National Aeronautics and Space Administration

Rural Doctor for Mars: Medicine in the Final Frontier

October 12, 2019

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Wonca World Rural Health Conference

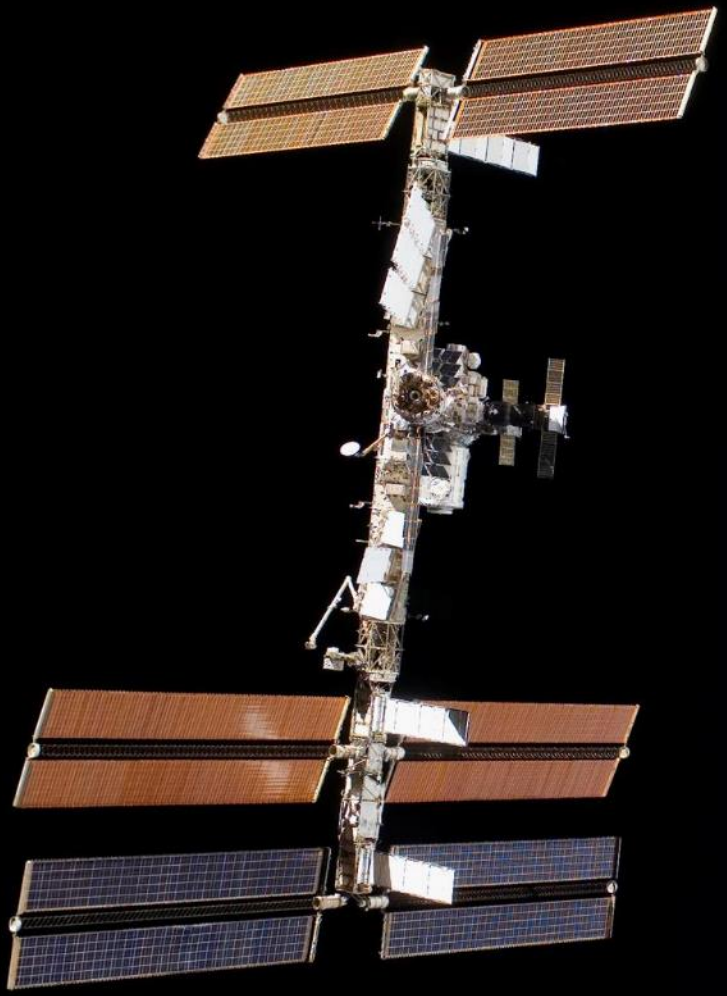
Conflicts of Interest Disclosure

1. Assistant Professor of Emergency Medicine, Baylor College of Medicine
2. Assistant Professor of Space Medicine, Center for Space Medicine
3. Attending Physician, Ben Taub General Hospital

4. Assistant Director, Human Health and Performance, NASA Johnson Space Center

I have financial interests in the above entities.

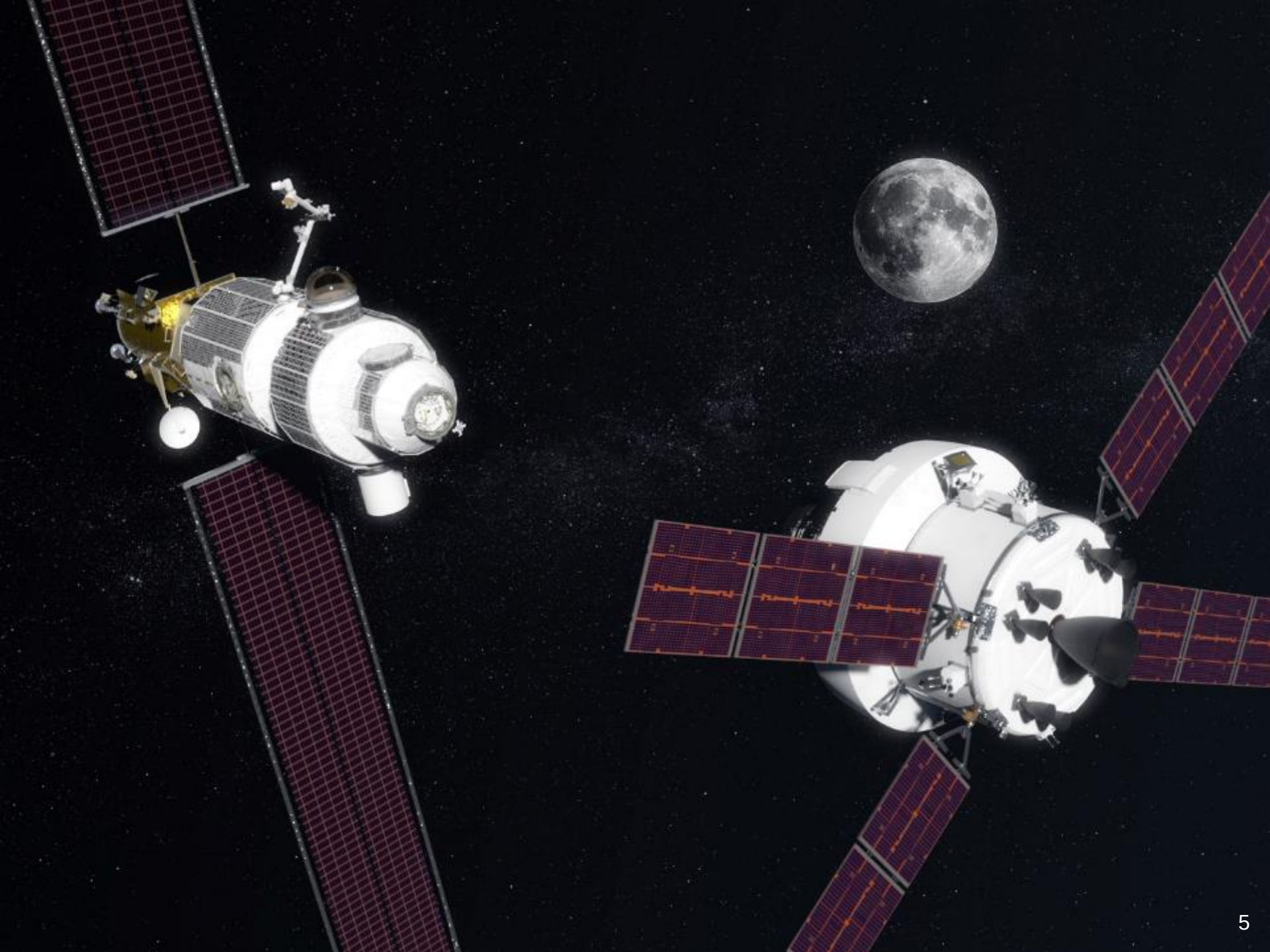
Today I am speaking in my capacity as an Assistant Director for NASA

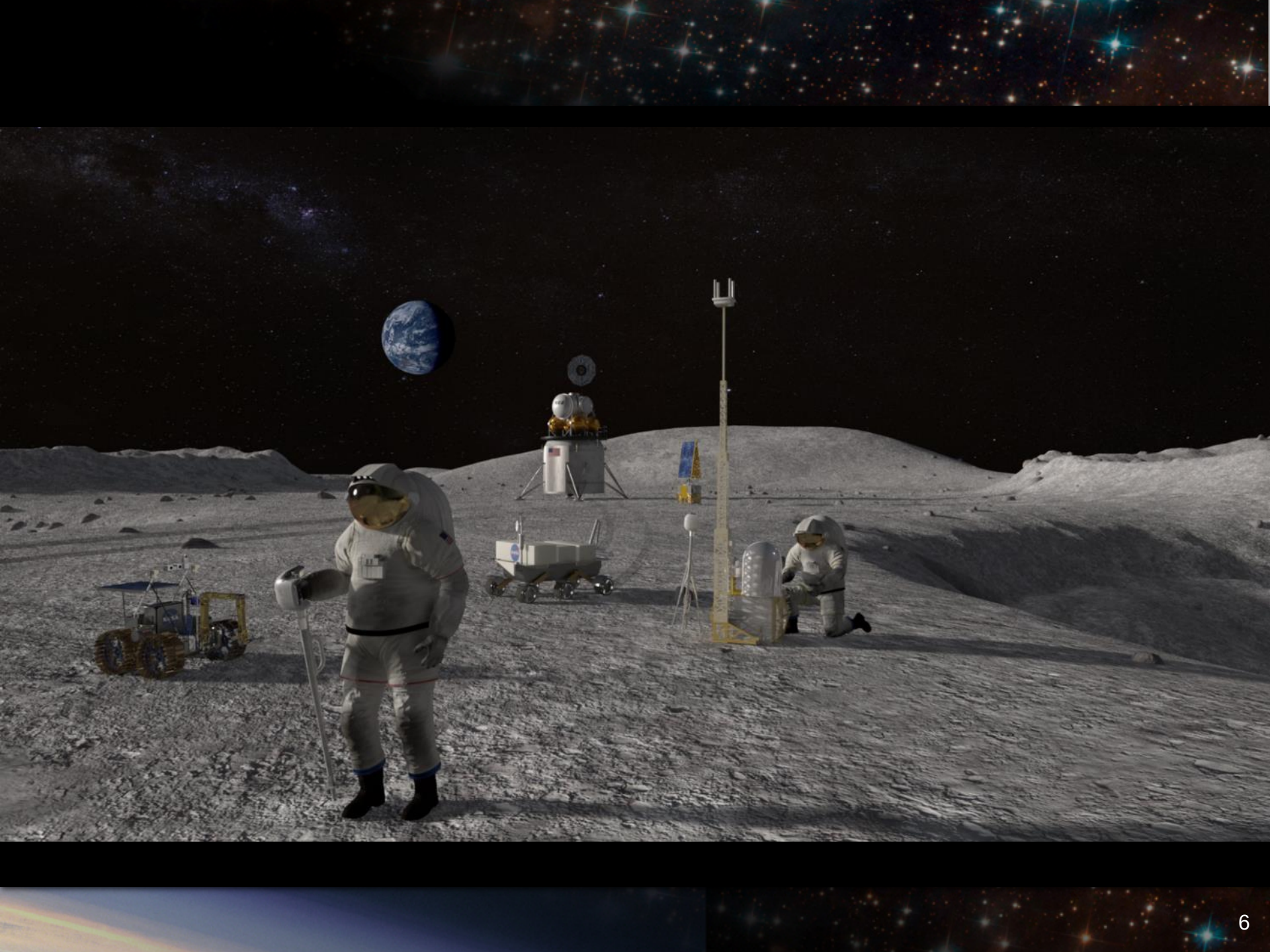


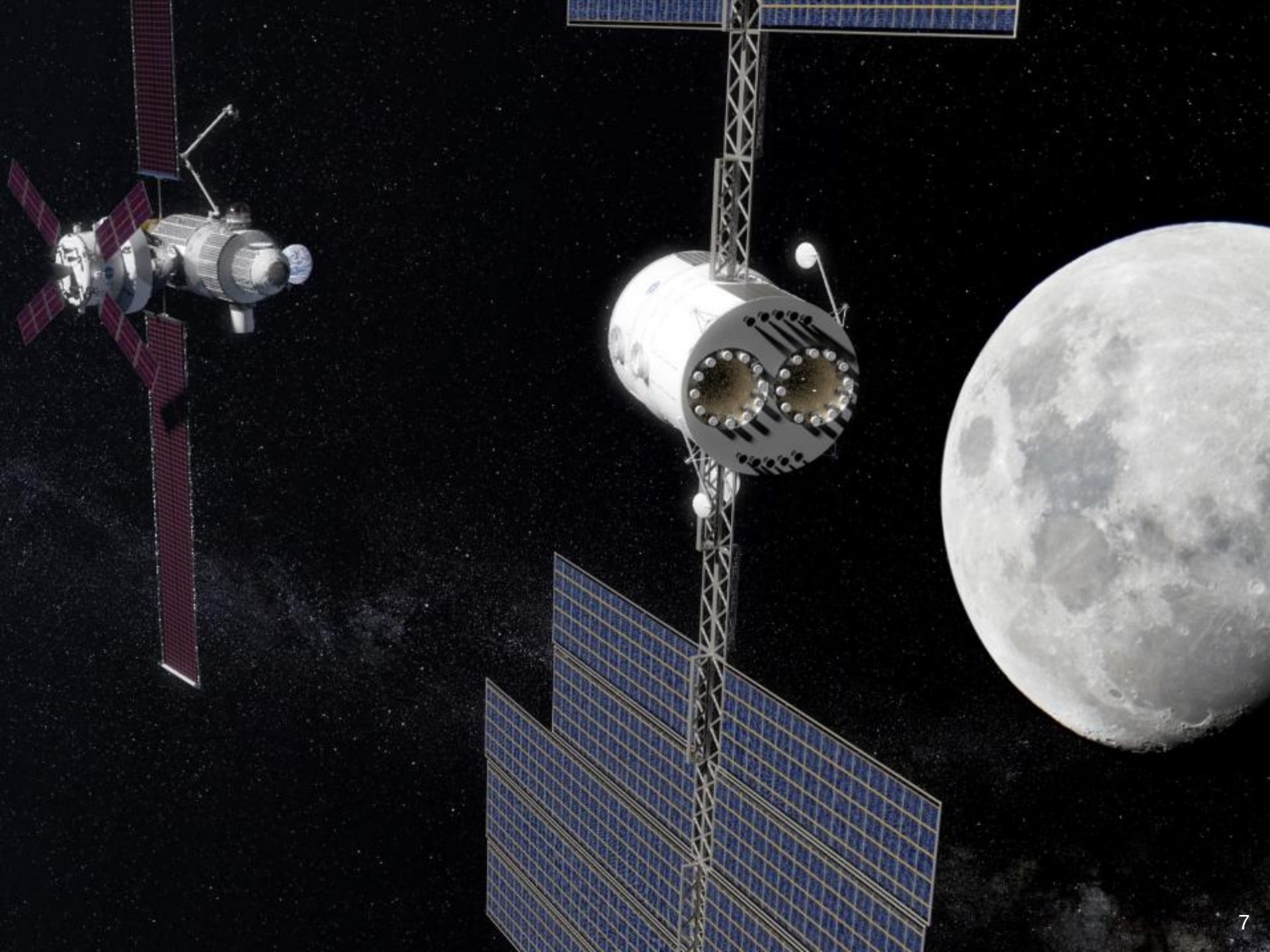
19

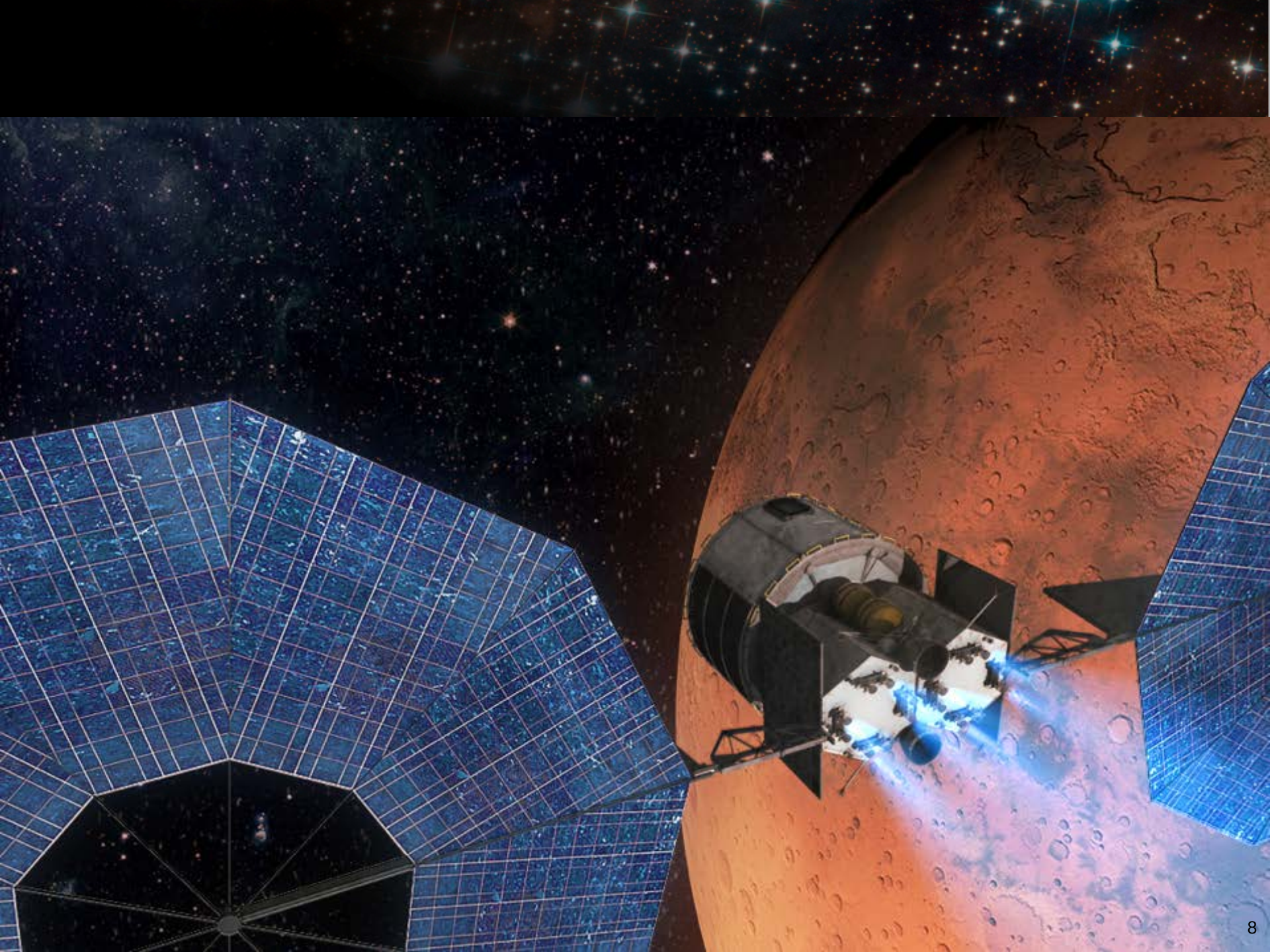
562

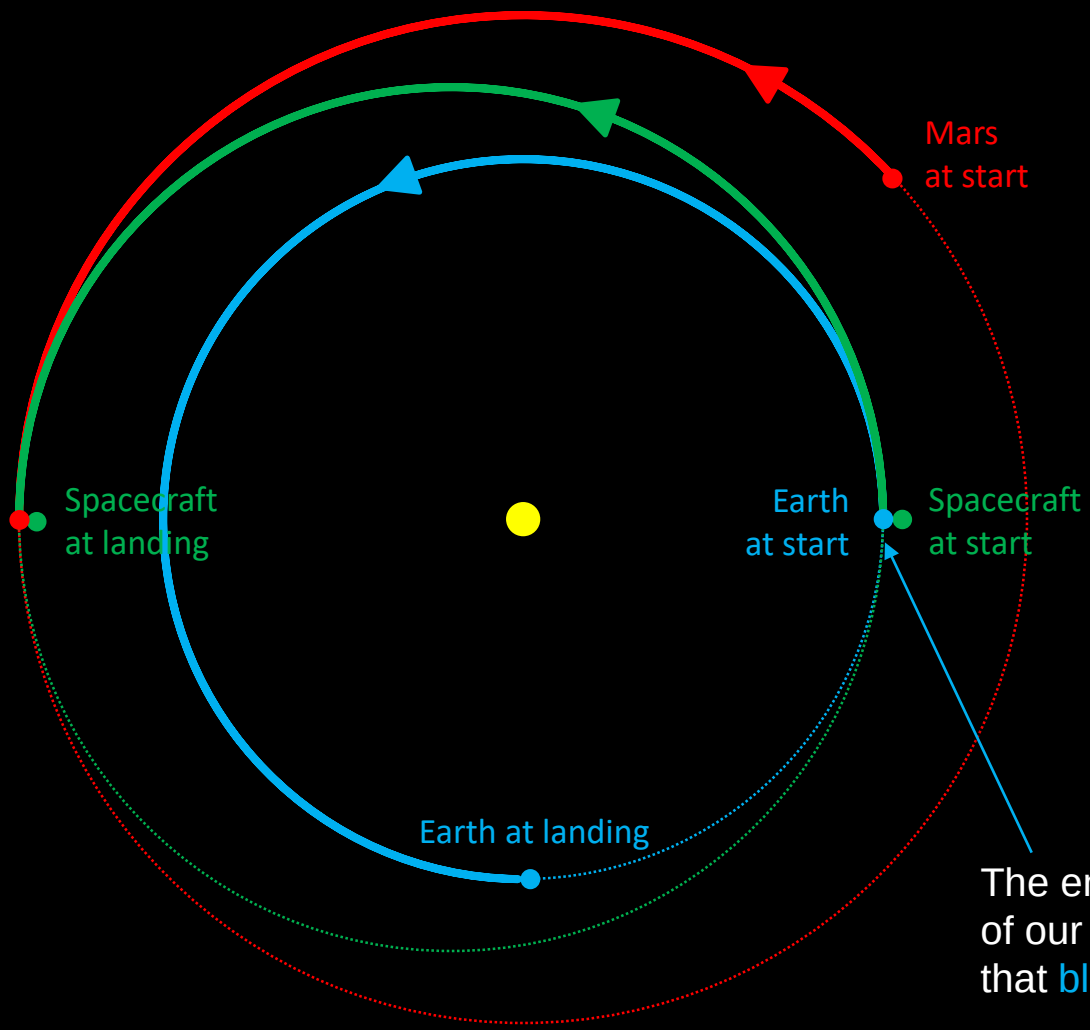
1 billion





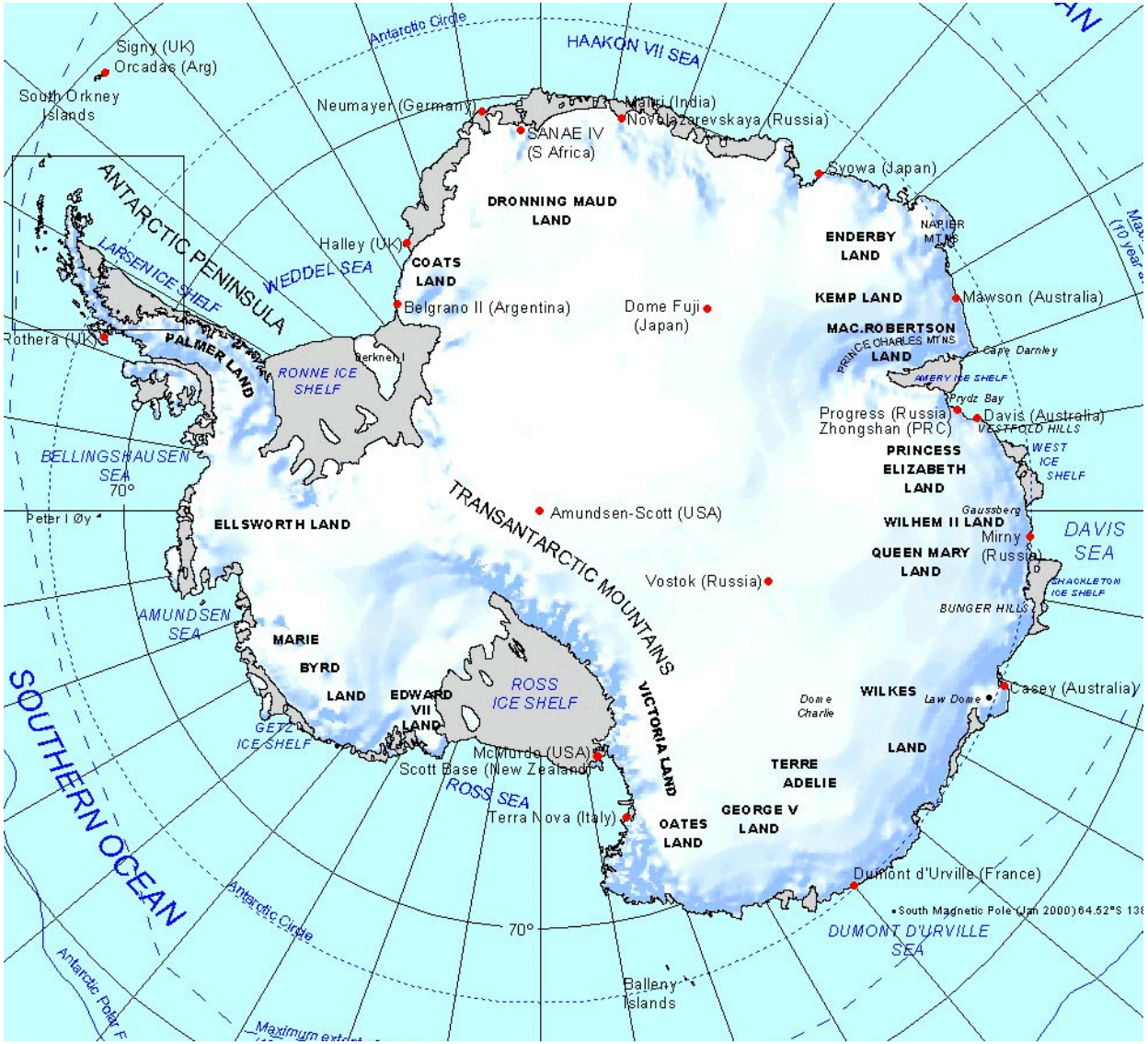






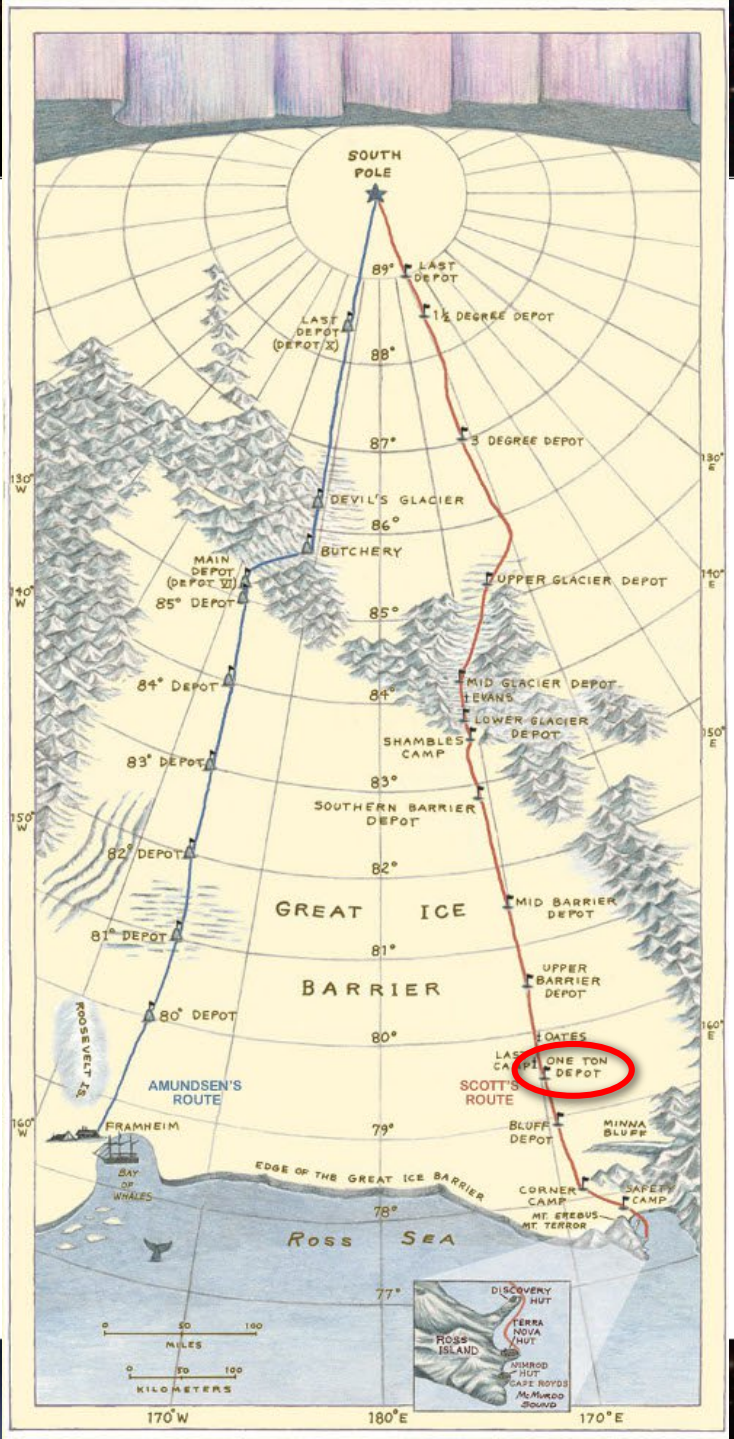
The entire experience of our species fits into that blue dot.

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

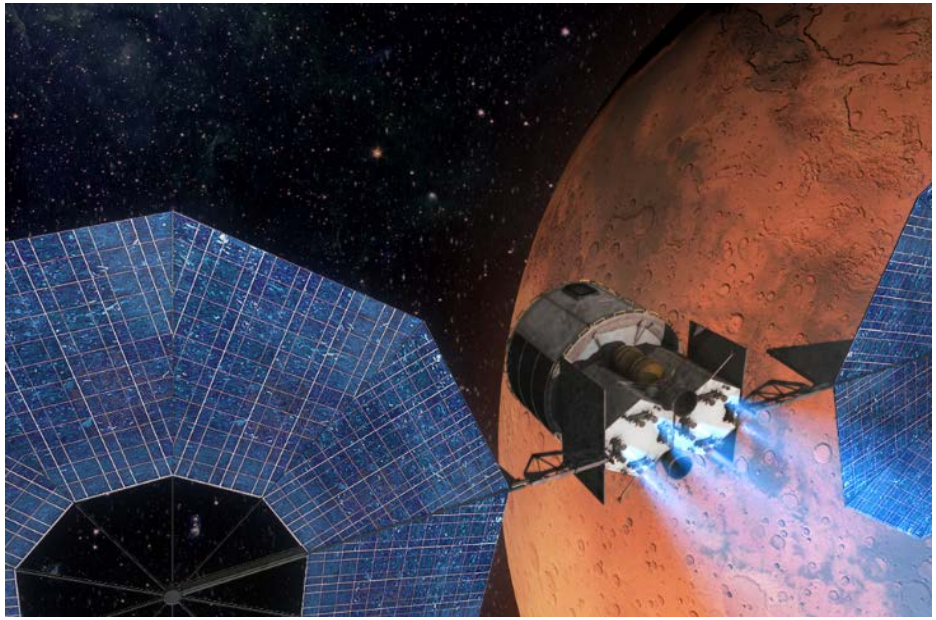

Signy (UK)
Orcadas (Arg)
South Orkney Islands
Antarctic Circle
HAAKON VII SEA
Neumayer (German)
Maitri (India)
Novolazarevskaya (Russia)
SANAE IV (S Africa)
Syowa (Japan)
DRONNING MAUD LAND
ENDERBY LAND
NAPIER MTNS
ANTARCTIC PENINSULA
LARSEN ICE SHELF
WEDDEL SEA
Halley (UK)
COATS LAND
Belgrano II (Argentina)
Dome Fuji (Japan)
KEMP LAND
Mawson (Australia)
MAC.ROBERTSON LAND
PRINCE CHARLES MTNS
Cape Darnley
AMERY ICE SHELF
Prydz Bay
Rothera (UK)
PALMER LAND
Berkner I.
RONNE ICE SHELF
Progress (Russia)
Zhongshan (PRC)
Davis (Australia)
VESTFOLD HILLS
PRINCESS ELIZABETH LAND
WEST ICE SHELF
BELLINGSHAUSEN SEA
70°
Peter I Øy
Amundsen-Scott (USA)
ELLSWORTH LAND
TRANSANTARCTIC MOUNTAINS
Gaussberg
WILHEM II LAND
Mirny (Russia)
DAVIS SEA
QUEEN MARY LAND
Vostok (Russia)
SHACKLETON ICE SHELF
BUNGER HILLS
AMUNDSEN SEA
MARIE BYRD LAND
EDWARD VII LAND
ROSS ICE SHELF
WILKES LAND
Dome Charlie
Law Dome
Casey (Australia)
GETZ ICE SHELF
SOUTHERN OCEAN
McMurdo (USA)
Scott Base (New Zealand)
VICTORIA LAND
TERRE ADELIE
ROSS SEA
Terra Nova (Italy)
GEORGE V LAND
OATES LAND
Dumont d'Urville (France)
South Magnetic Pole (Jan 2000) 64.52°S 138
Antarctic Circle
70°
DUMONT D'URVILLE SEA
Balleny Islands
Antarctic Polar F
Maximum extent

Observation Hill

1911 - 1912


SOUTH POLE
89° LAST DEPOT
1½ DEGREE DEPOT
LAST DEPOT (DEPOT X)
88°
87°
3 DEGREE DEPOT
DEVIL'S GLACIER
86°
BUTCHERY
MAIN DEPOT (DEPOT VI)
85° DEPOT
UPPER GLACIER DEPOT
85°
84° DEPOT
MID GLACIER DEPOT
84°
EVANS
LOWER GLACIER DEPOT
SHAMBLES CAMP
83° DEPOT
83°
SOUTHERN BARRIER DEPOT
82° DEPOT
82°
GREAT ICE
MID BARRIER DEPOT
81° DEPOT
81°
BARRIER
UPPER BARRIER DEPOT
80° DEPOT
80°
OATES
LAST CAMP
ONE TON DEPOT
ROOSEVELT IS.
AMUNDSEN'S ROUTE
SCOTT'S ROUTE
FRAMHEIM
79°
BLUFF DEPOT
MINNA BLUFF
BAY OF WHALES
EDGE OF THE GREAT ICE BARRIER
CORNER CAMP
SAFETY CAMP
MT. EREBUS
MT. TERROR
78°
ROSS SEA
77°
DISCOVERY HUT
TERRA NOVA HUT
ROSS ISLAND
ARMROD HUT
CAPE ROYDS
McMURDO SOUND
MILES
KILOMETERS
170°W
180°E
170°E

Can we just use what we already know?



How is medical care provided in mission?

- **Live remote guidance**




- **Live monitoring**

- **Store and forward**



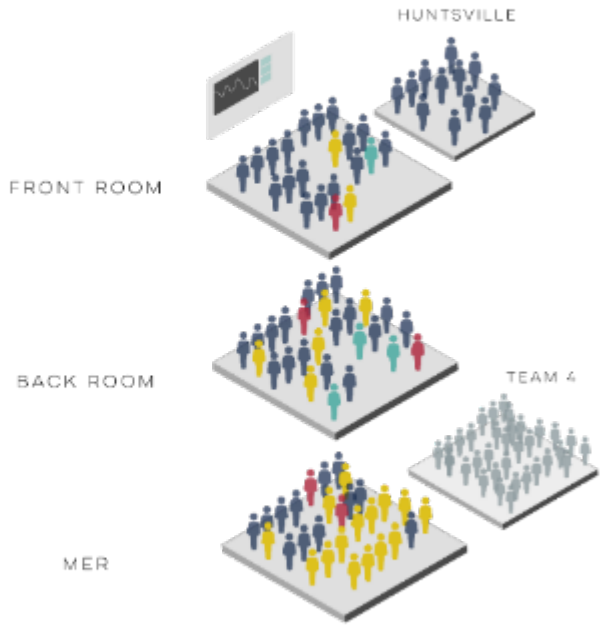

- **Autonomous**

What does autonomous mean?

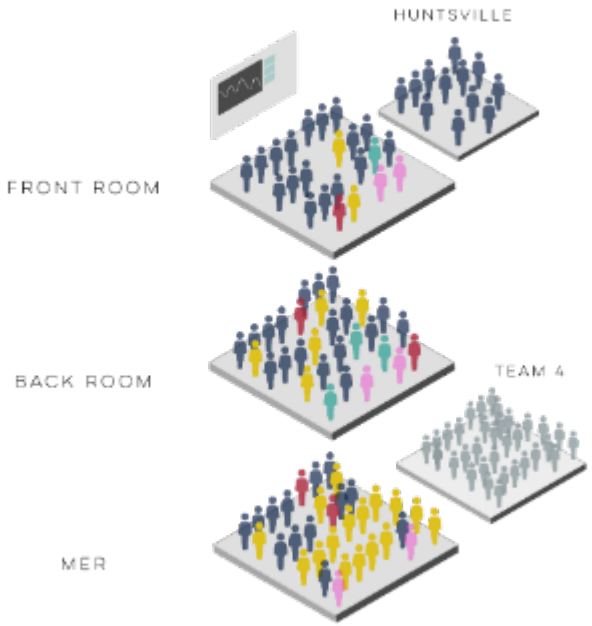
Can be up to 150 people working the first 1 hour of a critical situation

MCC Staffing

Early 2000s



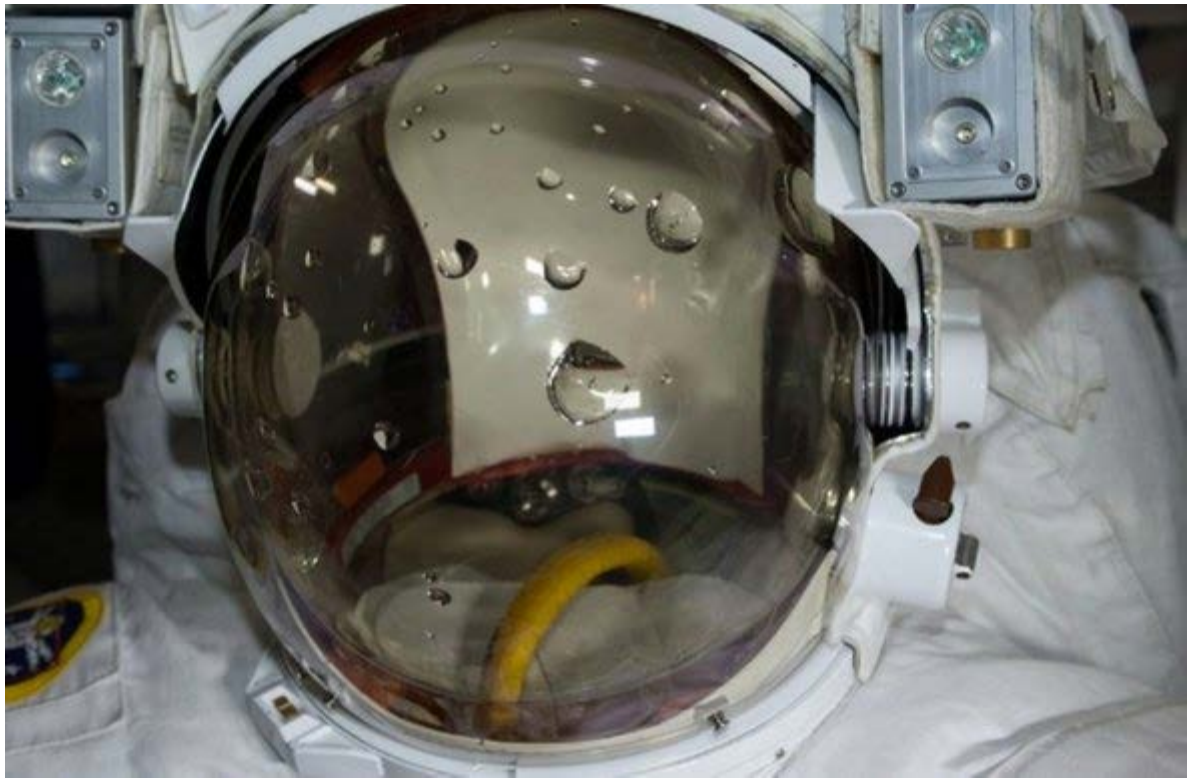
2019



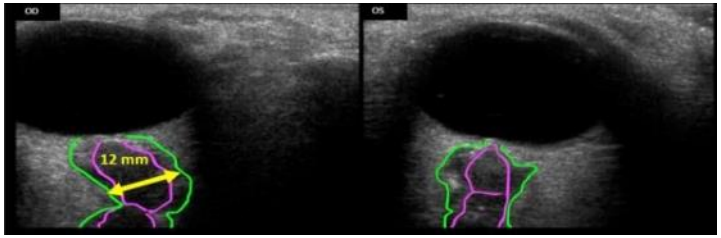
NOMINAL OPERATIONS
ROBOTICS OPERATIONS
EVA OPERATIONS
VISITING VEHICLE OPERATIONS AND STATION ASSEMBLY
JSL / OPS LAN SOFTWARE UPGRADE

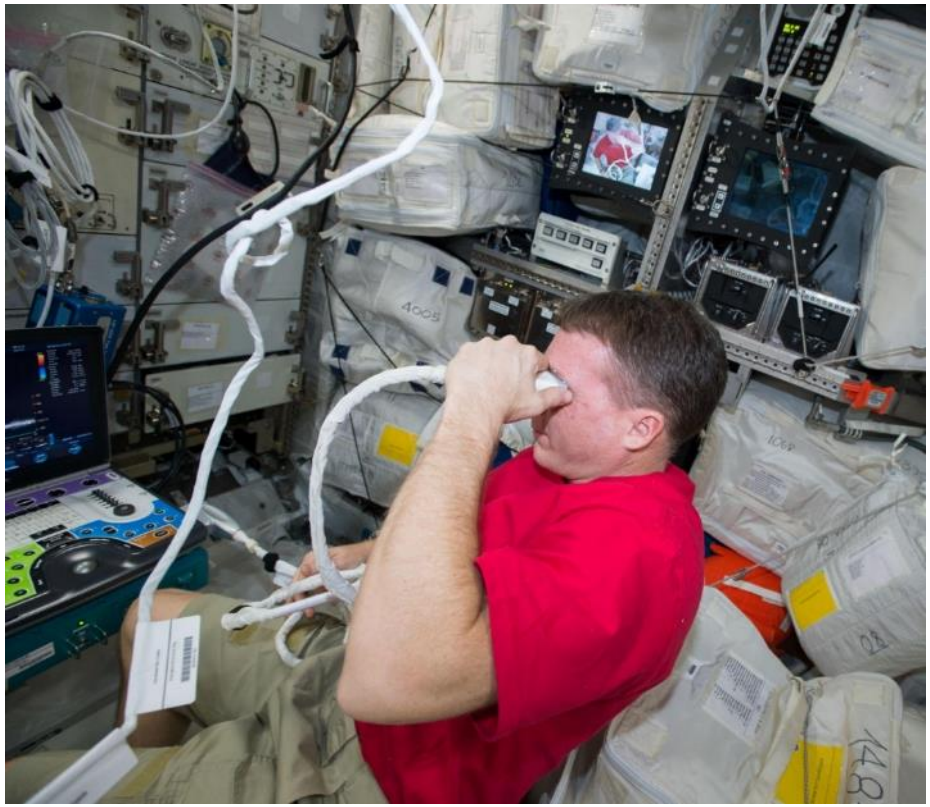
Fire and Toxic Exposure

Near Drowning in EVA

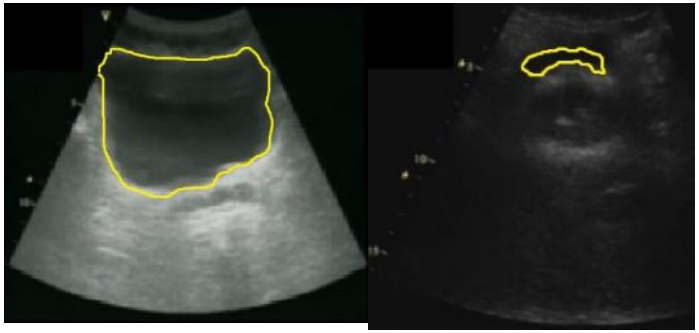


SANS – adaptation or pathology?





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
- Eye Penetration

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

PULMONARY
- Choking/Obstructed Airway
- Respiratory Infection
- Toxic Exposure: Ammonia
- Smoke Inhalation
- Chest Injury

*SA – Space Adaptation

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

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

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

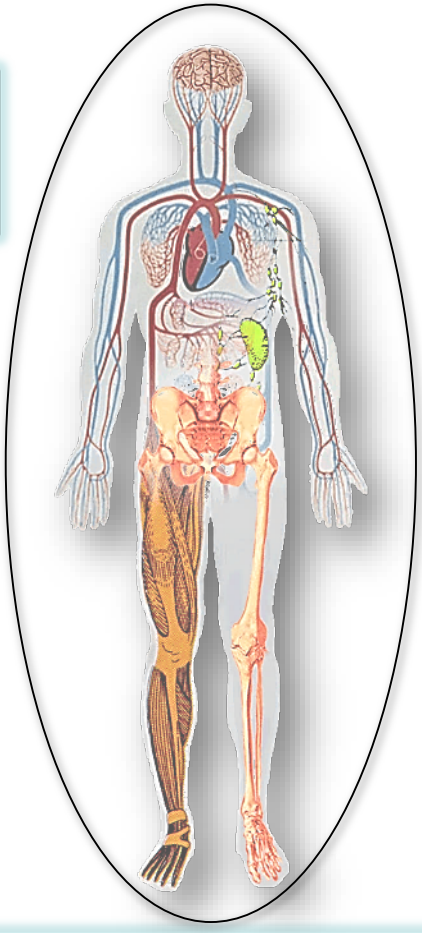
ENVIRONMENT
- Acute Radiation Syndrome
- Altitude Sickness
- Decompression Sickness (EVA)
- Headache (CO_2)

Hazards of Spaceflight

Hazards Drive Human Spaceflight Risks

Altered Gravity - Physiological Changes

Distance from earth



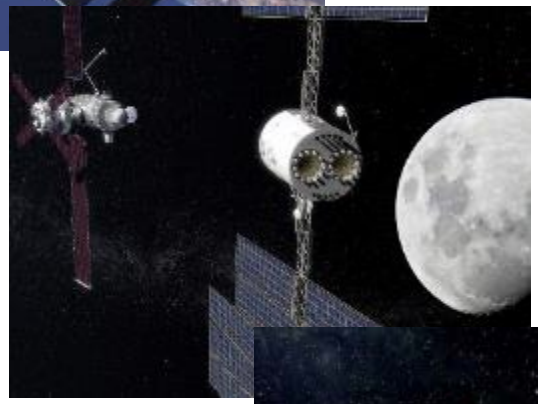
Hostile/ Closed Environment

Space Radiation

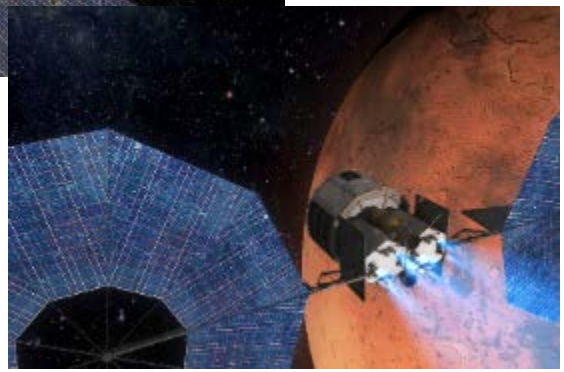
Isolation & Confinement

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

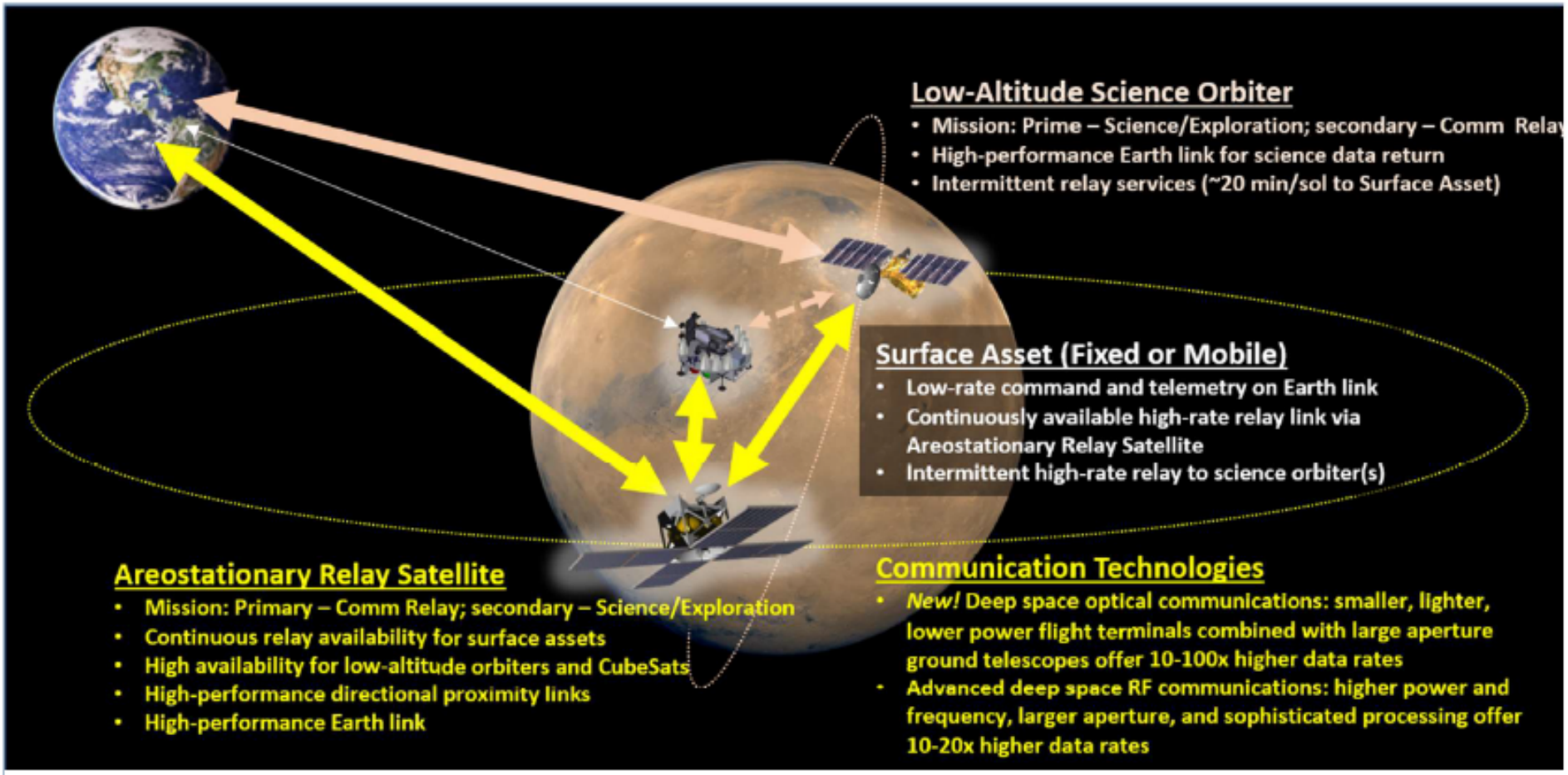
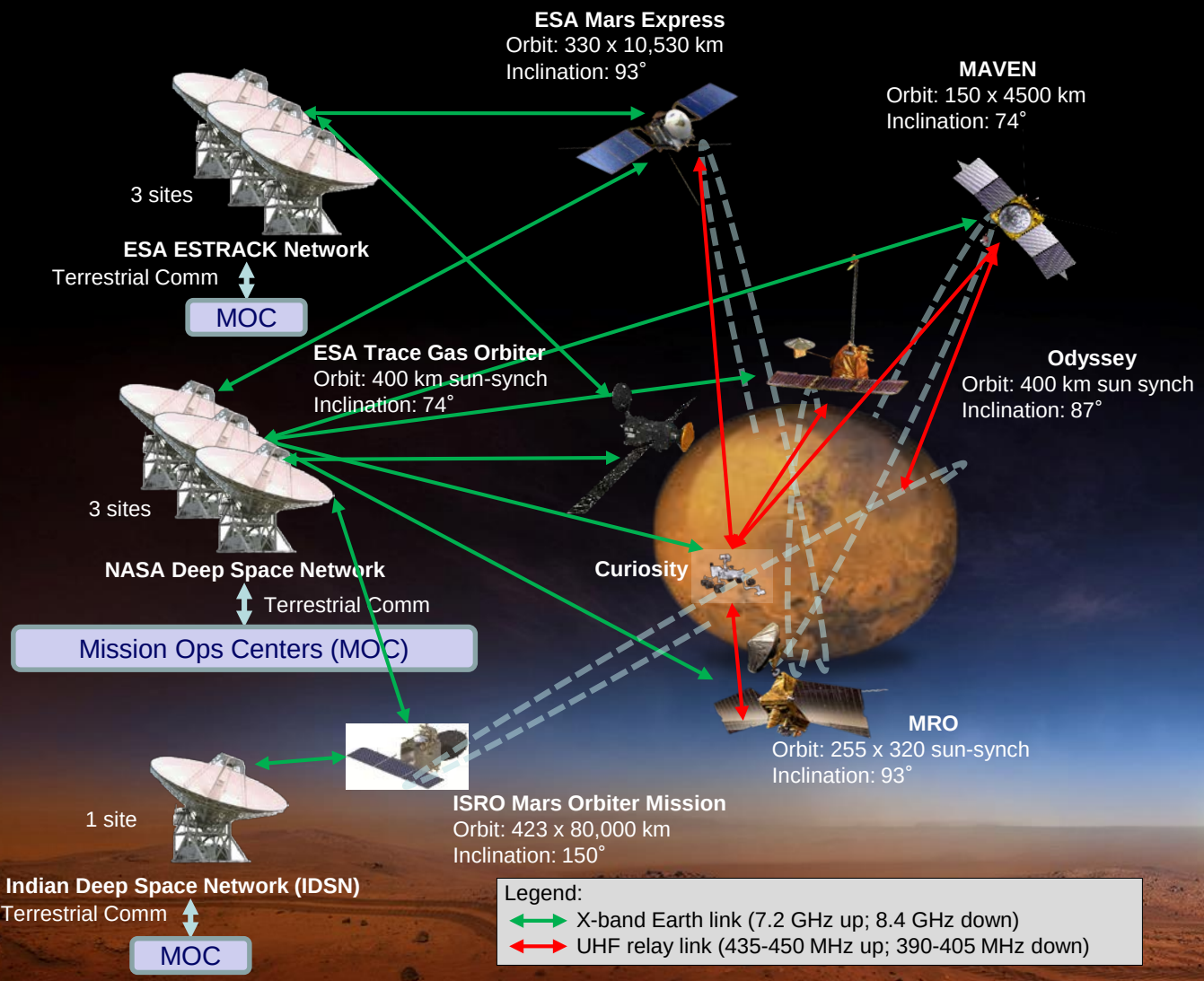


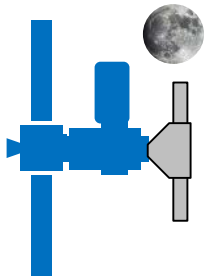
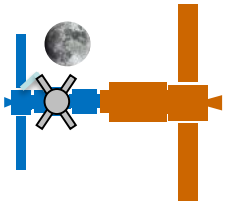
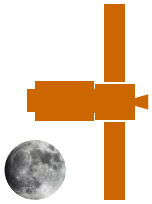
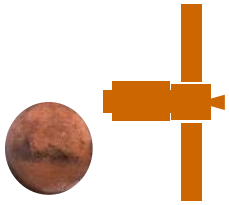
Figure 1. Advanced RF and optical communications technologies combined with using the areostationary orbit offer 100-1000x greater data return from Mars and nearly continuous availability.

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



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

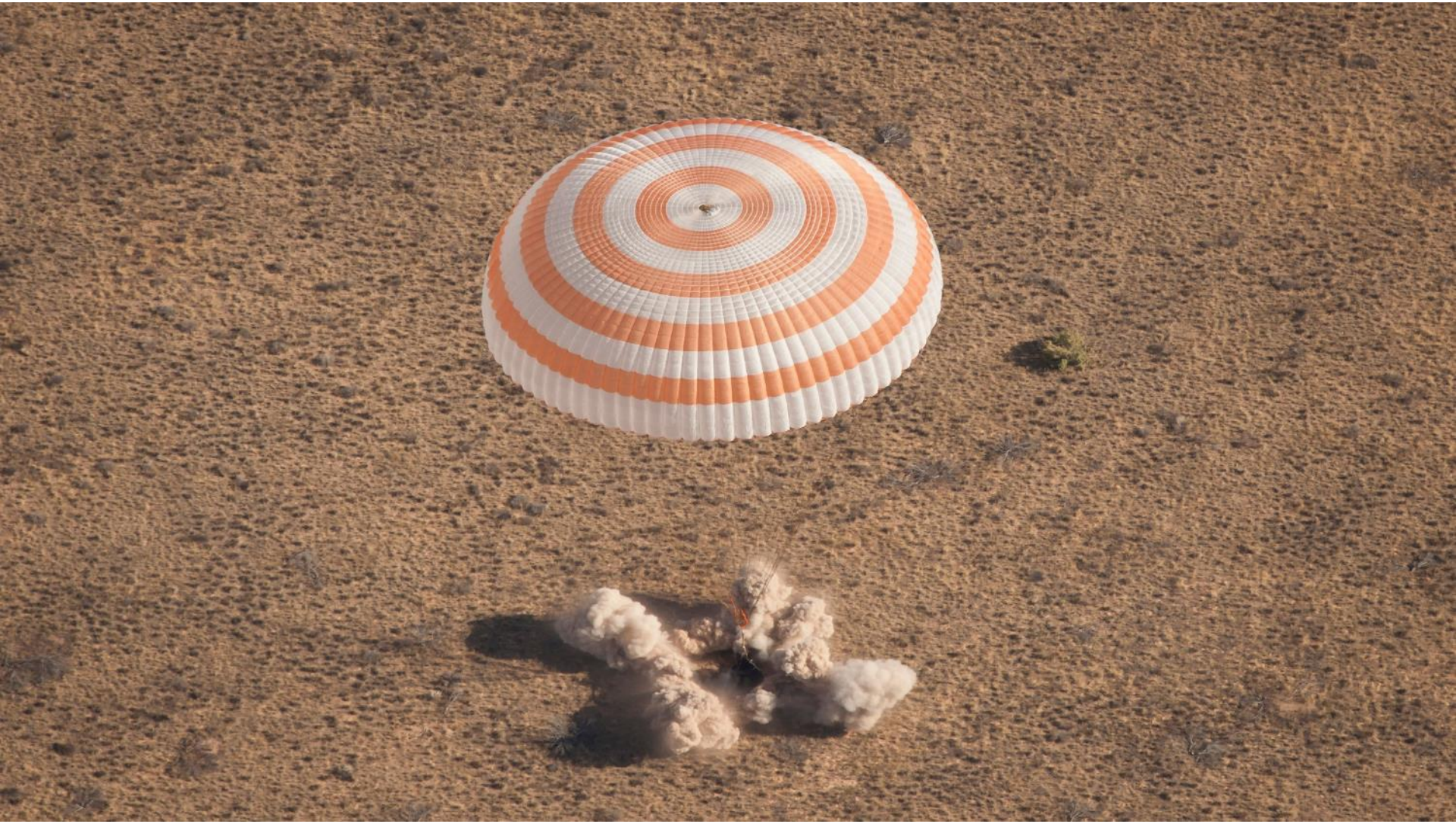
Consumables Resupply

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

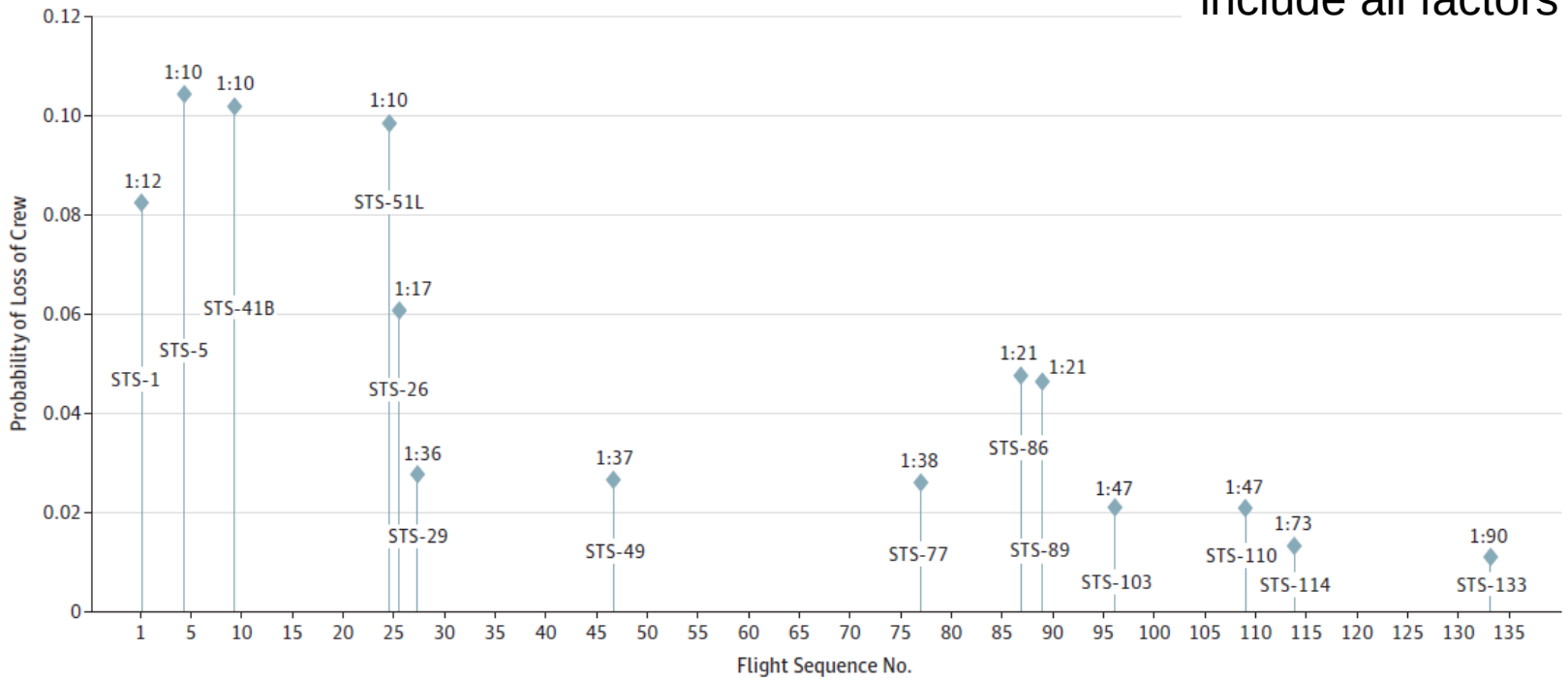
Current Operational Models Inadequate For Pharmacy Provision

Return to Gravity



A Word about Risk

Figure. Results on Retrospective Analysis on Shuttle Risk



These results include all factors

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.[4]

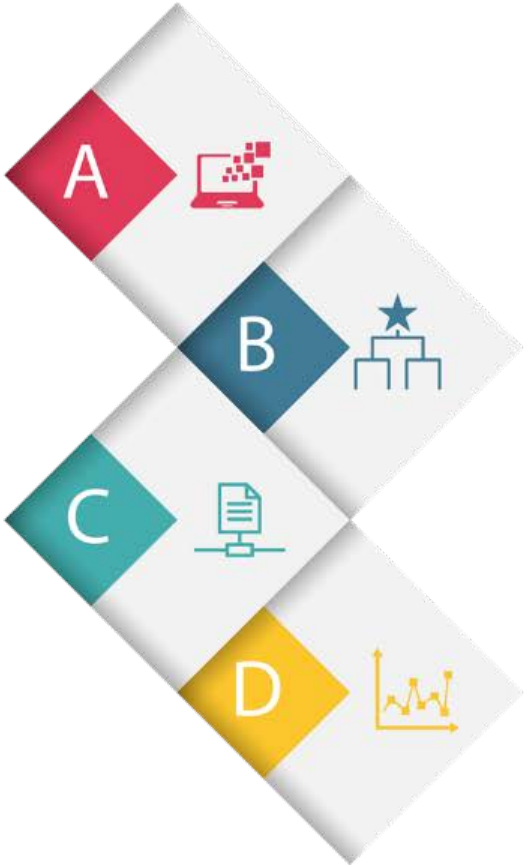
Bagian, JAMA Neurology January, 2019

Project ECHO®

UNM SCHOOL OF MEDICINE

Move Knowledge, Not People

Amplification – Use **Technology** to leverage scarce resources



Share **B**est **Practices** to reduce disparity

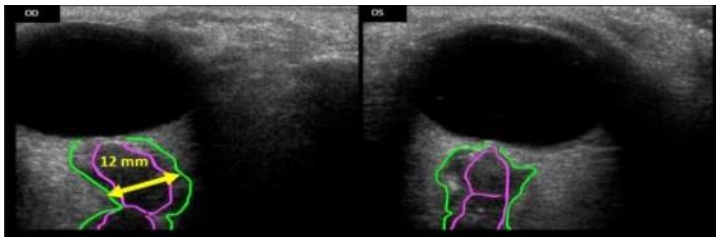
Case **Based Learning** to master complexity

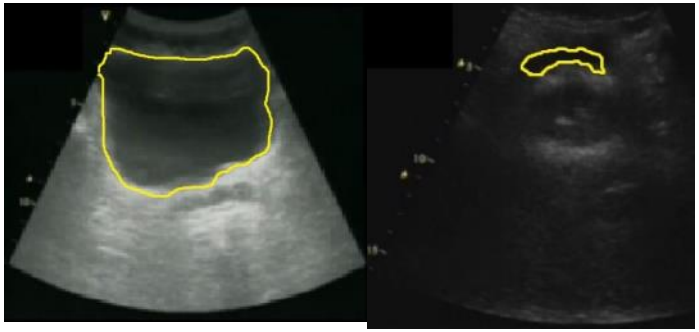
Web-based **D**atabase to **Monitor Outcomes**

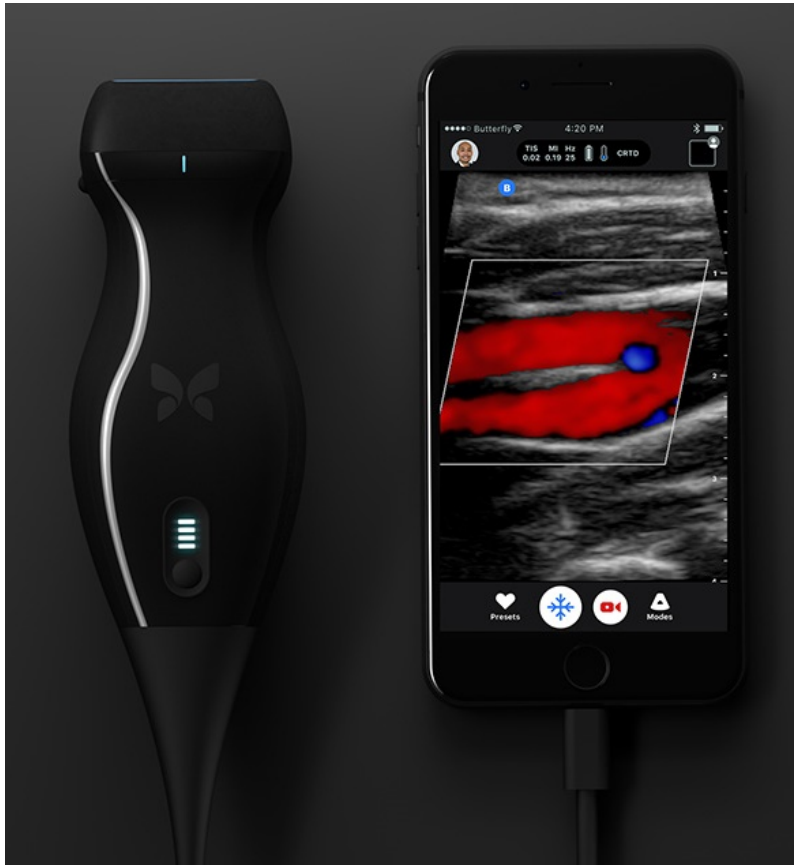
How do we validate tech for our environment?

A

Amplification - Use **Technology** to leverage scarce resources





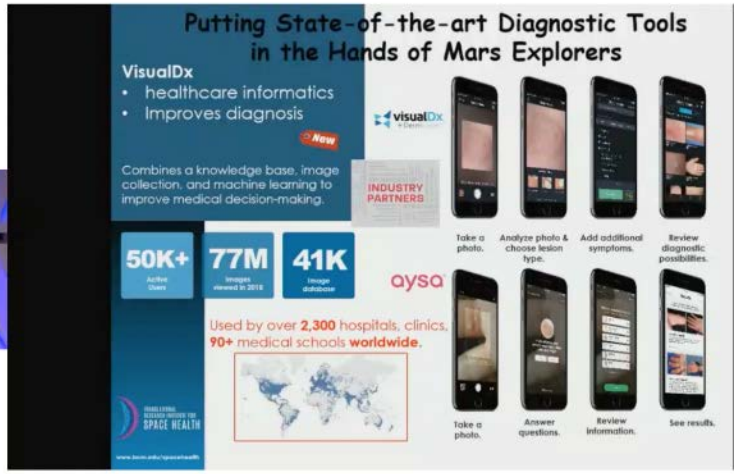


How do we provide up to date knowledge support?

B

Share **Best practices** to reduce disparity.

Baylor College of Medicine



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 - 23:49 CEST) — October 10, 2018 – Wolters Kluwer, Health today announced that the National Aeronautics and Space Administration (NASA) is piloting the use of UpToDate® on board the International Space Station (ISS).

EXPLORE MOON to MARS

Case-based learning
to master complexity

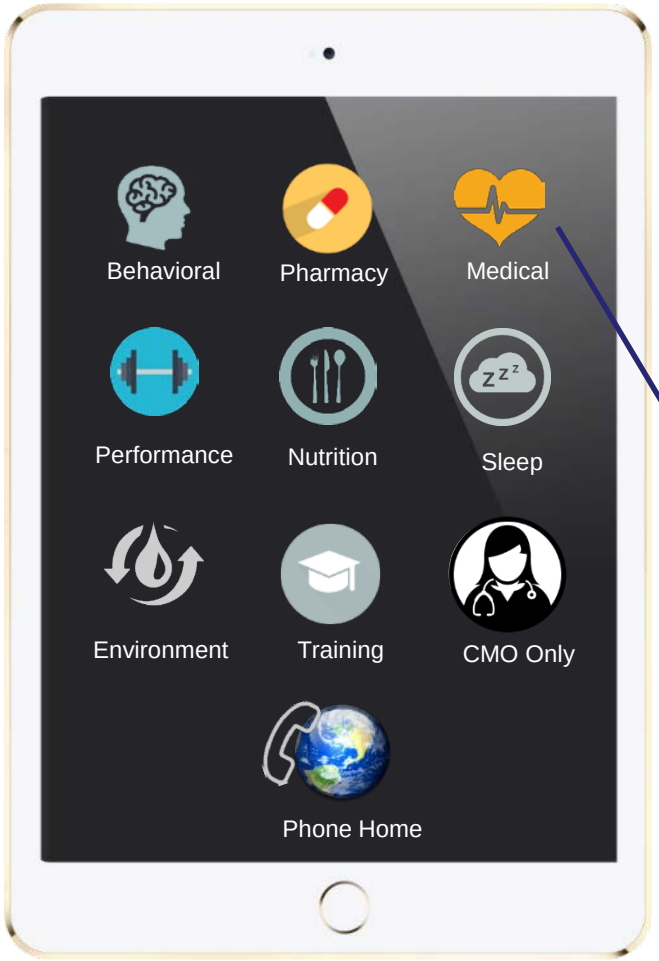
Level Ex® Receives Prestigious Grant from the Translational Research Institute for Space Health (TRISH) to help NASA Improve Medical Care During Space Missions

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.

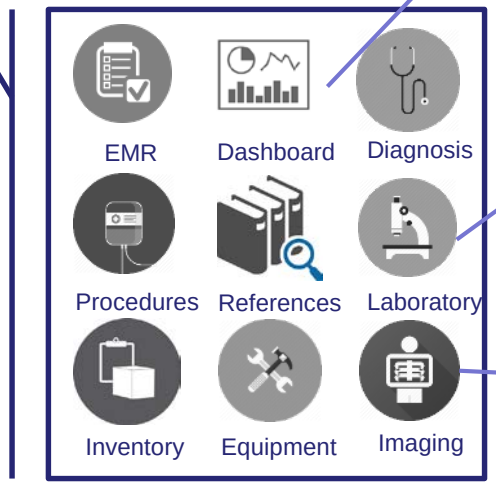
Astronauts can experience changes in the structure and function of the heart, eyes, vascular system, and other parts of the body due to prolonged exposure to space conditions. These significant transformations create a need for new methods to effectively understand

A Crew Health and Performance System

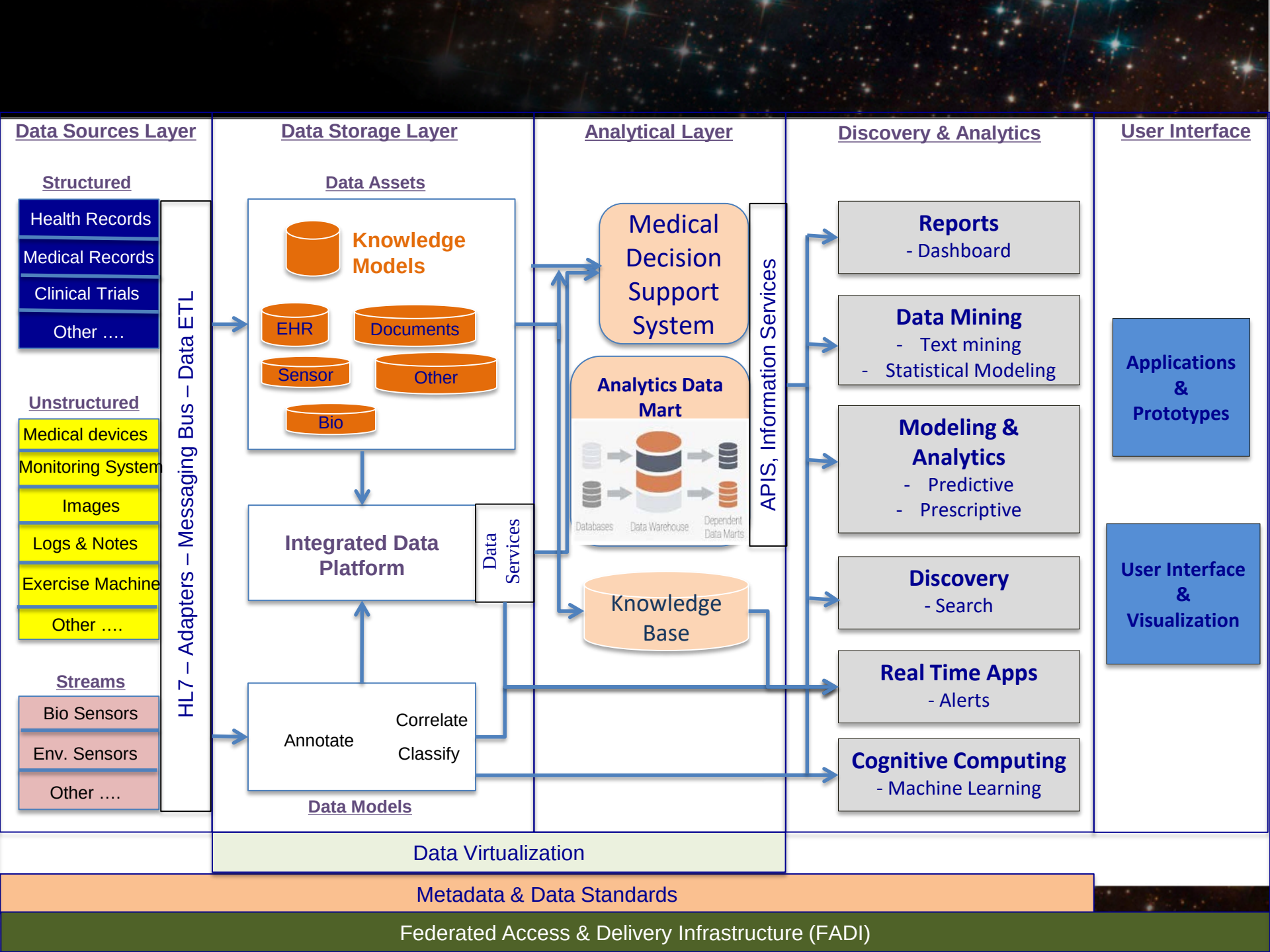


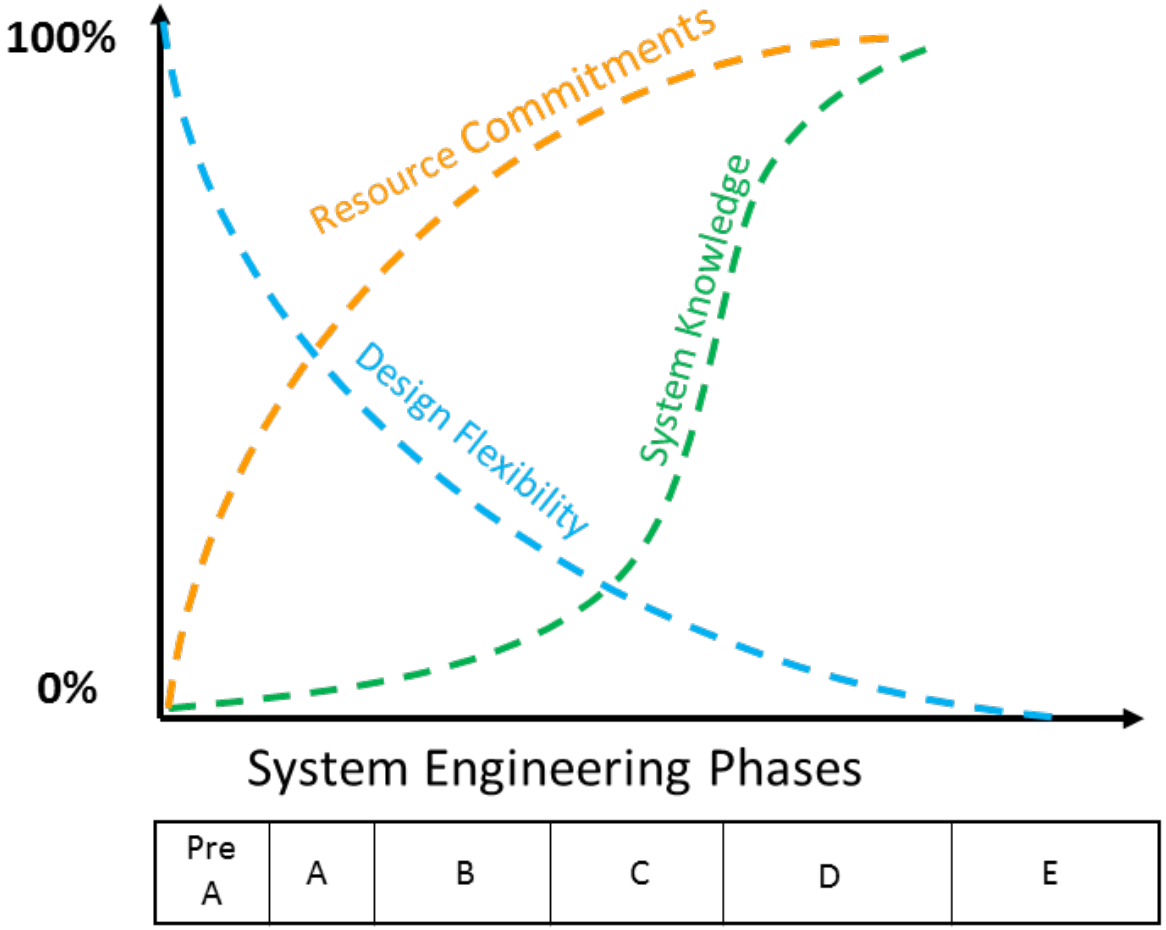
D

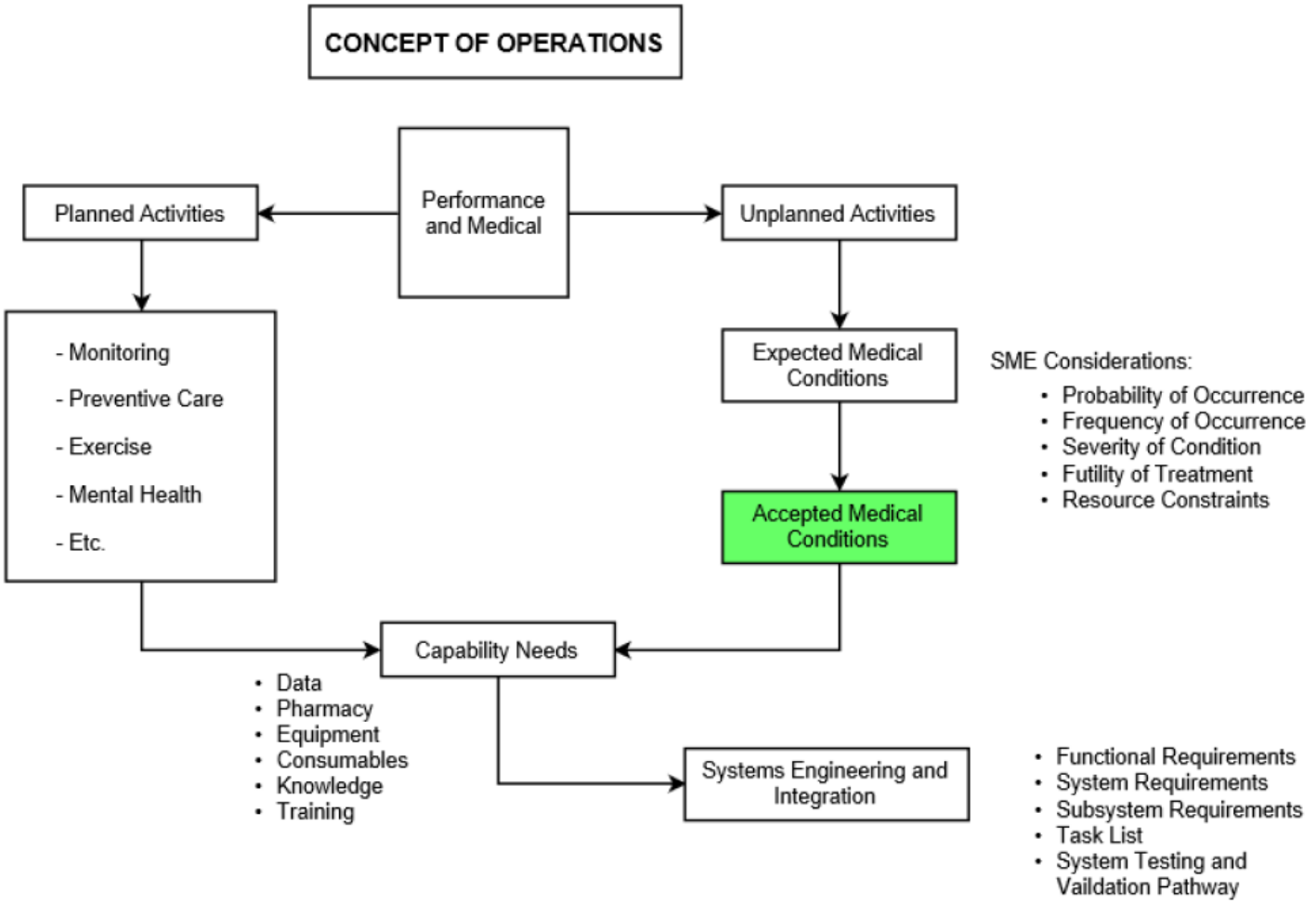
Web-based Database to Monitor Outcomes



Medical


Data Sources 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 ….
HL7 – Adapters – Messaging Bus – Data ETL
Data Storage Layer
Data Assets
Knowledge Models
EHR
Documents
Sensor
Other
Bio
Integrated Data Platform
Data Services
Annotate
Correlate
Classify
Data Models
Analytical Layer
Medical Decision Support System
Analytics Data Mart
Databases
Data Warehouse
Dependent Data Marts
Knowledge Base
APIS, Information Services
Discovery & Analytics
Reports
- Dashboard
Data Mining
- Text mining
- Statistical Modeling
Modeling & Analytics
- Predictive
- Prescriptive
Discovery
- Search
Real Time Apps
- Alerts
Cognitive Computing
- Machine Learning
User Interface
Applications & Prototypes
User Interface & Visualization
Data Virtualization
Metadata & Data Standards
Federated Access & Delivery Infrastructure (FADI)


100%
0%
Resource Commitments
Design Flexibility
System Knowledge
System Engineering Phases
Pre A
A
B
C
D
E


CONCEPT OF OPERATIONS
Performance and Medical
Planned Activities
Unplanned Activities
- Monitoring
- Preventive Care
- Exercise
- Mental Health
- Etc.
Expected Medical Conditions
Accepted Medical Conditions
SME Considerations:
• Probability of Occurrence
• Frequency of Occurrence
• Severity of Condition
• Futility of Treatment
• Resource Constraints
Capability Needs
• Data
• Pharmacy
• Equipment
• Consumables
• Knowledge
• Training
Systems Engineering and Integration
• Functional Requirements
• System Requirements
• Subsystem Requirements
• Task List
• System Testing and Vaildation Pathway

Curiosity Rover January 2014