Structural Changes

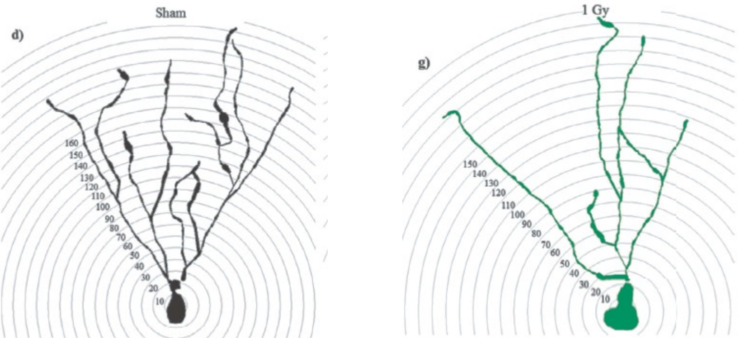
The complexity of dendritic arborization and the number of dendritic spines are reduced after exposures to charged particles. This will change the connectivity of neuronal networks.

Reduced Dendritic Spine Number 8 weeks post ^{16}O or ^{48}Ti ions exposure revealed by confocal microscopy of GFP-expressing neurons.



Parihar et al. Sci. Adv. 2015;1:e1400256

Reduction of dendritic complexity revealed by Golgi silver stain and Sholl analysis.



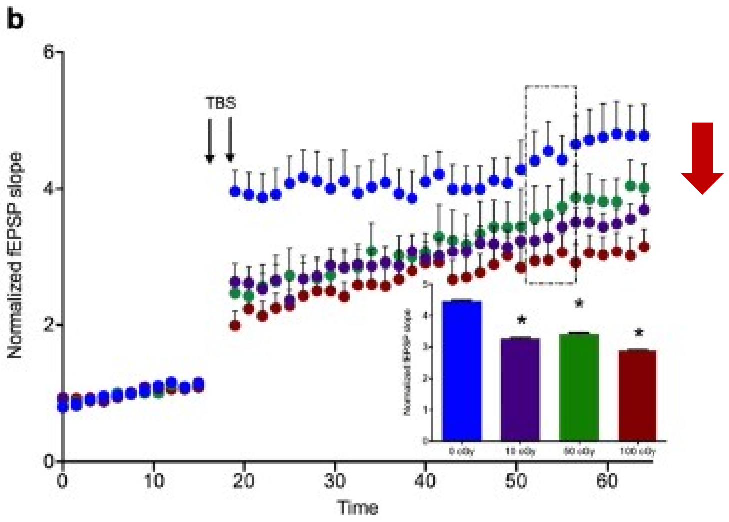
0 Gy **1 Gy ^{16}O**

Swinton et al. Behav. Brain Res. 407: 113257 2021

Physiological and Functional Changes

Electrophysiological and ion channel changes indicate persistent synaptic plasticity changes. These are accompanied by neuroinflammation and activation of microglia which can also regulate plasticity.

Hippocampal Slice Recordings at 2 Months after ^{56}FeExposure at 0, 10, 50 & 100 cGy Results in Reduction of Long Term Potentiation in Female Mice



Miry et al. Scientific Reports (2021) 11:4292

U-shaped dose responses for three glutamate receptor ion channels and a presynaptic marker. mRNA levels relative to controls for 10, 25 & 100 cGy ^{16}O ions.

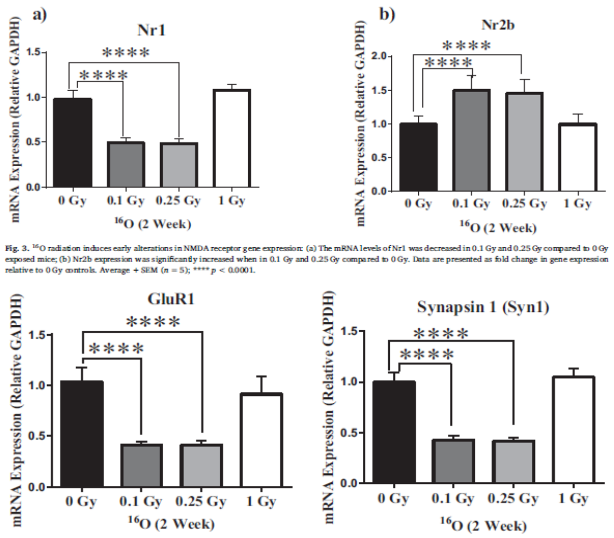
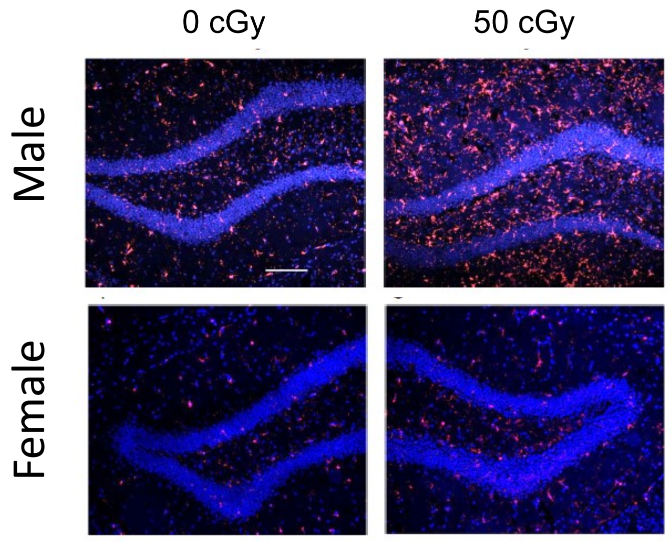


Fig. 3. ^{16}O radiation induces early alterations in NMDA receptor gene expression: (a) The mRNA levels of Nr1 was decreased in 0.1 Gy and 0.25 Gy compared to 0 Gy exposed mice; (b) Nr2b expression was significantly increased when in 0.1 Gy and 0.25 Gy compared to 0 Gy. Data are presented as fold change in gene expression relative to 0 Gy controls. Average + SEM ($n = 5$); **** $p < 0.0001$.

Kiffer et al. 2018. Radiat Res 189: 53–63

Sex differences: Microglia Activation (Red) in the Hippocampus (Nuclei Blue)

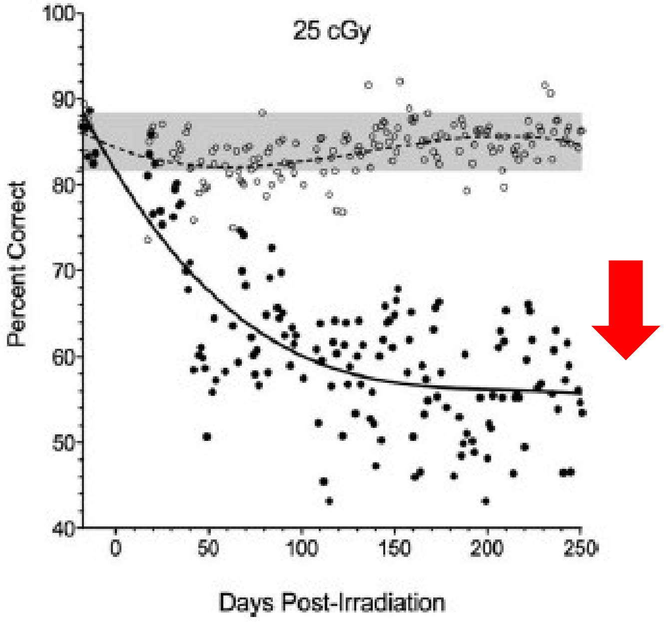


Krukowski et al. (2018) Brain, Behavior, & Immunity S0889-1591(18)30417-3

Behavioral Responses

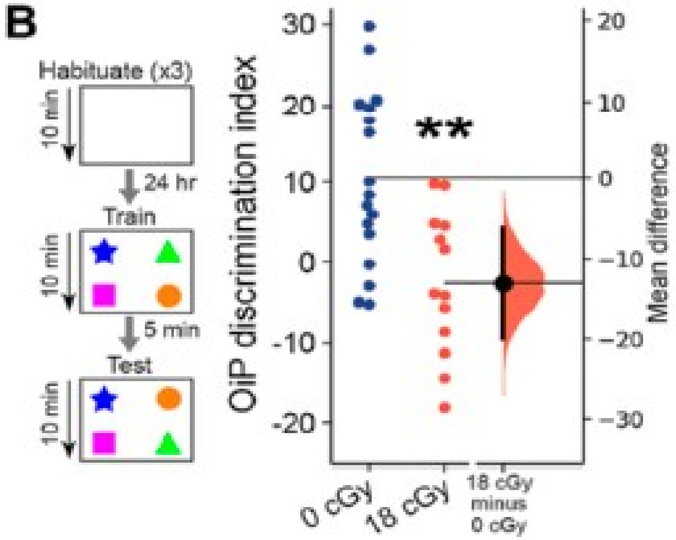
Persistent behavioral changes in cognitive, emotional and sensorimotor domains are observed in rats and mice after single or multi-ion exposures and neutrons.

In a high-fidelity human analog paradigm, psychomotor vigilance is impaired in rats after proton irradiation



Davis et al. (2014) Radiat. Res. 181, 258–271

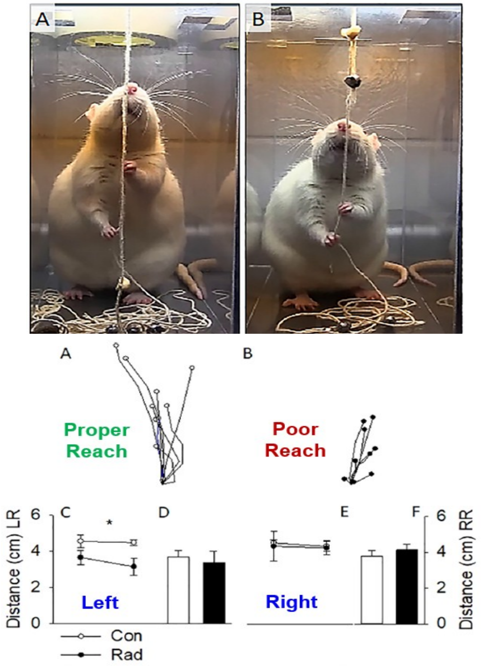
Object in Place Test Reveals Impairments in Spatial Memory after 18 cGy Neutron Exposure



Spatial memory behavior is perturbed by acute neutron irradiation in Object in Place (OiP) test to differentiate objects relocated to alternative locations.

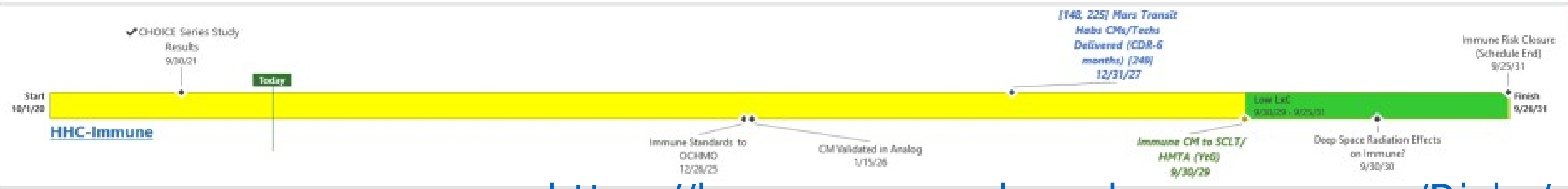
Klein et al. (2021) Int. J. Mol. Sci. 22:9020

Movement topography is altered in the fine motor skill "string-pulling" test in rats after Si exposure.

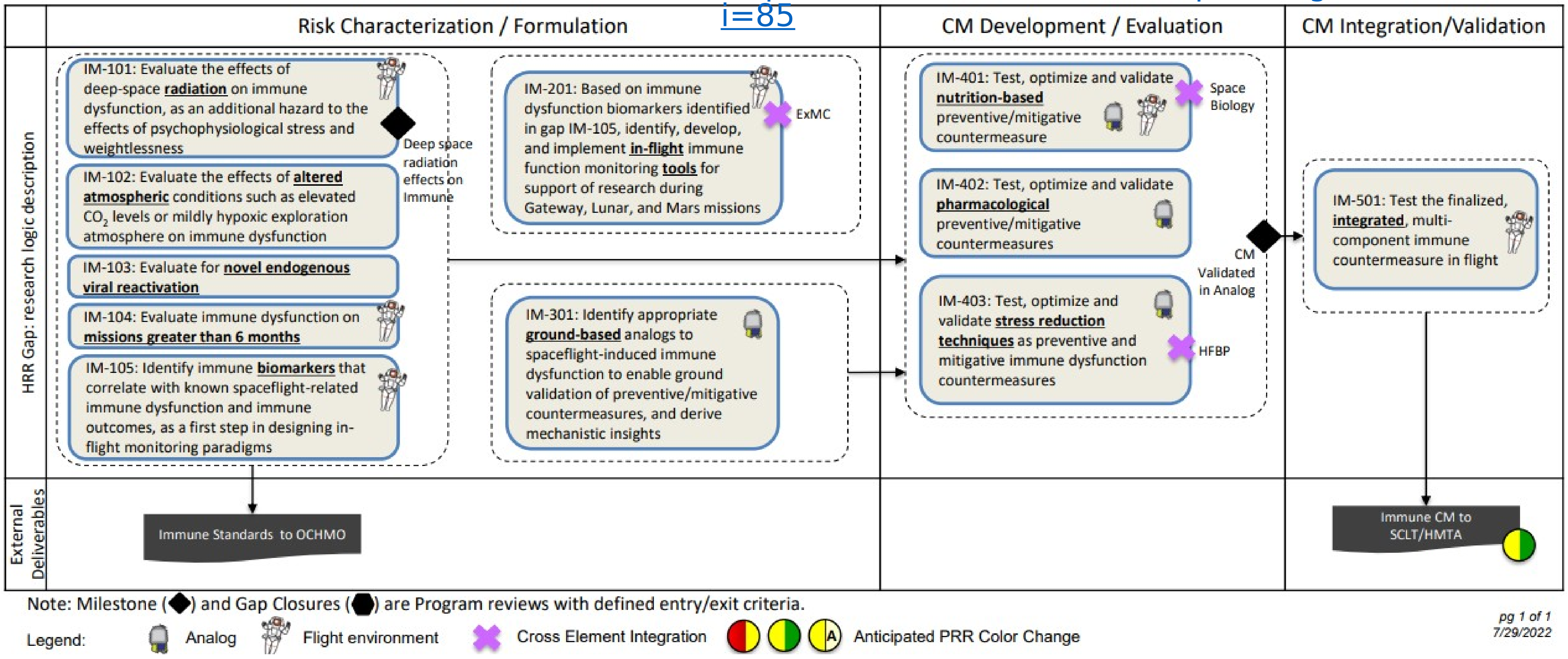


Blackwell et al. (2020) Behav. Brain Res. 400, 113010

Immune Risk Approach Plan



https://humanresearchroadmap.nasa.gov/Risks/risk.asp
i=85



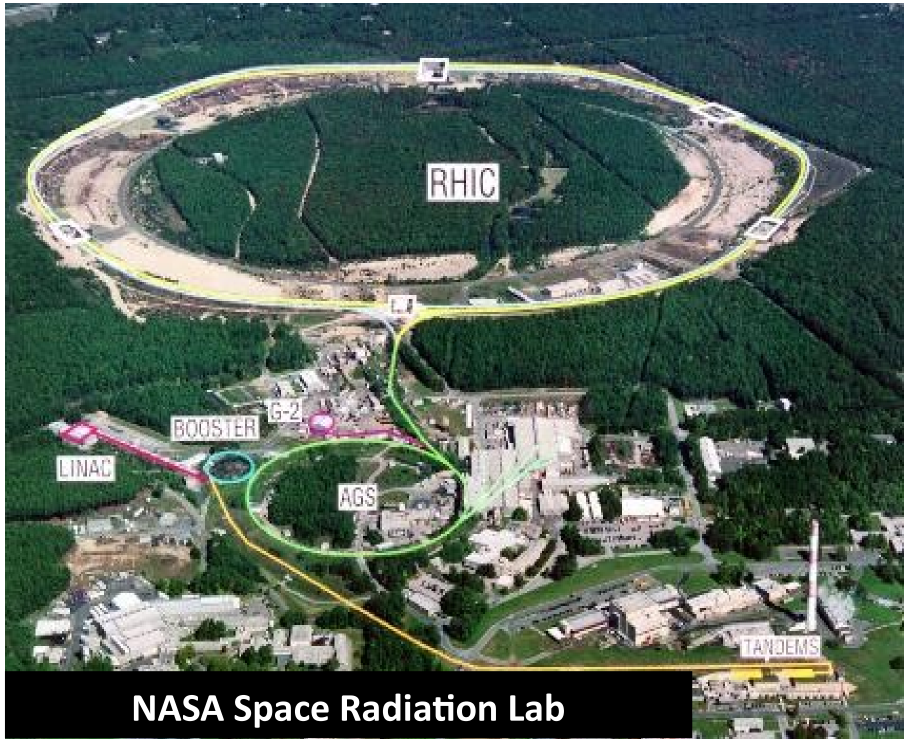
Immune risk

NASA Space Radiation Laboratory (NSRL)

A Ground Analog for Space Radiation

More on Analogs and NSRL in Seminar #4!

- Capabilities
  - Acute or fractionated exposures (chronic)
  - Single ions
  - Multiple ions
    - Simplified GCR sim [6 beams 5 ions: H (2 energies), Si, He, O, & Fe]
    - GCR sim [33 beams, 7 ions: H (14 energies), He (14 energies), C, O, Si, Ti, Fe]
- Personnel
  - NSRL physicist, Michael Sivertz
  - Biology support scientist, Dr. Peter Guida (guida@bnl.gov)
  - NSRL Management, Lisa Simonsen Ph.D.



NASA Space Radiation Lab

https://www.bnl.gov/nsrl/

NSRL Beam-Time Proposals

- Required to request access to the NSRL facility (one step of many…)
  - **Separate and additional** application to funding proposal
  - Reviewed by the SACRR
  - Approved experiments can then be scheduled
  - Do not have to be NASA funded to apply for NSRL beam-time
- Describes experimental proposal to justify beam-time request
  - Apply for beamtime: https://www.bnl.gov/nsrl/facility-users
  - Forms: https://nsrl.bnl.gov/Forms/FormsHome.aspx

NSRL Beam-Time Proposals

Experimental Proposal (Section 11A)

- Provide sufficient detail to justify **<u>why beam-time is needed</u>** to successfully fulfill the funded project objectives
- Limited to **<u>three (3)</u>** pages maximum
  - Title
  - Project summary/overview
  - Background and significance
  - Progress Report for renewal proposals OR Preliminary Results for new proposals
    - Renewals may submit the most recent funding agency grant progress report
    - Include progress accomplished in prior runs, problems encountered and lessons learned, any deferrals, and responses to previous SACRR review
  - List of three (3) publications (to evaluate previous work/experience and project feasibility)
  - Description of PI and team’s previous accelerator experience (1 paragraph maximum)
- Format as Word or PDF attachment

NSRL Beam-Time Proposals

Beam-Time Request (Section 11B)

- Detailed experimental plan for those to be conducted during the beam-time run
  - Provide sufficient detail to justify the amount of beam-time required
    - Demonstrate prior beam time was efficiently and judiciously used (if applicable)
    - Demonstrate current amount of time requested is sufficient and necessary
    - Justify ion species requested
- Beam-time calculations
  - Include the total time requested for all ions and energies in Section 5 (times requested must match)
  - Calculations must account for the **dose, dose rate, total number of samples, and logistical considerations**
  - Incomplete/inaccurate beam time calculations may require re-submission in a following review period if SACRR reviewers are not able to account for total requested time
  - See Section 12 for an example beam time calculation table
- Other information that may be helpful in justifying your beam time request to SACRR (optional)

NSRL Beam-Time Proposals

Logistical Items to Note

- Allow 30 min for experimental setup and beam tuning/dosimetry
- Allow 3 min for target room (cave) access per sample change
- Standard NSRL dose rates range from 0.1–1.0 Gy/min
  - Consult the NSRL physicists if dose-rates outside this range are desired
  - Report doses in either Gy or cGy, dose rates in Gy/min or cGy/min

Resources

Useful Websites and Resources

- NASA Human Research Roadmap – Link to risks, gaps, and evidence books
  - https://humanresearchroadmap.nasa.gov/
- NASA Taskbook – Summaries of current and previously funded projects
  - https://taskbook.nasaprs.com/tbp/welcome.cfm
- Life Science Data Archive – Can request past data and search tissue registry
  - https://lsda.jsc.nasa.gov/
  - https://lsda.jsc.nasa.gov/Biospecimen
  - Instructions - https://www.nasa.gov/hrp/elements/radiation/tissue-sharing
- NASA GeneLab – space-related omics database; users can upload, download, share, store, and analyze spaceflight and spaceflight-relevant data from experiments
  - https://genelab.nasa.gov/
- The Health Risks of Extraterrestrial Environments – open access space radiation literature
  - https://three.jsc.nasa.gov/#section=main

Acronyms

ALARA	As Low As Reasonably Achievable
ARD	Active Radiation Dosimeter
ARES	Active Radiation Environment Sensor
BMed	Behavioral Medicine Risk
BNL	Brookhaven National Laboratory (where NSRL is located)
CAD	Crew Active Dosimeter
CNS	Central Nervous System
CV	Cardiovascular
CVD	Cardiovascular Disease
DDREF	Dose & Dose Rate Effectiveness Factor
EVA	Extravehicular Activity
ExMC	Exploration Medical Capabilities
FDA	Food and Drug Administration
GCR	Galactic Cosmic Rays
GCRsim	Galactic Cosmic Ray Simulator (full 33-beam mixture)
Gy	Gray
HERA	Hybrid Electronic Radiation Assessor
HFBP	Human Factors and Behavioral Performance
HHC	Human Health Countermeasures
HRP	Human Research Program
IM	Immune risk
IND	Investigational New Drug
mGy	milliGray (measure of ABSORBED dose)
mSv	millisievert (measure of EFFECTIVE or EQUIVALENT dose)
NCRP	National Council on Radiation Protection and Measurements
NSRL	NASA Space Radiation Laboratory
ROI	Research Operation and Integration
SACRR	Scientific Advisory Committee for Radiation Research
SHINE	Space Health Impacts for the NASA Experience
SimGCRSim	Simplified Galactic Cosmic Ray Simulator (6-beam mixture)
SRE	Space Radiation Element
TRISH	Translational Research Institute for Space Health

QUESTIONS?

Thank you for your attention!

Knowledge Surveys: Will be sent out today and at the end of the course to gauge how well **WE** did
Simple self-assessment in the different knowledge areas

Speaker Reviews: Please respond at the end of each seminar to let us know how the speaker(s) did and the value of that lecture

All Lecture Materials will be made available