

Protecting and Predicting Astronaut Health and Performance

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Baylor
College of
Medicine®



NSBRI Mission:

**To lead biomedical research to support
long-term human exploration of space
And improve life on Earth**

Via a Cooperative Agreement with NASA
(NCC 9-58)

We Fund R&D through Grants

**Approach: Support Technologies and
Countermeasures for Space while also
making an impact on Earth**

NASA Human Research Program Integrated Path to Risk Reduction, Rev D



Planetary DRM (Mars)			FY15	FY16	FY17	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28	
		LxC	ISS 1YM	Asteroid Phase A	CCP			EM-2	AARM	EM-3	EM-4	EM-5	ISS End	EM-6 (ARCM)		Mars Phase A	
Space Radiation Exposure (Radiation)	3x4		Acute CNS Risk Characterized					Late CNS Risk Characterized				Acute CNS Side Updates	Control Model Updates	CVD BM Validated		Acute CM Validated	
Cognitive or Behavioral Conditions (BMed)	3x4						Risk Factors Understood				Monitoring Tools Developed		CMs & Treatment Developed				
Medications Long Term Storage (Stability)	3x4		Most Common Usage Determined				T1D Validated Stability Device			Small Animal Studies Completed		Risk Determined		Med Usage Understood			
Vision Impairment/Intracranial Pressure (VIIP)	3x4						Risk Understood, Potential CMs Identified				CMs Validated			CMs Optimized			
Inadequate Food and Nutrition (Food)	3x4						CM Validated		Food-02 Risk Understood		Food-01 Risk Understood					Rpts/Tools Validated	Nutrition CM Optimized
Team Performance Decrements (Team)	3x4						Risk Understood			Sids Developed, Measures Dev & Val		CMs Developed & Validated					
Inflight Medical Conditions (Medical)	3x4		Initial Concept of Operations			Integrated Medical System			ConOps AI DRMs		Pharmacy Recommendation		Selected Technologies			Optimized Med System	
Human-System Interaction Design (HSID)	3x4			HARI Risk Characterized			Train Risk Understood			Tools & NHV Validated		HCI CM Validated		MP Task CM Developed			
Bone Fracture (Fracture)	2x4		Update Bone Standards			Fracture Risk Characterized	Final Risk Review Updates		CMs Validated		In-flight CM Validated (Osteo)		Fracture Treatment Validated				
Renal Stone Formation (Renal)	3x4		CMs Validated			Treatment Validated					Treatment Validated						
Sensorimotor Alterations (SM)	3x3		Standard Update		CMs Identified		Standard Update 2		Risk Understood		Standard Validated		In-flight CMs Validated				
Injury from Dynamic Loads (OP)	3x3		Standards Update			Validated Analytical Tool				Risk Characterized, Standard Updated							
Altered Immune Response (Immune)	3x3			Determine Clinical Significance Altered Immune Response			Analog Identified				Risk Characterized, Identify CM		Inflight CM Validated				
Host-Microorganism Interactions (Microhost)	3x3									Micro-02 Inform Risk		Micro-04 & 05; Inform Risk		Micro-04/03; Inform Risk		Develop Virulence Countermeasures	
Injury Due to EVA Operations (EVA)	3x3			Suit Injury Data Identified				Update Suit Requirements				Updated Suit Requirements Crew and Ops		Fitness for Duty Standard		EVA Ops Optimized	
Hypobaric Hypoxia (ExAtm)	3x3									Risk Characterized							
Sleep Loss (Sleep)	3x3		Key Monitoring Tools Developed & Validated					Key CMs Validated & Individualized			Risk Understood		Integrated Monitoring Tools & CMs Validated				
Reduced Muscle Mass, Strength (Muscle)	3x3			Standard Update			Inflight CM Validated Current Hardware			Standard Validated				Inflight CM Validated Exploration Hardware			
Reduced Aerobic Capacity (Aerobic)	3x3			Standard Update			Inflight CM Validated Current Hardware			Standard Validated				Inflight CM Validated Exploration Hardware			
Celestial Dust Exposure (Dust)	TBD										Initial Risk Characterization Mars Dust						
Decompression Sickness (DCS)	3x3			Standard Update			Risk Understood		Risk Model Defined				Risk Model Update		Updated ConOps		
Orthostatic Intolerance (OI)	3x2								In/Post flight CM Validated								
Cardiac Rhythm Problems (Arrhythmia)	3x4			Risk Understood													
Concern of Intervertebral Disc Damage (IVD)	TBD			In-flight Monitoring Method Validated				Risk Understood, CM Identified									
Concern of Effects of Medication (PK/PD)	TBD			Most Common Usage Determined				Risk Characterized									

ISS Required
 ▲ Milestone Requires ISS
 ▼ ISS Mission Milestone
 Anticipated Milestone Shift
 ISS Not Required
▲ Ground-based Milestone
▼ Mission Milestone
 High Likelihood by Consequence
 Mid Likelihood by Consequence
 Low Likelihood by Consequence
 Optimized
 Insufficient Data

End ISS

HRPCB-approved
7/28/2016
PPBE18 baseline

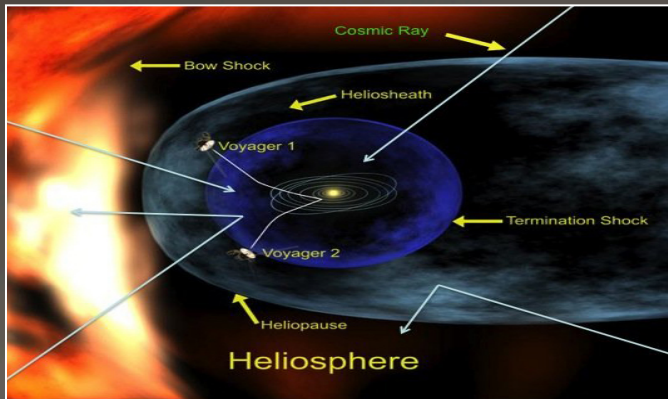
Space Radiation Environment

Galactic cosmic rays (GCR) - penetrating protons and heavy nuclei

Occurs continuously, omni-directional, varying in flux with solar cycle - lower GCR levels occur during solar maximum

Shielding is **NOT** effective due to secondary radiation produced in shielding and tissue

Countermeasure: Biological approaches with a great degree of uncertainties



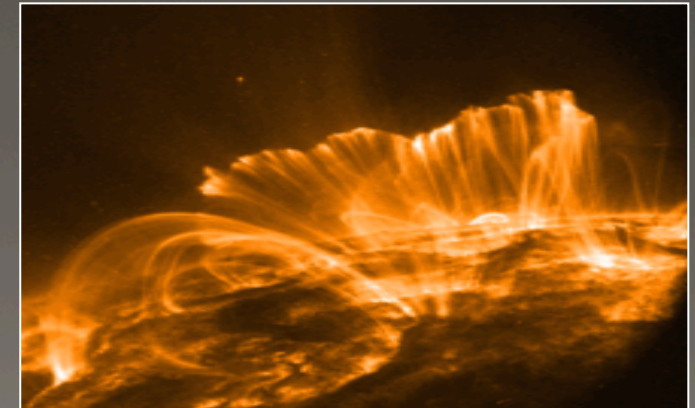
Omni-directional GCR

Solar Particle Events (SPE) - low to medium energy protons

Infrequent events occurring most often during solar cycle maximum (~11-year cycles) - peak activity during solar maximum

Shielding (5-20 g/cm² Al and polyethylene) IS effective, optimization to reduce weight

Countermeasures: Shielding, monitoring, accurate event determination, dosimetry and timely reporting to alert crew to seek shelter are essential for crew safety



Solar Flares - SPEs

NASA Risks of Space Radiation Exposure

Carcinogenesis

Focus of NASA Radiation Risk Model

- Solid Cancers – tumors
- Leukemia
- Issues emerging from research studies of GC solid cancer risks:
 - Possible earlier appearance and aggressive tumors not seen with controls, gamma-rays or proton tumors

Acute Radiation Syndromes

- Prodromal effects (nausea, vomiting, anorexia, and fatigue), skin injury, and depletion of the blood-forming organs



Central Nervous System (CNS) risks to the Brain

Central nervous system (CNS) damage leading to behavioral or cognitive effects and late disorders (Alzheimer's)

Chronic & Degenerative Tissue Risks

- *Circulatory Disease* concerns include CVD, IHD, and coronary revascularization and myocardial infarction
- Digestive diseases

Predict

Prevent

Diagnose

Treat

Predict

Risk Assessment

- *Environment

- *Mission Architecture

 - Time

 - Activities (planned and unplanned)

 - Resources (and lack of)

- *Individual Susceptibilities

Risk Posture Differs with Mission Architecture

Risk of Radiation Carcinogenesis

Short Title: Cancer

Last Published: 09/20/16 02:45:34 PM (Central)

Element: Space Radiation (SR)

Evidence: [Report](#)

Risk Master Logic Diagram: Logic Diagram Not Available

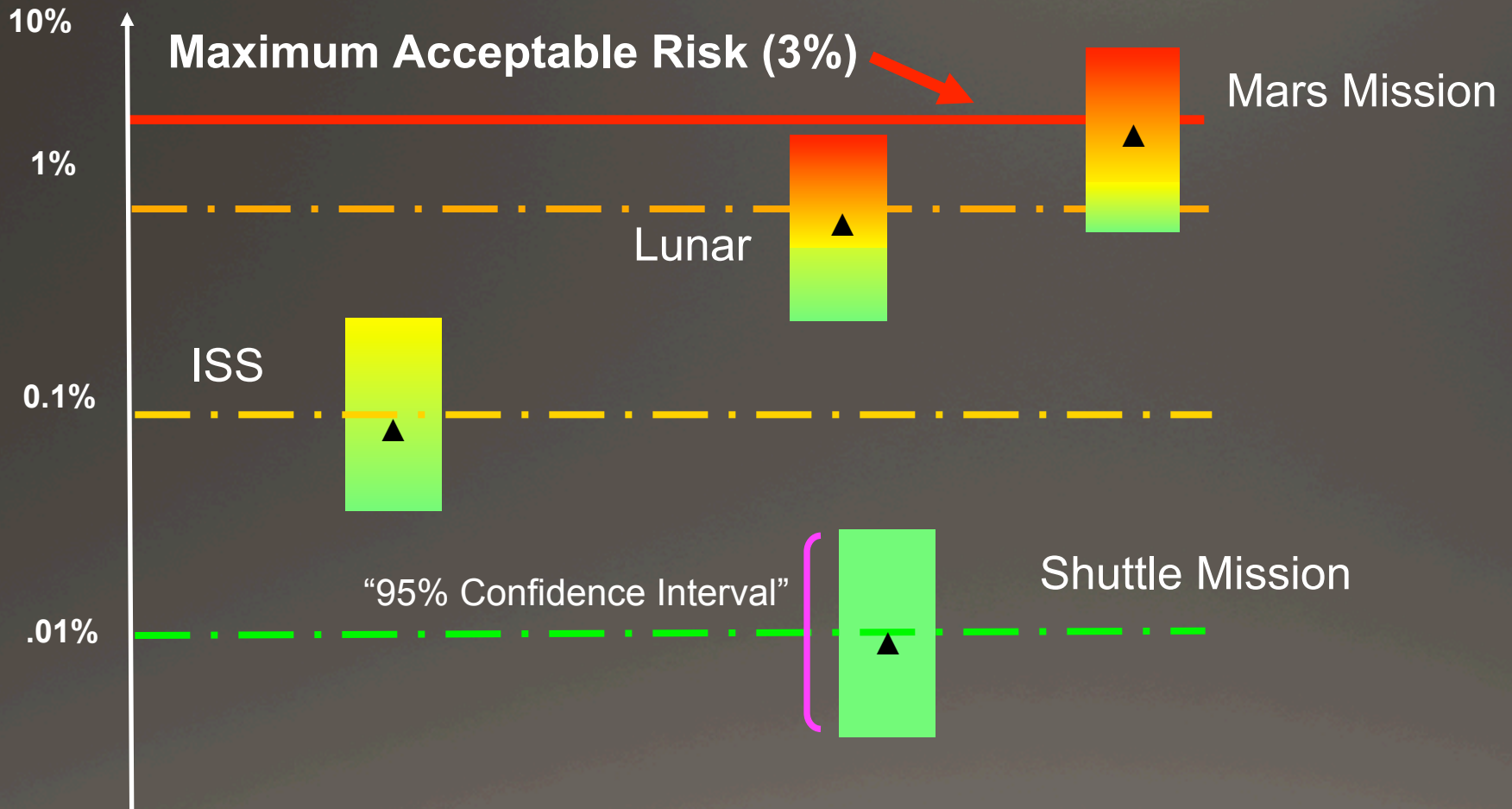
Point of Contact: [Janice Huff](#)

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	3x2	Accepted Within PELs
	1 year	1x1	Accepted	3x2	Accepted Within PELs
Deep Space Sortie	1 month	1x1	Accepted	3x1	Accepted Within PELs
Lunar Visit/ Habitation	6 months	1x1	Accepted	3x3	Requires Mitigation
Deep Space Journey/Habitation	1 year	1x1	Accepted	3x4	Requires Mitigation
Planetary	3 years	1x1	Accepted	3x4	Requires Mitigation

Note: LxC is the likelihood and consequence rating. This risk is mapped to the official (consolidated) HSRB risk "Risk of Adverse Health Outcomes and Performance Decrements resulting from Space Radiation Exposure (Acute, CNS, Deoxy, Cancer)". The HSRB evaluated the LxC and

“ACCEPTABLE” RISK THRESHOLDS



Individual Lifetime
Fatal Risk

Sex Differences: Maximum “Safe” Days in Deep Space

- Solar Min Maximum Days in Deep Space (heavy shielding) to 95% Confidence to be below NASA Limits for cancer risk: (parenthesis is deep solar min of 2009)

a_E, y	NASA 2005	NASA 2012 U.S. Avg. Population	NASA 2012 Never-smokers
Males			
35	158	209 (205)	271 (256)
45	207	232 (227)	308 (291)
55	302	274 (256)	351 (335)
Females			
35	129	106 (95)	187 (180)
45	173	139 (125)	227 (212)
55	259	161 (159)	277 (246)

- Solar Max Maximum Days in Deep Space (heavy shielding) to 95% Confidence to be below NASA Limits for cancer risk alone (parenthesis is for case of ideal storm shelter which negates any SPE cancer risk):

a_E, y	NASA 2012 U.S. Avg. Population	NASA 2012 Never-smokers
Males		
35	306 (357)	395 (458)
45	344 (397)	456 (526)
55	367 (460)	500 (615)
Females		
35	144 (187)	276 (325)
45	187 (232)	319 (394)
55	227 (282)	383 (472)

~ 30 % “Sex”
difference in
terms of days
that can be
spent in deep
space!

Tissue Sensitivities to Radiation

Single Dose (Gy)		Fractionated Dose (Gy)	
Ovary	2–6	Testes	1–2
Bone marrow	2–10	Ovary	6–10
Testes	2–10	Eye (lens)	6–12
Eye (lens)	2–10	Kidney	20–30
Mucosa	5–20	Thyroid	20–40
Gastrointestinal	5–10	Lung	23–28
Lung	7–10	Skin	30–40
Colorectal	10–20	Liver	35–40
Kidney	10–20	Bone marrow	40–50
Vasculoconnective tissue	10–20	Heart	43–50
Liver	15–20	Gastrointestinal	50–55
Skin	15–20	Vasculoconnective tissue	50–60
Peripheral nerve	15–20	Spinal cord	50–60
Spinal cord	15–20	Brain	55–70
Brain	15–25	Peripheral nerve	65–77
Heart	18–20	Mucosa	65–77
Bone and cartilage	>30	Bone and cartilage	>70
Muscle	>70	Muscle	>70

*From Rubin P. Law and order of radiation sensitivity: absolute versus relative. In: Vaeth JM, Meyer JL, eds. Frontiers of radiation therapy and oncology. Basel: Karger; 1989:7–40.

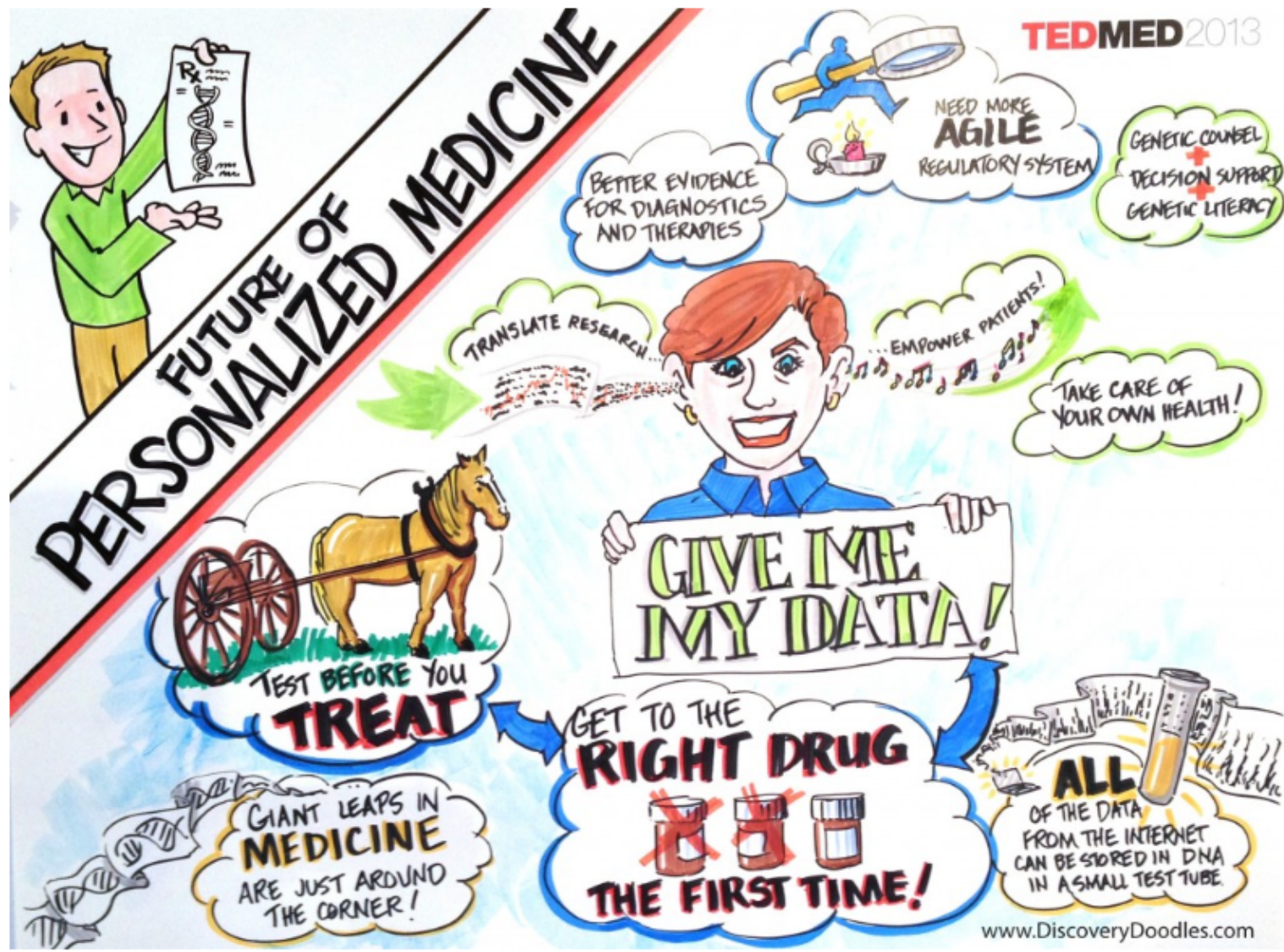
Individual Susceptibilities

- Minimally considered in NASA's risk assessments
- NASA "dipped a toe" into Omics and personalized medicine (Twins Study)
- Critical for radiation risk in particular

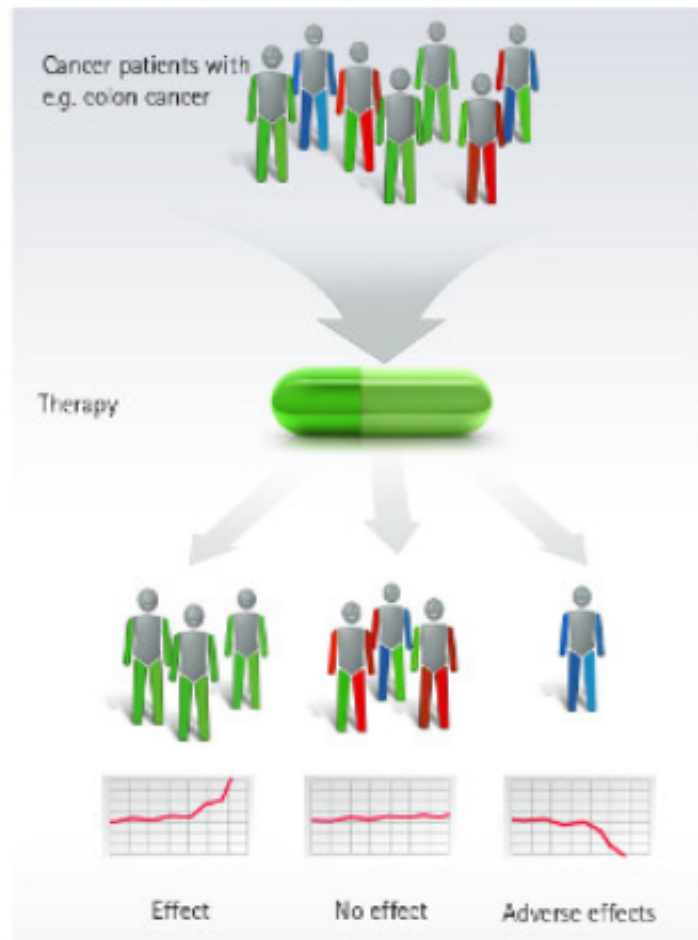


The Dawn of Personalized Medicine

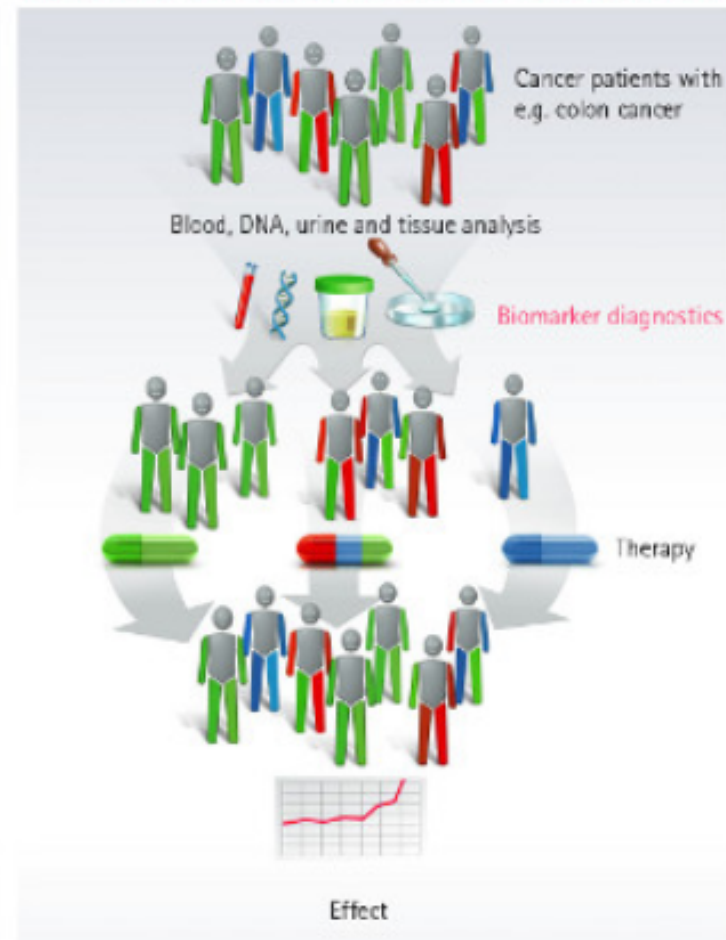
TEDMED 2013



Medicine of the present: one treatment fits all



Medicine of the future: more personalized diagnostics



*Different people respond differently to the same therapy: while one treatment brings about the desired success in one group of patients with e.g. colon cancer, it does not change the condition of other groups at all, or even leads to adverse effects (left). The reason: the genetic makeup and metabolic profile of each individual patient influences the effect of a drug. Personalized medicine takes these individual patterns of cellular and metabolic products into account in the diagnostic phase: **biomarker diagnostics** separates patients into groups with similar characteristics, and provides information on the best individual treatment. This should enable all patients to benefit from their own, "personal" therapy.*

Prognostics & Health Management

Predict

- Radiation Dosimetry
- Space Weather Prediction Models
- Genetic Analysis of Susceptibility

Prevent

- Shielding when possible
- Radiation prophylactics
- Pre-screen for resilience (or at least no known susceptibility – some genetic markers are known to be linked to higher risk of cancer)

Diagnose

- BioDosimetry (“Canary in Mine”) – Biomarkers

Treat – Personalized Medicine

OPPORTUNITIES

Biodosimetry

Biomarkers

Susceptibility markers

Information Fusion

Environmental sensors

Real-Time biological sensors

New NASA Translational Research Institute at Baylor College of Medicine With MIT and CalTech as partners

 JSC Features



 Archives Humans of JSC

NASA establishes institute to explore new ways to protect astronauts

July 20, 2016

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NASA is joining with Baylor College of Medicine in Houston to operate a new institute charged with researching and developing innovative approaches to reduce risks to humans on long-duration exploration missions, including NASA's Journey to Mars.

Work under the Translational Research Institute Cooperative Agreement, overseen by NASA's Human Research Program, begins Oct. 1.

Translational research is an interdisciplinary model of research that focuses on translating fundamental research concepts into practice, with appreciable health outcomes. The NASA Translational Research Institute (NTRI) will implement a "bench-to-spaceflight" model, moving results or methods from laboratory experiments or clinical trials to point-of-care astronaut health and performance applications. The goal of the research is to produce promising new approaches, treatments, countermeasures or technologies that have practical application to spaceflight.

"It's fitting
for our astro
Applications

Baylor
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Medicine



Caltech


Massachusetts
Institute of
Technology

will help reduce risks
ices Research and