REPORT OUTLINE

I. Introduction

II. Background
   A. The Human in Space
      i. Fig: The Human in Space: Environmental Challenges
      ii. Fig: Caring for the Human in Space
Altered FORCES on the Human Body

Changed PHYSICAL Factors: Decreased Weight, Fluid Pressure, Convection, Sedimentation

Body Fluids

Gravity Receptors

Weight-Bearing Structures

Dynamic Interactions

Adaptation

Altered Physiological STATE of the Body

THE WHOLE HUMAN INTERACTS WITH THE ENTIRE ENVIRONMENT
CARING FOR THE HUMAN IN SPACE

Altered Normal Activity, Sleep and Exercise

Artificial Internal Environment (Air, Water, Microbes, etc.)

Human Monitoring

Human in Space
(Altered Normal Earth Physiology)

Medical Care: Diagnosis and Therapy

Health and Performance Assessment

Individualized Pharmacological Prescription

Individualized Activity and Exercise Prescription

Radiation Protection Activities

Individualized Diet

Complete or Partial Weightlessness

Altered Radiation Environment

Altered Food and Meals

Altered Psycho-Social Environment
II. Background (cont)

B. Modeling the Human in Space – A Brief History

i. Fig: Biomedical Modeling & Space Flight

ii. Fig: The Whole-Body Algorithm: The Digital Astronaut of the 1970s

iii. Fig: Guyton Flow Chart

iv. Fig: Structure of Long-Term Circulatory, Fluid & Electrolyte Model

v. Fig: Short-Term Thermoregulatory Model

vi. Fig: Short-Term Respiratory Model

vii. Fig: Short-Term Cardiovascular Model
Space Physiological Modeling

Phase I - Early Human Flights
Problem: EVA suit overheating on Gemini 4; habitat environmental control; Apollo EVA consumables
First Computer Model of Human Physiological System in Space - Thermoregulatory Model - J.A.J. Stolwijk

Phase II - Skylab and Early Spacelab Missions
Problem: Development of integrated approach to analysis and synthesis of enormous physiological data return from Skylab Missions and of next generation of human experimentation to be carried out on Shuttle/Spacelab Missions.
Integration accomplished through central NASA-developed space-flight simulations using individual models for cardiovascular, respiratory, thermo-regulatory, and fluid-electrolyte-circulatory models and integration of models into the Whole-Body Algorithm.

Phase III - Later Spacelab Missions & Early ISS Research
Individual investigator prominence in space physiology. Clarifying questions of depth and substance addressed through use of a large variety of investigator-originated mathematical models of many of the body systems.

Phase IV - Future Modeling Activities
Where do we go from here: The Digital Astronaut?
THE WHOLE-BODY ALGORITHM - THE DIGITAL ASTRONAUT OF THE 1970'S

LONG-TERM CIRCULATORY, FLUID & ELECTROLYTE MODEL
(Modified Guyton Model)

SHORT-TERM THERMOREGULATORY MODEL
(Stolwijk Model)

SHORT-TERM CARDIOVASCULAR MODEL
(Croton Model)

SHORT-TERM RESPIRATORY MODEL
(Grodins Model)
ACTUAL FLOW CHART OF 1972 GUYTON MODEL
II. Background (cont)

C. The Digital Human and Related Projects

i. Fig: The Digital Human & Related Systems
INTEGRATIVE APPROACH TO BIOMEDICAL SCIENCE

20th Century Biology
Reductionist Approach
- Genome Sequencing
- Expression Profiling
- Proteomics
- Structural Biology

21st Century Biology
Integrative Approach
- Bioinformatics
- Systems Science
- Modeling & Computation
- Bioengineering

(McCulloch, UCSD, 2004)
INTEGRATIVE IN-SILICO BIOLOGY

Data Integration, Functional Integration, Structural Integration

(McCulloch, UCSD, 2004)
THE GENERAL DIGITAL HUMAN PROBLEM

Digital Human

General-Purpose Applications
- Biomedical Research
- Education/Training
- Medical Practice
- Human Factors

Special-Purpose Projects
- Digital Astronaut
- Virtual Soldier
- Patient

Bridging Projects
- Structural Integration Challenges
- Functional Integration Challenges
- Data Integration Challenges
- High Performance Computing
- Subsystem Physiological Models
- Data Representation
- Modeling Tool Development
- Interoperability
- Systems Biology
- Databases

Foundational Infrastructure
- Anatomy
- Geometry
- Standards
- Ontologies
- Biomedical Informatics

Courtesy of J. Coolahan
III. The Digital Astronaut

A. Definition

B. Goal

C. Approach

D. Difficulties

i. Foundational

ii. Structural Integration

iii. Functional Integration

iv. Data Integration
MANAGING RISK IN THIS COMPLEX SYSTEM

Advanced Countermeasure: Exercise, Artificial Gravity, Behavioral Health, Pharmacology and Nutrition

Altered Normal Activity, Sleep and Exercise

Altered Psycho-Social Environment

Physiological/Psychological Monitoring

Humans in Weightless Space Flight
(Altered Normal Earth Physiology)

Medical Monitoring

Altered Radiation Environment

Altered Food and Meals

Autonomous Medical System: Monitoring, Diagnosis and Therapy

Digital Astronaut:
- Integrated Modeling & Database System
- Knowledge Integration
- Analysis/Understanding
- Task Performance Prediction
- Reserve Capacity Estimation

Mission Tasks

Biomedical Informatics:
- Integrated Medical & Experimental Data Archive System
- Data Analysis & Display Tools
III. The Digital Astronaut (cont)

E. Benefits

i. Space Research Community
ii. Engineers & Managers
iii. Physicians
iv. General Health Care Benefits
v. Scientific Community (unsolved problems in physiology)