Future Spacesuits, the Moon vs Mars, and Engaging STEM Talent

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Space Spinoffs Inc
NASA Alumni League

FISO Telecon - June 8, 2016

Space experts warn Congress that NASA's "Journey to Mars" is illusory

Testimony says NASA lacks the financial resources and technology to do the mission.

by **Eric Berger** - Feb 4, 2016 1:11pm CST

House Republican Brian Babin chaired a hearing in which experts said NASA's plans for Mars lacked real substance.

He's not the only one: Neil DeGrasse Tyson and others have chimed i declaring we should go back to the Moon first….Why?

Why the Moon (the impression)

- The Moon is only 3 days away,
  We know how to get there
  It’s a good place to rehearse for Mars

  and

  Humans to Mars missions have too many unsolved technical barriers remaining

Moon vs Mars vs Antarctica

COMPARISON SUMMARY OF MOON, MARS LUNAR ENVIRONMENTS

	MARS	MOON	LEO (ISS)	ANTARCTIC
GRAVITY	0.38	0.16	0	1
PRESSURE-MB	10	0	0	1000
ATMOSPHERE	CO_2 (95%)	0	0	N_2 79% O_2 21%
TEMP MIN C	-73 EQUATOR	-247 craters	-273 shade	-94
TEMP MAX C	+22 EQUATOR	+123 sun	'+123 sun	+17.5
convection	yes	no	no	yes
evaporation	yes	no	no	yes
crop growth	easy	hard	NA	easy
sun % earth	44%	100%	100%	100%
day	24 hrs, 39 min	29 days	90 min	24 hrs
weather	dust storms	poss SPEs	poss SPEs	rain, lightning
Rad danger	GCR	GCR, SPE	GCR, SPE	GCR

NOTE MARS ENVIRONMENT IS CLOSER TO ANTARTCIA THAN the MOON

The Reality

- **The Moon is a bad place to rehearse for Mars**
  - The environment is drastically different
  - The G level is different (.166 vs .38)
  - The soil is different
  - Spacesuits and Life Support Systems must be completely different
  - In situ resource utilization will be different
  - The list goes on and on
  - Antarctica is a better analog
  - Kids, students and the public love Mars but are Moon indifferent

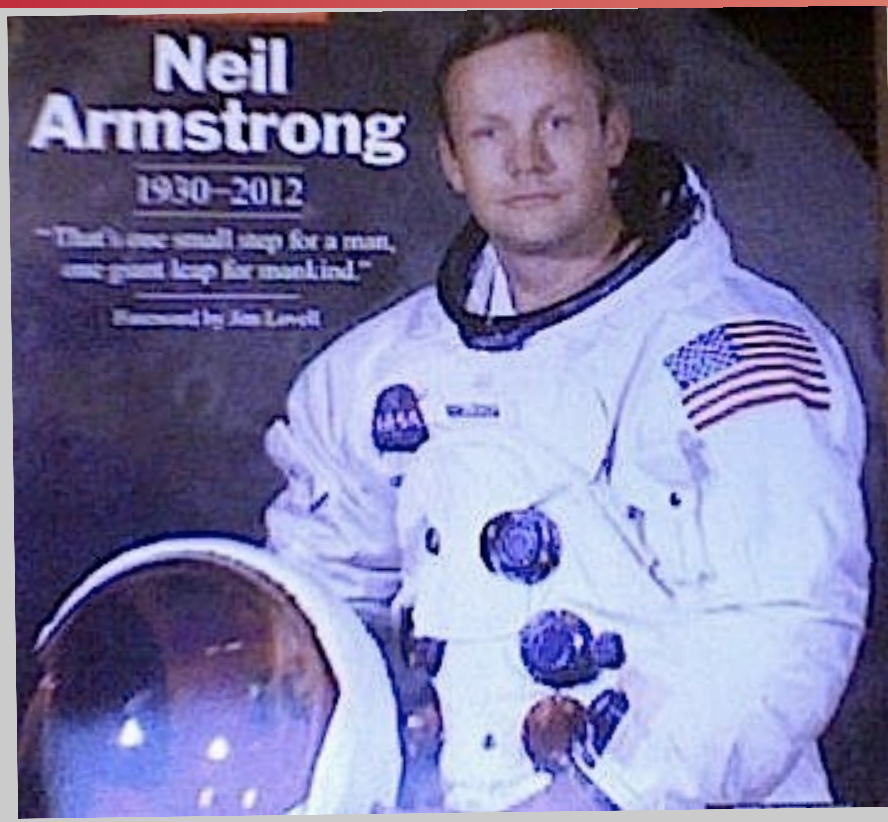
As for funding, those who ignore history are doomed to repeat it.

- Establishing a Moon base first will result in a black hole of funding shortfalls and delays that will push H2M to 2050 or later

As for the technical barriers remaining before H2M can be launched

- We know far more about Mars today than we did about the Moon at the start of the Apollo Program
- The barriers are all being addressed with various degrees of success as we speak
- These barriers are less intimidating than some of the perceived “insurmountable” ones that existed prior to Apollo

I've had the honor, privilege and good fortune of having 3 amazing highlights in my NASA career--being on console for Apollo 11, being on the Build Team for the first Space Shuttle, Columbia, and getting to know this man



"ALL WAS READY, EVERYTHING HAD BEEN DONE, THE TIME HAD COME
AS WE ASCENDED IN THE ELEVATOR TO THE TOP
WE KNEW THAT HUNDREDS OF THOUSANDS HAD GIVEN THEIR BEST
TO GIVE US THIS CHANCE
NOW IT WAS TIME FOR US TO GIVE OUR BEST"

The challenge then was greater than it is now and it was accomplished in less than a decade

Technical Barriers to Overcome prior to a Human Mission to Mars

- 1. EDL – landing a 25 ton payload within 7 minutes in an atmosphere 1/100 a thick as Earth's

  Proposed solution: the hypercone

  2, Can an astronaut land a descent craft after 6+ months in 0 G

  . Proposed solution: See Scott Kelly

- 3. Radiation Protection – increased cancer risk (up to 18%)

  Proposed solution: duty cycle, career limits, shielding

  4. Immunology – immune system degradation

  Proposed solution: ISS human research program

  5. Bone loss – up to 15% bone loss and fracture risk

- Proposed solutions: Exercise countermeasures, drugs

- *6. Spacesuits and Life Support Systems ???*

- *7. Others…*

SPACESUITS FOR MARS
What's wrong with this picture?

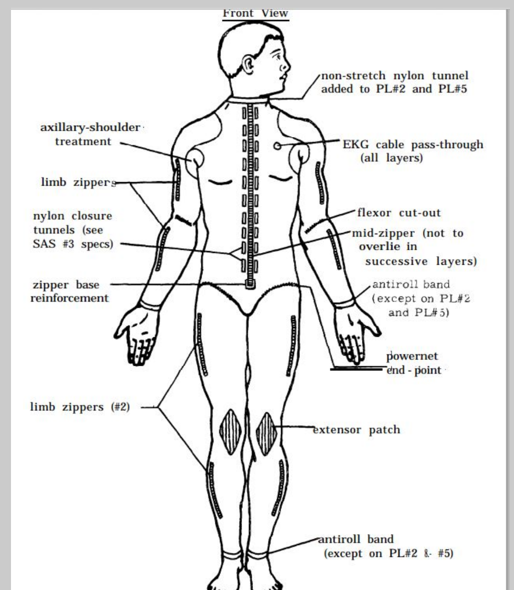
History of Mars spacesuit concepts

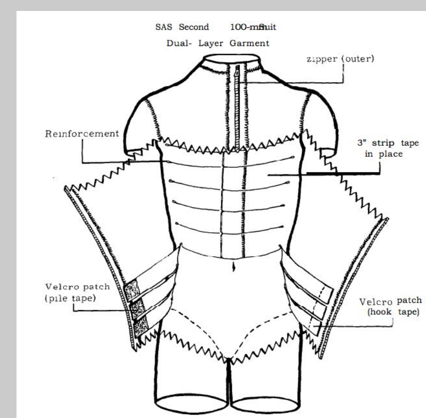
- Mechanical Counterpressure
- Space Activity Suit
- MIT BioSuit
- NASA Evolutionary Designs

1st Mechanical Counterpressure Suit
-Hans Mauch: 1959

- Used closed cell foam sandwiched between 2 fabric layers
- Developed for Air Force Dynosoar project
- Partially funded by NASA
- Alternative to Project Mercury rigid suit
- Tested successfully in 1962
- Dropped due to poor mobility, low interest

Space Activity Suit
– Paul Webb: 1967





Space Activity Suit

- Mechanical Counterpressure
- Powernet Spandex
- Multiple Material Layers
- Breathing bladder to balance chest pressure
- Tested successfully for 2.75 hours
- Individually tailored to user
- Great difficulty donning and doffing
- Uneven pressure, blood and fluid pooling

MIT Biosuit
-Dava Newman: 2002

MIT BioSuit

- Mechanical Counterpressure baseline
- Uses spandex, kevlar, elastic, urethane foam
- Lines of non extension reduces layers
- Breathing bladder to balance chest pressure
- Tested to 3.6 psi
- Custom tailored using whole body laser scan
- Cooling by evaporation through suit to ambient
- Difficulty donning and doffing
- Uses gas filled gloves and boots
- Simplified and improved over SAS designs
- Funded by NAIC but NOT baselined by NASA

NASA evolutionary designs NASA:1969-2016

What NASA suits have in common

- Oxygen pressurized
- Sublimation for cooling
- HUTs (hard upper torso)
- Fans, pumps, HX, closed loops
- Liquid cooling garments
- Hard upper torso
- Multilayer insulation
- Thermos Bottle Approach to handle temp extremes
- Complex
- Heavy Portable Life Support Systems (PLSS)

CAUTION !!!

- The SAS, MIT Biosuit and the NASA Mark 3 or new Z2 suit are **NOT** spacesuits, they are **PGA's** (Pressure Garment Assemblies)
- A spacesuit consists of a PGA, a Portable Life Support System (PLSS) and associated miscellaneous hardware together which form an Extravehicular Mobility Unit or EMU
- The PGA is usually the lightest component while the PLSS is the heaviest
- To distinguish it from Apollo, Shuttle or ISS, lets call an EMU for Mars a ***MarsSuit***

MASS
The holy grail of the MarsSuit

Interviews with geologists, astrogeologists, explorers, backpackers and military personnel have established that the maximum permissible mass that should be carried on one's back for daily blue collar work lasting 7-8 hours/day should not exceed 50 lbs (23 kg). A mass of 50 lbs in 0.38 Martian gravity is equivalent to 132 lbs on Earth.

Achieving this target requires:

PGA + PLSS + accessories **≤ 132 lbs** earth weight

PLSS Weights

Apollo PLSS 61 kg **(134 lbs)** EMU weight**:**100kg ***(220 lbs)***
Shuttle PLSS 73 kg **(161 lbs)** EMU weight 135kg ***(306 lbs)***
ISS PLSS 98 kg **(216 lbs)** EMU weight:165kg ***(365 lbs)***

Adding ***any of the above*** PLSS weights to the advanced lightweight and composite NASA Z2 or MCP PGAs will significantly exceed the target MarsSuit weight of 132 lbs on Earth (50 lbs on Mars)
…..unless the PLSS is completely redesigned…

This will require drastic weight reductions of at least 60% from current systems

IS THIS BEING CONSIDERED?

Future PLSS designs

- In 2005 NASA began a new, Advanced PLSS design program. The goals of the Advanced PLSS are:
- Simpler, more robust and reliable system design
- Optimized for low-earth orbit and Lagrangian point EVA operations. Provides flexibility for deep space or lunar missions, and is "Mars forward".
- Generate more sensor data
- Provide EVA capability in more severe situations (e.g. very hot environments)
- Provide additional emergency capabilities (60 minutes, as opposed to 30 minutes in Apollo and Shutte/ISS PLSSs)
- **TARGET Weight ≈ 150 lbs**

Summarizing

The PLSS is a work-in process, an effort to develop systems that include many new technologies for Mars. HOWEVER…

ITS TARGET EARTH WEIGHT ALONE EXCEEDS THE RECOMMENDED TOTAL MARSSUIT WEIGHT OF 132 LBS

Mass isn't the only problem

	Target	Biosuit	Z2
Mass, lbs (Mars, Earth).	50, 132	no	no
Primary heat xfer mode	Evap to ambient	no	no
Radiation protection	DNE career limit	no	no
F/B Contamination	DNE microbe limit	no	no
Glove Dexterity	> ISS	TBD	TBD
Walking Mobility	> Apollo	TBD	TBD
Prebreathe reqmt	0 minutes	no	no
Micromet protect.	Isolate 02 loss	no	no
Real time help	Legaci algorithm	no	no
Consumables	batt, 02 only	no	no

Others ?

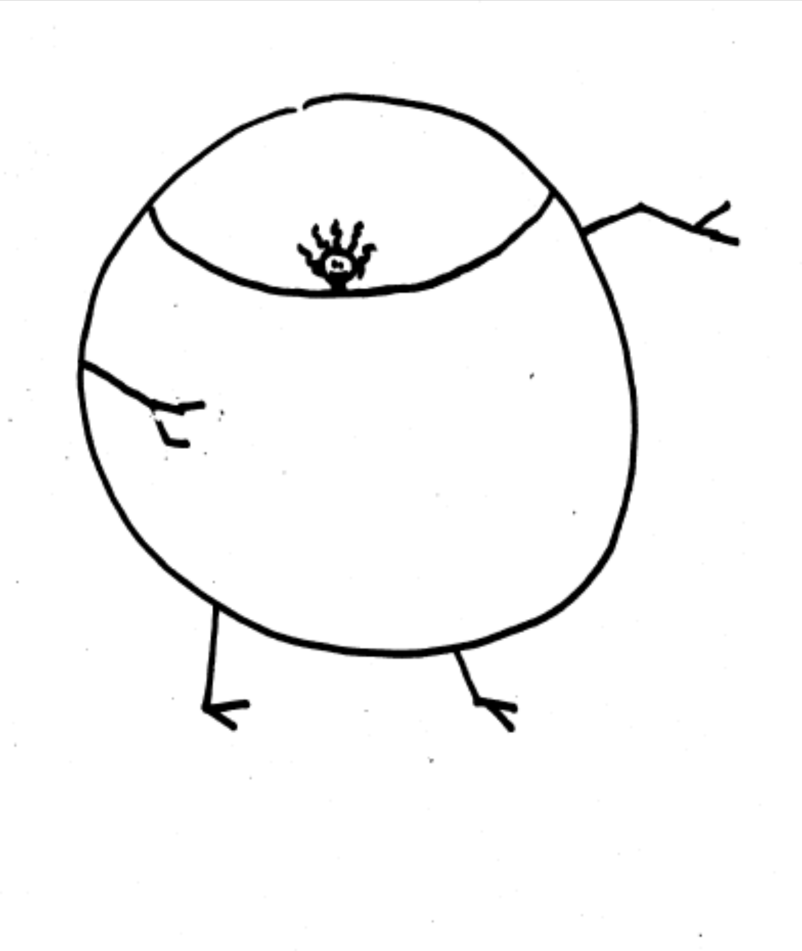
Conclusions

- MCP (MECHANICAL COUNTERPRESSURE) SUITS HAVE BEEN UNDER DEVELOPMENT FOR 50 YEARS WITH NO END IN SIGHT
- NASA EVOLUTIONARY DESIGNS SUCH AS THE MARK 3 OR Z2 ARE BASED ON APOLLO/SHUTTLE/ISS SUITS MEANT TO OPERATE IN A VACUUM WITH SIMULTANEOUS BOILING AND FREEZING TEMPERATURES
- CURRENT DESIGNS ARE EITHER TOO COMPLEX OR HEAVY
- EVOLVING A MARSSUIT from THESE SUITS IS PUTTING A SQUARE PEG IN A ROUND HOLE—IT WILL NOT WORK

THIS IS NOT A FASHION SHOW

HOUSTON…WE HAVE A PROBLEM

Unless significant breakthroughs occur, astronauts on Mars my look like this



What to do??

AIM FOR A SUIT THAT LOOKS LIKE THIS

HOW?

START WITH THE MARTIAN ENVIRONMENT
IT CAN HELP!!

THE PAST: Apollo / Shuttle Program / ISS

Engineering • EMU • Science

Is the slave

THE FUTURE: Mars Exploration

Science • Engineering • EMU

Is the slave

THE MARTIAN ENVIRONMENT
VS LEO, THE MOON, ANTARCTICA

Environment Comparison

Item	Mars	Leo	Lunar	Earth
Temp range (°C)	-140 to 30	-160 to 150	-172 to 150	-50 to 40
Radiation Flux (solar constant But/hr-ft2-°F)	195	440	440	440
Winds m/s	0 to 15	0	0	0 to 10
Atmospheric Composition	95% CO_2 3% N_2	NONE	NONE	80% N_2 20% O_2
Gravity (vs. Earth G's)	0.38	0	0.166	1
Terrain	variable	none	smooth	variable
Needed Leg Mobility	HIGH	NONE	MED.	HIGH
Micrometeorite Danger (puncture)	LOW	HIGH	HIGH	LOW
Geologic Activity	SOME	NONE	NONE	SOME
GCR Shielding (g/cm2 AL)	27	2	4	-
Weather	Dust storms, Seasons	-	-	Rain, Lightning
Day/Year	24.5hr 668 sols	29days/ -	-	24 hr 365 sols
Atm. Pressure (Atm)	1/100	-	-	1

FIRST: WHAT WON'T WORK

National Aeronautics and Space Administration

Ames Reseach Center
Moffett Field, California 94035

NASA

Conclusions:

- Multilayer insulation will not protect against thermal radiation on Mars
- EMU Sublimation system will not work on Mars
- All previous and projected EMU designs have excessive weights on Mars
- Weight reductions up to 55% are necessary

All Previous EMU designs will not function on Mars

- Pressurized suits are still necessary

A Mars EMU requires a Totally fresh approach

NEXT: WHAT WILL WORK

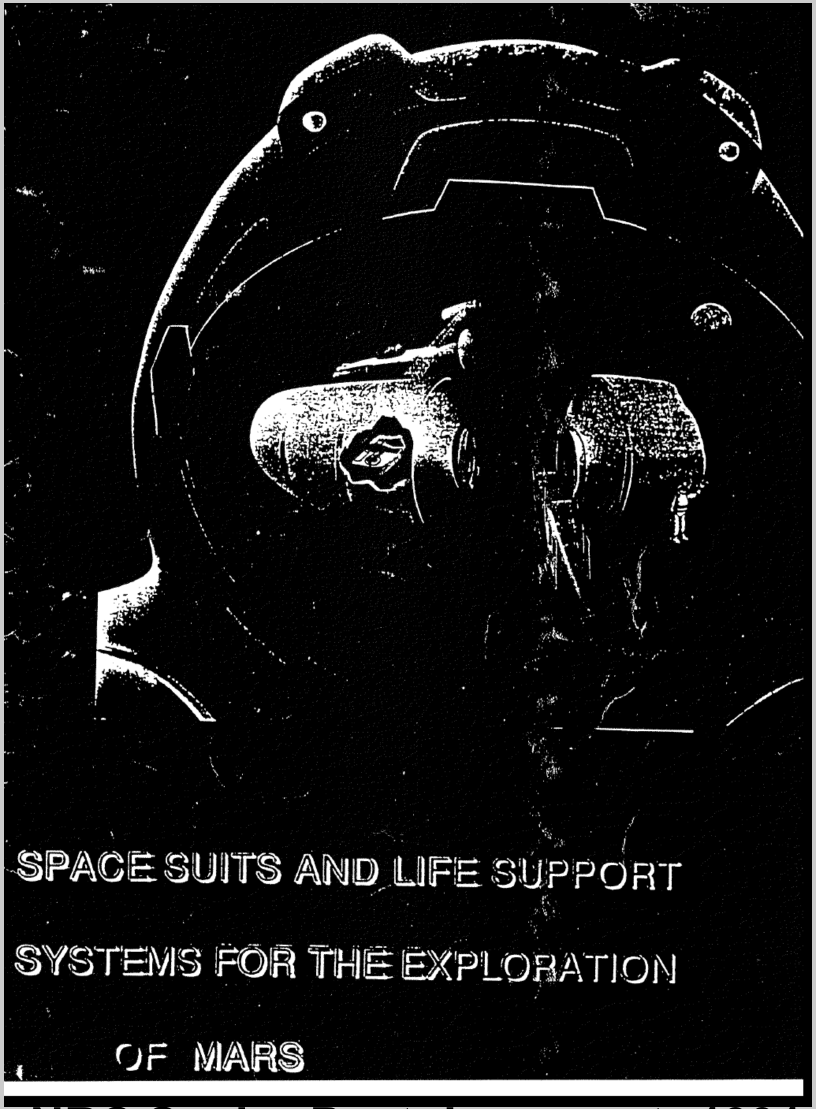
MARS

- Cold sink temperatures available for heat rejection to ground by radiation
- Range of -140 to +30 degrees C surface temps more benign than Lunar or LEO
- Convection loss (forced and free) to Mars atmosphere from suit is possible
- Evaporative loss from body through suit to atmosphere may be considered
- Micrometeorite danger is minimal on surface due to atmosphere
- GCR danger less than Lunar or LEO
- Solar flux is 1/2 that on Earth for same conditions
- Excessive heat leak into suit is unlikely

continued

- Latitude variations in climate make summer/winter EMU designs feasible
- Gradual temperature change in air make day/night differences advantageous
- Carbon dioxide in atmosphere may be used to generate oxygen for breathing
- Carbon dioxide in atmosphere could possibly be used to pressurize suit
- Mars atmosphere contains water vapor
- Mars soil contains water in permafrost

WITH THIS IN MIND, START WITH A FRESH SHEET OF PAPER



NRC Senior Post doc report--1991

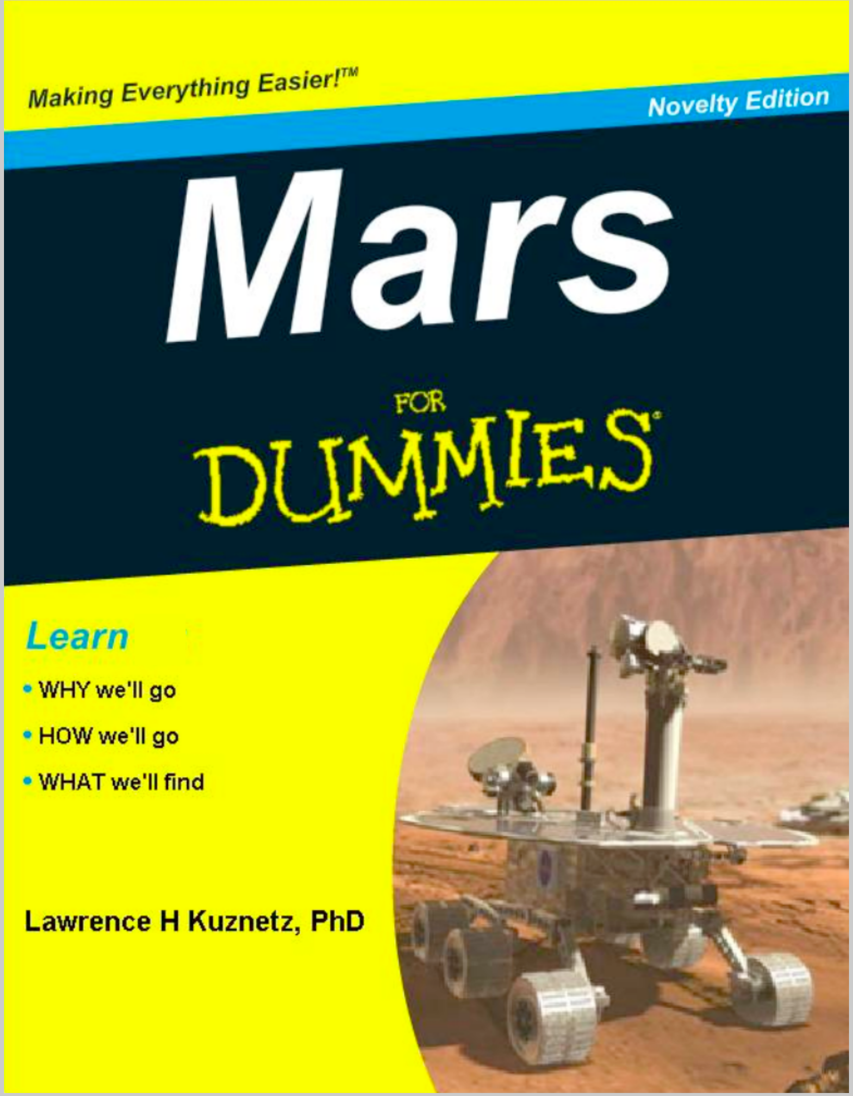
Study Features

- 1^{ST} Serious Analysis of Mars space suit design
- Low cost high return
- Based on a successful 5 year pilot study
- Utilized multi-university, industry and NASA expertise
- Unconventional out of box approach
- Mars and Science-centric ***not*** suit-centric
- Embraces ALL elements of MarsSuit design
- Treats the Marssuit like the human body--*a complex system with feedback loops requiring an Integrated multidisciplinary approach*–not like a simple black box

UPDATED IN 2005

Spacesuits and Life Support Systems for the Exploration of Mars

UPDATED 2010 and AGAIN IN 2016



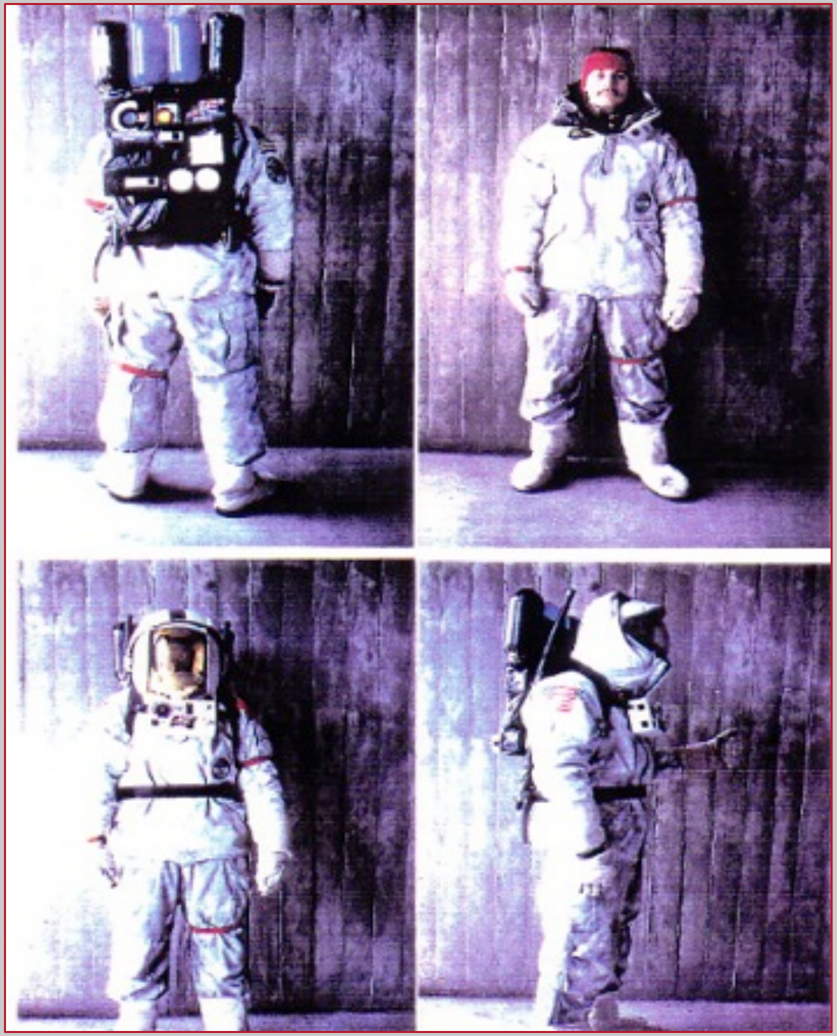
If it's so great why hasn't it flown?

The time wasn't right before, now it is.

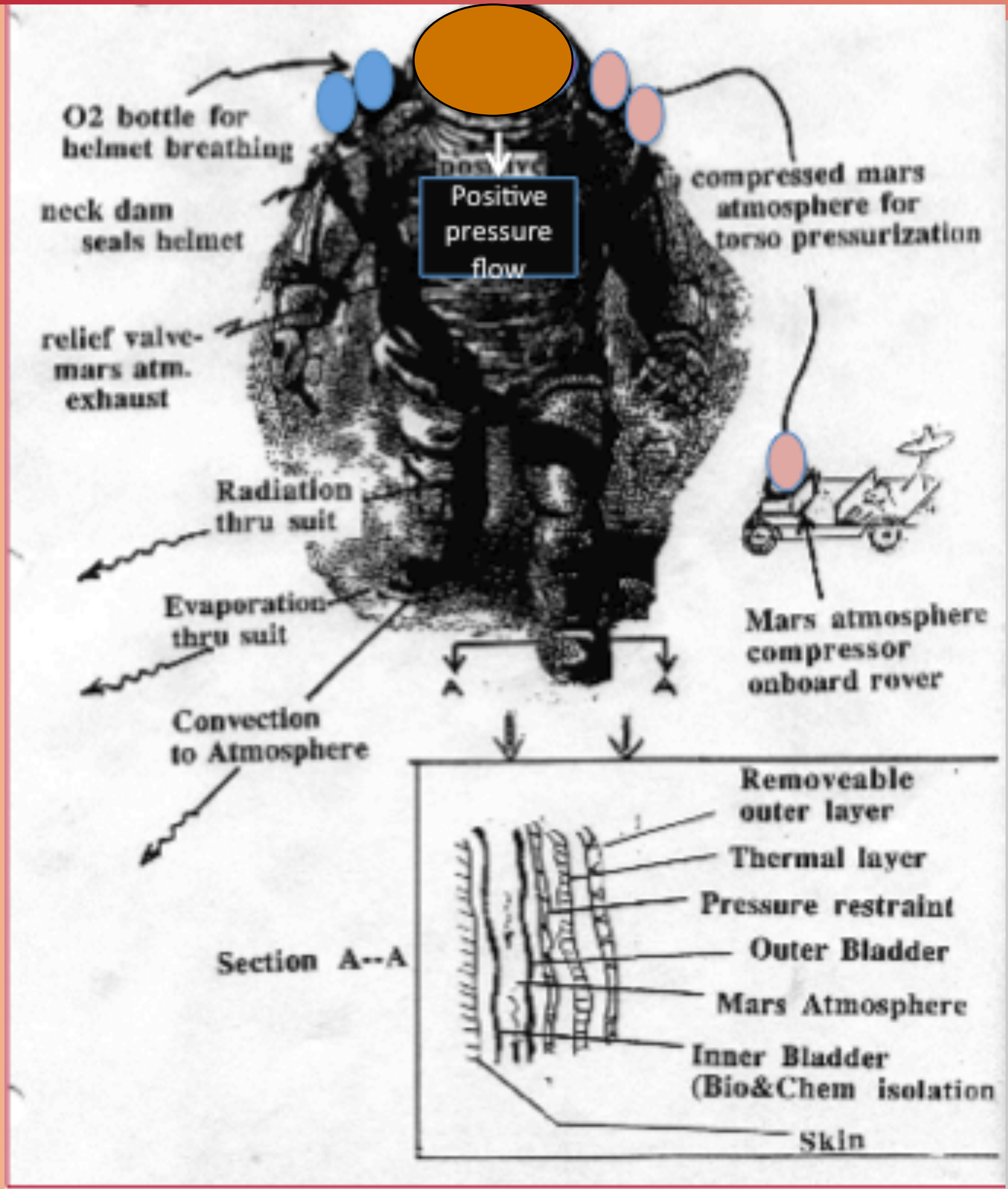
Why is it different, What does it say?

Without further ado..

HDSD: Hybrid Dual System Suit: an integrated multidisciplinary approach driven by the Martian environment



Distinguishing feature:
separate systems for helmet and torso



Safety-
helmet torso independence

Mass reduction
HX pumps, MLI reduced

Design
Thermos bottle → layers

Heat/mass transfer:
Natural Convection

Oxygen leakage rate:
Reduced to near zero

Planetary contamination
Minimized

Consumables usage
Minimized

In situ resources
Mars C02 used for pressure

Mass Reduction

Target: Build a lightweight EMU(132 lb on Earth, 50 lbs on Mars)

How? Open Loop ECLSS Design:

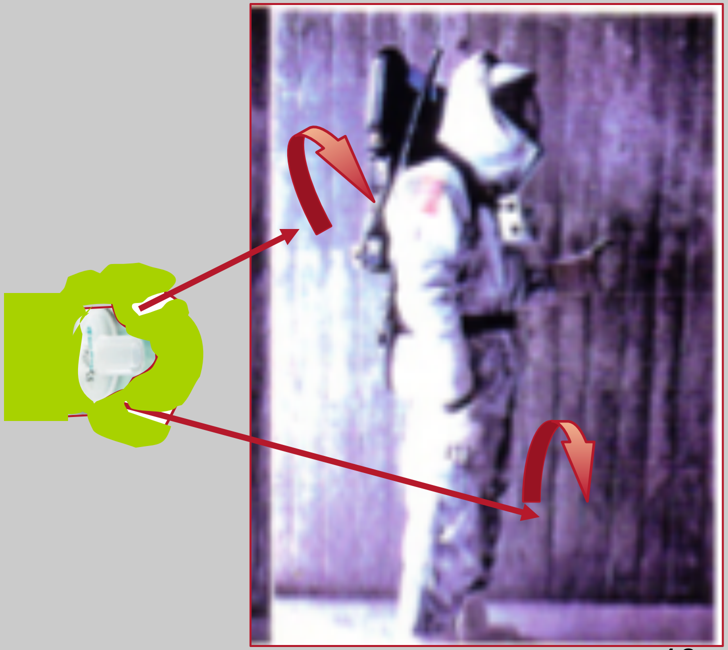
In-suit compressor blows filtered cool, dry Mars atmosphere through torso to remove heat, sweat, toxins, contaminants

Benefits: simple (closed loop hardware eliminated), suit leak and O2 loss minimized: Issues: power, size, safety

Planetary Protection

Problem: "Earth bugs" contaminating the Moon on Apollo 12 (and Mars)

Solution: Bacterial/viral filters at compressor inlet and relief valve outlet of MarsSuits



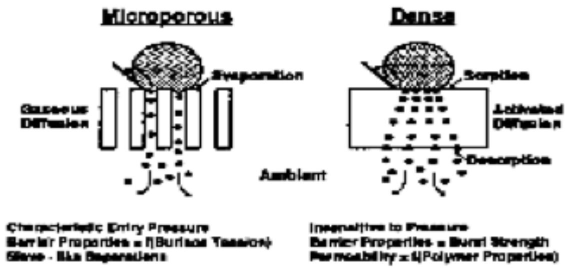
TOXICITY PROTECTION (from Mars atmosphere)

DENSE MONOLITHIC MEMBRANE (DMM) AGAINST SKIN

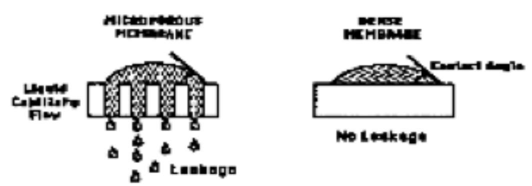
REPLACES RUBBER BLADDER—PROTECTS AND ALLOW HEAT/MASS XFER

Microporous vs Nonporous (Dense) Semi-Permeable Membranes

(Condensed/Liquid Phase Not Necessary for Transport)



Effect of Pressure and Contamination on Liquid Barrier Properties of BBFs



DMMs allow sweat evaporation at 5-8 psi

Life Sciences

Low CG Enhances Mobility and Performance

Bad CG

Better CG

conrad

cernan

Variable Pressure torso and gloves

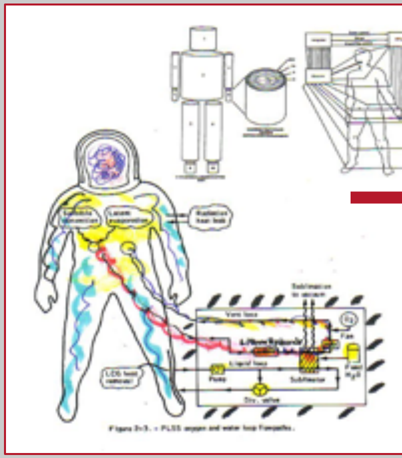
Variable glove pressure reduction allows greater dexterity

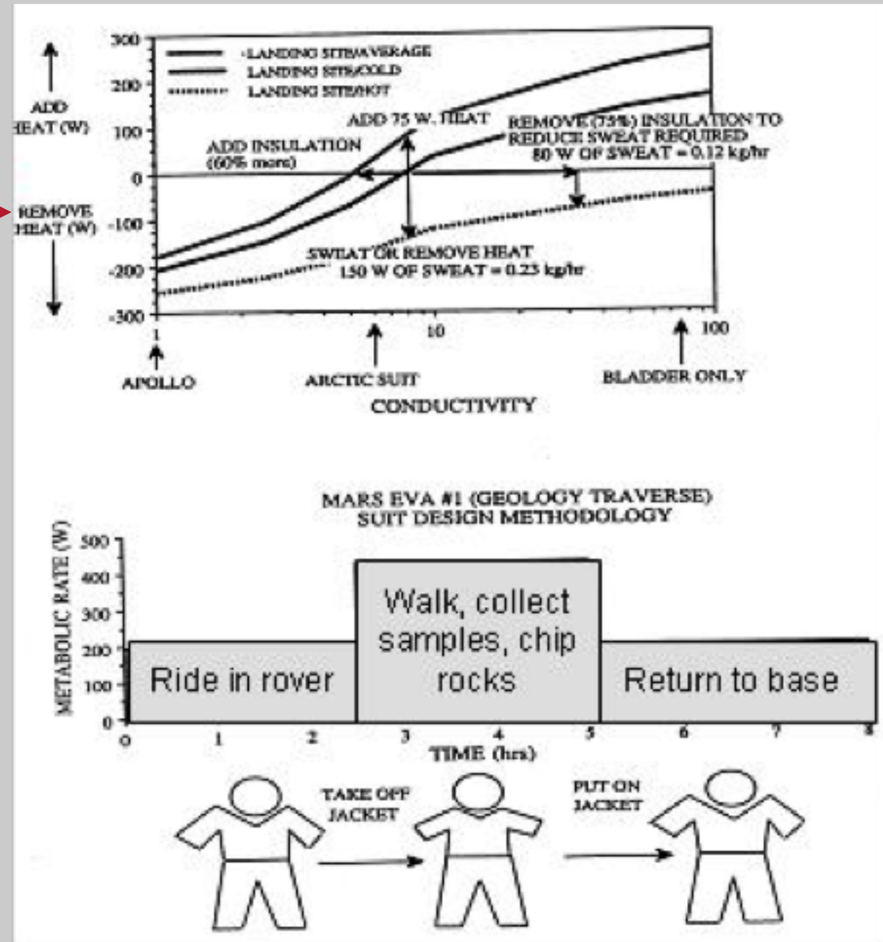
Compatible with Suit Port to allow instant EVA no prebreathe

Advanced Thermal Control

Eliminate thermos bottle approach--Mars is a big planet—

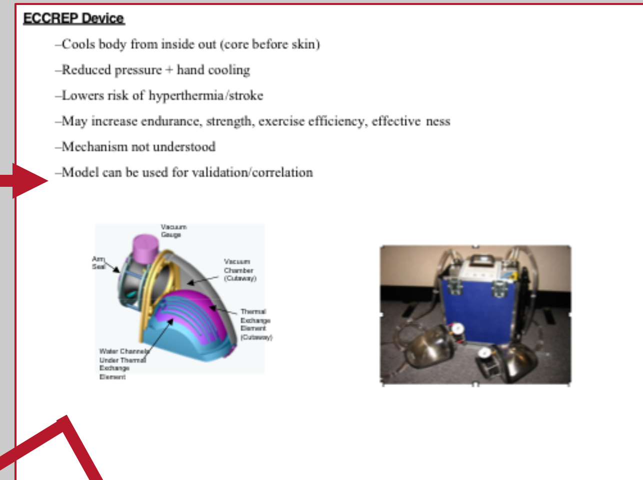
add layers where it's cold, peel them when its hot

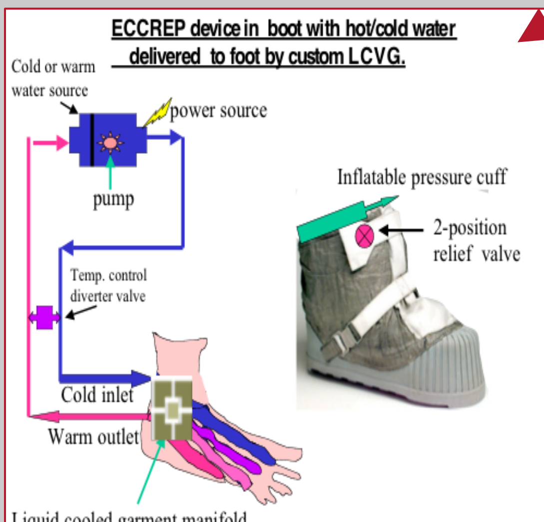


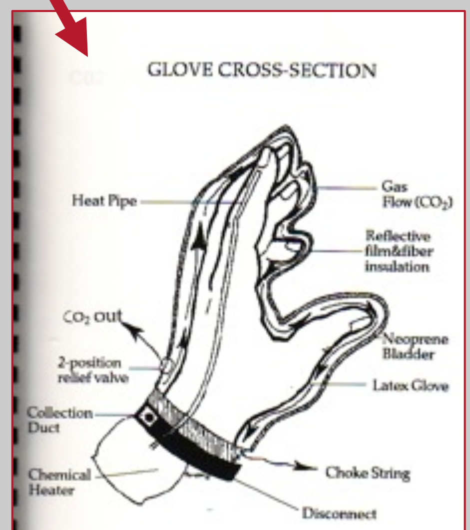


Advanced Thermal Control

Direct Blood Cooling/Heating

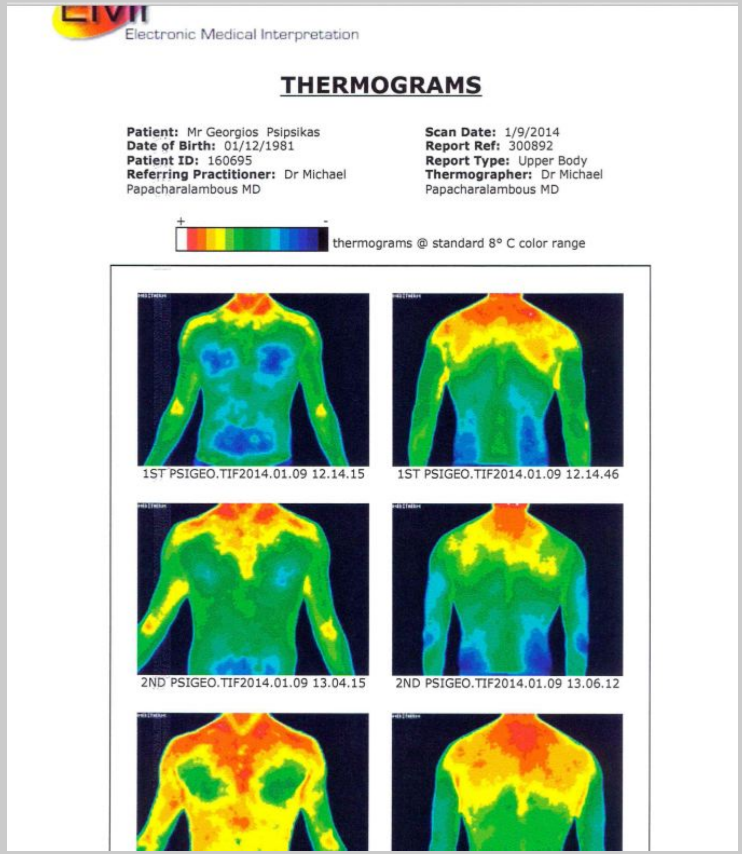






the External Cooling Coupled to Reduced Extremity Pressure (ECCREP) device

Ceramic textiles from mineral oxide microfibers to efficiently re emit infrared rays


Electronic Medical Interpretation

THERMOGRAMS

Patient: Mr Georgios Psipsikas
Date of Birth: 01/12/1981
Patient ID: 160695
Referring Practitioner: Dr Michael Papacharalambous MD

Scan Date: 1/9/2014
Report Ref: 300892
Report Type: Upper Body
Thermographer: Dr Michael Papacharalambous MD

thermograms @ standard 8° C color range

1ST PSIGEO.TIF2014.01.09 12.14.15
1ST PSIGEO.TIF2014.01.09 12.14.46
2ND PSIGEO.TIF2014.01.09 13.04.15
2ND PSIGEO.TIF2014.01.09 13.06.12

The technology employs nanoceramic fabrics to convert multi-frequecy emitted body heat IR radiation to a narrow band at the end of the long range spectrum (far infrared). The radiation is returned to the interior body penetrating several cm. (It may also have applications for Reynoulds syndrome and arthritis

Advanced Materials
Dust, Surface, Toxicity Protection

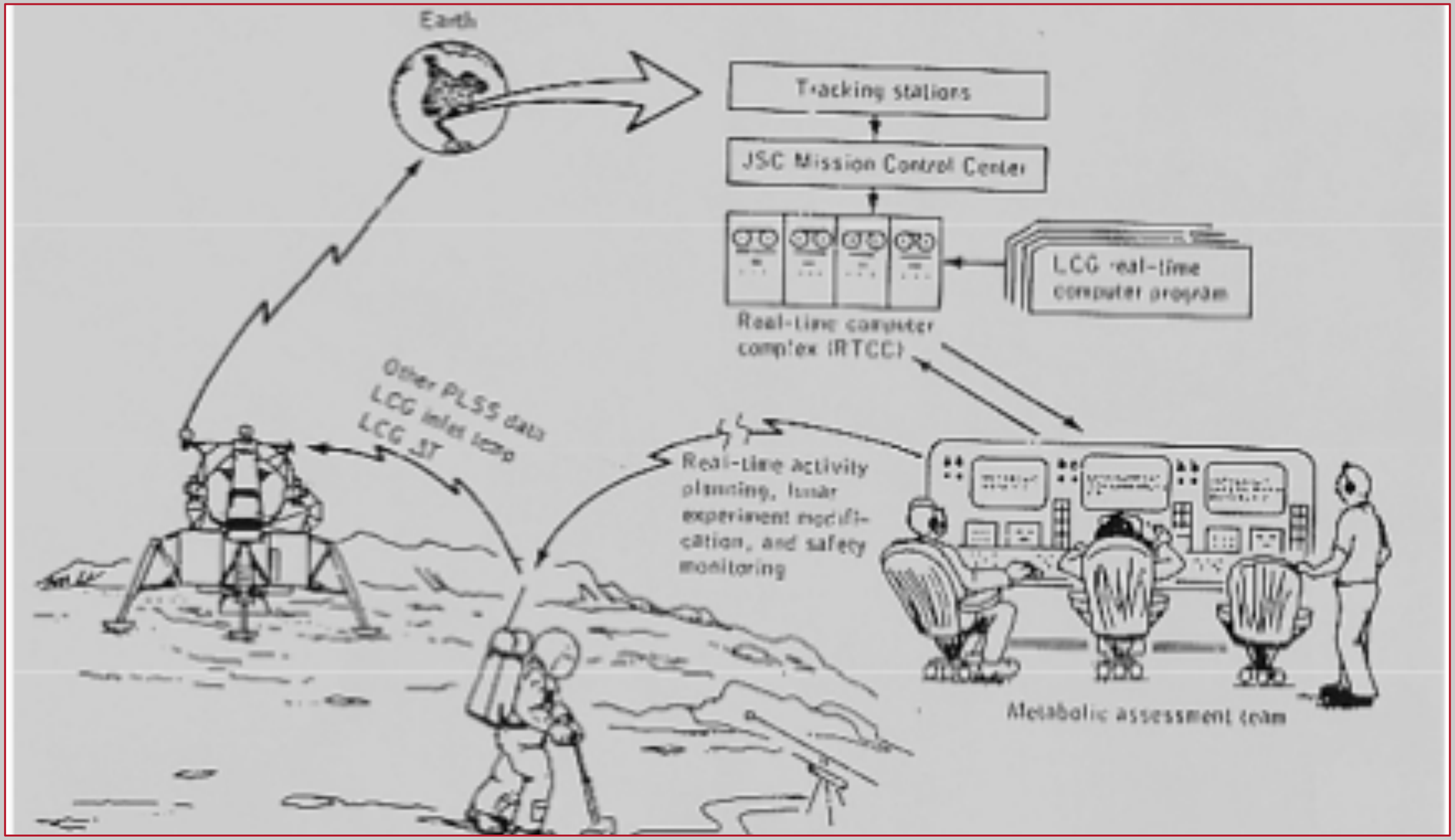
Dust bug exo-cover (disposable)

Smart Technology and Bioinformatics

Apollo used a ground team for advice

Round trip comm from Earth to the Moon in less than 4 seconds

Mars will require up to 40 minutes round trip for help



The suit will have be smart enough to provide that help instantly. Enter Legaci and Violet--the bio advisory algorithm

LEGACI

***L**unar/Mars **E**xploration **G**uidance **A**lgorithm and **C**onsumables **I**nterrogator*

Developed at JSC in EVA Physiology, Systems, and Performance Project

VIOLET

***V**oice **I**nitiated **O**perator for **L**unar/Mars **E**xploration **T**racking*

(The voice of LEGACI)

Developed at NASA-Ames Research Center

Legaci and Violet at work

What can it do?

- **Metabolic rate (4 methods + backup)**
  - pCO2; Liquid cooled garment temps;O2 tank pressure; Heart rate; Accelerometry
- **Energy cost of work tasks on the Moon and Mars**
- **Consumables remaining**
  - Portable Life Support System O2, feedwater, battery power & C02 scrub time remaining
- **Suit oxygen leakage**
  - Real time puncture awareness, out of spec suit leaks
- **Crew thermal comfort and Heat Storage Countermeasure**
  - Countermeasure to Cognitive Deficits (CDO)
  - Countermeasure to Loss of Tracking Skills (LOTS), hypo/hyperthermia
- **Automatic LCG inlet temperature management**
  - Minimizes crew distraction, consumables use
  - maximizes crew safety and productivity
- **Environmental heat leak management**
  - Real time thermal assessment and excessive albedo avoidance

- **EVA Surface Time remaining**
  - Time management, Traverse goal management, science prioritization
- **Guidance and navigation help back to habitat**
  - Walkback emergency management
    - Speed required, distance and time remaining to get back safely
- **Redundancy/ self-checkout**
  - *<u>41 node man running real time in the background</u>*
- **Alarms**
  - Excessive sweat
  - Excessive metabolic rates
  - Excessive heat storage
  - Low consumables (O_2, feedwater, battery power, CO_2 scrubber)
  - Excessive suit leak
  - Low suit pressure
  - High pCO_2
  - Nutrition required warning
  - Hydration (drinking) required warning
  - Radiation warning (desirable add on)

OK GOOD STUFF

BUT THIS IS JUST A PAPER STUDY, A POWERPOINT PITCH

How can we make it real, where do we go from here?

THE MARSSUIT PROJECT

Develop the lead technology for building a spacesuit for Mars

while supporting Math, Science, Technology and Engineering education

MarsSuit Project Features

The MarsSuit Project is:

- An EMU/education outreach development program
- A university/government/industry synergy
- An iterative approach
- Based on a successful pilot programs

GOALS

- ✓ Provide a Mars EMU design prior to hardware solicitation
- ✓ Reach and marshal a wide segment of the undergraduate and high school education community
- ✓ Galvanize thousands of students with vast creativity
- ✓ Involve the public and external organizations