NASA and Telemedicine
Now and Beyond

Erik Antonsen MD, PhD, FACEP FAAEM
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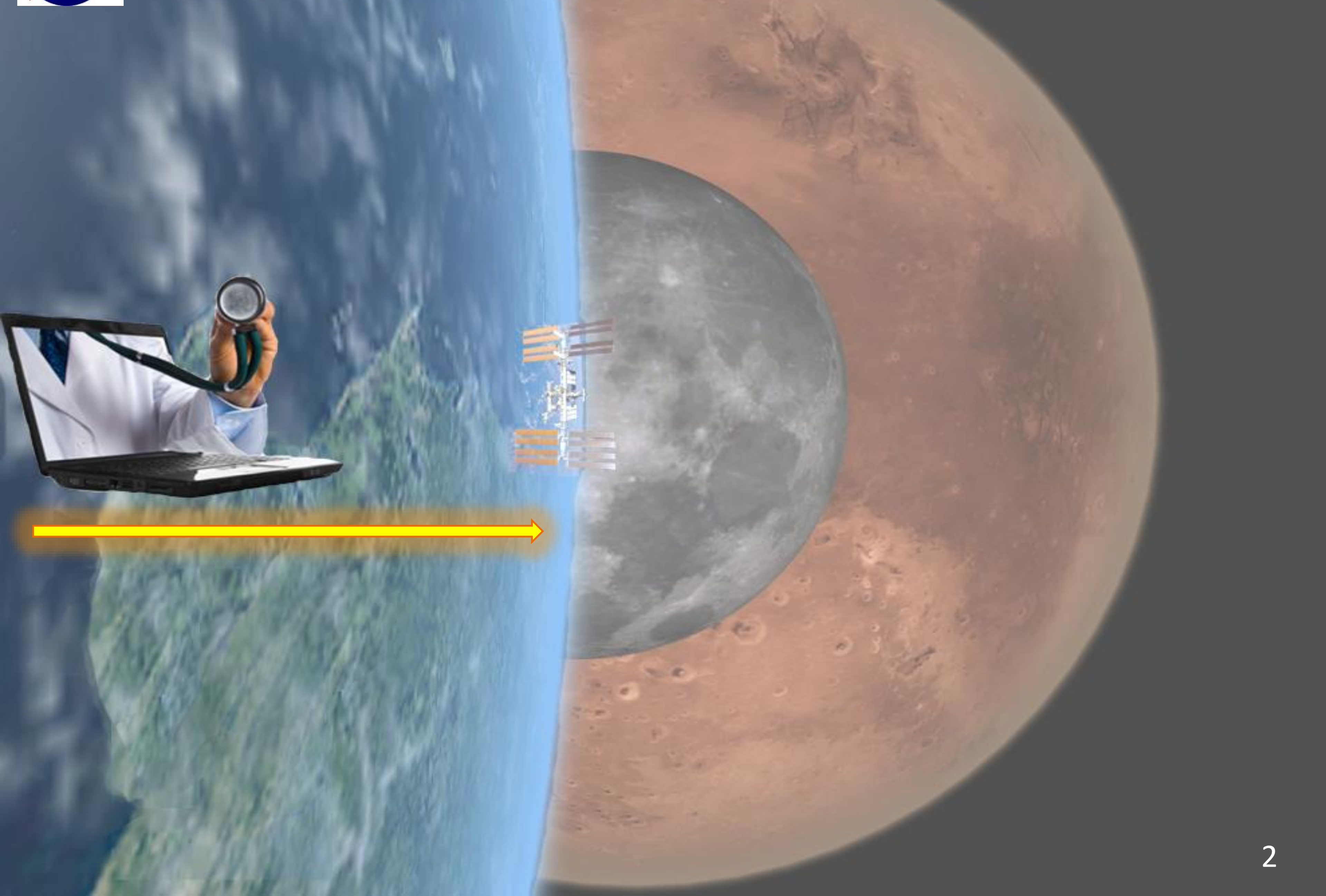
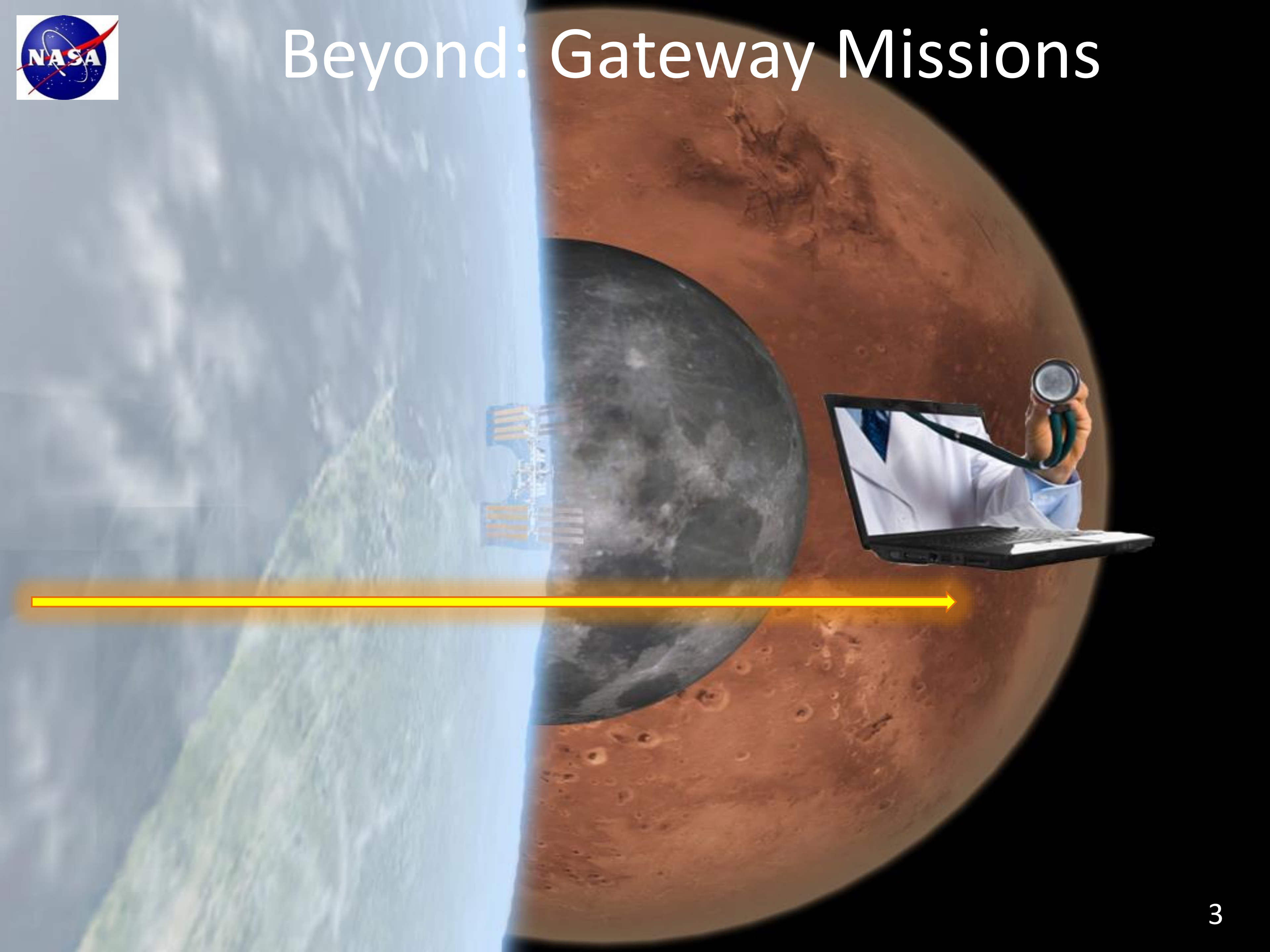
Element Scientist, Exploration Medical Capability
Johnson Space Center

May 9, 2017

Now: ISS Operations



Beyond: Gateway Missions




Donna Dempsey
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Joe Dervay
Melinda Hailey
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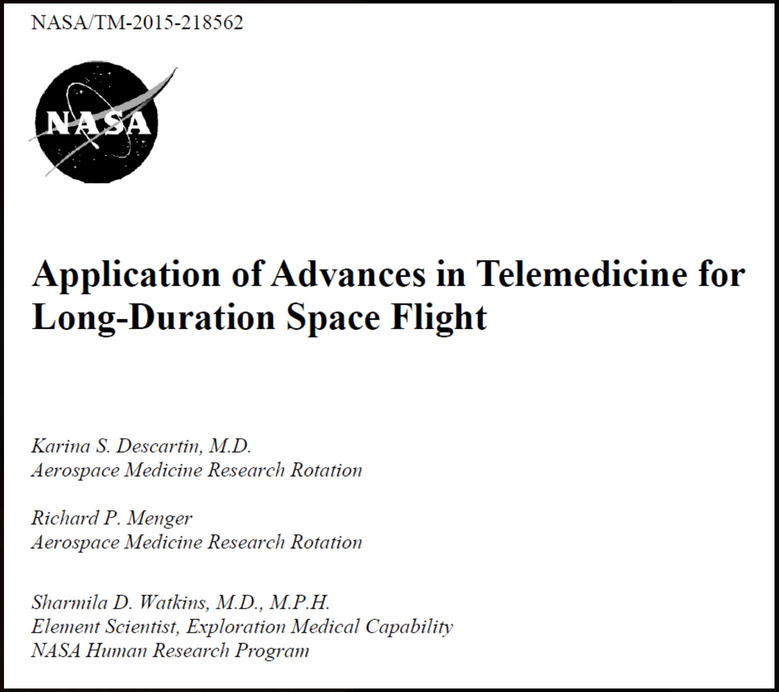
Todd Huhn
Chuck Doarn
Andrew Abercromby
Keith Brandt
David Reyes
Ashot Sargsyan
Tina Bayuse
Tom Williams
Ben Johansen
Meghan Downs
Jason Norcross
And many others!

The Human System is like any other vehicle system.
It requires prevention, maintenance, and repair.

- Dr. Thomas Williams

Outline

- Types of Telemedicine
  - Live remote Guidance
  - Live Monitoring
  - Store and forward
  - Autonomous
- Training
- Current Examples
- Lessons Learned
- Exploration Applications
- Terrestrial directions



NASA/TM-2015-218562

Application of Advances in Telemedicine for Long-Duration Space Flight

Karina S. Descartin, M.D.
Aerospace Medicine Research Rotation

Richard P. Menger
Aerospace Medicine Research Rotation

Sharmila D. Watkins, M.D., M.P.H.
Element Scientist, Exploration Medical Capability
NASA Human Research Program

Gateway Missions: Phase 0: ISS→ Phase 1: Cislunar→ Phase 2: Deep Space Transport→ Phases 3-4: Mars

Types of Telemedicine Care

- Live remote guidance

- Live monitoring

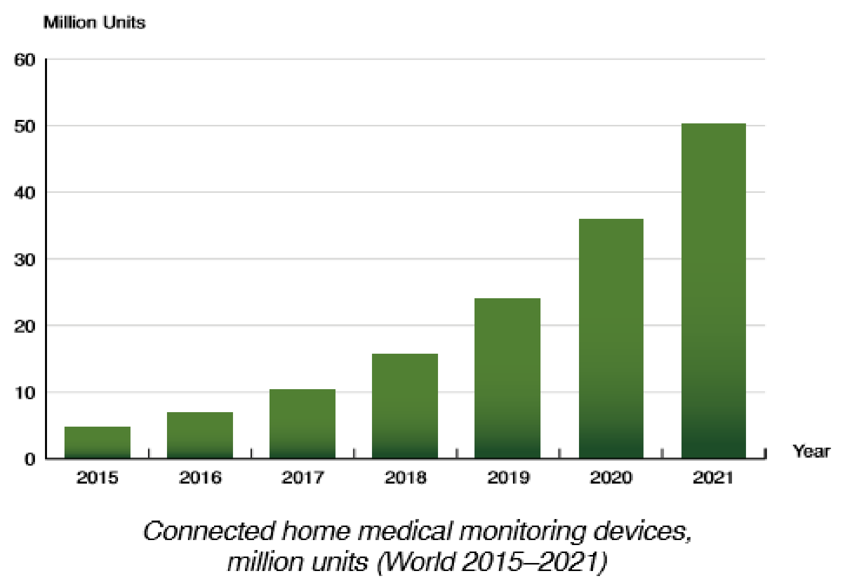
MEDB 1.3 PMC

MEDB 7.2 PPC

- Store and forward

- Autonomous

Telemedicine is fundamentally an information management problem



Berg Insight 2016

ISS Telemedicine Training

- Crew Medical Officer
  - Preflight
    - Initial (2-42 hrs): CPR, DCS, field training
    - Operators (7 hrs): Emergency
    - Specialists (26 hrs): Non-emergent
  - In-flight
    - Emergency drill (4-6 wks of arrival, 45 min)
    - Computer-based training (30 days/25 min)
- Ground Crew
  - communication coaching
  - situational awareness

Training: Lessons Learned

- Hardware ≠ capability
- Field medical training: suggested → required
- Time challenges
  - Competing priorities
  - Task mastery
- Current training not optimized
  - Training = in-flight success?
    - Not used → no validation
    - When used → no or limited validation (privacy, regulations)
  - No requirement to prove proficiency
    - Subjective instructor assessment
    - No in-flight assessment (crew or ground)

Exploration Telemedicine Training

Current ISS Ops

CMO

Training: limited
ground support

Limited compliance

Exploration

CMO

Training: maintain core medical knowledge
detailed spaceflight unique

High compliance

THE TRAINING CONTINUUM

Selection → Pre-Flight Initial → Pre-Flight Refresher → In-Flight Initial → In-Flight Refresher → In-Flight JITT → Perform. Support Tools → Post Flight

Prevent de-skilling

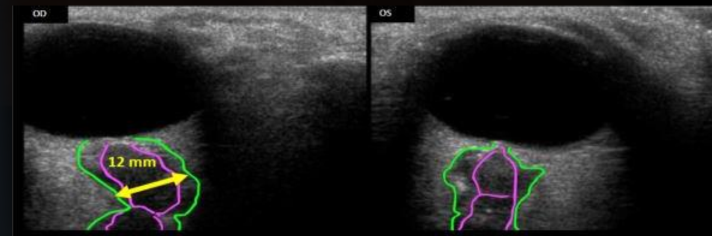
Core medical knowledge

Gateway Missions: Phase 0: ISS→ Phase 1: Cislunar→ Phase 2: Deep Space Transport→ Phases 3-4: Mars

Live Remote Guidance

ISS Telemedicine Ultrasound

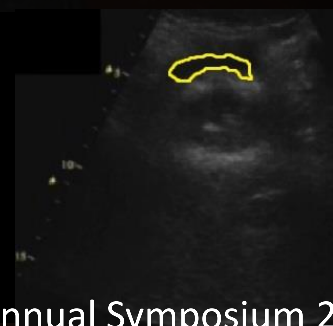
- Operations
  - Eye (SANS)
  - Spinal
  - Medical event



Life 4, p621, 2014. Nelson, E.S. et al.

- Research

In-flight Post-void Ultrasound



Ground Post-void Ultrasound

AsMA 86th Annual Symposium 2015. Cole, R.W. et al.

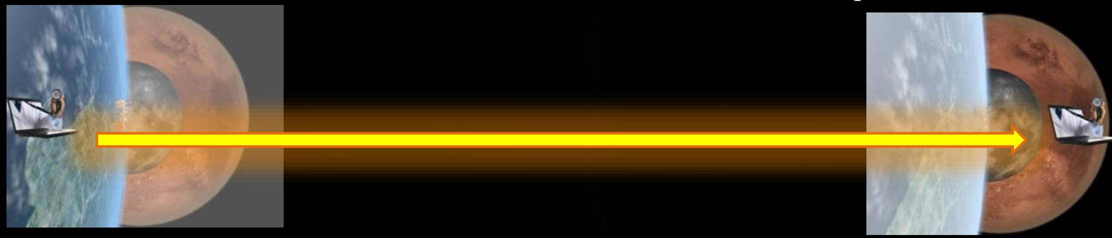
- Unique spaceflight applications
  - Atypical target (e.g. pneumothorax)
  - Potential countermeasure (e.g. bone, kidney stone)

Remote Guidance: Lessons Learned

- Current use not optimized → streamline!
  - Eliminate "common sense" procedures
    - Good images easily recognizable
    - Use intrinsic guidance, image enhancement capabilities
  - Time management key skill
    - Timeliness of clinical care
    - A la carte discrete modules – organize as needed
- Integrate Research and Ops information
- Evaluate Remote Guidance practices → autonomy

Exploration Remote Guidance

Current ISS Ops | **Exploration**



Remote guidance: reliant on ground

Store and forward underutilized

Data downlink:uplink ↑

Instrumentation: larger footprint
more resources
crew strapped to wall

Remote oversight → space-based expertise

↑use store and forward

Data uplink:downlink ↑

Best approach: data → crew

Instrumentation: streamlined
portable

Innovate: clinical ? addressed

Gateway Missions: Phase 0: ISS→ Phase 1: Cislunar→ Phase 2: Deep Space Transport→ Phases 3-4: Mars

Technology Watch: Remote Guidance

MENU | COMfORT | Baseline | Date: 2/9/2017 | ID: 9201 | NOTES | EXIT

FUNDOSCOPY | OBJECTIVE | FOUNDATION | SETUP | EXAM PROCEDURE | QUIZ | REFERENCE

Eye Anatomy | CellScope Use | Taking Images | Eye Pathology

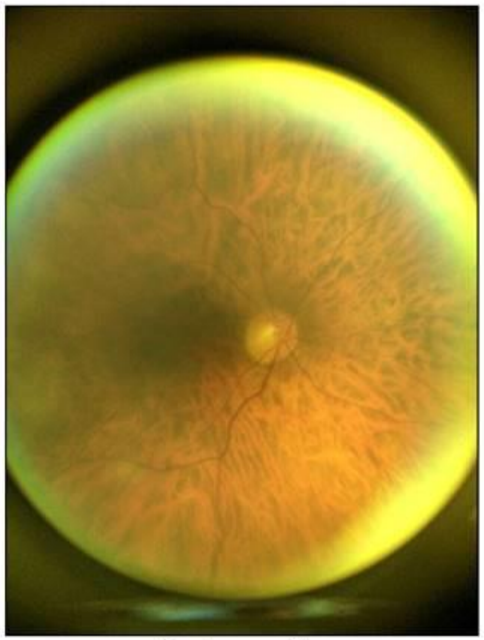
Taking a Good Image: Composition

Tips for good composition:

To move the optic disc down the subject needs to look up.

To move the optic disc right the subject needs to look right.

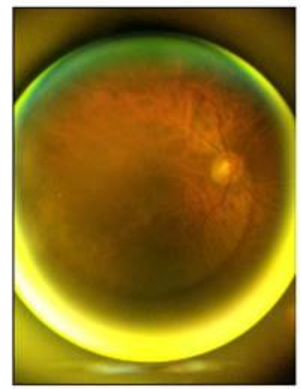
In a good composition the optic disc is centered.



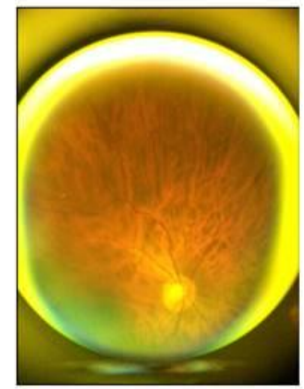
Good composition

Bad composition

In poor composition, the optic disc is not centered or not visible.



Bad composition
Optic disc is too far right



Bad composition
Optic disc is too low

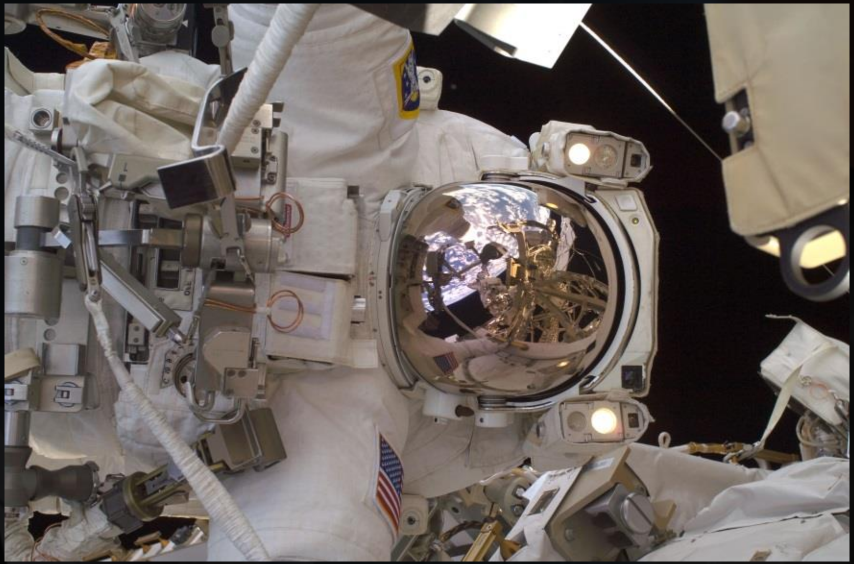
Comfort - NSBRI

PREVIOUS | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | NEXT

Technology Watch: Remote -> Autonomy

Augmented Reality Training
Tietronix

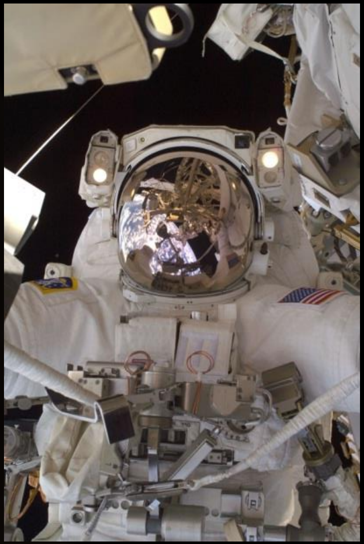
Live Monitoring



MEDB 7.2 PPC

ISS EVA Telemedicine

- Live monitoring by ground (including prebreathe)
  - Biomedical (update every 2 min)
    - 1-lead heart rate, inlet CO_2
    - MET rate: O_2 tank pressure drop
  - Consumables
- EVA crew focus is mission tasks
- Continuous ground:crew communication



ISS EVA: Lessons Learned

- Additional EVA crew bioinformatics needed
  - Health
  - Performance (cognitive, physical)
- Suit outlet CO_2 measurement needed
- In-suit maneuverability limited
- Suit = vehicle
  - "The most at home I felt in space was in my suit."
  - In-flight temperature changes extreme (vs training)
  - Airlock- first completely unique spaceflight experience

Exploration EVA

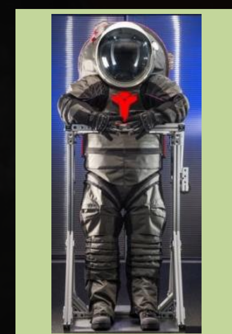
Current ISS Ops

Exploration

Live monitoring: reliant on ground

Live monitoring → space-based expertise

Mission tasks



Mission tasks

Bioadvisory information

Navigation

Consumables tracking

Gateway Missions: Phase 0: ISS→ Phase 1: Cislunar→ Phase 2: Deep Space Transport→ Phases 3-4: Mars

ISS Behavioral Telemedicine

- WinSCAT (5 tests: assess memory, baseline in case of head injury)
- Standard measures (preflight, 3x in-flight)
  - Actigraphy
  - Cognition testing (10 tests)
  - Self-reporting

Behavioral Telemed: Lessons Learned

- Losing key information
  - Collect, analyze current data
  - Ops impact → telemedicine feedback
    - Delay information before critical tasks?
    - Behavioral training
      - Mindfulness
      - Crew → effective and empowered
- Team communication more efficient
  - Behavioral training
  - Differing philosophies from international partners
- Guidelines: “countermeasure” → standard

Terrestrial Application: Live Monitoring

Zephyr's medical grade technology was originally developed in conjunction with Special Forces and NASA and designed to measure and monitor the vital signs of individuals and teams in training or when deployed in hazardous environments

RP-7 remote presence robot, nicknamed "Rosie"

The use of remote presence for health care delivery in a northern Inuit community: a feasibility study

Ivar Mendez[1]*, Michael Jong[2], Debra Keays-White[3] and Gail Turner[4]

[1]Remote Medicine Program, Division of Neurosurgery, Dalhousie University and Queen Elizabeth II Health Sciences Centre, Halifax, NS, Canada; [2]Faculty of Medicine, Memorial University, St. John's, NL, Canada; [3]Health Canada, First Nations and Inuit Health Branch Atlantic, Halifax, NS, Canada; [4]Nunatsiavut Department of Health and Social Development, St. John's, NL, Canada

Exploration Live Monitoring

Current ISS Ops

Live monitoring:
PMCs, PPCs reliant on ground

Ground-based Flight Surgeon

Exploration

Live monitoring → space-based

?

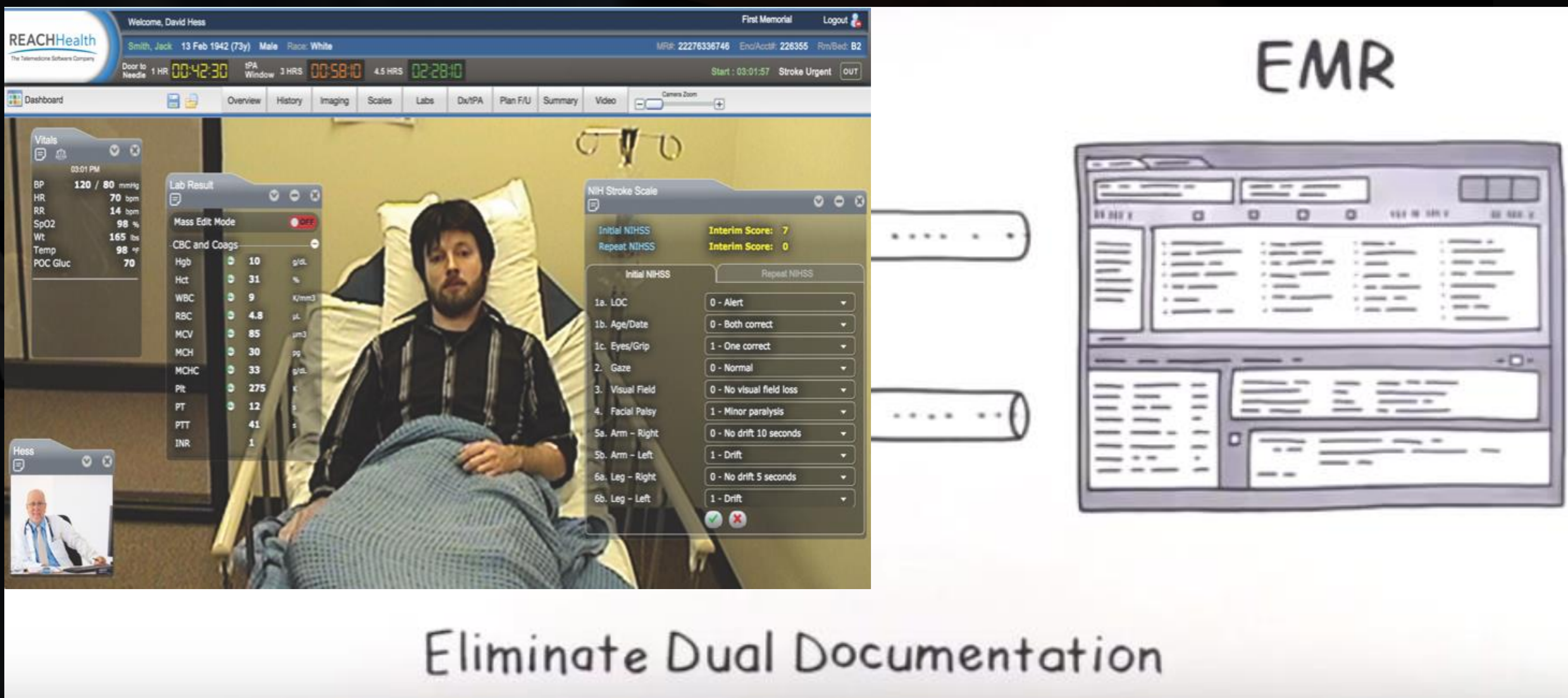
Crew Medical Officer? Self? Computer?

Physiological monitoring

Automated, integrated, interactive

Gateway Missions: Phase 0: ISS→ Phase 1: Cislunar→ Phase 2: Deep Space Transport→ Phases 3-4: Mars

Technology Watch: Live Monitoring



Technology Watch: Live Monitoring

Reveal LINQ™ ICM Remote Monitoring

Wireless Transmission with MyCareLink™ Patient Monitor

Supported by the Medtronic CareLink™ Network

MyCareLink Patient Monitor is easy to use and features global cellular technology

Medtronic CareAlert™ notifications can result in earlier clinical decisions compared to non-wireless devices[1]

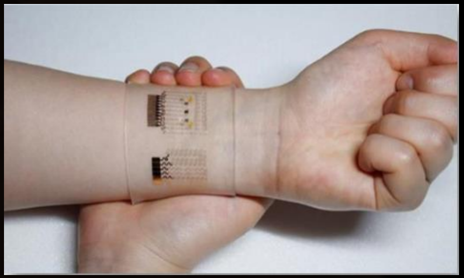
Patient compliance is easy and automatic with wireless device-to-monitor communication[2]

Continuous and wireless data collection and trending in the world's smallest insertable cardiac monitor.[3]

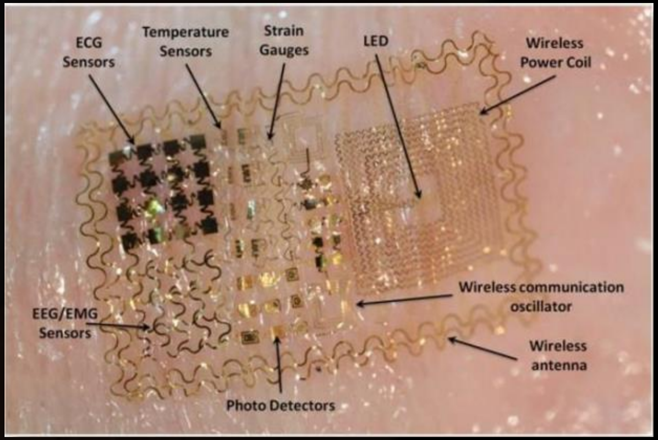
World's Smallest ICM

79%

of physicians said wireless CareAlert™ notifications resulted in earlier clinical decisions*[1]



Nature Nanotechnology 11, p566, 2016.



SEEQ Mobile Cardiac Telemetry System: Medtronic

Technology Watch: Live Monitoring

PTSD VR therapy session

A Multi-Media, Computer-Based, Self-Directed, Autonomous, Stress and Anxiety-Management Countermeasure Project

NSBRI

SMART OP

Therapist Training on Cognitive Behavior Therapy for Anxiety Disorders Using Internet-Based Technologies

Kenneth A. Kobak[1] · Kate Wolitzky-Taylor[2] · Michelle G. Craske[3] · Raphael D. Rose[3]

Cogn Ther Res (2017) 41:252–265

Store and Forward

ISS Telemedicine: Audiology

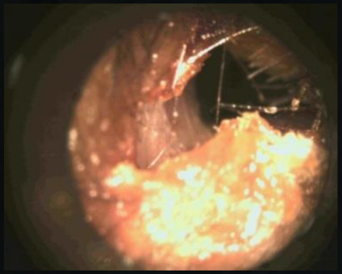
- Videotoscopy
  - Still images (nominal)
  - EVA (before, after)

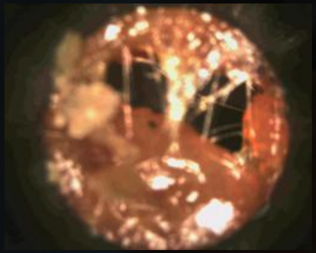

- On-orbit hearing assessment (OOHA)
  - 45 days  +EarQ software
  - Match OOHA with acoustic dosimetry

- Store and forward data exchange

Audiology: Lessons Learned

- Otoacoustic emissions (OAE)
  - More objective, sensitive than audiometric test
  - Earlier alert to auditory damage
- Match OOHA with time of acoustic dosimetry (taken every 60 days)
- EarQ software reliable
- Cerumen management plan required

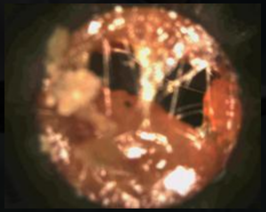




Exploration Telemedicine: Audiology

Current ISS Ops

Space vehicle noisy (legacy waivers)



?

Exploration

+

New space vehicle quieter ~~waivers~~

?

Gateway Missions: Phase 0: ISS→ Phase 1: Cislunar→ Phase 2: Deep Space Transport→ Phases 3-4: Mars

ISS Telemedicine: Exercise

- Exercise application software
  - Store and forward data for feedback
  - Limited real time feedback (HR, speed)
- Regular generated report (every 2 wks)
  - In-flight exercise monitoring- ASCRs
  - Exercise data review- crew surgeon

Store and Forward: Lessons Learned

- ISS exercise program successful ≠ 100% protective

Peak Exercise Oxygen Uptake During and Following Long-Duration Spaceflight

Alan D. Moore, Jr.[1], Meghan E. Downs[2], Stuart M. C. Lee[1], Alan H. Feiveson[3], Poul Knudsen[4], Lori Ploutz-Snyder[5]

Articles in PresS. J Appl Physiol (June 26, 2014). doi:10.1152/japplphysiol.01251.2013

Isokinetic Strength Changes Following Long-Duration Spaceflight on the ISS

Kirk L. English; Stuart M.C. Lee; James A. Loehr; Robert J. Ploutz-Snyder; Lori L. Ploutz-Snyder

AEROSPACE MEDICINE AND HUMAN PERFORMANCE Vol. 86, No. 12, Section II December 2015

- Challenge seeing crewmember as whole

 +  +  +  +  + 

- Multiple platforms → single extensible
  - Data portal, common interface, robust feedback
  - Common wearable/collection, device

Exploration Telemedicine: Store ↔ Forward

Current ISS Ops

Exploration

Store and Forward: ground support-based

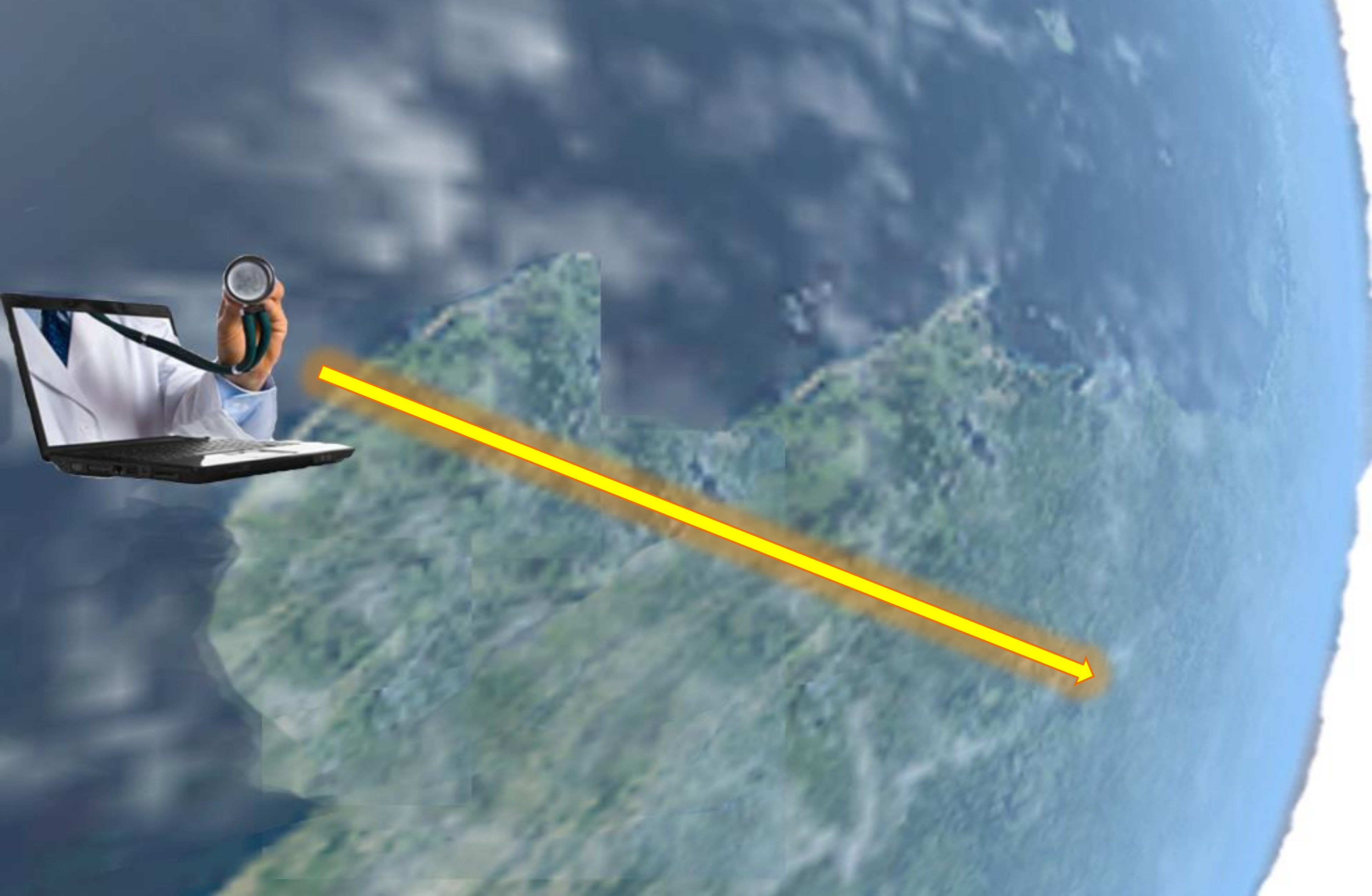
Store and Forward: space-based

Data

Data

Gateway Missions:	Phase 0: ISS→	Phase 1: Cislunar→	Phase 2: Deep Space Transport→	Phases 3-4: Mars

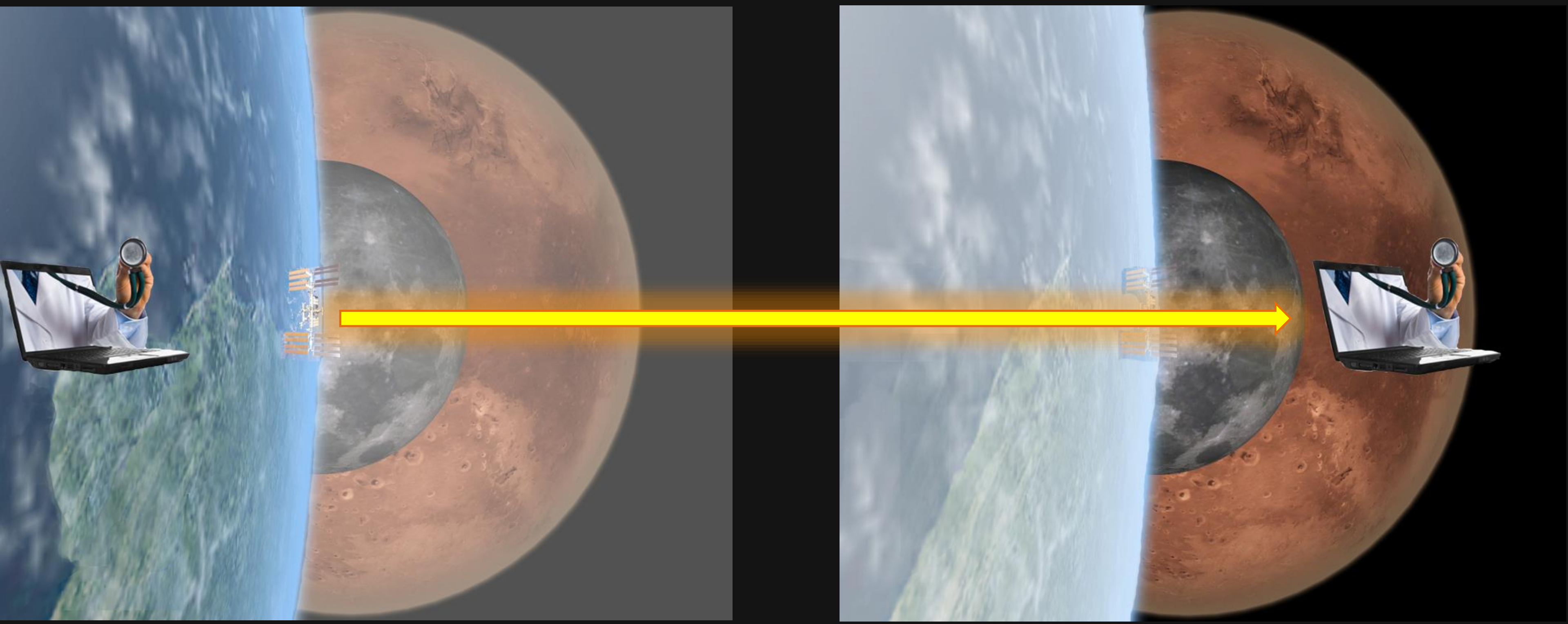
Autonomous



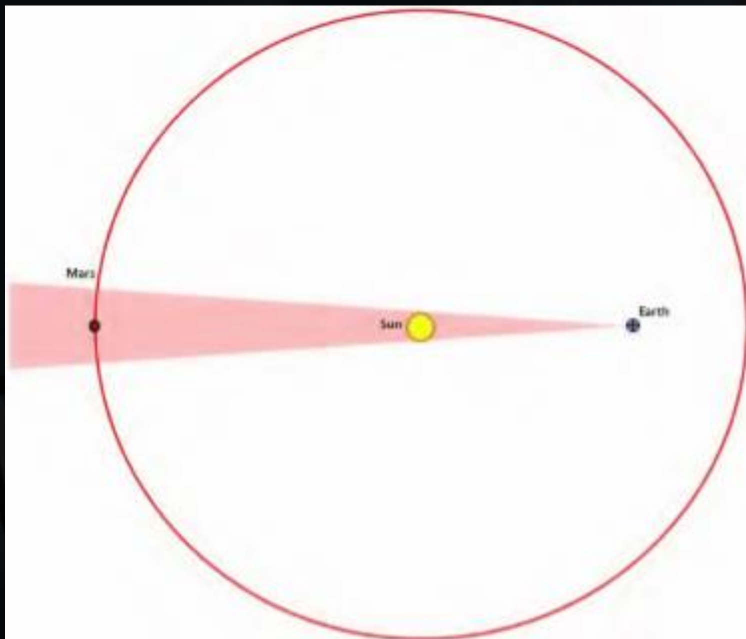
Autonomous: Antarctica

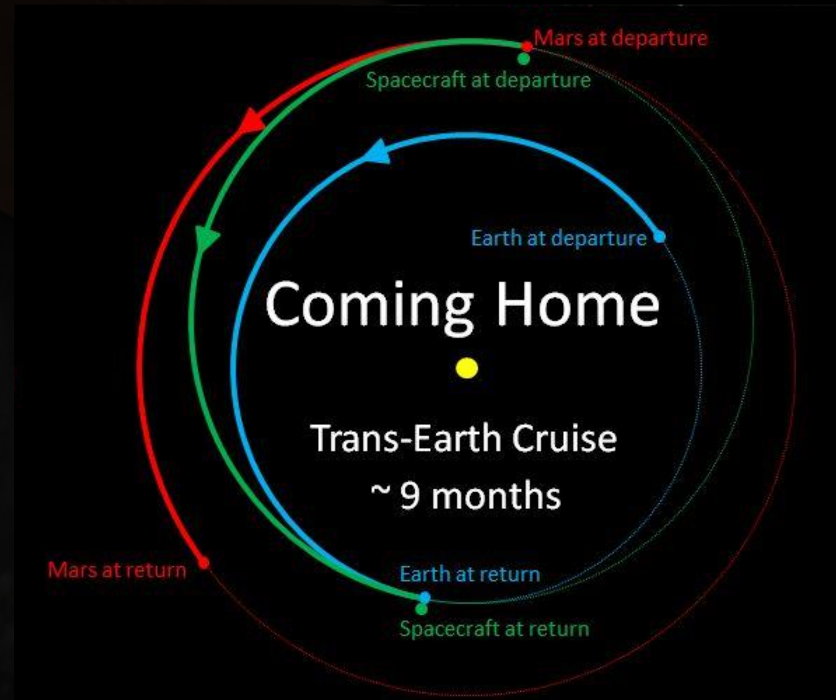
- Ops lessons learned
  - ISS training more streamlined
  - Isolated but telemedicine largely successful
- Lessons learned for Exploration
  - Need to be able to perform autonomous routine exams (including dental)
  - Exploration support
    - Telemedicine simulations (including in-flight training options) need to be refined now
    - Multipurpose supplies
- Excellent ICE analog

Moving Towards Mars



Moving Towards Mars





Mars Mission Concept of Operations, Aug 2016. S. Love, E. Nelson

Destination	Distance (kilometers)	One-Way Time Delay (minutes)
ISS	435	ε
Lunar	38,400,000	0.02
Mars (close)	545,000,000	3
Mars (opposition)	4,013,000,000	22.3

Approximate Comm Delays

Moving Towards Mars: Telemedicine

Current ISS Ops | **Exploration**

Reliant on ground
Limited compliance

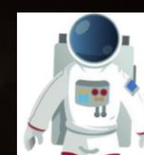
Space-based:  tasks, monitoring
High compliance

Data downlink:**uplink** ↑

Population-based: pharm, imm, predictive
Multiple system approach

Ethics contingencies, behavioral intervention
Equipment: larger footprint

Data **uplink**:downlink ↑



Crewmember tailored, integrative

Policy, procedure updates
Equipment: streamlined

Gateway Missions: Phase 0: ISS→ Phase 1: Cislunar→ Phase 2: Deep Space Transport→ Phases 3-4: Mars

2024 Gateway

Test data handling

Optimize for 42 day missions

2027 Deep Space

Exercise data handling and ground operations changes

2029 One Year Pathfinder

Exercise deep space comm, automony, and decision paths

Deploy revised ground con ops

2033 Mars Transit

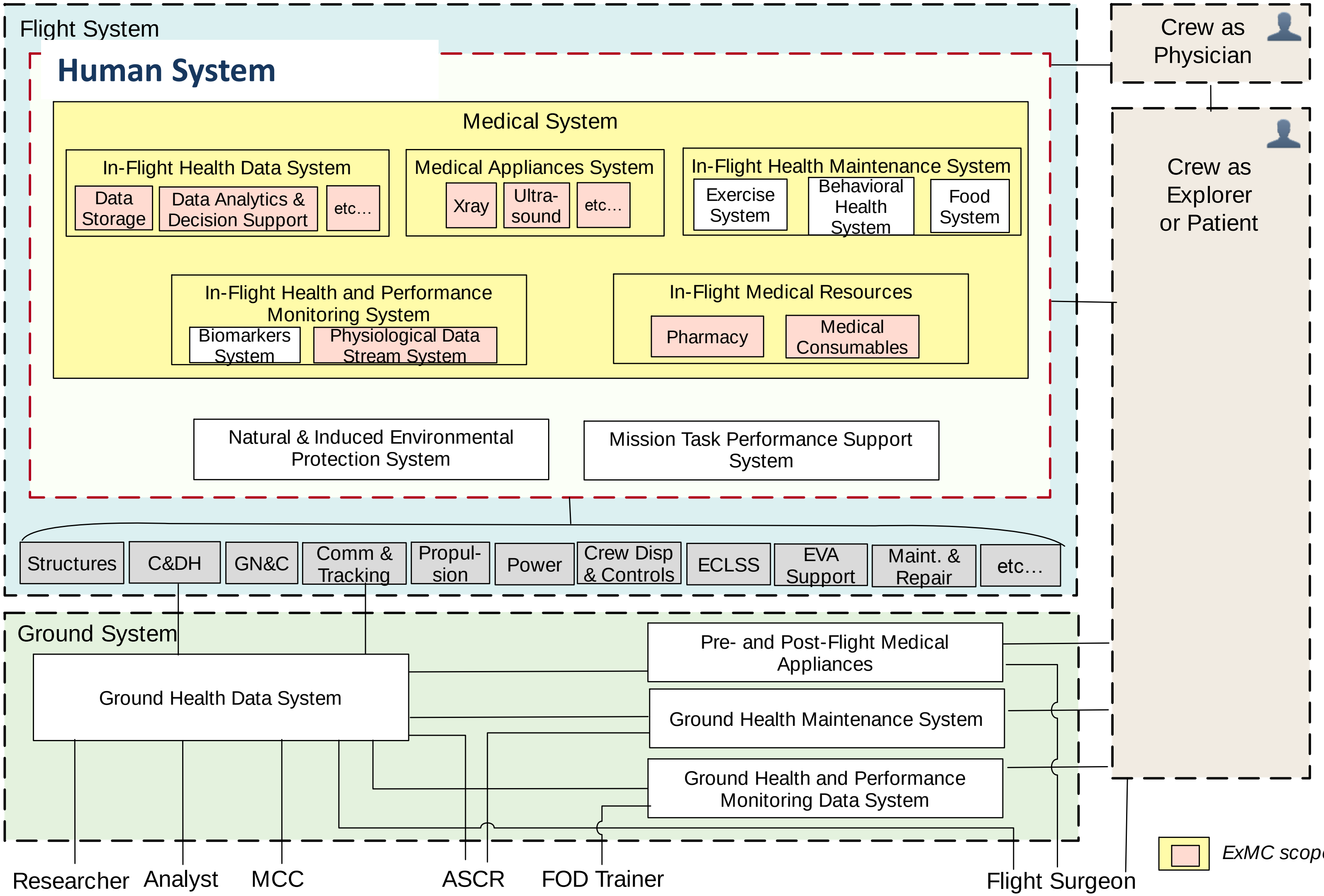
Fully autonomous health system

Redefined ground operations paradigm

System Integration

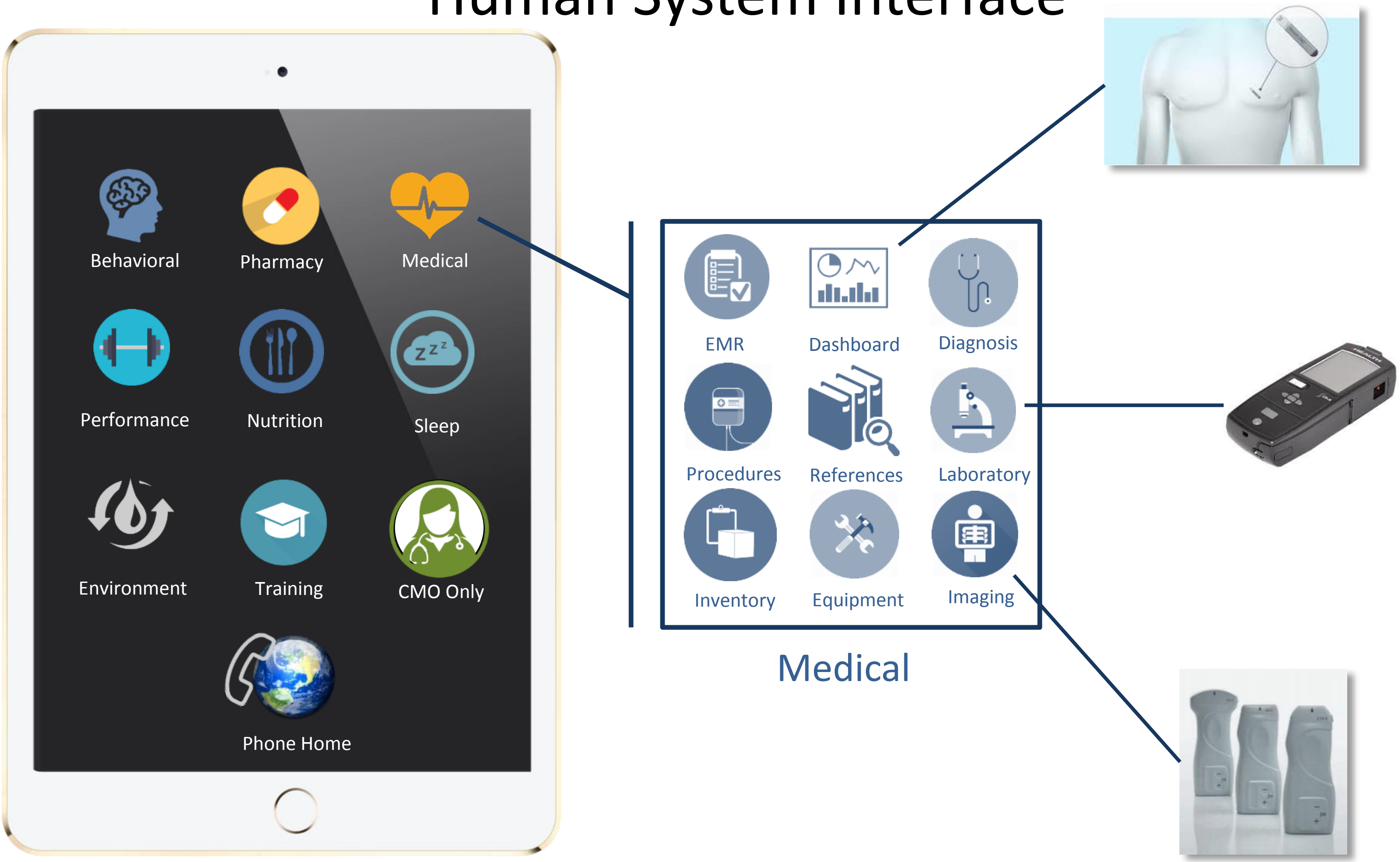
Work in Progress
3/16/17

Block Diagram - Medical System-Centric View



Notional

Human System Interface

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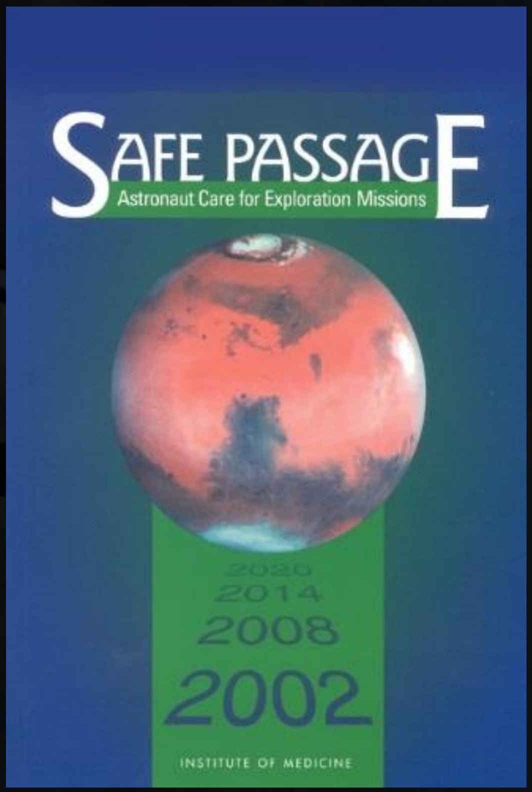
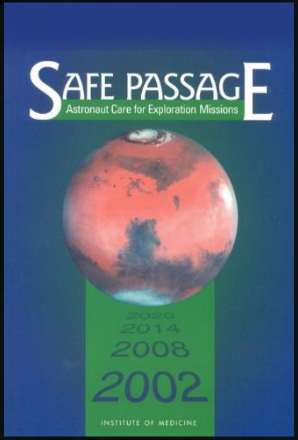


From Conclusion 6:
"The human being must be integrated into the space mission in the same way in which all other aspects of the mission are integrated."

Back up slides



From Conclusion 6:
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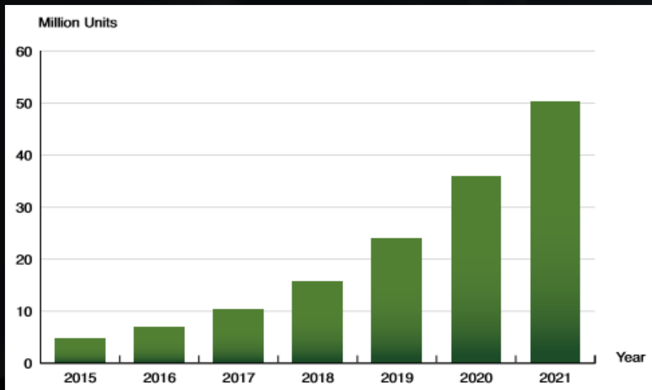
Technology Watch: Remote Guidance



Connected home medical monitoring devices, million units (World 2015–2021)

Berg Insight 2016

Augmented Reality Training
Tietronix

Robot-assisted ultrasound imaging: Overview and development of a parallel telerobotic system

REZA MONFAREDI[1,2], EMMANUEL WILSON[1], BAMSHAD AZIZI KOUTENAEI[1], BRENDAN LABRECQUE[3], KRISTEN LEROY[3], JAMES GOLDIE[3], ERIC LOUIS[3], DANIEL SWERDLOW[4] & KEVIN CLEARY[1]

Even where the sonographer is onsite, robotic-assisted US imaging could take some of the physical burden from the sonographer…

Lessons learned from the usability assessment of home-based telemedicine systems

"Small pop-up boxes showing the functions of icons could improve the information quality of the system."

"The system has four windows. It's confusing."

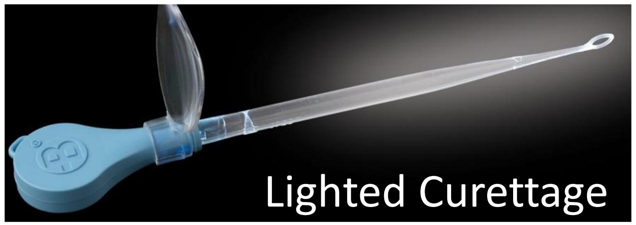
"Simple and clean interface"

"I really like the tool tips when I hover over the buttons."

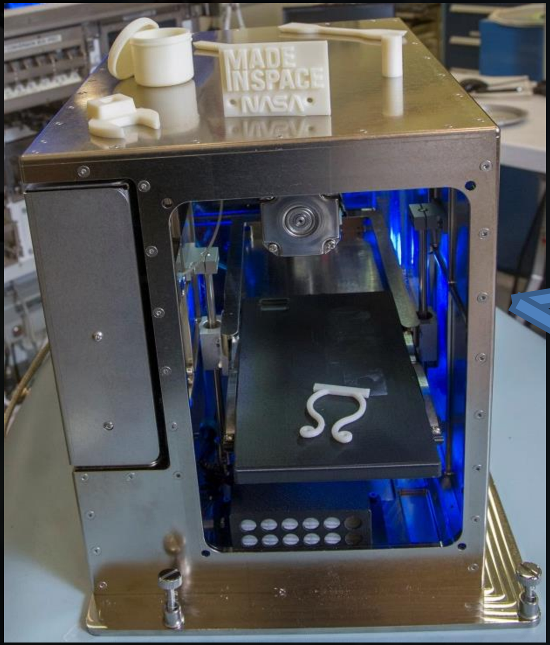
Applied Ergonomics 58 (2017) 424–434

Human Factors matter!

Technology Watch: Store and Forward



BIONIX GOING BEYOND



cellscope

Honeywell