

AI Applications for Astronaut Health

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NASA AND BIOSCIENCE INNOVATION

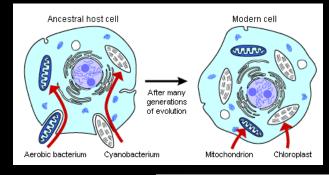
A LONG HISTORY OF HEALTH SCIENCE INNOVATION

 1971: NASA funded the groundbreaking research by Lynn Margulis that re-wrote life-science and evolution theory.

 NASA-led innovation has helped develop artificial hearts, patient cooling suits, LEDs to guide brain cancer surgery, programmable pacemakers, surgical tools for cataract surgery, and more.

> The Left Ventricular Assist Device was developed with assistance from JSC engineers – saving many hundreds of lives every year

Dr. Margulis' theory of symbiosis in evolution was rejected by 15 journals, and initial grant applications were firmly dismissed (*"Your research is crap, do not bother to apply again"*). But NASA was intrigued and funded her early work.





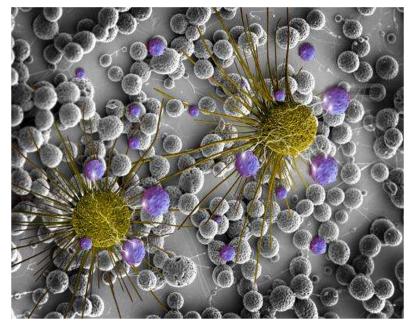


- 1. Space is becoming an extension of the research and manufacturing infrastructure for the healthcare industry.
- 2. Space medicine is a required core competence for space exploration and sustained operations.



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<u>Micro-encapsulation</u>: Particles are surrounded by a coating to create nano-scale capsules. Microgravity enables a far greater range of viable substances for encapsulation and superior shell wall structure.



Scanning electron micrograph of drug-loaded microspheres (grey) with brain cancers cells (yellow) and released drug therapy (purple)



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Techshot: "On Earth, when attempting to print with soft, easily flowing biomaterials that better mimic the body's natural environment, tissues collapse under their own weight – resulting in little more than a puddle. But if these same materials are used in space in a microgravity environment, 3D-printed soft tissues will maintain their shape."



Techshot 3D BioFabrication Facility (BFF) on board the ISS

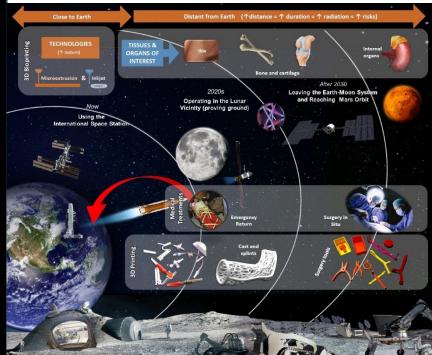


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"An ESA-led project is investigating the use of 3D bioprinting to support medical treatment of longduration space expeditions and planetary settlements."

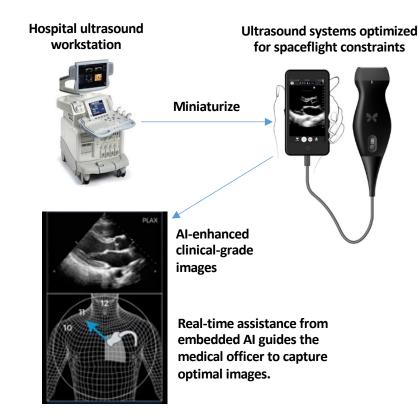
[ESA Directorate of Technology Newsletter, November 2018.]





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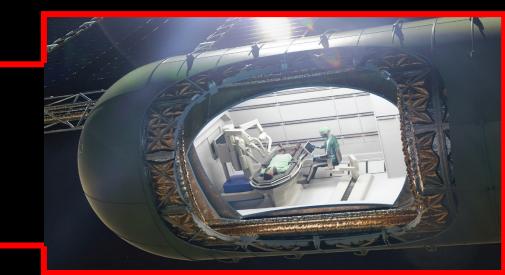
WHAT ASTROSKIN MONITORS Blood Oxygen Pressure Activity Level Skin Temperature Skin Temperature WHAT ASTROSKIN MONITORS Blood Oxygen Compared Blood O

Carre Technologies inc (Hexoskin) © 2018.





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Astronaut Health: The Two New Imperatives

1. Enable exploration and sustained operations by keeping astronauts healthy during long-duration deep space missions

NASA

2. Enable space commerce by adressing the health requirements of civilian crew and passengers.

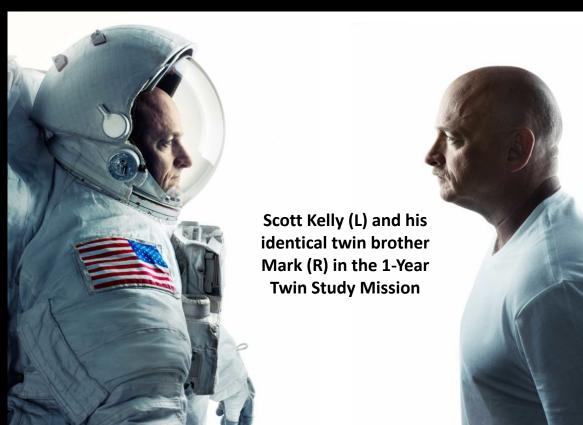


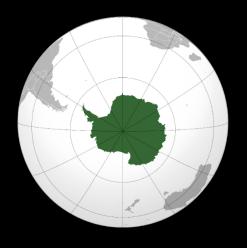


The Twin Study

"I lost bone mass, my muscles atrophied, and my blood redistributed itself in my body, which strained and shrank the walls of my heart.

I experienced problems with my vision, as many other astronauts had. I had been exposed to more than 30 times the radiation of a person on Earth, equivalent to about 10 chest X-rays every day. This exposure would increase my risk of a fatal cancer for the rest of my life." [Scott Kelly]



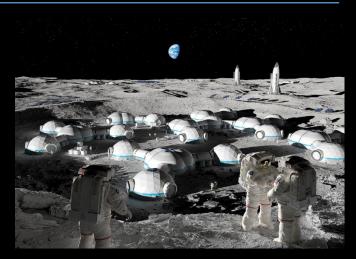








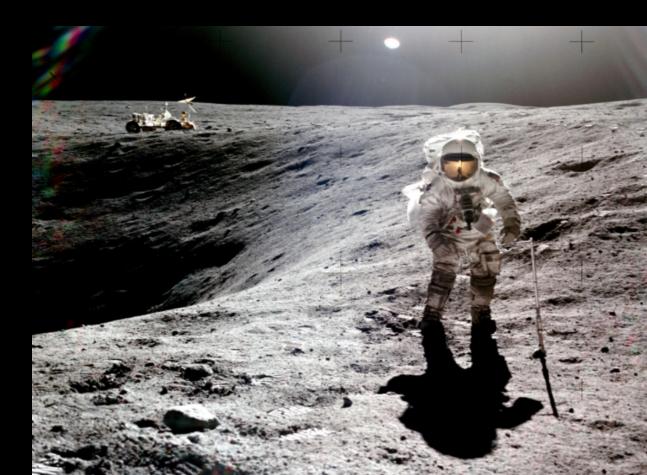




Astronaut Health Risks... Visit vs. Stay

Apollo 16 astronauts on the Moon just before the August 1972 solar flare.

Credits: NASA





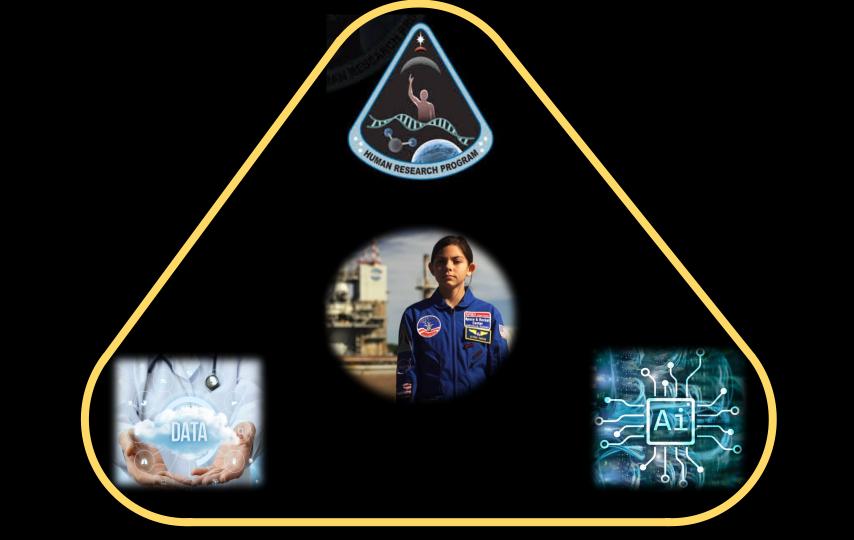




Solid Foundation of Data Assets Astronaut Health



AI Affinity



Concept study: Mars Artificial Gravity Transfer Vehicle [Credit: NASA]

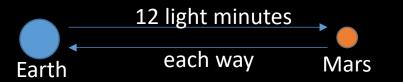
Concept study: Nuclear Thermal Propulsion Transfer Vehicle [Credit: NASA]

Distance – Intervention Protocols

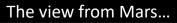
The view from LEO (last 50 years)...

- On the ISS stabilize and evacuate
 - Soyuz descent capsule can separate from the ISS within 3 minutes
 - Time from evac decision to landing is 3.5 hours

- In Deep space autonomous medical capability
 - No evac, no rescue
 - On board flight medical officer
 - Communication delays and occultations prevent "conversational" medical support.

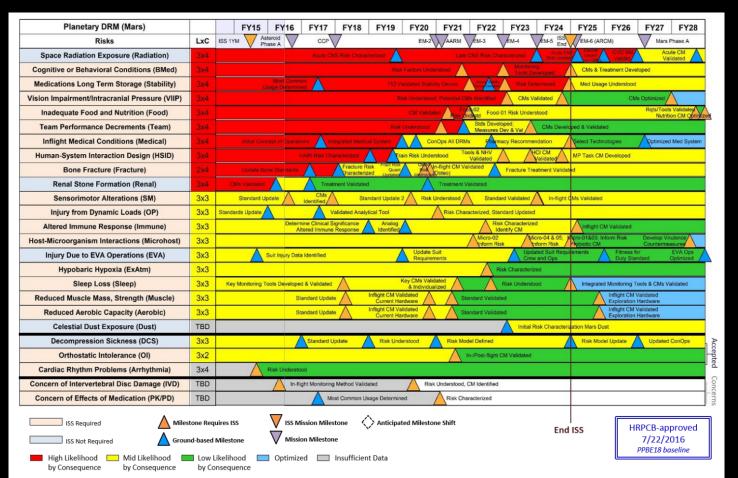








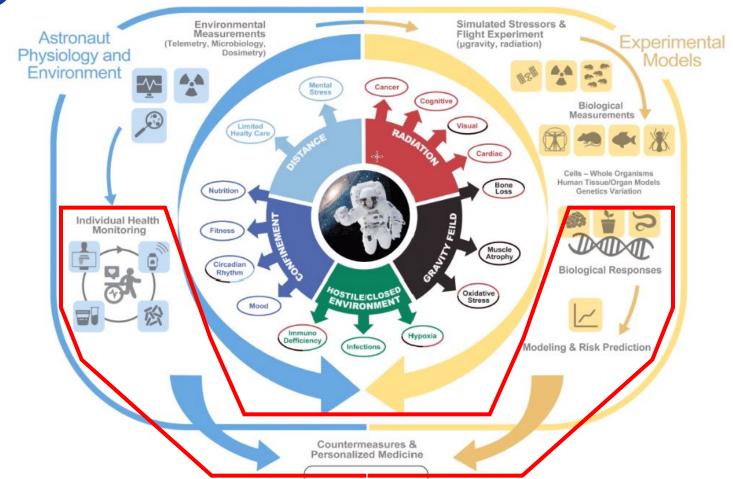
The HRP Integrated Path to Risk Reduction



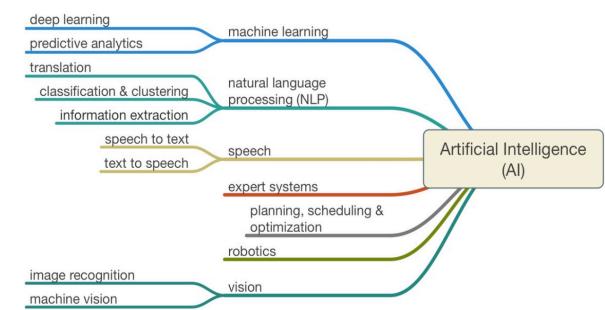




Astronaut Health... and AI









Its not magic.... just fancy statistics, matrix algebra, and non-linear functions.

Artificial Intelligence Machine Learning Deep Learning A subset of AI that includes abstruse The subset of machine learning composed of algorithms that permit statistical techniques software to train itself to perform tasks, that enable machines like speech and image recognition, by to improve at tasks exposing multilayered neural networks to with experience. The category includes vast amounts of data. deep learning

Any technique that enables computers to mimic human intelligence, using logic, if-then rules, decision trees, and machine learning (including deep learning)



Visualization of Neural Network for Number Recognition

Multilayer Perceptron

Artificial Intelligence

Machine Learning

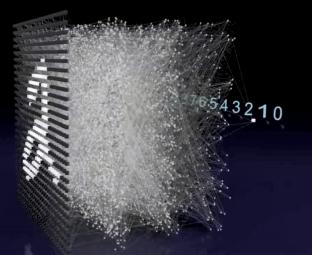
Deep Learning

The subset of machine learning composed of algorithms that permit software to train itself to perform tasks, like speech and image recognition, by exposing multilayered neural networks to vast amounts of data. A subset of AI that includes abstruse statistical techniques that enable machines to improve at tasks with experience. The category includes deep learning Any technique that enables computers to mimic human intelligence, using logic, if-then rules, decision trees, and machine learning (including deep learning)



Visualization of Neural Network for Number Recognition

Type: ML Perceptron Data Set: MNIST Hidden Layers: 3 Hidden Neurons: 10000 Synapses: 24864180 Synapses shown: 2% Learning: BP



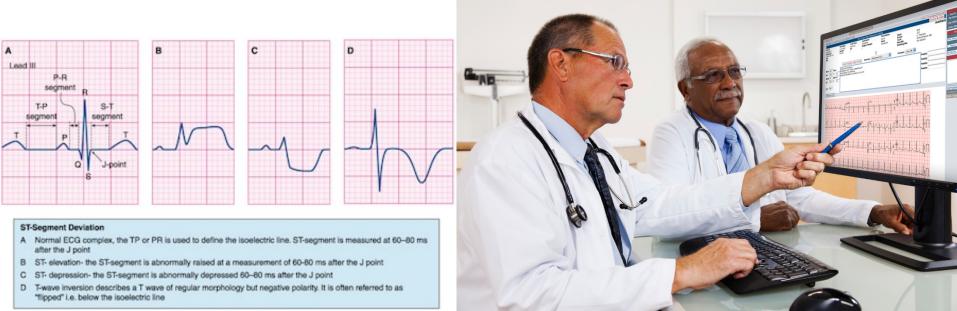
Artificial Intelligence

Machine Learning

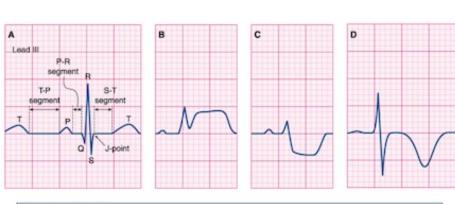
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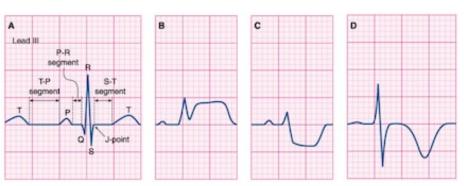
ST-Segment Deviation

- A Normal ECG complex, the TP or PR is used to define the isoelectric line. ST-segment is measured at 60-80 ms after the J point
- B ST-elevation- the ST-segment is abnormally raised at a measurement of 60-80 ms after the J point.
- C ST- depression- the ST-segment is abnormally depressed 60-80 ms after the J point
- D T-wave inversion describes a T wave of regular morphology but negative polarity. It is often referred to as "flipped" i.e. below the isoelectric line

QRS Interval	_	The ECG dataset
PR R Segment	_ In []:	<pre>raw_ecg_rdd = sc.textFile('/opt/SparkDatasets/ecg/ecg.csv')</pre>
	-	<pre>print raw_ecg_rdd.take(5)</pre>
	In []:	ecg_rdd_0 = \ raw_ecg_rdd \ .map(lambda s: s.split(',')) \ .map(lambda l: (int(l[0]), int(l[1])))
PR Interval QT Interval 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9	1	<pre>print ecg_rdd_0.take(15)</pre>
Time(ma)	In []:	<pre>ecg_rdd_2 = ecg_rdd_0.map(lambda (i, v): (i + 2, v)) ecg_rdd_3 = ecg_rdd_0.map(lambda (i, v): (i + 3, v)) print ecg_rdd_1.take(15)</pre>
mannanna	~	<pre>print ecg_rdd_2.take(15) print ecg_rdd_3.take(15)</pre>
	In []:	.groupWith(ecg_rdd_1, ecg_rdd_2, ecg_rdd_3) \
<pre>N = length(sig); duration in seconds = N*0.1/fs;</pre>		.take(3)
<pre>duration_in_seconds = w=0.1/is; duration_in_minutes = duration_in_seconds/60; BFM = beat_count/duration_in_minutes BFM =</pre>	In []:	<pre>prepared_for_pattern_matching_ecg_rdd \ .map(pattern_matching_fn) \ .collect()</pre>
78.0000	In []:	<pre>close_to_final_shape_ecg_rdd = \</pre>

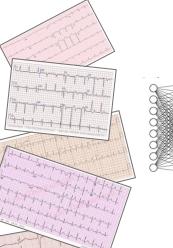
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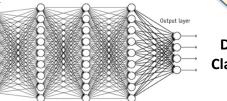


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Fun fact: Al researchers at the Mayo Clinic were able to train a NN model to look at 20 seconds of ECG data and predict the gender of the patient with 78% accuracy... something that leading cardiologists didn't even know was possible.



Diagnostic Classification



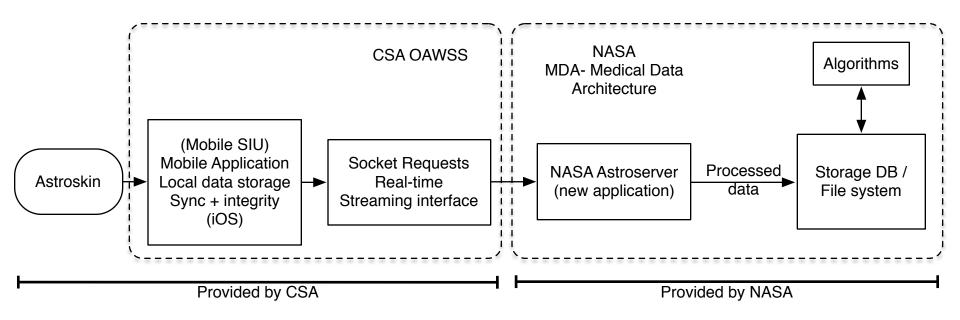


The 4-man crew of the NASA Human Exploration Research Analog (HERA) mission, wearing Astroskin biosensors Credit: NASA

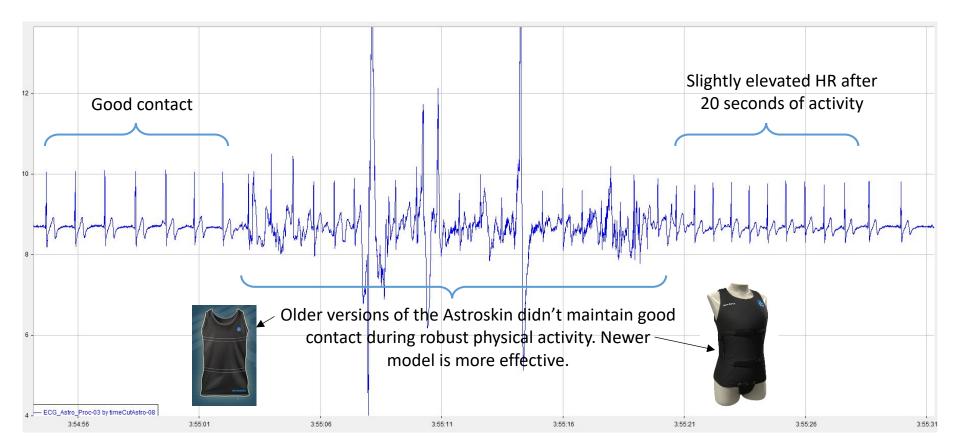
Canadian astronaut David Saint-Jacques tests out the Astroskin Bio-Monitor system on board the ISS (Credit: CSA/NASA)



CSA Astroskin & NASA Medical Data Architecture



Seven Astronaut Health Monitoring - Astroskin



Astronaut Health Monitoring - Astroskin

- **The Need:** Address the lack of in-flight medical data for use in crew training and to design/test onboard systems that monitor health of astronauts & commercial crew.
- The AI Solution: Use existing Astroskin data to train a generative AI model to produce additional synthetic biosensor data extrapolated for various scenarios and medical conditions.









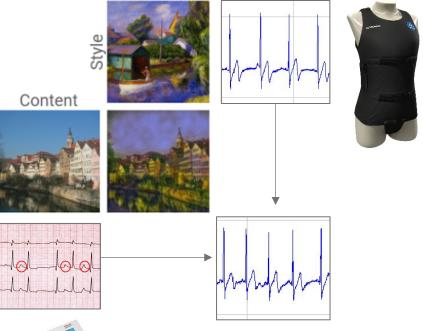
Content





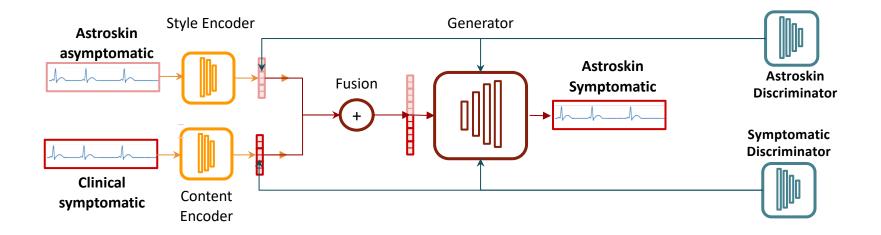


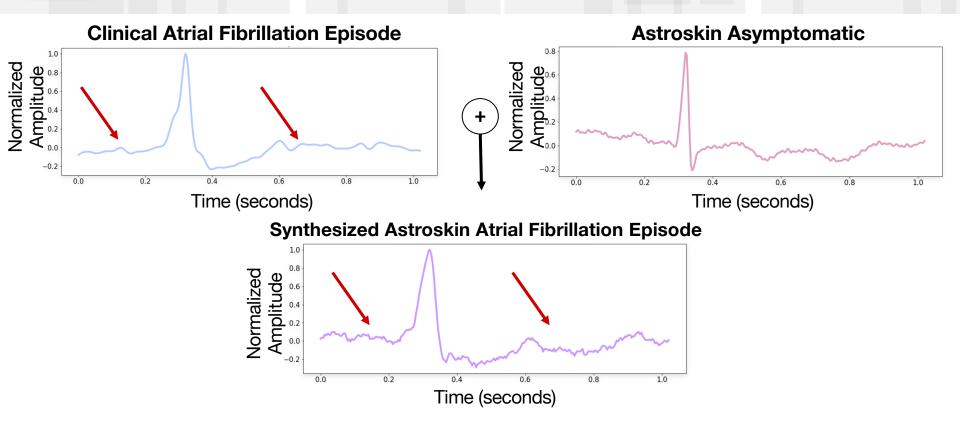
Generative AI - Astroskin Synthetic Data

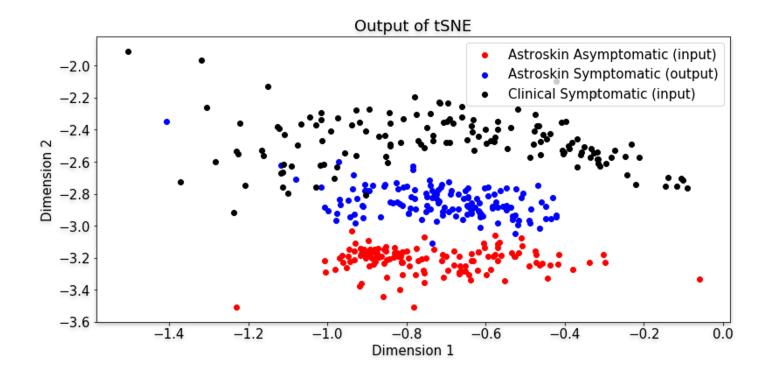




- Generate a fusion of Astroskin and Symptomatic ECG data
- Output can be used to help implement & test medicial decision support systems and train flight medical officers.

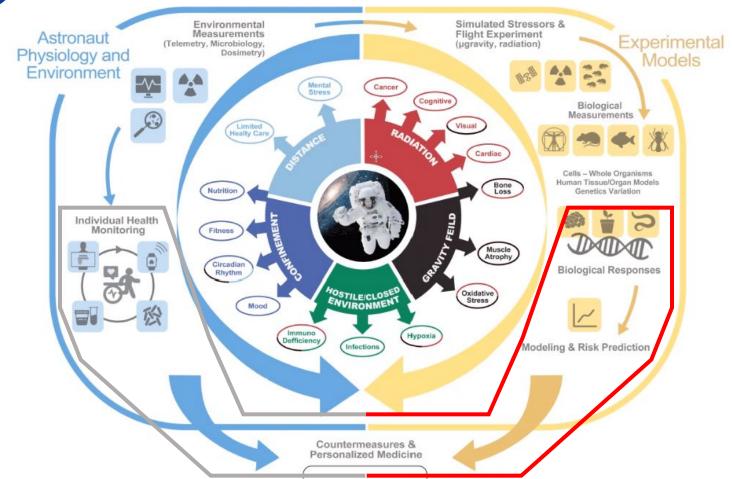








Astronaut Health... and AI



Astronaut Health – Radiation Carcinogensis

<u> </u>	HUMAN RESEARCH ROADMAP					DATA	EXPLORATIO		
								S	
Goals and Objectives Hum	an Research Ro	admap	HRP Organizational Struc	ture A	cronyms Reviews H	elp			
RISKS GAPS TASKS	REPORTS						EXPLORE	s	
							Next		
🔄 🗸 Risk of Radiat	tion Carcin	ogene	esis				Previous		
Served J							🚔 Print Viev	/	
Short Title: Cancer Element: Space Radiation Evidence: Report Risk Master Logic Diagra	m: Not Availa	able	Last Published:	08/03/2	20 03:51:22 PM (Central)		PRR		
Element: Space Radiation Evidence: Report Risk Master Logic Diagra Point of Contact: Janice HRP Risk Status: Active [Risk Ratings a	m: Not Availa Zawaski current resea	arch on		sion (D		, _			
Element: Space Radiation Evidence: Report Risk Master Logic Diagra Point of Contact: Janice HRP Risk Status: Active [m: Not Availa Zawaski current resea nd Dispositio	arch on	going] • Design Reference Mis	sion (D	RM) Category				
Element: Space Radiation Evidence: Report Risk Master Logic Diagra Point of Contact: Janice HRP Risk Status: Active [Risk Ratings a DRM Categories	m: Not Availa Zawaski current resea nd Dispositic Mission	arch on	going] • Design Reference Mis Operations	sion (D	RM) Category Long-Term Health				
Element: Space Radiation Evidence: Report Risk Master Logic Diagra Point of Contact: Janice HRP Risk Status: Active [Risk Ratings a	m: Not Availa Zawaski current resea nd Dispositic Mission Duration	arch on ons per LxC	going] Design Reference Mis Operations Risk Disposition *	sion (D	RM) Category Long-Term Health Risk Disposition *				
Element: Space Radiation Evidence: Report Risk Master Logic Diagra Point of Contact: Janice HRP Risk Status: Active [Risk Ratings a DRM Categories	m: Not Availa Zawaski current resea nd Dispositic Mission Duration 6 months	arch on ons per LxC 1x1	going] Design Reference Mis Operations Risk Disposition * Accepted	sion (D LxC 3x1	RM) Category Long-Term Health Risk Disposition * Accepted				
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Element: Space Radiation Evidence: Report Risk Master Logic Diagra Point of Contact: Janice HRP Risk Status: Active [Risk Ratings a DRM Categories Low Earth Orbit Deep Space Sortie Lunar Visit/	m: Not Availa Zawaski current resea nd Dispositic Mission Duration 6 months 1 year 1 month	LxC 1x1 1x1	going] Design Reference Mis Operations Risk Disposition * Accepted Accepted Accepted	sion (D LxC 3x1 3x2 3x1	RM) Category Long-Term Health Risk Disposition * Accepted To Be Determined Accepted				

"Requires Characterization", a new HSRB risk disposition not yet available in this tool.



ASTRONAUT HEALTH TEAM





Adrienne Hoarfrost



Arno Blaas



Samuel Budd



Kia Khezeli



Krittika D'Silva



John Kalantari



Graham Mackintosh



Frank Soboczenski















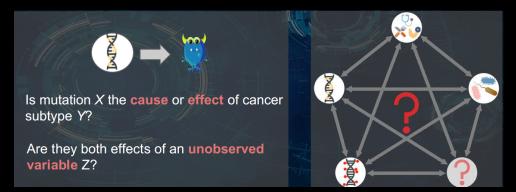
NASA

AI & Astronaut Health – Cancer Causal Inference

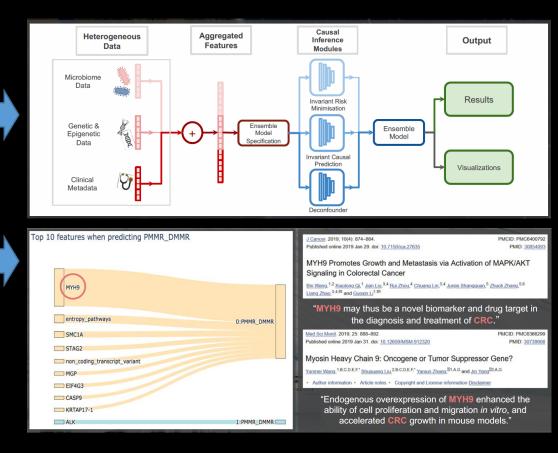
- Project goal: Develop a causality inference model for colorectal cancer (CRC) which could discern the causal relationships in multiomic data... a step towards prophylactic prevention of cancer instead of detection & therapeutics.
- Dataset was provided by Mayo Clinic - the largest CRC dataset in the world, with data from 100 tumors; specifically, microbiome data, genetic and epigenetic data, and clinical metadata.

The FDL team faced many challenges...

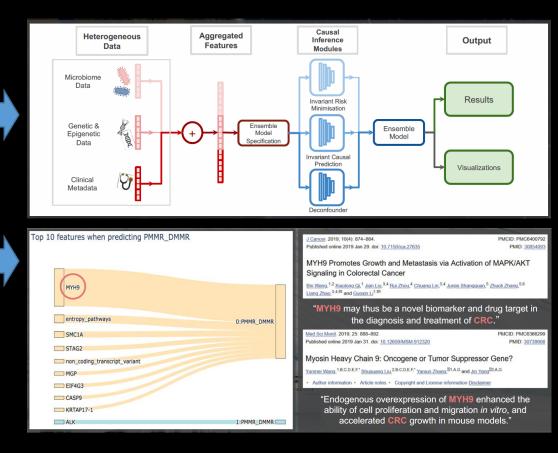
- High dimensionality 6.4 billion base pairs in the human genome.
- Low sample size: High volume of data, but from only 100 CRC patients
- Billions of correlations, but which ones are causal?



- 8-Week Sprint: "CRISP" (Causal Relation Inference & Search Platform) which used an ensemble of causal inference methods to identify causal relationships in heterogeneous data.
- Outcome Example: With no a priori knowledge, CRISP successfully identified the protein MYH9 as a top feature to identify whether the CRC causal relationships follow the chromosomal instability (CIN) pathway, or the less common pathway of tumorigenesis, which is characterized by proficient vs. deficient DNA mismatch repair (MMR) protein expression respectively.



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CRISP.... What's next?

- Completed workshops with FDL team, Mayo Clinic, NASA
 GeneLab, NASA HRP Space
 Radiation Element, NASA AI
- Three candidate project concepts emerged as top contenders:
- 1. Causality Model for Radiation Carcinogensis
- 2. Causal contributors for muscle and bone degeneration during long duration missions
- 3. Renal Stone Risk Prediction and Prevention

Planetary DRM (Mars)		FY15	FY16	FY17	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28
Risks	LxC		teroid ase A	CCP	7		EM-2	AARM	EM-3	EM-4	EM-5 End	EM-6 (ARC	CM)	Mars P	hase A
Space Radiation Exposure (Radiation)	3x4			Acute CN	S Risk Charac	terized		Late	CNS Risk Cha	racterized	Acute CNB State Updated	Lincer	CVD BM Validid	Acut Valie	dated
Cognitive or Behavioral Conditions (BMed)	3x4					Risk	Factors Under	stood		Monitorii Toolis De	ng eveloped	CMs & Tre	atment Devel	oped	
Medications Long Term Storage (Stability)	3x4		Most Cor sage Dater	nman nined				y Device		Risk De	termined	Med Usage	Understood		
Vision Impairment/Intracranial Pressure (VIIP)	3x4						sk Understood	Potential Ch	Is Identified	CMs V	alidated		CMs	Optimized	
Inadequate Food and Nutrition (Food)	3x4						CM Validate	Rest Pr	distd Food-	01 Risk Under	stood			Rqts/Tools Nutritio	Validated on CM Optini
Team Performance Decrements (Team)	3x4					Risk	Understood		Stds Devel Measures (oped; Dev & Val	CMs Develo	ed & Validate	d		
Inflight Medical Conditions (Medical)	3x4		cept of Dpe	rations 🔺 Int	egrated Medica	al System	Cont	Ops All DRM:	s pharm	acy Recomme	indation	Select Techni	ologies	Optimized I	Med System
Human-System Interaction Design (HSID)	3x4			HARI Risk Cha	racterized	Tra	in Risk Unders		ols & NHV Validated		ICI CM Validated	MP Task CM	Developed		
Bone Fracture (Fracture)	2x4	Update Bo	ne Standari	s 🔺 🖉	Fracture Ri haracterizi	sk Fract Risk Quant Updated		flight CM Va Isteo)	lidated	Fracture Tre	eatment Validate	d			
Renal Stone Formation (Renal)	3x4	CMs Validated		Treat	ment Validated			Treatment V	alidated						
Sensorimotor Alterations (SM)	3x3	Standard Up	pdate	CMs Identified	Star	ndard Update	Risk Ur	nderstood	Standa	rd Validated	In-flight C	Ms Validated			
Injury from Dynamic Loads (OP)	3x3	Standards Update			alidated Analyt	ical Tool	/	Risk Chara	acterized, Star	ndard Updated	1				
Altered Immune Response (Immune)	3x3		Det	ermine Clinical Si Altered Immune		Analog Identified				k Characterize entify CM	d		Validated		
Host-Microorganism Interactions (Microhost)	3x3								Micro-02 Inform Ris	*	nform Risk	cro-01803; In obiotic CM	orm Risk	Develop Viru Countermea	lence
Injury Due to EVA Operations (EVA)	3x3		Suit Injury D	lata Identified			Update Su Requireme				ated Suit Require and Ops	ements	Fitness fo Duty Stan		EVA Ops Optimized
Hypobaric Hypoxia (ExAtm)	3x3								R	isk Characteria	zed				
Sleep Loss (Sleep)	3x3	Key Monitoring T	ools Develo	ped & Validated	\wedge	,	key CMs Valida & Individuali			Risk Understo	pod	Integrated	Monitoring To	ols & CMs Val	idated
Reduced Muscle Mass, Strength (Muscle)	3x3			Standard Update		Inflight CM Va Current Ha	idated dware	Sta	andard Validat	ed			Inflight CM V Exploration H		
Reduced Aerobic Capacity (Aerobic)	3x3			Standard Update	•	Inflight CM Va Current Ha	idated dware	Sta	andard Validat	ed			Inflight CM V Exploration H		
Celestial Dust Exposure (Dust)	TBD		Initial Risk Charactergation Mans Dust												
Decompression Sickness (DCS)	3x3			Standard U	pdate /	Risk Unde	erstood	Risk Mod	del Defined			Risk Mode	Update	Updated C	onOps
Orthostatic Intolerance (OI)	3x2								n-/Post-flight (CM Validated					
Cardiac Rhythm Problems (Arrhythmia)	3x4		Risk Under	stood											
Concern of Intervertebral Disc Damage (IVD)	TBD		Ir	-flight Monitoring	Method Valida	ated	Risk U	Jnderstood, (CM Identified						
Concern of Effects of Medication (PK/PD)	TBD			Mo	st Common Us	age Determine	ed /	Risk Cha	racterized						
								- cl.10							
ISS Required Milest	one Req	uires ISS	$\overline{\nabla}$	Mission Miles	~	Anticipat	ed Mileston	e Shift			End	ISS	HF	PCB-app	
ISS Not Required Groun	d-based	Milestone	V Mi	ssion Mileston	e									7/22/20	
📕 High Likelihood 📃 Mid Likelihood 📃	Low I	Likelihood 📃	Optim	ized 🔲	Insufficien	t Data							′	PBE18 bas	enne
by Consequence by Consequence	by Co	onsequence													

Thank you!

NASA

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