HRP-48012

# Recommendation for a Medical System Concept of Operations for Gateway Missions

Exploration Medical Capability (ExMC) Element
Human Research Program

Verify that this is the correct version before use.

Baseline

April 2019

**National Aeronautics and Space Administration**
Lyndon B. Johnson Space Center
Houston, Texas

# Recommendation for a Medical System Concept of Operations for Gateway Missions

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## CHANGE HISTORY

| REV. | DESCRIPTION | DATE |
|---|---|---|
| Draft | This document was developed by the Exploration Medical Capability Element's Systems Engineering team and will be incorporated into the Crew Health and Performance Concept of Operations for Gateway Habitat. | 2/26/18 |
| Pre-Decision Draft | Watermark added. | 7/18/18 |
| Baseline | Incorporated comments from the Exploration Medical Capability Control Board, per SA-01082. | 4/24/19 |

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# 1. INTRODUCTION

## 1.1. Purpose

NASA's exploration missions to cis-lunar space will establish a permanent gateway to future transport missions to Mars. These missions mandate a significant paradigm change for mission planning, spacecraft design, human systems integration, and in-flight medical care due to constraints on mass, volume, power, resupply, and medical evacuation capability. These constraints require medical system development to be tightly integrated with mission and habitat design to provide a sufficient medical infrastructure and enable mission success.

This concept of operations provides a vision of medical care needs that will be used to guide the development of a medical system for the cis-lunar Gateway Habitat. This medical system will serve as the precursor to what is implemented in future exploration missions to Mars. This concept of operations documents an overview of the stakeholder needs and system goals of a medical system and provides examples of the types of activities for which the system will be used during the mission.

This concept of operations informs the ExMC systems engineering effort to define the Gateway Habitat Medical System by documenting the medical activities and capabilities relevant to Gateway missions, as identified by the ExMC clinician community. In addition, this concept of operations will inform the subsequent systems engineering process of developing technical requirements, system architectures, interfaces, and verification and validation approaches for the medical system.

This document supports the closure of ExMC Gap Med01: We do not have a concept of operations for medical care during exploration missions, corresponding to the ExMC-managed human system risk: Risk of Adverse Health Outcomes & Decrements in Performance due to Inflight Medical Conditions [1].

## 1.2. Scope

This document describes a concept of operations for a medical system for the proposed Gateway Habitat [2]. Assumptions about the Gateway Habitat used in this concept of operations are documented in Sections 3 and 4. When the Gateway concept of operations document (DSG-CONOP-001: Gateway Concept of Operations) is baselined, the current document will be updated if necessary to address any inconsistencies. The Gateway Habitat Medical System is a component of the Crew Health and Performance System (HRP-TBD Crew Health and Performance System Concept of Operations for Gateway Missions (Level IV)). Therefore, any descriptions of the Medical System in the Crew Health and Performance concept of operations supersede those in this Medical System Concept of Operations document.

The Gateway Habitat Medical System concept of operations is described via scenarios of medical events that may occur during a mission. These scenarios abide by the ExMC interpretation of NASA-STD-3001 as documented in NASA /TM_2017_219290 Interpretation of NASA-STD-3001 Levels of Care for Exploration Medical System Development. They have been developed with input from ExMC clinicians within the ExMC Systems Engineering team and other clinicians via the ExMC Clinicians Working Group. Each scenario is represented by a narrative and associated activity diagram, which displays one possible set of steps through the scenario and provides system developers an understanding of stakeholder needs and system goals.

The Gateway Habitat Medical System components outlined in this document, including all hardware, software, and knowledge management tools, are only representations of potential solutions. The inclusion of specific technologies in this document should not be interpreted as levied requirements. The focus of this concept of operations is to capture medical system functionality concepts, not methods of implementation.

## 1.3. Change Authority

This version of the HRP-48012 Recommendation for a Medical System Concept of Operations for Gateway Missions document will be controlled by the ExMC Control Board. If Programs outside of ExMC choose to utilize and change the content in this document, any changes must be communicated to ExMC management, and the changes must be processed through the respective control boards.

## 1.4. Applicable Documents

Applicable documents consist of documents that contain provisions or other pertinent requirements directly related to and necessary for the performance of the activities specified by the document.

| Document Number | Title |
|---|---|
| TBD-02 | ExMC Element Management Plan |
| TBD-03 | ExMC Systems Engineering Management Plan |
| NASA-STD-3001, Vol 1 | Space Flight Human-System Standard: Crew Health |
| NASA-STD-3001, Vol 2 | Space Flight Human-System Standard: Human Factors, Habitability, and Environmental Health |
| NASA/TM_2017_219290 | Interpretation of NASA-STD-3001 Levels of Care for Exploration Medical System Development |

## 1.5. Reference Documents

The following documents contain supplemental information and provide guidance in the application of the HRP-48012 Recommendation for a Medical System Concept of Operations for Gateway Missions document. These documents may or may not be specifically cited within the text of this document.

| Document Number | Title |
|---|---|
| TBD | Crew Health and Performance System Concept of Operations for Gateway Missions (Level IV) |
| HRP 47065, Rev H | Human Research Program Integrated Research Plan |
| NPR 7123.B, Appendix A | NASA Systems Engineering Processes and Requirements |
| N/A | Safe Passage: Astronaut Care for Exploration Missions |
| SSP 50260 | ISS Medical Operations Requirements Document |
| SSP 50667, Vol B | Medical Evaluations Document: Crew Medical Officer Health Status Evaluations |
| SSP 54045_54046-ANX4 | Increment Definition and Requirements Document for Increments 45 and 46, Annex 4: Medical Operations and Environmental Monitoring |
| IMM Data Request D-20160725-363 | IMM data request for the Integrated Medical Model Medical Condition List |
| IMM-GEN-309 | Integrated Medical Model Medical Condition List |
| NASA/SP-2010-3407 | Human Integration Design Handbook |
| [TBD-04] | [Systems Engineering Architecture Diagram Definitions] |

# 2. STAKEHOLDER NEEDS AND SYSTEM GOALS

In 2001, the Committee on Creating a Vision for Space Medicine During Travel Beyond Low Earth Orbit released a report entitled *Safe Passage: Astronaut Care for Exploration Missions* [3]. This committee acted on authority of the Institute of Medicine to assess what is known about the health effects of space travel and provide recommendations on how to approach health care during these missions. In the years since Safe Passage was published, some of its recommendations have been implemented in low Earth orbit. The recommendations from this report, and input from stakeholders who will rely on a higher level of crew autonomy than exists in low Earth orbit operations, formed the conceptual basis for the current workings of the Human Research Program and a roadmap for biomedical research [1]. Much work remains to extend the vision to exploration missions through the merging of engineering requirements and medical priorities in the context of technology and process development. As Safe Passage suggests, NASA's exploration goals will require an appropriately scoped crew health and performance system built on a strategic research plan while ensuring integration of the engineering and health sciences with vehicle design constraints.

## 2.1. Stakeholder Needs

Gateway Habitat Medical System stakeholder needs express the nature of goals, strategies, objectives, and key concerns about success, challenges, issues, risks, and problems related to the ability to provide medical care within the habitat. These needs serve as a foundation for defining system goals and requirements and, ultimately, defining the Gateway Habitat Medical System architecture.

### 2.1.1. Maintain Crew Health

*Stakeholders need a medical system that maintains crew health.*

Maintenance of crew health is dependent on capabilities to prevent, diagnose, treat, and manage crew health long term [Table 2.1]. This maintenance is needed to help keep healthy crew healthy and to manage disease and injury when necessary.

| **Capability Category** | **Description** |
|---|---|
| Prevention | Promotion of physical and mental health; prevention of disease through crew screening; Gateway Habitat monitoring and hazard mitigation. |
| Diagnosis | Determination of the nature of a disease or injury. |
| Treatment | Psychological or medical management of a patient. |
| Long-Term Management | Continuing in-flight management of persistent medical conditions, including re-assessment, ongoing treatment, rehabilitation, and palliative care. |

Table 2.1 – Maintain Crew Health and Safety Capabilities

### 2.1.2. Enable Mission Success

*Stakeholders need a medical system that enables mission success.*

A safe, reliable and effective medical system, which maximizes interoperability within the medical system and with other mission systems and minimizes physical and cognitive workload on the crew, is integral for optimal performance in achieving mission and science objectives.

### 2.1.3. Support Exploration Test Bed Activities

*Stakeholders need a medical system that supports exploration test bed activities.*

Verification and assurance that medical system capabilities and technologies can support the appropriate levels of care for future missions to Mars reduce the health and medical risks associated with those missions.

## 2.2. Medical System Goals

Gateway Habitat medical system goals provide a foundation for exploration medical system development. They establish a basis for medical system quality attributes and influence technical measures commonly used for insight into performance of the technical solution. These goals are based on constraints levied on the medical system by stakeholder needs, mission architecture, and stakeholder expectations.

### 2.2.1. Health Management

*The medical system should provide health management capabilities to enable mission success.*

Recognizing the distance from Earth during Gateway exploration missions, in-mission care capabilities must span prevention, diagnosis, and treatment of conditions to support the well-being and clinical health of the crew. The health management capabilities will use resources (e.g., skillsets, software, hardware, medication) to prepare for and execute planned and unplanned medical operations, pharmacy operations, personalized medicine, training, resource management, ethics considerations, data management, and risk estimation. Future analysis is required to determine the extent of these health management capabilities required to meet this goal.

This goal sets the stage for expanded health management capabilities during long-duration exploration missions to destinations such as Mars, during which long-term management of well-being and health must also be considered.

### 2.2.2. Crew Autonomy

*The medical system should enable crew autonomy in medical task execution and decision-making.*

While ground medical support will provide a director of care to serve as the primary in-mission decision maker, the Gateway Habitat Medical System should provide different levels of support to crew for medical care capabilities, from semi-autonomy (i.e., ground support provides guidance) to full autonomy (i.e., no guidance from ground support). This medical care paradigm requires sufficient Gateway Habitat capabilities and resources in the form of onboard medical references and decision support systems. This goal drives the eventual transition to autonomous operations that are necessary for missions to more distant destinations. Future analysis is required to determine the expected and required levels of autonomy during Gateway missions.

### 2.2.3. System Flexibility and Extensibility

*The medical system should conserve and extend the usable life of medical system resources through design, in-mission use, and medical system operations flexibility and extensibility.*

Constraints on mission resources and the inability to definitively predict all medical conditions that will occur during the mission drive the need for medical system flexibility and extensibility. Medical flexibility helps identify the broadest use opportunities for a limited resource set relevant for clinical needs. Extensibility addresses the use of medical resources towards conditions and situations outside of the target design conditions.

### 2.2.4. Medical, Habitat, and Mission Systems Integration

*All aspects of the medical system, including hardware, software, and human users, should be integrated with the mission and habitat design.*

The Gateway Habitat Medical System is a component of the Gateway Crew Health and Performance System, which, in turn, is a component of the overall integrated Gateway Habitat System. When allowed and appropriate, resources and interfaces should be shared between the different Gateway Habitat systems to facilitate the efficient use of crew time, vehicle stowage, and data collection and analysis.

### 2.2.5. Crew and Medical System Integration

*The medical system should fit the needs, abilities, and limitations of the crew.*

A well-designed Gateway Habitat Medical System lowers mission medical risk, in part, by minimizing training time and operational complexity. It accounts for the various modes of data entry, input devices, computing platforms, and user preferences employed in the Gateway Habitat. This Gateway Habitat Medical System incorporates human system integration and human factors guidelines to reduce the cognitive and physical workload while using the medical system. A well-designed, usable medical system is easy to learn and operate, keeps the user informed on what is going on, reduces the number of errors and makes them easy to recover from, and assists in the timely completion of tasks. The expectation is that unobtrusive automated and manual processes are available to support crew activities.

### 2.2.6. Crew Health Privacy Protection

*The medical system should ensure privacy of health and medical activities and data.*

To protect the privacy of crewmembers, the Gateway Habitat Medical System should provide space and privacy within the habitat for the execution of health and medical activities. The medical system should also provide the necessary safeguards to ensure the privacy and integrity of sensitive health and medical data.

### 2.2.7. Ground Awareness

*The medical system should maintain ground situation awareness of crew health and medical system status, as flight communication constraints permit.*

The ground support system should be periodically informed of crew and medical system status to assess impacts to mission goals and objectives and to provide support as needed. Future analysis is required to determine the level and frequency of monitoring and transmission of data to the ground support system to ensure proper medical support.

### 2.2.8. Continual Information Application & Learning

*The medical system should support medical system knowledge augmentation over the mission lifetime.*

Knowledge gained during the mission, both inflight and on the ground, is needed for updating medical system elements, such as task training, decision support, and models for estimation and prediction of crew health and system status.

### 2.2.9. Crew Performance

*The medical system should enable the crew to perform mission tasks by enabling fitness for duty.*

Exploration missions expose crewmembers to environmental and social conditions that may have deleterious effects on their ability to perform tasks. Fitness assessments of crewmember physical, cognitive, and behavioral states, using data collected by medical and non-medical systems, support the crew in achieving mission objectives by identifying degradation in crewmembers' ability to perform tasks. This goal's importance increases with mission duration and supports the development of operational capabilities for long-duration exploration missions.

### 2.2.10. Research Support

*The medical system should enable in-mission crew health and performance research through the hardware, software, human, and operational aspects of the medical system.*

To minimize in-flight resource redundancy, the Gateway Habitat Medical System should be compatible with the collection, storage, and maintenance of crew health and performance research samples and data. The consolidation of clinical and research protocols, when appropriate, reduces the overall data collection workload on the crew. The management of clinical and research data by a single system expedites the sharing of data for improved crew care and more meaningful research.

### 2.2.11. Future Capabilities Test Bed

*The medical system should serve as a platform for developing and testing capabilities required to enable medical system aspects of the crew health and performance system during Mars transport missions.*

To prepare for long-duration exploration missions to Mars, the Gateway Habitat Medical System should be designed and built to support the continued development and testing of components that expand long-term health management, autonomous capabilities, and crew performance support. While the medical system should be primarily developed to meet operational medical needs of the current mission, it should be built upon an infrastructure that supports an evolution of capabilities as they are needed for the current mission and also as a testbed for capabilities needed for future missions.

## 3. GATEWAY HABITAT MEDICAL SYSTEM DESCRIPTION

The Gateway Habitat Medical System described in this document is one of many systems envisioned within the mission environment (Figure 3-1). The Gateway Habitat System and Gateway Ground Crew Health and Performance (CHP) System are defined in this section, as they provide important interactions with the Gateway Habitat Medical System.

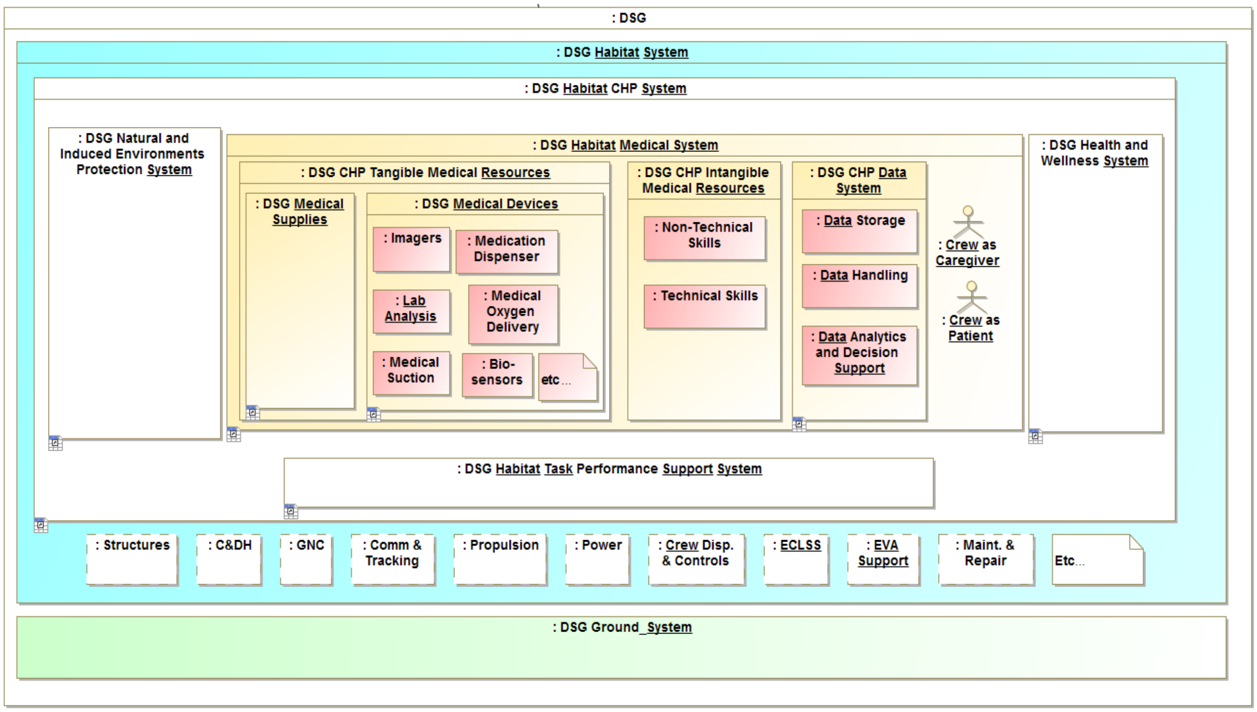


Figure 3-1 – Context Architectural View of Gateway Systems

This draft system context architecture was developed based on the needs, goals, and medical system behaviors as described in this document and will be further refined as requirements are written. As system development continues, additional details will be defined and system functions will be mapped to physical components.

## 3.1. Gateway Habitat System

The Gateway Habitat System includes the Gateway Habitat CHP System and other habitat systems.

### 3.1.1. Gateway Habitat Crew Health and Performance System

The Gateway Habitat Crew Health and Performance (CHP) System includes all functional habitat subsystems required to sustain crew operations. In this draft context architecture, the technical aspects of the Gateway Habitat Crew Health and Performance System are represented by the Gateway Habitat Medical System, Gateway Natural and Induced Environments Protection System, Gateway Habitat Task Performance Support System, and Gateway Health and Wellness System. Systems other than the Gateway Habitat Medical System are notional at this time and will be further defined and iterated with subject matter experts from those areas.

The Gateway Habitat Medical System consists of the crewmembers, hardware, software, skillsets and knowledge resources required for healthcare of in-mission crewmembers, including the prevention, diagnosis, treatment, and long-term management of medical conditions for both clinical and well-being aspects of health.

While this Concept of Operations focuses on the Gateway Habitat Medical System, current work performed by the ExMC Element includes the other systems, which will be addressed outside of this document. Interfaces between these systems and the Gateway Habitat Medical System are currently being identified. The contents of these systems may be referenced by the Gateway Habitat Medical System but will not be controlled by it.

The Gateway Habitat Medical System is divided into three subsystems, as described in Table 3-1.

| Subsystem | Description |
|---|---|
| Tangible Medical Resources | Resources with mass, power, and volume that have attributes of limitation (e.g., availability, quantity, reuse, expiration, replenishment, interface). These tangible resources (e.g., bandages, oximeter, and medications) are required for the execution of medical activities. |
| Intangible Medical Resources | Resources without mass, power, and volume (e.g., skills, decision-making, and training) required for the execution of medical activities. These resources are provided by various means, such as through a crewmember or software system. |
| Gateway CHP Data Systems | Collects, processes, and stores all medically relevant data from disparate sources (e.g., radiation environment, biosensors, exercise regimens, medications, lab diagnostics, and electronic medical records) and provides them to crew members via user interfaces. These data are available for consultation onboard the spacecraft and are also transmitted to the ground for additional analysis. The system provides data to other onboard systems as needed through software interfaces and enables decision support capability by tracking and trending biometric data and implementing analytical algorithms that augment the crewmember knowledge. |

Table 3.1 – Gateway Habitat Medical System Subsystems

The Gateway Habitat Medical System also includes crew interaction. Within a mission, the flight crew can function in patient, flight caregiver, and non-medical (e.g., maintenance) crewmember roles. The Gateway Habitat Medical System must be developed to support both roles. Future analysis is required to determine the skill, knowledge, training, and continuing educational needs required for the crew to meet the medical expectations of Gateway missions.

### 3.1.2. Other Habitat Systems

Other Gateway Habitat systems, such as Structure, Command and Data Handling at the vehicle level, Environmental Control and Life Support Systems (ECLSS) and Power systems, are included in this diagram as referenced elements that potentially interact with Gateway Habitat CHP Systems. This would occur through physical interfaces (e.g., the use of fluids, power, and gasses for medical purposes) or digital interfaces (e.g., the transfer of data between systems). Intangible interactions, such as process steps for medical activities impacting vehicle operational constraints, are also possible.

## 3.2. Gateway Ground System

The Gateway Ground System includes all functional subsystems and personnel required to support mission operations from Earth-based support facilities. This definition will be further defined and iterated with subject matter experts from appropriate areas.

# 4. GATEWAY MISSION CONSTRAINTS AND ASSUMPTIONS

In lieu of an official NASA design reference mission (DRM), this concept of operations uses constraints and assumptions identified by the ExMC Systems Engineering team based upon NASA exploration missions EM-3, EM-4, and EM-5 defined in the “Progress in Defining the Deep Space Gateway and Transport Plan” presentation to the NASA Advisory Council [2]. The EM-3, EM-4, and EM-5 missions will use the Orion vehicle to transport crew between Earth and the Gateway Habitat, which will be in a Near-Rectilinear Halo Orbit (NRHO) around the moon [2]. ExMC understands that the DRM implemented by a future NASA Gateway program may differ [TBD-05].

## 4.1. Duration

The estimated mission duration of GM-2 is 10 days, with GM-4, GM-5, and GM-7 estimated at 30 days and subsequent missions estimated at up to 90 days. Transit to and from the Gateway will each take ~4 days [TBC-01].

## 4.2. Communication

Due to the distance between Earth and the moon, unobstructed communication between the crew and ground has an average one-way light-time delay of approximately 1.3 seconds. Communication between the crew and ground support will occur through a combination of synchronous (e.g., near-real-time audio and video) and asynchronous (e.g., email, recorded audio and video) methods. Other operational constraints, such as network availability and bandwidth, will further limit communication frequency, duration, and data volume. The extent of these constraints is still to be defined by the overall mission architecture.

## 4.3. Equipment and Consumable Availability

The availability of consumables and equipment onboard the Gateway is dependent on pre-deployment and resupply. Pre-deployment is defined as the manifest and shipment of supplies onboard a cargo vehicle to the destination before arrival of the crew. Resupply is defined as the manifest and shipment of supplies onboard a cargo vehicle to the destination after the crew has arrived. While no resupply is expected during the GM-2, GM-4, GM-5, and GM-7 Gateway missions, each mission will deliver portions of the Gateway system, and this concept of operations assumes reasonable, but not unlimited, supplies for each mission.

In-situ resource utilization is the collection, processing, storing, and use of local resources to replace resources that would otherwise be brought from Earth. This concept of operations assumes no in-situ resource utilization capability during any mission phases.

## 4.4. Evacuation

Evacuation is required to provide definitive medical care for issues that exceed the capabilities provided within the Gateway Habitat. This concept of operations defines “definitive medical care” as Earth-based care rendered to conclusively manage a patient’s condition, such as the full range of preventive, diagnostic, treatment, and long-term management of medical care. In this context, “time to definitive care” is defined by the length of time required for the crew to return to Earth per nominal mission trajectory and be transported to the definitive medical care facility. The medical implication for evacuation times is that the capability to sustain life or treatment for up to [TBC-02] days during return to Earth may be required for certain medical conditions.

## 4.5. Crew Size and Composition

This concept of operations assumes Gateway missions will have a four-person crew, comprising two females and two males.

### 4.6. Vehicle and Habitat Configuration

The Orion vehicle consists of livable space without dedicated or reconfigurable volume for medical care delivery. The Gateway Habitat consists of a livable space with stowage of medical equipment and consumables and dedicated or reconfigurable volume for medical care delivery.

The crew will be transported to the NRHO within the Orion vehicle, which will then dock to the Gateway Habitat [2]. For Earth return, the crew will ingress the Orion vehicle and undock from the Gateway Habitat.

This concept of operations assumes that parameters such as operational volume, power allocation, environmental maintenance, and system interfaces differ between the Gateway Habitat and the Orion vehicle. As such, these parameters will not be consistent across all phases of Gateway missions. In addition, data storage and processing and the capability to transmit that data between the Orion vehicle, Gateway Habitat, and ground resources is dependent on available resources and mission phase needs.

### 4.7. Target Level of Care

NASA-STD-3001 Space Flight Human-System Standard: Crew Health, defines five levels of medical care. The target level of care applied to Gateway missions described in this document is Level of Care IV. However, when interpreting the Level of Care guidelines from NASA-STD-3001, factors such as crew complement, destination, mission objectives and habitat design limitations must be considered when selecting in-flight medical capabilities and resources [4]. These factors may impose constraints on certain types of medical care, resulting in capabilities that are consistent with lower levels of care. These exceptions to the Level of Care IV guidelines will be addressed on a case-by-case basis.

Level of Care summaries are as follows:

**Level of Care I:** Identifies the need for first aid, including anaphylaxis response, care for space motion sickness, basic life support, and includes the use of private audio.

**Level of Care II:** Adds clinical diagnostics and ambulatory care to the care identified in Level I. It also includes the use of private video and private telemedicine.

**Level of Care III:** Adds limited advanced life support, trauma care, and limited dental care to the care identified in Level II.

**Level of Care IV:** Adds sustainable advanced life support, limited surgical care and dental care to the care identified in Level III. It also includes the use of medical imaging.

**Level of Care V:** Adds autonomous advance life support, autonomous ambulatory care, and autonomous basic surgical care to the care identified in Level IV. It also includes the presence of a physician-level trained caregiver who is the director of care of the crew during the mission. This autonomous care model also drives the use of medical support on the ground as consultants rather than directors of care.

As specified by the NASA-STD-3001 Level of Care IV standard, no crewmember is required to have physician-level medical training. This concept of operations assumes that at least two crewmembers will have medical proficiency at a level that has yet to be determined and will serve as the crew medical officers (CMOs). Future analysis is required to determine the level of skill and training required for a Gateway CMO.

# 5. GATEWAY MISSION PHASE DESCRIPTIONS

The mission phases used by this concept of operations are described in this section. Note that for the Pre-launch, Launch to Trans-lunar Injection (TLI), TLI to NRHO, and NRHO Departure for Earth Return through Earth Entry, Descent, and Landing (EDL) phases, Orion's medical system will be relied upon; the Gateway Medical System will only be available during the NRHO phase.

## 5.1. Pre-Launch

The Pre-Launch phase includes activities that occur before crew ingress into the Orion vehicle at the launch pad. This includes integration, testing, and validation of the system, along with activities to prepare the crew for the mission, such as training, medical certification, and pre-flight medical care. Further analysis is needed to determine level of pre-launch medical system activities.

| Parameter | Assumption |
|---|---|
| Phase Start | Not defined |
| Phase End | Crew transport to Orion vehicle for launch |
| Duration | Not defined |
| Communication | Not defined |
| Crew Size & Composition | Four prime crewmembers and four backup crewmembers, including two crew medical officers for each crew |
| Orion Configuration | Uncrewed (ground Orion trainer is available for training and integration) |
| Gateway Habitat Configuration | Uncrewed (ground Gateway Habitat trainer is available for training and integration) |
| Equipment & Consumable Availability | Orion and Gateway Habitat: n/a |
| Evacuation | n/a |
| Target Level of Care | [TBD-06] |
| Medical System | Ground Medical System |

Table 5.1 – Pre-Launch Phase Assumptions

## 5.2. Launch to Trans-Lunar Injection (TLI)

| Parameter | Assumption |
|---|---|
| Phase Start | Crew ingresses the Orion vehicle on the launch pad |
| Phase End | Orion reaches the TLI point |
| Duration | [TBD-07] |
| Communication | One-way delays of 0 (launch) to [TBD-08] seconds (TLI) |
| Crew Size & Composition | Four crewmembers, including two crew medical officers |
| Orion Configuration | Crewed |
| Gateway Habitat Configuration | Uncrewed |
| Equipment & Consumable Availability | No pre-deployment, resupply, or ISRU |
| Evacuation | Access to definitive medical care is possible on the order of minutes (launch pad) to hours (TLI) |
| Target Level of Care | [TBD-09] |
| Medical System | Orion Medical System |

Table 5.2 –TLI Phase Assumptions

## 5.3. TLI to NRHO

| Parameter | Assumption |
|---|---|
| Phase Start | Orion initiates TLI for transit to NRHO |
| Phase End | Orion docks with Gateway in NRHO |
| Duration | ~4 days |
| Communication | One-way delays of [TBD-08] seconds (TLI) to ~1.3 seconds (NRHO) |
| Crew Size & Composition | Four crewmembers, including two crew medical officers |
| Orion Configuration | Crewed; docks with the Gateway Habitat upon reaching NRHO |
| Gateway Habitat Configuration | Uncrewed |
| Equipment & Consumable Availability | No pre-deployment, resupply, or ISRU |
| Evacuation | Access to definitive medical care is possible on the order of days |
| Target Level of Care | [TBD-10] |
| Medical System | Orion Medical System |

Table 5.3 – TLI to NRHO Phase Assumptions

### 5.4. NRHO

| Parameter | Assumption |
|---|---|
| Phase Start | Crew ingresses Gateway Habitat from Orion in NRHO |
| Phase End | Crew egresses Gateway Habitat in NRHO for return to Earth |
| Duration | 22-82 days [TBC-03] |
| Communication | One-way delays of ~1.3 seconds (NRHO) |
| Crew Size & Composition | Four crewmembers, including two crew medical officers |
| Orion Configuration | Uncrewed; docked with the Gateway Habitat |
| Gateway Habitat Configuration | Crewed |
| Equipment & Consumable Availability | Pre-deployment or resupply are possible; no ISRU |
| Evacuation | Access to definitive medical care is possible on the order of 3-6 days [TBC-04] |
| Target Level of Care | IV |
| Medical System | Gateway Medical System |

Table 5.4 – NRHO Phase Assumptions

### 5.5. NRHO Departure for Earth Return through Earth Entry, Descent, and Landing (EDL)

| Parameter | Assumption |
|---|---|
| Phase Start | Orion vehicle undocks from Gateway Habitat in NRHO |
| Phase End | Orion vehicle touches down on Earth (prior to crew egress) |
| Duration | ~4 days |
| Communication | One-way delays of ~1.3 seconds (NRHO) to 0 seconds (EDL) |
| Crew Size & Composition | Four crewmembers, including two crew medical officers |
| Orion Configuration | Crewed |
| Gateway Habitat Configuration | Uncrewed |
| Equipment & Consumable Availability | No pre-deployment, resupply, or ISRU |
| Evacuation | Access to definitive medical care is possible on the order of days (NRHO Departure) to hours (EDL) |
| Target Level of Care | [TBD-11] |
| Medical System | Orion Medical System |

Table 5.5 – NRHO Departure for Earth Return through EDL Phase Assumptions

### 5.6. Immediate Post-Landing Recovery

| Parameter | Assumption |
|---|---|
| Phase Start | Crew egresses the Orion vehicle after return to Earth |
| Phase End | Not defined |
| Duration | Not defined |
| Communication | Not defined |
| Crew Size & Composition | Four crewmembers, including two crew medical officers |
| Orion Configuration | Uncrewed |
| Gateway Habitat Configuration | Uncrewed |
| Equipment & Consumable Availability | Not defined |
| Evacuation | Evacuation to definitive medical care is possible on the order of minutes to hours |
| Target Level of Care | [TBD-12] |
| Medical System | Ground Medical System |

Table 5.6 – Immediate Post-Landing Recovery Phase Assumptions

## 6. MEDICAL CARE DEFINITIONS

Medical care within this concept of operations is defined by the actors (roles) involved and four characteristics: activity location, activity scheduling, autonomy mode, and activity type. The medical scenarios described in Section 7 explore Medical System functionality through permutations of these roles and characteristics.

### 6.1. Roles

The roles defined here include the human and system actors, both ground-based and in-flight, that participate in the execution of mission medical care.

| Role | Definition |
|---|---|
| Caregiver | The crewmember(s) providing medical care in each scenario. This includes the crew medical officers and any crewmember aiding the provision of care. |
| Ground Caregiver | Ground-based clinicians, specialists, remote guiders, and other allied health professionals who will provide medical support during a mission. A ground caregiver, typically a flight surgeon, will serve as director of care and the primary source for in-mission medical decision making. |
| Patient | The crewmember receiving medical care. |
| Crewmember | Any crewmember who is not a caregiver or patient. |
| Ground System | Any medical hardware, software, or data infrastructure system on Earth used to support a crewed mission. |
| Gateway Habitat Medical System | Any medical hardware, software, consumables, and data infrastructure within the Gateway CHP Habitat System. |
| Gateway CHP Habitat System | Any non-medical hardware, software, and data infrastructure that supports habitat operations. |

Table 6.1 – Gateway Habitat Medical System Role Definitions

## 6.2. Characteristics

The characteristics defined here were derived, in part, from the medical activities documented in the ISS Increment Definition and Requirements Document (IDRD) Annex 4, the ISS Medical Operations Requirements Document (MORD), and the ISS Medical Evaluation Document Vol B: Crew Medical Officer Health Status Evaluations (MED Vol B). These references were used to determine logical groupings of planned activities in the context of the role-based approach taken in this concept of operations. The Integrated Medical Model (IMM) Medical Condition List (IMCL) was used to identify medical conditions of concern for exploration missions and determine potential unplanned activities during Gateway operations.

| Characteristic | Category | Definition |
|---|---|---|
| Activity Location | Extravehicular Activities (EVA) | Occurs external to the vehicle or habitat |
| | Intravehicular Activities (IVA) | Occurs internal to the vehicle or habitat |
| Activity Scheduling | Planned | Expected or required to occur |
| | Unplanned | Not expected nor required to occur but addressed on an as-needed basis |
| Autonomy Mode | Autonomous | No expectation or no opportunity for ground input |
| | Semi-Autonomous | Expectation or desire for ground input when available |
| Activity Type | Self-Care | Self-treatment by the patient |
| | Directed Care | Medical decision making from a caregiver |
| | Emergent Care | Immediate intervention initiated by any crewmember |
| | Medical System Maintenance | Preventive or corrective maintenance to Medical System software applications or hardware |
| | Medical Training and Education | Acquisition and maintenance of medical knowledge and skills. |

Table 6.2 – Medical Care Characteristic Definitions

# 7. GATEWAY MEDICAL SCENARIOS

The medical scenarios in this concept of operations present a broad, but not comprehensive, set of Medical System functionalities that exemplify the Gateway Habitat Medical System vision. Each scenario contains a list of included functionalities, a narrative, and an activity diagram. Narratives are descriptive medical activity stories that include potential Gateway Habitat Medical System implementations. They portray what the system may be able to do and not how it should do it. Activity diagrams are graphical representations of the narratives that illustrate system functions and roles and are used by ExMC Systems Engineering as a basis for system interface identification, functional requirements, and architecture development. For the purposes of this concept of operations, diagram activities are presented serially with the understanding that, when actually implemented, some activities may be performed in parallel.

The scenarios were written to provide a vivid picture of potential Medical System functionalities. In some cases, these functionalities may appear to conflict or be redundant across scenarios (e.g., the use of both manual and automated data collection and entry). This was done intentionally to fully explore the functionality space.

## 7.1. Pre-Launch Phase

[TBD-13]

## 7.2. Launch to TLI Phase

[TBD-14]

## 7.3. TLI to NRHO Phase

[TBD-15]

## 7.4. Gateway in NRHO Phase

### 7.4.1. Intravehicular Activity Scenarios

The scenarios for this mission phase are outlined in Figure 7-1. Some activity scheduling, autonomy mode, and type combinations do not have scenarios either because the relevant system functionalities were demonstrated in other scenarios or those scenarios are not expected for Gateway missions; these combinations are indicated by grayed out text in the figure.

The following assumptions apply to all scenarios:

a) The Gateway Habitat Medical System support of the caregiver supplements the caregiver's medical proficiency. The caregiver can adjust the level of support provided by the Medical System, as needed.

b) The Gateway Habitat System is responsible for non-medical monitoring, maintenance, and tracking of the habitat and crew (e.g., environmental constituents, power, inventory, scheduling). The Gateway Habitat Medical System interfaces with the Gateway Habitat to utilize this data, as needed.

c) The Gateway Habitat Medical System communicates with the ground via the Gateway Habitat System communication subsystem. The reliability and frequency of synchronization between the Gateway Habitat Medical System and the Ground System is dependent on telemetry link availability and bandwidth, prioritization of data downlink/uplink, and other factors.

The following conventions apply to all scenarios:

a) In the scenarios, the term "information" is shorthand for "raw data and processed data/information".

b) The term "record and report" indicates that the Medical System stores the collected information and presents that information back to the crewmember.

The scenarios in this concept of operations are outlined in Figure 7-1.

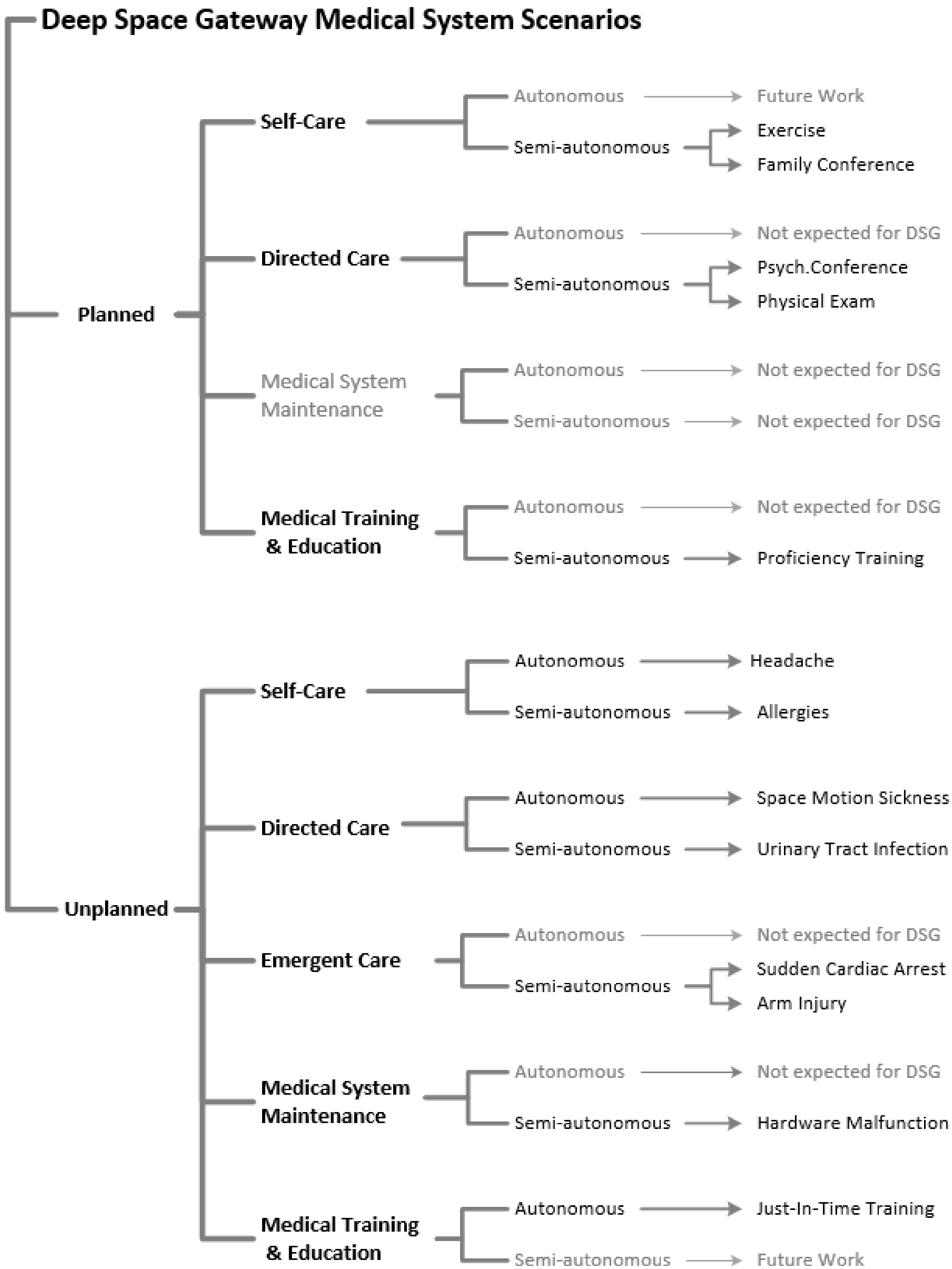


Figure 7-1 – Gateway in NRHO Phase IVA Scenario Tree

#### 7.4.1.1. Exercise (IVA, Planned, Self-Care, Semi-Autonomous)

##### 7.4.1.1.1. Context

This scenario was developed in the context of an exercise protocol.

##### 7.4.1.1.2. Highlighted Functionality

This scenario shows that the Gateway Habitat Medical System can:

a) Prompt the initiation of an activity per the crewmember's schedule.
b) Interpret information gathered during an activity and create a summary report.
c) Provide exercise prescriptions.
d) Create flags of potential issues using information from sensors.

The scenario shows that the Ground System can:

a) Interpret information gathered during an activity.
b) Generate an alert to the ground caregiver.
c) Generate an alert in the Gateway Habitat Medical System.

##### 7.4.1.1.3. Assumptions

This scenario assumes that:

a) Exercise equipment is integrated with the Medical System.
b) The "Crew as Patient" (activity diagram) is the "crewmember" (narrative).

### 7.4.1.1.4. Activity Diagram

The following is a graphical representation of the scenario narrative:

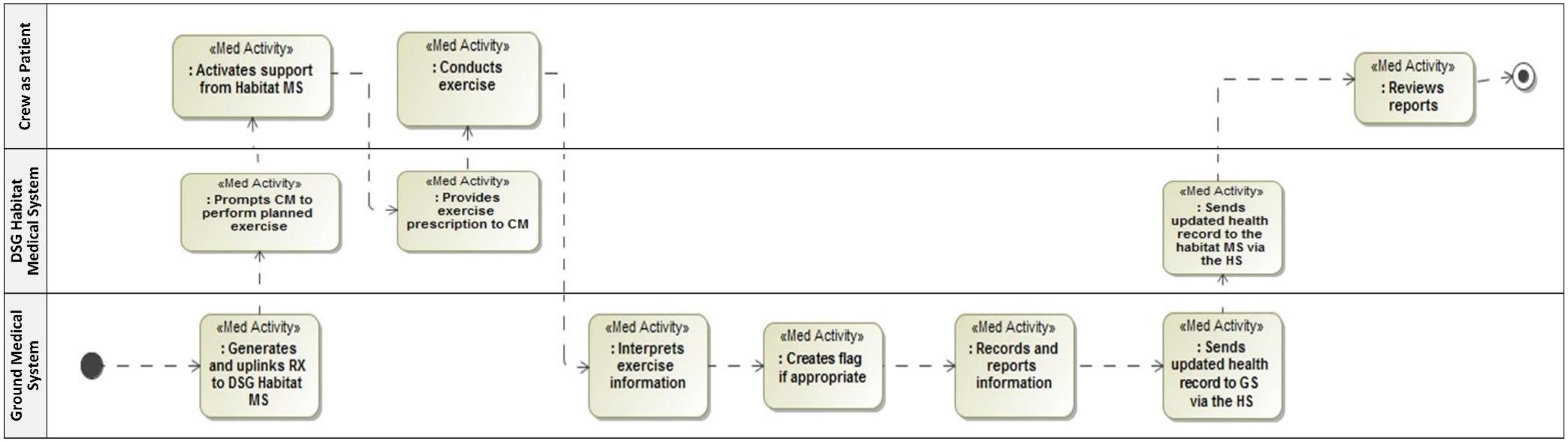


Figure 7-2 – Exercise (IVA, Planned, Self-Care, Semi-Autonomous)

#### 7.4.1.1.5. Narrative

*Note: This narrative is a descriptive story meant to provide a vivid picture to the reader. Specific technologies are only representative and are not intended to indicate requirements.*

The crew scheduling system sends an alert to a crewmember's personal electronic device that she has an upcoming scheduled exercise session. She prepares for her workout and floats to the exercise system. The crewmember activates the user interface of the exercise system, and the device verifies her identity and logs her in. The interface displays her personal exercise prescription, which had previously been uplinked to the Habitat Medical System. After donning her harness and attaching the loading mechanisms, she notifies the exercise system that she is ready to begin her exercise. Her vital signs are transmitted wirelessly through the adhesive patch interface on her chest that is worn by all crewmembers throughout the mission. Heart rate data are displayed to the crewmember as she exercises. Upon completion of her exercise session, the exercise system transmits the vital signs, exertion, and force data to the medical system, which downlinks the data to the ground medical system at the next communication opportunity. The crewmember disconnects the loading mechanism and doffs and stows the harness. She then heads back to the hygiene station to get cleaned up and continue with the rest of her workday. She makes a mental note to review her exercise session data from her personal computing device during her rest period.

Upon receipt of the crewmember's exercise-related data, the ground medical system processes it and generates an interpretation, which is stored within the crewmember's ground health record. The ground medical system detects a change in the crewmember's heart rate data but determines that it is within normal limits. No action is required, but a flag is placed in her record for the flight surgeon to read at his next crew status review and discuss with the crewmember during her weekly private medical conference.

The ground medical system coordinates with the habitat's communication system to uplink a health status to the crewmember's personal medical record in the medical system that is available for the crewmember to view on her personal computing device.

### 7.4.1.2. Family Conference (IVA, Planned, Self-Care, Semi-Autonomous)

#### 7.4.1.2.1. Context

This scenario was developed in the context of a family conference.

#### 7.4.1.2.2. Highlighted Functionality

This scenario shows that the Ground System can:

a) Record occurrence of a conference with an outside party

#### 7.4.1.2.3. Assumptions

This scenario assumes that:

a) Conferences are conducted and transmitted to the ground by the Gateway Habitat System.
b) The Gateway Habitat System records the conference.
c) The Gateway Habitat Medical System keeps a record of conference occurrence but does not record it.
d) The "Crewmember" (activity diagram) is the "crewmember" (narrative).

### 7.4.1.2.4. Activity Diagram

The following is a graphical representation of the scenario narrative:

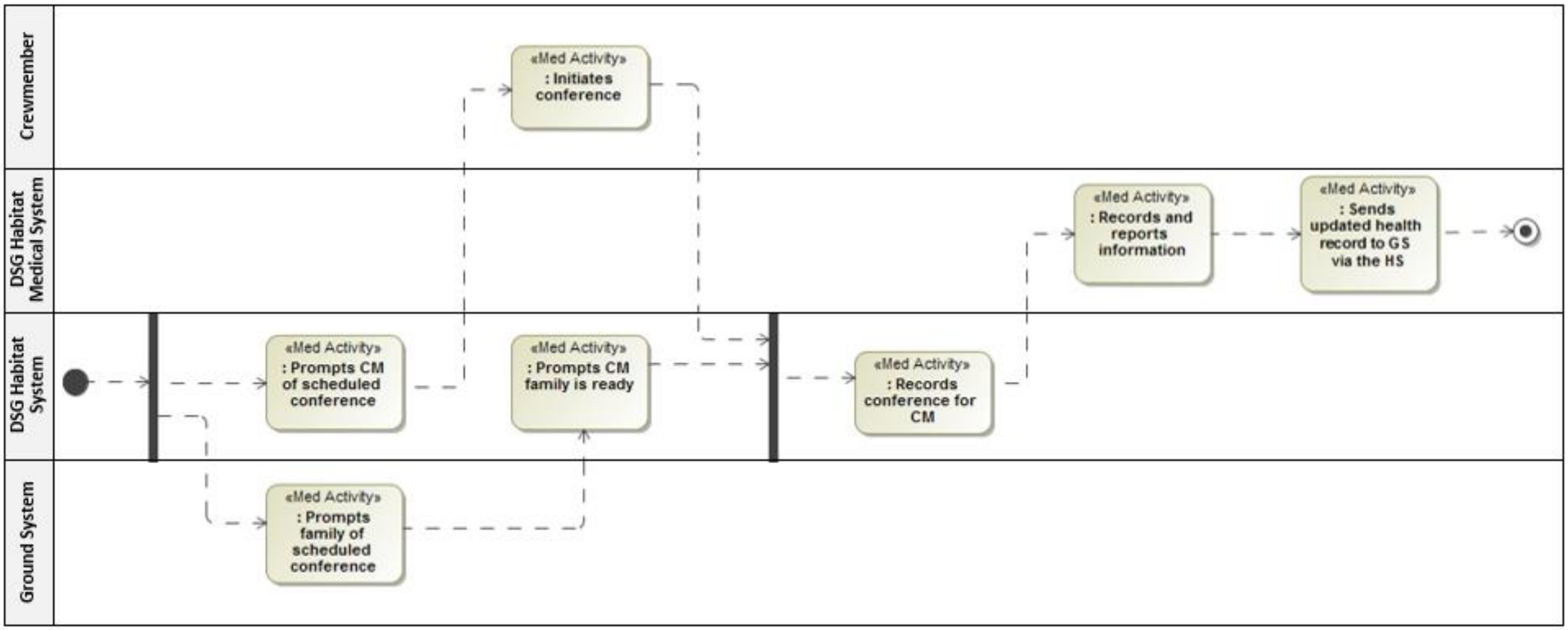


Figure 7-3 – Family Conference (IVA, Planned, Self-Care, Semi-Autonomous)

#### 7.4.1.2.5. Narrative

*Note: This narrative is a descriptive story meant to provide a vivid picture to the reader. Specific technologies are only representative and are not intended to indicate requirements.*

The crew scheduling system sends an alert to a crewmember's personal computing device that he has an upcoming scheduled private family conference. Simultaneously, the ground system sends an alert to the crewmember's family and prompts them to log into the conferencing system, which is interfaced with the ground system. Once the family is logged in and ready to start the conference, the habitat system informs the crewmember that his party is online and ready to start. The crewmember initiates the conference call using his personal computing device. A recording of the conference is saved and is available for later viewing by the crewmember. The Gateway Medical System records that this transaction has occurred in the crewmember's health record, and the updated health record is downlinked to the Ground Medical System

### 7.4.1.3. Psychological Conference (IVA, Planned, Directed Care, Semi-Autonomous)

#### 7.4.1.3.1. Context

This scenario was developed in the context of a planned psychological conference.

#### 7.4.1.3.2. Highlighted Functionality

This scenario shows that the Gateway Habitat Medical System can:

a) Facilitate the interface between a ground clinician and in-flight crewmember.
b) Record reports in the ground system that can be reviewed by the flight-based system.
c) Create summary reports for crew using downlinked device data.

This scenario shows that the Ground Medical System can:

a) Interpret information gathered during an activity.
b) Facilitate the interface between a ground clinician and in-flight crewmember.

#### 7.4.1.3.3. Assumptions

This scenario assumes that:

a) The "Crew as Patient" (activity diagram) is the "crewmember" (narrative).
b) The "Ground Caregiver" (activity diagram) is the "Behavioral Health clinician" (narrative).

### 7.4.1.3.4. Activity Diagram

The following is a graphical representation of the scenario narrative:

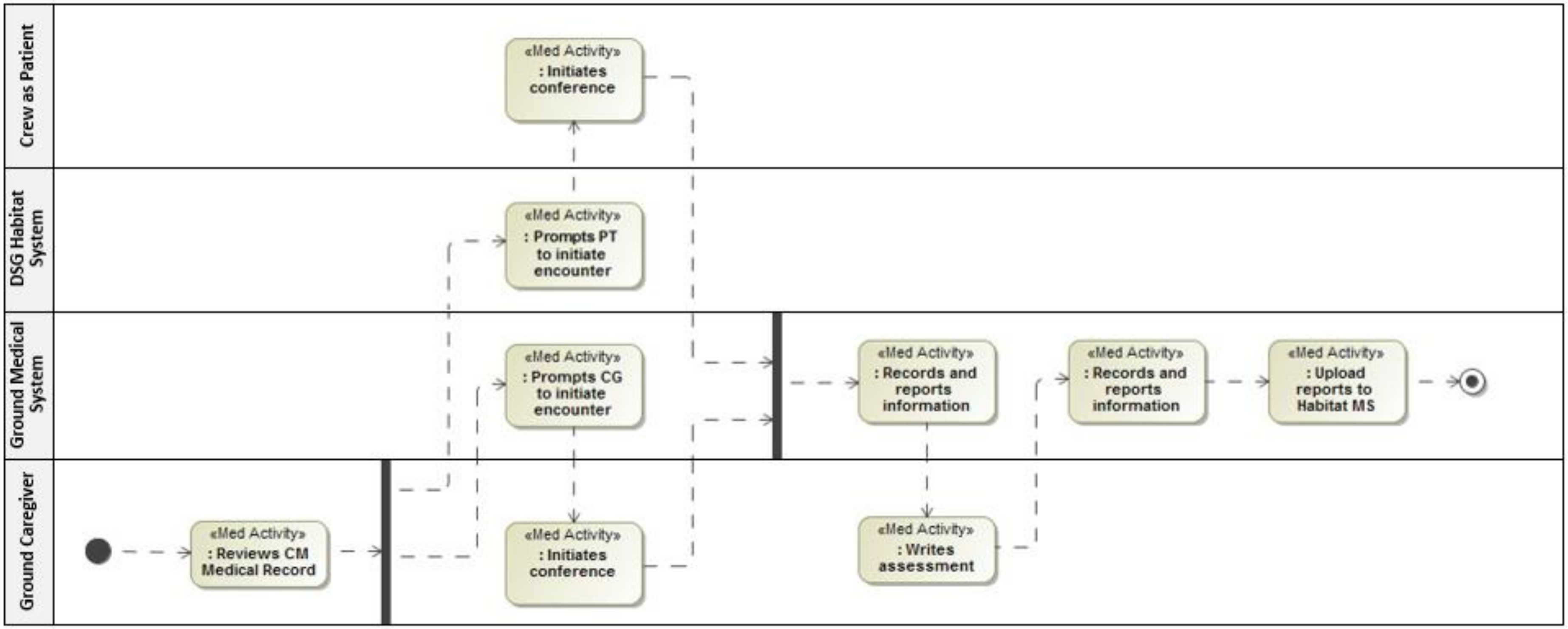


Figure 7-4 – Psychological Conference (IVA, Planned, Directed Care, Semi-Autonomous)

#### 7.4.1.3.5. Narrative

*Note: This narrative is a descriptive story meant to provide a vivid picture to the reader. Specific technologies are only representative and are not intended to indicate requirements.*

In preparation for a planned psychological conference with a Gateway crewmember, the ground-based Behavioral Health clinician reviews the crewmember's medical record in the ground medical system and data collected from onboard cognition tools, sleep monitoring devices, and journals.

At the time of the scheduled conference, the crew scheduling system alerts the crewmember through his personal computing device that he has a private psychological conference. Simultaneously, the ground medical system sends an alert to the Behavioral Health clinician and prompts him to log into the conferencing system, which is interfaced with the ground system. Once the Behavioral Health clinician is logged in and ready to start the conference, the habitat system informs the crewmember that his party is online and ready to start. The crewmember initiates the conference call using his personal computing device and joins the conference with the clinician. The Ground Medical System records that this transaction has occurred in the crewmember's health record.

At the completion of the conference, the Behavioral Health clinician documents his assessment of the crewmember in the Ground Medical System. The Ground Medical System creates a summary of the caregiver's assessment, along with summary reports based on the onboard cognition tool, sleep monitoring device, and journal data sets. All reports are then queued for uplink to the Gateway Medical System.

### 7.4.1.4. Physical Exam (IVA, Planned, Directed Care, Semi-Autonomous)

#### 7.4.1.4.1. Context

This scenario was developed in the context of a routine physical exam.

#### 7.4.1.4.2. Highlighted Functionality

This scenario shows that the Gateway Habitat Medical System can:

a) Prompt and facilitate nominal data collection for routine examinations including verification of validity of existing information contained in the Gateway Habitat Medical System.
b) Receive data entry from the patient about the patient.
c) Wirelessly transmit, display and record vital sign, imaging and laboratory data from devices into the Gateway Habitat Medical System.
d) Provide direction to support data collection based upon crewmember request.
e) Analyze and report information received from devices.
f) Provide summary reports back to the crew after Ground Medical System interpretation/analysis.

#### 7.4.1.4.3. Assumptions

This scenario assumes that:

a) The "Crew as Patient" (activity diagram) is the "crewmember" (narrative).
b) The "Ground Caregiver" (activity diagram) is the "flight surgeon" (narrative).

#### 7.4.1.4.4. Activity Diagram

The following is a graphical representation of the scenario narrative:

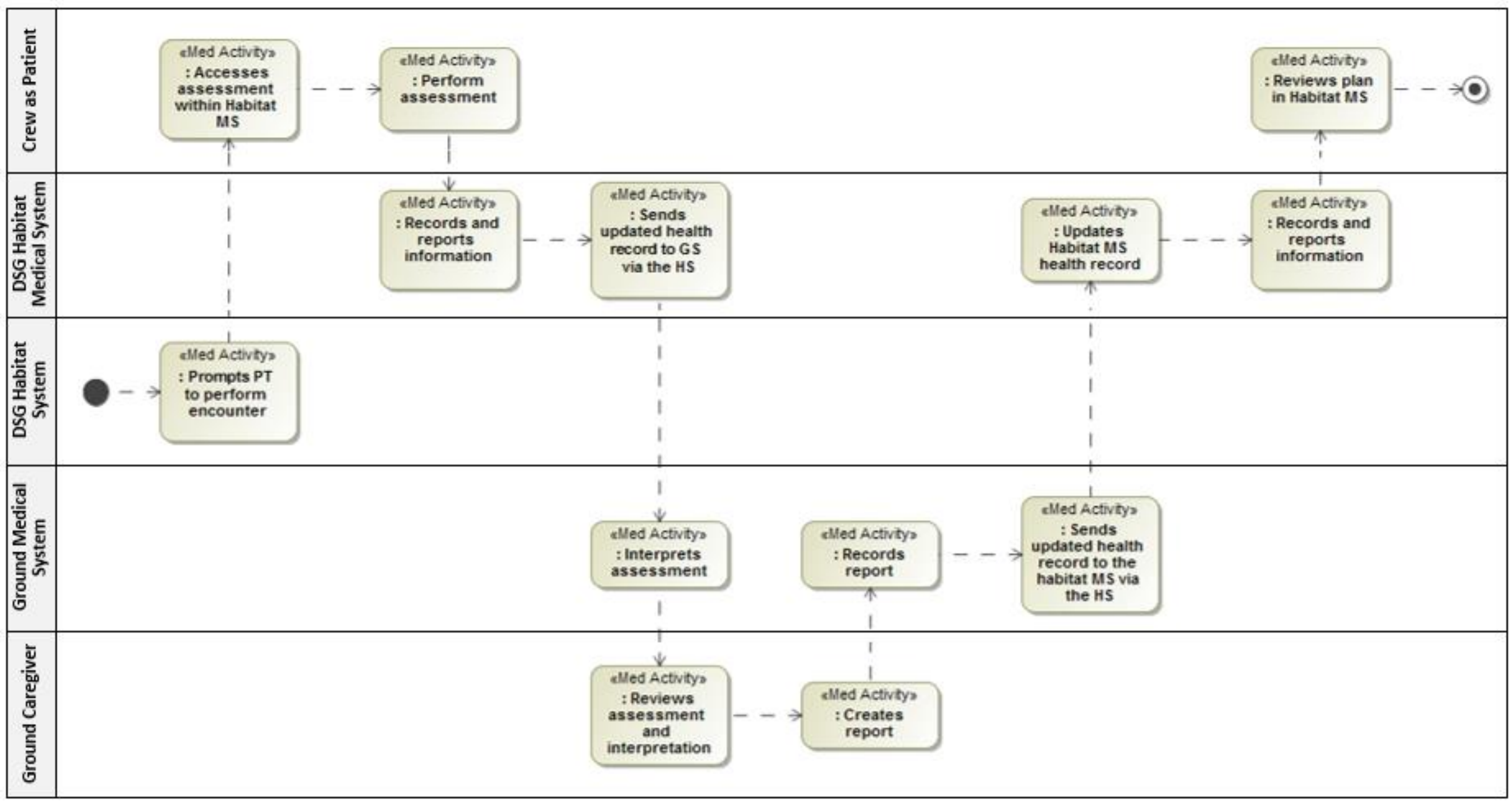


Figure 7-5 – Physical Exam (IVA, Planned, Directed Care, Semi-Autonomous)

#### 7.4.1.4.5. Narrative

*Note: This narrative is a descriptive story meant to provide a vivid picture to the reader. Specific technologies are only representative and are not intended to indicate requirements.*

The crew scheduling system sends an alert to a crewmember's personal computing device that she has an upcoming scheduled medical exam on her timeline. She heads to the medical workstation to prepare for the exam. She brings her personal computing device, launches the medical system on the display, and opens the medical exam application.

The medical system prompts her to review her health record documentation for accuracy and update it if needed. Areas of review include past medical, surgical, and dental treatment history, allergies, and current medications, followed by a series of questions to complete a review of systems. She is prompted to import vital sign data (blood pressure, heart rate, oxygen saturation, temperature, and respiratory rate) collected from her wireless monitor by clicking the 'import' button in the application. These data are all automatically saved to her health record and displayed back to her.

As part of the routine medical exam, the medical system prompts the crewmember to perform imaging of her ears and any skin rashes or injuries she might have. She elects to receive direction from the Medical System on imaging device configuration and how to capture the desired images. The Medical System displays the procedural instructions. Blood and urine analyses are also requested by the Medical System, so the crewmember collects and provides samples for analysis per a procedure provided by the Medical System. Medical images and laboratory results are automatically imported into the Medical System by the designated devices at the completion of testing. Data collected during the medical exam are stored for automated downlink to the Ground Medical System later that day. The crewmember stows the imaging hardware and proceeds with her next scheduled task.

The Ground Medical System receives the crewmember medical data after downlink and imports it into the crewmember's health record in the Ground Medical System. The interview, imagery, and laboratory data are analyzed by the Ground Medical System, and a report is automatically generated and queued for review by the flight surgeon. Using the Ground Medical System report, the flight surgeon creates a summary report of the examination and saves it in the Ground Medical System. The Ground Medical System coordinates with the habitat's communication system to uplink a health status to the crewmember's personal medical record that is available for her and the CMO to view on their personal computing devices.

### 7.4.1.5. Medical Familiarization Training (IVA, Planned, Medical Training and Education, Semi-Autonomous)

#### 7.4.1.5.1. Context

This scenario was developed in the context of inflight medical familiarization training.

#### 7.4.1.5.2. Highlighted Functionality

This scenario shows that the Gateway Habitat Medical System can:

a) Retrieve training material from the Ground System.
b) Generate alerts and reports in the Ground System, reflecting the completion of inflight activities.

The scenario shows that the Ground System can:

a) Send crewmember training requirements to the Gateway Habitat Medical System.
b) Generate reports in the patient's medical record for ground caregiver review.

#### 7.4.1.5.3. Assumptions

This scenario assumes that:

a) The crew scheduling system is part of the Gateway Habitat System.
b) The "Crew as Caregiver" (activity diagram) is the "CMO" (narrative).

#### 7.4.1.5.4. Activity Diagram

The following is a graphical representation of the scenario narrative:

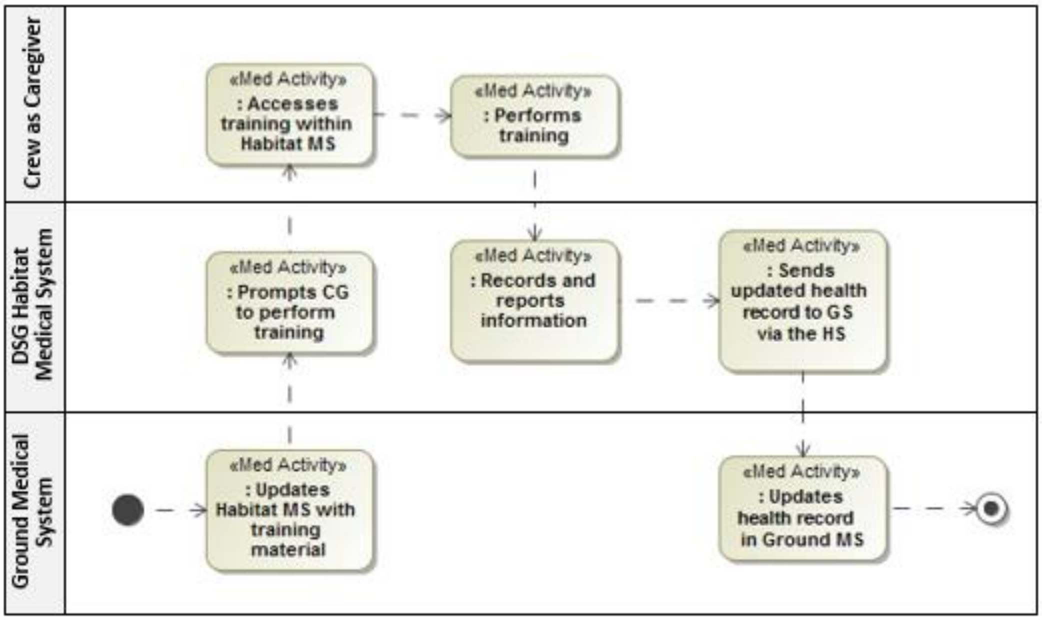


Figure 7-6 – Medical Familiarization Training (IVA, Planned, Medical Training and Education, Semi-Autonomous)

#### 7.4.1.5.5. Narrative

*Note: This narrative is a descriptive story meant to provide a vivid picture to the reader. Specific technologies are only representative and are not intended to indicate requirements.*

The crew have just arrived at the Gateway Habitat, and the crew medical officers have a scheduled medical familiarization training session to give them a chance to become comfortable with the location and use of emergency medical equipment. In preparation for this session, the ground medical support team uplinks a medical emergency scenario simulation script that is designed for the crew medical officer's level of expertise with respect to the Medical System. This uplinked script is accessible to the crew medical officers from the Medical System. This scheduled training must be completed at the crew medical officers' convenience inside a 3-day window after Gateway Habitat ingress. This task is reflected in the crew scheduling system and seen by the crew medical officers via a reminder on their personal computing devices, which states, "Please fulfill your assigned medical familiarization training." The reminder provides a shortcut to access the training script. When the crew medical officers are ready, they select the link and the script is displayed. The crew medical officers then complete their Medical System familiarization training requirements. The Medical System records that the training has been completed, and it coordinates with the habitat communication system to downlink their updated health records and synchronize the onboard and ground electronic health systems.

Notifications are sent to the crew medical officers' flight surgeon and training team to advise them of the training completion. The Ground Medical System generates an automated report that reflects the training completion for the relevant flight control team members. This information is also reflected in the flight surgeon's report, which is available for use in support of the crewmember's weekly private medical conference.

### 7.4.1.6. Headache (IVA, Unplanned, Self-Care, Autonomous)

#### 7.4.1.6.1. Context

This scenario was developed in the context of a headache.

#### 7.4.1.6.2. Highlighted Functionality

This scenario shows that the Gateway Habitat Medical System can:

a) Prompt and facilitate data collection for unplanned medical events.
b) Receive data entry from the patient about the patient.
c) Provide limited decision support for self-care conditions.
d) Assess known inventory and report stowage locations to the crew via the Gateway Habitat Medical System interface.
e) Automatically report inventory status to the Ground Medical System.
f) Generate alerts for the Ground Medical System based upon inflight interactions with the system.
g) Record and transmit medically oriented, attributable information to ground clinicians.
h) Retrieve reports in the Ground System that can be reviewed by the Gateway Habitat Medical System.

This scenario shows that the Ground System can:

a) Receive data entry from the caregiver about the patient.

#### 7.4.1.6.3. Assumptions

This scenario assumes that:

a) The “resource” in this scenario is a medication.
b) The “Crew as Patient” (activity diagram) is the “crewmember” (narrative).
c) The “Ground Caregiver” (activity diagram) is the “flight surgeon” (narrative).

#### 7.4.1.6.4. Activity Diagram

The following is a graphical representation of the scenario narrative:

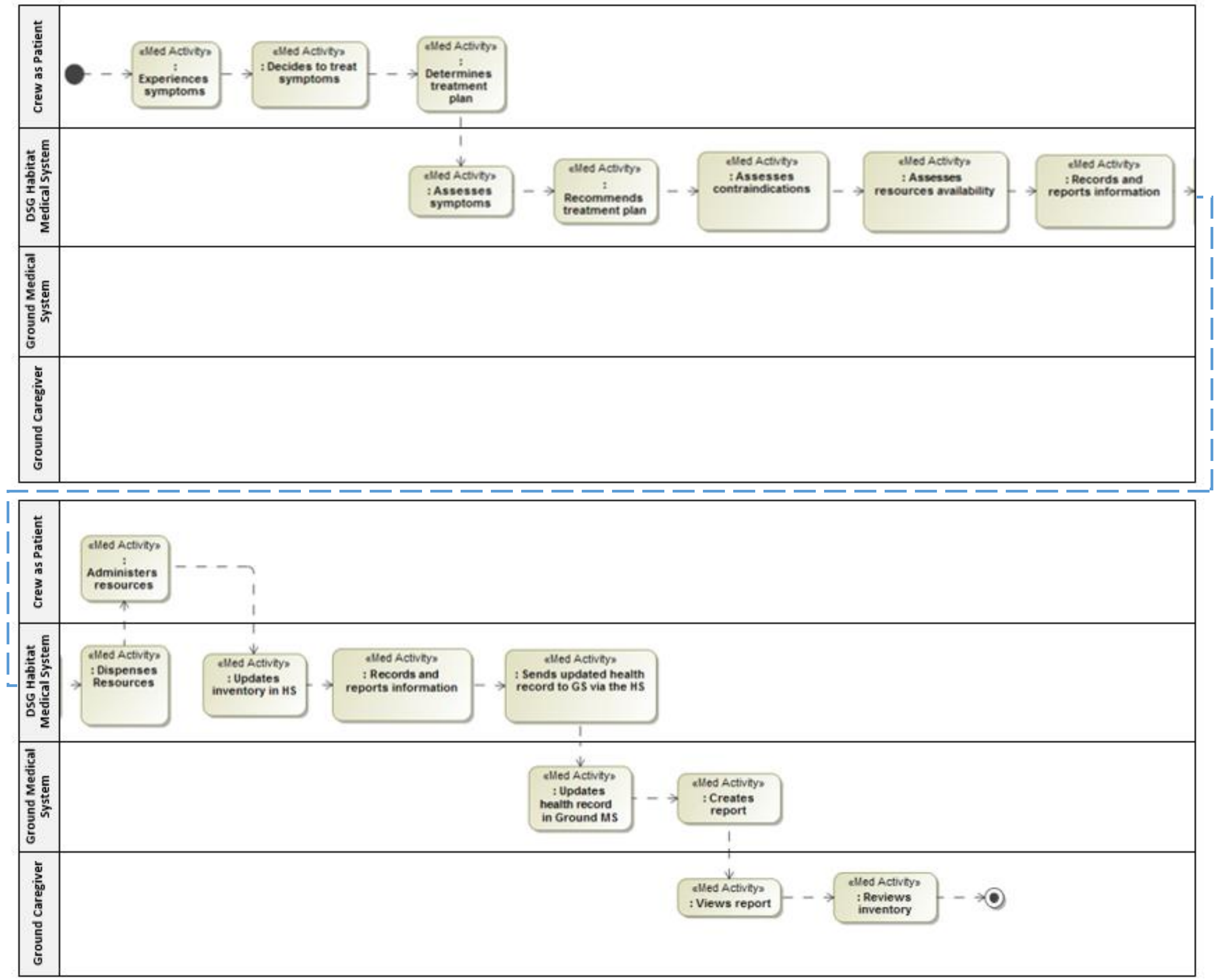


Figure 7-7 – Headache (IVA, Unplanned, Self-Care, Autonomous)

#### 7.4.1.6.5. Narrative

*Note: This narrative is a descriptive story meant to provide a vivid picture to the reader. Specific technologies are only representative and are not intended to indicate requirements.*

For the past few hours, a crewmember has been experiencing a headache of moderate intensity that he recognizes as typical of those he has had in the past. Given that he has no other symptoms, he decides that there is no need to involve the crew medical officer or ground flight surgeon and will treat it with acetaminophen, as he had for the previous headaches. He accesses his personal medical record within the medical system on his portable computing device and logs his symptoms.

The Medical System takes him through a series of questions that assesses symptoms. Based on data entered by the crewmember, the Medical System provides a recommended medication, dose and location.

He locates the pharmacy kit in the medical rack, finds the medication, and removes the dose. He washes the tablet down with water from a drink bag and then logs the medication use in the medical system on his personal computing device. This information is stored for automated downlink to the Ground Medical System at the end of the workday. The crewmember's flight surgeon will have a notification available through the Ground Medical System to alert him of the medication consumption when he arrives in mission control the next morning.

At the end of the workday, an automated RFID scan of the medical rack shows that a one-unit dose of acetaminophen was taken from the medical pharmacy kit. This information is queued for automated downlink at the next available opportunity to the Ground Medical System, which then updates the pharmacy kit's inventory.  The Ground Medical System generates an automated report for the flight surgeon that is available for use in support of the crewmember's weekly private medical conference.

### 7.4.1.7. IVA, Unplanned Self Care, Semi-Autonomous

#### 7.4.1.7.1. Context

This scenario was developed in the context of allergies.

#### 7.4.1.7.2. Highlighted Functionality

This scenario shows that the Gateway Habitat Medical System can:

a) Receive data entry from the patient about the patient.
b) Facilitate serial transmission of medically sensitive messages between the ground caregiver, ground-based members of an interdisciplinary clinical team and the Gateway Habitat Medical System.
c) Document information exchanges and medical decision making as a component of the message interchange.
d) Generate alerts for crew via an interface between the Ground and Gateway Habitat Medical Systems.

This scenario shows that the Ground System can:

a) Receive data entry from the flight surgeon about the patient.
b) Send messages between users of the system.

#### 7.4.1.7.3. Assumptions

This scenario assumes that:

a) The "Crew as Patient" (activity diagram) is the "crewmember" (narrative).
b) The "Ground Caregiver" (activity diagram) is the "flight surgeon" and "pharmacist" (narrative).

### 7.4.1.7.4. Activity Diagram

The following is a graphical representation of the scenario narrative:

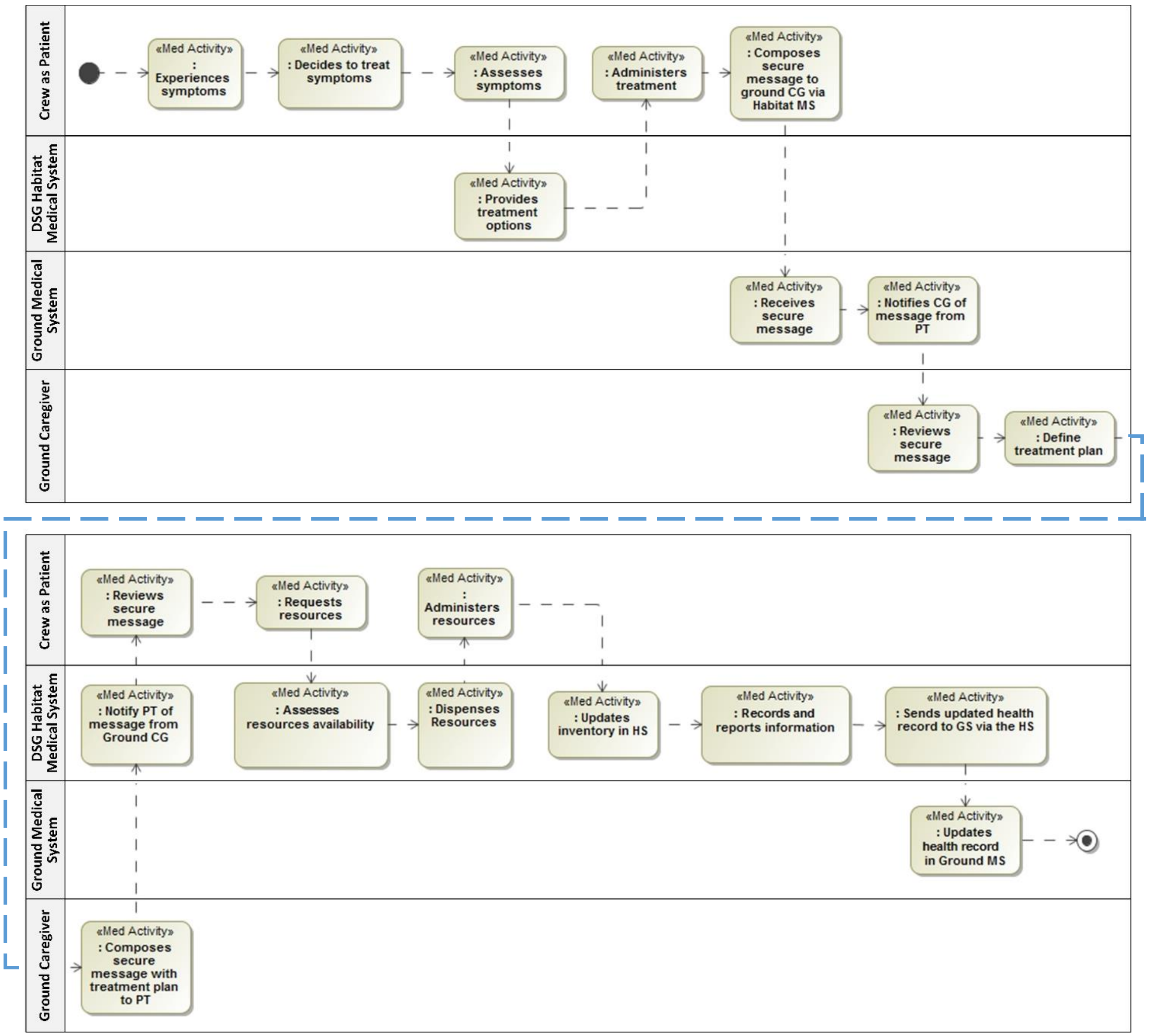


Figure 7-8 – Allergies (IVA, Unplanned Self Care, Semi-Autonomous)

#### 7.4.1.7.5. Narrative

For the past few days, a crewmember has self-treated a skin irritation using a topical medication recommended by the Medical System. The symptoms have not resolved and appear to be worsening. The crewmember composes a message with his questions within the Medical System and sends it to his flight surgeon. The message is queued for downlink at the next available opportunity.

The flight surgeon receives a notification of the new message via the Ground Medical System. After reviewing the crewmember's questions, the flight surgeon decides that she would like to consult the pharmacist for alternative medication suggestions. The message is sent via the Ground Medical System to the pharmacy, and the on-staff pharmacist reviews the message, provides written feedback, and sends the message back to the flight surgeon, who incorporates the pharmacist's feedback in his response to the crewmember. She sends the file to the crewmember, and, after uplink, the crewmember receives notification of a new message via the Medical System and requests a medication based on the information in the message. Based on data entered by the crewmember, the Medical System provides the requested medication, dose and location.

The crewmember locates the pharmacy kit in the medical rack, finds the medication, and removes the item. He applies the medication and then logs its use in the Medical System on his personal computing device. This information is stored for automated downlink to the Ground Medical System at the end of the workday. The crewmember's flight surgeon will have a notification through the Ground Medical System to alert him of the medication consumption when he arrives in mission control the next morning.

At the end of the workday, an automated RFID scan of the medical rack shows that the item was taken from the medical pharmacy kit. This information is queued for automated downlink at the next available opportunity to the Ground Medical System, which then updates the pharmacy kit's inventory. The Ground Medical System generates an automated report for the flight surgeon that is available for use in support of the crewmember's weekly private medical conference.

### 7.4.1.8. Space Motion Sickness (IVA, Unplanned, Directed Care, Autonomous)

#### 7.4.1.8.1. Context

This scenario was developed in the context of space motion sickness.

#### 7.4.1.8.2. Highlighted Functionality

This scenario shows that the Gateway Habitat Medical System can:

a) Prompt and facilitate off-nominal data collection for non-emergent, unplanned medical events. Data collection prompts are tailored to the medical event, and interventions are recorded in the Gateway Habitat Medical System.
b) Provide limited decision support for a pre-determined set of presenting complaints for unplanned events.
c) Receive data entry from the crew medical officer about the patient.
d) Wirelessly transmit, display and record vital sign data from devices into the Gateway Habitat Medical System.
e) Prioritize medical data downlink for off-nominal medical events as recorded in the Gateway Habitat Medical System.

f) Automatically report inventory status to the Ground System.
g) Generate alerts for the Ground System based upon inflight interactions with the Gateway Habitat Medical System.

This scenario shows that the Ground Medical System can:

a) Generate reports in the patient's medical record for ground caregiver review.
b) Update the Ground Medical System with the Gateway Habitat medical supply inventory.

#### 7.4.1.8.3. Assumptions

This scenario assumes that:

a) The "Crew as Patient" (activity diagram) is the "crewmember" (narrative).
b) The "Crew as Caregiver" (activity diagram) is the "CMO" (narrative).
c) The "Ground Caregiver" (activity diagram) is the "flight surgeon" (narrative).

#### 7.4.1.8.4. Activity Diagram

The following is a graphical representation of the scenario narrative:

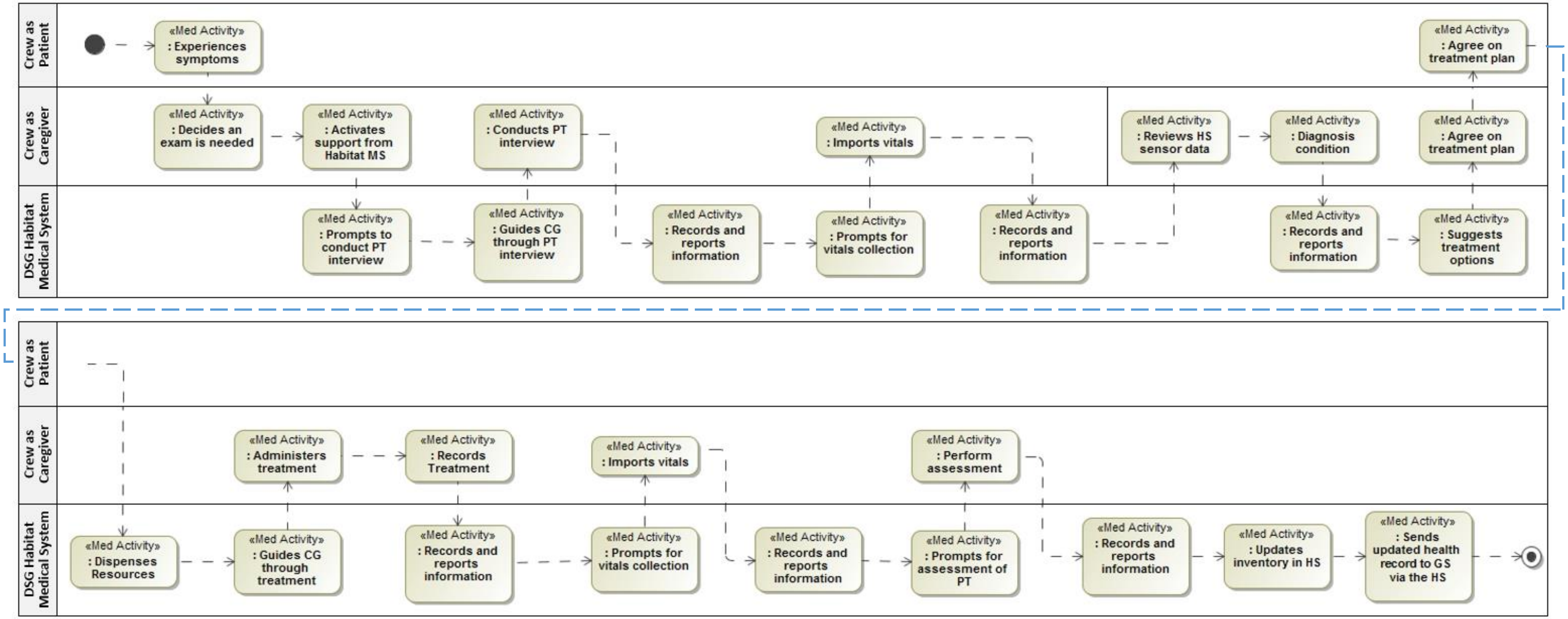


Figure 7-9 – Space Motion Sickness (IVA, Unplanned, Directed Care, Autonomous)

#### 7.4.1.8.5. Narrative

*Note: This narrative is a descriptive story meant to provide a vivid picture to the reader. Specific technologies are only representative and are not intended to indicate requirements.*

Shortly after Gateway Habitat ingress from Orion, the newly arrived crewmember notices the recurrence of space motion sickness (SMS) symptoms including stomach awareness and nausea. Despite his best efforts to limit head movement, he vomits. His crewmates pass him a space motion sickness bag and a drink bag with water to rinse his mouth, and he restrains himself in a position of comfort while the rest of the crew continue unstowing hardware from Orion. The vomiting persists for >1 hour, and the crew medical officer suggests that the crewmember consider taking medication to assist with the symptoms while he adapts to the new environment. The crewmember concedes, and the crew medical officer proceeds to launch and log into the medical system application on his personal computing device. He accesses the crewmember's medical record file, and the medical system takes him through a series of questions that assess the crewmember's symptoms. The Medical System then prompts him to import vital sign data (blood pressure, heart rate, oxygen saturation, temperature, and respiratory rate) collected from the crewmember's wireless monitor by clicking the 'import' button in the app. The crew medical officer reviews habitat sensor data and does not see anything that could be the cause of the crewmember's symptoms. Based on all this information, the crew medical officer logs his diagnosis of space motion sickness. All of the information is automatically saved to the crewmember's health record and displayed back to the crew medical officer.

Based on the diagnosis and the SMS standing order protocol, the Medical System reports that medication for treatment of the SMS symptoms is available by intramuscular injection or by suppository. The crew medical officer relays the options to the crewmember, and the crewmember elects to receive an injection. The crew medical officer accesses medication preparation and administration directions within the Medical System and reviews the content, including embedded videos. The crew medical officer administers the medication to the crewmember and logs the dose in the crewmember's medical record. The Medical System prompts him to import a second set of vital signs from the crewmember's wireless monitor 30 minutes after the medication is administered and to record a reassessment of the crewmember's symptoms with feedback on the crewmember's perception of the medication's effectiveness.

This information in the Medical System is stored and prioritized for automated downlink to the Ground Medical System at the next available communication opportunity. The crewmember's flight surgeon will have a notification through the Ground Medical System to alert her of the medical event as soon as the data downlink is complete. The Ground Medical System generates an automated report that is available to support an unscheduled private medical conference, if needed.

At the end of the workday, an automated RFID scan of the medical rack shows a one-unit dose of the injectable medication missing from the medical pharmacy kit, as well as a syringe, needle, skin prep and self-adhesive bandage missing from the medical consumables kit. This information is updated in the habitat's inventory system and queued for automated downlink at the next available opportunity to the Ground Medical System. The Ground Medical System adds this medical event to the automated report for the flight surgeon for use in support of the crewmember's weekly private medical conference.

### 7.4.1.9. Urinary Tract Infection (IVA, Unplanned, Directed Care, Semi-Autonomous)

#### 7.4.1.9.1. Context

This scenario was developed in the context of a urinary tract infection.

#### 7.4.1.9.2. Highlighted Functionality

This scenario shows that the Gateway Habitat Medical System can:

a) Record and transmit medically oriented, attributable medical information to ground clinicians.
b) Receive orders generated by the Ground Medical System and allow documentation of results of tests/exams per the ground-generated orders.
c) Display vital sign data without recording in the Gateway Habitat Medical System (i.e., it can allow either manual collection of blood pressure via cuff, pulse via fingers, and respiratory rate via eye sight, as well as have devices that display the actual data without having to interface with the Gateway Habitat Medical System application (e.g., a numerical display on a portable pulse ox or electronic portable blood pressure cuff).
d) Provide summary reports back to the crew after Ground Medical System interpretation/analysis.

This scenario shows that the Ground Medical System can:

a) Receive medically oriented, attributable medical information and make it available to ground clinicians.
b) Generate and transmit orders for medical exams and tests to be performed by in-flight crewmembers.
c) Generate alerts to inflight crewmembers reflecting new messages and orders in the Gateway Habitat Medical System.
d) Prompt and facilitate data collection for non-emergent, unplanned medical events.
e) Provide decision support for a pre-determined set of presenting complaints for unplanned events.
f) Provide information augmentation resources to users.
g) Receive data entry from the flight surgeon about the patient.
h) Record and display images collected via the Gateway Habitat Medical System.
i) Cross-check prescriptions with patient health records for contraindications.

#### 7.4.1.9.3. Assumptions

This scenario assumes that:

a) The “Crew as Patient” (activity diagram) is the “crewmember” (narrative).
b) The “Ground Caregiver” (activity diagram) is the “flight surgeon” (narrative).

### 7.4.1.9.4. Activity Diagram

The following is a graphical representation of the scenario narrative:

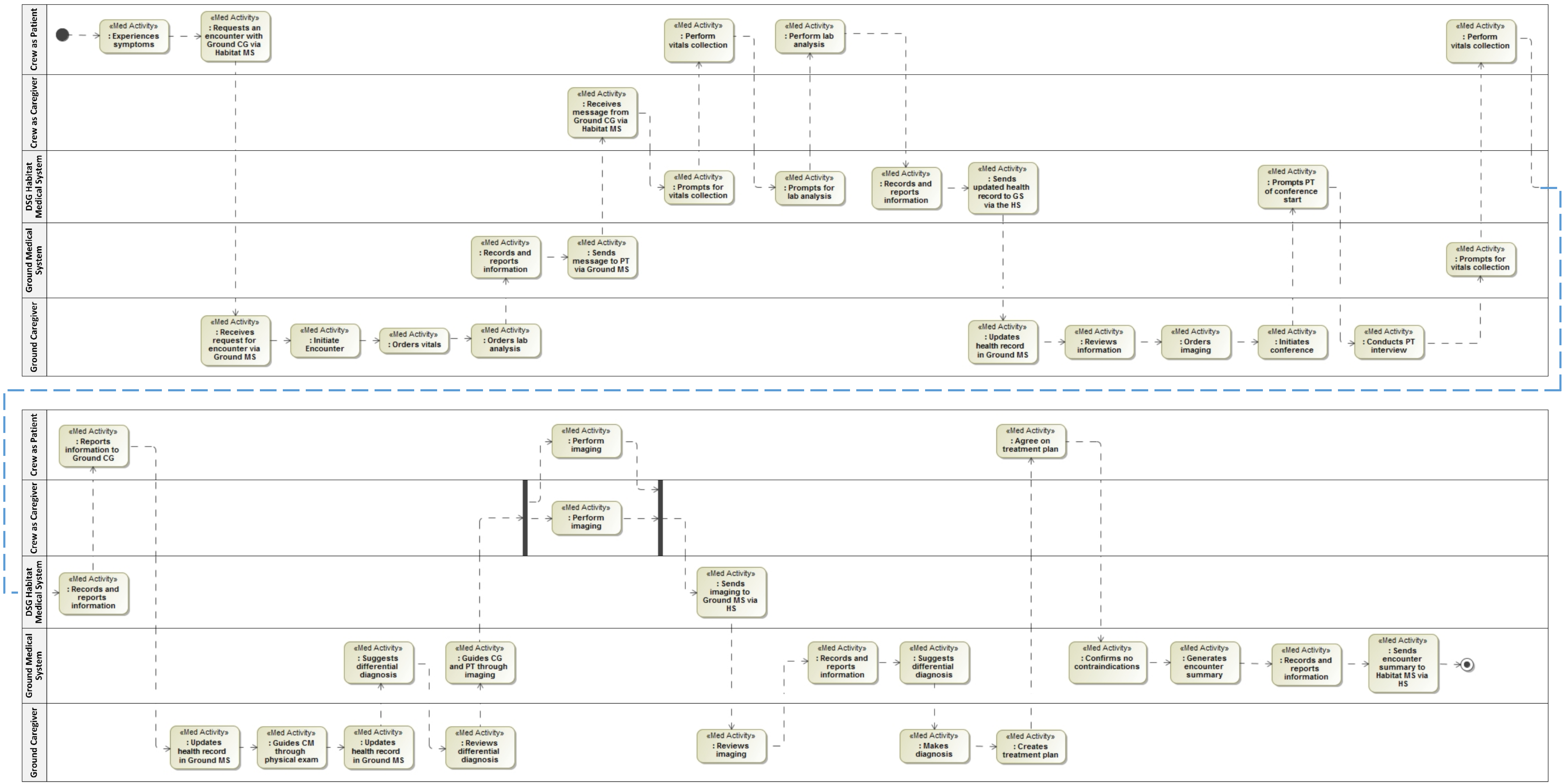


Figure 7-10 – Urinary Tract Infection (IVA, Unplanned, Directed Care, Semi-Autonomous)

### 7.4.1.9.5. Narrative

*Note: This narrative is a descriptive story meant to provide a vivid picture to the reader. Specific technologies are only representative and are not intended to indicate requirements.*

For a few days, a crewmember had been experiencing burning with urination, fatigue, and an increase in urination frequency. Concerned, he contacts his flight surgeon using the Medical System messaging system on his personal computing device and shares his symptoms and concerns. Upon receiving the message, the flight surgeon creates a new encounter for the crewmember in the Ground Medical System, records the crewmember's subjective information, and generates an electronic order for vital sign, urinalysis, and habitat environment data. He writes a response to the crewmember using the Ground Medical System messaging system, providing an overview of the data that he is requesting and notifying him to expect an unscheduled private medical conference (PMC) later in the afternoon so they can review the test results and conduct a more thorough interview and exam.

The Ground Medical System queues the updated information for uplink to the Medical System at the next available communication opportunity. The crewmember receives a pop-up message on his personal computing device notifying him of the new message from the flight surgeon. The crewmember launches the Medical System, reads the message, and navigates to the encounter form, which shows the information populated by the flight surgeon and links to the tests that are requested. Once the data are collected and imported to the Medical System, the updated file is queued for downlink to the Ground Medical System. The flight surgeon reviews the downlinked data in the Ground Medical System and decides that an ultrasound exam is needed during that afternoon's PMC session. The ground control team notifies remote guider personnel needed to support ultrasound imaging along with coordinating with the appropriate teams to configure two-way private video and voice communications for the conference.

At the beginning of the PMC, the flight surgeon launches an encounter in the Ground Medical System and waits for crewmember notification that he is ready to begin the conference. The crewmember joins the conference, and the exam commences. The Ground Medical System prompts, records, reviews and summarizes the interview in the patient's medical record for the flight surgeon. The Ground Medical System then prompts the flight surgeon to import a new set of vital signs from the crewmember. He coaches the crew through gathering and applying the equipment for measuring blood pressure, heart rate, oxygen saturation, temperature, and respiratory rate. The crewmember calls out the results, and the flight surgeon manually records them in the crewmember's health record within the Ground Medical System. The physical exam of the crewmember follows, and the flight surgeon populates his findings in the ground medical system. He finds that the crewmember has slight suprapubic tenderness on his abdominal exam, as well as some right-sided tenderness in the costo-vertebral angle. Based on the physical exam findings and vital signs, the Ground Medical System produces a differential diagnosis and presents it to the flight surgeon, who disregards the low-risk conditions and focuses on the higher risk conditions. Each suggested condition contains a link to additional information, such as variation in presentation, diagnostic approach, and treatment modalities, all stored within the Ground Medical System and accessible to the flight surgeon if desired. The flight surgeon knows that the most likely diagnosis is that the crewmember has a urinary tract infection, but he needs additional data to confirm the diagnosis and to ensure there are no other medical issues, such as kidney stones. The ground remote guider joins the conference and provides verbal coaching to obtain ultrasound data from the crewmember, who operates the ultrasound with assistance from the Crew Medical Officer. The flight surgeon observes the images collected to help form his impression of the CM's condition. The images are stored within the Ground Medical System for further review and report generation.

With this new data, the initial list of conditions in the differential diagnosis provided by the Ground Medical System is reduced. The flight surgeon makes an update in the Ground Medical System to indicate that a urinary tract infection is the most likely condition and conveys this information to the crewmember. He then develops a treatment plan that includes antibiotics. The Ground Medical System cross-checks the antibiotic prescription with the crewmember's health record to verify that there are no contraindications for that particular medication. The treatment plan is logged into the encounter form in the Ground Medical System, which displays the entered information for review. The Ground Medical System then coordinates with the habitat's communication system to uplink a summary of the encounter to the patient's medical system app. The summary provides information on the diagnosis, directions for medication administration, a list of possible medication side effects, recommendations for dietary changes related to the illness and medication usage as well as instructions on when to follow up with the flight surgeon.

### 7.4.1.10. Arm Injury (IVA, Unplanned, Emergent Care, Semiautonomous)

#### 7.4.1.10.1. Context

This scenario was developed in the context of an arm injury.

#### 7.4.1.10.2. Highlighted Functionality

This scenario shows the Gateway Habitat Medical System can:

a) Prompt the initiation of an activity based on a protocol.
b) Execute an emergent medical event mode of an operation initiation sequence.
c) Notify the Ground Medical System of an emergent medical event.
d) Retrieve information from the patient in an automated manner, once directed.
e) Provide relevant reference material.
f) Conduct and report a real-time analysis of collected vital sign information.
g) Facilitate real-time conference with the ground.
h) Capture a rehabilitation plan.
i) Capture and transmit a mission impact statement.
j) Wirelessly transmit, display and record vital sign, imaging and laboratory data from devices.
k) Prioritize medical data for downlink.

This scenario also shows that multiple crewmembers can be involved during an emergent medical event.

This scenario shows that the Ground System can:

a) Support teleconferencing with crewmembers.
b) Receive inflight medically oriented, attributable medical information and display it to ground clinicians.
c) Uplink a change to a crewmember's health record.
d) Receive data entry from the caregiver about the patient.

#### 7.4.1.10.3. Assumptions

This scenario assumes that:

a) The "Crew as Patient" (activity diagram) is the "patient" (narrative).
b) The "Crew as Caregiver" (activity diagram) is the "CMO" and "crewmember" (narrative).
c) The transit vehicle can support the use of Gateway Habitat Medical System resources.

### 7.4.1.10.4. Activity Diagram

The following is a graphical representation of the scenario narrative:

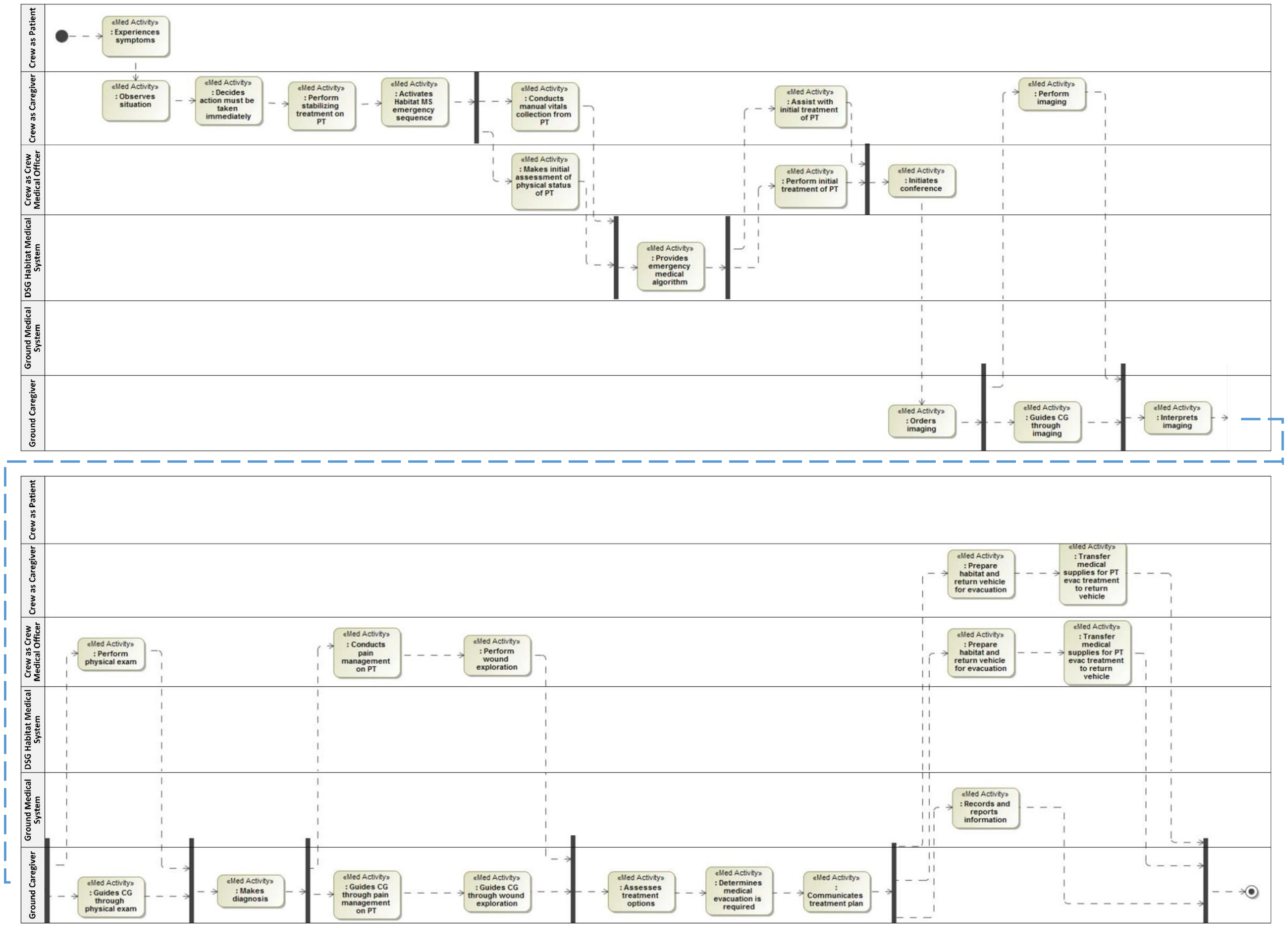


Figure 7-11 – Arm Injury (IVA, Unplanned, Emergent Care, Semiautonomous)

#### 7.4.1.10.5. Narrative

*Note: This narrative is a descriptive story meant to provide a vivid picture to the reader. Specific technologies are only representative and are not intended to indicate requirements.*

Due to a malfunctioning hatch, a crewmember's arm is pinned by the door just above the wrist. Another crewmember acts quickly to re-open the hatch door and, seeing the blood dome expanding from the injured crewmember's forearm, realizes that immediate emergency medical care is required.

It appears to him that the injured crewmate (patient) has a deep skin laceration on her forearm about 4 inches long. He applies pressure to the wound to slow down the bleeding and notifies the crew medical officer that assistance is required. The crew medical officer takes over care from the crewmember, directing the crewmember to unstow the emergency medical kit. While waiting for the supplies, the CMO executes a memorized response and performs a quick assessment of the patient. He finds her alert, with her eyes open. She is able to speak, answers questions appropriately, breathes at a normal rate and has a palpable pulse below the injury. Upon arrival of the emergency medical kit, the CMO places a pressure dressing on the wound. He asks the crewmember to notify the ground medical support team to inform them of the current emergent situation and to prepare them to provide assistance if needed. After checking the vehicle computer, the crewmember notifies the crew medical officer that the next communication pass with the ground is not possible for another 25 minutes.

The crew medical officer asks a crewmember to grab a personal computing device, open the Medical System, access the patient's medical record and launch an emergency encounter. Once launched, the emergency encounter form forces an exported report for downlink from the Medical System application at 2-minute intervals until the encounter is ended. From the medical kit, the CMO directs the crewmember to apply the blood pressure cuff and pulse oximeter to the patient's non-affected arm and start the measurements while the CMO references the emergency algorithm, using it to perform a cursory neurological check of the affected extremity and finds sensation and gross motor function intact. Once the encounter in the Medical System application is created, the crew medical officer asks the crewmember to import the vital signs and document the findings of the neurovascular exam. The crew medical officer notes that the patient's pulse is 120 bpm and the systolic blood pressure is 110 mmHg. Noting the patient's report of severe pain and her elevated heart rate, the CMO removes a dose of oral pain medication and gives it to the patient with water from her drink bag while waiting for the ground to respond.

A communication link is established, and the flight surgeon appears on the video communication link of the personal computing device for consultation. The crew medical officer activates the call from his end, briefs the flight surgeon on the events that occurred and the patient's status, and shows the wound to the device's camera. The device image resolution is not sufficient for diagnostic purposes, so the crew medical officer hands the device to the patient so she may speak directly to the flight surgeon while he grabs a digital camera, collects several still images of the patient's wound and imports the files to the medical encounter form in the Medical System for downlink. After seeing the images, the flight surgeon determines that an arterial injury has possibly occurred but that more information is required to make an accurate diagnosis and create a treatment plan. The flight surgeon directs the crewmember to unstow surgical tools, personal protection equipment and injectable medication kits in preparation for the examination. He points the crewmember to the procedures in the medical app to help guide setup and use of the surgical tools. While the crewmember performs this setup and review, the flight surgeon completes a focused examination and interview of the patient. The crew medical officer joins briefly to assist with a more comprehensive neurovascular exam of the hand of the affected extremity. The flight surgeon documents the findings of this shared exam in the ground system version of the encounter form, which also syncs with the inflight version every 2 minutes.

Once the CMO and medical equipment are prepared, the flight surgeon first coaches the crew medical officer through administration of local anesthesia, followed by the application of a tourniquet to enable better visualization as they explore the wound, and the CMO attempts repair. At completion of the repair, the tourniquet is released and a dressing is applied. During this process, the flight surgeon references ground-based procedures and protocols, along with real-time video feeds from the cabin. Still imagery captured during the examination and procedure, along with the flight surgeon's assessment, is documented in the Ground Medical System and used by the ground team to assess options for treatment. The Ground Medical System saves all imaging data to the patient's health record as it is downlinked from the Habitat Medical System.

Neurovascular and wound checks performed in the two hours after repair demonstrate continued bleeding that requires increased pressure to control along with increasing numbness of the thumb, pointer and middle fingers. Upon direction of the flight surgeon, the dressing is removed and reveals that the wound is seeping blood. The tourniquet is reapplied and observed to stop the bleeding. Based on the examination, the ground team is concerned that flight environment limitations would prevent the crew medical officer from adequately and safely performing the additional treatment needed, even with active remote guidance from a ground subject matter expert physician. The ground team weighs the ability to deliver the patient to Earth-based definitive care within 48 hours against the perceived risks of injury and crew disability from an in-flight repair attempt and decides to terminate the mission and return the crew. The flight director informs the crew of the plan and points them to procedures for preparing the habitat for an uninhabited state and transit vehicle undock. The flight surgeon uplinks to the crew medical officer a patient treatment plan, which provides directions for care during the return flight. This plan includes required examinations, orders for medication administration, and a list of medical supplies (e.g., pain medication, wound management supplies, intravenous fluids and personal protective supplies) to be transferred from the Gateway to the return vehicle. The ground teams activate protocols to mobilize landing site medical resources in preparation for crew return.

#### 7.4.1.11. Sudden Cardiac Arrest (IVA, Unplanned, Emergent Care, Semi-Autonomous)

##### 7.4.1.11.1. Context

This scenario was developed in the context of sudden cardiac arrest.

### 7.4.1.11.2. Highlighted Functionality

This scenario shows the Gateway Habitat Medical System can:

a) Prompt the initiation of an activity based on a memorized protocol without interfacing with Gateway Habitat Medical System hardware or software.

### 7.4.1.11.3. Assumptions

This scenario assumes that:

a) All crewmembers are trained on how to respond to an emergency medical event.
b) The “Crew as Caregiver” (activity diagram) is the “CMO” (narrative).
c) The “Crew as Patient” (activity diagram) is the “crewmember/patient” (narrative).

### 7.4.1.11.4. Activity Diagram

The following is a graphical representation of the scenario narrative:

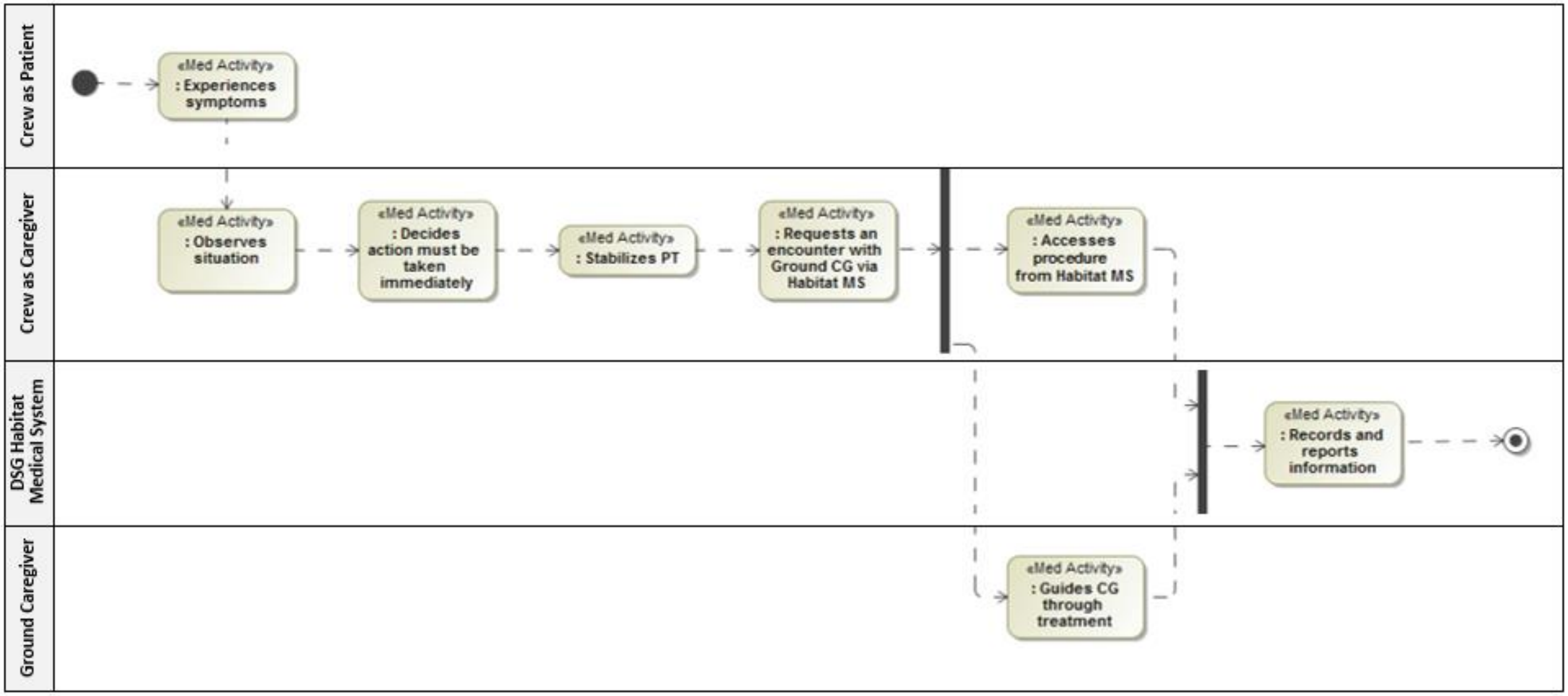


Figure 7-12 – Sudden Cardiac Arrest (IVA, Unplanned, Emergent Care, Autonomous)

### 7.4.1.11.5. Narrative

*Note: This narrative is a descriptive story meant to provide a vivid picture to the reader. Specific technologies are only representative and are not intended to indicate requirements.*

A crewmember is exercising on the exercise system when he starts to feel nauseous and lightheaded. He reduces his exertion but finds that does not relieve his symptoms. He therefore begins a shutdown of the hardware in preparation for a call to his flight surgeon. As he begins to doff his harness, the crew medical officer floats by and comments 'you don't look well'. The crewmember starts to respond but then closes his eyes and is no longer responsive. The crew medical officer asks him 'are you okay?' but does not get a response.

Relying upon a memorized emergency response, the crew medical officer grabs the crewmember (patient) by the shoulders, shakes him, and then pinches the skin on his chest. The patient does not respond. The crew medical officer notices that the patient does not appear to be breathing and that his skin is pale, sweaty and cool to the touch. Recognizing these ominous signs, the crew medical officer calls for help in the cabin as he starts to move the patient toward the medical treatment area.

He restrains the patient and starts delivering chest compressions and rescue breathing, directing the arriving two crewmembers to deploy the automated external defibrillator (AED) and activate the medical emergency alert to the ground. The AED is powered on, and the crewmember applies the pads to the patient. The AED states 'Stand clear, analyzing now. Shock advised, push shock button'. The crew medical officer calls for everyone to stand clear, pushes the shock button to deliver the energy to the patient and then resumes chest compressions. After 2 cycles of compressions, the crew medical officer notices the patient purposely moving his arms and hears him vocalizing. The crew medical officer stops compressions and places his fingers on the patient's neck. Feeling a pulse, he notes the patient attempting to take breaths in a rhythmic fashion at about 10 breaths/minute. The patient's skin is cool, moist, and pale, and his gums appear to be pinker than seen previously.

A crewmember calls to the ground to notify the flight surgeon of the patient status change while the crew medical officer accesses the Medical System on the portable computing device and locates the post-resuscitation steps in the emergency response algorithm. Using procedure guidance provided by the algorithm, the crew medical officer locates, deploys, and applies the medical oxygen patient interface system. The flight surgeon requests that an intraosseous device be placed, and the crew medical officer locates those procedure steps in the algorithm using a second electronic medical device.

## 7.4.1.12. Hardware Malfunction (IVA, Unplanned, Medical System Maintenance, Semi-Autonomous)

### 7.4.1.12.1. Context

This scenario was developed in the context of malfunctioning Gateway Habitat Medical System hardware.

### 7.4.1.12.2. Highlighted Functionality

This scenario shows the Gateway Habitat Medical System can:

a) Identify the need for maintenance.
b) Report a maintenance need to the crewmembers.

c) Report a maintenance need to the Ground System.
d) Confirm repairs.

#### 7.4.1.12.3. Assumptions

This scenario assumes that:

a) Required replacement hardware is available within the Gateway Habitat.
b) The "Crewmember" (activity diagram) is the "crewmember" (narrative).

#### 7.4.1.12.4. Activity Diagram

The following is a graphical representation of the scenario narrative:

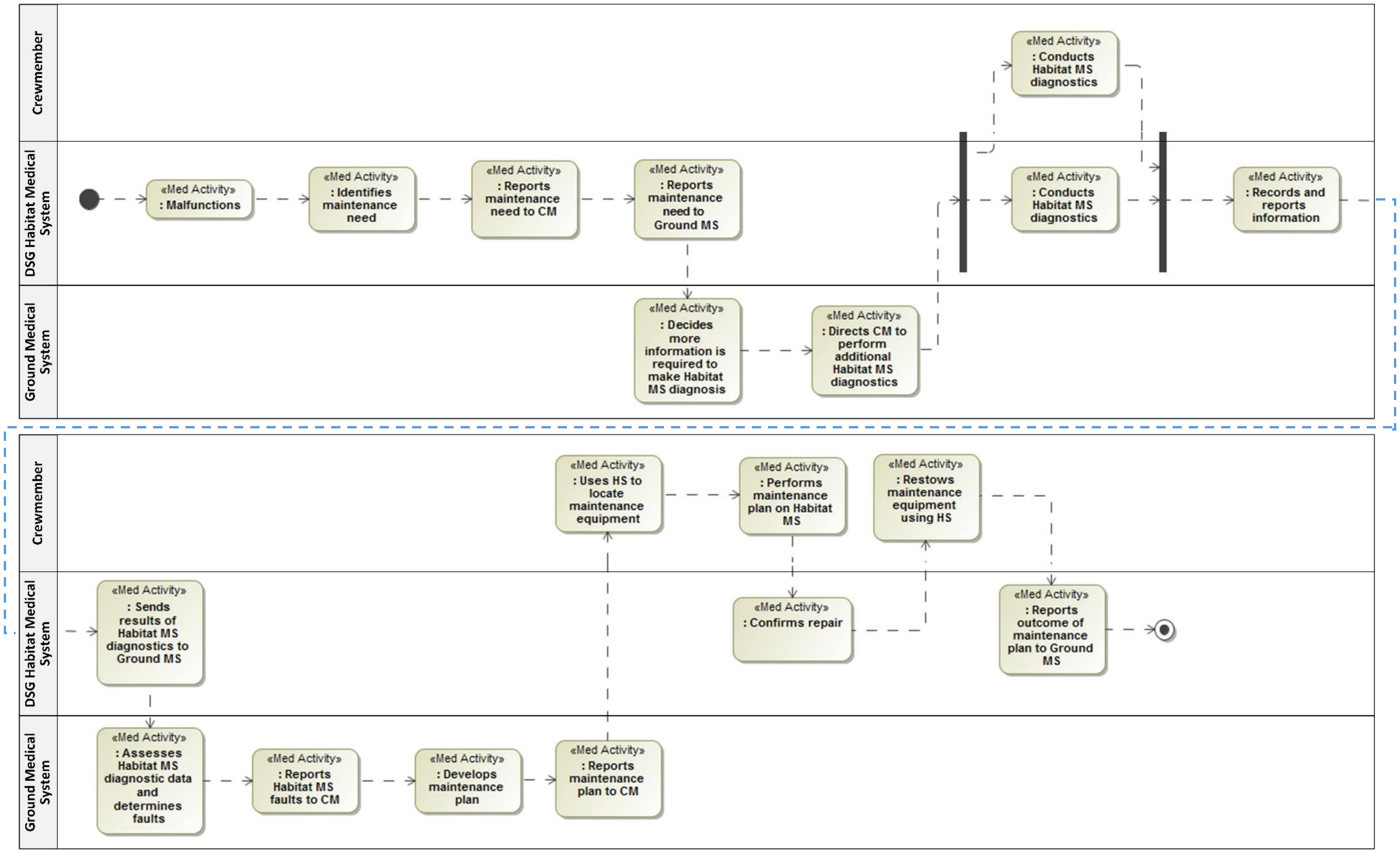


Figure 7-13 – Hardware Malfunction (IVA, Unplanned, Medical System Maintenance, Semi-Autonomous)

#### 7.4.1.12.5. Narrative

*Note: This narrative is a descriptive story meant to provide a vivid picture to the reader. Specific technologies are only representative and are not intended to indicate requirements.*

A crewmember completes a diagnostic imaging session and is about to log out of the system when she sees that the system is displaying a maintenance flag. She directs the Medical System to provide more information, and she is told that the imaging device fan has prematurely failed and a replacement activity is required. The Medical System also informs her that a message has been sent to the ground caregiver and relevant engineering teams with the same information.

Despite the flag, the ground team wants to collect additional data to confirm that the message is not erroneous or that it is not an artifact of another issue. Fortunately, the Medical System has additional diagnostic algorithms that could be run by the crew to provide additional data. The ground team sends a message to the crewmember with instructions to perform the diagnostic procedure.

Upon receiving the message, the crewmember performs the diagnostic steps. When the diagnostic test is complete, the Medical System records the results, displays them to the crewmember, and transmits them to the ground team for analysis. The ground team reviews the diagnostic data after they are downlinked and confirms the recommendation to change out the fan. They send a message to the crewmember directing her to perform this maintenance activity at the next available opportunity.

The Medical System presents her with the procedure, and she uses the habitat's inventory system to locate all necessary parts and tools. She unstows and pre-positions everything near the imaging device and gets to work. After completing the maintenance procedure, the crewmember performs a successful activation and checkout and informs her crewmates that the imaging device is back up and running. She restows the tools she had used and disposes of the old fan. The Medical System then sends a message to the ground medical support and engineering teams notifying them of her success and the resumption of device functionality.

### 7.4.1.13. Just-In-Time Training (IVA, Unplanned, Medical Training and Education, Autonomous)

#### 7.4.1.13.1. Context

This scenario was developed in the context of just-in-time training.

#### 7.4.1.13.2. Highlighted Functionality

This scenario shows that the Gateway Habitat Medical System can:

a) Provide training material.
b) Accommodate crew training as needed.

This scenario shows that the Ground System can:

a) Uplink a change to a crewmember's health record.
b) Inform designated ground personnel of the updated record.

#### 7.4.1.13.3. Assumptions

This scenario assumes that:

a) The Gateway Habitat Medical System contains the desired training material.
b) The “Crew as Caregiver” (activity diagram) is the “CMO” (narrative).

### 7.4.1.13.4. Activity Diagram

The following is a graphical representation of the scenario narrative:

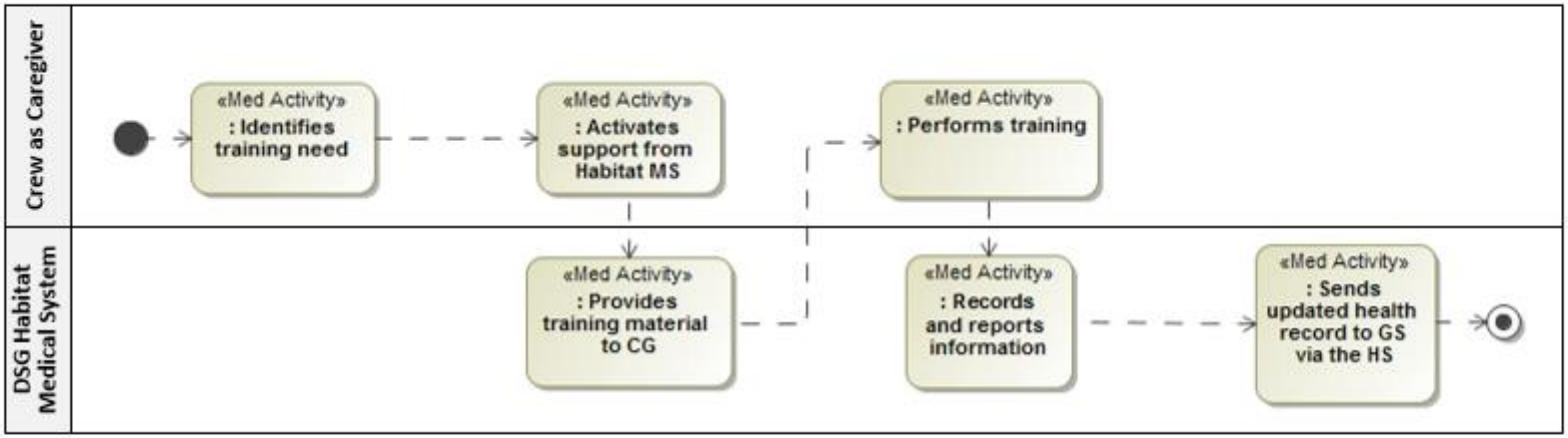


Figure 7-14 – Just-In-Time-Training (IVA, Unplanned, Medical Training and Education, Autonomous)

#### 7.4.1.13.5. Narrative

*Note: This narrative is a descriptive story meant to provide a vivid picture to the reader. Specific technologies are only representative and are not intended to indicate requirements.*

The crew medical officer sees that he is scheduled to insert an intravenous catheter into a crewmember tomorrow as part of a planned research study. In preparation for this task, he decides he would like to refresh his memory of the hardware preparation and catheter insertion process. He accesses the Medical System from his personal computing device and locates the training material for the IV catheterization task. He completes the training, and it is documented in his training record by the Medical System. The Medical System generates a report that is queued with all other nonpriority downlink data during an upcoming communication opportunity. The Ground Medical System receives the report and updates the crew medical officer training files. An alert of the completed training is sent to the interested team members.

### 7.4.2. Extravehicular Activity Scenarios

[TBD-16]

## 7.5. NRHO Departure for Earth Return through EDL Phase

[TBD-17]

## 7.6. Immediate Post-Landing Recovery Phase

[TBD-18]

# 8. APPENDIX A: ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| AED | Automated External Defibrillator |
| BPM | Beats Per Minute |
| C&DH | Command & Data Handling |
| CG | Caregiver |
| CHP | Crew Health and Performance |
| CM | Crew Member |
| CMO | Crew Medical Officer |
| DRM | Design Reference Mission |
| DSG | Deep Space Gateway |
| ECLSS | Environmental Control and Life Support Systems |
| EDL | Entry, Descent, &Landing |
| EM | Exploration Mission |
| EVA | Extravehicular Activity |
| ExMC | Exploration Medical Capability |
| GNC | Guidance, Navigation, and Control |
| HRP | Human Research Program |
| HS | Habitat System |
| IDRD | Increment Definition and Requirements Document |
| IMCL | IMM Medical Condition List |
| IMM | Integrated Medical Model |
| ISRU | In-Situ Resource Allocation |
| ISS | International Space Station |
| IV | Intravenous |
| IVA | Intravehicular Activity |
| JSC | Johnson Space Center |
| LEO | Low Earth Orbit |
| MED | Medical Evaluation Document |
| MORD | Medication Operations Requirements Document |
| MS | Medical System |
| n/a | Not Applicable |
| NASA | National Aeronautics and Space Administration |
| NPR | NASA Procedural Requirements |
| NRHO | Near Rectilinear Halo Orbit |
| PMC | Private Medical Conference |
| PT | Patient |
| RFID | Radio Frequency Identification |
| SMS | Space Motion Sickness |
| STD | Standard |
| TBC | To Be Confirmed |
| TBD | To Be Determined |
| TLI | Trans-Lunar Insertion |
| TM | Technical Memo |

# 9. APPENDIX B: REFERENCES

[1] NASA Human Research Program, "Human Research Roadmap, Risk of Adverse Health Outcomes & Decrements in Performance due to Inflight Medical Conditions," [Online]. Available: https://humanresearchroadmap.nasa.gov/Risks/risk.aspx?i=95.

[2] W. Gerstenmaier, *Progress in Defining the Deep Space Gateway and Transport Plan,* Presentation to the NASA Advisory Council, 2017.

[3] Committee on Creating a Vision for Space Medicine During Travel Beyond Earth Orbit, "Safe Passage: Astronaut Care for Exploration Missions," in *Institute of Medicine of the National Academies Press*, 2001.

[4] ExMC Systems Engineering and Concept of Operations teams, "Exploration Mission Assumptions and Constraints," TBD.

[5] "NASA/TP-2014-217392 Telemedicine Operational Concepts for Human Exploration Missions to Near Earth Asteroid".

[6] "MediLexicon," [Online]. Available: www.medilexicon.com.

# 10.APPENDIX C: ACTIVITIES

[TBD-19]. This section is for representative medical activities and their frequencies of occurrence.

# 11.APPENDIX D: "TO BE DETERMINED" (TBD) TABLE

| | |
|---|---|
| **Error! Reference source not found.** | Gateway Habitat Concept of Operations details |
| TBD-02 | ExMC Element Management Plan document number |
| TBD-03 | ExMC Systems Engineering Management Plan document number |
| TBD-04 | Systems Engineering Architecture Diagram Definitions Document |
| TBD-05 | Gateway Habitat Concept of Operations details |
| TBD-06 | Pre-Launch Phase Target Level of Care |
| TBD-07 | Launch to TLI Phase Duration |
| TBD-08 | Communication delay at TLI |
| TBD-09 | Launch to TLI Phase Target Level of Care |
| TBD-10 | TLI to NRHO Target Level of Care |
| TBD-11 | NRHO Departure for Earth Return through EDL Phase Target Level of Care |
| TBD-12 | Immediate Post-Landing Recovery Phase Target Level of Care |
| TBD-13 | Pre-Launch Phase Scenarios |
| TBD-14 | Launch to TLI Phase Scenarios |
| TBD-15 | TLI to NRHO Phase Scenarios |
| TBD-16 | Extravehicular Activity Scenarios |
| TBD-17 | NRHO Departure for Earth Return through EDL Phase Scenarios |
| TBD-18 | Immediate Post-Landing Recovery Phase Scenarios |
| TBD-19 | Appendix C: Medical Activities List |

# 12.APPENDIX E: "TO BE CONFIRMED" (TBC) TABLE

| | |
|---|---|
| TBC-01 | Transit duration between TLI and NRHO |
| TBC-02 | NRHO time to definitive care |
| TBC-03 | NRHO phase durations |
| TBC-04 | NRHO time to definitive care |

# 13.APPENDIX E: FUTURE WORK

| Section | Future Work |
| --- | --- |
| 2.2.1 | Determine the extent of health management capabilities required to meet goal. |
| 2.2.2 | Determine the expected and required levels of crew autonomy. |
| 4.7 | Determine the level of skill and training required for a Gateway crew medical officer. |