Using A Model-Based Systems Engineering Approach For Exploration Medical System Development

A. Hanson, J. Mindock, K. McGuire, J. Reilly, J. Cerro, W. Othon, D. Rubin, M. Urbina, M. Canga

NASA Johnson Space Center, Houston, 2101 NASA Parkway, TX, USA 77058, KBRWyle, 2400 NASA Parkway, Houston, TX, USA 77058,

* Corresponding Authors andrea.m.hanson@nasa.gov, michael.a.canga@nasa.gov
Introduction

• NASA’s Human Research Program’s Exploration Medical Capabilities (ExMC) element is defining the medical system needs for exploration class missions.

• Our approach is to:
  • Establish collaborative tools to support the model infrastructure,
  • Capture stakeholder needs,
  • Design of the model architecture and emerging technical content,
  • Interact with owners of related models to coordinate model expansion.

Mission Statement
Define, develop, validate, and manage the technical system design needed to implement exploration medical capabilities for Mars and test the design in a progression of proving grounds.
Model-Based Systems Engineering (MBSE)

- The formalized application of modeling to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases.¹

¹ INCOSE SE Vision 2020 (INCOSE-TP-2004-004-02, Sep 2007)
Context and Approach

- Strive to have the team share a common mental model of the stakeholder needs, approach, and expected outcomes.
- Control, measure and report progress of technical solution throughout the project lifecycle including requirements, analysis, design, implementation, verification and operations of the system.
- Abstraction that contains only the details needed to address the intended use of the model.
- Not an analytical model.
- Team attended training courses in use of the SysML language, and a SysML Methodology Course together with other modeling groups with which we would integrate future work.
Infrastructure

- Model infrastructure is an important foundational element and forms the underlying framework to implement MBSE.
- Infrastructure design will have long-term consequences and impact the effectiveness of the overall modelling effort.
- Systems Modeling Language (SysML) as the modeling language to support this work.
- NASA-wide teamwork server in use, and allows the geographically diverse and cross-agency group to readily access the working model.
- Roles and responsibilities of model team members were established.
Guidance on model development was organized into 4 generic life cycle development phases.

- Defining the *Context* and activities in each phase of the project lifecycle, to clarify the level of detail expected in the model,
- Identifying the *Model Content*, to define what elements of the modeling process should be applied at that phase, and
- Listing the *Model Outcomes*, to develop a form that can be interpreted by stakeholders to demonstrate value (and which may have to be transformed from the model to ease communication).
• Representation of the Medical System as an internal component of the CHPS.

• Communicates that the crewmembers are important components *within* the Flight System.

• Promote awareness and understanding of the impacts the integrated human and technical portions of the system have on each other.
Concept of Operations

In-Flight Medical System Scenarios

Planned

Self-Care
  - Autonomous
  - Semi-autonomous
  - Exercise
  - Family Conference

Directed Care
  - Autonomous
  - Semi-autonomous
  - Dental Exam
  - Psychological Conference

Medical System Maintenance
  - Autonomous
  - Semi-autonomous
  - No Scenario Provided 2

Medical Training & Education
  - Autonomous
  - Semi-autonomous
  - No Scenario Provided 3
  - Cont’d Med. Education

Unplanned

Self-Care
  - Autonomous
  - Semi-autonomous
  - Headache
  - No Scenario Provided 1

Directed Care
  - Autonomous
  - Semi-autonomous
  - Urinary Tract Infection
  - Dental Abscess
  - Acute Rad. Sickness

Medical System Maintenance
  - Autonomous
  - Semi-autonomous
  - No Scenario Provided 2

Medical Training & Education
  - Autonomous
  - Semi-autonomous
  - Exercise HW Malfun
  - Just In Time Training

Emergent Care
  - Autonomous
  - Semi-autonomous
  - Arm Injury
  - DCS 2

1 System functionality is demonstrated in other scenarios
2 Patient is the physician astronaut
Model Organization and Containment Tree

- A common template for model organization ensures consistency in development of model products.
- When adopted across teams, this organization makes navigation through shared models easier.
- The Deep Space Transit model is the highest level of modeling fidelity, shorter exploration mission may use a subset of these packages.
A modeling process was created for consistency in product development and work flow.

The use case scenarios from the ConOps were used as the starting point.

The modeling process shows this activity as a looped and iterative process, which allows for model updates as needs are negotiated and trades are made throughout the project lifecycle.
Thematic analysis\(^2\) was used to identify what the functions were for the medical system.

- **Phase 1 - Familiarization with the data**
- **Phase 2 – Generating initial codes**
- **Phase 3 – Searching for themes**
- **Phase 4 – Reviewing themes**
- **Phase 5 – Defining and naming themes**
- **Phase 6 – Producing the report**

\(^2\)V. Braun, & V. Clark.. Using thematic analysis in psychology. Qualitative research in psychology, 3(2), 77-101. 2006.
System Architecture Model
Next Steps and Applications

**Model Expansion**

- Interface definitions.
- Customized tools.
- Model libraries.
- Model profiles and stereotypes.
- Style Guide.

**Applications**

- What we want
- Libraries inform implementation options
- Risk and layout evaluations of options
- Tie it all together

- What we can have in architecture option

- Trade Option Characterization
  - Med conditions addressed
  - Standards and requirements met
  - Master equipment list
  - Risk evaluation
  - Layout evaluation

- AMCL
- Planned Activities
- Capabilities
- SysML Model
- MEDPRAT
- MEDMEL
- Medical Data Tool
- Habitat Tool
- Common assumptions
  - Repository Configuration & Data Management
Summary

• Successful implementation of any system or subsystem in a complex project, such as a Mars transit vehicle, requires thoughtful and structured design from project initiation through maturation and implementation.

• The MBSE approach and team methodology is key to ensuring consistent workflow, practices, and streamlined integration with vehicle design.