Red Risk School
TRISH Disruptions on Display

Level Ex Virtual Human Simulator and Digital Twin Projects

December 9th, 2020

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TRANSLATIONAL
RESEARCH INSTITUTE FOR
SPACE HEALTH

Outline

Overview

- Introductions and Level Ex background

Virtual Human Simulator Project

- Medical research and content identification
- Visual content development
- Ultrasound simulation R&D
- VHS Platform Demonstration
  - Anatomy Viewer
  - Clinical training scenario concept
- TRISH COVID-19 content
  - Airway Management
  - Cardiology Diagnosis

Digital Twin Framework Project

- Digital Twin Framework Prototype Plans
  - Medical Research, Analysis, and Reporting
  - Personalized Anatomical Imaging R&D
  - Collaborative Spaceflight Medical Procedures and Techniques
- Virtual Technique Guides and Collaborative Remote Play Demos

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Presenter: Sam Glassenberg

Virtual Human Simulator

Presenter: Erik Funkhouser

VHS Project: NASA Risk and Gaps

NASA Risks and Gaps (https://humanresearchroadmap.nasa.gov/intro/)

Risks:

- **Primary:** Risk of Adverse Health Outcomes & Decrements in Performance due to Inflight Medical Conditions
- **Secondary:** Risk of Performance Errors Due to Training Deficiencies

Gaps:

- Med05: We do not know how to train crew for medical decision making and medical skills to enable extended mission or autonomous operations
- Med10: We do not have the capability to provide computed medical decision support during exploration missions
- TRAIN-02: We need to identify effective methods and tools that can be used to train for long-duration, long-distance space missions.
- TRAIN-03: We need to develop guidelines for effective onboard training systems that provide training traditionally assumed for pre-flight.

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VHS Project Description

Project Description

Need: Long duration deep space missions will require tools and solutions to support autonomous medical care.

The goals of the VHS project are to:

- Research and aggregate data on spaceflight adaptations, medical conditions, medical checklists, diagnostic and treatment information from terrestrial and space medicine to support research insights and training opportunities for flight crews.

- Develop a data driven virtual human simulator that provides a foundation for future development of medical training and real-time guidance solutions

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VHS Objective Overview

Research and Needs Identification

- SME interviews, research, and analysis on adaptations & countermeasures
- Collection of research data and reference material needed to develop platform content, decision support systems, and just-in-time training solutions
- Author research reports summarizing methods, activites, findings, gaps, and next steps.

Software Feature Development

- Spacecraft environment
- Female and male astronaut bodies
- High fidelity anatomy: Heart, IJV, common carotid, lungs, ocular
- Virtual ultrasound simulation
  - Real time US simulation capability
  - Scannable volumetric content pipeline
  - Application to IJV thrombosis

Training Demonstration Scenario Development

- IJV thrombosis clinical scenario demonstration

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Virtual Human Simulator Project: Medical Research Analysis and Design

Presenter: Victoria Perizes

Research Process

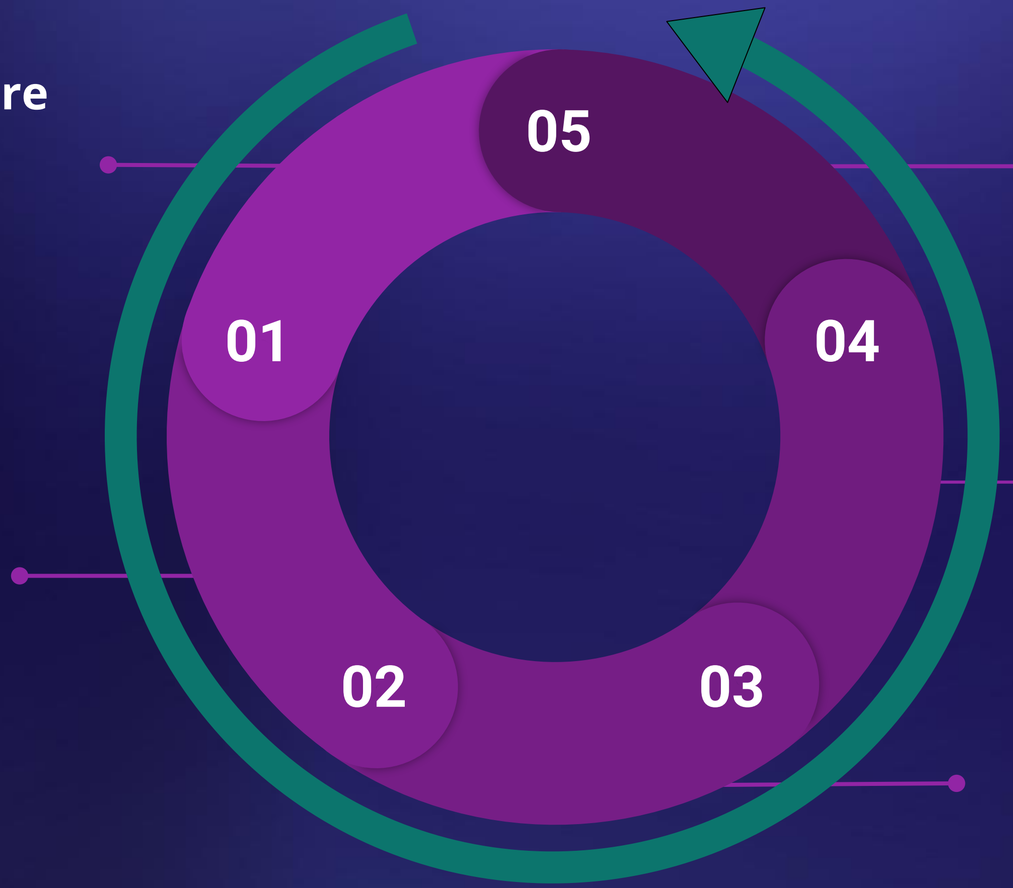
Data Capture

Identification and collection of:

- HRP evidence reports
- Peer-reviewed publications
- NTRS publications (limited access)
- LSDA + LSAH experiment data

Filter

- Published on 1/1/99 or later
- Language: English
- Subject: Human
- Study/experiment type: Spaceflight studies and spaceflight analogues*



Gap ID

- Knowledge/information gaps that impacted development
- “We need x to do y”

Synthesis

- Story of condition and/or SA
- Stakeholder specific documentation

Analysis

- Changes to relevant condition parameters
- Level of evidence/ NASA categories of evidence
- Consensus or conflict

**Qualifying analogues will vary by target - specifics available upon request.*

Medical conditions researched in year 1 with findings included in the medical reports and the VHS platform prototype deliverable

Medical conditions researched in year 1 with findings included in the medical reports, but not included in the VHS platform prototype deliverable

Medical conditions for which research was not performed in year 1 of the VHS Platform project

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
- Venous Thromboembolism

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 (SA) → SANS

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

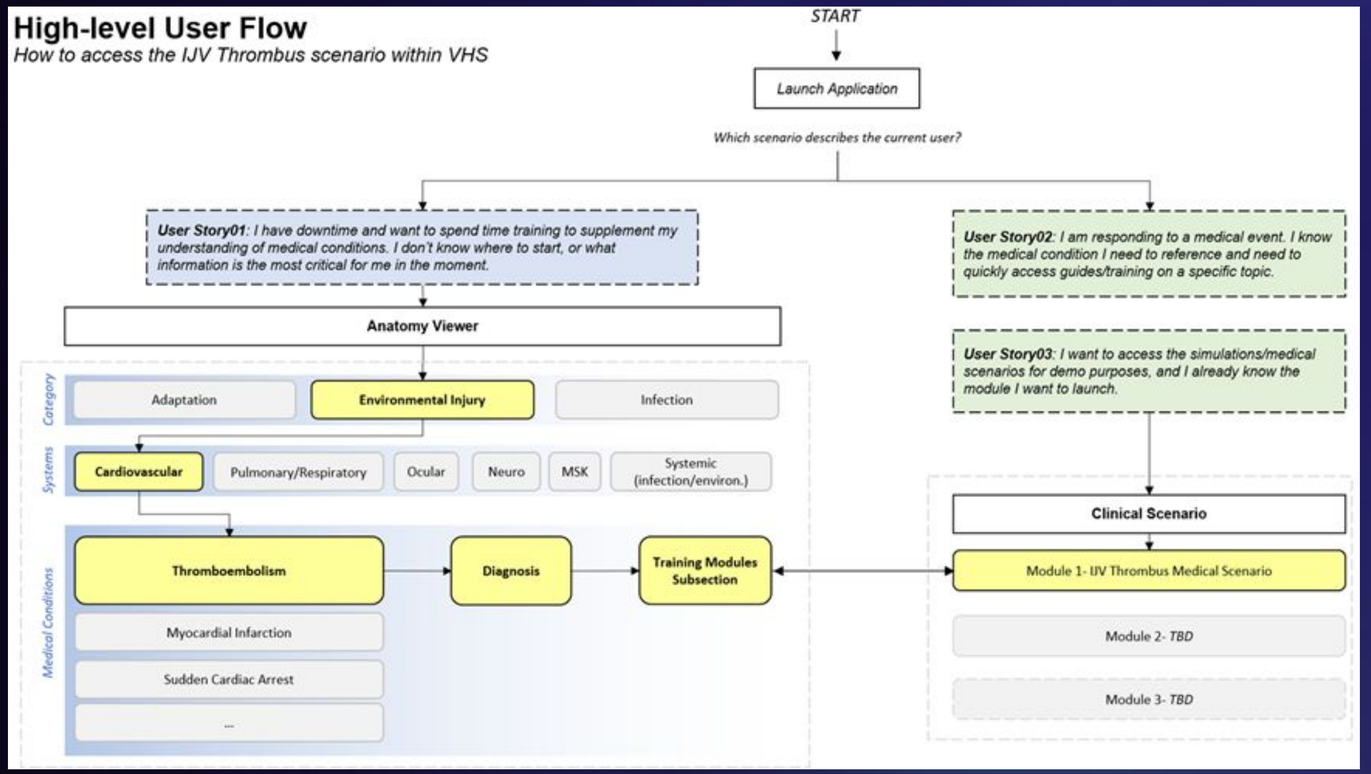
INFECTION
- Herpes Zoster (shingles)
- Influenza
- Mouth Ulcer
- Sepsis
- Skin Infection
- Urinary Tract Infection

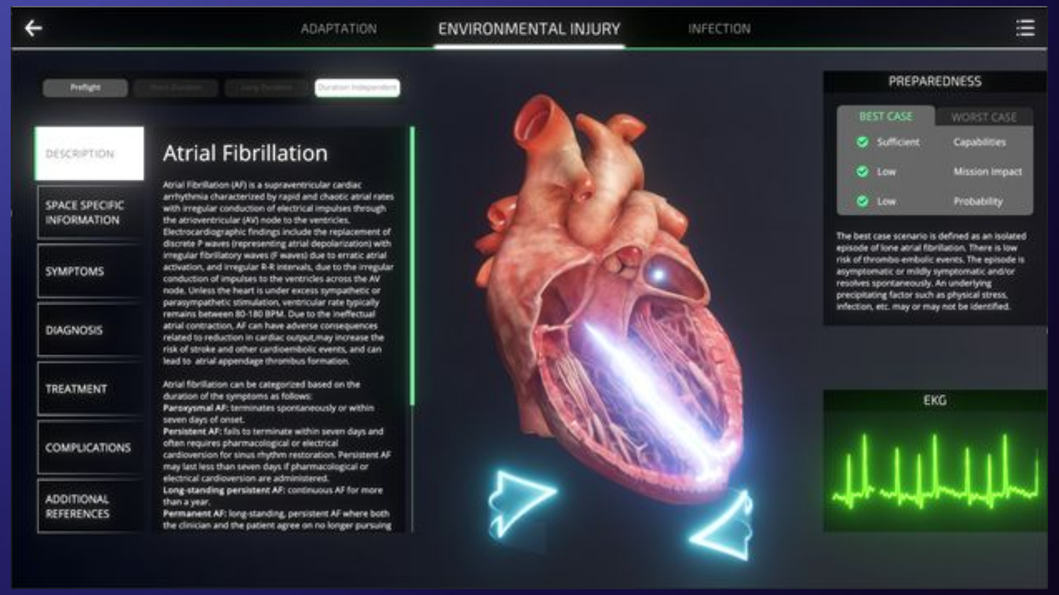
IMMUNE
- Allergic Reaction
- Anaphylaxis
- Skin Rash
- Medication Reaction

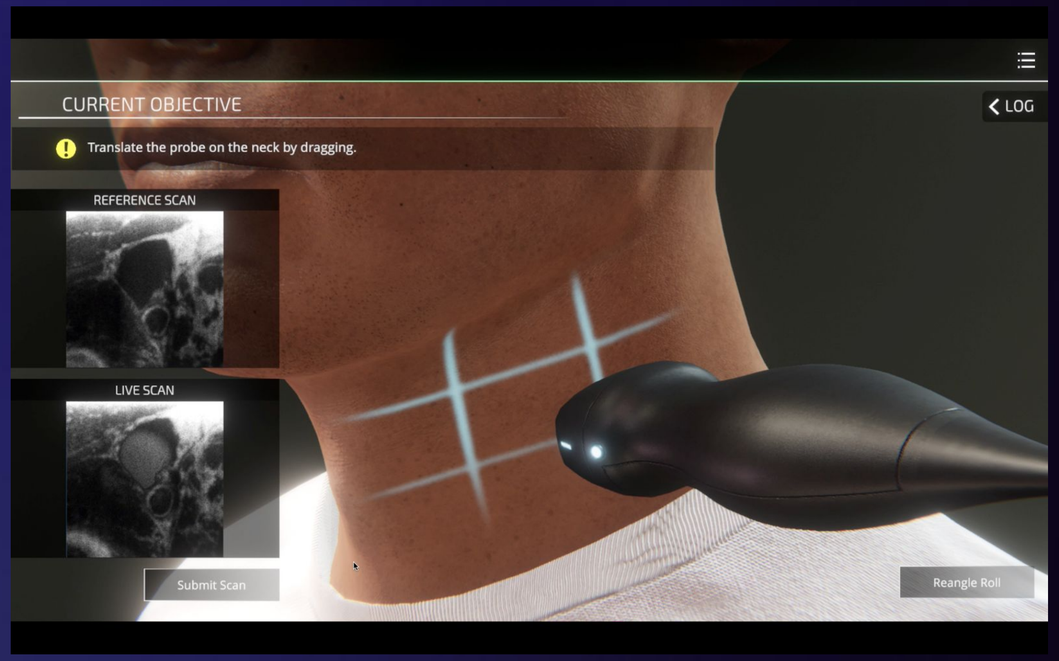
ENVIRONMENT
- Acute Radiation Syndrome
- Altitude Sickness
- Decompression Sickness (EVA)
- Headache (CO_2)

VHS Software Design

Stakeholder centered design based on input captured in SME interviews



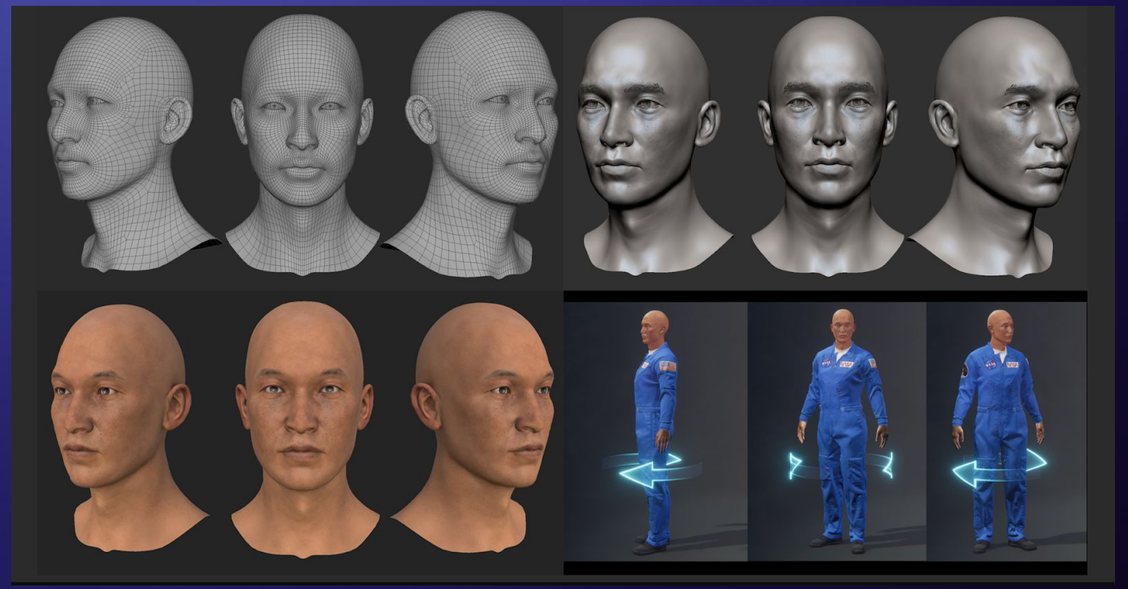


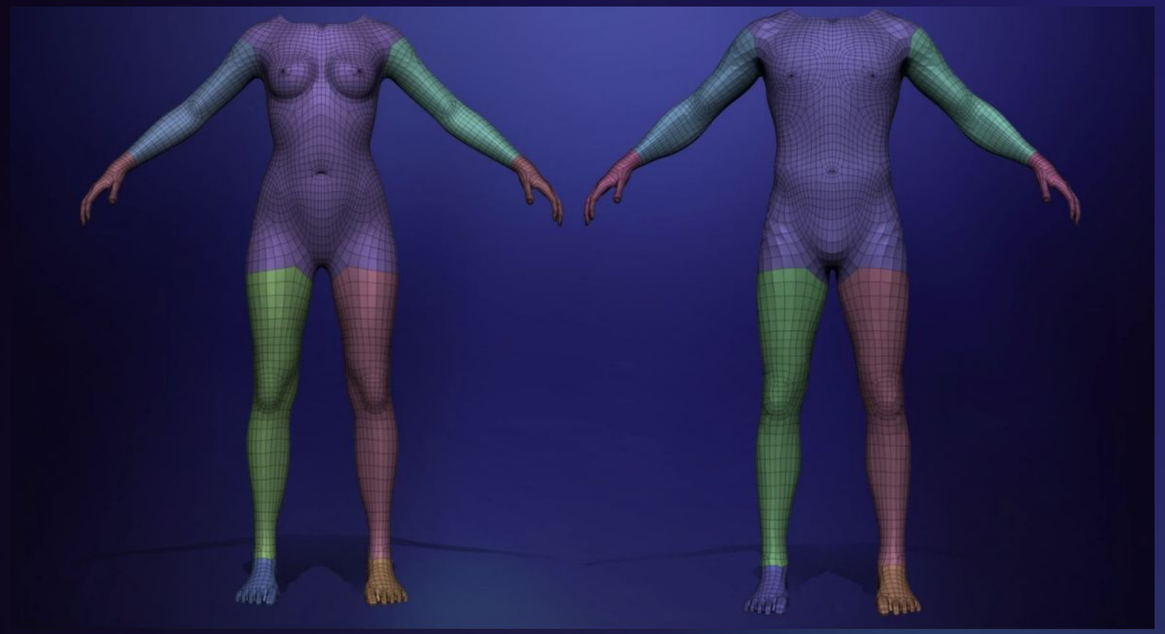


Virtual Human Simulator Project: Artistic Asset Development

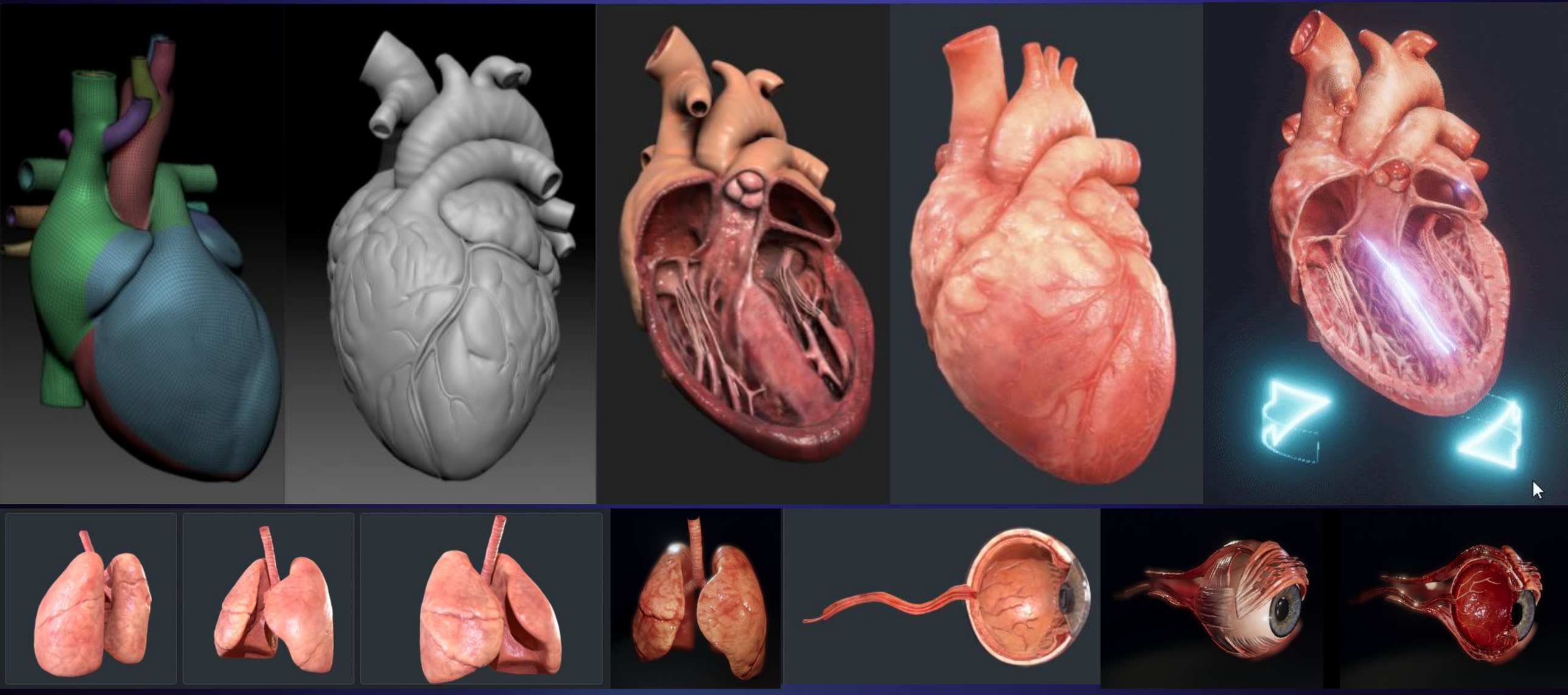
Presenter: Clifton Garner

Artistic Astronaut Model Development

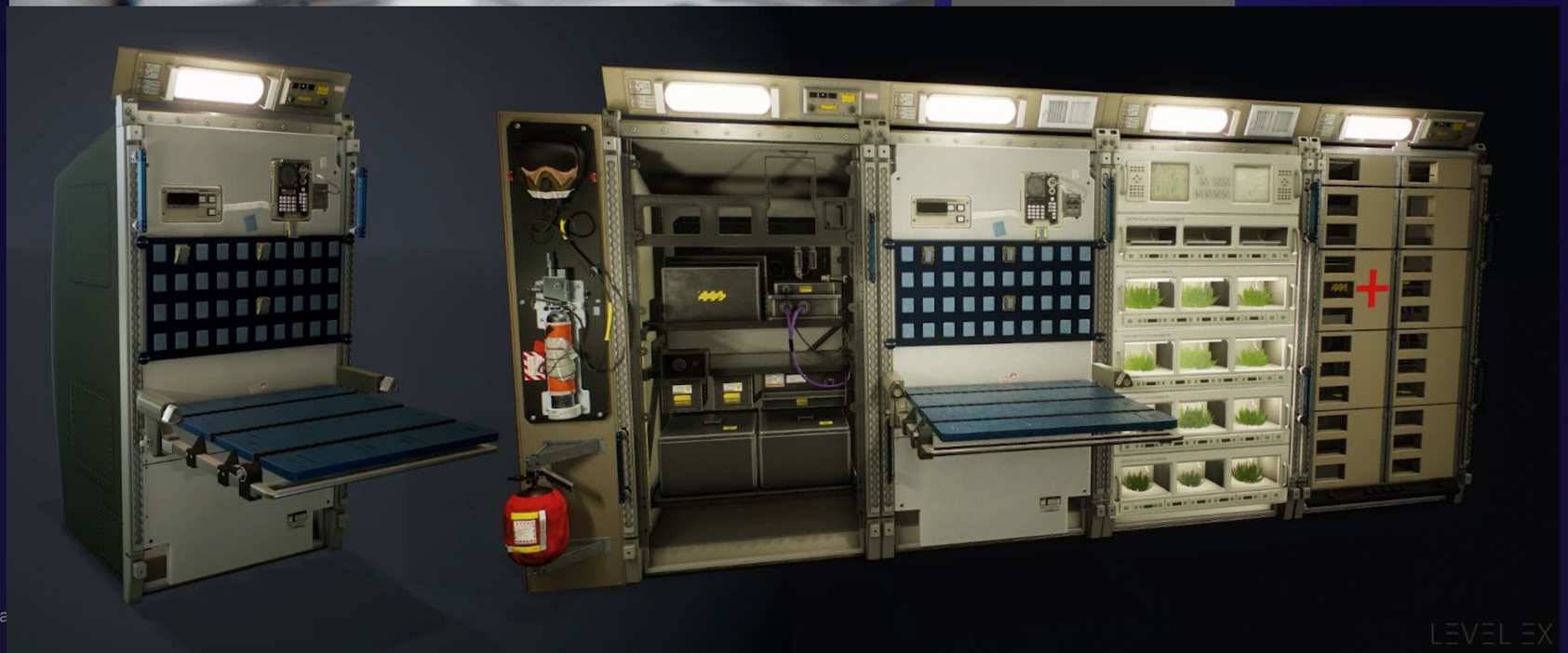




Artistic Anatomy Model Development



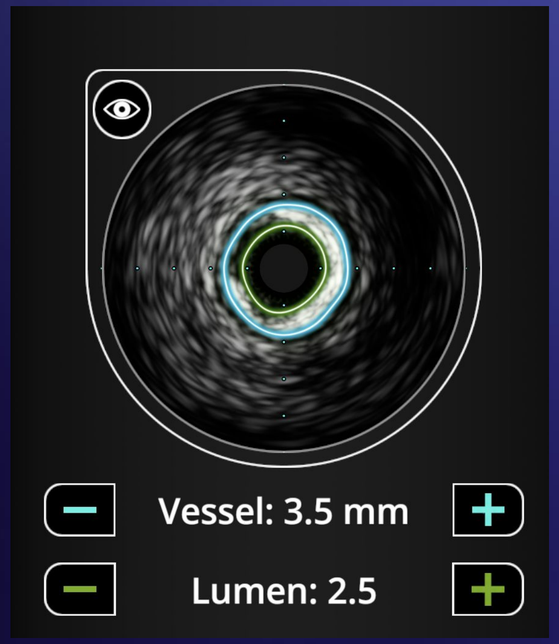
Artistic Spacecraft Model Development

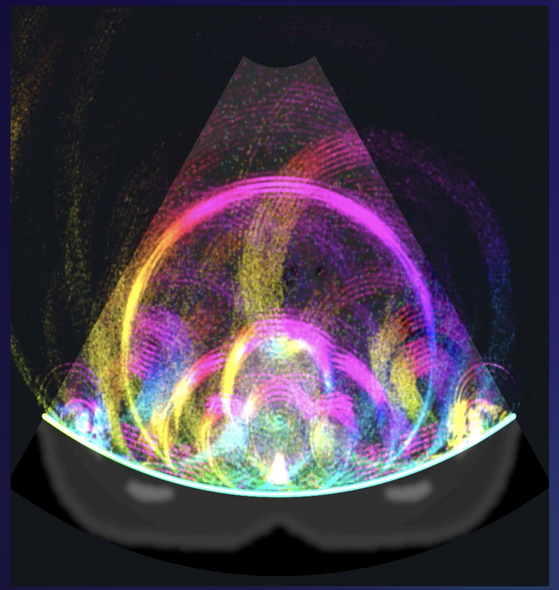


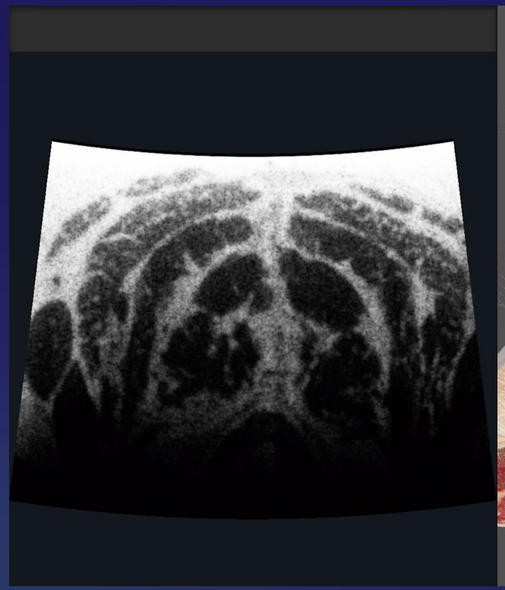
Virtual Human Simulator Project: Ultrasound Development

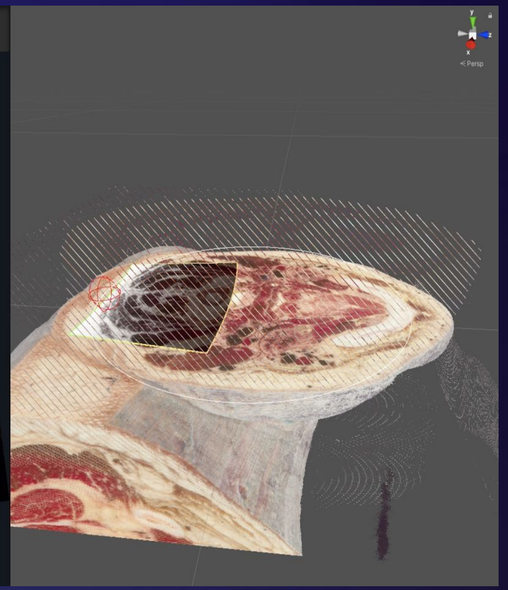
Presenter: Clifton Garner

Ultrasound Development

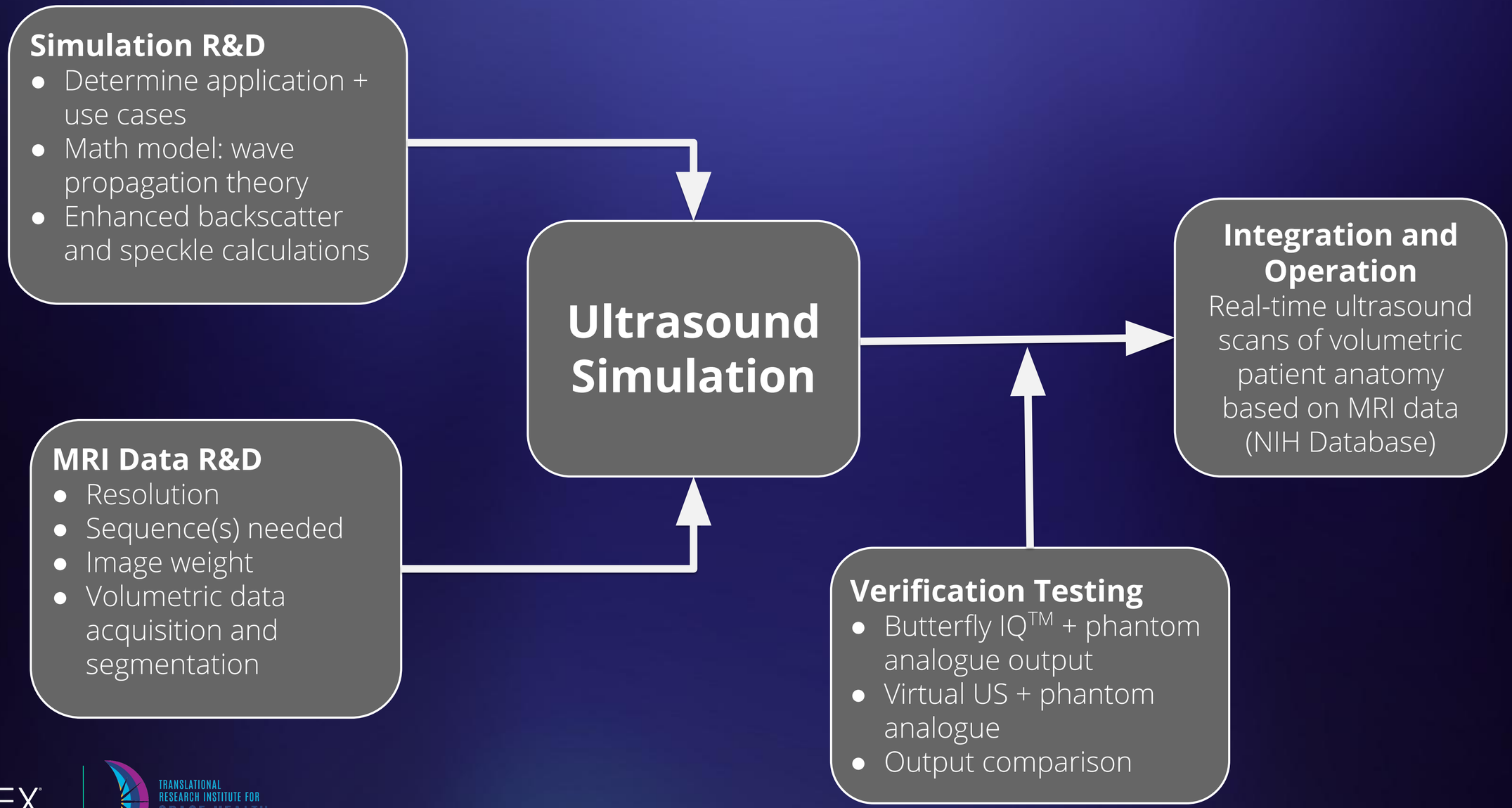








Ultrasound Simulation Process



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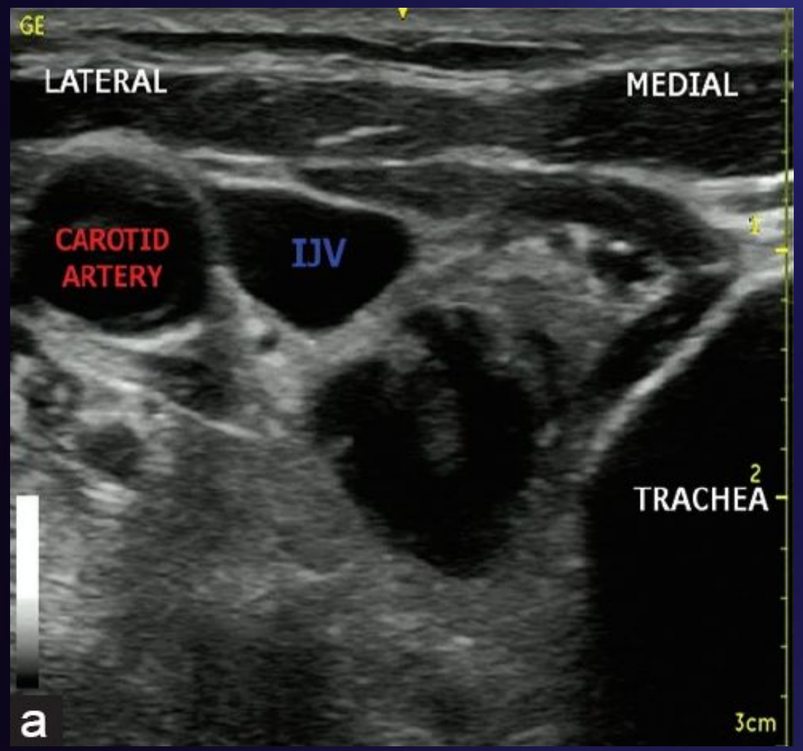
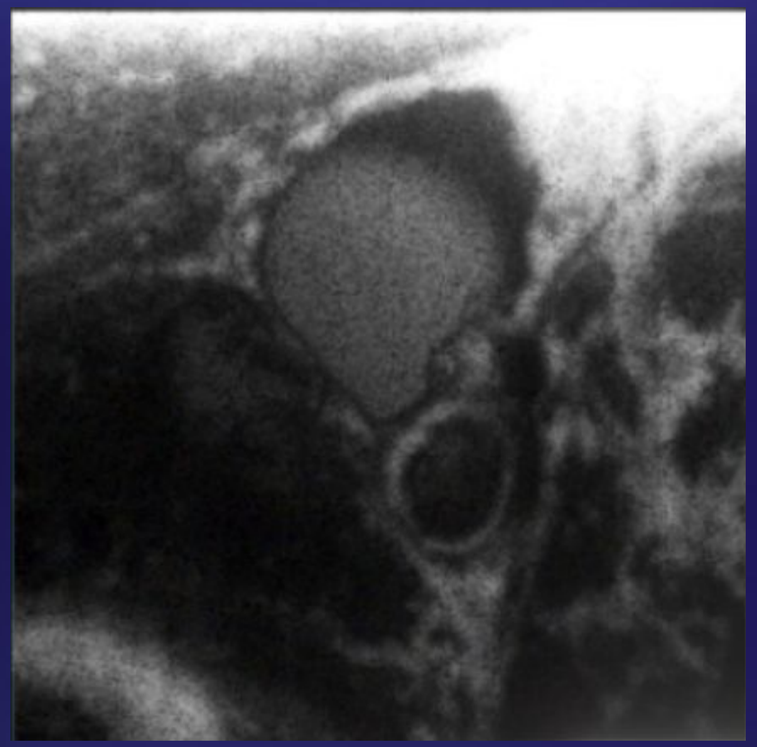
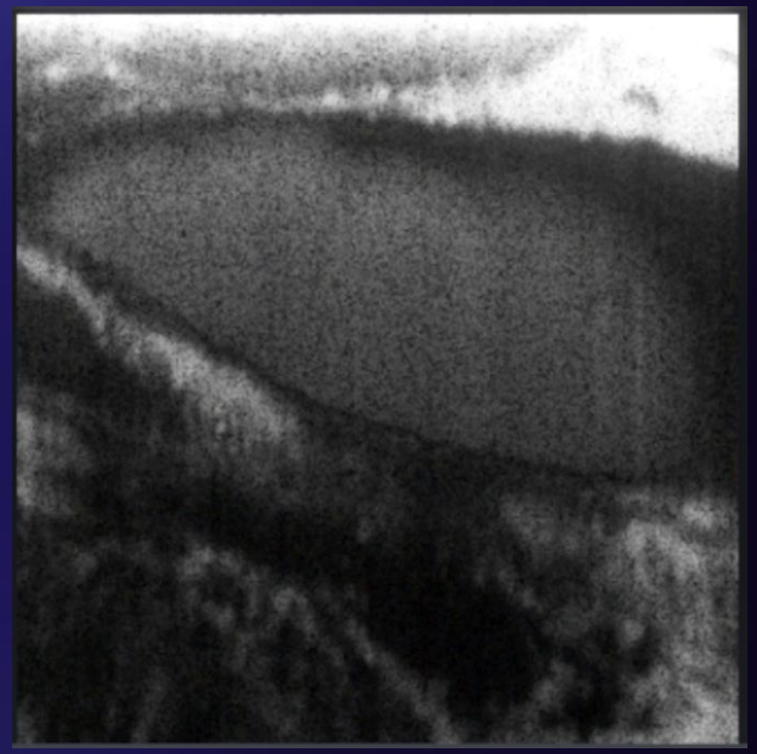
Ultrasound Simulation Comparison

Real Ultrasound

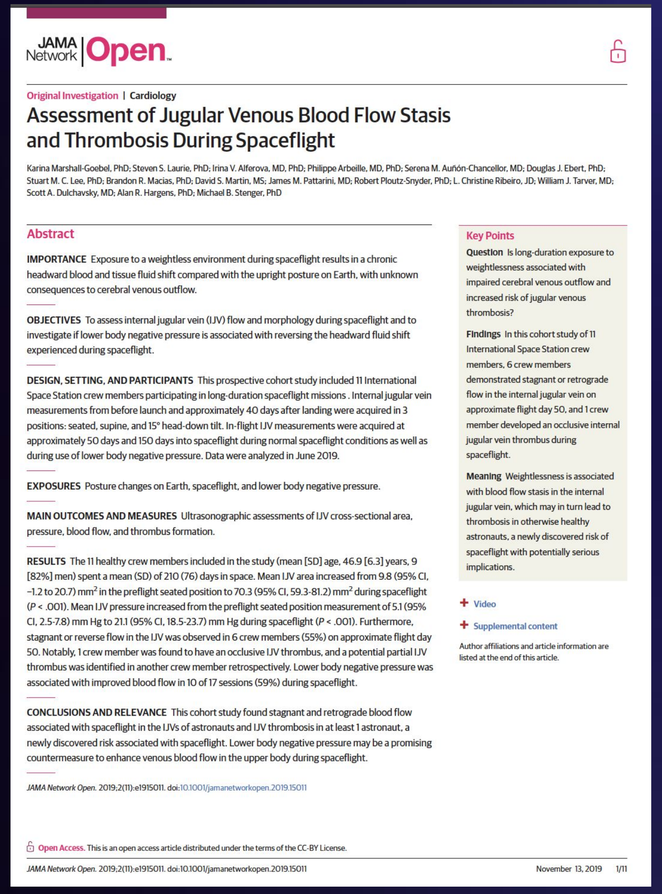


Dynamic ultrasound simulation integrated into VHS Platform





Ultrasound Simulation Application - Spaceflight Associated IJV Thrombosis



JAMA Network | Open

Original Investigation | Cardiology

Assessment of Jugular Venous Blood Flow Stasis and Thrombosis During Spaceflight

Karina Marshall-Goebel, PhD; Steven S. Laurie, PhD; Irina V. Alferova, MD, PhD; Philippe Arbeille, MD, PhD; Serena M. Auñón-Chancellor, MD; Douglas J. Ebert, PhD; Stuart M. C. Lee, PhD; Brandon R. Macias, PhD; David S. Martin, MS; James M. Pattarini, MD; Robert Ploutz-Snyder, PhD; L. Christine Ribeiro, JD; William J. Tarver, MD; Scott A. Dulchavsky, MD; Alan R. Hargens, PhD; Michael B. Stenger, PhD

Abstract

IMPORTANCE Exposure to a weightless environment during spaceflight results in a chronic headward blood and tissue fluid shift compared with the upright posture on Earth, with unknown consequences to cerebral venous outflow.

OBJECTIVES To assess internal jugular vein (IJV) flow and morphology during spaceflight and to investigate if lower body negative pressure is associated with reversing the headward fluid shift experienced during spaceflight.

DESIGN, SETTING, AND PARTICIPANTS This prospective cohort study included 11 International Space Station crew members participating in long-duration spaceflight missions . Internal jugular vein measurements from before launch and approximately 40 days after landing were acquired in 3 positions: seated, supine, and 15° head-down tilt. In-flight IJV measurements were acquired at approximately 50 days and 150 days into spaceflight during normal spaceflight conditions as well as during use of lower body negative pressure. Data were analyzed in June 2019.

EXPOSURES Posture changes on Earth, spaceflight, and lower body negative pressure.

MAIN OUTCOMES AND MEASURES Ultrasonographic assessments of IJV cross-sectional area, pressure, blood flow, and thrombus formation.

RESULTS The 11 healthy crew members included in the study (mean [SD] age, 46.9 [6.3] years, 9 [82%] men) spent a mean (SD) of 210 (76) days in space. Mean IJV area increased from 9.8 (95% CI, −1.2 to 20.7) mm^2 in the preflight seated position to 70.3 (95% CI, 59.3-81.2) mm^2 during spaceflight ($P < .001$). Mean IJV pressure increased from the preflight seated position measurement of 5.1 (95% CI, 2.5-7.8) mm Hg to 21.1 (95% CI, 18.5-23.7) mm Hg during spaceflight ($P < .001$). Furthermore, stagnant or reverse flow in the IJV was observed in 6 crew members (55%) on approximate flight day 50. Notably, 1 crew member was found to have an occlusive IJV thrombus, and a potential partial IJV thrombus was identified in another crew member retrospectively. Lower body negative pressure was associated with improved blood flow in 10 of 17 sessions (59%) during spaceflight.

CONCLUSIONS AND RELEVANCE This cohort study found stagnant and retrograde blood flow associated with spaceflight in the IJVs of astronauts and IJV thrombosis in at least 1 astronaut, a newly discovered risk associated with spaceflight. Lower body negative pressure may be a promising countermeasure to enhance venous blood flow in the upper body during spaceflight.

JAMA Network Open. 2019;2(11):e1915011. doi:10.1001/jamanetworkopen.2019.15011

Key Points

Question Is long-duration exposure to weightlessness associated with impaired cerebral venous outflow and increased risk of jugular venous thrombosis?

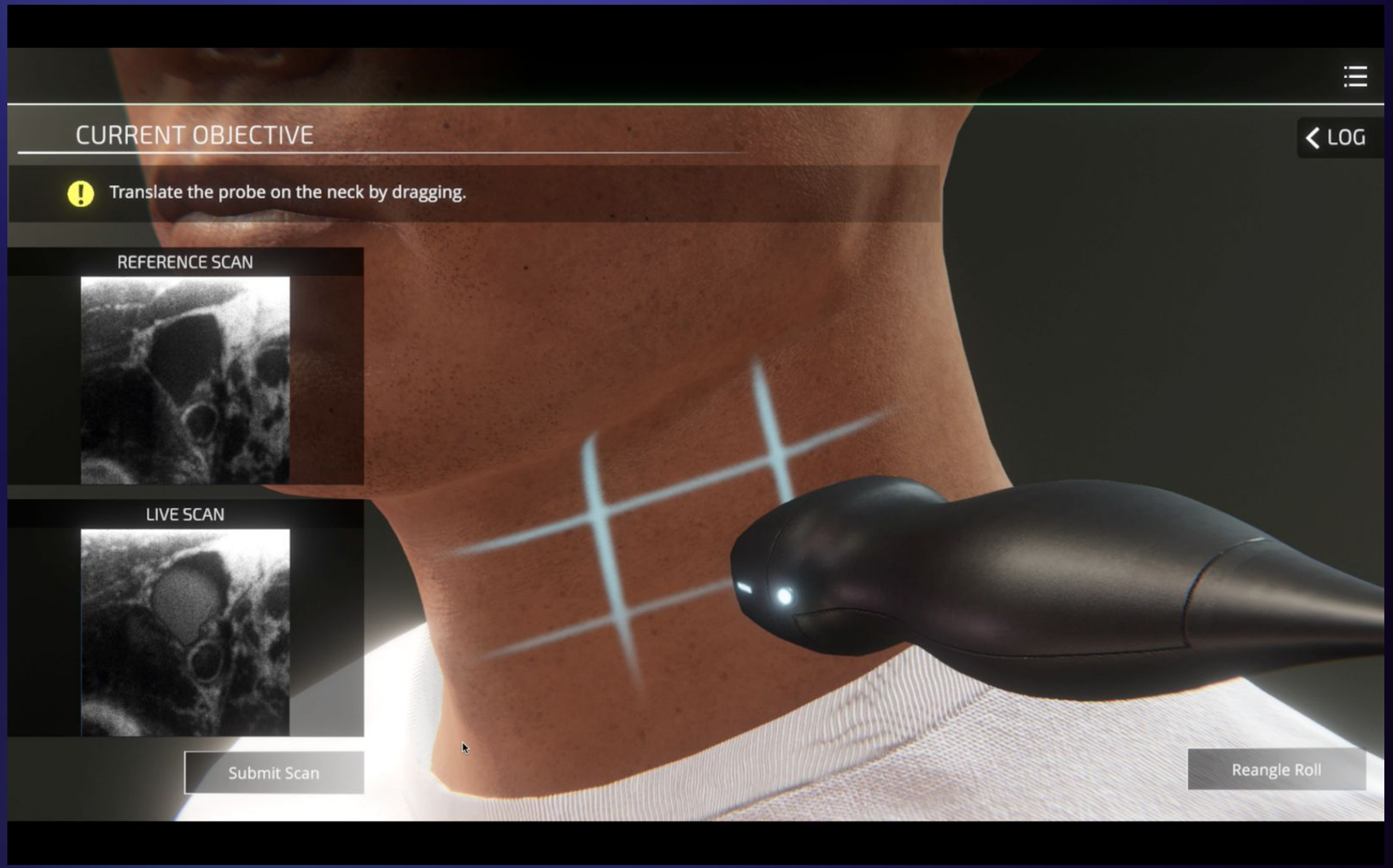
Findings In this cohort study of 11 International Space Station crew members, 6 crew members demonstrated stagnant or retrograde flow in the internal jugular vein on approximate flight day 50, and 1 crew member developed an occlusive internal jugular vein thrombus during spaceflight.

Meaning Weightlessness is associated with blood flow stasis in the internal jugular vein, which may in turn lead to thrombosis in otherwise healthy astronauts, a newly discovered risk of spaceflight with potentially serious implications.

+ Video

+ Supplemental content

Author affiliations and article information are listed at the end of this article.

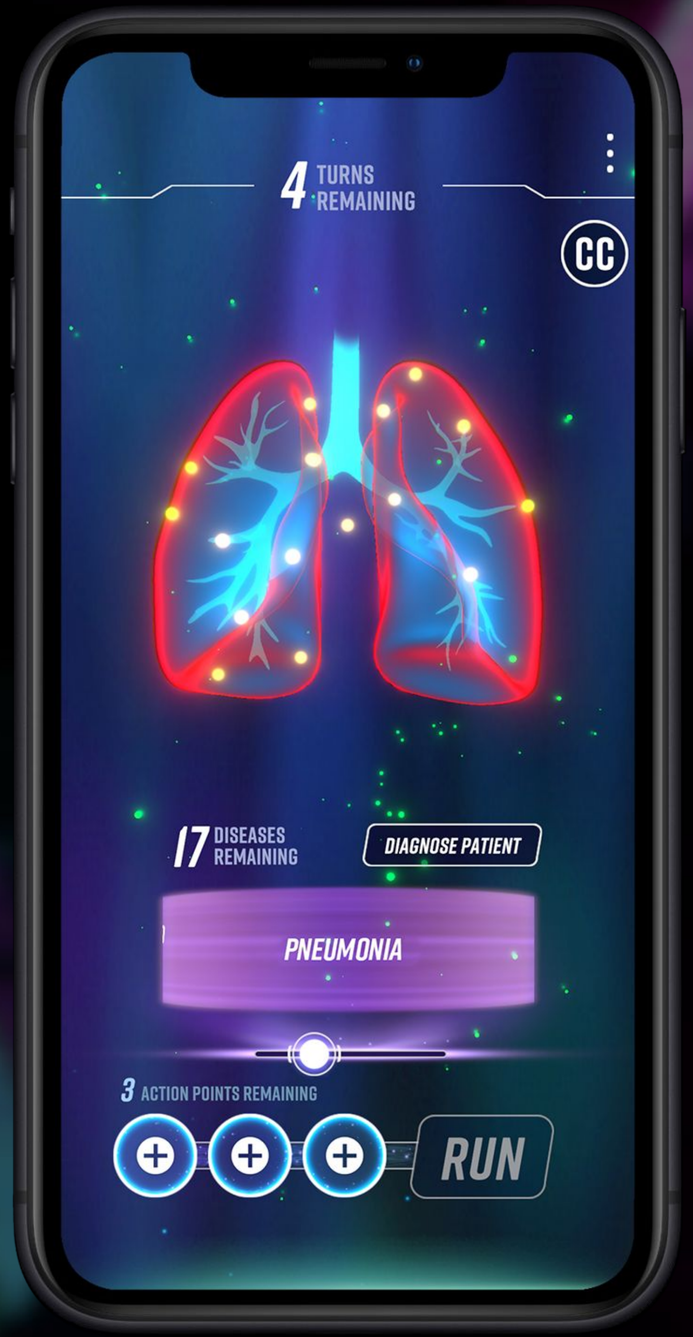



PROJECT V.H.S.
BY TRISH AND LEVEL EX
VIRTUAL HUMAN
CLINICAL SCENARIO
ABOUT
SETTINGS

COVID-19 Airway Management Training

Level Ex's *Difficult Airway* unit is being repurposed to train frontline medical professionals to:

- Secure and manage compromised airways
- Minimize spread of the virus



COVID-19 Diagnosis Challenges

Level Ex has developed challenging COVID-19 patient cases that harness the power of our existing **Diagnosis** game mechanics, requiring HCPs to flex their deductive reasoning skills.

Digital Twin Framework Project

Presenter: Erik Funkhouser

DIGITAL TWIN CONCEPT

Digital Human Framework that enables advanced, hyper-personalized Clinical Decision Support systems for Mars astronauts

VISION FOR LONG DURATION EXPLORATION MISSIONS

In the future, each astronaut will have a personalized “digital twin” that captures an accurate model of their anatomy and physiology. The “digital twin” is seen as a key component among a host of solutions to support personalized medical training, precision medicine, and real-time clinical support for flight surgeons and astronauts on crewed exploration class mission to Mars.

KEY COMPONENTS

- Personalized baseline volumetric anatomical data
- High fidelity visualization of key anatomy
- Integration of ultrasound capabilities
- Integration with physiological models
- Dynamic representation of medical conditions and space flight adaptations

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NASA

BRAINLAB

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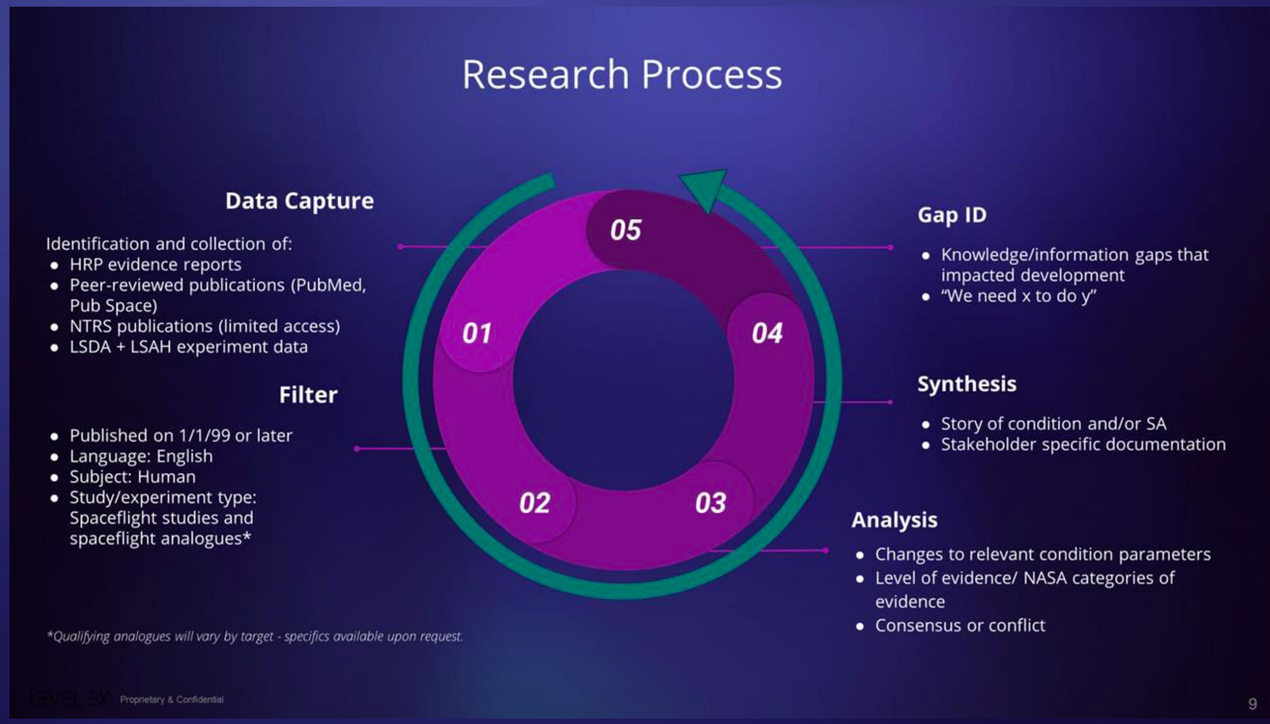
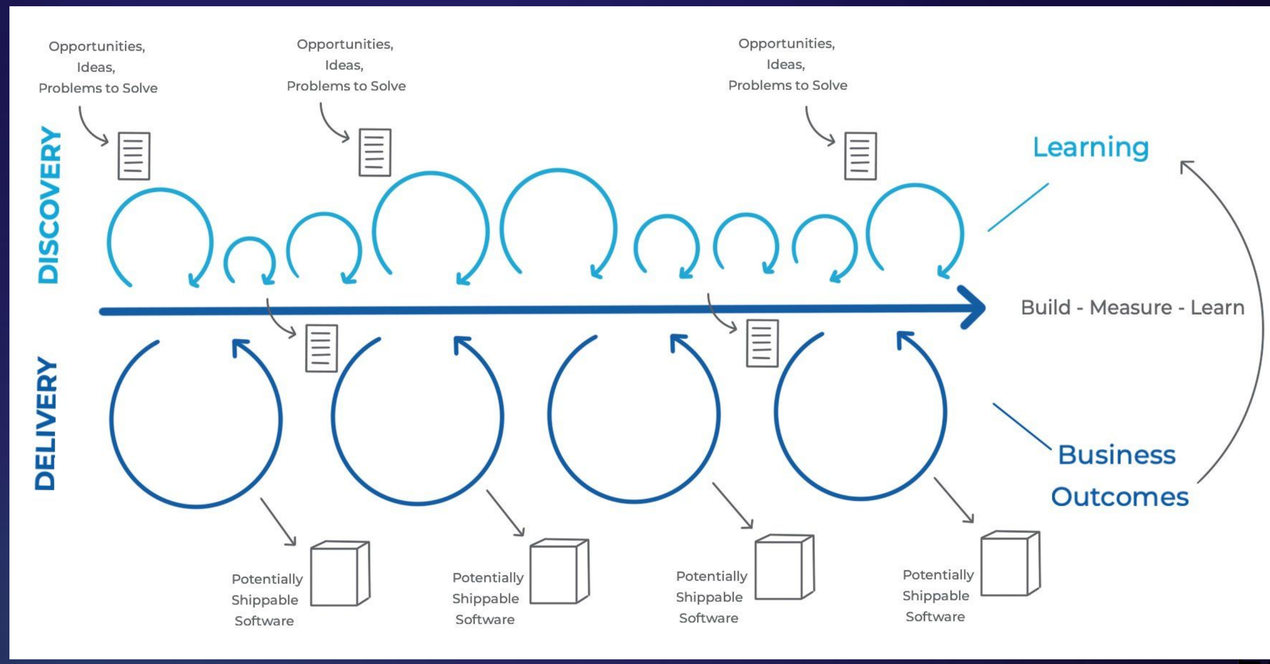
Digital Twin Framework Project: Research Analysis and Dev Process





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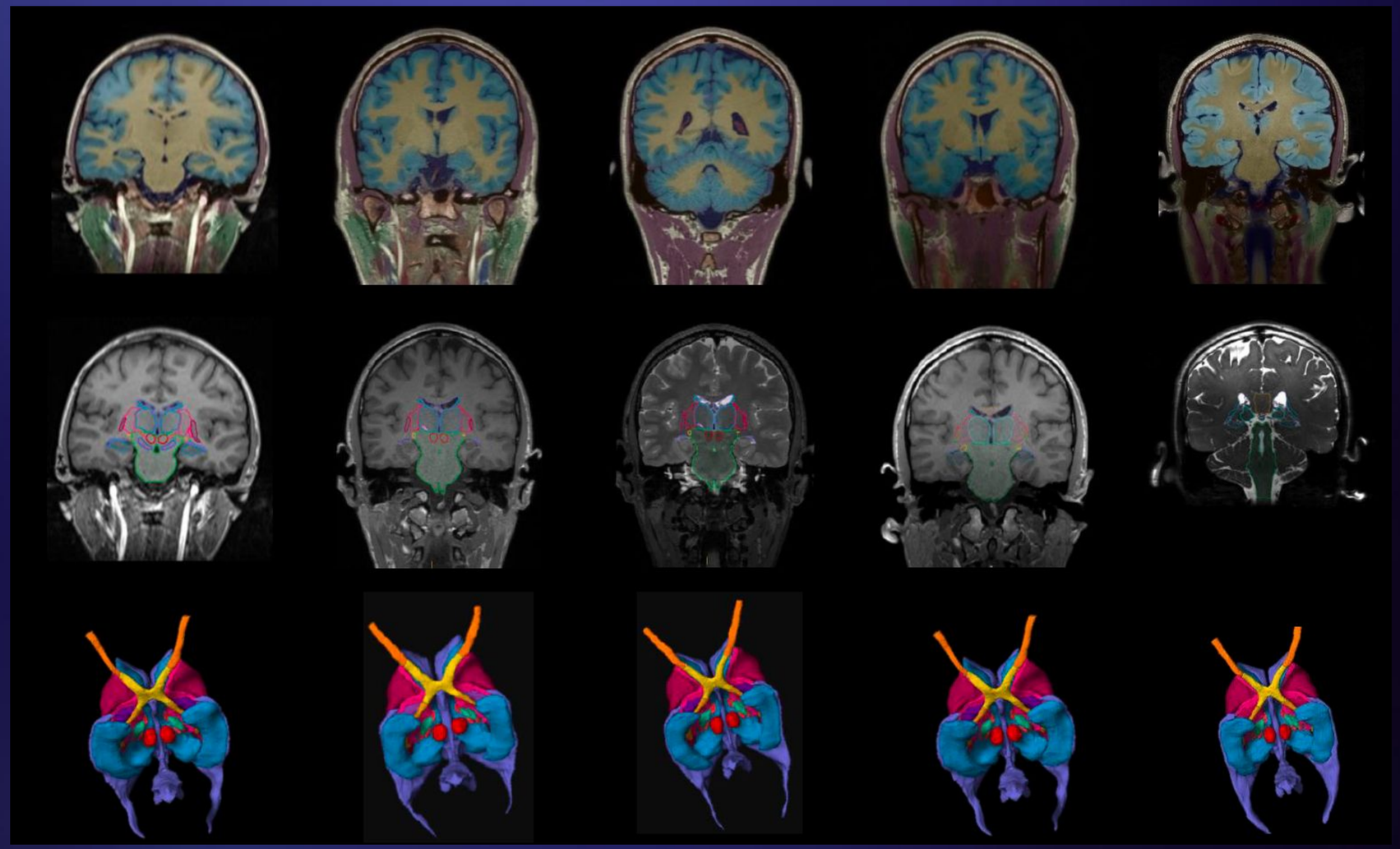
BrainLab - Image Fusion Technology

Digital Twin Framework Project: Image Fusion Prototyping



Example composition of patient MRI and CT imagery and volumetric data segmentation to identify anatomical components of the brain for surgical planning and intraoperative anatomy tracking.

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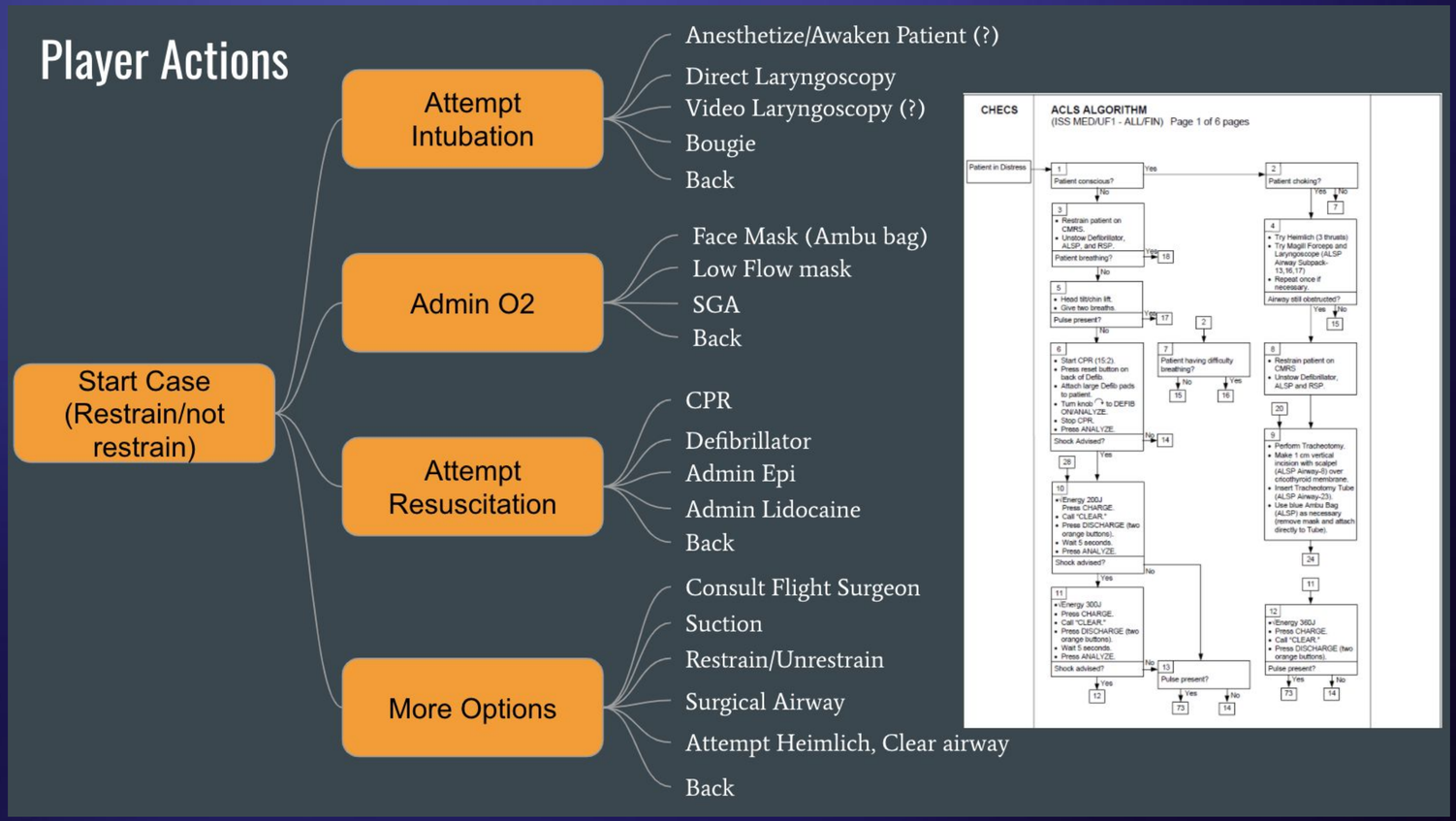
Digital Twin Framework Project: Collaborative Clinical Procedures

Presenter: Victoria Perizes

Digital Twin Framework Project: Collaborative Virtual Clinical Techniques



Example user interface adaptations from current DAA to NASA life support algorithm

Medical and artistic content for four new patient cases will be created to replace the existing content

Health gauges may be added or changed to represent other key vitals, like Heart Rate.

Risk factors will change to align with the key risk factors identified in operational checklists and by SMEs.

Player actions will change to align with the procedural decisions identified in the current life support algorithm.

Powered by Remote Play

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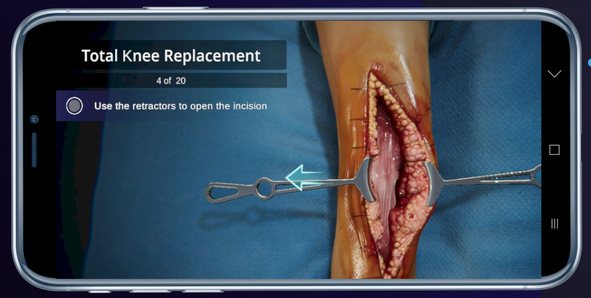

Jen Jones, MD

John Smith

Users interact with the content simultaneously, making observation and immediate feedback possible

Real-time interactivity and high-fidelity visuals

Shared platform access via standard video conferencing tools, including WebEx, Zoom, Veeva Engage, Microsoft Teams, etc.

Platform content is web-based and accessible via mobile and desktop browsers

Feedback and Discussion