Lunar Orbit Mission Risk Analysis using the Integrated Medical Model

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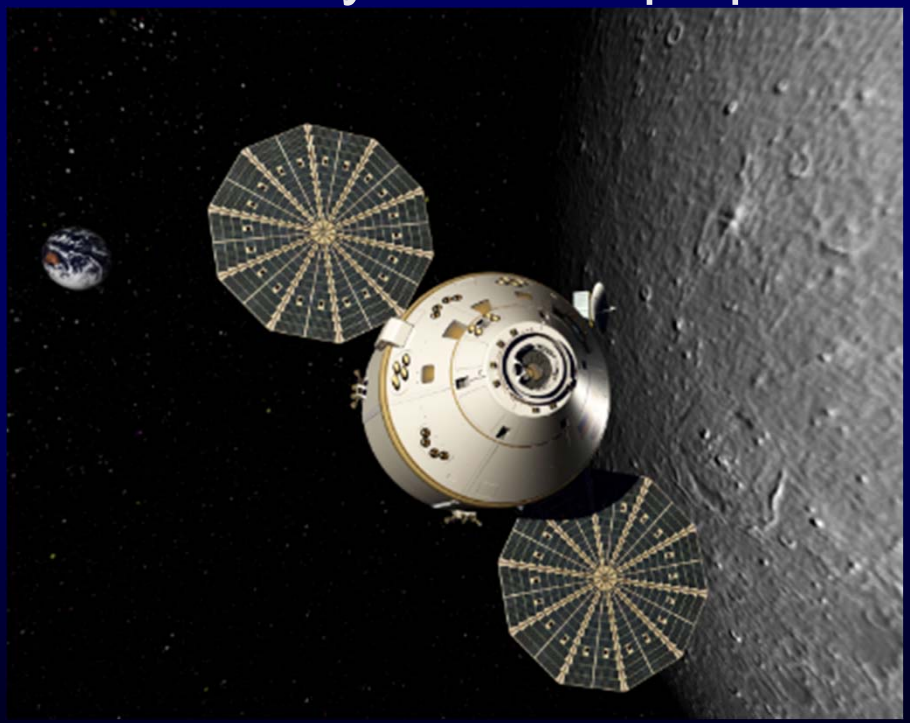
Orion Multipurpose Crew Vehicle

- Carries the crew to orbit and exploration destinations
- Sustains the crew while in space
- Provides safe re-entry from deep space

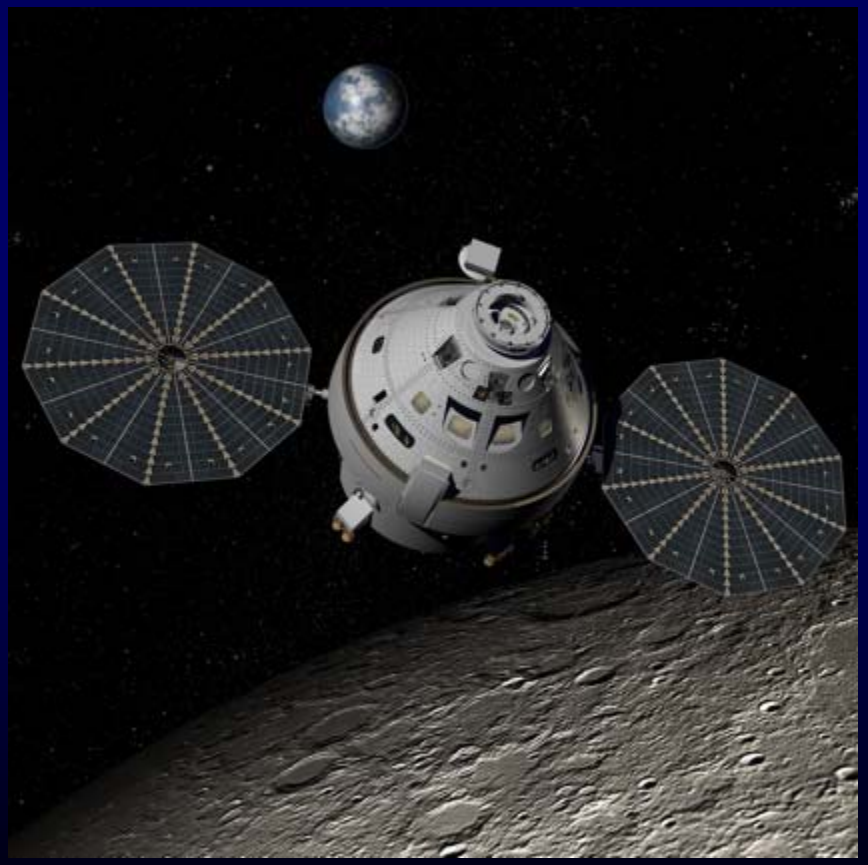


Exploration Flight Test–1 (EFT-1)

- Scheduled for September of 2014
- High earth orbit of 3600 miles
- Re-entry speed of 20,000 mph

Exploration Mission-1 (EM-1)

- An un-crewed mission beyond earth orbit (lunar flyby)
- Planned for 2017



Exploration Mission-2 (EM-2)

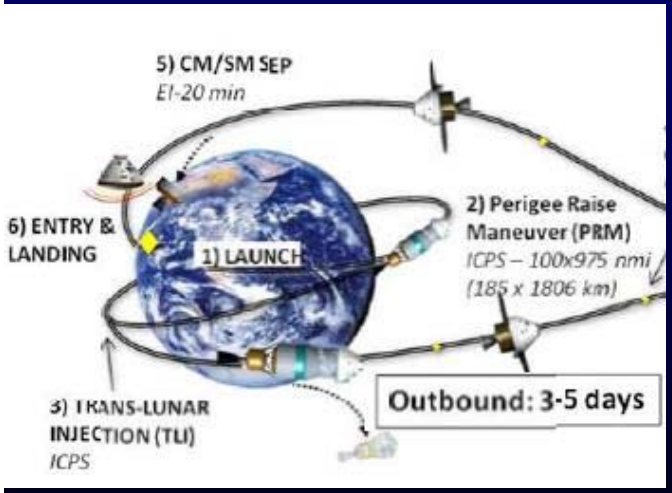
- A crewed mission beyond earth orbit (lunar orbit)
- Planned for 2021
- Mission duration of 10 to 14 days
- Mission Objectives
  - Demonstrate safe crewed flight beyond low earth orbit
  - Validate the life support system
  - Validate crew operations

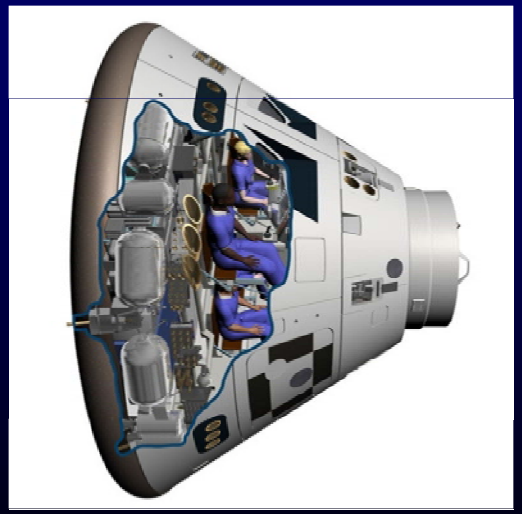
EM-2 Design Reference Missions

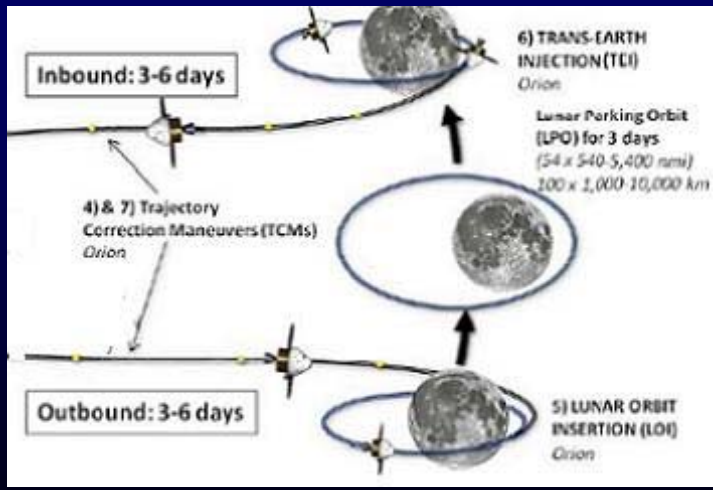
- EM-2 Crewed Lunar Orbit (CLO)
  - 14 days
  - 4 crew members
  - No extravehicular activity
- EM-2 Distant Retrograde Orbit (DRO)
  - 25 days
  - 2 crew members
  - No extravehicular activity
- EM-2 Hybrid
  - 12 days
  - 2 crew members
  - No extravehicular activity

EM-2 Medical Risk Analysis

- What is the probability of loss of crew life (death) due to a medical event during a lunar orbit mission?







Integrated Medical Model (IMM)

- IMM Background
  - Software model used to simulate manned space flight missions
  - Simulates medical events during space flight missions
  - Estimates the impact of these medical events on crew health and mission success
  - Outputs include estimates of crew health, probability of medical evacuation, and probability of medical loss of crew life
  - Optimization routines can be used to design medical systems which maximize crew health and probability of mission success

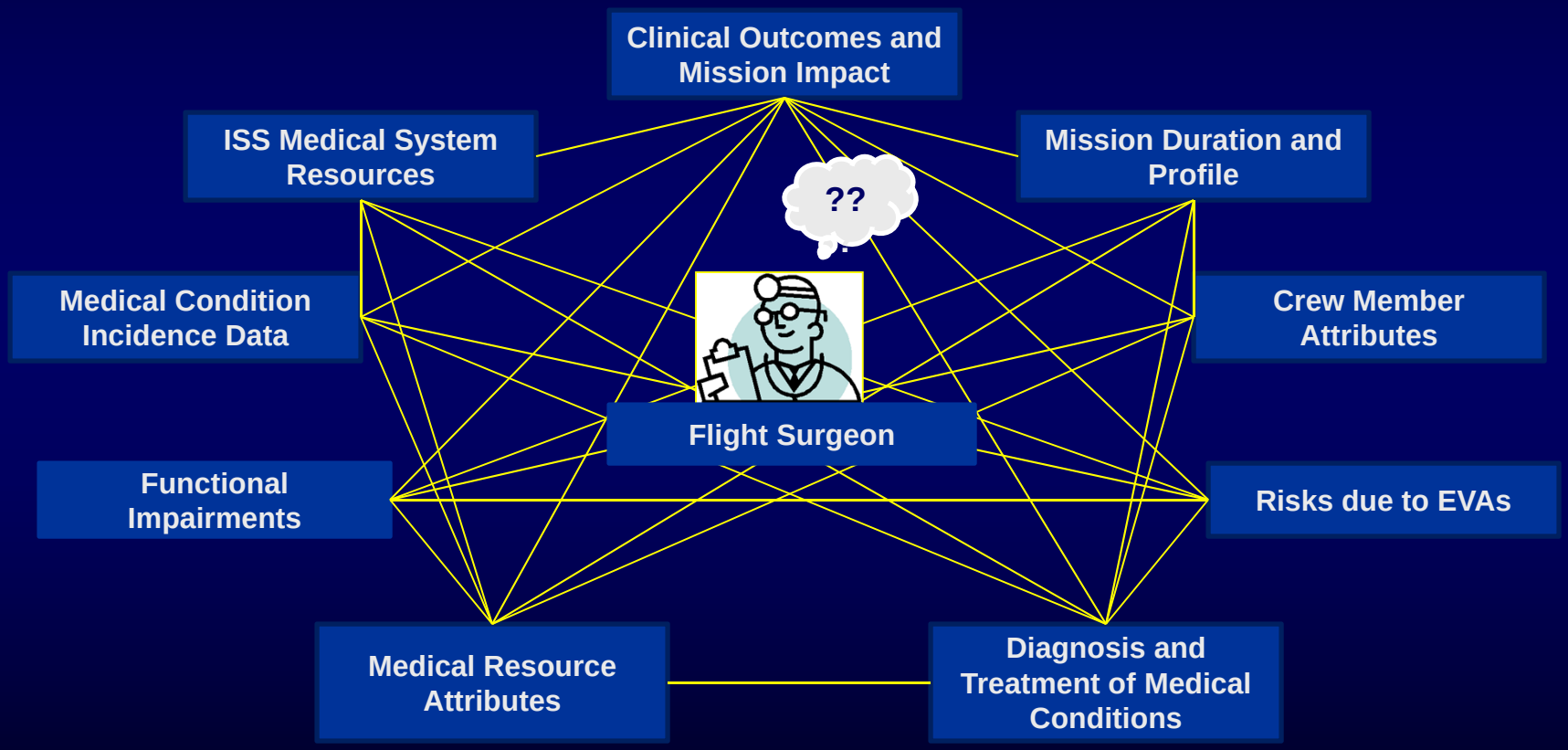
Life Before IMM

What is the likelihood of a medical evacuation?

What is the risk of Loss of Crew Life due to illness on ISS?

What medical devices should we have on ISS?

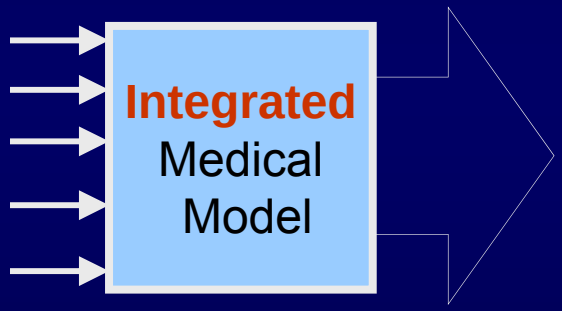
What should be in the Exploration Medical Kit?



IMM Conceptual Model

Inputs

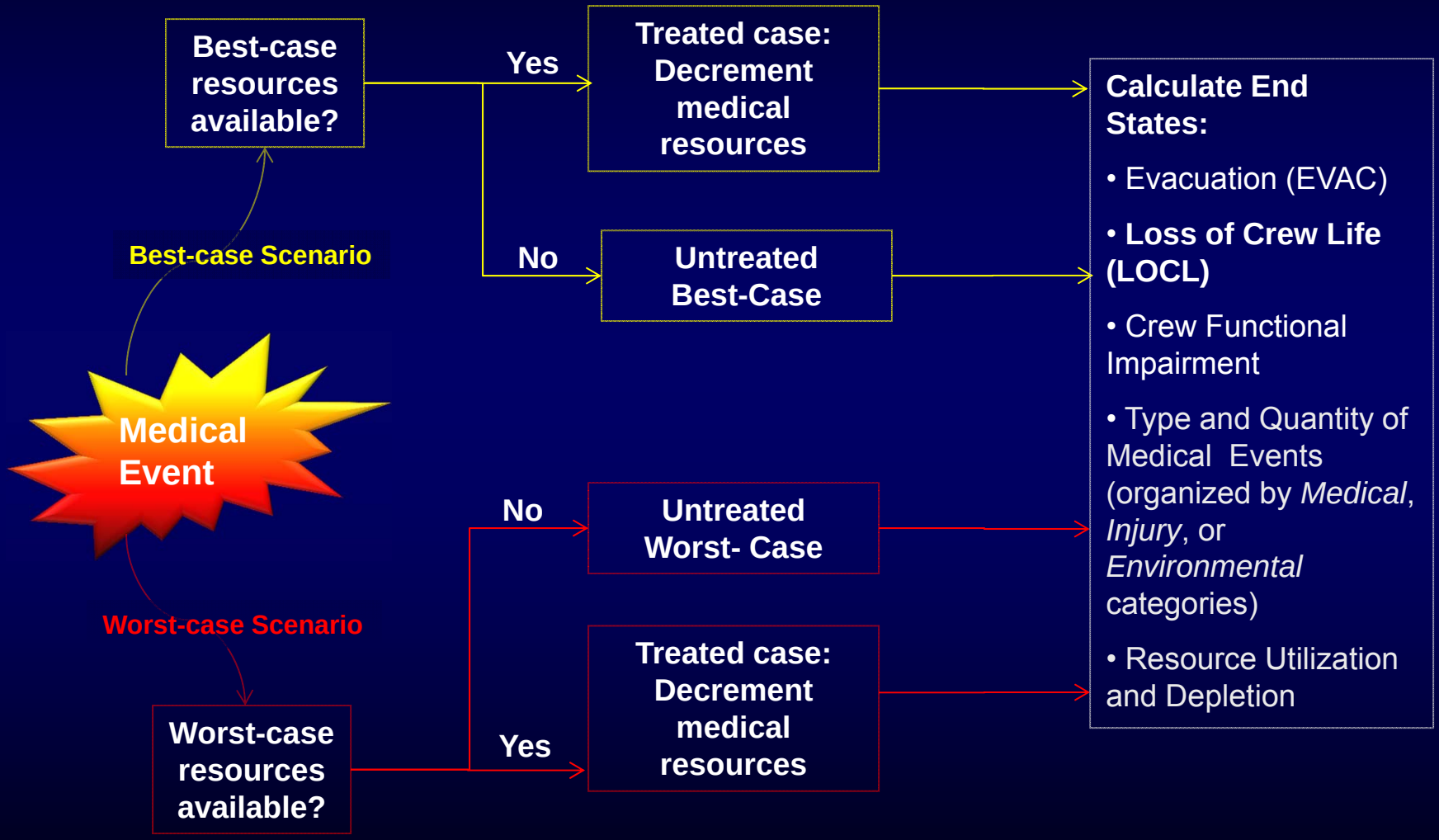
- Medical Conditions & Incidence Data
- Crew Profile
- Mission Profile & Constraints
- Potential Crew Impairments
- Potential Mission End states
- In-flight Medical Resources



Outputs

- Medical Condition Occurrences
- Crew Impairments
- Clinical End States
- Mission End States
- Resource Utilization
- Optimized Medical System

IMM Logic - Event Sequence Diagram



Life Now with IMM

Mission Specific Inputs

- Crew Member Attributes
- Crew Composition
- Mission Duration and Profile

Monte Carlo Simulations

Integrated Medical Model

13,500+ data elements

- ISS Medical System Resources
- Diagnosis and Treatment of Medical Conditions
- Medical Condition Incidence Data
- Risks due to EVAs

IMM Relational Database

Quantified Outputs

- Type and Quantity of all Medical Events
- Risk of EVAC
- Risk of Loss of Crew
- Medical Resources Used
- Optimized Medical System within Vehicle Constraints

Informed Analysis

Flight Surgeon

Methods

- What is the probability of loss of crew life (death) due to a medical event during a lunar orbit mission?
- IMM Analysis of EM-2 CLO
  - Define DRM (4 crew, 14 days, no extravehicular activity)
  - Define medical system constraints (13.6 kg, 6144 cm^3)
  - Simulate 100K missions using Monte Carlo methodology
  - Use the IMM optimization routine to minimize the probability of LOCL within the above medical system constraints

Results

- *Optimized medical kit had a mass of 4 kg and a volume of 6144 cm^3
- **Probability of LOCL = 0.1% (1in 1000 missions)** with 95% confidence interval of 0.08% to 0.11%
- Probability of EVAC = 2.45%
- Crew Health Index = 87.52%

*No allowance for packing factor (typically 20% to 30%)

Summary and Conclusions

- A crewed mission beyond earth orbit (lunar orbit) is planned for 2021
- DRM EM-2 Crewed Lunar Orbit (CLO) is a 14 day mission with 4 crew members and no scheduled EVAs
- Based on IMM analysis, the probability of LOCL due to a medical event is estimated as 0.1%
- The optimized medical kit reached volume constraints prior to mass constraints
- IMM can be used to estimate crew health, and probabilities of LOCL, EVAC for exploration missions
- IMM can be used to help optimize medical kits for exploration missions with mass and volume constraints

Questions and Discussion

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Back-up Slides

Medical Kit Contents

Medications	Quantity
Afrin	1
Amoxicillin	30
Aspirin	24
Azithromycin	6
Bacitracin	1
Bactrim	20
Bactroban	1
Imodium	16
Levaquin	2
Motrin	40
Pepto-Bismol	12
Prilosec	7
Rocephin	1
Sudafed	29
Tobradex Eye Drops	1
Tylenol	50
Vicodin HP	30
Zithromax	6

Equipment	Quantity
ACE Bandage	1
Blood Pressure Cuff	1
Camera	1
Dental Mirror	1
Finger Splint	1
Fluorescein Strips	3
IV Administration Set	1
Otoscope	1
Ophthalmoscope	1
Medical Oxygen	1
Pulse Oximeter	1
SAM Splint	1
Silver Nitrate Stick	1
Tourniquet	1
Urine Chemstrips	2
Urinary Catheter	1

Medical Conditions in IMM by Category

Injury/Trauma

- Acute Compartment Syndrome
- Abdominal Injury
- Back Injury
- Chest Injury/Pneumothorax
- Dental Tooth Avulsion
- Eye Abrasion
- Eye Penetration
- Elbow Dislocation
- Finger Dislocation
- Fingernail Delamination (EVA)
- Head Injury (TBI)
- Hip/Proximal Femur Fracture
- Hypovolemic Shock
- Lower Extremity Stress Fracture
- Lumbar Spine Fracture
- Neck Injury
- Neurogenic Shock
- Paresthesias/Hot Spots (EVA)
- Shoulder Dislocation
- Skin Abrasion
- Skin Laceration
- Sprain/Strain
- Wrist Fracture

Environmental

- Acute Radiation Sickness
- Altitude Sickness
- Barotrauma (ear/sinus block)
- Burns
- Decompression Sickness (EVA)
- Eye Chemical Burn
- Headache (CO_2 induced)
- Smoke Inhalation
- Toxic Exposure

Medical Conditions by Category

Medical Illness	Urinary Retention	Visual Impairment (VIIP)
Abnormal Uterine Bleeding	Dental Crown Replacement	Medication Overdose
Acute Arthritis	Dental Exposed Pulp	Mouth Ulcer
Acute Prostatitis	Dental Filling Replacement	Nasal Congestion (SAS)
Allergic Reaction	Depression	Nosebleed (SAS)
Anaphylaxis	Diarrhea	Otitis Externa
Angina	Eye Corneal Ulcer	Otitis Media
Anxiety	Eye Infection	Pharyngitis
Appendicitis	Gastroenteritis	Respiratory Infection
Afib/Aflutter	Acute Glaucoma	Shingles
Back Pain (SAS)	Headache (late)	Seizures
Behavioral Emergency	Headache (SAS)	Sepsis
Biliary Colic	Hemorrhoids	Sinusitis
Cardiogenic Shock	Hypertension	Skin Infection
Choking	Indigestion	Skin Rash
Constipation (SAS)	Influenza	SMS (SAS)
Dental Abscess	Insomnia (SAS)	Stroke
Dental Avulsion	Insomnia (late)	Sudden Cardiac Arrest
Dental Caries	Kidney Stone	Urinary Incontinence
Urinary Tract Infection	Vaginal Yeast Infection	Urinary Retention

SAS = Space Adaptation Syndrome

IMM Team

- Douglas Butler, MBA – Project Manager
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