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FILL 'ER UP! A FUNCTIONAL ANALYSIS OF A CRYOGENIC PROPELLANT DEPOT AT EARTH-MOON L1

Abstract

Purpose: To present a functional analysis for a robotic cryogenic propellant depot located at Earth-Moon L1. A functional analysis is a necessary step to identify and describe the actual tasks the depot must perform to meet established requirements. Functional and subsystem interfaces will also be identified.

Methodology: Numerous studies and concept papers will be reviewed to synthesize a concept of operations. Requirements from the ConOps will be translated into functions that must be performed. Functions will be decomposed and allocated to lower levels of the product breakdown structure and depicted in a functional flow block diagram showing inputs, outputs, controls, and mechanisms. Functional and subsystem interfaces will be identified and illustrated.

Results: Depot operations will include routine spacecraft operations and propellant operations. Propellant operations will comprise four broad areas: 1) Depot Standby Operations in which the depot maintains and manages its supply of liquid hydrogen and liquid oxygen; 2) Propellant Receiving Operations in which the depot receives propellants from a supply vehicle; 3) Propellant Supply Operations in which the depot transfers propellants to customer vehicle(s); and 4) Contingency Operations in which the depot responds to off-nominal or emergency conditions to protect itself, its propellant supply, and other space vehicles. Each area will be the subject of a more detailed functional analysis.

Conclusions:

1- The major difference between the depot and other space vehicles is the depot will transfer hazardous commodities to and from other spacecraft. Handling cryogenic propellants safely is difficult. Safety for both the depot and customer vehicles will be paramount.

2- Depot operations will require numerous individual tasks/technologies (cryogenic fluid management) not yet demonstrated in microgravity. These include active cooling of the propellants, multilayer insulation with structural stiffness, low conductivity structures, control of propellant tank pressure in microgravity, mass gauging, and propellant transfer.

3- Communications delay will be a critical aspect of depot operations. There will be a one second delay each way in Earth-to-depot communications. Routine propellant transfer could be initiated from the ground, but emergency responses to hazardous conditions must be automated.

4- The extent to which depot spacecraft operations and depot propellant operations should be integrated deserves serious examination. For example, how will the depot perform station keeping? Will the depot use a separate system of hydrazine thrusters, or will the depot bus access the depot's propellant supply to maintain the depot orbit?