Rural Doctor for Mars: Medicine in the Final Frontier

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I have financial interests in the above entities.

Today I am speaking in my capacity as an Assistant Director for NASA
The entire experience of our species fits into that blue dot.

Adapted from S. Love, E. Nelson, Mars Mission Concept of Operations, Aug 2016
Observation Hill
Can we just use what we already know?
How is medical care provided in mission?

- **Live remote guidance**

- **Live monitoring**

- **Store and forward**

- **Autonomous**
What does autonomous mean?

Can be up to 150 people working the first 1 hour of a critical situation

MCC Staffing

Early 2000s

2019
Fire and Toxic Exposure
Near Drowning in EVA
SANS – adaptation or pathology?
Urinary Tract Infections and Sepsis

In-flight Post-void Ultrasound

Ground Post-void Ultrasound
## Exploration Medical Conditions

### SKIN
- Burns secondary to Fire
- Skin Abrasion
- Skin Laceration

### EYES
- Acute Glaucoma
- Eye Corneal Ulcer
- Eye Infection
- Retinal Detachment
- Eye Abrasion
- Eye Chemical Burn

### EARS, NOSE, THROAT
- Barotrauma (sinus block)
- Nasal Congestion (SA)
- Nosebleed (SA)
- Acute Sinusitis
- Hearing Loss
- Otitis Externa
- Otitis Media
- Pharyngitis

### DENTAL
- Abscess
- Caries
- Exposed Pulp
- Tooth Loss
- Crown Loss
- Filling Loss

### CARDIOVASCULAR
- Angina/Myocardial Infarction
- Atrial Fibrillation / Atrial Flutter
- Cardiogenic Shock secondary to Myocardial Infarction
- Hypertension
- Sudden Cardiac Arrest
- Traumatic Hypovolemic Shock

### GASTROINTESTINAL
- Constipation (SA)
- Abdominal Injury
- Acute Cholecystitis
- Acute Diverticulitis
- Acute Pancreatitis
- Appendicitis
- Diarrhea
- Gastroenteritis
- Hemorrhoids
- Indigestion
- Small Bowel Obstruction

### MUSKULOSKELETAL
- Back Pain (SA)
- Abdominal Wall Hernia
- Acute Arthritis
- Back Injury
- Ankle Sprain/Strain
- Elbow Dislocation
- Elbow Sprain/Strain
- Finger Dislocation
- Fingernail Delamination (EVA)
- Hip Sprain/Strain
- Hip/Proximal Femur Fracture
- Knee Sprain/Strain
- Lower Extremity Stress fracture
- Lumbar Spine Fracture
- Shoulder Dislocation
- Shoulder Sprain/Strain
- Acute Compartment Syndrome
- Neck Injury
- Wrist Sprain/Strain
- Wrist Fracture

### NEUROLOGIC
- Space Motion Sickness (SA)
- Head Injury
- Seizures
- Headache
- Stroke
- Paresthesia
- Headache (SA)
- Neurogenic Shock
- VIIP/SANS (SA)

### PSYCHIATRIC
- Insomnia (Space Adaptation)
- Late Insomnia
- Anxiety
- Behavioral Emergency
- Depression

### GENITOURINARY
- Abnormal Uterine Bleeding
- Acute Prostatitis
- Nephrolithiasis
- Urinary Incontinence (SA)
- Urinary Retention (SA)
- Vaginal Yeast Infection

### INFECTION
- Herpes Zoster (shingles)
- Influenza
- Mouth Ulcer
- Sepsis
- Skin Infection
- Urinary Tract Infection

### IMMUNE
- Allergic Reaction
- Anaphylaxis
- Skin Rash
- Medication Reaction

### ENVIRONMENT
- Acute Radiation Syndrome
- Altitude Sickness
- Decompression Sickness (EVA)
- Headache (CO2)
Hazards of Spaceflight
Hazards Drive Human Spaceflight Risks

- Altered Gravity - Physiological Changes
- Distance from earth
- Space Radiation
- Hostile/ Closed Environment
- Isolation & Confinement
Progressive Earth Independence

- Real Time Communications
- Evacuation Capability (1.5 – 36 hrs)
- ‘Strong’ Consumables Resupply

- Near Real Time Communications
- Evacuation Capability (3-11 days)
- Limited Consumables Resupply

- No Real Time Communications
- No Evacuation Capability
- No Consumables Resupply

Increasing exposure to Hazards
Figure 1. Advanced RF and optical communications technologies combined with using the areostationary orbit offer 100-1000x greater data return from Mars and nearly continuous availability.

Source: SCaN Team (M.Seibert, J.Schier, D.Abraham, D.Cornwell, G.Fujikawa)
Legend:

- **X-band Earth link** (7.2 GHz up; 8.4 GHz down)
- **UHF relay link** (435-450 MHz up; 390-405 MHz down)

**ESA Mars Express**
- Orbit: 330 x 10,530 km
- Inclination: 93°

**MAVEN**
- Orbit: 150 x 4500 km
- Inclination: 74°

**Odyssey**
- Orbit: 400 km sun-synch
- Inclination: 87°

**MAVEN**
- Orbit: 150 x 4500 km
- Inclination: 74°

**ISRO Mars Orbiter Mission**
- Orbit: 423 x 80,000 km
- Inclination: 150°

Source: SCaN Team (M.Seibert, J.Schier, D.Abraham, D.Cornwell, G.Fujikawa)
Consumables Resupply

Gateway-Artemis
2024

Mars Transfer Vehicle
2027

Precursor
2029

Mars
2033

26-41 days
190-221 days
1 year
2 years
3 years

100%
100%
100%?
80%?
16%?

Current Operational Models Sufficient For Pharmacy Provision
Current Operational Models Inadequate For Pharmacy Provision
Return to Gravity
A Word about Risk

These results include all factors

Figure. Results on Retrospective Analysis on Shuttle Risk

STS-1 estimate includes crew escape with ejection seats (risk is 1:9 ratio without ejection seats). STS-1 risk may have been higher because of unquantified risks. The vertical lines indicate individual flights. Adapted from the National Aeronautics and Space Administration Aerospace Safety Advisory Panel.*

Bagian, JAMA Neurology January, 2019
Move Knowledge, Not People
Amplification – Use **Technology** to leverage scarce resources

**Case Based Learning** to master complexity

Share **Best Practices** to reduce disparity

Web-based **Database** to **Monitor Outcomes**
How do we validate tech for our environment?

Amplification - Use Technology to leverage scarce resources
How do we provide up to date knowledge support?

Share Best practices to reduce disparity.

For Clinical Decision Support in Space, NASA Astronauts Aboard International Space Station Turn to UpToDate from Wolters Kluwer

UpToDate is the first evidence-based clinical decision support system to be used in space as part of ISS Expedition.

(October 09, 2018 – 22:09 CEST) – October 10, 2018 – Wolters Kluwer (Nasdaq: WK) today announced that the National Aeronautics and Space Administration (NASA) is piloting the use of UpToDate® on board the International Space Station (ISS).
Level Ex® Receives Prestigious Grant from the Translational Research Institute for Space Health (TRISH) to help NASA Improve Medical Care During Space Missions

August 7, 2019

CHICAGO, August 7, 2019—Level Ex, creator of industry-leading medical video games for physicians, today announced it has received a significant grant from the Translational Research Institute for Space Health (TRISH) to build a virtual human simulation framework for NASA. Level Ex will simulate the human body’s anatomical and physiological changes in space, demonstrate how medical devices and procedures function differently in microgravity, and create high-fidelity simulations of the spacecraft environment. Level Ex will expand on this framework to recreate spaceflight medical scenarios for astronauts to train prior to space missions.

Astronauts can experience changes in the structure and function of the heart, eyes, vascular system, and other parts of the body due to prolonged exposure to space conditions. These significant transformations create a need for new methods to effectively understand...
A Crew Health and Performance System

Web-based Database to Monitor Outcomes

Behavioral
Pharmacy
Medical
Performance
Nutrition
Sleep
Environment
Training
CMO Only
Phone Home

EMR
Dashboard
Diagnosis
Procedures
References
Laboratory
Inventory
Equipment
Imaging

Medical
Data Sources Layer
- Health Records
- Medical Records
- Clinical Trials
- Other

Data Storage Layer
- Structured
  - Health Records
  - Medical Records
  - Clinical Trials
  - Other
- Unstructured
  - Medical devices
  - Monitoring System
  - Images
  - Logs & Notes
  - Exercise Machine
  - Other
- Streams
  - Bio Sensors
  - Env. Sensors
  - Other

Data Assets
- Knowledge Models
  - EHR
  - Documents
  - Sensor
  - Bio
  - Other

Analytical Layer
- Integrated Data Platform
- Data Models
  - Annotate
  - Correlate
  - Classify

Data Services
- Medical Decision Support System
- Analytics Data Mart
- Knowledge Base
- Reports
  - Dashboard
- Data Mining
  - Text mining
  - Statistical Modeling
- Modeling & Analytics
  - Predictive
  - Prescriptive
- Discovery
  - Search
- Real Time Apps
  - Alerts
- Cognitive Computing
  - Machine Learning

Discovery & Analytics
- Applications & Prototypes
- User Interface & Visualization

User Interface
- MetaData & Data Standards
- Federated Access & Delivery Infrastructure (FADI)
System Engineering Phases

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- Resource Commitments
- Design Flexibility
- System Knowledge