A Tool for the Automated Collection of Space Utilization Data: *Three Dimensional Space Utilization Monitor*

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Background and Introduction

- Space Human Factors and Habitability (SHFH) Element within the Human Research Program (HRP), in collaboration with the Behavioral Health and Performance (BHP) Element, is conducting research regarding Net Habitable Volume (NHV), the internal volume within a spacecraft or habitat that is available to crew for required activities, as well as layout and accommodations within that volume.
- NASA is looking for innovative methods to unobtrusively collect NHV data without impacting crew time. Data required includes metrics such as location and orientation of crew, volume used to complete tasks, internal translation paths, flow of work, and task completion times.
- In less constrained environments methods for collecting such data exist yet many are obtrusive and require significant post-processing.
- Example technologies used in terrestrial settings include infrared (IR) retro-reflective marker based motion capture, GPS sensor tracking, inertial tracking, and multiple camera filmography.
- However due to constraints of space operations many such methods are infeasible, such as inertial tracking systems which typically rely upon a gravity vector to normalize sensor readings, and traditional IR systems which are large and require extensive calibration.
- However multiple technologies have not yet been applied to space operations for these explicit purposes. Two of these include:
  - 3-Dimensional Radio Frequency Identification Real-Time Localization Systems (3D RFID-RTLS)
  - Depth imaging systems which allow for 3D motion capture and volumetric scanning (such as those using IR-depth cameras like the Microsoft Kinect or Light Detection and Ranging / Light-Radar systems, referred to as LIDAR)

Objective

- Develop an automated methodology for collecting the data and metrics needed to mitigate NHV and space utilization risks by:
  - Adapting and integrating two independent technologies, 3D RFID-RTLS and Microsoft Kinect 3D volumetric and anatomical scanning tools, into a single solution.
  - Developing a methodology for using the integrated solution in the collection of 3D space utilization data,
  - Formatting the data in such a way that it can be used in computational modeling, and
  - Validating the resulting system and data outcomes against standard measures presently used in terrestrial environments (e.g. IR motion capture, multi-camera systems, and other traditional industrial engineering time and motion study methods).
- The integrated solution will be developed and pilot tested in a controlled laboratory setting, as well as validated in the representative vehicle and mission analog environment at the Human Exploration Research Analog (HERA).
- This synthesis of 2 technologies will enable allow collection of the following data:
  - The number of crew present in each area of the vehicle at any given time
  - The quantity of time crew spend at each workstation in the performance of tasks
  - The physical orientation of crew while utilizing the provided volume
  - Frequent or common translation paths and traffic flow patterns within the volume
  - Operational flow/volume required for mission tasks by single or multiple crew in the vehicle
  - 3D biomechanical and postural data related to individual and team based tasks

Significance

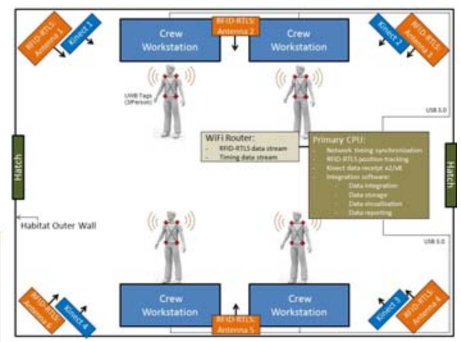
- This project will provide NASA with a quantitative methodology for collecting data 3D space utilization data that is validated for use in flight analogs and has potential direct applicability for use in actual flight environments.
- This capability does not currently exist at NASA, and will have a significant positive impact on NASA's ability to generate quantitatively derived NHV requirements by task and mission.
- It will also feed directly into the use of computational modeling and simulation for habitat/vehicle design by providing a valid method to generate input data for modeling efforts.

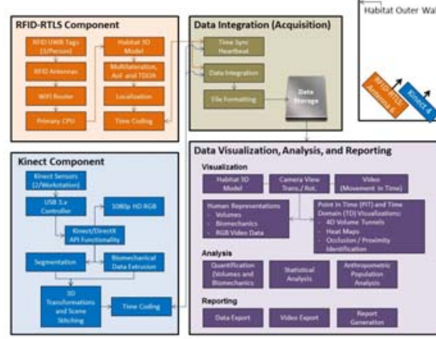
Overall Approach

- The plan of work for this project includes several steps spread across a three year period:
  - The first portion focusses on integration of the hardware technologies involved (3D RFID-RTLS and Kinect) and initial development of software interfaces.
  - The second portion includes development and refinement of the system and its software interfaces, ensuring that best practices in usability and human centered design are followed, finalization of data formats for storing datasets, and conducting engineering pilot tests in a laboratory environment.
  - The third portion includes full validation of the completed system in the HERA analog environment, delivery of final project deliverables, and publication of results.
- Collaborations:
  - University of Nebraska-Lincoln which has extensive experience in RFID-RTLS
  - NASA's EV8 Antenna and Wireless Systems Branch which has extensive experience and ongoing work with RFID technology projects at NASA
  - NASA EV3 Wearable Electronics Group (The Wear Lab)

System Design

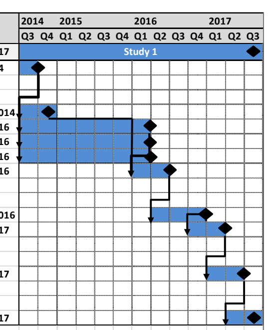
- The ultra-wide band 3D RFID-RTLS system will utilize 4-8 antennas, with 4 active tags on each person, to minimize occlusion.
- The volumetric scanning and biomechanical tracking system will utilize 4-6 Kinect V2 systems, also to minimize occlusion
- The software design for the system uses a functional design model with a centralized integration and analysis capability.





Schedule

Task Name	Duration *(days)*	Start	Finish
Study 1: Funded Flagship Study (DDT&E, Ground Validation)	**3 Years**	**7/21/2014**	**7/17/2017**
Project kickoff	**35**	**7/21/2014**	**9/1/2014**
Team coordination and planning	15		
Acquisition of hardware and software	20		
CPHS/IRB approval for overall project plans	**60**	**9/1/2014**	**10/31/2014**
Development of the 3D RFID-RTLS component	**540**	**9/1/2014**	**2/23/2016**
Development of the Kinect component	**540**	**9/1/2014**	**2/23/2016**
Development of interface and integration software	**540**	**9/1/2014**	**2/23/2016**
Pilot testing of the integrated system	**90**	**2/23/2016**	**5/23/2016**
Conduct initial pilot testing	60		
Results from pilot testing used to generate revision plans	30		
Iteration on the design of all components and software	**150**	**5/23/2016**	**10/20/2016**
Final pilot testing of the integrated system	**90**	**10/20/2016**	**1/18/2017**
Conduct final pilot testing	60		
Results used to determine readiness for validation in HERA	30		
Validation of the integrated system in HERA	**120**	**1/18/2017**	**5/18/2017**
Conduct validation testing	90		
Data analysis and results generation	30		
Final reporting	**60**	**5/18/2017**	**7/17/2017**



Note: *Duration in days reflect full calendar days, not just working days.*