Lunar Logistics Drivers and Needs

Introduction

For human exploration missions, it is critical to provide items such as food, water, air, spare parts, and other similar products required to sustain life, maintain systems, and allow for productive science and utilization activities. Together, these types of goods are referred to as logistics items. This white paper breaks down the different types of logistics items, explains the mission and architecture drivers that determine logistics item needs, and identifies the types of logistics items that tend to dominate overall needs.

NASA has established a consistent process for developing initial estimates of logistics item needs for conceptual exploration missions. This process, which is based on previous spaceflight experience and input from technical experts, provides a comprehensive assessment of the logistics items needed to support exploration missions. Using a consistent process to estimate logistics item needs allows for proper assessment of logistics systems and consistent analysis of mission and architecture concepts.

The process for estimating logistics item needs for conceptual missions does not dictate requirements for future missions; formal logistics item needs for those missions will be determined based on detailed mission requirements. However, the process described here provides a comparable initial estimate of logistics item needs.

Composition of Logistics Items

Logistics items are all the equipment and supplies needed to support mission activities and are not part of a vehicle or element dry mass, with the exception of vehicle propellant and pressurants, which are not considered to be logistics items. Logistics items can be divided into the following categories:

Consumables: Includes all commodities that support the conduct of mission activities (often related to mission crew needs) that are not related to a specific payload or research activity. In some cases, this category also includes consumables driven by non-crew activities (e.g., air to account for air leakage and re-pressurizations). Examples of specific items include food, clothing, personal items, operational supplies, hygiene items, trash bags and other waste collection, towels, extravehicular activity consumables, and gases and liquids.

Maintenance items: Includes planned replacement hardware and associated tools for system components that have known limited lifetimes and have scheduled replacement plans. Planned maintenance needs are largely system dependent.

Spares: Includes spares and associated tools that address corrective maintenance for unexpected/unplanned failures of system hardware. The actual spares needs will depend on the system.

Utilization (payloads and research): Additional hardware and items (e.g., science, research, capability demonstration, outreach) that take advantage of the space-based architecture but are not required for crew or vehicle operations. For exploration mission planning, mass and volume allocations are typically defined rather than specific utilization hardware, as the latter often depends on specific mission objectives.

Outfitting: Subsystem hardware or components that are flown after the initial module delivery for permanent installation or use are defined as outfitting. As items are identified for outfitting, they are typically tracked as part of the integrated logistics plan. Outfitting often occurs when there are insufficient resources to implement all the desired functions within the initial launch mass or schedule, so key systems are delivered on alternate flights. Specific outfitting estimates depend on the mission.

Packaging, overhead, and carriers: Materials required to safely and effectively transport and store each of the logistics items. (This category does not include any spacecraft secondary structures required to house or contain logistics items).

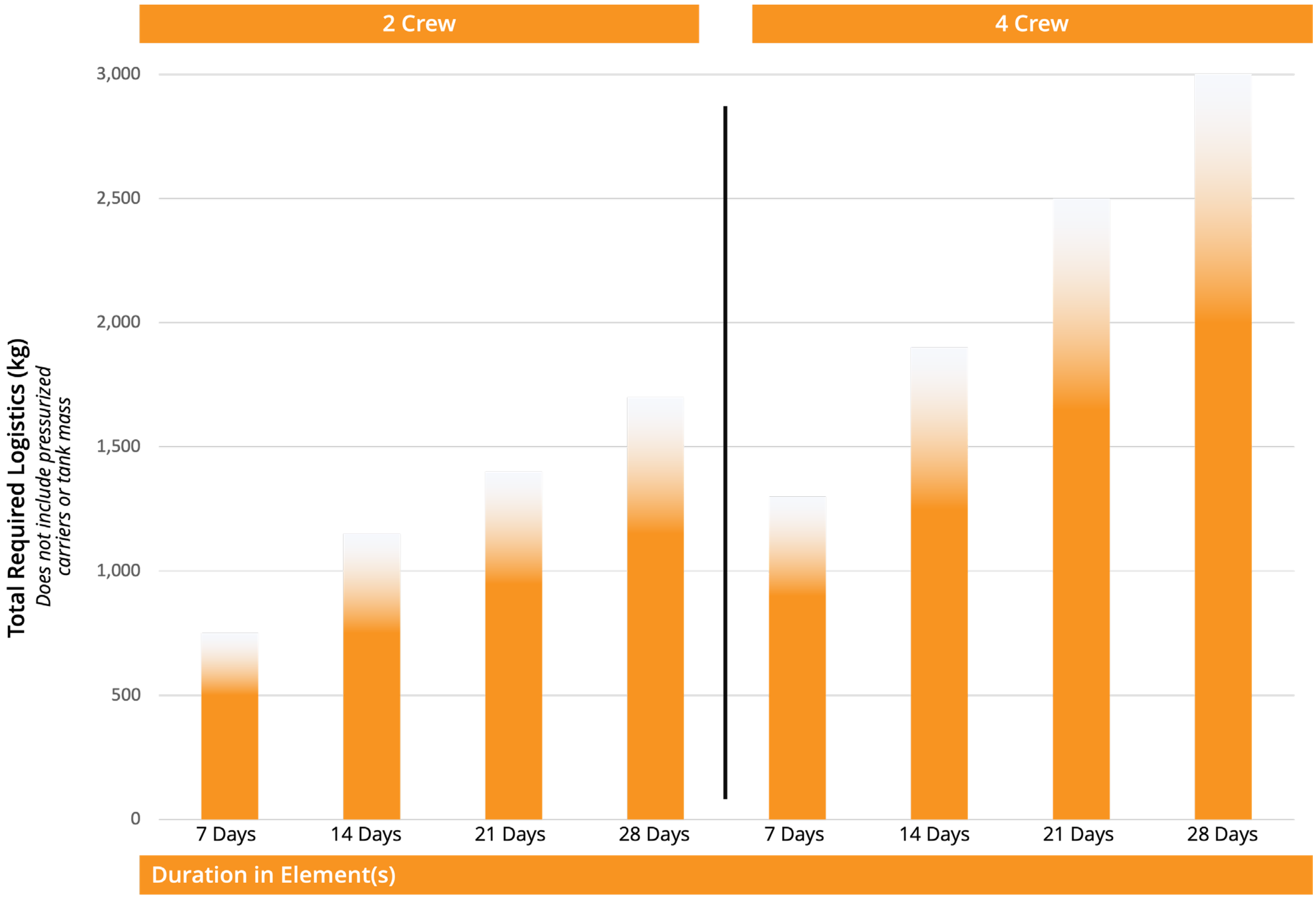

Figure 1. *Approximate Logistics Item Needs for Representative Lunar Surface Missions*

Lunar Logistics Drivers

Lunar mission logistics item needs are a function of the candidate mission and the proposed mission architecture. Although logistics item needs are determined by many factors, there are a few key contributors that have a predominant impact on overall logistics item needs. Typically, mission duration, crew size, environmental control and life support system (ECLSS) architecture, and extravehicular activity (EVA) cadence are the primary drivers. Mission crew size and mission duration are generally the most significant factors in determining the mass of logistics items. A large fraction of logistics item needs stems from crew support; these needs increase with the number of crew members and the mission duration.

The proposed ECLSS architecture is also an important consideration. An open-loop ECLSS, where waste products are not collected and recycled, will result in large needs for gas and water consumables. A regenerative ECLSS, where some waste products are recycled to produce water and gas, can significantly reduce or even eliminate gas and water resupply needs.

Crew EVAs on lunar missions can also be a significant driver of logistics item needs. EVA systems use significant amounts of water, oxygen, and other dry consumables. In addition, maintenance items, spares, and tools are required to maintain EVA systems. For missions with many planned EVAs, such as lunar surface missions, the overall EVA support mass can be a significant fraction of overall logistics item mass.

Logistics Item Estimates

Figure 1 shows approximate logistics item needs for representative lunar surface mission of varying crew sizes and mission durations. These estimates are for the mass of logistics items themselves and do not include carrier overhead mass. The uncertainty in the estimates shown in Figure 1 represents potential variability in mission operations and architecture. Changes in EVA cadence, ECLSS architecture, and element design can have substantial impacts on overall logistics item needs. While logistics item needs increase with crew size and mission duration, the increase is not linear, as certain fixed items are needed regardless of duration or crew size.

Figure 2 shows a representative breakdown by mass of logistics needs for a conceptual lunar surface mission with a significant planned cadence of EVAs. In this example, the habitation sub-architecture utilizes a fully open-loop ECLSS with no waste recycling. The water and gases needed to support the mission, including those for EVA, represent about half of the total logistics needs. Crew food and other crew consumables and EVA support items each represent about 20 percent of the overall needs. System maintenance and spare items and utilization items make up the remaining needs.

As missions progress to longer durations, spares and maintenance items can become larger drivers of overall logistics mass.

The ECLSS sub-architecture can have a significant impact on the overall distribution and total logistics item needs. With a high level of closure, the oxygen and water needs described in Figure 1, totaling almost 40 percent of overall needs, could be largely eliminated. However, regenerative ECLSS will generally increase subsystem mass and logistics item needs for maintenance and spares items.

The use of in-situ resource utilization capabilities can also have a substantial impact on logistics resupply. While in-situ resource utilization does not reduce the need for logistics items, it can reduce the need to deliver certain items, such as water and gas, to the exploration location.

Note that the mass of packaging, overhead, and carriers is not included in Figure 1. The bags, foam, and tanks that contain cargo items, as well as the pressurized carriers needed to deliver logistics to the lunar surface can add a large amount of overhead beyond the mass of the logistics items themselves. Based on historical performance, this added overhead could be between 75 percent and 150 percent of the base logistics item mass. However, the carrier mass depends heavily on the design of bags, tanks, and carriers.

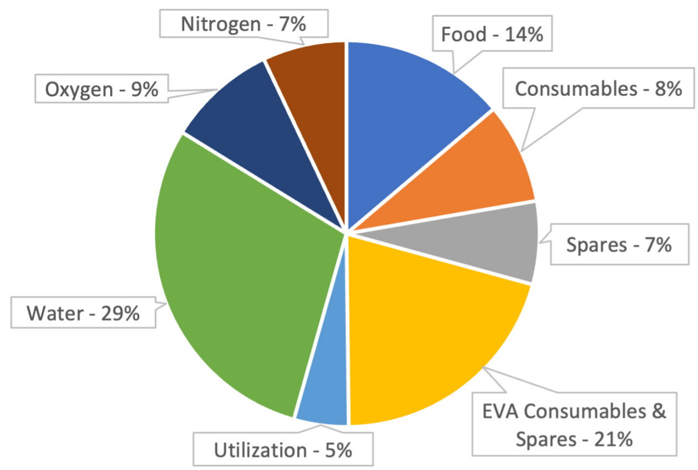

Figure 2. *Open-Loop Mass Breakdown Example*

Summary

As the exploration architecture is conceptualized and planned, it is imperative to accurately predict logistics resupply needs. The total amount of logistics items required to keep the crew alive and healthy, to maintain systems, and to perform productive science and utilization can be relatively large. It can also heavily influence the design of the architecture and exploration missions. The architecture must therefore be based on comprehensive, accurate estimates of logistics item needs and include assessment of a suitable logistics sub-architectures to deliver those needs.

Key Take-Aways

Logistics items are all equipment and supplies not initially delivered as part of a vehicle or element dry mass that are needed to support mission activities.

Crew size, mission duration, ECLSS sub-architecture capabilities, and planned EVA cadence are the primary drivers for the total logistics needs.

Water, gases, and food dominate overall logistics needs by mass.

The amount of logistics items that exploration missions require to keep the crew alive and healthy, to maintain systems, and to perform productive science and utilization is significant, and therefore it is important that the design and planning of the exploration architecture include comprehensive, accurate estimates of logistics item needs.