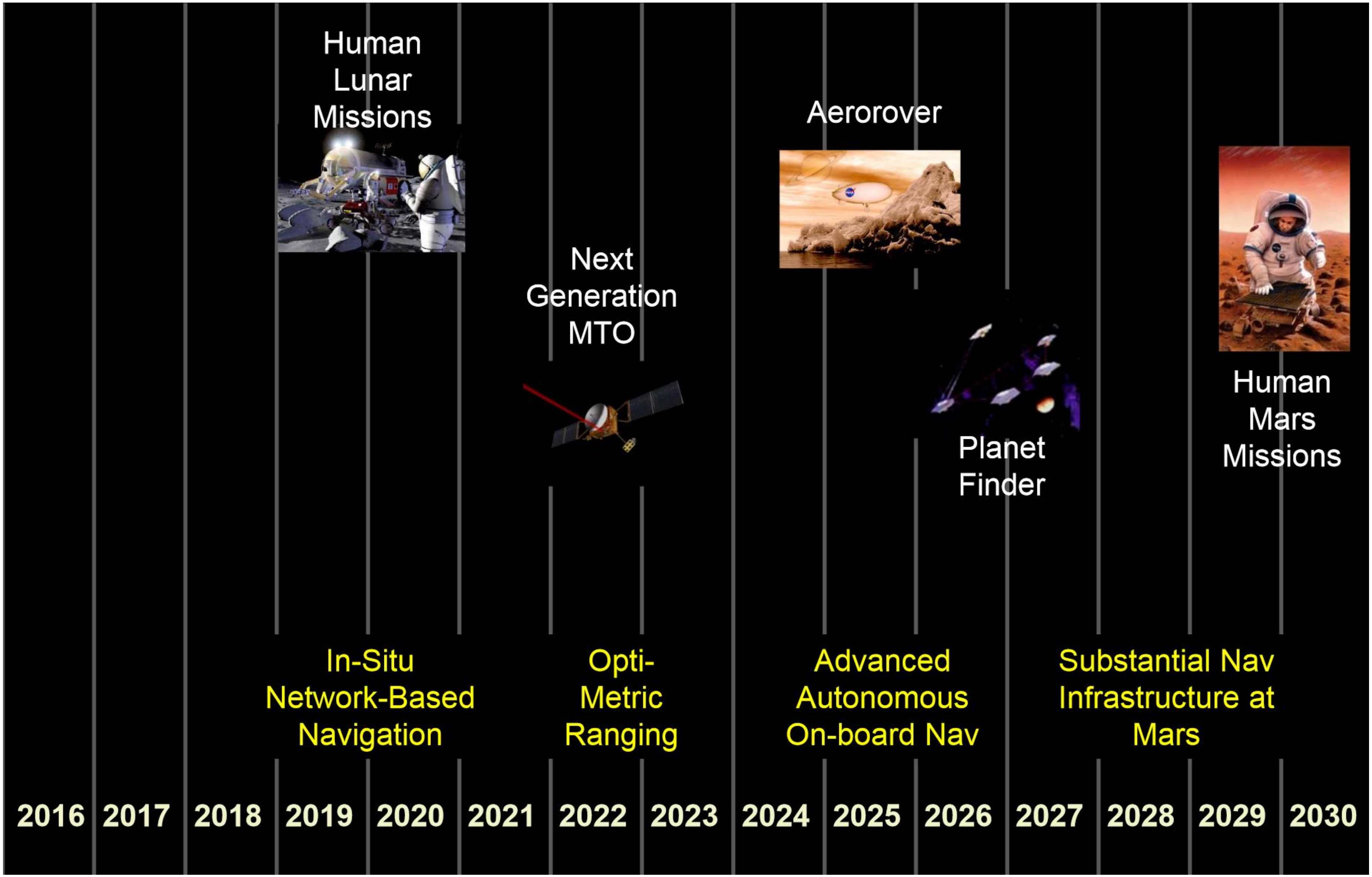
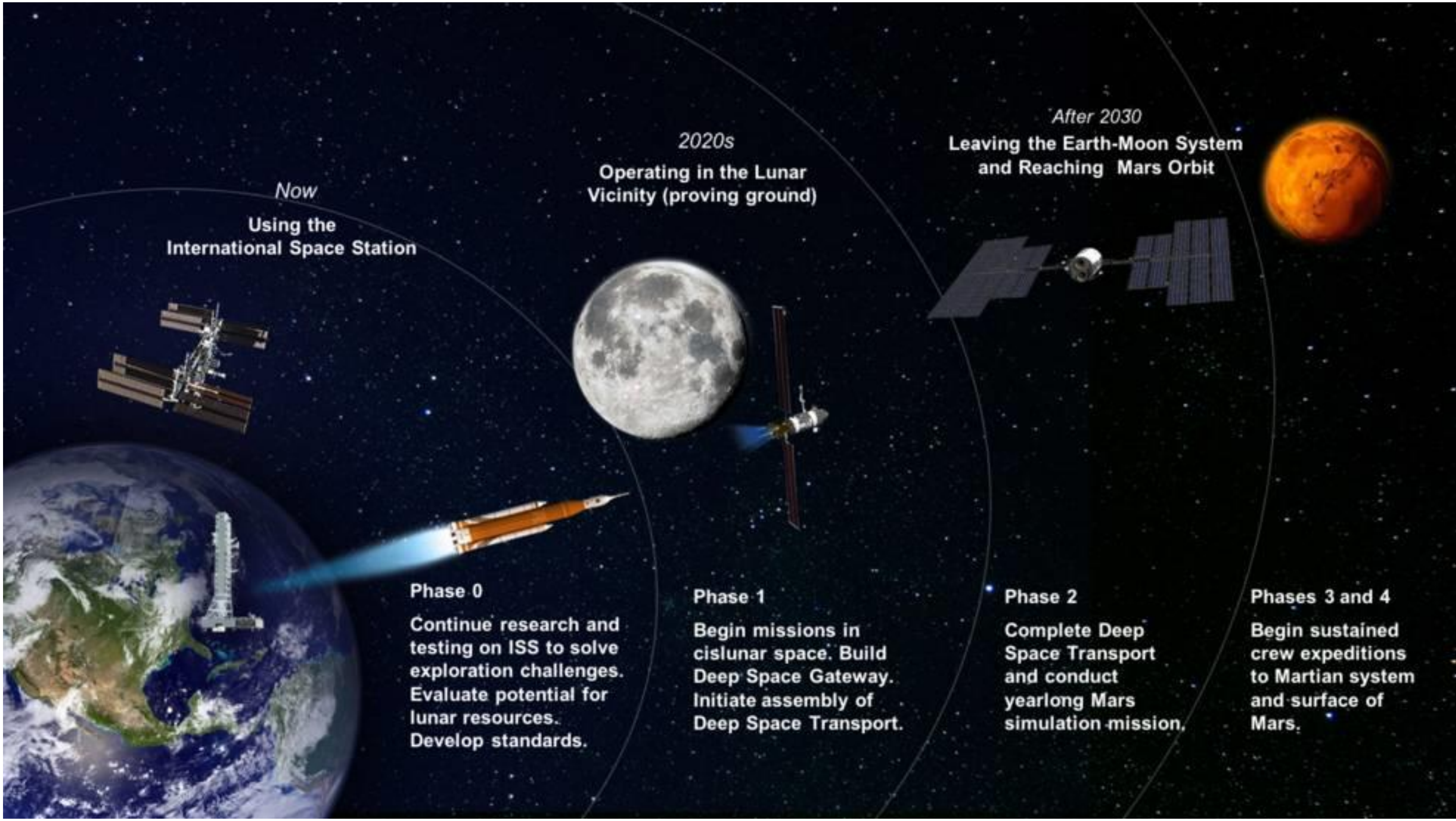
Bio-stasis: a strategy for survivability and payload cost reduction in long-duration space missions

Yuri Griko, Ph.D.
Laboratory of Countermeasures Development,
Life Sciences Division, NASA Ames Research Center

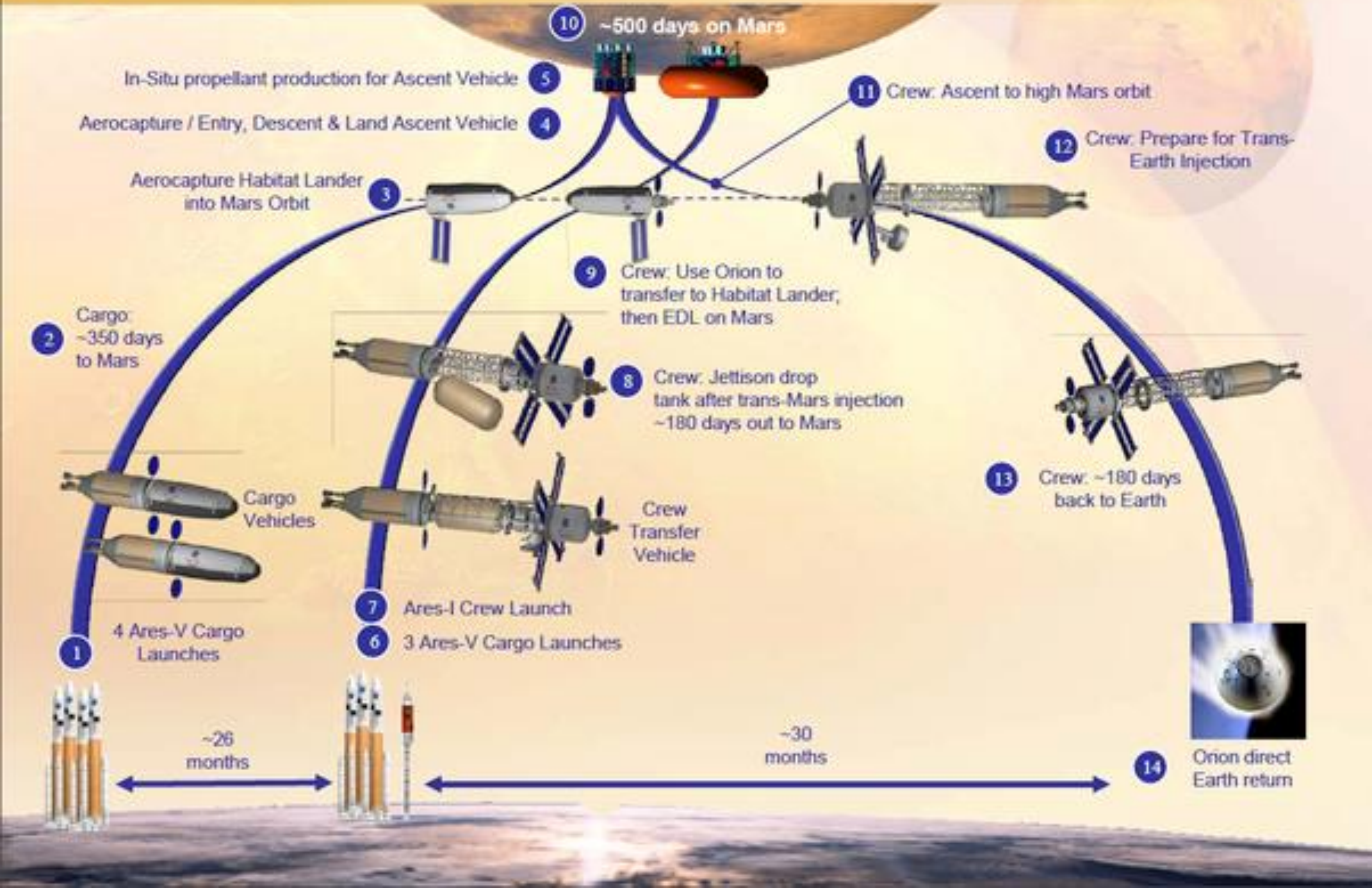
A Timeline of Capabilities



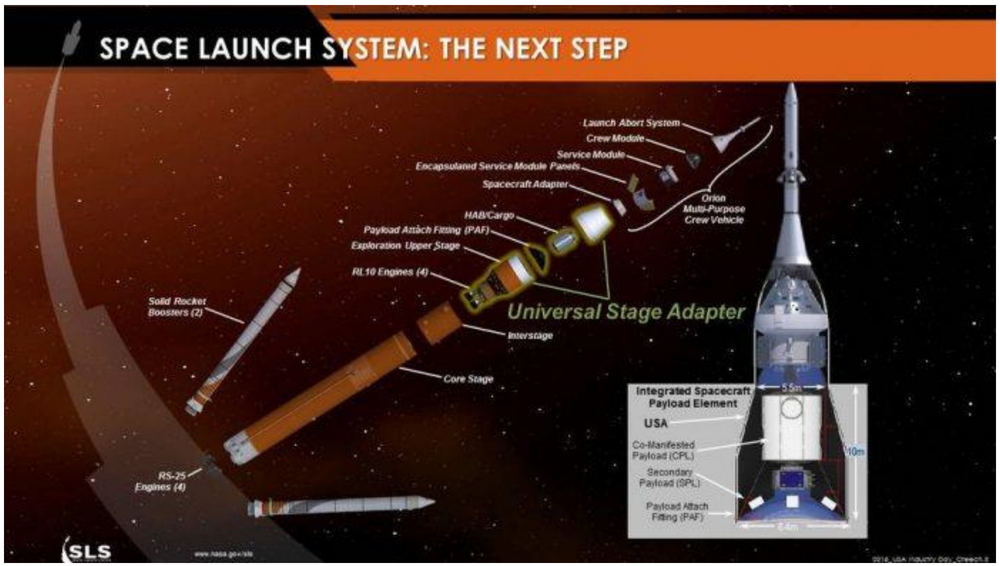
A Timeline of Capabilities (Cont.)

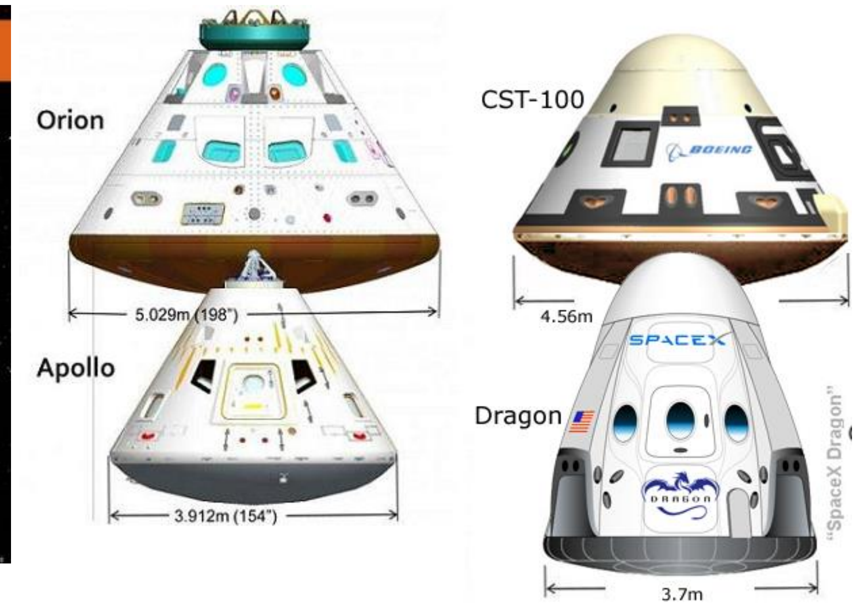


Mars Design Reference Architecture 5.0 Mission Profile
NTR Reference Shown



Mars Mission





Elon Musk's plans may be too ambitions, but NASA plans may be too conservative

Entrepreneur Elon Musk's announcement accelerating plans for manned flights to Mars ratchets up political and public-relations pressure on NASA's efforts to reach the same goal. *Wall Street Journal Oct. 4, 2017*

… The biggest challenging reality is that we, humans, evolutionary adopted to leave under conditions of earth gravity and acceptable level of radiation, cannot adopt to permanently leave in space without significant alteration in our physiology which may make us not humans at the end

Human Physiological Adaptations to Long-Duration Weightlessness in Space Flight

Cardiovascular

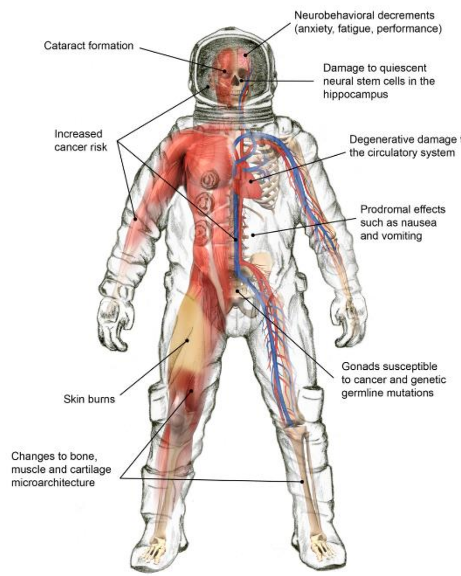
↑ resting heart rate
↑ stroke volume early in flight
↑ PACs & PVCs
↓ fluid volume
↓ orthostatic tolerance
↓ aerobic & anaerobic capacity
↓ resting blood pressure postflight
↓ central venous pressure (indirect)
↓ cardio/thoracic ratio postflight

Sensory-motor

↑ vestibular disturbances
↑ space motion sickness *early in flight*
↓ postural stability
↓ sensorimotor function
↑ intraocular pressure in flight
↑ retinal blood vessel constriction postflight
↓ visual motor task performance
↓ contrast discrimination
↓ visual field postflight

Immunology

↑ viral reactivation & shedding
↓ DTH skin test response
↓ Cell mediated immunity
↓ lymphocyte function
-- unchanged humoral immunity



Muscle & Bone

↓ muscle mass
↓ muscle endurance & strength
↓ bone mineral content
↓ bone integrity

Body Fluids

↑ hemoglobin & hematocrit postflight
↓ total body water
↓ plasma & urine volumes postflight

Electrolytes

↑ urinary Ca, PO_4 postflight
↓ plasma K & Mg postflight
↓ urinary Na, K, Cl, Mg

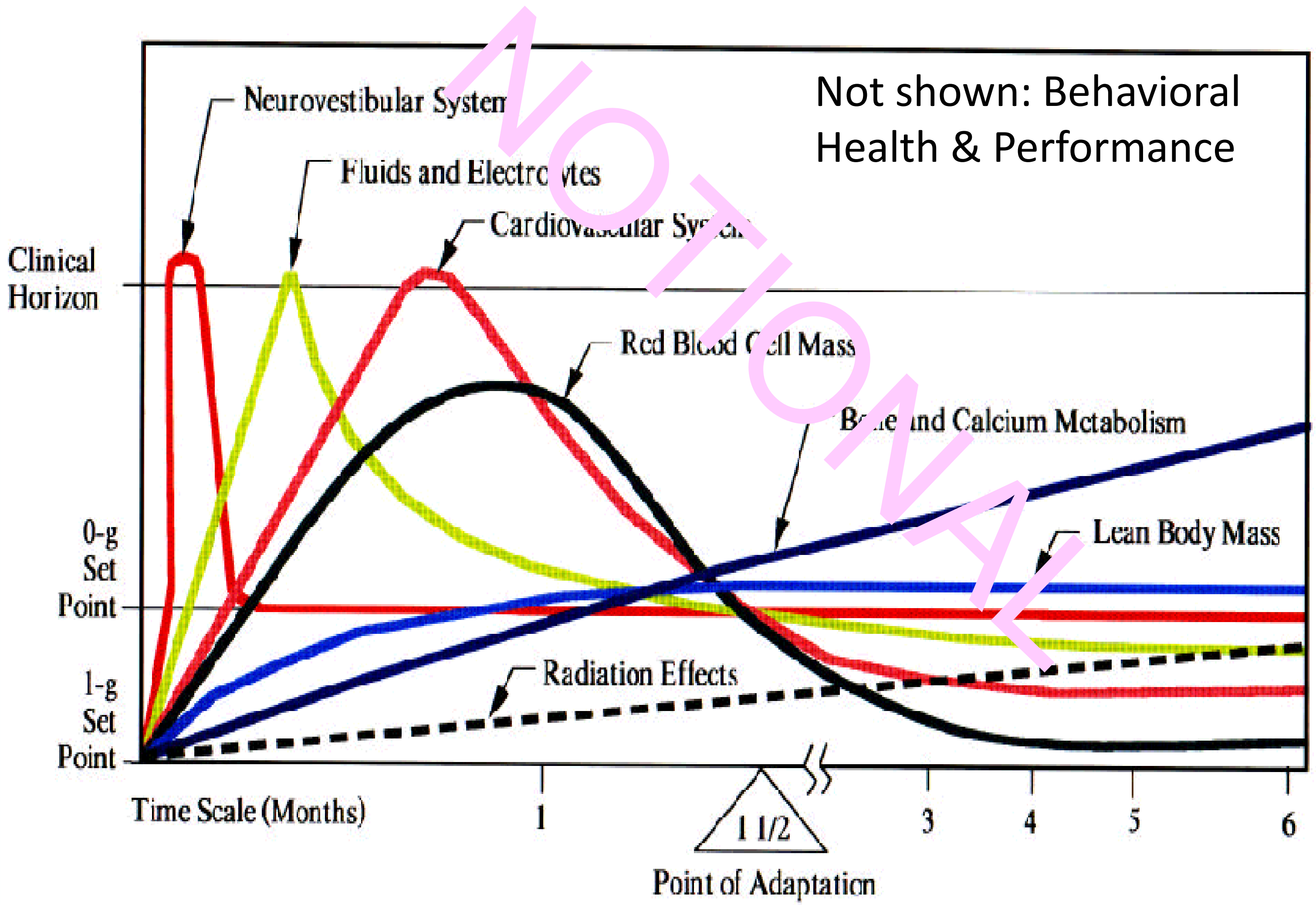
Hormones

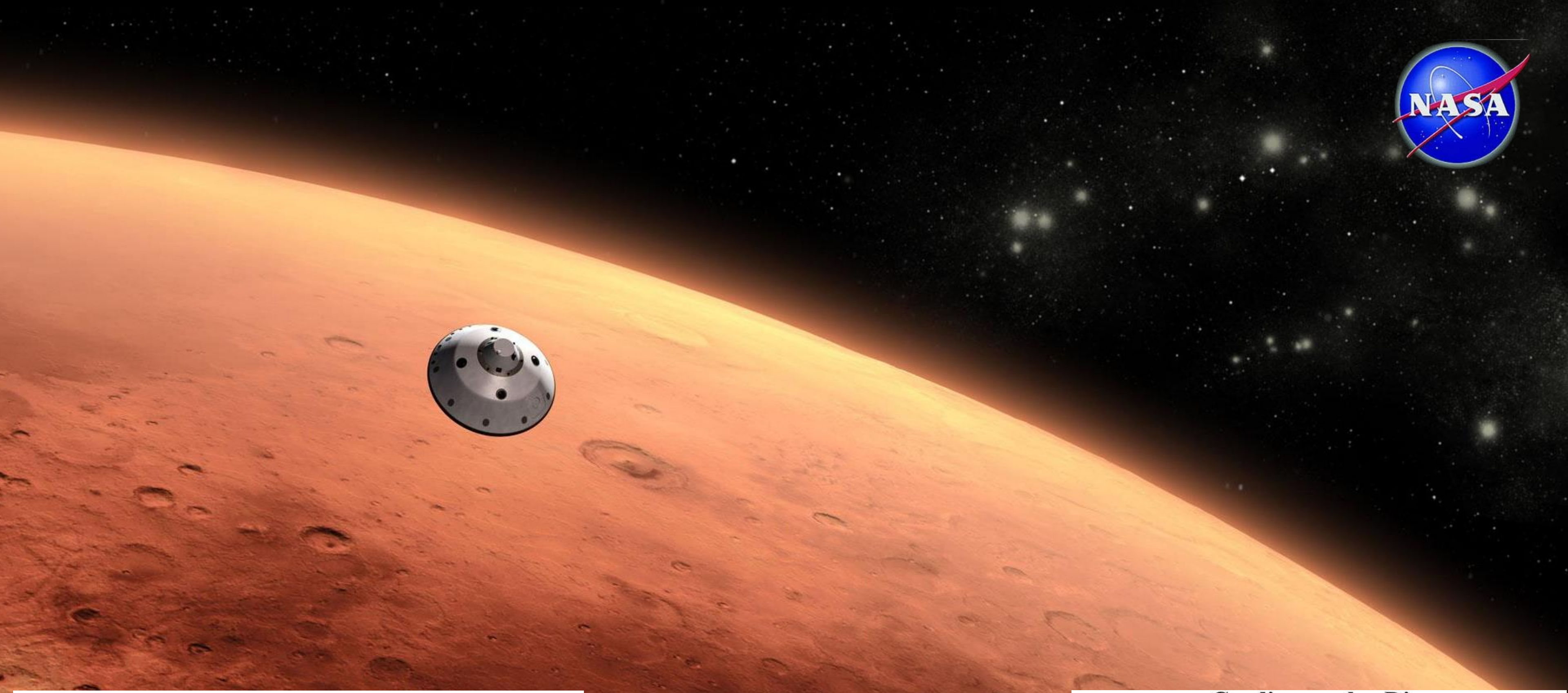
↑ plasma ADH, ANF
↑ urinary aldosterone
↑ urinary ADH, cortisol postflight
↓ urinary epinephrine, androsterone postflight
↓ plasma ACTH, aldosterone, cortisol

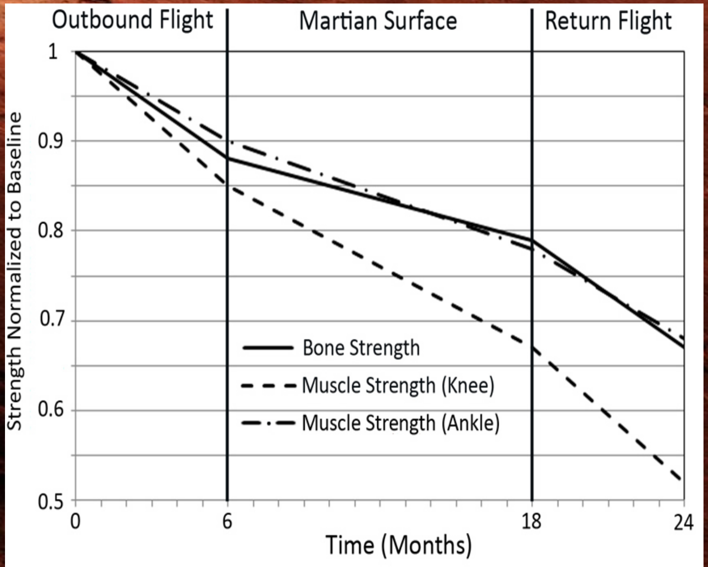
Metabolites

↑ plasma glucose, creatinine, BUN postflight
↓ albumin, cholesterol, triglycerides, uric acid

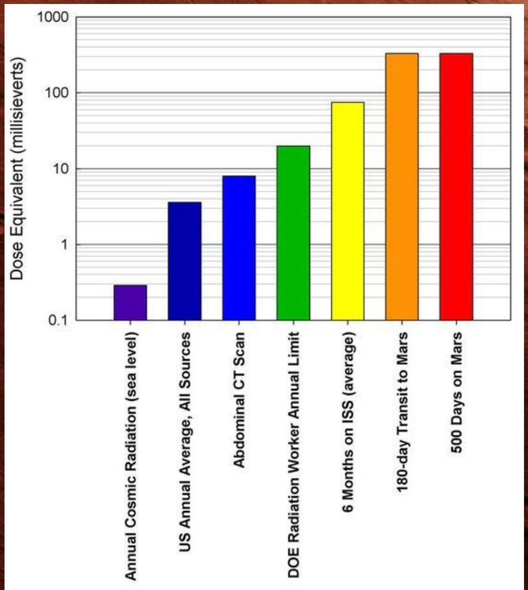
Time course of physiological changes in long-duration weightlessness (notional) based on Skylab data

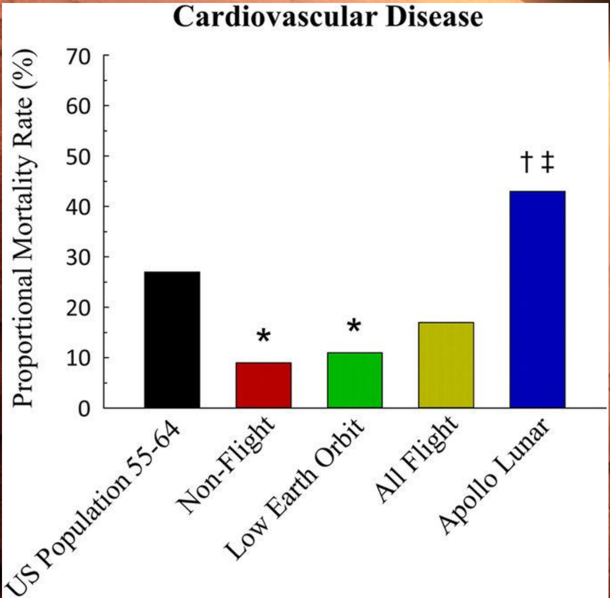






Journal of Cosmology, 2010, Vol 12, 3778-3780





Metabolic Control Technology

for Human Space Exploration to Mars and Beyond

Ultimate Goal

Development of methodology/technology to achieve metabolic control, which allows the metabolism of animals and humans to be reduced to a minimum level for a period of time followed by subsequent restoration

Strategic Value

The possibility of manipulating metabolic mechanism will provide solutions to a broad range of NASA mission requirements and mitigate negative space environment factors on humans, such as radiation and low gravity associated with long-duration space missions.

Potential NASA and Ground-based Applications

NASA	Biomedical	Military
Radiation Protection	Paramedics	Battlefield Medical Response
Reduction of Payload	Cancer Treatment	Radiation Exposure Protection
Medical Emergency Situations	Organ Transplant Patients	Casualty Reduction/ Healing
Psychological Factors	Surgical Procedures	Bio- Chemical Agents Mitigation

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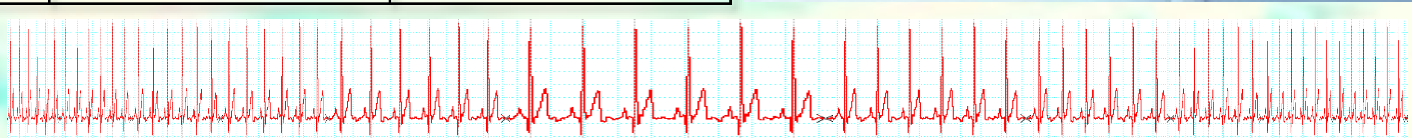


- Extended space flight duration logistics
- Lower payloads (reduce the required life-support resources)
- Eliminate psychological stressors associated with the space environment
- Provide emergency rescue in long-duration missions
- Protection against radiation

Hypometabolic

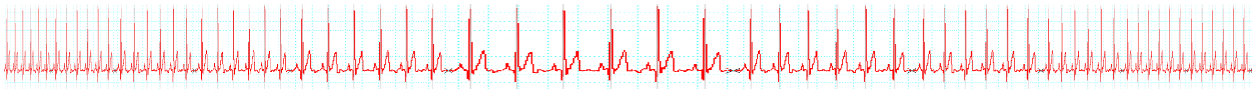
STASIS

for NASA needs

Laboratory of Countermeasures Development,
Life Sciences Division NASA Ames Research Center

The Hypometabolic Stasis

Carnegie Mellon Innovations Lab



"Stasis Technology will enable Human Long-Duration Space Exploration to Mars and Beyond"

Ultimate Goal

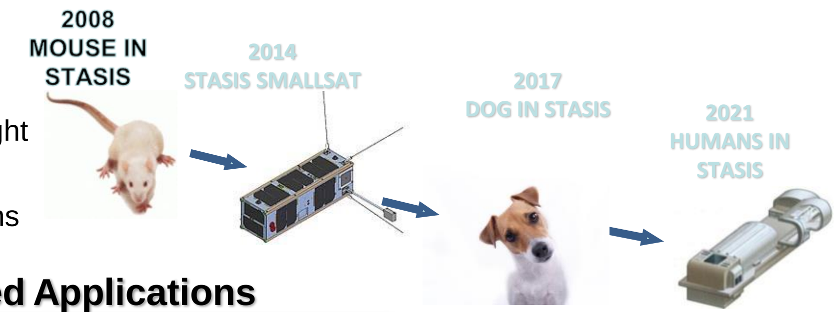
Development of methodology/technology to achieve metabolic control, which allows the metabolism of animals and humans to be reduced to a minimum level for a period of time followed by subsequent restoration to normal levels with no apparent effect.

Strategic Value

The possibility of manipulating metabolic mechanism will provide solutions to a broad range of NASA mission requirements and mitigate negative space environment factors on humans, such as radiation and low gravity associated with long-duration space missions.

Project Milestones

- Reversible stasis in mice
- Demonstration of stasis during space flight
- Induction of stasis in larger animals
- Development of stasis system for humans



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Reduction of Payload	Cancer Treatment	Radiation Exposure Protection
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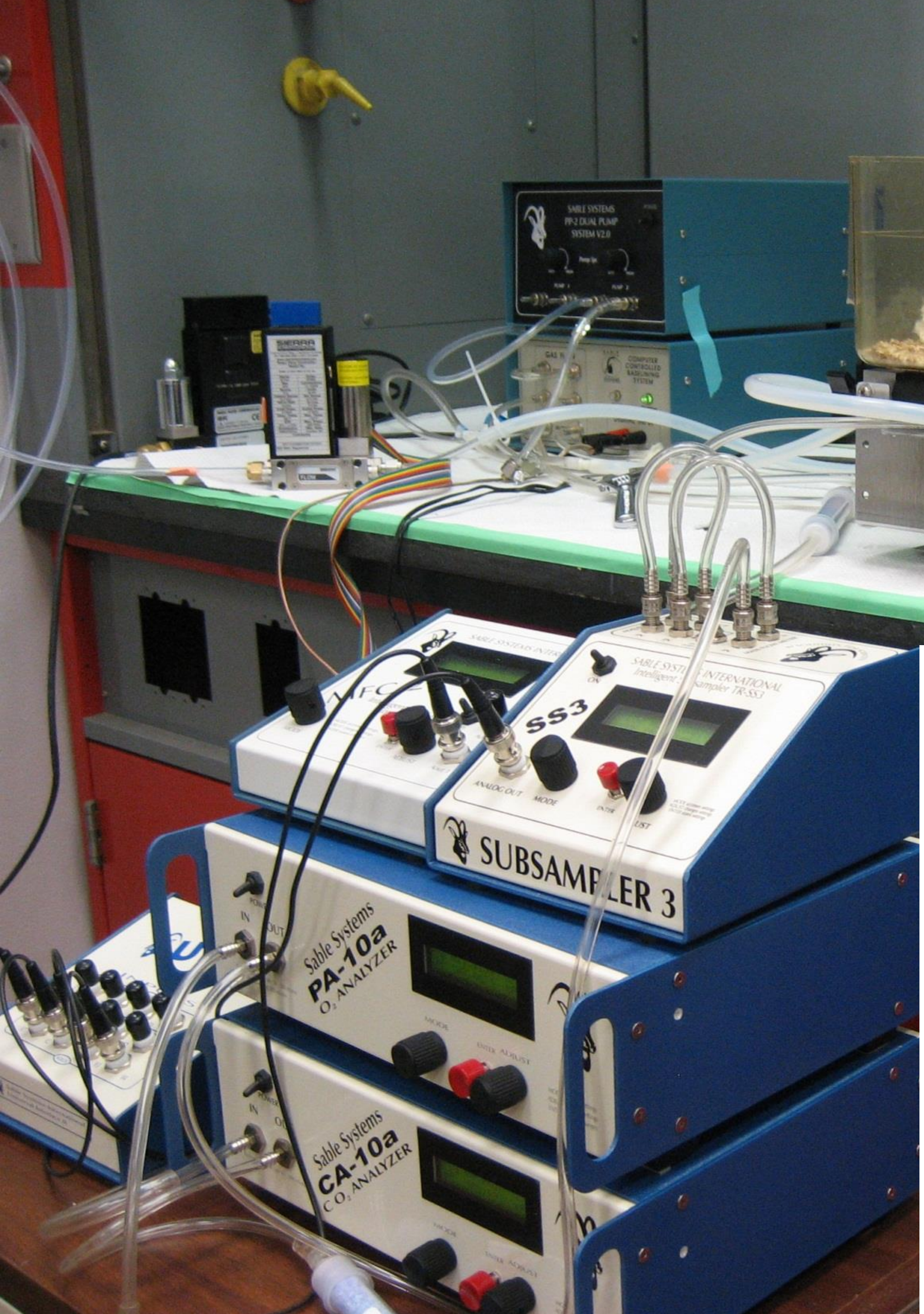
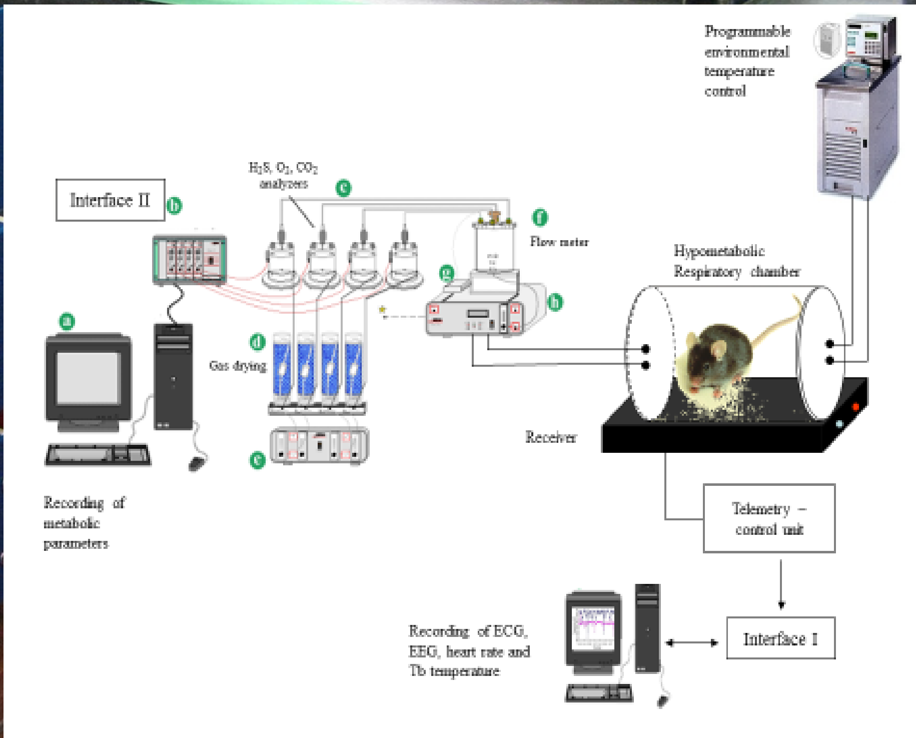
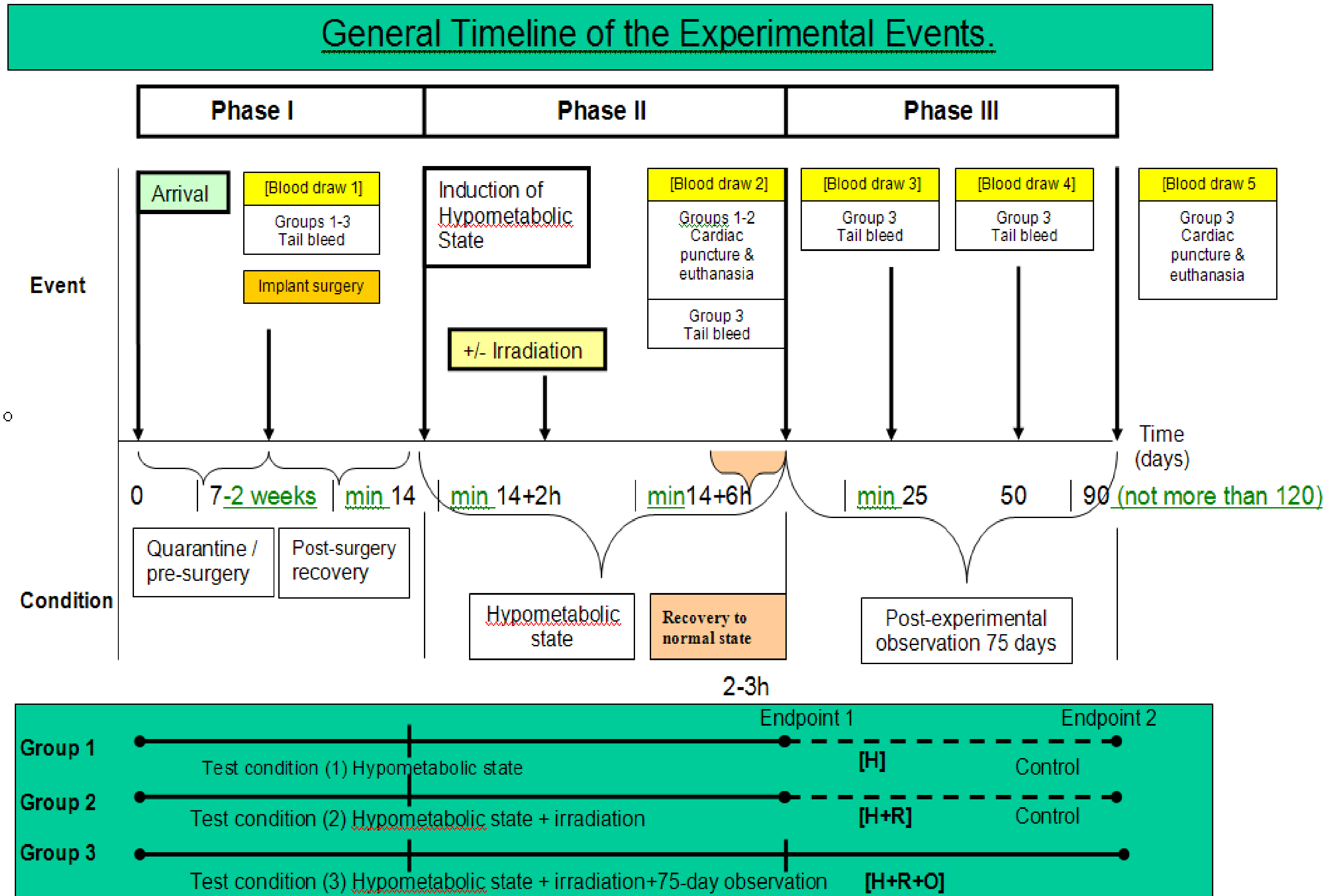
Psychological Factors	Surgical Procedures	Bio- Chemical Agents Mitigation

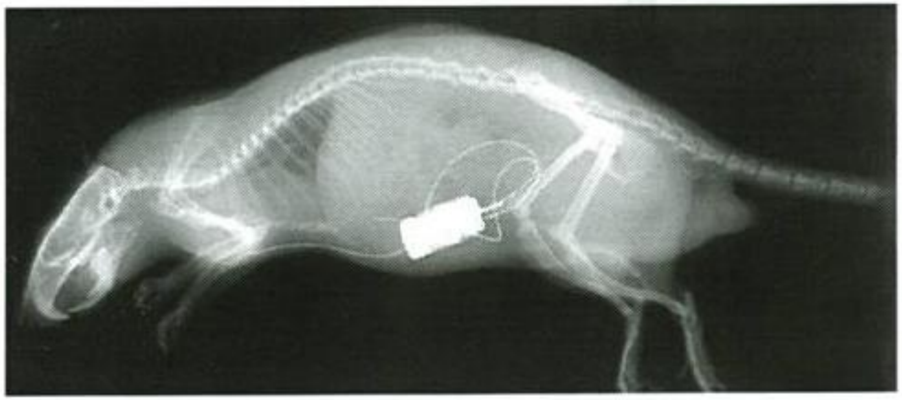

SABLE SYSTEMS
PP-2 DUAL PUMP
SYSTEM V2.0
SS3
SUBSAMPLER 3
ANALOG OUT
MODE
Sable Systems
PA-10a
O_2 ANALYZER
Sable Systems
CA-10a
CO_2 ANALYZER


Programmable
environmental
temperature
control
H_2S, O_2, CO_2
analyzers
Interface II
Flow meter
Hypometabolic
Respiratory chamber
Gas drying
Receiver
Recording of
metabolic
parameters
Telemetry –
control unit
Recording of ECG,
EEG, heart rate and
Tb temperature
Interface I

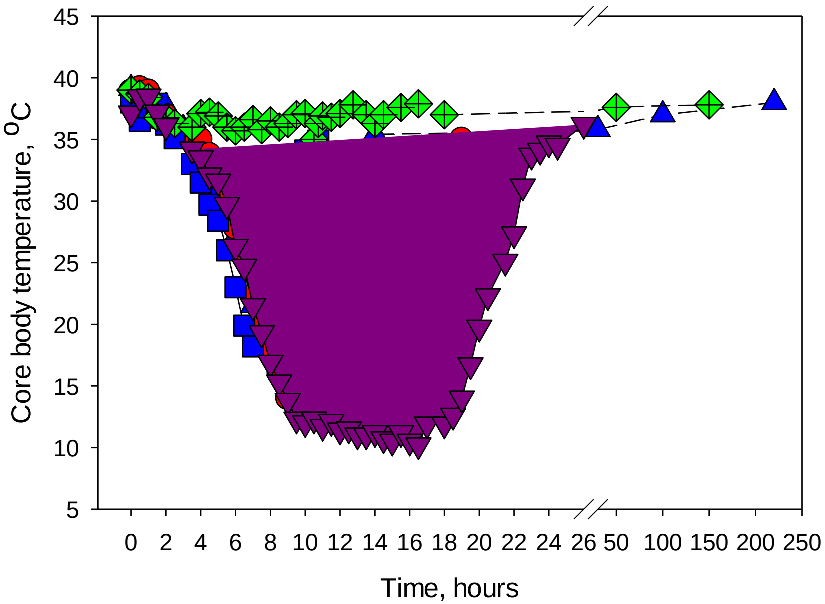
Mice experiments (C57BL/6J)

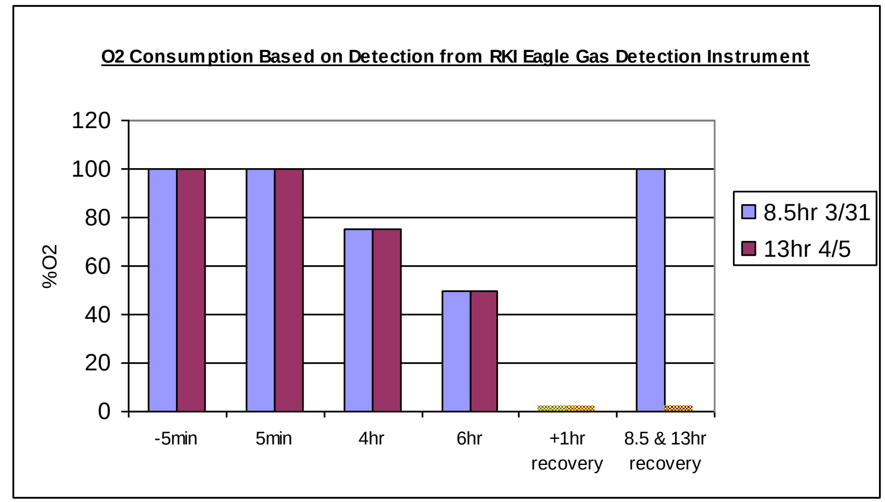


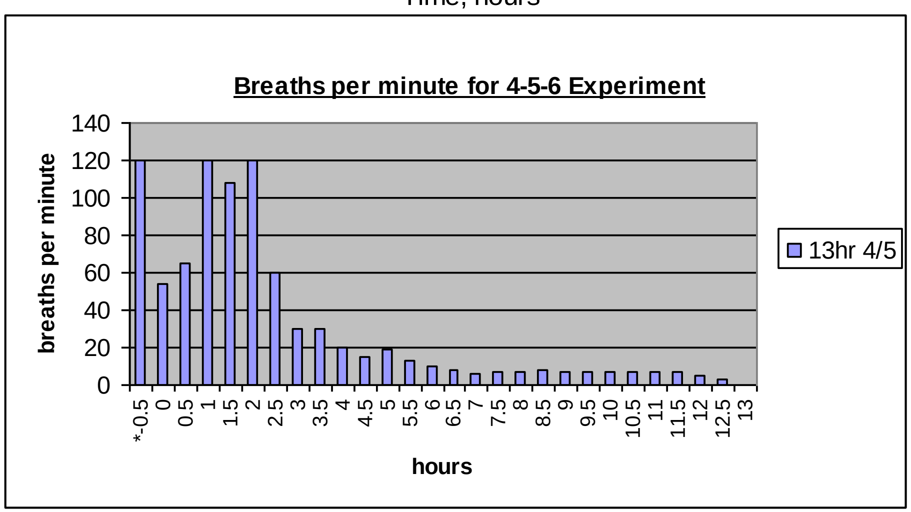
ECG lead II configuration

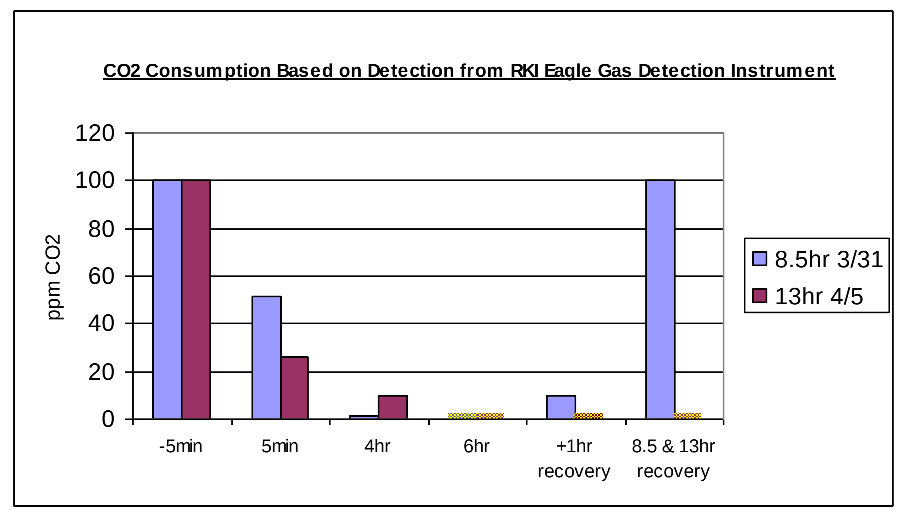


Metabolic parameters

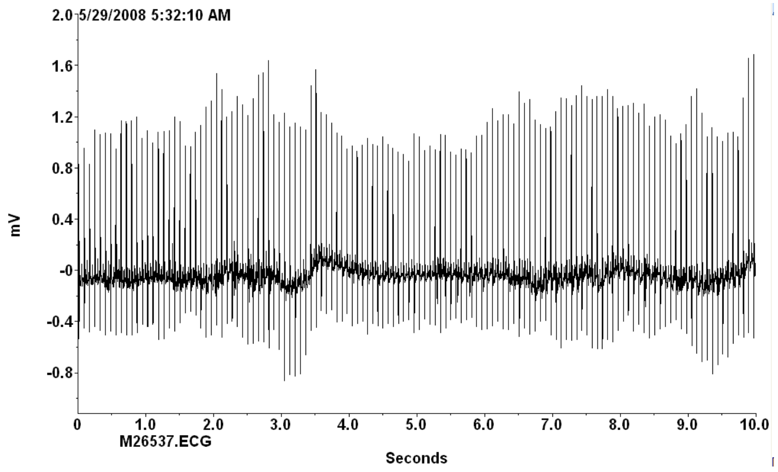


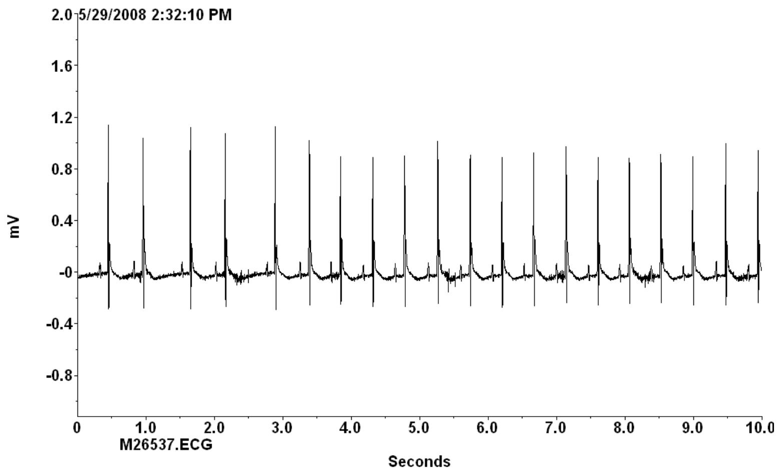


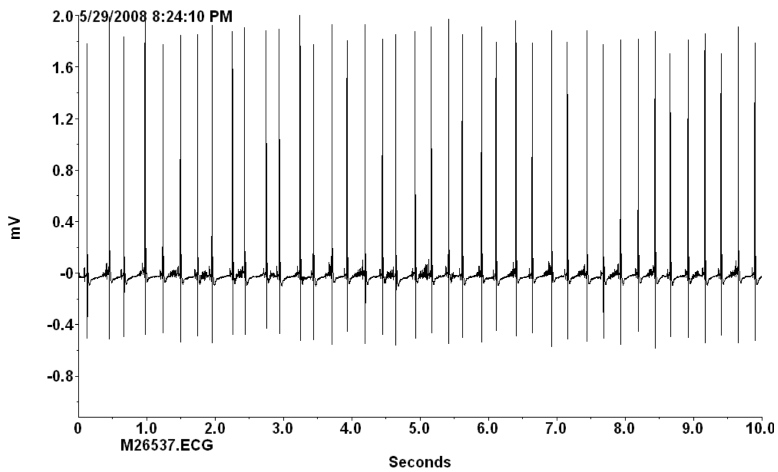


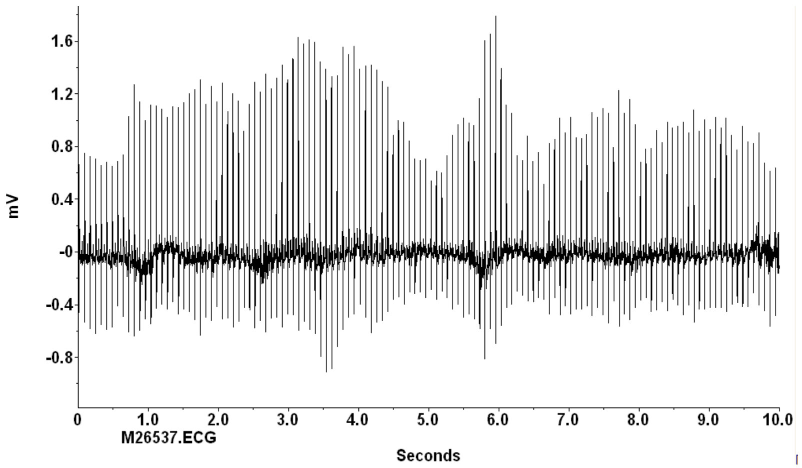


Mice electrocardiographic changes









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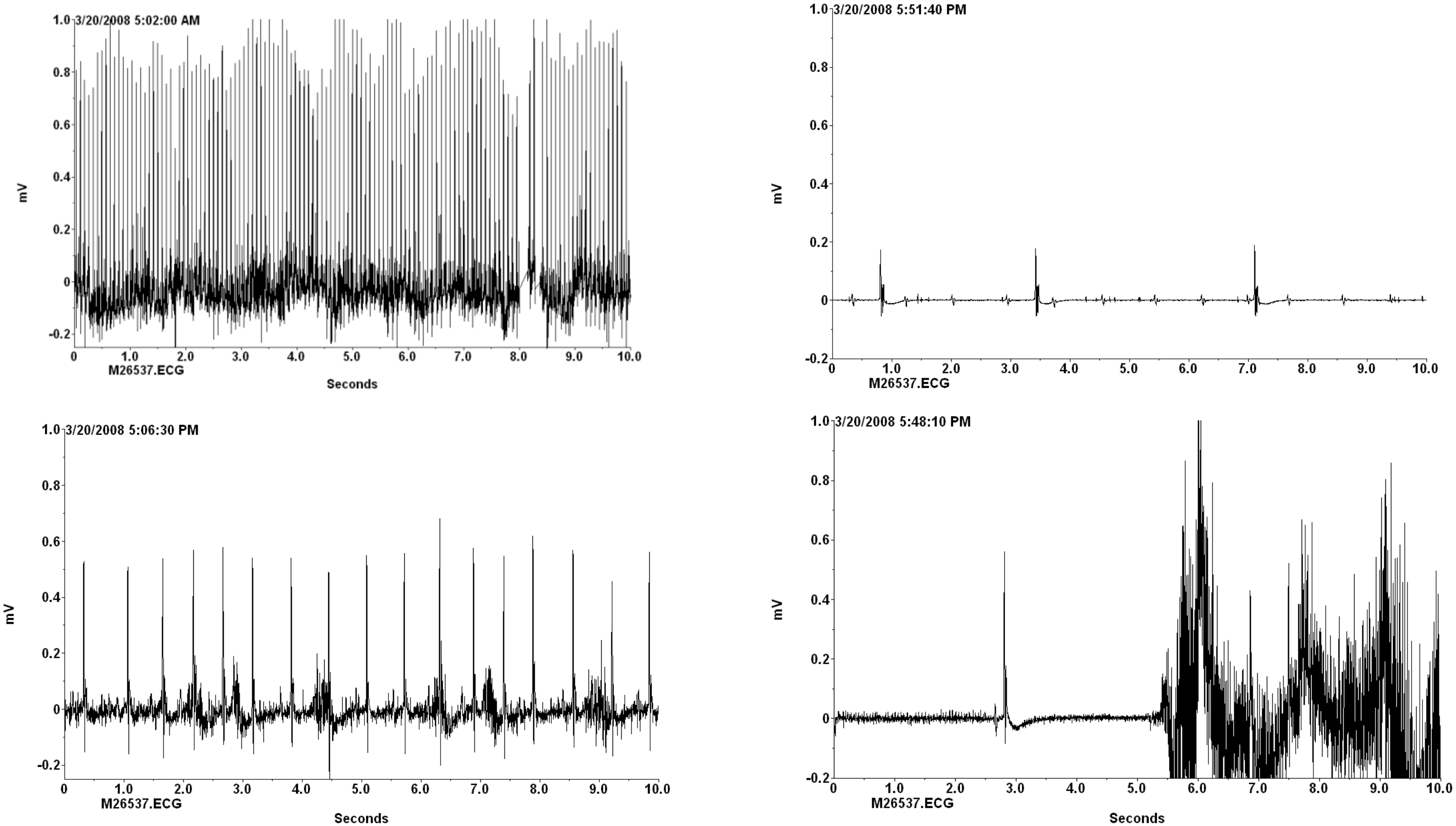
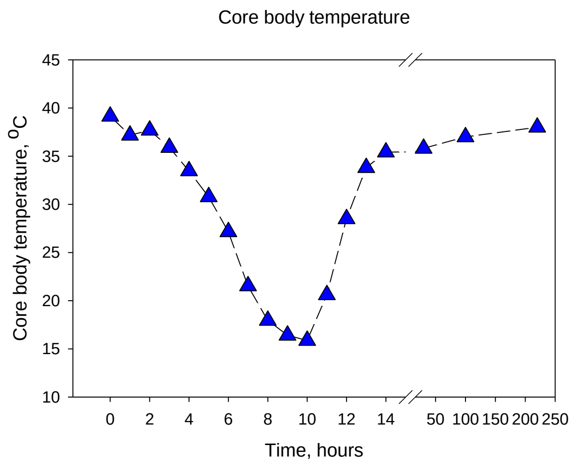
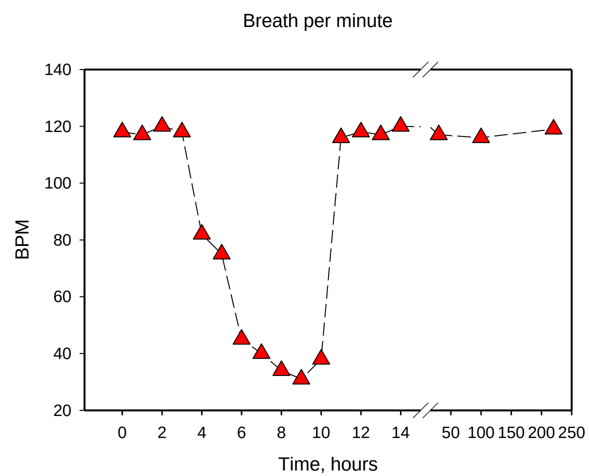
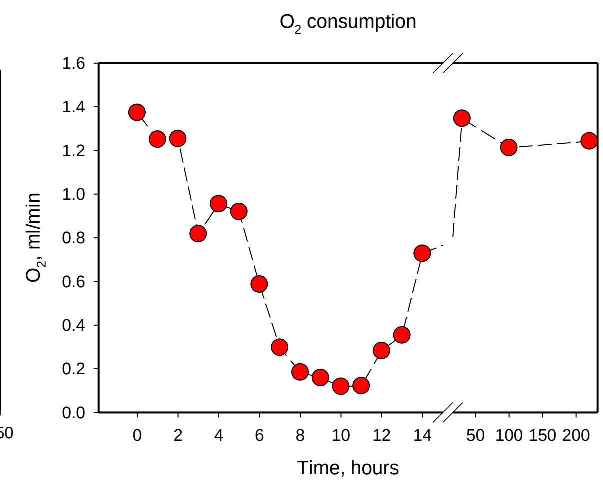
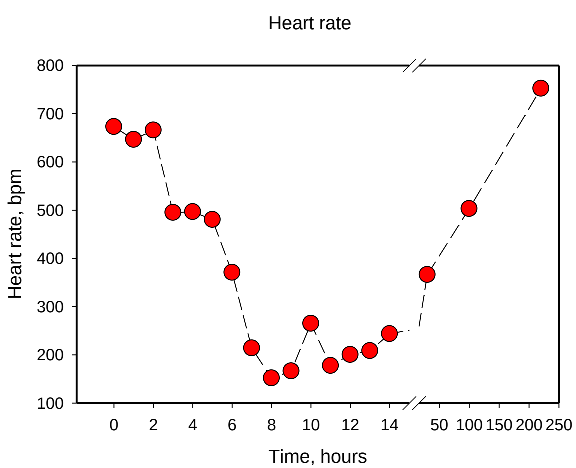


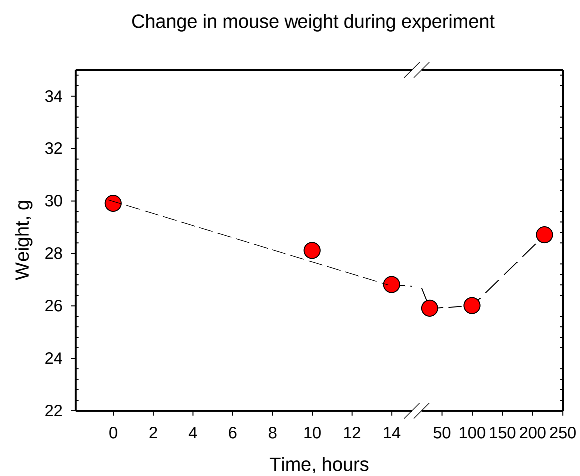
Changes in metabolic parameters

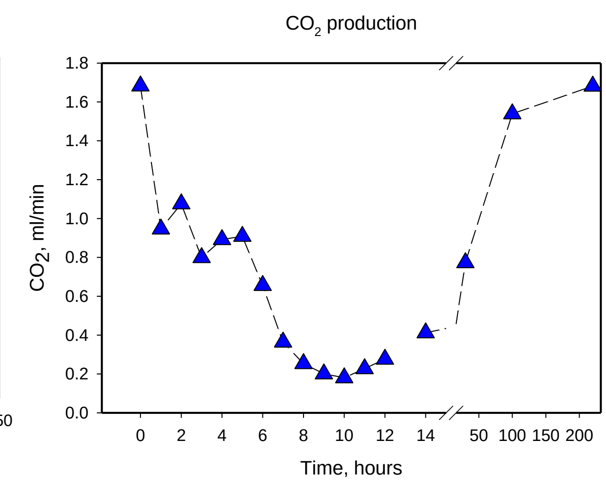






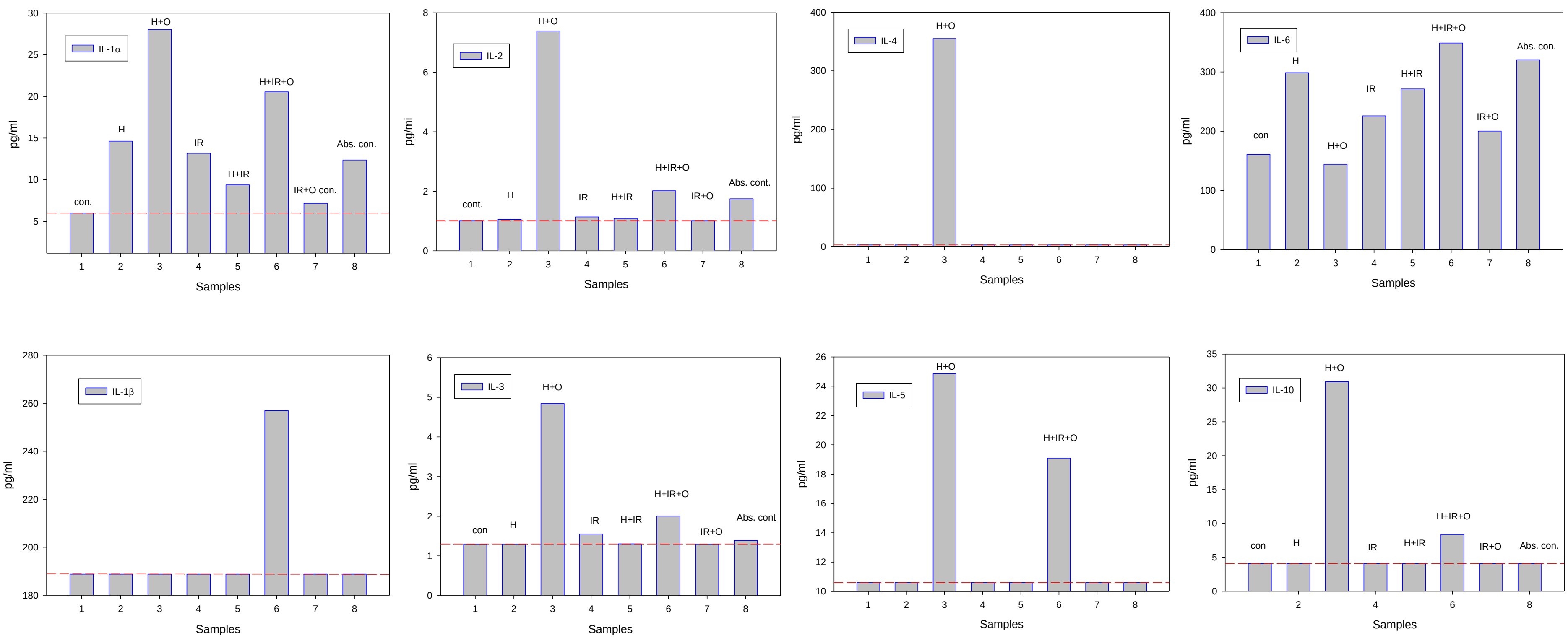




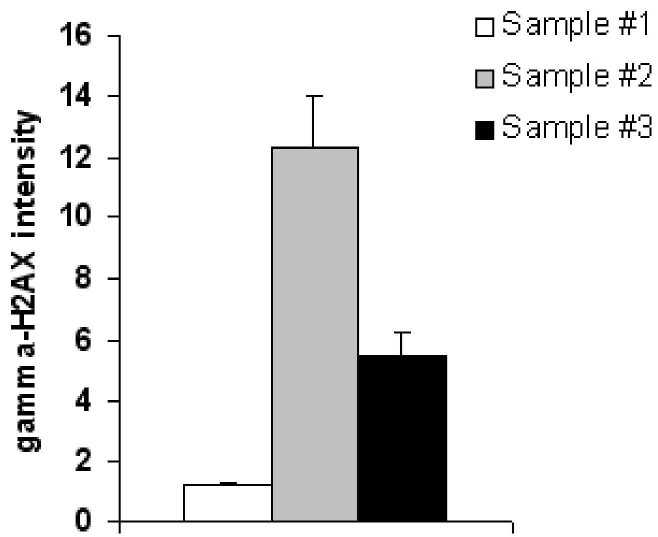


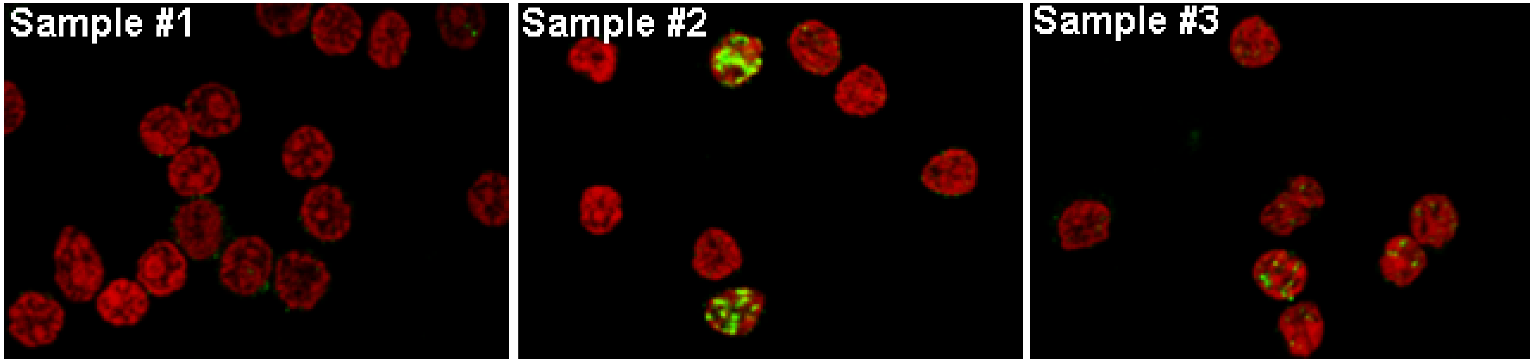

DELL
DELL
SUBSAMPLER 3
PA-10a
CA-10a

Enzyme-linked immunosorbent assay (ELISA) of inflammatory cytokines



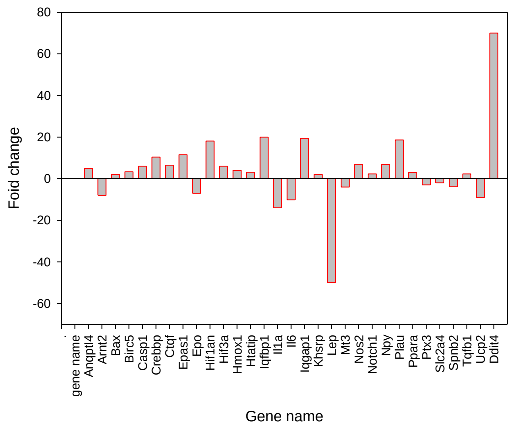
Protection against radiation



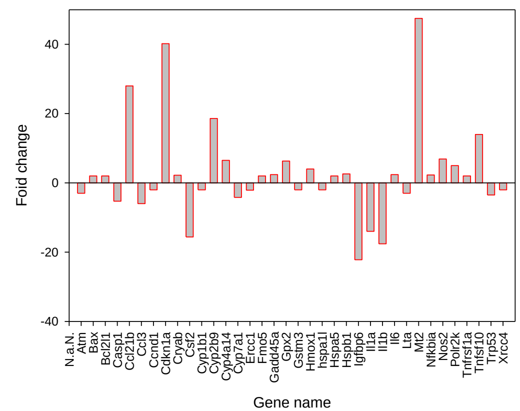


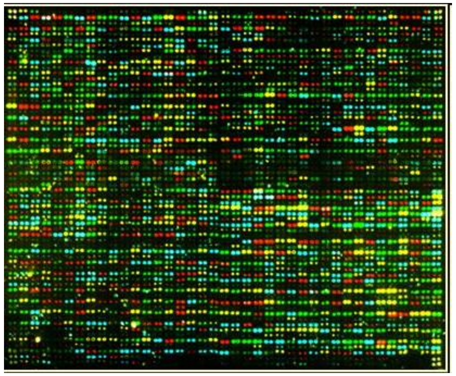
Differential gene expression in hypometabolic mice

Differential expression of the hypoxia pathway -related genes in hypometabolic state of mice vs. normal state

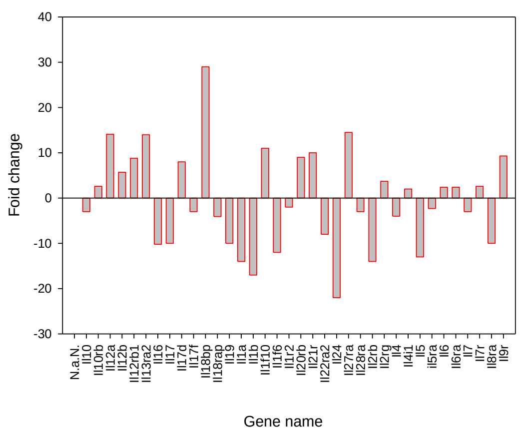


Differential expression of the Stress/Toxicity pathway - related genes in hypometabolic state of mice vs. normal state

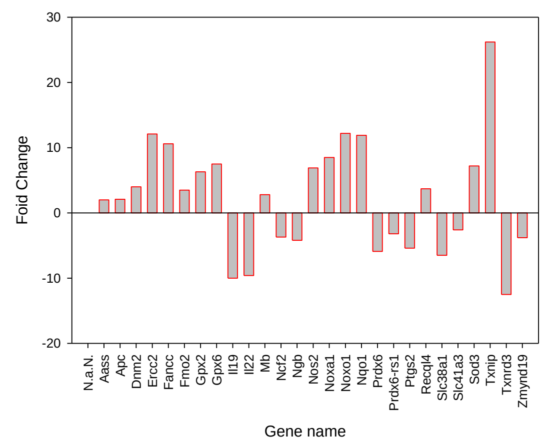


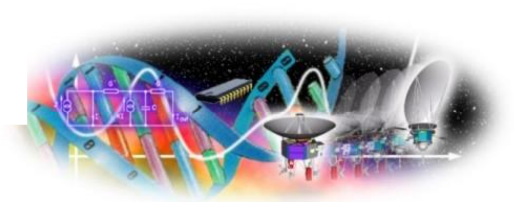


Differential expression of the Interleukins genes in hypometabolic state of mice vs. normal state



Differential expression of the Oxidative Pathway genes in hypometabolic state of mice vs. normal state

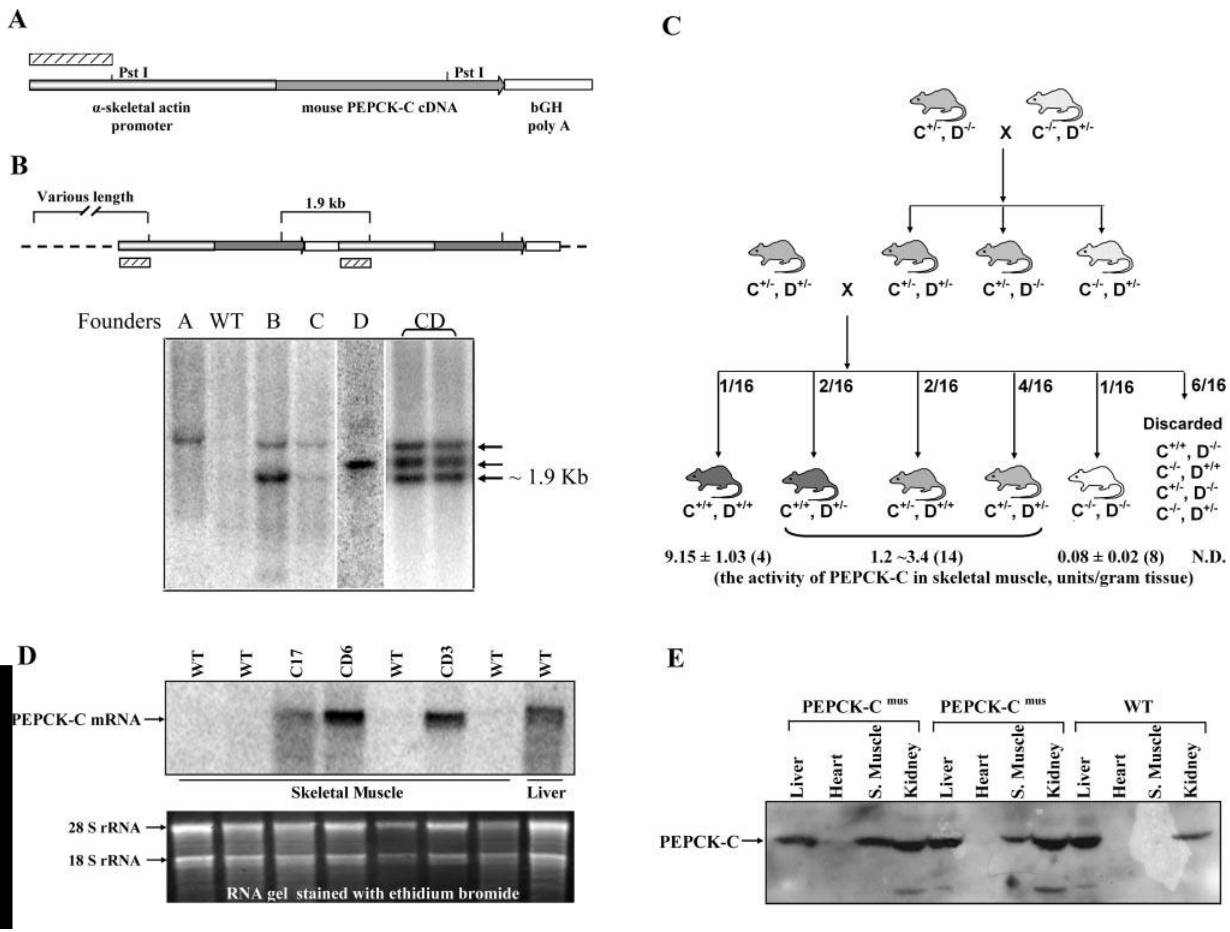




Metabolic role of PEPCK-C

Genetic key to super-humans capabilities

Dr. Richard Hanson (Case Western Reserve University)



More Powerful Than
a Locomotive?
PEPCK-C^{mus} Supermouse
vs.
Wild Type

The genetic alteration to a gene involved in glucose metabolism appears to stimulate the efficient use of body fat for energy production

The Approach:

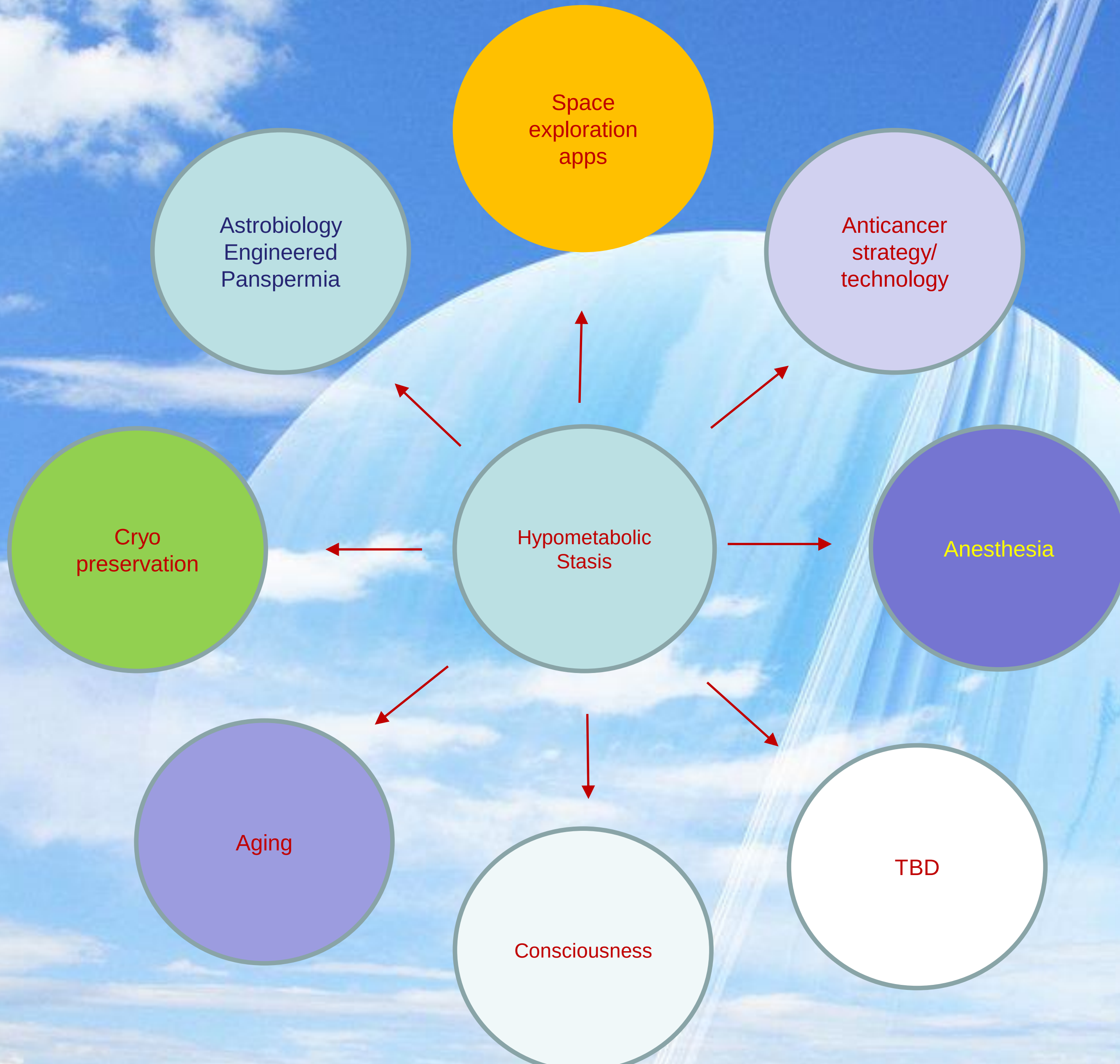
What is proposed is a new animal life support systems with ability to provide Hypometabolic Stasis to be deployed on a SmallSat platform, in order to demonstrate stable autonomous operation and system performance during a real orbital flight experiment

CubeSat space flight utilizing the “close loop” rodent-algal life support system and the metabolic control technology

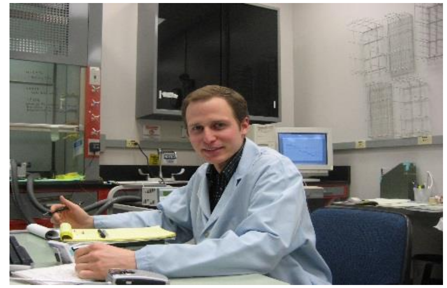
Mission Outcome

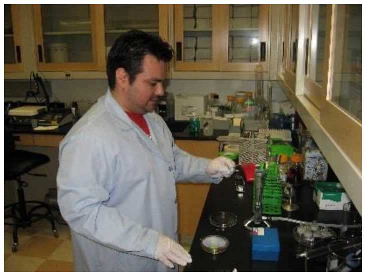
- Commercial platform to perform physiological and pharmacological experiments on animals in space
- Fundamentally reduce life support payload cost
- Increase mouse survival in an environment where the normal pace of life is not possible or practical
- Demonstrate stable autonomous operation and system performance during space flight

Potential applications:



Acknowledgements

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