AI Applications for Astronaut Health

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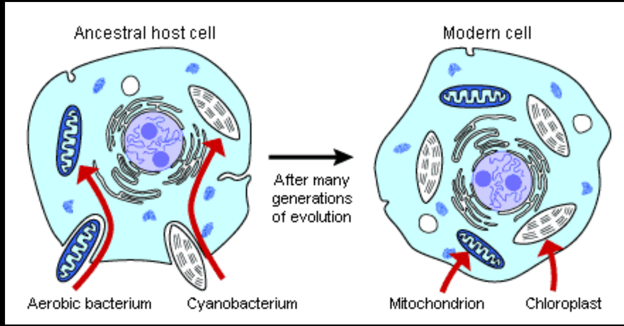
NASA AND BIOSCIENCE INNOVATION

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.

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.



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

Space and Bioscience

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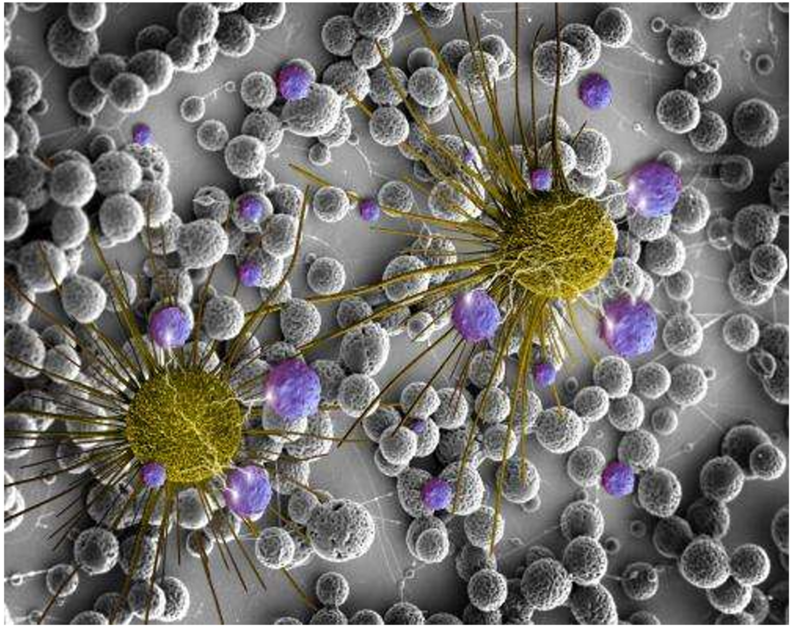
Micro-encapsulation: Particles are surrounded by a coating to create nano-scale capsules. Microgravity enables a far greater range of viable substances for encapsulation and superior shell wall structure.



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 long-duration space expeditions and planetary settlements."

[ESA Directorate of Technology Newsletter, November 2018.]

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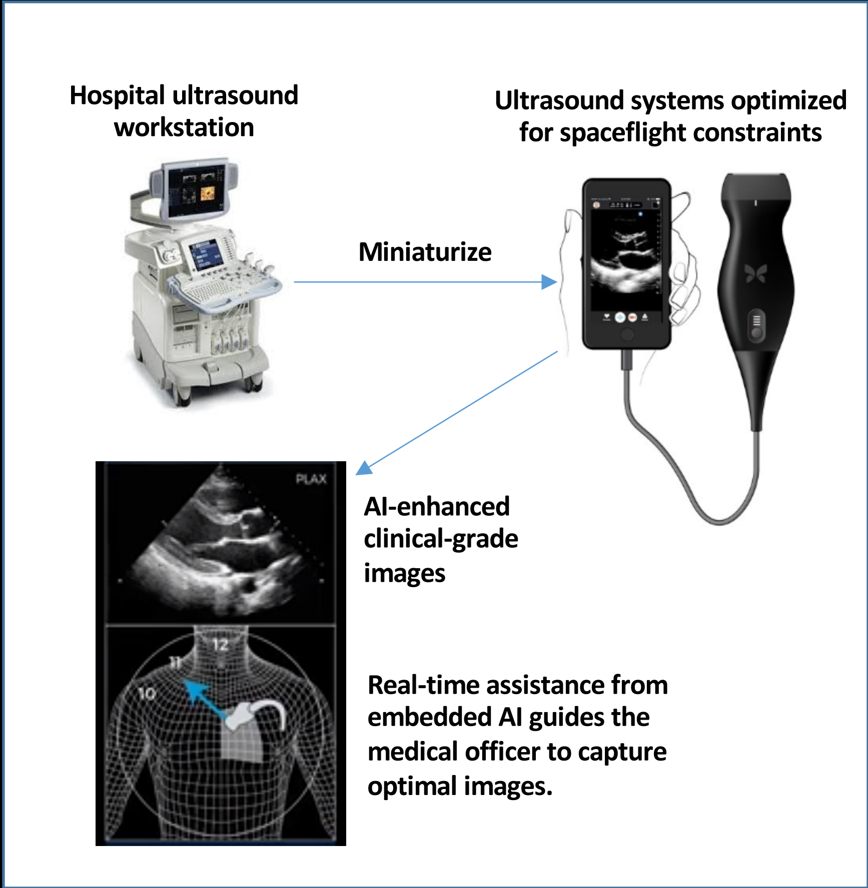
(with results that usually have terrestrial benefits to the human condition)



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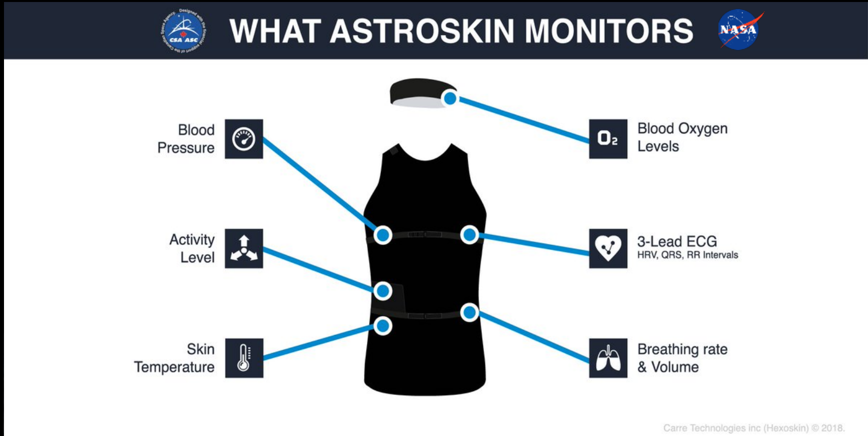

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Astronaut Health: The Two New Imperatives

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

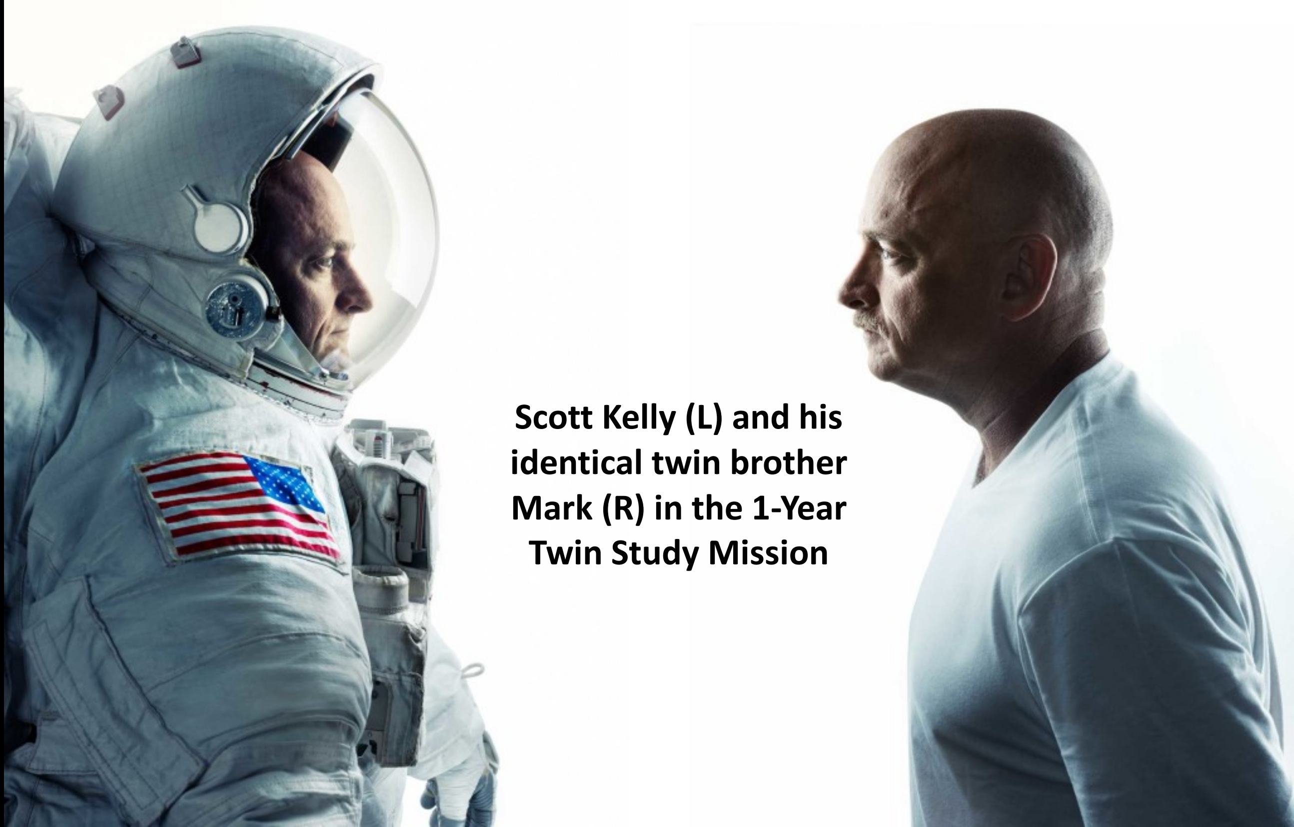
2. Enable space commerce by adressing the health requirements of civilian crew and passengers.


NASA

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.

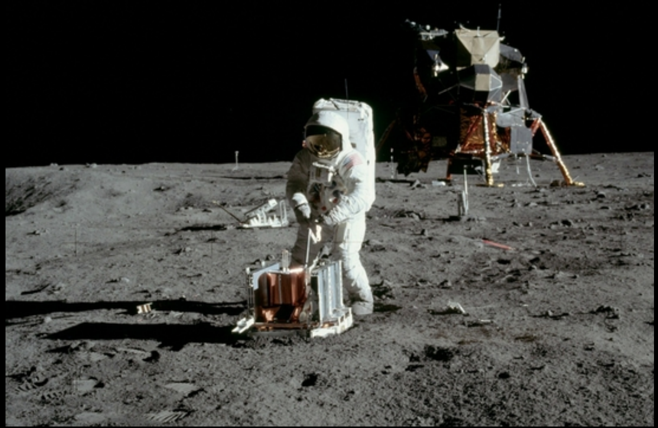
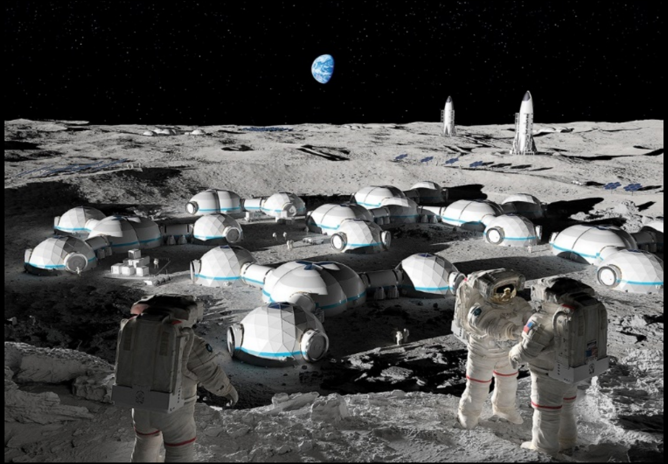
I experienced problems with my vision, as many other astronauts had. I had been exposed to more than 30 times the radiation of a person on Earth, equivalent to about 10 chest X-rays every day. This exposure would increase my risk of a fatal cancer for the rest of my life." [Scott Kelly]



Scott Kelly (L) and his identical twin brother Mark (R) in the 1-Year Twin Study Mission



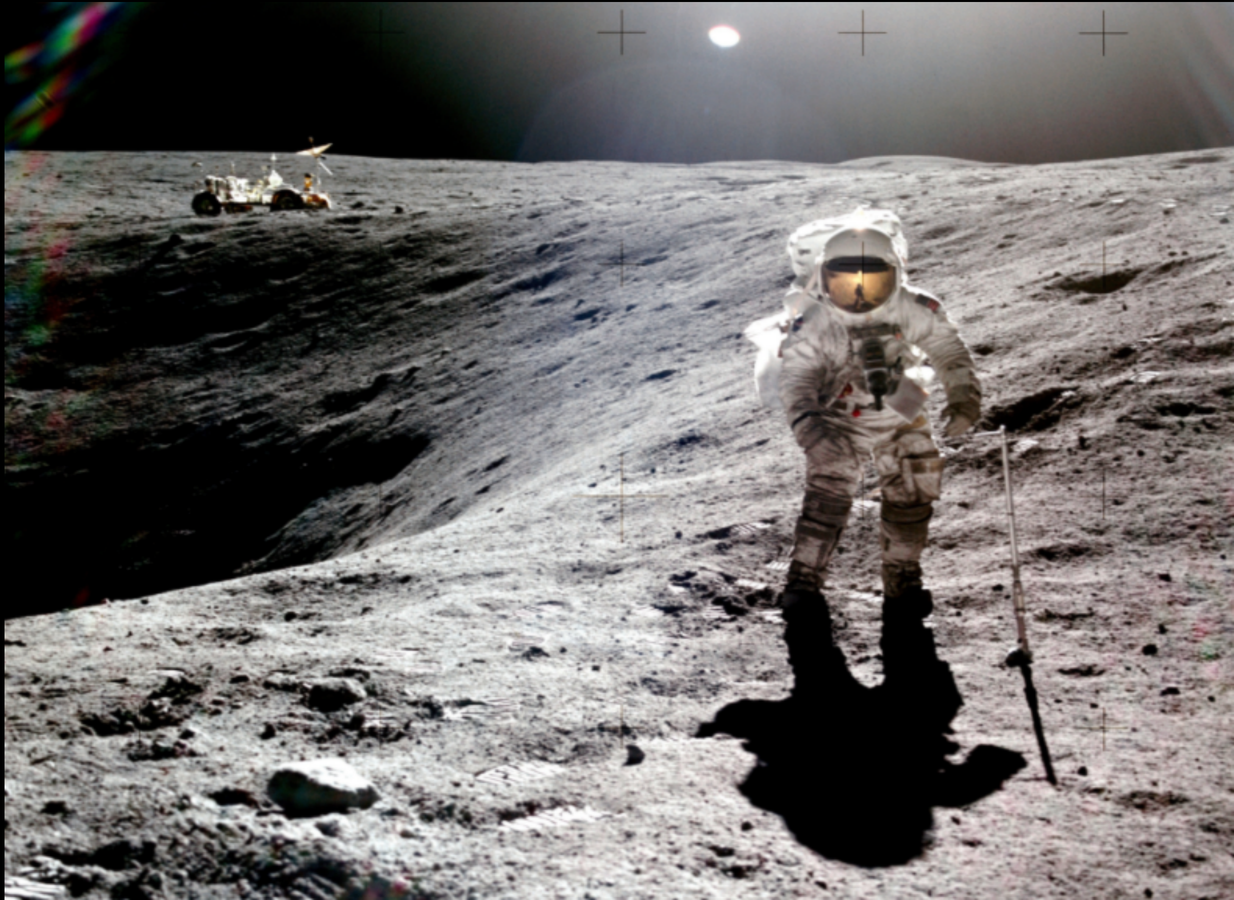


Astronaut Health Risks… Visit vs. Stay

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

Credits: NASA



Clear and
Present
Health Risk

Astronaut Health

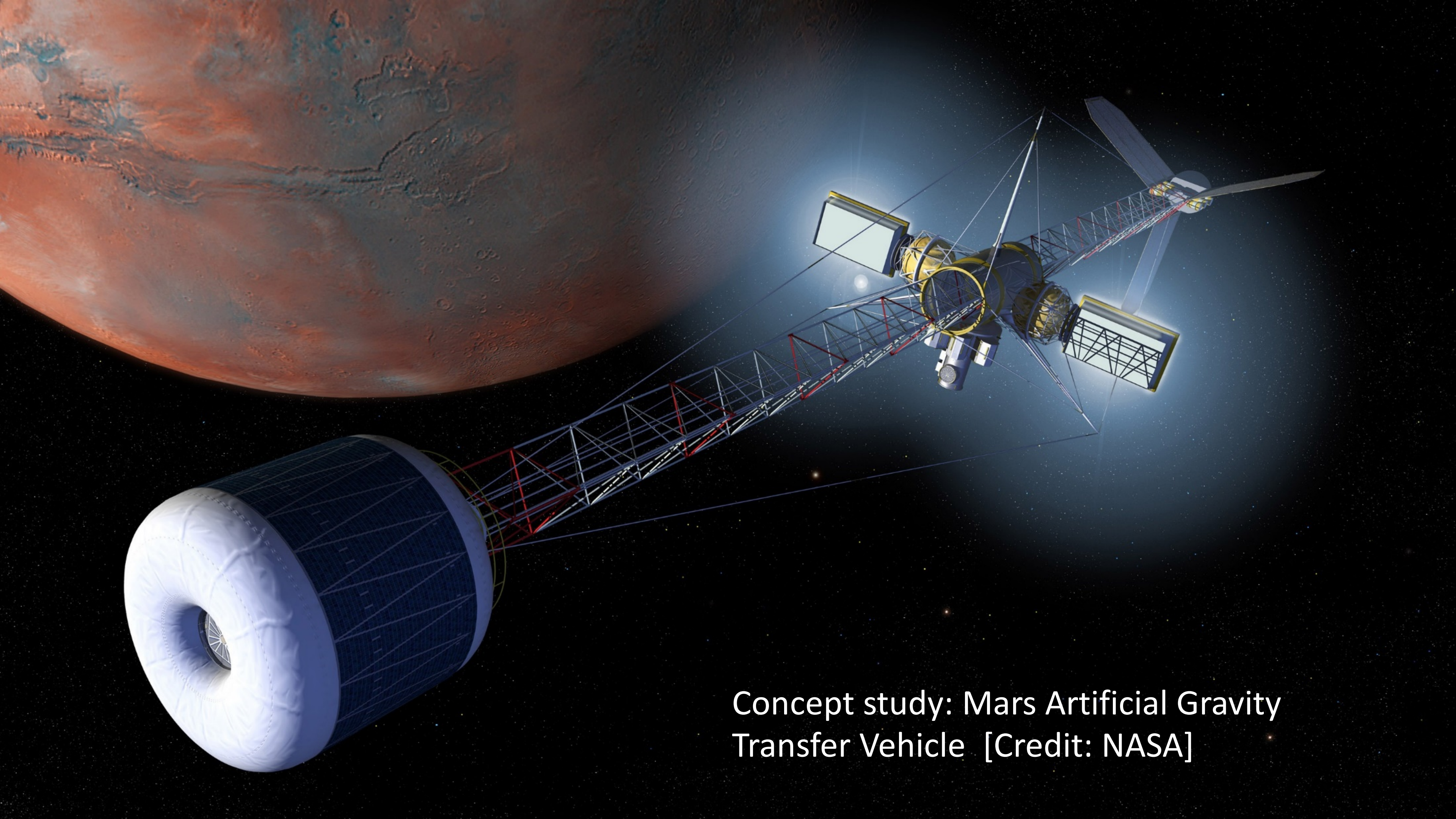
Solid Foundation of
Data Assets

AI Affinity

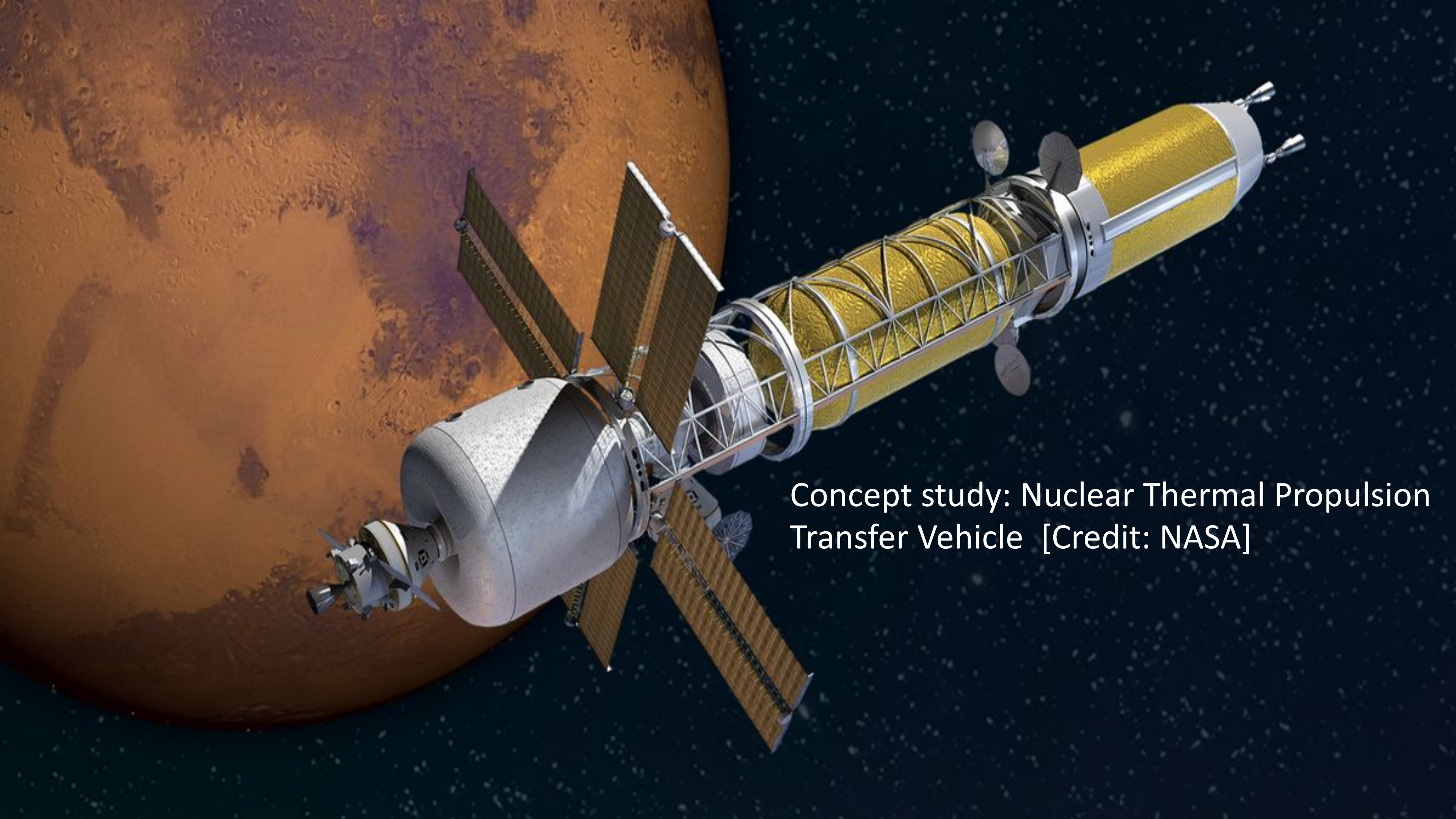

HUMAN RESEARCH PROGRAM


DATA


Ai



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

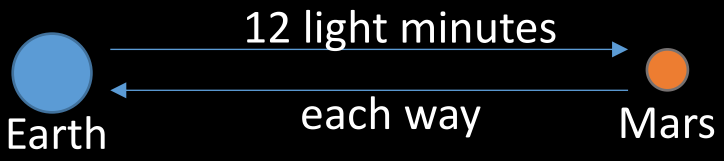


Concept study: Nuclear Thermal Propulsion Transfer Vehicle [Credit: NASA]

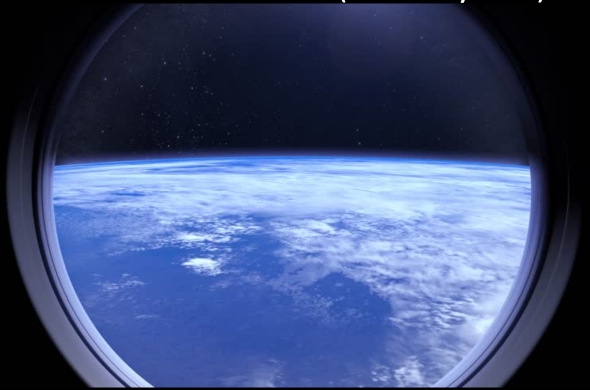
Distance – Intervention Protocols

- 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.

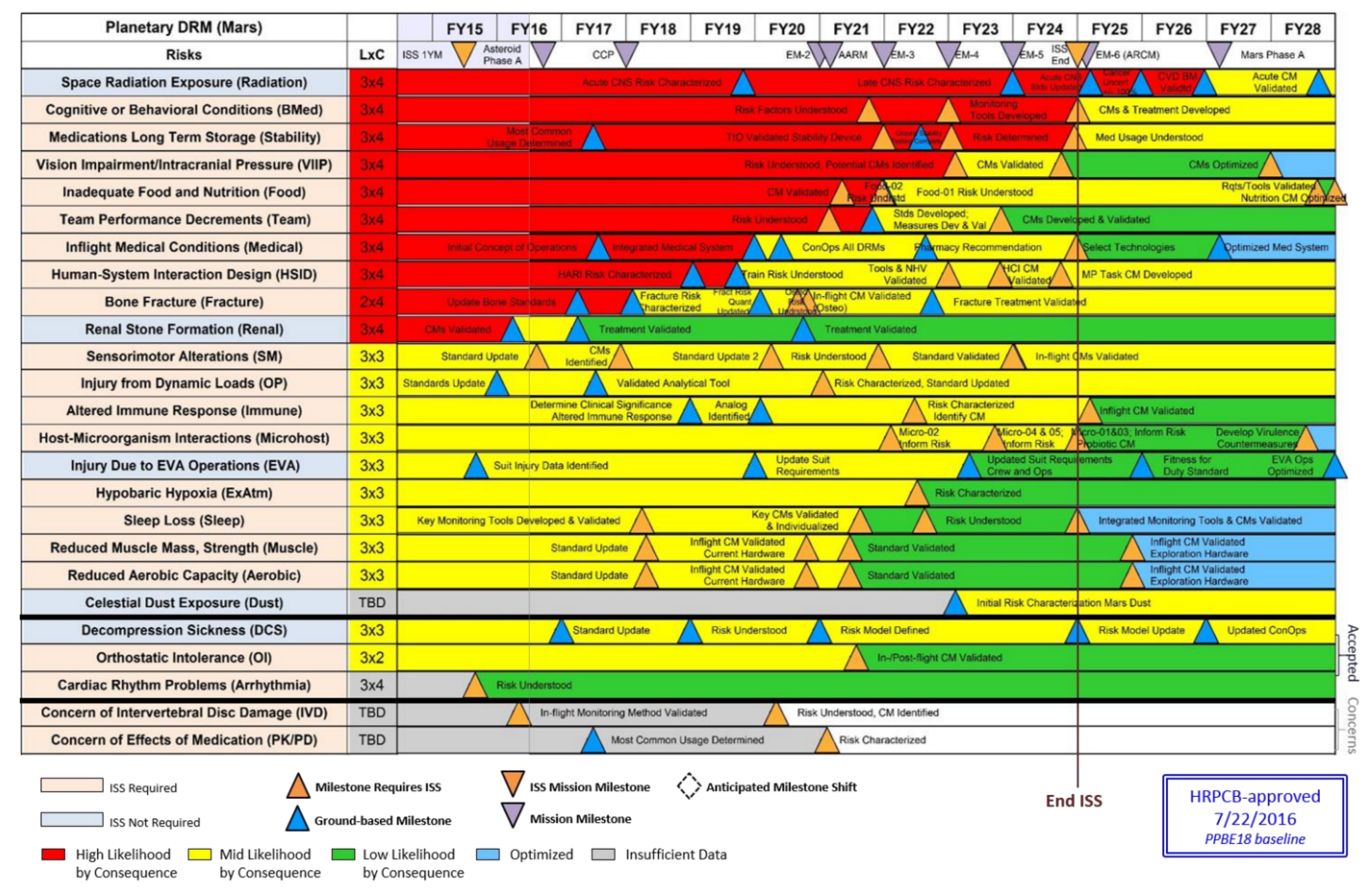


The view from LEO (last 50 years)…

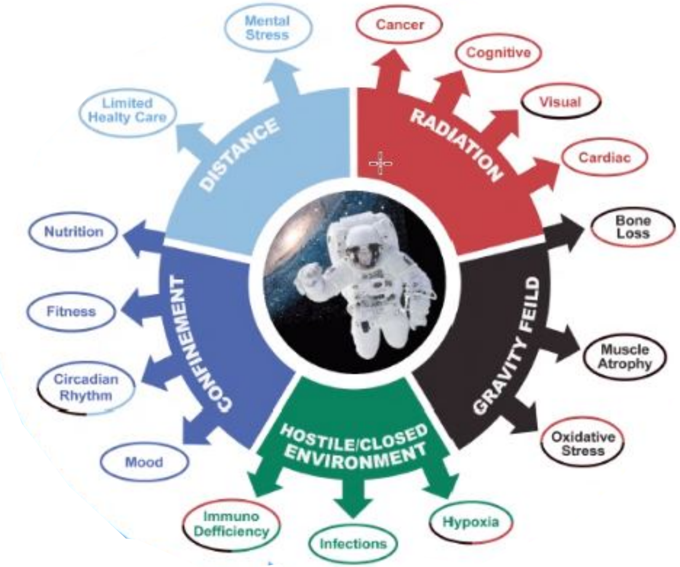


The view from Mars…

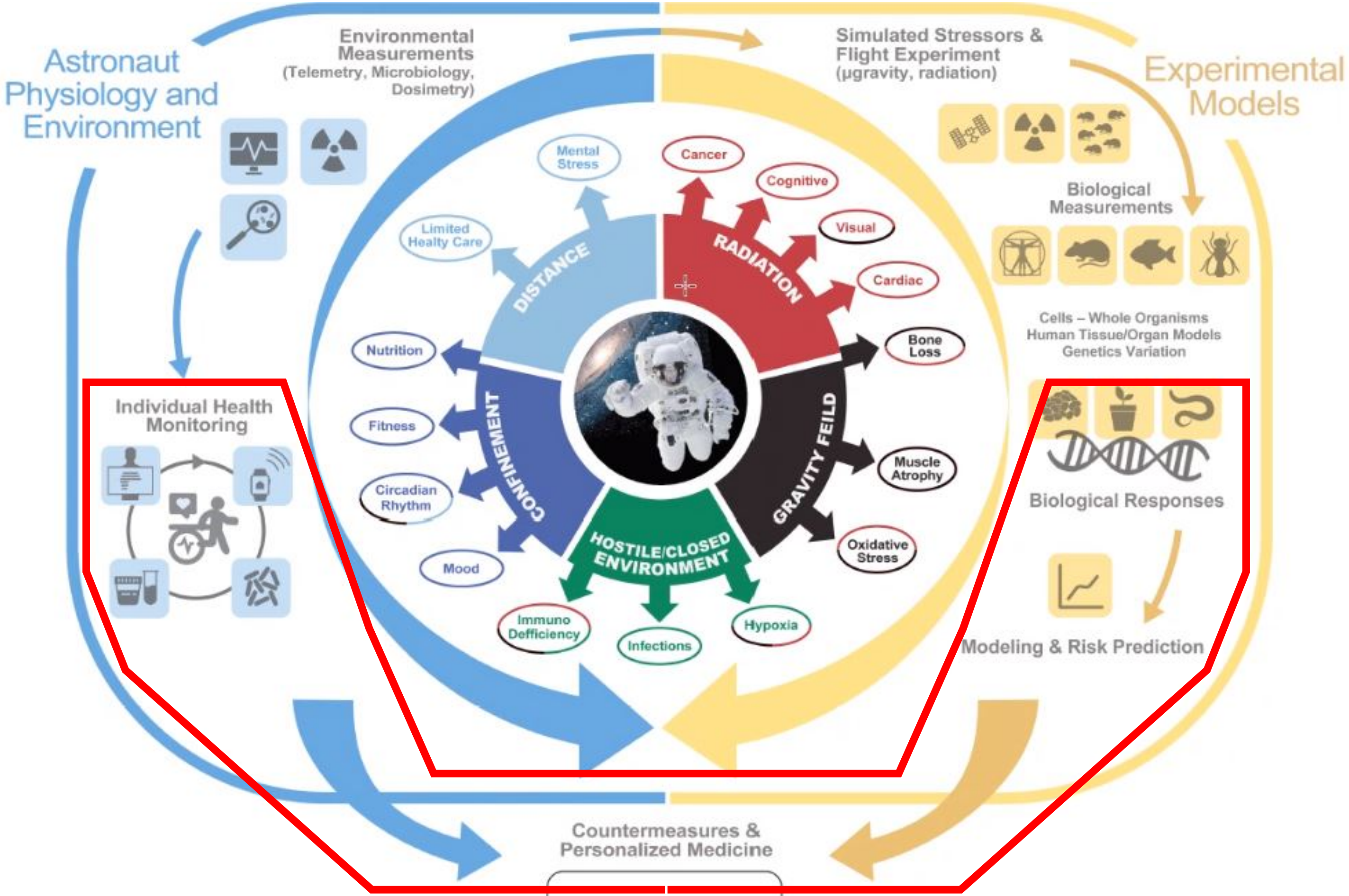
The HRP Integrated Path to Risk Reduction



Astronaut Health

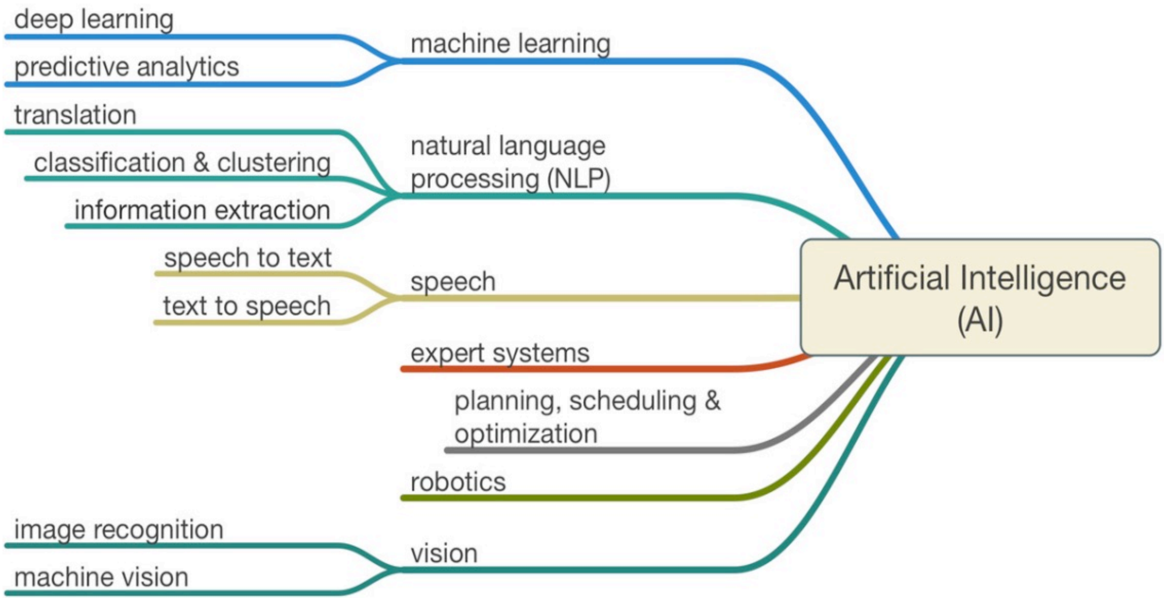


Astronaut Health… and AI



Medicine and Artificial Intelligence

- AI: *The science of making computers behave in ways that we thought required human intelligence until we saw a computer do it.*



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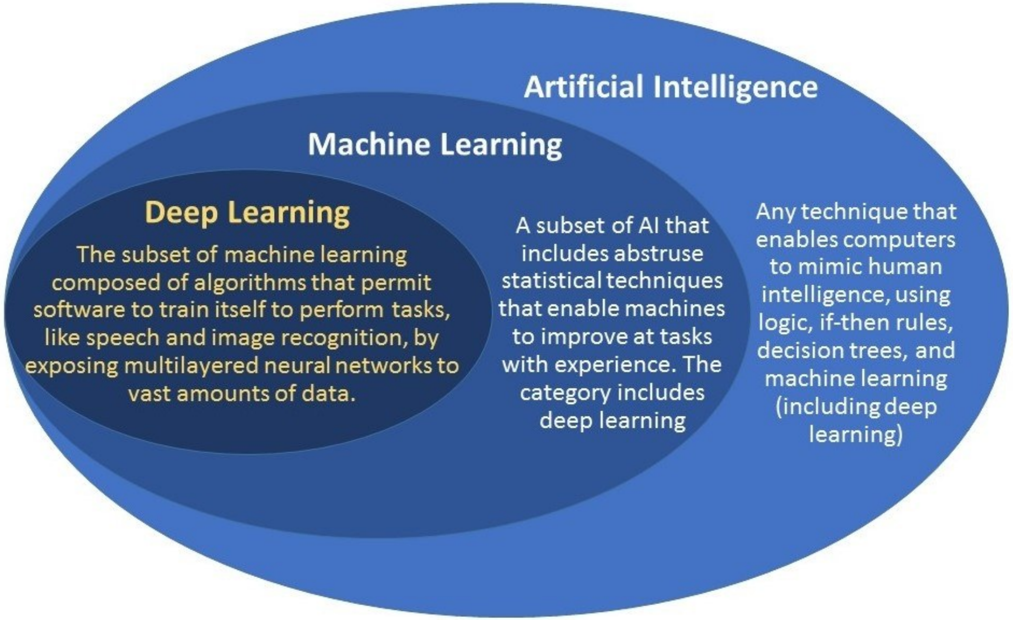
Its not magic…. just fancy statistics, matrix algebra, and non-linear functions.



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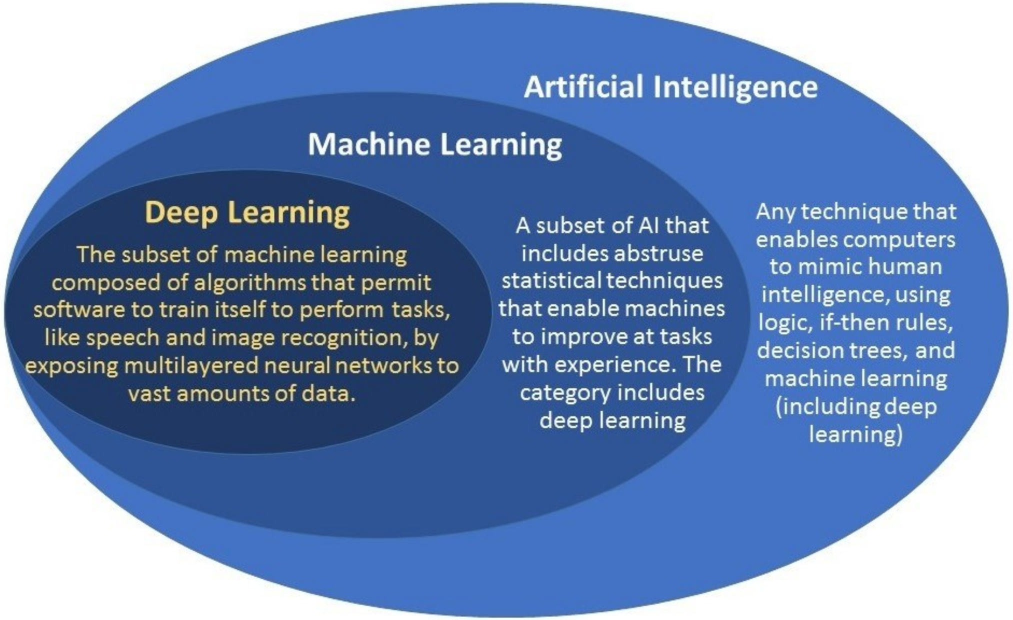
Visualization of Neural Network for Number Recognition



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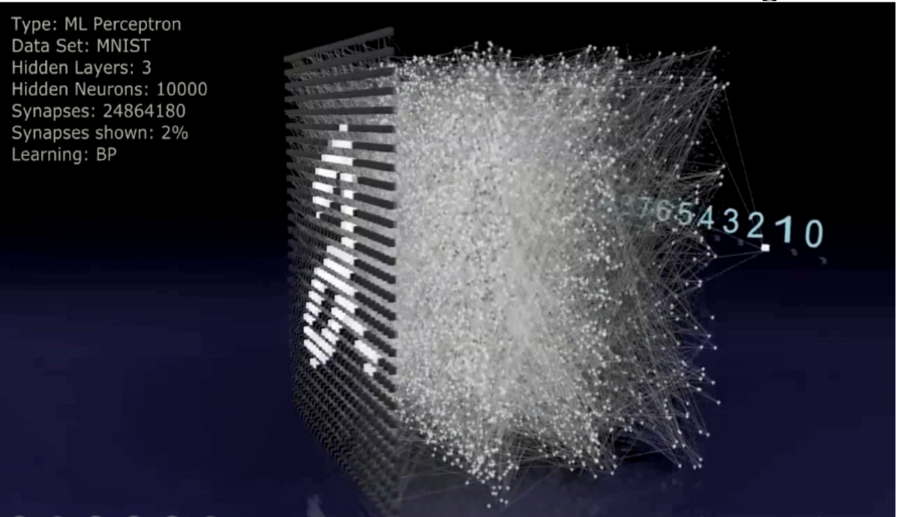

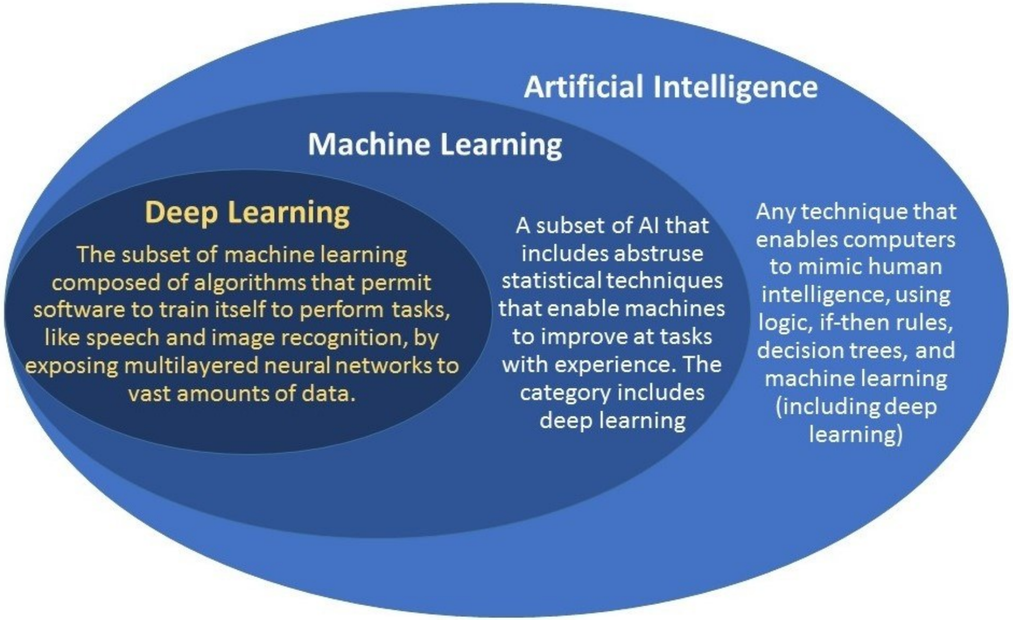

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ST-Segment Deviation

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

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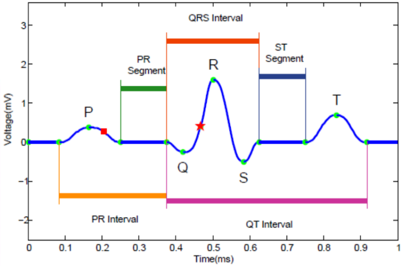

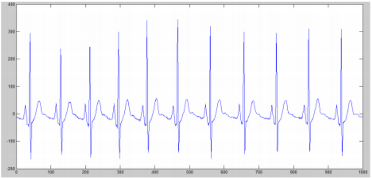

```
N = length(sig);
duration_in_seconds = N*0.1/fs;
duration_in_minutes = duration_in_seconds/60;
BPM = beat_count/duration_in_minutes

BPM =

   78.0000
```

The ECG dataset

```
In [ ]: raw_ecg_rdd = sc.textFile( '/opt/SparkDatasets/ecg/ecg.csv' )

        print raw_ecg_rdd.take(5)

In [ ]: ecg_rdd_0 = \
        raw_ecg_rdd \
        .map( lambda s: s.split(',') ) \
        .map( lambda l: ( int(l[0]), int(l[1]) ) )

        print ecg_rdd_0.take(15)

In [ ]: ecg_rdd_1 = ecg_rdd_0.map( lambda (i, v): (i + 1, v) )
        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)
        print ecg_rdd_2.take(15)
        print ecg_rdd_3.take(15)

In [ ]: ecg_rdd_0 \
        .groupWith( ecg_rdd_1, ecg_rdd_2, ecg_rdd_3 ) \
        .take(3)

In [ ]: prepared_for_pattern_matching_ecg_rdd \
        .map(pattern_matching_fn) \
        .collect()

In [ ]: close_to_final_shape_ecg_rdd = \
        prepared_for_pattern_matching_ecg_rdd \
```

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Fun fact: AI 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.

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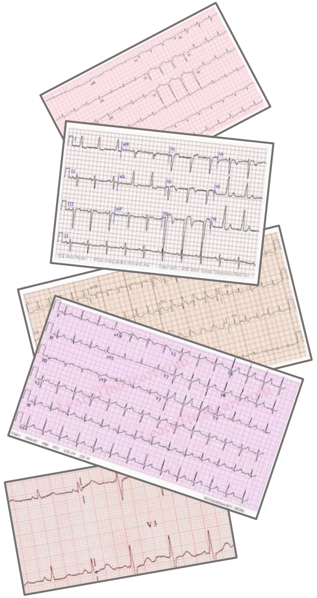
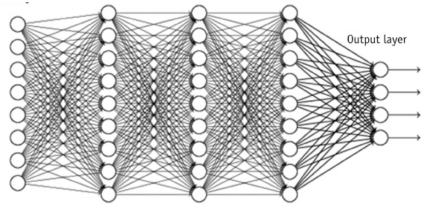




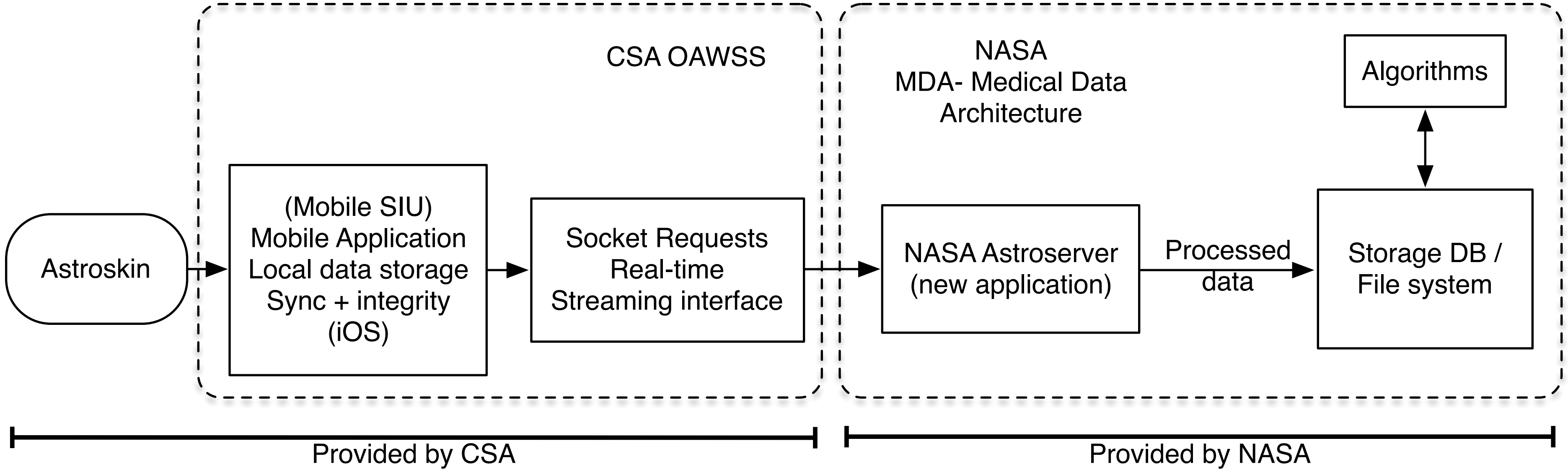
Diagnostic Classification

Monitoring - Astroskin

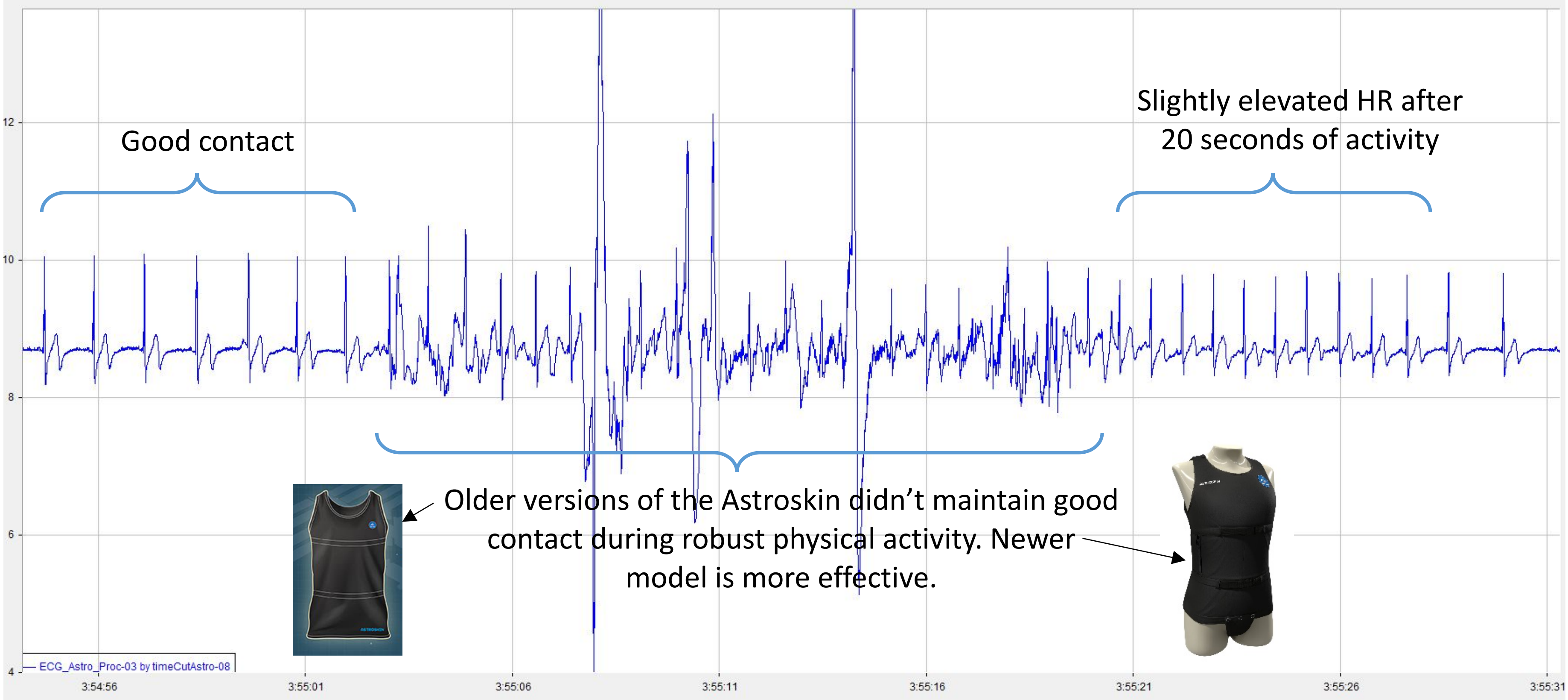
The 4-man crew of the NASA Human Exploration Research Analog (HERA) mission, wearing Astroskin biosensors
Credit: NASA

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



Astronaut Health Monitoring - Astroskin

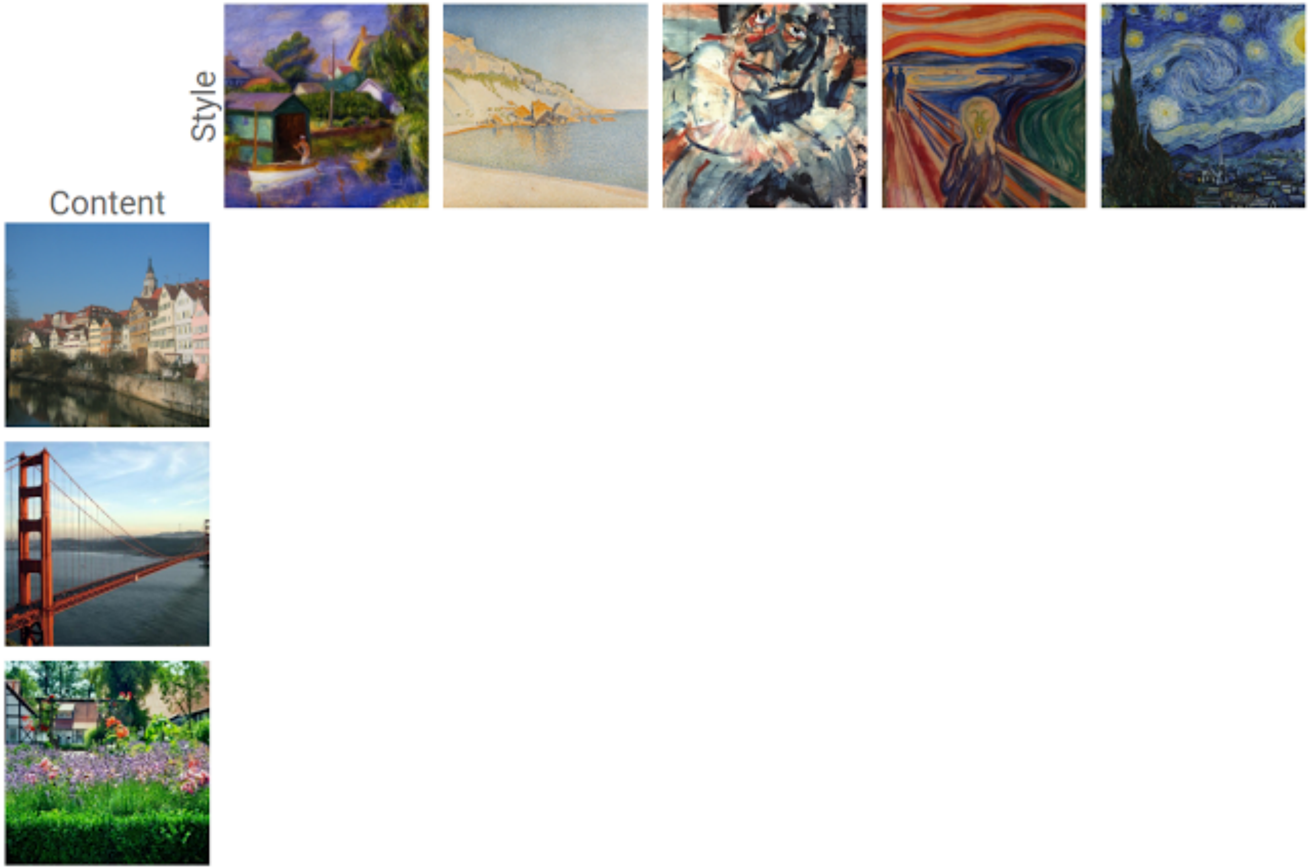


Astronaut Health Monitoring - Astroskin

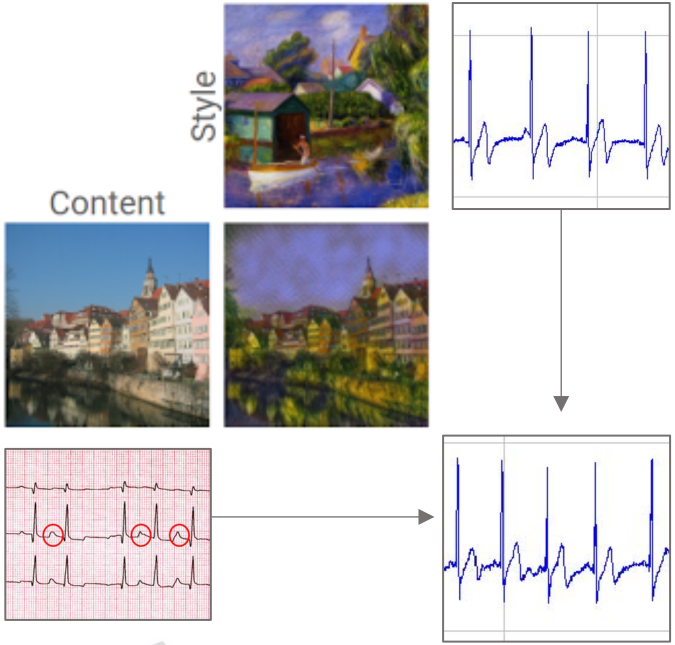
- **The Need:** Address the lack of in-flight medical data for use in crew training and to design/test onboard systems that monitor health of astronauts & commercial crew.

- **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.

Generative AI

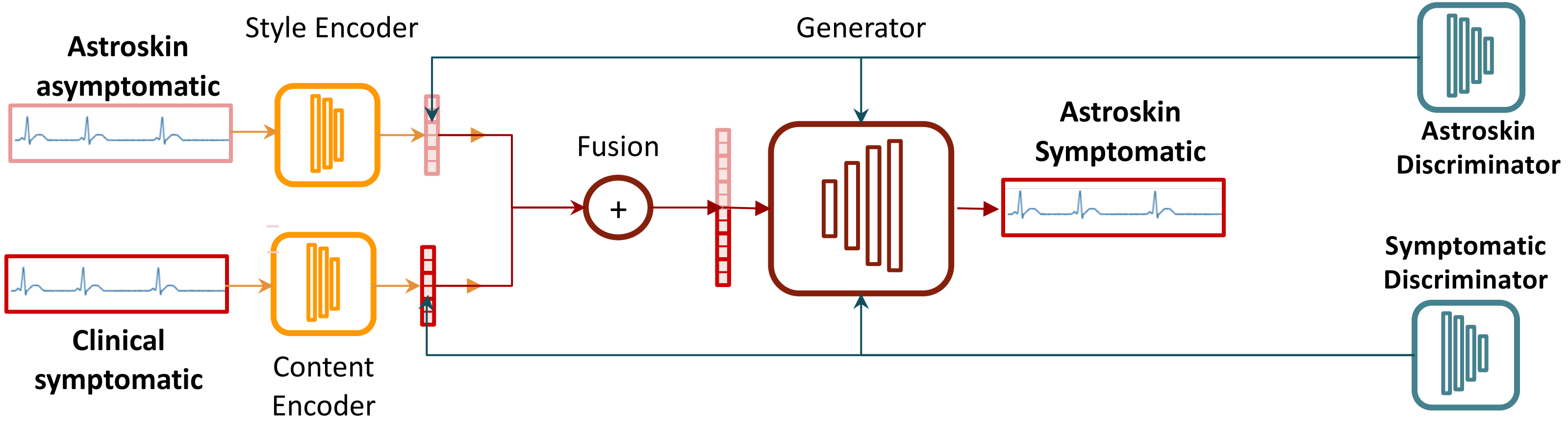


Generative AI - Astroskin Synthetic Data



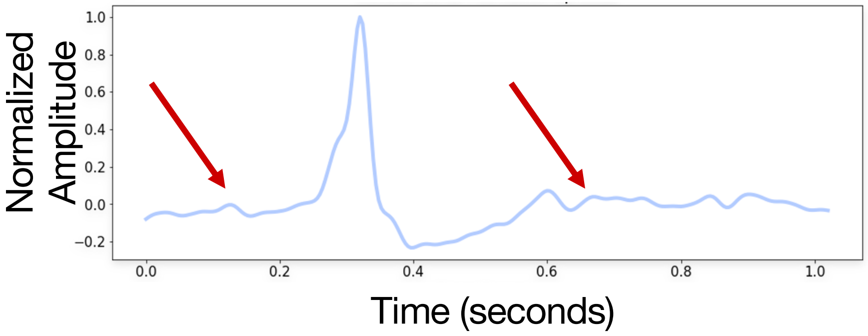
Generative AI - Synthetic Astroskin Data

- 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.

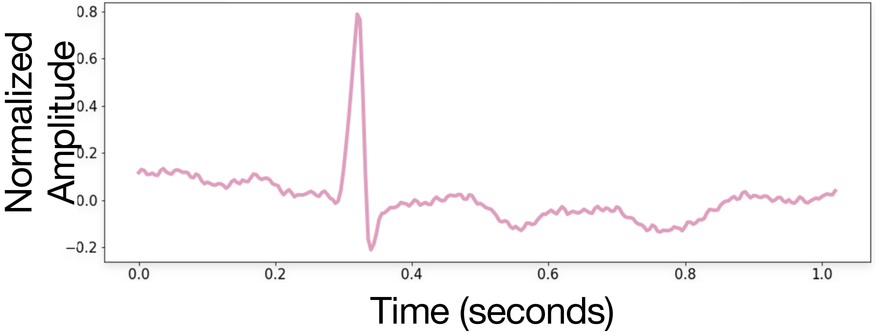


Generative AI - Synthetic Astroskin Data

Clinical Atrial Fibrillation Episode



Astroskin Asymptomatic



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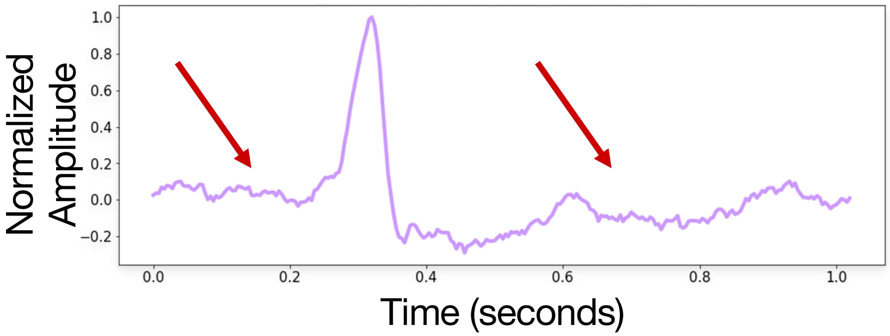
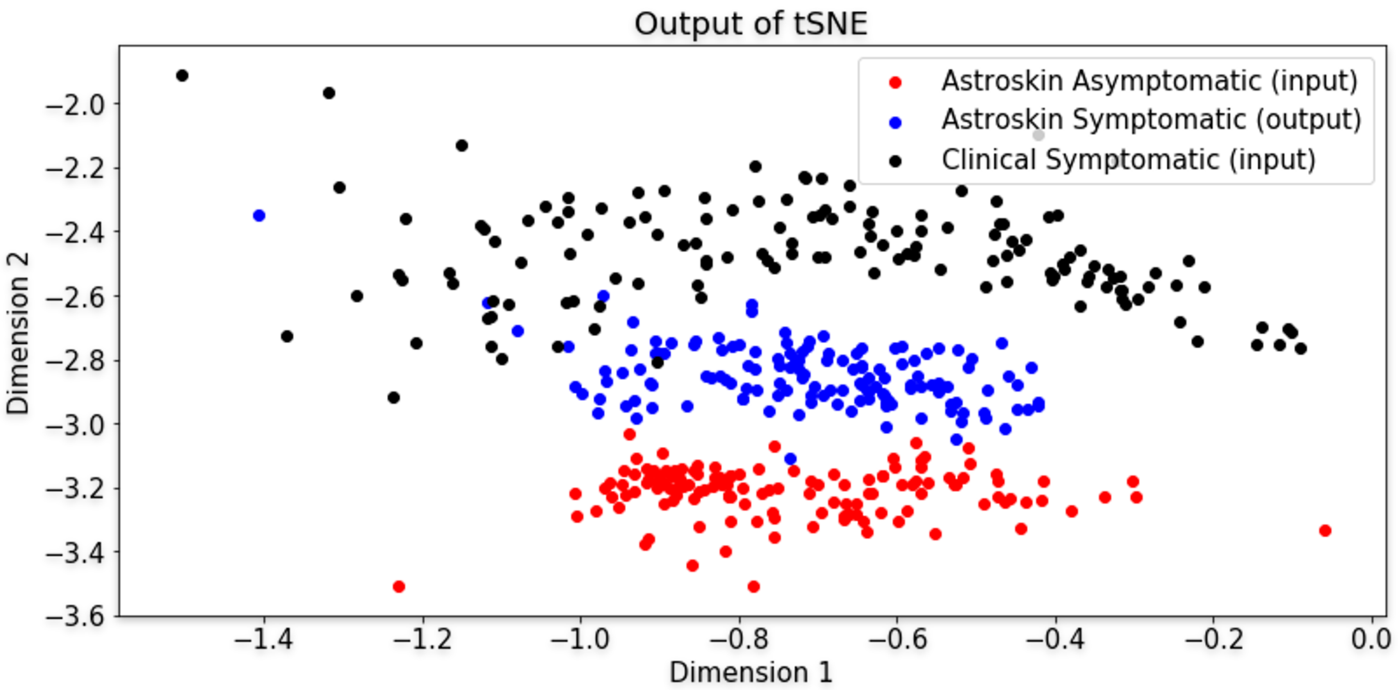
Synthesized Astroskin Atrial Fibrillation Episode

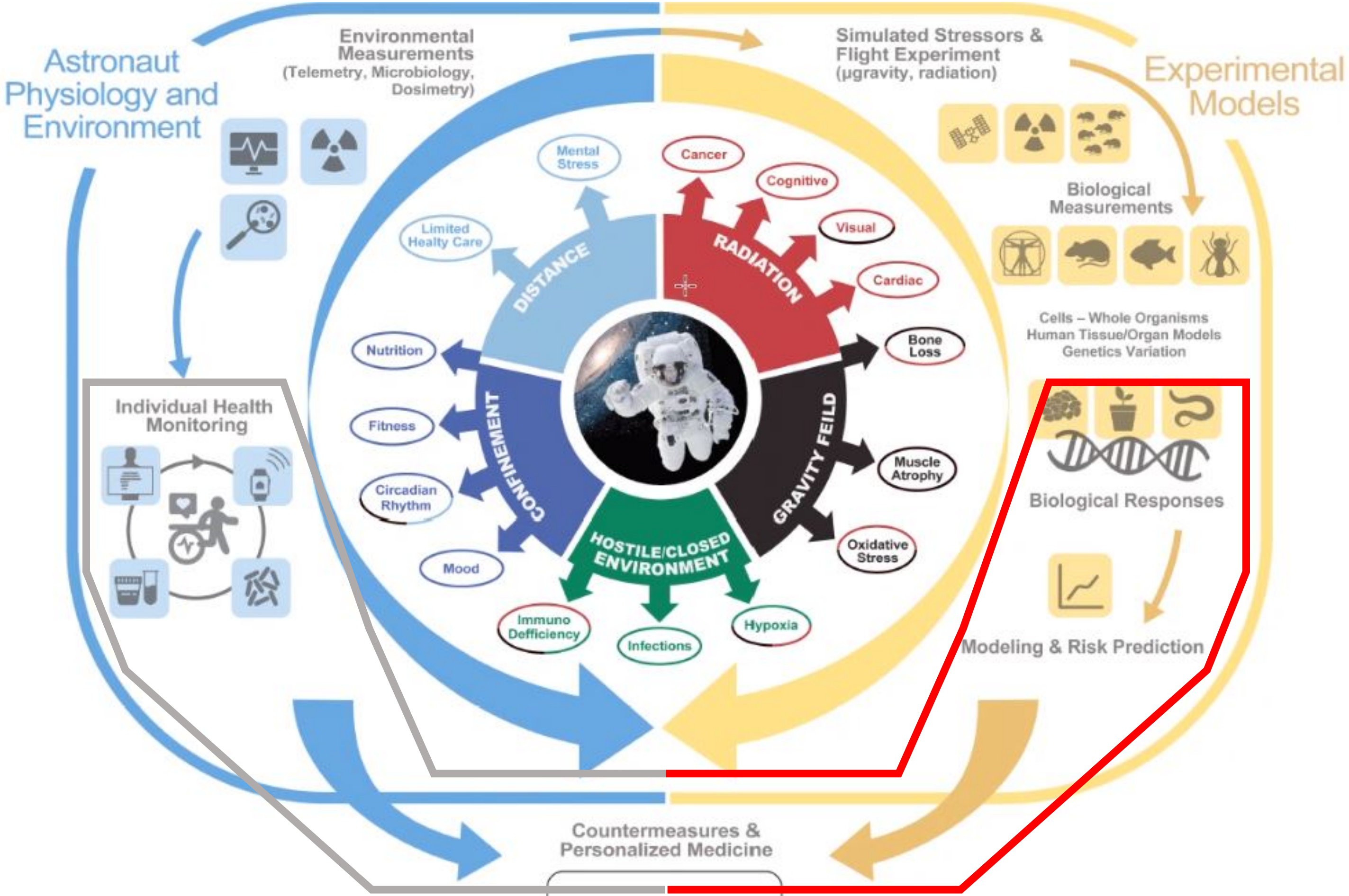


Generative AI - Synthetic Astroskin Data



Generative AI - Synthetic Astroskin Data

Astronaut Health… and AI



Astronaut Health – Radiation Carcinogensis

HUMAN RESEARCH ROADMAP | HRP | DATA | EXPLORATION

Search Search

Home | HRP Goals and Objectives | Human Research Roadmap | HRP Organizational Structure | Acronyms | Reviews | Help

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PRR

Risk of Radiation Carcinogenesis

Short Title: Cancer
Last Published: 08/03/20 03:51:22 PM (Central)
Element: Space Radiation (SR)
Evidence: Report
Risk Master Logic Diagram: Not Available
Point of Contact: Janice Zawaski
HRP Risk Status: Active [current research ongoing]

Risk Ratings and Dispositions per Design Reference Mission (DRM) Category

DRM Categories	Mission Duration	Operations		Long-Term Health	
		LxC	Risk Disposition *	LxC	Risk Disposition *
Low Earth Orbit	6 months	1x1	Accepted	3x1	Accepted
	1 year	1x1	Accepted	3x2	**To Be Determined**
Deep Space Sortie	1 month	1x1	Accepted	3x1	Accepted
Lunar Visit/ Habitation	1 year	1x1	Accepted	3x2	**To Be Determined**
Deep Space Journey/Habitation	1 year	1x1	Accepted	3x3	Requires Mitigation
Planetary	3 years	1x1	Accepted	3x3	Requires Mitigation

Note: LxC is the likelihood and consequence rating. The information above was last approved by the Human System Risk Board in 2/2020. ** NOTE: the "To Be Determined" dispositions indicate "Requires Characterization", a new HSRB risk disposition not yet available in this tool.

AI & Astronaut Health – Cancer Causal Inference

ASTRONAUT HEALTH **TEAM**

FDL FRONTIER DEVELOPMENT LAB


Adrienne Hoarfrost


Arno Blaas


Samuel Budd


Kia Khezeli


Krittika D’Silva


John Kalantari


Graham Mackintosh


Frank Soboczenski

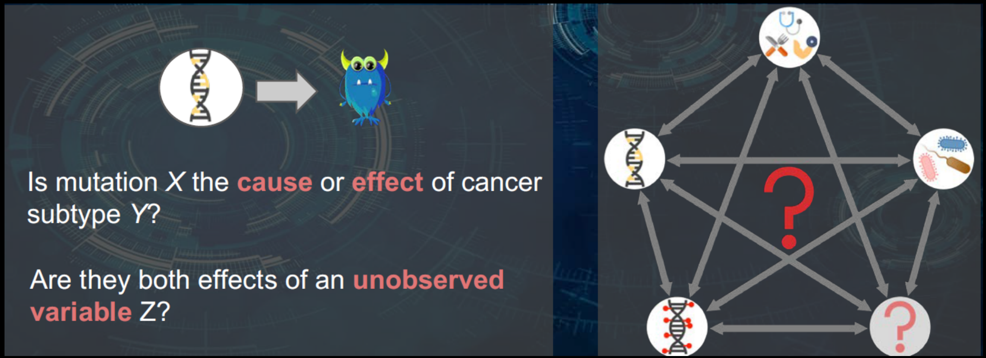
AI & Astronaut Health – Cancer Causal Inference

- 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.

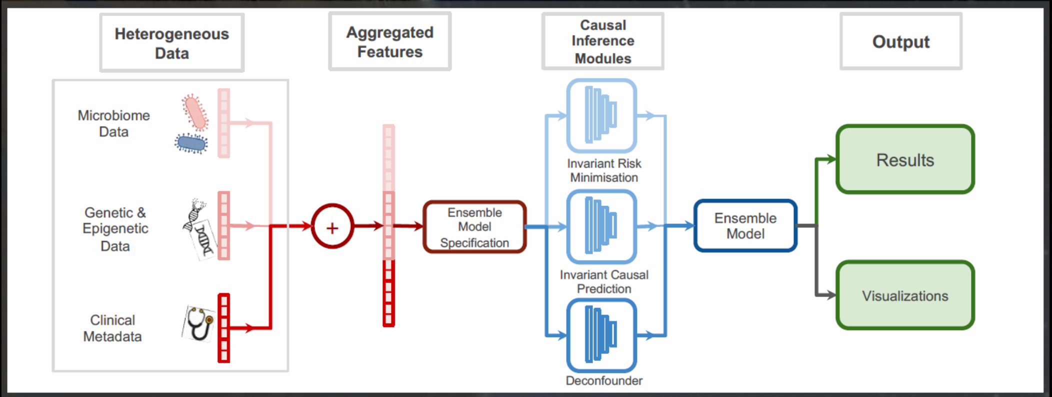
The FDL team faced many challenges…

- 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?

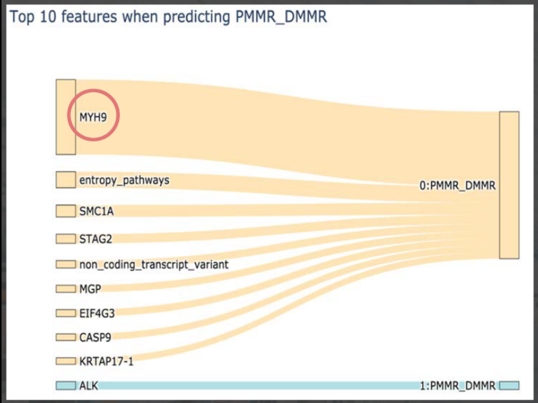


AI & Astronaut Health – Cancer Causal Inference

- **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.



J Cancer. 2019; 10(4): 874–884. PMCID: PMC6400792
Published online 2019 Jan 29. doi: 10.7150/jca.27635 PMID: 30854093

MYH9 Promotes Growth and Metastasis via Activation of MAPK/AKT Signaling in Colorectal Cancer

Bin Wang,[1,2] Xiaolong Qi,[1] Jian Liu,[3,4] Rui Zhou,[4] Chuang Lin,[3,4] Junjie Shangguan,[5] Zhuoli Zhang,[5,6] Liang Zhao,[3,4,✉] and Guoxin Li[1,✉]

“**MYH9** may thus be a novel biomarker and drug target in the diagnosis and treatment of **CRC**.”

Med Sci Monit. 2019; 25: 888–892. PMCID: PMC6366299
Published online 2019 Jan 31. doi: 10.12659/MSM.912320 PMID: 30739906

Myosin Heavy Chain 9: Oncogene or Tumor Suppressor Gene?

Yunmei Wang,[1,B,C,D,E,F,*] Shuguang Liu,[2,B,C,D,E,F,*] Yanjun Zhang,[1,A,G] and Jin Yang[3,A,G]

▸ Author information ▸ Article notes ▸ Copyright and License information Disclaimer

“Endogenous overexpression of **MYH9** enhanced the ability of cell proliferation and migration *in vitro*, and accelerated **CRC** growth in mouse models.”

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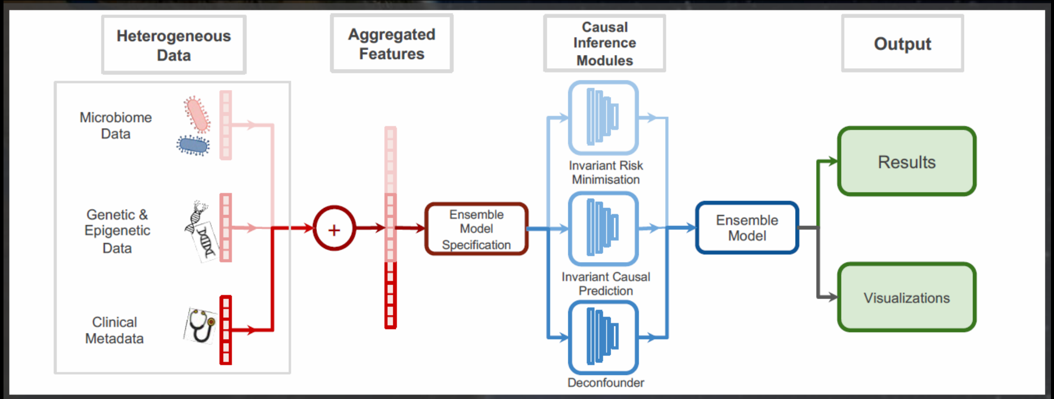
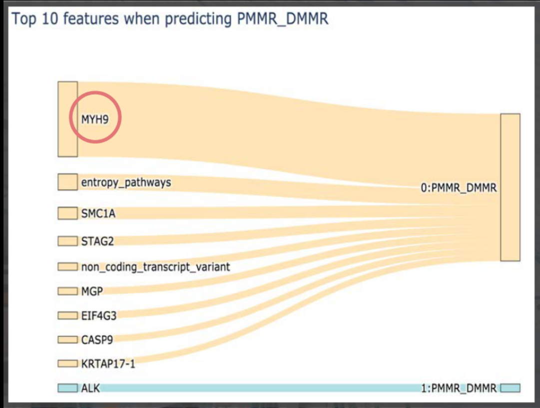


- Outcome Example: With no a priori knowledge, CRISP successfully identified the protein MYH9 as a top feature to identify whether the CRC causal relationships follow the chromosomal instability (CIN) pathway, or the less common pathway of tumorigenesis, which is characterized by proficient vs. deficient DNA mismatch repair (MMR) protein expression respectively.



J Cancer. 2019; 10(4): 874–884. PMCID: PMC6400792
Published online 2019 Jan 29. doi: 10.7150/jca.27635 PMID: 30854093

MYH9 Promotes Growth and Metastasis via Activation of MAPK/AKT Signaling in Colorectal Cancer

Bin Wang,[1,2] Xiaolong Qi,[1] Jian Liu,[3,4] Rui Zhou,[4] Chuang Lin,[3,4] Junjie Shangguan,[5] Zhuoli Zhang,[5,6] Liang Zhao,[3,4] and Guoxin Li[1]

"MYH9 may thus be a novel biomarker and drug target in the diagnosis and treatment of CRC."

Med Sci Monit. 2019; 25: 888–892. PMCID: PMC6366299
Published online 2019 Jan 31. doi: 10.12659/MSM.912320 PMID: 30739906

Myosin Heavy Chain 9: Oncogene or Tumor Suppressor Gene?

Yunmei Wang,[1,B,C,D,E,F] Shuguang Liu,[2,B,C,D,E,F] Yanjun Zhang,[1,A,G] and Jin Yang[3,A,G]

▸ Author information ▸ Article notes ▸ Copyright and License information Disclaimer

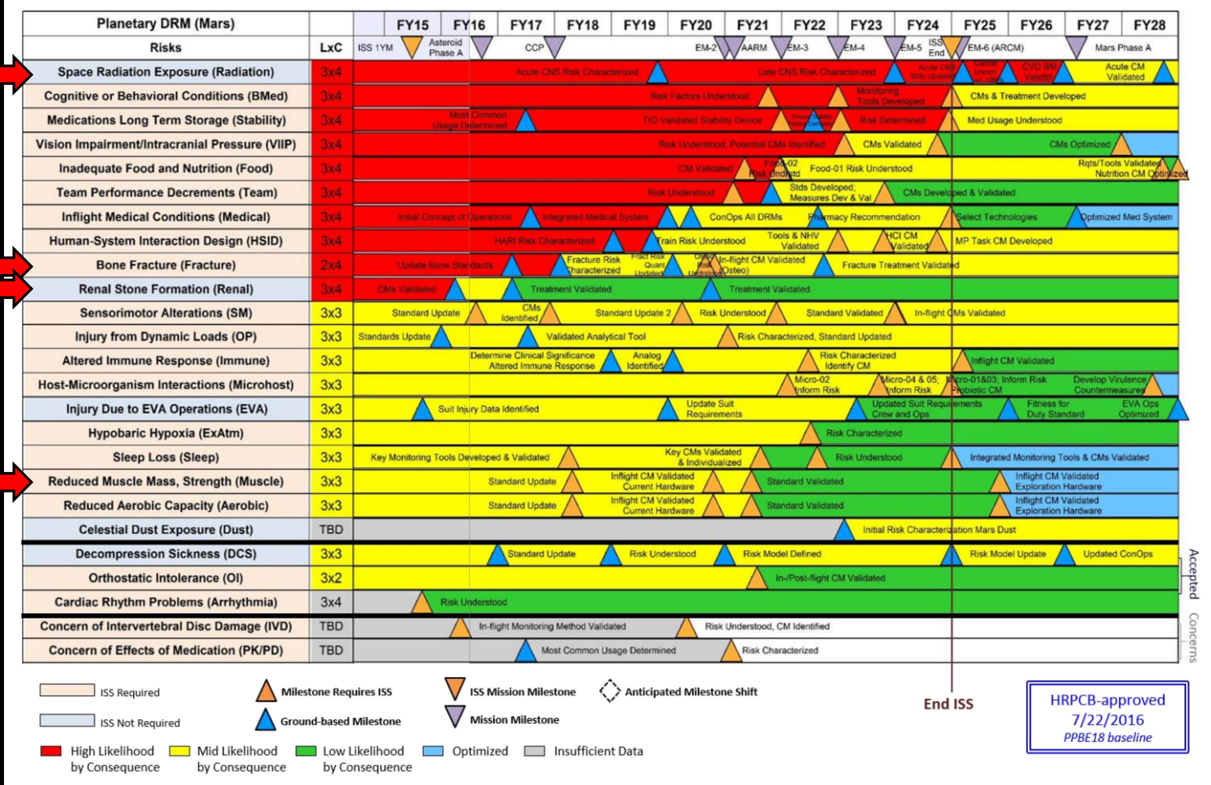
"Endogenous overexpression of MYH9 enhanced the ability of cell proliferation and migration *in vitro*, and accelerated CRC growth in mouse models."

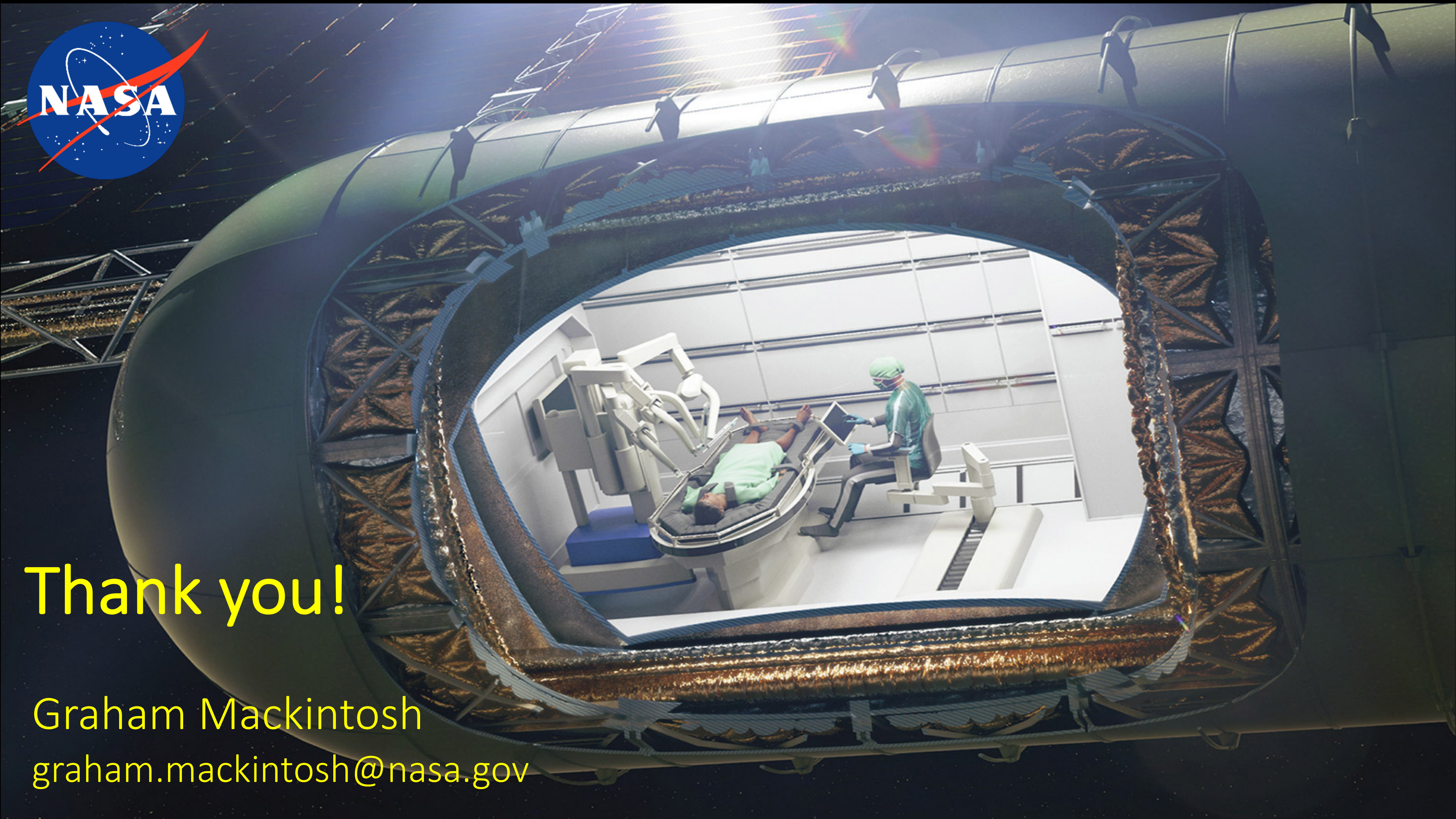
AI & Astronaut Health – Cancer Causal Inference

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





Thank you!

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