# *Supplemental Information to:*
# Biomanufacturing for Space Exploration – What to Take and When to Make

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## Assumptions and Methodology of Inventory Analysis

In order to construct a set of comparable mission profile scenarios for preliminary techno-economic analysis, we leveraged the NASA 'Advanced Life Support Sizing Analysis Tool' (ALSSAT)[1]; an analysis of cargo inventory broken down for each scenario and compared by means of Equivalent Systems Mass (ESM)[2] was conducted. In its current form[3], the total ESM $\mathfrak{M}$ is defined only for the operations at a specific location as the sum over the set of all systems as:

$$\mathfrak{M} = L_{\text{eq}} \sum_{i=1}^{\mathscr{A}} [\underbrace{(M_i \cdot M_{\text{eq}}) + (V_i \cdot V_{\text{eq}}) + (P_i \cdot P_{\text{eq}}) + (C_i \cdot C_{\text{eq}})}_{\mathfrak{M}_{\text{NCT}}} + \underbrace{(CT_i \cdot D \cdot CT_{eq})}_{\mathfrak{M}_{\text{CT}}}] \tag{1}$$

for subsystem $i \in \mathscr{A}$ of the ESM excluding crew-time $\mathfrak{M}_{\text{NCT}}$ and the ESM including crew-time $\mathfrak{M}_{\text{CT}}$ where $M_i$, $V_i$, $P_i$, $C_i$ are the initial mass [kg], volume [$m^3$], power requirement [$kW_e$], and cooling requirement [$kg/kW_{th}$], $D$ is the duration of the mission segment [sol], $T_i$ is the crew-time requirement based on an astronaut crew-member (CM) [CM-h/sol], $M_{\text{eq}}$ is the stowage factor accounting for additional structural masses for a subsystem such as shelving [kg/kg], $V_{\text{eq}}$ is the mass equivalency factor for the pressurized volume support infrastructure [$kg/m^3$], $P_{\text{eq}}$ is the mass equivalency factor for the power generation support infrastructure [$kg/kW_e$], $C_{eq}$ is the mass equivalency factor for the cooling infrastructure [$kg/kW_{th}$], $CT_{\text{eq}}$ is the mass equivalency factor for the crew-time [kg/CM-h], and $L_{\text{eq}}$ is the location factor for the mission segment [kg/kg] which accounts for the cost to transport mass from one location in space to another (such as Earth-orbit to Mars-orbit). Mass equivalency factors ($V_{\text{eq}}$, $P_{\text{eq}}$, $C_{\text{eq}}$, $CT_{\text{eq}}$) are used to convert the non-mass parameters to mass.

### Inventory Analysis by Equivalent Systems Mass

Using values sourced from literature, the ALSSAT, and the NASA 'Baseline Values and Assumptions Documentation'[4], we constructed our scenario definitions and parameters as outlined in Table S1. Table 1 includes the Scenario Identifier (A-E), duration of surface mission operations in days, primary surface operation destination (Moon or Mars), and sortie number $S_{\text{num}}$. The sortie number corresponds to the number of "trips" for a given scenario. Also included are the equivalency factors ($M_{\text{eq}}$, $V_{\text{eq}}$, $P_{\text{eq}}$, $C_{\text{eq}}$, $CT_{\text{eq}}$) and location factor $L_{\text{eq}}$, which allow for the comparable calculation of ESM $\mathfrak{M}$.

**Table S1.** Parameter description of exemplar scenarios—scenarios 'A' and 'B' correspond to single sorties ($N = 1$) to Moon and Mars respectively using standard surface operation duration[4], while scenarios 'C' and 'D' correspond to multi-sortie campaigns with the same 5,400 days of surface operation as the single-sortie scenario 'E'. All scenarios consider a crew-strength of four astronauts. These parameters can be used to calculate the ESM cost and include equivalency factors for volume ($V_{\text{eq}}$), power ($P_{\text{eq}}$), cooling ($C_{\text{eq}}$), crew-time ($CT_{\text{eq}}$), and location ($L_{\text{eq}}$).

| Scenario | Duration | Destination | $S_{\text{num}}$ | $V_{\text{eq}}$ | $P_{\text{eq}}$ | $C_{\text{eq}}$ | $CT_{\text{eq}}$ | $L_{\text{eq}}$ |
|---|---|---|---|---|---|---|---|---|
| A | 180 | Moon | 1 | 126 | 136 | 55.4 | 0.7 | 7.2 |
| B | 540 | Mars | 1 | 117.7 | 162 | 96 | 0.7 | 30 |
| C | 180 | Moon | 30 | 126 | 136 | 55.4 | 0.7 | 7.2 |
| D | 540 | Mars | 10 | 117.7 | 162 | 96 | 0.7 | 30 |
| E | 5,400 | Mars | 1 | 117.7 | 162 | 96 | 0.7 | 30 |

The ALSSAT was then used to generate an exemplar set of inventory elements for all systems and subsystems ($i \in \mathscr{A}$) as shown in Table S2. Table S2 includes a uniformized breakdown for all inventory elements by system, subsystem, and item name – as well as the ESM terms ($M$, $V$, $P$, $C$, $CT$) for each element in each scenario. Using the data from Tables S1 and S2, we calculated the total ESM $\mathfrak{M}_t$ for each scenario using the form $\mathfrak{M}_t = S_{\text{num}} \mathfrak{M}_{S_{\text{num}}=1}$.

### Inventory Analysis by Elemental Composition

The inventory element composition analysis was carried out by first creating a set of composition classes: Structural Metal, Plastic, Electronics, Fabric, Glass, Rubber, Ceramics, Gas, Biomass, Water, Other. These classes were created as *prima facie* estimates. Next, we estimated the fractional composition for each inventory element as shown in Table S3. We note that these estimates were carried out as approximations and based on a number of factors such as literature and other official NASA resources. However, we acknowledge that often our estimates amount to assumptions and educated guestimations, due to the lack of exact data. That being said, we argue that exact values are not required in these calculations which should be considered an important first step in defining the order of magnitude envelope for a mission inventory's elemental composition.

**Table S2.** ESM parameters for all inventory items broken down by system and subsystem for each scenario described in Table S1. Parameters included are mass $M$ [kg], $V$ [$m^3$], power $P$ [kW], cooling $C$ [kW], and crew-time $CT$ [hr][1,4]. The ESM values correspond to a single sortie $S_{num} = 1$. (ORU = Orbital Replacement Unit)

| | | | A | | | | | B | | | | | C | | | | | D | | | | | E | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **System** | **Subsystem** | **Item** | **M** | **V** | **P** | **C** | **CT** | **M** | **V** | **P** | **C** | **CT** | **M** | **V** | **P** | **C** | **CT** | **M** | **V** | **P** | **C** | **CT** | **M** | **V** | **P** | **C** | **CT** |
| Air | APC | Vent/Relief Valve | 5.40 | 0.01 | 0.00 | 0.00 | 0.00 | 5.40 | 0.01 | 0.00 | 0.00 | 0.00 | 5.40 | 0.01 | 0.00 | 0.00 | 0.00 | 5.40 | 0.01 | 0.00 | 0.00 | 0.00 | 5.40 | 0.01 | 0.00 | 0.00 | 0.00 |
| Air | APC | Pressure Control Panel | 11.20 | 0.03 | 18.00 | 18.00 | 0.00 | 11.20 | 0.03 | 18.00 | 18.00 | 0.00 | 11.20 | 0.03 | 18.00 | 18.00 | 0.00 | 11.20 | 0.03 | 18.00 | 18.00 | 0.00 | 11.20 | 0.03 | 18.00 | 18.00 | 0.00 |
| Air | APC | Manual Pressure Equalization Valve | 9.60 | 0.01 | 0.00 | 0.00 | 0.00 | 9.60 | 0.01 | 0.00 | 0.00 | 0.00 | 9.60 | 0.01 | 0.00 | 0.00 | 0.00 | 9.60 | 0.01 | 0.00 | 0.00 | 0.00 | 9.60 | 0.01 | 0.00 | 0.00 | 0.00 |
| Air | APC | Positive Pressure Relief Valve | 1.80 | 0.00 | 0.00 | 0.00 | 0.00 | 1.80 | 0.00 | 0.00 | 0.00 | 0.00 | 1.80 | 0.00 | 0.00 | 0.00 | 0.00 | 1.80 | 0.00 | 0.00 | 0.00 | 0.00 | 1.80 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | APC | Negative Pressure Relief Valve | 3.00 | 0.01 | 0.00 | 0.00 | 0.00 | 3.00 | 0.01 | 0.00 | 0.00 | 0.00 | 3.00 | 0.01 | 0.00 | 0.00 | 0.00 | 3.00 | 0.01 | 0.00 | 0.00 | 0.00 | 3.00 | 0.01 | 0.00 | 0.00 | 0.00 |
| Air | APC | Nitrogen Interface Assembly | 7.50 | 0.01 | 5.50 | 5.50 | 0.00 | 7.50 | 0.01 | 5.50 | 5.50 | 0.00 | 7.50 | 0.01 | 5.50 | 5.50 | 0.00 | 7.50 | 0.01 | 5.50 | 5.50 | 0.00 | 7.50 | 0.01 | 5.50 | 5.50 | 0.00 |
| Air | APC | Vacuum Access Jumper 5-ft | 0.70 | 0.00 | 0.00 | 0.00 | 0.00 | 0.70 | 0.00 | 0.00 | 0.00 | 0.00 | 0.70 | 0.00 | 0.00 | 0.00 | 0.00 | 0.70 | 0.00 | 0.00 | 0.00 | 0.00 | 0.70 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | APC | Vacuum Access Jumper 35-ft | 3.20 | 0.00 | 0.00 | 0.00 | 0.00 | 3.20 | 0.00 | 0.00 | 0.00 | 0.00 | 3.20 | 0.00 | 0.00 | 0.00 | 0.00 | 3.20 | 0.00 | 0.00 | 0.00 | 0.00 | 3.20 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | ACMA | Verification Gas Assembly | 5.40 | 0.01 | 0.10 | 0.10 | 0.00 | 5.40 | 0.01 | 0.10 | 0.10 | 0.00 | 5.40 | 0.01 | 0.10 | 0.10 | 0.00 | 5.40 | 0.01 | 0.10 | 0.10 | 0.00 | 5.40 | 0.01 | 0.10 | 0.10 | 0.00 |
| Air | ACMA | Mass Spectrometer | 13.90 | 0.02 | 31.80 | 31.80 | 0.00 | 13.90 | 0.02 | 31.80 | 31.80 | 0.00 | 13.90 | 0.02 | 31.80 | 31.80 | 0.00 | 13.90 | 0.02 | 31.80 | 31.80 | 0.00 | 13.90 | 0.02 | 31.80 | 31.80 | 0.00 |
| Air | ACMA | Sample Pump | 3.40 | 0.00 | 4.00 | 4.00 | 0.00 | 3.40 | 0.00 | 4.00 | 4.00 | 0.00 | 3.40 | 0.00 | 4.00 | 4.00 | 0.00 | 3.40 | 0.00 | 4.00 | 4.00 | 0.00 | 3.40 | 0.00 | 4.00 | 4.00 | 0.00 |
| Air | ACMA | Sample Distributor | 2.10 | 0.00 | 0.10 | 0.10 | 0.00 | 2.10 | 0.00 | 0.10 | 0.10 | 0.00 | 2.10 | 0.00 | 0.10 | 0.10 | 0.00 | 2.10 | 0.00 | 0.10 | 0.10 | 0.00 | 2.10 | 0.00 | 0.10 | 0.10 | 0.00 |
| Air | ACMA | Data + Control | 8.00 | 0.01 | 34.90 | 34.90 | 0.00 | 8.00 | 0.01 | 34.90 | 34.90 | 0.00 | 8.00 | 0.01 | 34.90 | 34.90 | 0.00 | 8.00 | 0.01 | 34.90 | 34.90 | 0.00 | 8.00 | 0.01 | 34.90 | 34.90 | 0.00 |
| Air | ACMA | Low Voltage Power Supply | 5.70 | 0.01 | 30.80 | 30.80 | 0.00 | 5.70 | 0.01 | 30.80 | 30.80 | 0.00 | 5.70 | 0.01 | 30.80 | 30.80 | 0.00 | 5.70 | 0.01 | 30.80 | 30.80 | 0.00 | 5.70 | 0.01 | 30.80 | 30.80 | 0.00 |
| Air | ACMA | Chassis | 15.80 | 0.02 | 0.00 | 0.00 | 0.00 | 15.80 | 0.02 | 0.00 | 0.00 | 0.00 | 15.80 | 0.02 | 0.00 | 0.00 | 0.00 | 15.80 | 0.02 | 0.00 | 0.00 | 0.00 | 15.80 | 0.02 | 0.00 | 0.00 | 0.00 |
| Air | ACMA | Inlet Valve Assembly | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | ACMA | EMI Filter | 0.00 | 0.00 | 1.80 | 1.80 | 0.00 | 0.00 | 0.00 | 1.80 | 1.80 | 0.00 | 0.00 | 0.00 | 1.80 | 1.80 | 0.00 | 0.00 | 0.00 | 1.80 | 1.80 | 0.00 | 0.00 | 0.00 | 1.80 | 1.80 | 0.00 |
| Air | SDS | 3-way Solenoid Valves | 31.50 | 0.03 | 0.00 | 0.00 | 0.00 | 31.50 | 0.03 | 0.00 | 0.00 | 0.00 | 31.50 | 0.03 | 0.00 | 0.00 | 0.00 | 31.50 | 0.03 | 0.00 | 0.00 | 0.00 | 31.50 | 0.03 | 0.00 | 0.00 | 0.00 |
| Air | SDS | Manual Valves | 2.53 | 0.01 | 0.00 | 0.00 | 0.00 | 2.53 | 0.01 | 0.00 | 0.00 | 0.00 | 2.53 | 0.01 | 0.00 | 0.00 | 0.00 | 2.53 | 0.01 | 0.00 | 0.00 | 0.00 | 2.53 | 0.01 | 0.00 | 0.00 | 0.00 |
| Air | SDS | Sample probes | 1.08 | 0.00 | 0.00 | 0.00 | 0.00 | 1.08 | 0.00 | 0.00 | 0.00 | 0.00 | 1.08 | 0.00 | 0.00 | 0.00 | 0.00 | 1.08 | 0.00 | 0.00 | 0.00 | 0.00 | 1.08 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | $CO_2$ | Air Selector Valve | 12.81 | 0.01 | 0.70 | 0.70 | 0.99 | 12.81 | 0.01 | 0.70 | 0.70 | 0.99 | 12.75 | 0.01 | 0.70 | 0.70 | 0.99 | 12.65 | 0.01 | 0.68 | 0.68 | 2.74 | 12.60 | 0.01 | 0.68 | 0.68 | 29.59 |
| Air | $CO_2$ | Desiccant Bed | 24.29 | 0.25 | 0.00 | 0.00 | 0.24 | 24.29 | 0.25 | 0.00 | 0.00 | 0.24 | 24.07 | 0.25 | 0.00 | 0.00 | 0.24 | 23.69 | 0.24 | 0.00 | 0.00 | 0.66 | 23.50 | 0.24 | 0.00 | 0.00 | 7.10 |
| Air | $CO_2$ | Adsorbent Bed | 33.13 | 0.00 | 578.43 | 578.43 | 0.00 | 33.13 | 0.00 | 578.43 | 578.43 | 0.00 | 32.83 | 0.00 | 573.16 | 573.16 | 0.00 | 32.32 | 0.00 | 564.28 | 564.28 | 0.00 | 32.06 | 0.00 | 559.74 | 559.74 | 0.00 |
| Air | $CO_2$ | Air Check Valve | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | $CO_2$ | Heater Controller | 6.60 | 0.00 | 38.00 | 38.00 | 0.01 | 6.60 | 0.00 | 38.00 | 38.00 | 0.01 | 6.60 | 0.00 | 38.00 | 38.00 | 0.01 | 6.60 | 0.00 | 38.00 | 38.00 | 0.03 | 6.60 | 0.00 | 38.00 | 38.00 | 0.30 |
| Air | $CO_2$ | Air Blower | 0.82 | 0.02 | 40.71 | 40.71 | 0.06 | 0.82 | 0.02 | 40.71 | 40.71 | 0.06 | 0.82 | 0.02 | 40.34 | 40.34 | 0.06 | 0.81 | 0.02 | 39.72 | 39.72 | 0.18 | 0.81 | 0.02 | 39.40 | 39.40 | 1.92 |
| Air | $CO_2$ | Pre-cooler | 2.22 | 0.00 | 0.00 | 0.00 | 0.00 | 2.22 | 0.00 | 0.00 | 0.00 | 0.00 | 2.21 | 0.00 | 0.00 | 0.00 | 0.00 | 2.19 | 0.00 | 0.00 | 0.00 | 0.00 | 2.18 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | $CO_2$ | Blower/Pre-cooler Motor Controller | 1.30 | 0.00 | 5.00 | 5.00 | 0.00 | 1.30 | 0.00 | 5.00 | 5.00 | 0.00 | 1.30 | 0.00 | 5.00 | 5.00 | 0.00 | 1.30 | 0.00 | 5.00 | 5.00 | 0.00 | 1.30 | 0.00 | 5.00 | 5.00 | 0.00 |
| Air | $CO_2$ | $CO_2$ Pump | 6.73 | 0.00 | 13.34 | 13.34 | 0.04 | 6.73 | 0.00 | 13.34 | 13.34 | 0.04 | 6.70 | 0.00 | 13.22 | 13.22 | 0.04 | 6.65 | 0.00 | 13.01 | 13.01 | 0.11 | 6.62 | 0.00 | 12.91 | 12.91 | 1.18 |
| Air | $CO_2$ | $CO_2$ Pump Motor Controller | 1.30 | 0.01 | 2.00 | 2.00 | 0.00 | 1.30 | 0.01 | 2.00 | 2.00 | 0.00 | 1.30 | 0.01 | 2.00 | 2.00 | 0.00 | 1.30 | 0.01 | 2.00 | 2.00 | 0.01 | 1.30 | 0.01 | 2.00 | 2.00 | 0.15 |
| Air | $CO_2$ | Temperature Sensor | 0.40 | 0.00 | 1.00 | 1.00 | 0.00 | 0.40 | 0.00 | 1.00 | 1.00 | 0.00 | 0.40 | 0.00 | 1.00 | 1.00 | 0.00 | 0.40 | 0.00 | 1.00 | 1.00 | 0.00 | 0.40 | 0.00 | 1.00 | 1.00 | 0.00 |
| Air | $CO_2$ | Differential Pressure Sensor | 0.20 | 0.00 | 1.00 | 1.00 | 0.00 | 0.20 | 0.00 | 1.00 | 1.00 | 0.00 | 0.20 | 0.00 | 1.00 | 1.00 | 0.00 | 0.20 | 0.00 | 1.00 | 1.00 | 0.00 | 0.20 | 0.00 | 1.00 | 1.00 | 0.00 |
| Air | $CO_2$ | Absolute Pressure Sensor | 0.20 | 0.00 | 1.00 | 1.00 | 0.00 | 0.20 | 0.00 | 1.00 | 1.00 | 0.00 | 0.20 | 0.00 | 1.00 | 1.00 | 0.00 | 0.20 | 0.00 | 1.00 | 1.00 | 0.00 | 0.20 | 0.00 | 1.00 | 1.00 | 0.00 |
| Air | $CO_2$ | Electrical Harness | 4.50 | 0.00 | 0.00 | 0.00 | 0.00 | 4.50 | 0.00 | 0.00 | 0.00 | 0.00 | 4.50 | 0.00 | 0.00 | 0.00 | 0.00 | 4.50 | 0.00 | 0.00 | 0.00 | 0.00 | 4.50 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | $CO_2$ | Plumbing | 4.85 | 0.00 | 0.00 | 0.00 | 0.00 | 4.85 | 0.00 | 0.00 | 0.00 | 0.00 | 4.82 | 0.00 | 0.00 | 0.00 | 0.00 | 4.78 | 0.00 | 0.00 | 0.00 | 0.00 | 4.76 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | $CO_2$ | Support Structure | 29.64 | 0.00 | 0.00 | 0.00 | 0.00 | 29.64 | 0.00 | 0.00 | 0.00 | 0.00 | 29.51 | 0.00 | 0.00 | 0.00 | 0.00 | 29.27 | 0.00 | 0.00 | 0.00 | 0.00 | 29.15 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | $CO_2$ | Fluid Disconnects | 1.97 | 0.00 | 0.00 | 0.00 | 0.00 | 1.97 | 0.00 | 0.00 | 0.00 | 0.00 | 1.96 | 0.00 | 0.00 | 0.00 | 0.00 | 1.95 | 0.00 | 0.00 | 0.00 | 0.00 | 1.94 | 0.00 | 0.00 | 0.00 | 0.00 |

**Table S2.** ESM parameters for all inventory items broken down by system and subsystem for each scenario described in Table S1. Parameters included are mass $M$ [kg], $V$ [$m^3$], power $P$ [kW], cooling $C$ [kW], and crew-time $CT$ [hr][1,4]. The ESM values correspond to a single sortie $S_{num} = 1$. (ORU = Orbital Replacement Unit)

| | | | A | | | | | B | | | | | C | | | | | D | | | | | E | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **System** | **Subsystem** | **Item** | **M** | **V** | **P** | **C** | **CT** | **M** | **V** | **P** | **C** | **CT** | **M** | **V** | **P** | **C** | **CT** | **M** | **V** | **P** | **C** | **CT** | **M** | **V** | **P** | **C** | **CT** |
| Air | $CO_2$ | Electronics Cold-Plate | 2.71 | 0.00 | 0.00 | 0.00 | 0.00 | 2.71 | 0.00 | 0.00 | 0.00 | 0.00 | 2.70 | 0.00 | 0.00 | 0.00 | 0.00 | 2.68 | 0.00 | 0.00 | 0.00 | 0.00 | 2.67 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | $CO_2$ | Electronics Interface Plate | 1.60 | 0.00 | 0.00 | 0.00 | 0.00 | 1.60 | 0.00 | 0.00 | 0.00 | 0.00 | 1.60 | 0.00 | 0.00 | 0.00 | 0.00 | 1.60 | 0.00 | 0.00 | 0.00 | 0.00 | 1.60 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | $N_2$ | MD Shield Instl | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | $N_2$ | Multilayer Insulation Assembly-T #1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | $N_2$ | Multilayer Insulation Assembly-T #2 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | $N_2$ | Primary Structure Assembly-HPG ORU | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | $N_2$ | Tank ORU Assembly | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | $N_2$ | Utilities Installation - $O_2$/$N_2$ Tank | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | $N_2$ | $N_2$ Bare Tank | 80.37 | 0.00 | 0.00 | 0.00 | 0.00 | 80.37 | 0.00 | 0.00 | 0.00 | 0.00 | 80.43 | 0.00 | 0.00 | 0.00 | 0.00 | 163.98 | 0.00 | 0.00 | 0.00 | 0.00 | 1443.26 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | $N_2$ | HPGA Fluid | 81.74 | 0.00 | 0.00 | 0.00 | 0.00 | 81.74 | 0.00 | 0.00 | 0.00 | 0.00 | 81.83 | 0.00 | 0.00 | 0.00 | 0.00 | 144.73 | 0.00 | 0.00 | 0.00 | 0.00 | 1107.91 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | $N_2$ | Handhold, top mounted | 0.22 | 0.00 | 0.00 | 0.00 | 0.00 | 0.22 | 0.00 | 0.00 | 0.00 | 0.00 | 0.22 | 0.00 | 0.00 | 0.00 | 0.00 | 0.38 | 0.00 | 0.00 | 0.00 | 0.00 | 2.92 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | $N_2$ | Handrail 21.941 in custom | 0.38 | 0.00 | 0.00 | 0.00 | 0.00 | 0.38 | 0.00 | 0.00 | 0.00 | 0.00 | 0.38 | 0.00 | 0.00 | 0.00 | 0.00 | 0.67 | 0.00 | 0.00 | 0.00 | 0.00 | 5.12 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | $N_2$ | Handrail, top mounted | 0.40 | 0.00 | 0.00 | 0.00 | 0.00 | 0.40 | 0.00 | 0.00 | 0.00 | 0.00 | 0.40 | 0.00 | 0.00 | 0.00 | 0.00 | 0.70 | 0.00 | 0.00 | 0.00 | 0.00 | 5.36 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | $N_2$ | Grapple Fixture, flt releasable | 11.11 | 0.00 | 0.00 | 0.00 | 0.00 | 11.11 | 0.00 | 0.00 | 0.00 | 0.00 | 11.13 | 0.00 | 0.00 | 0.00 | 0.00 | 19.68 | 0.00 | 0.00 | 0.00 | 0.00 | 150.63 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | $N_2$ | Accessories | 4.02 | 0.00 | 0.00 | 0.00 | 0.00 | 4.02 | 0.00 | 0.00 | 0.00 | 0.00 | 4.03 | 0.00 | 0.00 | 0.00 | 0.00 | 8.21 | 0.00 | 0.00 | 0.00 | 0.00 | 72.24 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | $O_2$ | MD Shield Instl | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | $O_2$ | Multilayer Insulation Assembly-T #1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | $O_2$ | Multilayer Insulation Assembly-T #2 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | $O_2$ | Primary Structure Assembly-HPG ORU | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | $O_2$ | Tank ORU Assembly | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | $O_2$ | Utilities Installation - $O_2$/$N_2$ Tank | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | $O_2$ | $O_2$ Bare Tank | 56.08 | 0.00 | 0.00 | 0.00 | 0.00 | 56.08 | 0.00 | 0.00 | 0.00 | 0.00 | 53.53 | 0.00 | 0.00 | 0.00 | 0.00 | 112.19 | 0.00 | 0.00 | 0.00 | 0.00 | 1010.35 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | $O_2$ | HPGA Fluid | 48.00 | 0.00 | 0.00 | 0.00 | 0.00 | 48.00 | 0.00 | 0.00 | 0.00 | 0.00 | 44.47 | 0.00 | 0.00 | 0.00 | 0.00 | 72.80 | 0.00 | 0.00 | 0.00 | 0.00 | 506.64 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | $O_2$ | Handhold, top mounted | 0.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.19 | 0.00 | 0.00 | 0.00 | 0.00 | 1.34 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | $O_2$ | Handrail 21.941 in custom | 0.22 | 0.00 | 0.00 | 0.00 | 0.00 | 0.22 | 0.00 | 0.00 | 0.00 | 0.00 | 0.21 | 0.00 | 0.00 | 0.00 | 0.00 | 0.34 | 0.00 | 0.00 | 0.00 | 0.00 | 2.34 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | $O_2$ | Handrail, top mounted | 0.23 | 0.00 | 0.00 | 0.00 | 0.00 | 0.23 | 0.00 | 0.00 | 0.00 | 0.00 | 0.22 | 0.00 | 0.00 | 0.00 | 0.00 | 0.35 | 0.00 | 0.00 | 0.00 | 0.00 | 2.45 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | $O_2$ | Grapple Fixture, flt releasable | 6.53 | 0.00 | 0.00 | 0.00 | 0.00 | 6.53 | 0.00 | 0.00 | 0.00 | 0.00 | 6.05 | 0.00 | 0.00 | 0.00 | 0.00 | 9.90 | 0.00 | 0.00 | 0.00 | 0.00 | 68.88 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | $O_2$ | Accessories | 2.81 | 0.00 | 0.00 | 0.00 | 0.00 | 2.81 | 0.00 | 0.00 | 0.00 | 0.00 | 2.68 | 0.00 | 0.00 | 0.00 | 0.00 | 5.62 | 0.00 | 0.00 | 0.00 | 0.00 | 50.57 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | Condensing Heat Exchanger | 1.47 | 0.00 | 0.00 | 0.00 | 0.00 | 1.47 | 0.00 | 0.00 | 0.00 | 0.00 | 1.49 | 0.00 | 0.00 | 0.00 | 0.00 | 1.48 | 0.00 | 0.00 | 0.00 | 0.00 | 1.48 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | AAA Heat Exchanger | 2.47 | 0.00 | 0.00 | 0.00 | 0.00 | 2.47 | 0.00 | 0.00 | 0.00 | 0.00 | 2.50 | 0.00 | 0.00 | 0.00 | 0.00 | 2.49 | 0.00 | 0.00 | 0.00 | 0.00 | 2.49 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | ITCS Coolant Water Inlet QD | 0.47 | 0.00 | 0.00 | 0.00 | 0.00 | 0.47 | 0.00 | 0.00 | 0.00 | 0.00 | 0.48 | 0.00 | 0.00 | 0.00 | 0.00 | 0.48 | 0.00 | 0.00 | 0.00 | 0.00 | 0.48 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | ITCS Coolant Water Outlet QD | 0.36 | 0.00 | 0.00 | 0.00 | 0.00 | 0.36 | 0.00 | 0.00 | 0.00 | 0.00 | 0.36 | 0.00 | 0.00 | 0.00 | 0.00 | 0.36 | 0.00 | 0.00 | 0.00 | 0.00 | 0.36 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | Heat Exchanger Inlet Temp | 0.36 | 0.00 | 0.00 | 0.00 | 0.00 | 0.36 | 0.00 | 0.00 | 0.00 | 0.00 | 0.36 | 0.00 | 0.00 | 0.00 | 0.00 | 0.36 | 0.00 | 0.00 | 0.00 | 0.00 | 0.36 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | Heat Exchanger Outlet Temp | 0.36 | 0.00 | 0.00 | 0.00 | 0.00 | 0.36 | 0.00 | 0.00 | 0.00 | 0.00 | 0.36 | 0.00 | 0.00 | 0.00 | 0.00 | 0.36 | 0.00 | 0.00 | 0.00 | 0.00 | 0.36 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | Manifold, $CO_2$ | 4.72 | 0.00 | 0.00 | 0.00 | 0.00 | 4.72 | 0.00 | 0.00 | 0.00 | 0.00 | 4.80 | 0.00 | 0.00 | 0.00 | 0.00 | 4.77 | 0.00 | 0.00 | 0.00 | 0.00 | 4.76 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | $CO_2$ Inlet Check Valve | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | $CO_2$ Inlet Filter | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 |

**Table S2.** ESM parameters for all inventory items broken down by system and subsystem for each scenario described in Table S1. Parameters included are mass $M$ [kg], $V$ [$m^3$], power $P$ [kW], cooling $C$ [kW], and crew-time $CT$ [hr][1,4]. The ESM values correspond to a single sortie $S_{num} = 1$. (ORU = Orbital Replacement Unit)

| | | | A | | | | | B | | | | | C | | | | | D | | | | | E | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **System** | **Subsystem** | **Item** | **M** | **V** | **P** | **C** | **CT** | **M** | **V** | **P** | **C** | **CT** | **M** | **V** | **P** | **C** | **CT** | **M** | **V** | **P** | **C** | **CT** | **M** | **V** | **P** | **C** | **CT** |
| Air | Sabatier | Pressure Sensor, $CO_2$ Inlet | 0.41 | 0.00 | 0.00 | 0.00 | 0.00 | 0.41 | 0.00 | 0.00 | 0.00 | 0.00 | 0.41 | 0.00 | 0.00 | 0.00 | 0.00 | 0.41 | 0.00 | 0.00 | 0.00 | 0.00 | 0.41 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | $CO_2$ Inlet QD | 0.47 | 0.00 | 0.00 | 0.00 | 0.00 | 0.47 | 0.00 | 0.00 | 0.00 | 0.00 | 0.48 | 0.00 | 0.00 | 0.00 | 0.00 | 0.48 | 0.00 | 0.00 | 0.00 | 0.00 | 0.48 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | $CO_2$ Inlet Regulator | 0.92 | 0.00 | 0.00 | 0.00 | 0.00 | 0.92 | 0.00 | 0.00 | 0.00 | 0.00 | 0.93 | 0.00 | 0.00 | 0.00 | 0.00 | 0.93 | 0.00 | 0.00 | 0.00 | 0.00 | 0.93 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | $CO_2$ Inlet NC Solenoid | 0.47 | 0.00 | 0.00 | 0.00 | 0.00 | 0.47 | 0.00 | 0.00 | 0.00 | 0.00 | 0.48 | 0.00 | 0.00 | 0.00 | 0.00 | 0.48 | 0.00 | 0.00 | 0.00 | 0.00 | 0.48 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | $CO_2$ Inlet Flow Control | 2.15 | 0.00 | 0.00 | 0.00 | 0.00 | 2.15 | 0.00 | 0.00 | 0.00 | 0.00 | 2.18 | 0.00 | 0.00 | 0.00 | 0.00 | 2.17 | 0.00 | 0.00 | 0.00 | 0.00 | 2.17 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | $CO_2$ Flow Control Orifice | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | Delta P Sensor, Flow Sensor $CO_2$ | 0.91 | 0.00 | 0.00 | 0.00 | 0.00 | 0.91 | 0.00 | 0.00 | 0.00 | 0.00 | 0.91 | 0.00 | 0.00 | 0.00 | 0.00 | 0.91 | 0.00 | 0.00 | 0.00 | 0.00 | 0.91 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | $CO_2$ Flow Meter Orifice | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | Manifold, Hydrogen | 4.38 | 0.00 | 0.00 | 0.00 | 0.00 | 4.38 | 0.00 | 0.00 | 0.00 | 0.00 | 4.45 | 0.00 | 0.00 | 0.00 | 0.00 | 4.43 | 0.00 | 0.00 | 0.00 | 0.00 | 4.42 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | Water Outlet Quick Disconnect | 0.47 | 0.00 | 0.00 | 0.00 | 0.00 | 0.47 | 0.00 | 0.00 | 0.00 | 0.00 | 0.48 | 0.00 | 0.00 | 0.00 | 0.00 | 0.48 | 0.00 | 0.00 | 0.00 | 0.00 | 0.48 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | Hydrogen Inlet Check Valve | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | Hydrogen Inlet Filter | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | $H_2O$ Outlet Pressure Sensor | 0.82 | 0.00 | 0.00 | 0.00 | 0.00 | 0.82 | 0.00 | 0.00 | 0.00 | 0.00 | 0.82 | 0.00 | 0.00 | 0.00 | 0.00 | 0.82 | 0.00 | 0.00 | 0.00 | 0.00 | 0.82 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | Hydrogen Inlet Quick Disconnect | 0.47 | 0.00 | 0.00 | 0.00 | 0.00 | 0.47 | 0.00 | 0.00 | 0.00 | 0.00 | 0.48 | 0.00 | 0.00 | 0.00 | 0.00 | 0.48 | 0.00 | 0.00 | 0.00 | 0.00 | 0.48 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | Hydrogen Inlet NC Solenoid | 0.94 | 0.00 | 0.00 | 0.00 | 0.00 | 0.94 | 0.00 | 0.00 | 0.00 | 0.00 | 0.96 | 0.00 | 0.00 | 0.00 | 0.00 | 0.95 | 0.00 | 0.00 | 0.00 | 0.00 | 0.95 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | Delta P Sensor, Flow Sensor $H_2$ | 0.91 | 0.00 | 0.00 | 0.00 | 0.00 | 0.91 | 0.00 | 0.00 | 0.00 | 0.00 | 0.91 | 0.00 | 0.00 | 0.00 | 0.00 | 0.91 | 0.00 | 0.00 | 0.00 | 0.00 | 0.91 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | $H_2$ Flow Meter Orifice | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | Manifold, Vent | 5.06 | 0.00 | 0.00 | 0.00 | 0.00 | 5.06 | 0.00 | 0.00 | 0.00 | 0.00 | 5.14 | 0.00 | 0.00 | 0.00 | 0.00 | 5.12 | 0.00 | 0.00 | 0.00 | 0.00 | 5.10 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | Liquid Sensor | 1.09 | 0.00 | 0.00 | 0.00 | 0.00 | 1.09 | 0.00 | 0.00 | 0.00 | 0.00 | 1.09 | 0.00 | 0.00 | 0.00 | 0.00 | 1.09 | 0.00 | 0.00 | 0.00 | 0.00 | 1.09 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | Vent Pressure Sensor | 0.82 | 0.00 | 0.00 | 0.00 | 0.00 | 0.82 | 0.00 | 0.00 | 0.00 | 0.00 | 0.82 | 0.00 | 0.00 | 0.00 | 0.00 | 0.82 | 0.00 | 0.00 | 0.00 | 0.00 | 0.82 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | Vent Outlet Quick Disconnect | 0.47 | 0.00 | 0.00 | 0.00 | 0.00 | 0.47 | 0.00 | 0.00 | 0.00 | 0.00 | 0.48 | 0.00 | 0.00 | 0.00 | 0.00 | 0.48 | 0.00 | 0.00 | 0.00 | 0.00 | 0.48 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | Vent Regulator | 0.92 | 0.00 | 0.00 | 0.00 | 0.00 | 0.92 | 0.00 | 0.00 | 0.00 | 0.00 | 0.93 | 0.00 | 0.00 | 0.00 | 0.00 | 0.93 | 0.00 | 0.00 | 0.00 | 0.00 | 0.93 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | Vent Relief/Check #1 | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | Vent Relief/Check #2 | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | Vent Outlet NO Solenoid | 0.94 | 0.00 | 0.00 | 0.00 | 0.00 | 0.94 | 0.00 | 0.00 | 0.00 | 0.00 | 0.96 | 0.00 | 0.00 | 0.00 | 0.00 | 0.95 | 0.00 | 0.00 | 0.00 | 0.00 | 0.95 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | Water Pressure Sensor | 0.82 | 0.00 | 0.00 | 0.00 | 0.00 | 0.82 | 0.00 | 0.00 | 0.00 | 0.00 | 0.82 | 0.00 | 0.00 | 0.00 | 0.00 | 0.82 | 0.00 | 0.00 | 0.00 | 0.00 | 0.82 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | Water Relief | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | Water Outlet NC Solenoid | 0.47 | 0.00 | 0.00 | 0.00 | 0.00 | 0.47 | 0.00 | 0.00 | 0.00 | 0.00 | 0.48 | 0.00 | 0.00 | 0.00 | 0.00 | 0.48 | 0.00 | 0.00 | 0.00 | 0.00 | 0.48 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | Rotary Water Separator Assembly | 4.04 | 0.00 | 22.66 | 22.66 | 0.00 | 4.04 | 0.00 | 22.66 | 22.66 | 0.00 | 4.10 | 0.00 | 22.93 | 22.93 | 0.00 | 4.08 | 0.00 | 22.84 | 22.84 | 0.00 | 4.07 | 0.00 | 22.80 | 22.80 | 0.00 |
| Air | Sabatier | Sabatier Reactor Assembly | 2.52 | 0.00 | 3.24 | 3.24 | 0.00 | 2.52 | 0.00 | 3.24 | 3.24 | 0.00 | 2.56 | 0.00 | 3.28 | 3.28 | 0.00 | 2.55 | 0.00 | 3.26 | 3.26 | 0.00 | 2.54 | 0.00 | 3.26 | 3.26 | 0.00 |
| Air | Sabatier | Structure (A/R) | 9.15 | 0.00 | 0.00 | 0.00 | 0.00 | 9.15 | 0.00 | 0.00 | 0.00 | 0.00 | 9.30 | 0.00 | 0.00 | 0.00 | 0.00 | 9.25 | 0.00 | 0.00 | 0.00 | 0.00 | 9.23 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | Miscellaneous Hardware (clamps, bolts, etc.) (A/R) | 1.77 | 0.00 | 0.00 | 0.00 | 0.00 | 1.77 | 0.00 | 0.00 | 0.00 | 0.00 | 1.77 | 0.00 | 0.00 | 0.00 | 0.00 | 1.77 | 0.00 | 0.00 | 0.00 | 0.00 | 1.77 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | Air Cooling NC Solenoid | 0.63 | 0.00 | 0.00 | 0.00 | 0.00 | 0.63 | 0.00 | 0.00 | 0.00 | 0.00 | 0.64 | 0.00 | 0.00 | 0.00 | 0.00 | 0.64 | 0.00 | 0.00 | 0.00 | 0.00 | 0.63 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | Air Inlet Filter | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | Air Sabatier Orifice | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | Heat Exchanger Inlet Duct | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | Heat Exchanger Outlet Duct | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 |

**Table S2.** ESM parameters for all inventory items broken down by system and subsystem for each scenario described in Table S1. Parameters included are mass $M$ [kg], $V$ [$m^3$], power $P$ [kW], cooling $C$ [kW], and crew-time $CT$ [hr][1,4]. The ESM values correspond to a single sortie $S_{num} = 1$. (ORU = Orbital Replacement Unit)

| | | | A | | | | | B | | | | | C | | | | | D | | | | | E | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **System** | **Subsystem** | **Item** | **M** | **V** | **P** | **C** | **CT** | **M** | **V** | **P** | **C** | **CT** | **M** | **V** | **P** | **C** | **CT** | **M** | **V** | **P** | **C** | **CT** | **M** | **V** | **P** | **C** | **CT** |
| Air | Sabatier | Reactor Inlet Duct | 0.21 | 0.00 | 0.00 | 0.00 | 0.00 | 0.21 | 0.00 | 0.00 | 0.00 | 0.00 | 0.21 | 0.00 | 0.00 | 0.00 | 0.00 | 0.21 | 0.00 | 0.00 | 0.00 | 0.00 | 0.21 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | Reactor Outlet Duct | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | Tubing (A/R) | 0.68 | 0.00 | 0.00 | 0.00 | 0.00 | 0.68 | 0.00 | 0.00 | 0.00 | 0.00 | 0.69 | 0.00 | 0.00 | 0.00 | 0.00 | 0.69 | 0.00 | 0.00 | 0.00 | 0.00 | 0.69 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | Harnesses | 11.45 | 0.00 | 0.00 | 0.00 | 0.00 | 11.45 | 0.00 | 0.00 | 0.00 | 0.00 | 11.45 | 0.00 | 0.00 | 0.00 | 0.00 | 11.45 | 0.00 | 0.00 | 0.00 | 0.00 | 11.45 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | Valves + Sensors' total power | 0.00 | 0.00 | 7.37 | 7.37 | 0.00 | 0.00 | 0.00 | 7.37 | 7.37 | 0.00 | 0.00 | 0.00 | 7.76 | 7.76 | 0.00 | 0.00 | 0.00 | 7.63 | 7.63 | 0.00 | 0.00 | 0.00 | 7.57 | 7.57 | 0.00 |
| Air | Sabatier | Mechanical Compressor ORU | 18.88 | 0.00 | 45.32 | 45.32 | 0.00 | 18.88 | 0.00 | 45.32 | 45.32 | 0.00 | 19.18 | 0.00 | 45.86 | 45.86 | 0.00 | 19.09 | 0.00 | 45.69 | 45.69 | 0.00 | 19.04 | 0.00 | 45.60 | 45.60 | 0.00 |
| Air | Sabatier | Compressor Manifold Assembly | 4.62 | 0.00 | 0.00 | 0.00 | 0.00 | 4.62 | 0.00 | 0.00 | 0.00 | 0.00 | 4.69 | 0.00 | 0.00 | 0.00 | 0.00 | 4.67 | 0.00 | 0.00 | 0.00 | 0.00 | 4.65 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | Sabatier | Controller Assembly | 28.59 | 0.00 | 55.00 | 55.00 | 0.00 | 28.59 | 0.00 | 55.00 | 55.00 | 0.00 | 28.59 | 0.00 | 55.00 | 55.00 | 0.00 | 28.59 | 0.00 | 55.00 | 55.00 | 0.00 | 28.59 | 0.00 | 55.00 | 55.00 | 0.00 |
| Air | Sabatier | $CO_2$ Accumulator | 10.03 | 0.01 | 0.00 | 0.00 | 0.00 | 10.03 | 0.01 | 0.00 | 0.00 | 0.00 | 10.19 | 0.01 | 0.00 | 0.00 | 0.00 | 10.14 | 0.01 | 0.00 | 0.00 | 0.00 | 10.11 | 0.01 | 0.00 | 0.00 | 0.00 |
| Air | $O_2$-gen | Deionizing Bed ORU (Inlet) | 7.79 | 0.01 | 0.00 | 0.00 | 0.00 | 7.79 | 0.01 | 0.00 | 0.00 | 0.00 | 8.19 | 0.01 | 0.00 | 0.00 | 0.00 | 8.07 | 0.01 | 0.00 | 0.00 | 0.00 | 8.00 | 0.01 | 0.00 | 0.00 | 0.00 |
| Air | $O_2$-gen | Deionizing Bed ORU (Recirculating) | 7.79 | 0.01 | 0.00 | 0.00 | 0.00 | 7.79 | 0.01 | 0.00 | 0.00 | 0.00 | 8.19 | 0.01 | 0.00 | 0.00 | 0.00 | 8.07 | 0.01 | 0.00 | 0.00 | 0.00 | 8.00 | 0.01 | 0.00 | 0.00 | 0.00 |
| Air | $O_2$-gen | Oxygen/Water ORU | 36.40 | 0.02 | 0.00 | 0.00 | 0.00 | 36.40 | 0.02 | 0.00 | 0.00 | 0.00 | 37.01 | 0.03 | 0.00 | 0.00 | 0.00 | 36.82 | 0.03 | 0.00 | 0.00 | 0.00 | 36.72 | 0.02 | 0.00 | 0.00 | 0.00 |
| Air | $O_2$-gen | Pump ORU | 6.46 | 0.01 | 23.33 | 23.33 | 0.00 | 6.46 | 0.01 | 23.33 | 23.33 | 0.00 | 6.56 | 0.01 | 24.53 | 24.53 | 0.00 | 6.53 | 0.01 | 24.15 | 24.15 | 0.00 | 6.51 | 0.01 | 23.96 | 23.96 | 0.00 |
| Air | $O_2$-gen | Oxygen Phase Separator ORU | 21.83 | 0.01 | 0.00 | 0.00 | 0.00 | 21.83 | 0.01 | 0.00 | 0.00 | 0.00 | 22.20 | 0.01 | 0.00 | 0.00 | 0.00 | 22.08 | 0.01 | 0.00 | 0.00 | 0.00 | 22.02 | 0.01 | 0.00 | 0.00 | 0.00 |
| Air | $O_2$-gen | Hydrogen ORU | 95.46 | 0.05 | 30.78 | 30.78 | 0.00 | 95.46 | 0.05 | 30.78 | 30.78 | 0.00 | 97.07 | 0.05 | 32.37 | 32.37 | 0.00 | 96.56 | 0.05 | 31.87 | 31.87 | 0.00 | 96.30 | 0.05 | 31.61 | 31.61 | 0.00 |
| Air | $O_2$-gen | Hydrogen Sensor ORU | 4.59 | 0.00 | 0.00 | 0.00 | 0.00 | 4.59 | 0.00 | 0.00 | 0.00 | 0.00 | 4.59 | 0.00 | 0.00 | 0.00 | 0.00 | 4.59 | 0.00 | 0.00 | 0.00 | 0.00 | 4.59 | 0.00 | 0.00 | 0.00 | 0.00 |
| Air | $O_2$-gen | Process Controller | 40.09 | 0.14 | 148.00 | 148.00 | 0.00 | 40.09 | 0.14 | 148.00 | 148.00 | 0.00 | 40.09 | 0.14 | 148.00 | 148.00 | 0.00 | 40.09 | 0.14 | 148.00 | 148.00 | 0.00 | 40.09 | 0.14 | 148.00 | 148.00 | 0.00 |
| Air | $O_2$-gen | Power Supply Module (PSM) | 13.45 | 0.02 | 1069.25 | 0.00 | 0.00 | 13.45 | 0.02 | 1069.25 | 0.00 | 0.00 | 14.14 | 0.02 | 1124.36 | 562.18 | 0.00 | 13.92 | 0.02 | 1106.94 | 553.47 | 0.00 | 13.81 | 0.02 | 1098.05 | 549.02 | 0.00 |
| Air | Fire-det-sup | Fire Detection Assembly | 1.50 | 0.00 | 1.48 | 1.48 | 0.03 | 1.50 | 0.00 | 1.48 | 1.48 | 0.03 | 1.50 | 0.00 | 1.48 | 1.48 | 0.03 | 1.50 | 0.00 | 1.48 | 1.48 | 0.08 | 1.50 | 0.00 | 1.48 | 1.48 | 0.89 |
| Air | Fire-det-sup | Portable Fire Extinguisher | 6.80 | 0.04 | 0.00 | 0.00 | 0.00 | 6.80 | 0.04 | 0.00 | 0.00 | 0.00 | 6.80 | 0.04 | 0.00 | 0.00 | 0.00 | 6.80 | 0.04 | 0.00 | 0.00 | 0.00 | 6.80 | 0.04 | 0.00 | 0.00 | 0.00 |
| Air | $ACO_2R$ | Regenerator 1 | 45.30 | 0.17 | 397.00 | 397.00 | 0.00 | 45.30 | 0.17 | 397.00 | 397.00 | 0.00 | 45.30 | 0.17 | 397.00 | 397.00 | 0.00 | 45.30 | 0.17 | 397.00 | 397.00 | 0.00 | 45.30 | 0.17 | 397.00 | 397.00 | 0.00 |
| Air | $ACO_2R$ | Metox Canisters | 136.00 | 0.06 | 0.00 | 0.00 | 0.00 | 136.00 | 0.06 | 0.00 | 0.00 | 0.00 | 136.00 | 0.06 | 0.00 | 0.00 | 0.00 | 136.00 | 0.06 | 0.00 | 0.00 | 0.00 | 136.00 | 0.06 | 0.00 | 0.00 | 0.00 |
| Air | TCCS-ISS | Activated Charcoal Bed | 4.63 | 0.01 | 0.00 | 0.00 | 0.00 | 4.63 | 0.01 | 0.00 | 0.00 | 0.00 | 4.63 | 0.01 | 0.00 | 0.00 | 0.00 | 12.87 | 0.03 | 0.00 | 0.00 | 0.00 | 139.02 | 0.29 | 0.00 | 0.00 | 0.00 |
| Air | TCCS-ISS | Blower Assembly | 2.49 | 0.00 | 30.39 | 30.39 | 0.00 | 2.49 | 0.00 | 30.39 | 30.39 | 0.00 | 2.49 | 0.00 | 30.39 | 30.39 | 0.00 | 2.49 | 0.00 | 30.39 | 30.39 | 0.00 | 2.49 | 0.00 | 30.39 | 30.39 | 0.00 |
| Air | TCCS-ISS | Flow Meter Assembly | 1.10 | 0.00 | 11.50 | 11.50 | 0.00 | 1.10 | 0.00 | 11.50 | 11.50 | 0.00 | 1.10 | 0.00 | 11.50 | 11.50 | 0.00 | 1.10 | 0.00 | 11.50 | 11.50 | 0.00 | 1.10 | 0.00 | 11.50 | 11.50 | 0.00 |
| Air | TCCS-ISS | Catalytic Oxidizer Assembly | 8.46 | 0.02 | 92.19 | 92.19 | 0.00 | 8.46 | 0.02 | 92.19 | 92.19 | 0.00 | 8.46 | 0.02 | 92.19 | 92.19 | 0.00 | 8.46 | 0.02 | 92.19 | 92.19 | 0.00 | 8.46 | 0.02 | 92.19 | 92.19 | 0.00 |
| Air | TCCS-ISS | LiOH Sorbent Bed Assembly | 0.31 | 0.00 | 0.00 | 0.00 | 0.00 | 0.31 | 0.00 | 0.00 | 0.00 | 0.00 | 0.31 | 0.00 | 0.00 | 0.00 | 0.00 | 0.87 | 0.00 | 0.00 | 0.00 | 0.00 | 9.43 | 0.02 | 0.00 | 0.00 | 0.00 |
| Air | TCCS-ISS | Electrical Interface Assembly | 4.50 | 0.00 | 7.60 | 7.60 | 0.00 | 4.50 | 0.00 | 7.60 | 7.60 | 0.00 | 4.50 | 0.00 | 7.60 | 7.60 | 0.00 | 4.50 | 0.00 | 7.60 | 7.60 | 0.00 | 4.50 | 0.00 | 7.60 | 7.60 | 0.00 |
| Waste | PMWC | Aluminum Compaction Cylinder | 9.40 | 0.02 | 0.00 | 0.00 | 180.00 | 9.40 | 0.02 | 0.00 | 0.00 | 180.00 | 9.41 | 0.02 | 0.00 | 0.00 | 180.00 | 9.41 | 0.02 | 0.00 | 0.00 | 500.00 | 9.41 | 0.02 | 0.00 | 0.00 | 5400.00 |
| Waste | PMWC | Band-type Heating Unit | 0.00 | 0.00 | 136.34 | 0.00 | 0.00 | 0.00 | 0.00 | 136.34 | 0.00 | 0.00 | 0.00 | 0.00 | 162.58 | 0.00 | 0.00 | 0.00 | 0.00 | 162.39 | 0.00 | 0.00 | 0.00 | 0.00 | 162.29 | 0.00 | 0.00 |
| Waste | PMWC | Lightweight, Oil-Less, Compressor/Vacuum Pump | 0.00 | 0.00 | 2.71 | 0.00 | 0.00 | 0.00 | 0.00 | 2.71 | 0.00 | 0.00 | 0.00 | 0.00 | 3.23 | 0.00 | 0.00 | 0.00 | 0.00 | 3.22 | 0.00 | 0.00 | 0.00 | 0.00 | 3.22 | 0.00 | 0.00 |
| Waste | PMWC | Temperature Sensor | 0.22 | 0.00 | 0.00 | 0.00 | 0.00 | 0.22 | 0.00 | 0.00 | 0.00 | 0.00 | 0.22 | 0.00 | 0.00 | 0.00 | 0.00 | 0.22 | 0.00 | 0.00 | 0.00 | 0.00 | 0.22 | 0.00 | 0.00 | 0.00 | 0.00 |
| Waste | PMWC | Pressure Sensor | 0.30 | 0.00 | 0.33 | 0.00 | 0.00 | 0.30 | 0.00 | 0.33 | 0.00 | 0.00 | 0.30 | 0.00 | 0.33 | 0.00 | 0.00 | 0.30 | 0.00 | 0.33 | 0.00 | 0.00 | 0.30 | 0.00 | 0.33 | 0.00 | 0.00 |
| Waste | PMWC | Housing + Mounting Equipment | 23.86 | 0.48 | 0.00 | 0.00 | 0.00 | 23.86 | 0.48 | 0.00 | 0.00 | 0.00 | 23.89 | 0.48 | 0.00 | 0.00 | 0.00 | 23.89 | 0.48 | 0.00 | 0.00 | 0.00 | 23.89 | 0.48 | 0.00 | 0.00 | 0.00 |
| Waste | PMWC | Condensing Heat Exchanger | 1.91 | 0.00 | 0.00 | 0.00 | 0.00 | 1.91 | 0.00 | 0.00 | 0.00 | 0.00 | 2.86 | 0.01 | 0.00 | 0.00 | 0.00 | 2.86 | 0.01 | 0.00 | 0.00 | 0.00 | 2.85 | 0.01 | 0.00 | 0.00 | 0.00 |
| Waste | PMWC | Cooling system | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 145.14 | 145.14 | 0.00 | 0.00 | 0.00 | 144.97 | 144.97 | 0.00 | 0.00 | 0.00 | 144.89 | 144.89 | 0.00 |
| Waste | Waste-storage | Low Density PolyEthylene Box | 17.70 | 0.49 | 0.00 | 0.00 | 0.00 | 17.70 | 0.49 | 0.00 | 0.00 | 0.00 | 17.70 | 0.49 | 0.00 | 0.00 | 0.00 | 49.18 | 1.37 | 0.00 | 0.00 | 0.00 | 531.15 | 14.75 | 0.00 | 0.00 | 0.00 |

**Table S2.** ESM parameters for all inventory items broken down by system and subsystem for each scenario described in Table S1. Parameters included are mass $M$ [kg], $V$ [$m^3$], power $P$ [kW], cooling $C$ [kW], and crew-time $CT$ [hr][1,4]. The ESM values correspond to a single sortie $S_{num} = 1$. (ORU = Orbital Replacement Unit)

| | | | A | | | | | B | | | | | C | | | | | D | | | | | E | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **System** | **Subsystem** | **Item** | **M** | **V** | **P** | **C** | **CT** | **M** | **V** | **P** | **C** | **CT** | **M** | **V** | **P** | **C** | **CT** | **M** | **V** | **P** | **C** | **CT** | **M** | **V** | **P** | **C** | **CT** |
| Waste | Waste-col | Commode/Urinal | 58.40 | 0.30 | 0.00 | 0.00 | 29.59 | 58.40 | 0.30 | 0.00 | 0.00 | 29.59 | 58.40 | 0.30 | 0.00 | 0.00 | 29.59 | 58.40 | 0.30 | 0.00 | 0.00 | 82.19 | 58.40 | 0.30 | 0.00 | 0.00 | 887.67 |
| Waste | Waste-col | Fan | 0.00 | 0.00 | 102.00 | 102.00 | 0.00 | 0.00 | 0.00 | 102.00 | 102.00 | 0.00 | 0.00 | 0.00 | 102.00 | 102.00 | 0.00 | 0.00 | 0.00 | 102.00 | 102.00 | 0.00 | 0.00 | 0.00 | 102.00 | 102.00 | 0.00 |
| Waste | Waste-col | Urine Separator | 0.00 | 0.00 | 125.00 | 125.00 | 0.00 | 0.00 | 0.00 | 125.00 | 125.00 | 0.00 | 0.00 | 0.00 | 125.00 | 125.00 | 0.00 | 0.00 | 0.00 | 125.00 | 125.00 | 0.00 | 0.00 | 0.00 | 125.00 | 125.00 | 0.00 |
| Waste | Waste-col | Urine Vent Heater | 0.00 | 0.00 | 14.00 | 14.00 | 0.00 | 0.00 | 0.00 | 14.00 | 14.00 | 0.00 | 0.00 | 0.00 | 14.00 | 14.00 | 0.00 | 0.00 | 0.00 | 14.00 | 14.00 | 0.00 | 0.00 | 0.00 | 14.00 | 14.00 | 0.00 |
| Waste | Waste-col | Fecal Bags | 19.64 | 0.22 | 0.00 | 0.00 | 0.00 | 19.64 | 0.22 | 0.00 | 0.00 | 0.00 | 19.64 | 0.22 | 0.00 | 0.00 | 0.00 | 54.55 | 0.61 | 0.00 | 0.00 | 0.00 | 589.09 | 6.58 | 0.00 | 0.00 | 0.00 |
| Waste | Waste-col | Wipes, Dry | 6.55 | 0.09 | 0.00 | 0.00 | 0.00 | 6.55 | 0.09 | 0.00 | 0.00 | 0.00 | 6.55 | 0.09 | 0.00 | 0.00 | 0.00 | 18.18 | 0.25 | 0.00 | 0.00 | 0.00 | 196.36 | 2.65 | 0.00 | 0.00 | 0.00 |
| Waste | Waste-col | Wipes, Wet | 10.23 | 0.05 | 0.00 | 0.00 | 0.00 | 10.23 | 0.05 | 0.00 | 0.00 | 0.00 | 10.23 | 0.05 | 0.00 | 0.00 | 0.00 | 28.41 | 0.15 | 0.00 | 0.00 | 0.00 | 306.82 | 1.59 | 0.00 | 0.00 | 0.00 |
| Waste | Waste-col | Wipes, Toilet Tissue | 3.53 | 0.04 | 0.00 | 0.00 | 0.00 | 3.53 | 0.04 | 0.00 | 0.00 | 0.00 | 3.53 | 0.04 | 0.00 | 0.00 | 0.00 | 9.82 | 0.12 | 0.00 | 0.00 | 0.00 | 106.04 | 1.29 | 0.00 | 0.00 | 0.00 |
| Waste | Waste-col | Gloves | 5.60 | 0.03 | 0.00 | 0.00 | 0.00 | 5.60 | 0.03 | 0.00 | 0.00 | 0.00 | 5.60 | 0.03 | 0.00 | 0.00 | 0.00 | 15.55 | 0.07 | 0.00 | 0.00 | 0.00 | 167.89 | 0.76 | 0.00 | 0.00 | 0.00 |
| Waste | Waste-col | Fecal Bags Odor Lids | 29.45 | 0.28 | 0.00 | 0.00 | 0.00 | 29.45 | 0.28 | 0.00 | 0.00 | 0.00 | 29.45 | 0.28 | 0.00 | 0.00 | 0.00 | 81.82 | 0.77 | 0.00 | 0.00 | 0.00 | 883.64 | 8.26 | 0.00 | 0.00 | 0.00 |
| Waste | Waste-col | Fecal Collection Canisters | 35.06 | 0.46 | 0.00 | 0.00 | 0.00 | 35.06 | 0.46 | 0.00 | 0.00 | 0.00 | 35.06 | 0.46 | 0.00 | 0.00 | 0.00 | 97.40 | 1.28 | 0.00 | 0.00 | 0.00 | 1051.95 | 13.77 | 0.00 | 0.00 | 0.00 |
| Waste | Waste-col | Fecal collection Canisters lids | 17.53 | 0.07 | 0.00 | 0.00 | 0.00 | 17.53 | 0.07 | 0.00 | 0.00 | 0.00 | 17.53 | 0.07 | 0.00 | 0.00 | 0.00 | 48.70 | 0.20 | 0.00 | 0.00 | 0.00 | 525.97 | 2.15 | 0.00 | 0.00 | 0.00 |
| Waste | Waste-col | Urine Prefilters | 30.68 | 0.17 | 0.00 | 0.00 | 0.00 | 30.68 | 0.17 | 0.00 | 0.00 | 0.00 | 30.68 | 0.17 | 0.00 | 0.00 | 0.00 | 85.23 | 0.46 | 0.00 | 0.00 | 0.00 | 920.45 | 5.01 | 0.00 | 0.00 | 0.00 |
| Waste | Waste-col | Urine Filters | 4.38 | 0.04 | 0.00 | 0.00 | 0.00 | 4.38 | 0.04 | 0.00 | 0.00 | 0.00 | 4.38 | 0.04 | 0.00 | 0.00 | 0.00 | 12.18 | 0.10 | 0.00 | 0.00 | 0.00 | 131.49 | 1.06 | 0.00 | 0.00 | 0.00 |
| Waste | Waste-col | Urine Funnels | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.16 | 0.01 | 0.00 | 0.00 | 0.00 | 1.16 | 0.01 | 0.00 | 0.00 | 0.00 | 1.16 | 0.01 | 0.00 | 0.00 | 0.00 |
| Waste | Waste-col | Flush Water Transfer Bags | 5.61 | 0.08 | 0.00 | 0.00 | 0.00 | 5.61 | 0.08 | 0.00 | 0.00 | 0.00 | 5.61 | 0.08 | 0.00 | 0.00 | 0.00 | 15.58 | 0.22 | 0.00 | 0.00 | 0.00 | 168.31 | 2.35 | 0.00 | 0.00 | 0.00 |
| Waste | TCCS-ISS-x3 | Activated charcoal bed | 9.27 | 0.02 | 0.00 | 0.00 | 0.00 | 9.27 | 0.02 | 0.00 | 0.00 | 0.00 | 9.27 | 0.02 | 0.00 | 0.00 | 0.00 | 25.74 | 0.05 | 0.00 | 0.00 | 0.00 | 278.04 | 0.57 | 0.00 | 0.00 | 0.00 |
| Waste | TCCS-ISS-x4 | Blower Assembly | 4.97 | 0.01 | 60.79 | 60.79 | 0.00 | 4.97 | 0.01 | 60.79 | 60.79 | 0.00 | 4.97 | 0.01 | 60.79 | 60.79 | 0.00 | 4.97 | 0.01 | 60.79 | 60.79 | 0.00 | 4.97 | 0.01 | 60.79 | 60.79 | 0.00 |
| Waste | TCCS-ISS-x5 | Flow Meter Assembly | 2.20 | 0.00 | 23.00 | 23.00 | 0.00 | 2.20 | 0.00 | 23.00 | 23.00 | 0.00 | 2.20 | 0.00 | 23.00 | 23.00 | 0.00 | 2.20 | 0.00 | 23.00 | 23.00 | 0.00 | 2.20 | 0.00 | 23.00 | 23.00 | 0.00 |
| Waste | TCCS-ISS-x6 | Catalytic Oxidizer Assembly | 16.91 | 0.04 | 184.38 | 184.38 | 0.00 | 16.91 | 0.04 | 184.38 | 184.38 | 0.00 | 16.91 | 0.04 | 184.38 | 184.38 | 0.00 | 16.91 | 0.04 | 184.38 | 184.38 | 0.00 | 16.91 | 0.04 | 184.38 | 184.38 | 0.00 |
| Waste | TCCS-ISS-x7 | LiOH Sorbent Bed Assembly | 0.63 | 0.00 | 0.00 | 0.00 | 0.00 | 0.63 | 0.00 | 0.00 | 0.00 | 0.00 | 0.63 | 0.00 | 0.00 | 0.00 | 0.00 | 1.75 | 0.00 | 0.00 | 0.00 | 0.00 | 18.86 | 0.04 | 0.00 | 0.00 | 0.00 |
| Waste | TCCS-ISS-x8 | Electrical Interface Assembly | 9.00 | 0.01 | 15.20 | 15.20 | 0.00 | 9.00 | 0.01 | 15.20 | 15.20 | 0.00 | 9.00 | 0.01 | 15.20 | 15.20 | 0.00 | 9.00 | 0.01 | 15.20 | 15.20 | 0.00 | 9.00 | 0.01 | 15.20 | 15.20 | 0.00 |
| Water | $H_2O$-rec | MLS Filter ORU | 3.32 | 0.00 | 0.00 | 0.00 | 0.00 | 3.32 | 0.00 | 0.00 | 0.00 | 0.00 | 3.96 | 0.01 | 0.00 | 0.00 | 0.00 | 10.97 | 0.02 | 0.00 | 0.00 | 0.00 | 118.21 | 0.17 | 0.00 | 0.00 | 0.00 |
| Water | $H_2O$-rec | Particulate Filter ORU | 17.22 | 0.04 | 0.00 | 0.00 | 0.00 | 17.22 | 0.04 | 0.00 | 0.00 | 0.00 | 20.54 | 0.05 | 0.00 | 0.00 | 0.00 | 56.83 | 0.14 | 0.00 | 0.00 | 0.00 | 612.48 | 1.56 | 0.00 | 0.00 | 0.00 |
| Water | $H_2O$-rec | Multifiltration Bed #1 + #2 ORUs | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 167.74 | 0.22 | 0.00 | 0.00 | 0.00 | 464.08 | 0.60 | 0.00 | 0.00 | 0.00 | 5001.86 | 6.51 | 0.00 | 0.00 | 0.00 |
| Water | $H_2O$-rec | Sensor ORU | 3.64 | 0.01 | 2.13 | 2.13 | 0.00 | 3.64 | 0.01 | 2.13 | 2.13 | 0.00 | 3.64 | 0.01 | 2.13 | 2.13 | 0.00 | 3.64 | 0.01 | 2.13 | 2.13 | 0.00 | 3.64 | 0.01 | 2.13 | 2.13 | 0.00 |
| Water | $H_2O$-rec | Piping | 5.37 | 0.01 | 0.00 | 0.00 | 0.00 | 5.37 | 0.01 | 0.00 | 0.00 | 0.00 | 0.74 | 0.00 | 0.00 | 0.00 | 0.00 | 0.74 | 0.00 | 0.00 | 0.00 | 0.00 | 0.74 | 0.00 | 0.00 | 0.00 | 0.00 |
| Water | $H_2O$-rec | Pump/MLS ORU | 30.28 | 0.09 | 51.17 | 51.17 | 0.00 | 30.28 | 0.09 | 51.17 | 51.17 | 0.00 | 18.42 | 0.06 | 19.62 | 19.62 | 0.00 | 18.40 | 0.06 | 19.54 | 19.54 | 0.00 | 18.38 | 0.06 | 19.50 | 19.50 | 0.00 |
| Water | $H_2O$-rec | Catalytic Reactor + Preheeater ORU | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 107.90 | 107.90 | 0.00 | 0.00 | 0.00 | 107.47 | 107.47 | 0.00 | 0.00 | 0.00 | 107.25 | 107.25 | 0.00 |
| Water | $H_2O$-rec | Oxygen Filter | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Water | $H_2O$-rec | Microbial Check Valve | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.16 | 0.01 | 0.00 | 0.00 | 0.00 | 5.13 | 0.01 | 0.00 | 0.00 | 0.00 | 5.12 | 0.01 | 0.00 | 0.00 | 0.00 |
| Water | $H_2O$-rec | Gas Separator ORU | 43.11 | 0.09 | 132.33 | 132.33 | 0.00 | 43.11 | 0.09 | 132.33 | 132.33 | 0.00 | 26.24 | 0.06 | 50.73 | 50.73 | 0.00 | 26.20 | 0.06 | 50.53 | 50.53 | 0.00 | 26.17 | 0.06 | 50.43 | 50.43 | 0.00 |
| Water | $H_2O$-rec | Hygiene $H_2O$ Tank | 95.90 | 0.18 | 7.05 | 7.05 | 0.00 | 95.90 | 0.18 | 7.05 | 7.05 | 0.00 | 58.36 | 0.11 | 4.72 | 4.72 | 0.00 | 58.27 | 0.11 | 4.71 | 4.71 | 0.00 | 58.22 | 0.11 | 4.71 | 4.71 | 0.00 |
| Water | $H_2O$-rec | Product $H_2O$ Tank | 53.97 | 0.19 | 7.85 | 7.85 | 0.00 | 53.97 | 0.19 | 7.85 | 7.85 | 0.00 | 32.84 | 0.12 | 5.25 | 5.25 | 0.00 | 32.79 | 0.12 | 5.24 | 5.24 | 0.00 | 32.76 | 0.12 | 5.24 | 5.24 | 0.00 |
| Water | $H_2O$-rec | Process Controller | 36.91 | 0.08 | 156.18 | 156.18 | 0.00 | 36.91 | 0.08 | 156.18 | 156.18 | 0.00 | 36.91 | 0.08 | 156.18 | 156.18 | 0.00 | 36.91 | 0.08 | 156.18 | 156.18 | 0.00 | 36.91 | 0.08 | 156.18 | 156.18 | 0.00 |
| Water | $H_2O$-rec | Reactor Health Sensor | 8.64 | 0.04 | 4.72 | 4.72 | 0.00 | 8.64 | 0.04 | 4.72 | 4.72 | 0.00 | 8.64 | 0.04 | 4.72 | 4.72 | 0.00 | 8.64 | 0.04 | 4.72 | 4.72 | 0.00 | 8.64 | 0.04 | 4.72 | 4.72 | 0.00 |
| Water | $H_2O$-rec | $H_2O$ Delivery System | 42.97 | 0.11 | 2.88 | 2.88 | 0.00 | 42.97 | 0.11 | 2.88 | 2.88 | 0.00 | 26.15 | 0.06 | 1.93 | 1.93 | 0.00 | 26.11 | 0.06 | 1.93 | 1.93 | 0.00 | 26.09 | 0.06 | 1.92 | 1.92 | 0.00 |

**Table S2.** ESM parameters for all inventory items broken down by system and subsystem for each scenario described in Table S1. Parameters included are mass $M$ [kg], $V$ [$m^3$], power $P$ [kW], cooling $C$ [kW], and crew-time $CT$ [hr][1,4]. The ESM values correspond to a single sortie $S_{num} = 1$. (ORU = Orbital Replacement Unit)

| | | | A | | | | | B | | | | | C | | | | | D | | | | | E | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **System** | **Subsystem** | **Item** | **M** | **V** | **P** | **C** | **CT** | **M** | **V** | **P** | **C** | **CT** | **M** | **V** | **P** | **C** | **CT** | **M** | **V** | **P** | **C** | **CT** | **M** | **V** | **P** | **C** | **CT** |
| Water | WRS | Ion Exchange Bed | 2.78 | 0.00 | 0.00 | 0.00 | 0.00 | 2.78 | 0.00 | 0.00 | 0.00 | 0.00 | 2.78 | 0.00 | 0.00 | 0.00 | 0.00 | 7.70 | 0.01 | 0.00 | 0.00 | 0.00 | 83.02 | 0.11 | 0.00 | 0.00 | 0.00 |
| Water | Urine-proc | Pressure Control + Pump (PCPA) | 27.14 | 0.04 | 5.73 | 5.73 | 0.00 | 27.14 | 0.04 | 5.73 | 5.73 | 0.00 | 33.73 | 0.05 | 9.83 | 9.83 | 0.00 | 33.64 | 0.05 | 9.77 | 9.77 | 0.00 | 33.60 | 0.05 | 9.75 | 9.75 | 0.00 |
| Water | Urine-proc | Fluid Control + Pump (FCPA) | 27.63 | 0.04 | 8.30 | 8.30 | 0.00 | 27.63 | 0.04 | 8.30 | 8.30 | 0.00 | 34.35 | 0.05 | 14.26 | 14.26 | 0.00 | 34.26 | 0.05 | 14.18 | 14.18 | 0.00 | 34.21 | 0.05 | 14.14 | 14.14 | 0.00 |
| Water | Urine-proc | Recycle Filter Tank (RFTA) | 11.55 | 0.06 | 0.00 | 0.00 | 0.00 | 11.55 | 0.06 | 0.00 | 0.00 | 0.00 | 14.35 | 0.08 | 0.00 | 0.00 | 0.00 | 14.32 | 0.08 | 0.00 | 0.00 | 0.00 | 14.30 | 0.08 | 0.00 | 0.00 | 0.00 |
| Water | Urine-proc | Wastewater Storage Tank Assembly (WSTA) | 28.95 | 0.02 | 0.08 | 0.08 | 0.00 | 28.95 | 0.02 | 0.08 | 0.08 | 0.00 | 35.98 | 0.03 | 0.14 | 0.14 | 0.00 | 35.89 | 0.03 | 0.14 | 0.14 | 0.00 | 35.84 | 0.03 | 0.14 | 0.14 | 0.00 |
| Water | Urine-proc | Distillation Assembly (DA) | 45.81 | 0.09 | 79.35 | 79.35 | 0.00 | 45.81 | 0.09 | 79.35 | 79.35 | 0.00 | 56.94 | 0.11 | 136.22 | 136.22 | 0.00 | 56.79 | 0.11 | 135.46 | 135.46 | 0.00 | 56.72 | 0.11 | 135.08 | 135.08 | 0.00 |
| Water | Urine-proc | Separator Plumbing Assembly (SPA) | 9.87 | 0.02 | 0.00 | 0.00 | 0.00 | 9.87 | 0.02 | 0.00 | 0.00 | 0.00 | 12.27 | 0.02 | 0.00 | 0.00 | 0.00 | 12.24 | 0.02 | 0.00 | 0.00 | 0.00 | 12.22 | 0.02 | 0.00 | 0.00 | 0.00 |
| Water | Urine-proc | Power Module (Included in FCA) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Water | Urine-proc | Firmware Controller Assembly (Data Module, Power Module) | 24.09 | 0.03 | 150.09 | 150.09 | 0.00 | 24.09 | 0.03 | 150.09 | 150.09 | 0.00 | 24.09 | 0.03 | 150.09 | 150.09 | 0.00 | 24.09 | 0.03 | 150.09 | 150.09 | 0.00 | 24.09 | 0.03 | 150.09 | 150.09 | 0.00 |
| Water | Urine-proc | Piping | 7.55 | 0.01 | 0.00 | 0.00 | 0.00 | 7.55 | 0.01 | 0.00 | 0.00 | 0.00 | 9.38 | 0.02 | 0.00 | 0.00 | 0.00 | 9.36 | 0.02 | 0.00 | 0.00 | 0.00 | 9.34 | 0.02 | 0.00 | 0.00 | 0.00 |
| Water | Volatile-rem | Catalytic Reactor + Preheater ORU | 0.00 | 0.00 | 90.48 | 90.48 | 0.00 | 0.00 | 0.00 | 90.48 | 90.48 | 0.00 | 0.00 | 0.00 | 90.48 | 90.48 | 0.00 | 0.00 | 0.00 | 90.48 | 90.48 | 0.00 | 0.00 | 0.00 | 90.48 | 90.48 | 0.00 |
| Water | Volatile-rem | Gas Separator ORU | 24.54 | 0.05 | 42.54 | 42.54 | 0.00 | 24.54 | 0.05 | 42.54 | 42.54 | 0.00 | 24.54 | 0.05 | 42.54 | 42.54 | 0.00 | 24.54 | 0.05 | 42.54 | 42.54 | 0.00 | 24.54 | 0.05 | 42.54 | 42.54 | 0.00 |
| Water | Volatile-rem | Oxygen Filter | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Water | Volatile-rem | Piping | 1.26 | 0.00 | 0.00 | 0.00 | 0.00 | 1.26 | 0.00 | 0.00 | 0.00 | 0.00 | 1.26 | 0.00 | 0.00 | 0.00 | 0.00 | 1.26 | 0.00 | 0.00 | 0.00 | 0.00 | 1.26 | 0.00 | 0.00 | 0.00 | 0.00 |
| Water | Tank | Product $H_2O$ Tank | 101.12 | 0.36 | 13.65 | 13.65 | 0.00 | 101.12 | 0.36 | 13.65 | 13.65 | 0.00 | 84.82 | 0.30 | 11.64 | 11.64 | 0.00 | 137.09 | 0.49 | 18.07 | 18.07 | 0.00 | 937.43 | 3.33 | 116.48 | 116.48 | 0.00 |
| Water | Tank | $H_2O$ Stored | 256.99 | 0.00 | 0.00 | 0.00 | 0.00 | 256.99 | 0.00 | 0.00 | 0.00 | 0.00 | 205.56 | 0.00 | 0.00 | 0.00 | 0.00 | 370.55 | 0.00 | 0.00 | 0.00 | 0.00 | 2897.03 | 0.00 | 0.00 | 0.00 | 0.00 |
| Food | Food-storage | Packaging | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 990.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2707.39 | 0.00 | 0.00 | 0.00 | 0.00 | 29004.85 | 0.00 | 0.00 | 0.00 | 0.00 |
| Food | Food-storage | Lockers/Storage | 218.86 | 3.05 | 0.00 | 0.00 | 0.00 | 218.86 | 3.05 | 0.00 | 0.00 | 0.00 | 242.76 | 3.39 | 0.00 | 0.00 | 0.00 | 663.88 | 9.26 | 0.00 | 0.00 | 0.00 | 7112.33 | 99.24 | 0.00 | 0.00 | 0.00 |
| Food | Food-processing | Rehydration Unit and Conduction Oven | 36.30 | 0.09 | 960.00 | 960.00 | 0.00 | 36.30 | 0.09 | 960.00 | 960.00 | 0.00 | 36.30 | 0.09 | 10.00 | 10.00 | 0.00 | 36.30 | 0.09 | 10.00 | 10.00 | 0.00 | 36.30 | 0.09 | 10.00 | 10.00 | 0.00 |
| Thermal | CCAA | Inlet ORU | 0.00 | 0.00 | 312.64 | 312.64 | 0.00 | 0.00 | 0.00 | 312.64 | 312.64 | 0.00 | 0.00 | 0.00 | 299.23 | 299.23 | 0.00 | 0.00 | 0.00 | 299.08 | 299.08 | 0.00 | 0.00 | 0.00 | 299.00 | 299.00 | 0.00 |
| Thermal | CCAA | Condensing Heat Exchanger | 37.69 | 0.07 | 0.00 | 0.00 | 0.00 | 37.69 | 0.07 | 0.00 | 0.00 | 0.00 | 34.91 | 0.07 | 0.00 | 0.00 | 0.00 | 34.90 | 0.07 | 0.00 | 0.00 | 0.00 | 34.89 | 0.07 | 0.00 | 0.00 | 0.00 |
| Thermal | CCAA | Water Separator | 6.41 | 0.04 | 10.19 | 10.19 | 0.00 | 6.41 | 0.04 | 10.19 | 10.19 | 0.00 | 5.31 | 0.04 | 3.38 | 3.38 | 0.00 | 5.30 | 0.04 | 3.35 | 3.35 | 0.00 | 5.30 | 0.04 | 3.34 | 3.34 | 0.00 |
| Thermal | CCAA | Temp. Control + Check Valve | 4.09 | 0.03 | 0.06 | 0.06 | 0.00 | 4.09 | 0.03 | 0.06 | 0.06 | 0.00 | 3.89 | 0.03 | 0.06 | 0.06 | 0.00 | 3.89 | 0.03 | 0.06 | 0.06 | 0.00 | 3.89 | 0.03 | 0.06 | 0.06 | 0.00 |
| Thermal | CCAA | Electrical Interface Box (EIB) | 4.10 | 0.01 | 8.00 | 8.00 | 0.00 | 4.10 | 0.01 | 8.00 | 8.00 | 0.00 | 4.10 | 0.01 | 8.00 | 8.00 | 0.00 | 4.10 | 0.01 | 8.00 | 8.00 | 0.00 | 4.10 | 0.01 | 8.00 | 8.00 | 0.00 |
| Thermal | CCAA | Temp. Sensor | 0.24 | 0.00 | 0.01 | 0.01 | 0.00 | 0.24 | 0.00 | 0.01 | 0.01 | 0.00 | 0.24 | 0.00 | 0.01 | 0.01 | 0.00 | 0.24 | 0.00 | 0.01 | 0.01 | 0.00 | 0.24 | 0.00 | 0.01 | 0.01 | 0.00 |
| Thermal | CCAA | Liquid Sensor | 0.47 | 0.00 | 0.01 | 0.01 | 0.00 | 0.47 | 0.00 | 0.01 | 0.01 | 0.00 | 0.47 | 0.00 | 0.01 | 0.01 | 0.00 | 0.47 | 0.00 | 0.01 | 0.01 | 0.00 | 0.47 | 0.00 | 0.01 | 0.01 | 0.00 |
| Thermal | CCAA | Fan Delta P Sensor | 0.40 | 0.00 | 0.20 | 0.20 | 0.00 | 0.40 | 0.00 | 0.20 | 0.20 | 0.00 | 0.40 | 0.00 | 0.20 | 0.20 | 0.00 | 0.40 | 0.00 | 0.20 | 0.20 | 0.00 | 0.40 | 0.00 | 0.20 | 0.20 | 0.00 |
| Thermal | CCAA | Pressure Sensor | 0.30 | 0.00 | 0.20 | 0.20 | 0.00 | 0.30 | 0.00 | 0.20 | 0.20 | 0.00 | 0.30 | 0.00 | 0.20 | 0.20 | 0.00 | 0.30 | 0.00 | 0.20 | 0.20 | 0.00 | 0.30 | 0.00 | 0.20 | 0.20 | 0.00 |
| Thermal | Atmos-cont | HEPA Filter Element | 49.22 | 0.19 | 0.00 | 0.00 | 0.99 | 49.22 | 0.19 | 0.00 | 0.00 | 0.99 | 49.22 | 0.19 | 0.00 | 0.00 | 0.99 | 49.22 | 0.19 | 0.00 | 0.00 | 2.74 | 49.22 | 0.19 | 0.00 | 0.00 | 29.59 |
| Thermal | Atmos-cont | Catalytic Filter Element | 54.00 | 0.08 | 0.00 | 0.00 | 0.00 | 54.00 | 0.08 | 0.00 | 0.00 | 0.00 | 54.00 | 0.08 | 0.00 | 0.00 | 0.00 | 54.00 | 0.08 | 0.00 | 0.00 | 0.00 | 54.00 | 0.08 | 0.00 | 0.00 | 0.00 |
| Thermal | Atmosphere-circ | IMV Fan | 4.77 | 0.01 | 55.00 | 55.00 | 0.00 | 4.77 | 0.01 | 55.00 | 55.00 | 0.00 | 4.77 | 0.01 | 55.00 | 55.00 | 0.00 | 4.77 | 0.01 | 55.00 | 55.00 | 0.00 | 4.77 | 0.01 | 55.00 | 55.00 | 0.00 |
| Thermal | Atmosphere-circ | IMV Valve | 5.10 | 0.01 | 6.00 | 6.00 | 0.00 | 5.10 | 0.01 | 6.00 | 6.00 | 0.00 | 5.10 | 0.01 | 6.00 | 6.00 | 0.00 | 5.10 | 0.01 | 6.00 | 6.00 | 0.00 | 5.10 | 0.01 | 6.00 | 6.00 | 0.00 |
| Thermal | AAA | Avionics Air Assembly | 12.40 | 0.03 | 175.00 | 175.00 | 0.00 | 12.40 | 0.03 | 175.00 | 175.00 | 0.00 | 12.40 | 0.03 | 175.00 | 175.00 | 0.00 | 12.40 | 0.03 | 175.00 | 175.00 | 0.00 | 12.40 | 0.03 | 175.00 | 175.00 | 0.00 |
| Thermal | ITCS | ITCS | 211.83 | 0.36 | 2585.10 | 2585.10 | 0.00 | 211.83 | 0.36 | 2585.10 | 2585.10 | 0.00 | 211.83 | 0.36 | 2585.10 | 2585.10 | 0.00 | 212.49 | 0.36 | 2595.44 | 2595.44 | 0.00 | 217.23 | 0.36 | 2669.94 | 2669.94 | 0.00 |

**Table S3.** Estimation of inventory items into exemplar classes broken down by system and subsystem for each scenario described in Table S1. Classes include: Structural Metal, Plastic, Electronics, Fabric, Glass, Rubber, Ceramics, Gas, Biomass, Water, Other. (ORU = Orbital Replacement Unit)

| System | Subsystem | Item | Structural Metal | Plastic | Electronics | Fabric | Glass | Rubber | Ceramics | Gas | Biomass | Water | Other |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air | APC | Vent/Relief Valve | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | APC | Pressure Control Panel | 0.2 | 0.1 | 0.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | APC | Manual Pressure Equalization Valve | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | APC | Positive Pressure Relief Valve | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | APC | Negative Pressure Relief Valve | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | APC | Nitrogen Interface Assembly | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | APC | Vacuum Access Jumper 5-ft | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | APC | Vacuum Access Jumper 35-ft | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | ACMA | Verification Gas Assembly | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 | 0 |
| Air | ACMA | Mass Spectrometer | 0.5 | 0 | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | ACMA | Sample Pump | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | ACMA | Sample Distributor | 0.95 | 0 | 0 | 0.05 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | ACMA | Data + Control | 0.5 | 0 | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | ACMA | Low Volt. Power supply | 0.7 | 0 | 0 | 0 | 0 | 0.1 | 0.1 | 0 | 0 | 0 | 0.1 |
| Air | ACMA | Chassis | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | ACMA | Inlet Valve Assembly | 0.9 | 0 | 0 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0.09 | 0 |
| Air | ACMA | EMI Filter | 0.98 | 0.02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | SDS | 3-way Solenoid Valves | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | SDS | Manual Valves | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | SDS | Sample Probes | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | $CO_2$-rem | Air Selector Valve | 0.9 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0 |
| Air | $CO_2$-rem | Desiccant Bed | 0.4 | 0 | 0 | 0 | 0 | 0 | 0.6 | 0 | 0 | 0 | 0 |
| Air | $CO_2$-rem | Adsorbent Bed | 0.5 | 0 | 0 | 0.2 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 |
| Air | $CO_2$-rem | Air Check Valve | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | $CO_2$-rem | Heater Controller | 0.8 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | $CO_2$-rem | Air Blower | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | $CO_2$-rem | Pre-cooler | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | $CO_2$-rem | Blower/Pre-cooler Motor Controller | 0.6 | 0 | 0.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | $CO_2$-rem | $CO_2$ Pump | 0.99 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 |
| Air | $CO_2$-rem | $CO_2$ Pump Motor Controller | 0.3 | 0 | 0.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | $CO_2$-rem | Temperature Sensor | 0 | 0 | 0.6 | 0 | 0.4 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | $CO_2$-rem | Differential Pressure Sensor | 0.1 | 0.25 | 0.65 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | $CO_2$-rem | Absolute Pressure Sensor | 0.75 | 0 | 0 | 0 | 0 | 0 | 0.25 | 0 | 0 | 0 | 0 |
| Air | $CO_2$-rem | Electrical Harness | 0.9 | 0.05 | 0 | 0.05 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | $CO_2$-rem | Plumbing | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | $CO_2$-rem | Support Structure | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | $CO_2$-rem | Fluid Disconnects | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | $CO_2$-rem | Electronics Cold-Plate | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | $CO_2$-rem | Electronics Interface Plate | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | $N_2$ | MD Shield Instl | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | $N_2$ | Multilayer Insulation Assembly-T #1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | $N_2$ | Multilayer Insulation Assembly-T #2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | $N_2$ | Primary Structure Assembly-HPG ORU | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 | 0 |
| Air | $N_2$ | Tank ORU Assembly | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | $N_2$ | Utilities Installation - $O_2$/$N_2$ Tank | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 | 0 |
| Air | $N_2$ | $N_2$ Bare Tank | 0.9 | 0 | 0 | 0 | 0 | 0.05 | 0 | 0.05 | 0 | 0 | 0 |
| Air | $N_2$ | HPGA Fluid | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Air | $N_2$ | Handhold, top mounted | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | $N_2$ | Handrail 21.941 in custom | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | $N_2$ | Handrail, top mounted | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | $N_2$ | Grapple Fixture, flt releasable | 0.5 | 0 | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | $N_2$ | Accessories | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | $O_2$ | MD Shield Instl | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | $O_2$ | Multilayer Insulation Assembly-T #1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | $O_2$ | Multilayer Insulation Assembly-T #2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | $O_2$ | Primary Structure Assembly-HPG ORU | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 | 0 |
| Air | $O_2$ | Tank ORU Assembly | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | $O_2$ | Utilities Installation - $O_2$/$N_2$ Tank | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 | 0 |
| Air | $O_2$ | $O_2$ Bare Tank | 0.95 | 0 | 0 | 0 | 0 | 0 | 0 | 0.05 | 0 | 0 | 0 |
| Air | $O_2$ | HPGA Fluid | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Air | $O_2$ | Handhold, top mounted | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | $O_2$ | Handrail 21.941 in custom | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | $O_2$ | Handrail, top mounted | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | $O_2$ | Grapple Fixture, flt releasable | 0.5 | 0 | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | $O_2$ | Accessories | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Condensing Heat Exchanger | 0.9 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | AAA Heat Exchanger | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | ITCS Coolant Water Inlet QD | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | ITCS Coolant Water Outlet QD | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Heat Exchanger Inlet Temp | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Heat Exchanger Outlet Temp | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Manifold, $CO_2$ | 0.95 | 0.05 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | $CO_2$ Inlet Check Valve | 0.9 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table S3.** Estimation of inventory items into exemplar classes broken down by system and subsystem for each scenario described in Table S1. Classes include: Structural Metal, Plastic, Electronics, Fabric, Glass, Rubber, Ceramics, Gas, Biomass, Water, Other. (ORU = Orbital Replacement Unit)

| System | Subsystem | Item | Structural Metal | Plastic | Electronics | Fabric | Glass | Rubber | Ceramics | Gas | Biomass | Water | Other |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air | Sabatier | $CO_2$ Inlet Filter | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Pressure Sensor, $CO_2$ Inlet | 0 | 0 | 0.6 | 0 | 0.4 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | $CO_2$ Inlet QD | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | $CO_2$ Inlet Regulator | 0.9 | 0.05 | 0 | 0 | 0.05 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | $CO_2$ Inlet NC Solenoid | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | $CO_2$ Inlet Flow Control | 0.85 | 0.05 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | $CO_2$ Flow Control Orifice | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Delta P Sensor, Flow Sensor $CO_2$ | 0 | 0 | 0.6 | 0 | 0.4 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | $CO_2$ Flow Meter Orifice | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Manifold, Hydrogen | 0.95 | 0.05 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Water Outlet Quick Disconnect | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Hydrogen Inlet Check Valve | 0.9 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Hydrogen Inlet Filter | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | $H_2O$ Outlet Pressure Sensor | 0 | 0 | 0.6 | 0 | 0.4 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Hydrogen Inlet Quick Disconnect | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Hydrogen Inlet NC Solenoid | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Delta P Sensor, Flow Sensor $H_2$ | 0 | 0 | 0.6 | 0 | 0.4 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | $H_2$ Flow Meter Orifice | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Manifold, Vent | 0.95 | 0.05 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Liquid Sensor | 0 | 0.5 | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Vent Pressure Sensor | 0 | 0 | 0.6 | 0 | 0.4 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Vent Outlet Quick Disconnect | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Vent Regulator | 0.9 | 0.05 | 0 | 0 | 0.05 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Vent Relief/Check #1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Vent Relief/Check #2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Vent Outlet NO Solenoid | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Water Pressure Sensor | 0 | 0 | 0.6 | 0 | 0.4 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Water Relief | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Water Outlet NC Solenoid | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Rotary Water Separator Assembly | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Sabatier Reactor Assembly | 0.9 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Structure (A/R) | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Miscellaneous Hardware (clamps, bolts, etc.) (A/R) | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Air Cooling NC Solenoid | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Air Inlet Filter | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Air Sabatier Orifice | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Heat Exchanger Inlet Duct | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Heat Exchanger Outlet Duct | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Reactor Inlet Duct | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Reactor Outlet Duct | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Tubing (A/R) | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Harnesses | 0.9 | 0.05 | 0 | 0.05 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Valves + Sensors' Total Power | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Mechanical Compressor ORU | 0.9 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.001 |
| Air | Sabatier | Compressor Manifold Assembly | 0.95 | 0.05 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | Controller Assembly | 0 | 0.2 | 0.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Sabatier | $CO_2$ Accumulator | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | $O_2$-gen | Deionizing Bed ORU (Inlet) | 0.05 | 0.15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.8 |
| Air | $O_2$-gen | Deionizing Bed ORU (Recirculating) | 0.05 | 0.15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.8 |
| Air | $O_2$-gen | Oxygen/Water ORU | 0.33 | 0 | 0 | 0 | 0 | 0 | 0 | 0.33 | 0 | 0.33 | 0 |
| Air | $O_2$-gen | Pump ORU | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | $O_2$-gen | Oxygen Phase Separator ORU | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | $O_2$-gen | Hydrogen ORU | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | $O_2$-gen | Hydrogen Sensor ORU | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | $O_2$-gen | Process Controller | 0.3 | 0.001 | 0.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | $O_2$-gen | Power Supply Module (PSM) | 0.7 | 0 | 0 | 0 | 0 | 0.1 | 0.1 | 0 | 0 | 0 | 0.1 |
| Air | Fire-det-sup | Fire Detection Assembly | 0.05 | 0.9 | 0.05 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | Fire-det-sup | Portable Fire Extinguisher | 0.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0.2 | 0 | 0 | 0.2 |
| Air | $ACO_2R$ | Regenerator 1 | 0.98 | 0.01 | 0 | 0 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | $ACO_2R$ | Metox Canisters | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | TCCS-ISS | Activated Charcoal Bed | 0 | 0.5 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 | 0 | 0 |
| Air | TCCS-ISS | Blower Assembly | 0.8 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | TCCS-ISS | Flow Meter Assembly | 0.7 | 0.1 | 0.1 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | TCCS-ISS | Catalytic Oxidizer Assembly | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Air | TCCS-ISS | LiOH Sorbent Bed Assembly | 0.07 | 0.03 | 0 | 0 | 0 | 0 | 0.9 | 0 | 0 | 0 | 0 |
| Air | TCCS-ISS | Electrical interface assembly | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Waste | PMWC | Aluminum Compaction cylinder | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Waste | PMWC | Band-type heating unit | 0.9 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0 |
| Waste | PMWC | Lightweight, Oil-Less, Compressor/Vacuum Pump | 0.9 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Waste | PMWC | Temperature Sensor | 0 | 0 | 0.6 | 0 | 0.4 | 0 | 0 | 0 | 0 | 0 | 0 |
| Waste | PMWC | Pressure Sensor | 0.1 | 0.25 | 0.65 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Waste | PMWC | Housing + Mounting Equipment | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Waste | PMWC | Condensing Heat Exchanger | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table S3.** Estimation of inventory items into exemplar classes broken down by system and subsystem for each scenario described in Table S1. Classes include: Structural Metal, Plastic, Electronics, Fabric, Glass, Rubber, Ceramics, Gas, Biomass, Water, Other. (ORU = Orbital Replacement Unit)

| System | Subsystem | Item | Structural Metal | Plastic | Electronics | Fabric | Glass | Rubber | Ceramics | Gas | Biomass | Water | Other |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Waste | PMWC | Cooling system | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Waste | Waste-storage | Low Density PolyEthylene Box | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Waste | Waste-col | Commode/Urinal | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Waste | Waste-col | Fan | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Waste | Waste-col | Urine Separator | 0.9 | 0 | 0.09 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Waste | Waste-col | Urine Vent Heater | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Waste | Waste-col | Fecal Bags | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Waste | Waste-col | Wipes, Dry | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Waste | Waste-col | Wipes, Wet | 0 | 0 | 0 | 0.6 | 0 | 0 | 0 | 0 | 0 | 0.4 | 0 |
| Waste | Waste-col | Wipes, Toilet Tissue | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Waste | Waste-col | Gloves | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Waste | Waste-col | Fecal Bags Odor Lids | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Waste | Waste-col | Fecal collection Canisters | 0 | 0.9 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Waste | Waste-col | Fecal collection Canisters lids | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Waste | Waste-col | Urine Prefilters | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Waste | Waste-col | Urine Filters | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Waste | Waste-col | Urine Funnels | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Waste | Waste-col | Flush Water Transfer Bags | 0 | 0.3 | 0 | 0.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Waste | TCCS-ISS-x3 | Activated Charcoal Bed | 0 | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 |
| Waste | TCCS-ISS-x4 | Blower Assembly | 0.8 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Waste | TCCS-ISS-x5 | Flow Meter Assembly | 0.7 | 0.1 | 0.1 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Waste | TCCS-ISS-x6 | Catalytic Oxidizer Assembly | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Waste | TCCS-ISS-x7 | LiOH Sorbent Bed Assembly | 0.07 | 0.03 | 0 | 0 | 0 | 0 | 0.9 | 0 | 0 | 0 | 0 |
| Waste | TCCS-ISS-x8 | Electrical Interface Assembly | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Water | Water-rec | MLS Filter ORU | 0.5 | 0 | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Water | Water-rec | Particulate Filter ORU | 0.9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 |
| Water | Water-rec | Multifiltration Bed #1 + #2 ORUs | 0.07 | 0.03 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.9 | 0 |
| Water | Water-rec | Sensor ORU | 0 | 0.6 | 0.2 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 |
| Water | Water-rec | Piping | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Water | Water-rec | Pump/MLS ORU | 0.5 | 0 | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Water | Water-rec | Catalytic Reactor + Preheater ORU | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Water | Water-rec | Oxygen Filter | 0.5 | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Water | Water-rec | Microbial Check Valve | 0.99 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 |
| Water | Water-rec | Gas Separator ORU | 0.9 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.001 |
| Water | Water-rec | Hygiene $H_2O$ Tank | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Water | Water-rec | Product $H_2O$ Tank | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Water | Water-rec | Process Controller | 0.3 | 0.001 | 0.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Water | Water-rec | Reactor Health Sensor | 0.1 | 0.2 | 0.6 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0 |
| Water | Water-rec | $H_2O$ Delivery System | 0.9 | 0 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0 |
| Water | Urine-proc | Pressure Control + Pump (PCPA) | 0.7 | 0.2 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Water | Urine-proc | Fluid Control + Pump (FCPA) | 0.7 | 0.2 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Water | Urine-proc | Recycle Filter Tank (RFTA) | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Water | Urine-proc | Wastewater Storage Tank Assembly (WSTA) | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Water | Urine-proc | Distillation Assembly (DA) | 0.6 | 0 | 0.1 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 |
| Water | Urine-proc | Separator Plumbing Assembly (SPA) | 0.99 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Water | Urine-proc | Power Module (Included in FCA) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Water | Urine-proc | Firmware Controller Assembly (Data Module, Power Module) | 0.8 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Water | Urine-proc | Piping | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Water | Volatile-rem | Catalytic Reactor + Preheater ORU | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Water | Volatile-rem | Gas Separator ORU | 0.9 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.001 |
| Water | Volatile-rem | Oxygen Filter | 0.5 | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Water | Volatile-rem | Piping | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Water | Tank | Product $H_2O$ Tank | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Water | Tank | $H_2O$ Stored | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Food | Food-stor | Lockers | 0.25 | 0.25 | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 |
| Food | Food-proc | Rehydration Unit and Conduction Oven | 0.7 | 0.05 | 0.25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Thermal | CCAA | Inlet ORU | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Thermal | CCAA | Condensing Heat Exchanger | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Thermal | CCAA | Water Separator | 0.99 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 |
| Thermal | CCAA | Temp Control + Check Valve | 0.8 | 0.15 | 0 | 0.05 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Thermal | CCAA | Electrical Interface Box (EIB) | 0.9 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Thermal | CCAA | Temp Sensor | 0 | 0 | 0.6 | 0 | 0.4 | 0 | 0 | 0 | 0 | 0 | 0 |
| Thermal | CCAA | Liquid Sensor | 0 | 0.5 | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Thermal | CCAA | Fan Delta P Sensor | 0.9 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Thermal | CCAA | Pressure Sensor | 0.1 | 0.25 | 0.65 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Thermal | Atmos-con | HEPA Filter Element | 0.7 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Thermal | Atmos-con | Catalytic Filter Element | 0 | 0.7 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Thermal | Atmos-circ | IMV Fan | 0.9 | 0.05 | 0 | 0.05 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Thermal | Atmos-circ | IMV Valve | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Thermal | AAA | Avionics Air Assembly | 0.8 | 0.1 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## Opportunities for Biomanufacturing-based 3D- and bio-printing in Space

### Bioprinting for Medical Applications

Advancing manufacturing and application concepts now aim to enable non-terran medical therapeutics beyond conventional pharmacological and medical device design, production, and treatment strategies translated from Earth deployment[5]. Among these developments are *in vitro* biofabrication models being prepared and tested in Space for the reduction to practice of biofical tissue and organ manufacturing capable of supporting on-demand personalized medicine through autologous organs and systems repair or replacement. Nearly two-decades of Earth-based demonstrations show that 3D bio-printing of live cells provides feasible physical healthcare solutions in nonsurgical and surgical settings[6–8]. The constraints of Space and extraterrestrial environments, however, demand specialized standards for bio-printing, bio-product utilization, and medical/surgical procedures that currently restrict the near-term state-of-art to high positive-outcome healthcare interventions, such as bone and skin repair, which are more easily performed by suitably trained spaceflight surgeons and assistive medical staff using portable biomedical technologies and additional infrastructure in microgravity[9–11].

Despite these constraints, existing in-Space manufacturing technologies and methods outpace the readiness to practice sophisticated Earth medical and surgical procedures in off-Earth scenarios. For example, the Russian Space Agency and partners printed the first live tissue, a mouse thyroid, aboard the ISS using self-assembly magnetic manipulation, eliminating the need for traditional bio-compatible scaffolding techniques to organize and support cell structure, proliferation, differentiation, and extracellular matrix production[12,13]. Alternate scaffold-free preparations, such as those employing hydrogels and metallic needles or electrostatic, acoustic, and gravitational forces, also offer practical solutions for implementing tissue and organ bio-printing in Space. NASA's Centennial Vascular Tissue Challenge will evaluate two of these methods, gel- and gravity-directed organ assembly, using the ISS BioFabrication Facility (BFF). The BFF is a collaboration between private industry and NASA that was launched to study and perfect the printing of human cells and organ-like tissues in microgravity.

Although human joint menisci with simple vascular zones have been already constructed on the ISS, technical obstacles remain for the bio-printing of sustainably viable complex organs believed necessary to replace astronaut anatomy, which may become damaged or diseased from long-duration space-travel and habitation. Th winners of the Centennial Vascular Tissue Challenge will, for instance, focus on improving organotypic vascular engineering of artificial liver -– the building of vascular networks that perfuse cells with nutrients and oxygen while removing metabolic waste and other biological toxins and debris[14]. Achieving naturalistic blood supplies for artificial organ systems continues to be a major limitation for both Earth and Space science and such manufacturing endeavors will help realize cell-differentiated organ bio-printing for Space regenerative medicine, complementing a range of other envisioned off-Earth cell and tissue medical bio-printing applications, including the recent European Space Agency demonstration of skin-wound patching and accelerated healing with use of the hand-held Bioprint First Aid. Importantly, because 3D bio-printing presumably benefits from a near weightless manufacturing environment with atomic-level low mechanical stresses and viscosity[15], orbital facilities similar to the BFF may become significant supply-chain contributors to the Earth-based regenerative medicine industry, improving the health, wellness, and longevity of millions or more patients worldwide by catalyzing technology innovation and application[16].

### Fabricating Finished Goods

In 2014, the first three-dimensional (3-D) printed object in space was produced on the ISS Additive Manufacturing Facility (AMF). Since then, additive manufacturing is actively being explored and developed in LEO as proving-ground for various off-world scenarios, as also exemplified by fused filament fabrication (FFF) of ABS (acrylnitril-butadien-styrol), conducted on the ISS in 2016[17]. The tests showed that 3D-printing of synthetic polymers in microgravity is reliable, because of automation, which privileges new material exploration: public and private sector alike have 3D-printed hundreds of parts aboard the ISS made from polymers of various classes[18]. Also the Space-based additive manufacturing of non-polymeric materials is being explored: flight-demo technology has featured flexible electronics, including laser-sintering of copper, printed ceramic sensors, batteries, and antennas[19]. A build-to-print RF antenna was successfully produced through additive manufacturing, reducing up-mass and enabling in-Space design customization[20]. Private companies provide hardware and printing solutions for conductors and dielectrics through stand-alone R&D printers as well as OEM print-heads that can be integrated with other additive manufacturing tools and robotic arms, even enabling plasma jet printing.

Potential applications and benefits are manifold and range from ISM to commercialization of on-Orbit manufacturing techniques. The Redwire Regolith Print study, for example, optimized on-orbit construction of civil infrastructure with an adoption plan for the Artemis Program. Material sources are a hybrid of locally (on the Moon) available regolith and Earth-made binder whose performance holds promise to be matched by biologically-produced adhesives of macromolecular nature[21]. While theoretically an abundant resource for construction at destination Moon, Lunar regolith is characteristically unlike any Earth material. Without wind and rain, Lunar regolith particles stay sharp, instead of eroding smooth[22]. This unique topology in combination with small size not only poses significant respiratory risk to astronauts, as observed during the Apollo missions, but also causes frictional damage of mechanical equipment[23], which must be accounted for in hardware development.

Aside from applications in ISM, the partial gravity of Space is being explored as a potentially advantageous environment for additive manufacturing of premium goods, because of suspected benefits in crystallographic consistency, and therefore enhanced performance of certain products. The first step is to "space-optimize" material processing windows to account for gravity-mediated changes in sedimentation, rheology, crystallographic organization, and thermodynamics[24]. If successful, microgravity theoretically promotes the more uniform solidification of materials, which transforms the microstructure-dependent performance of space forged materials. However, the fabrication of high-fidelity optical ZBLAN fibers in 2017[25], for example, found less crystallization, resulting in reduced optical performance of the microgravity-manufactured product[26]. Nevertheless, platforms like the Turbine Ceramics Manufacturing Module (Turbine CMM) and the Turbine Superalloy Casting Module (Turbine SCM) for microgravity-based production of ceramics and metal alloys build on this work and explore microgravity similarly, as means to increase the microhardness of Space-made parts. Overall, the exploration of material processing in Space does not only serve the advancement of ISM, but translates discoveries back to improve terrestrial applications[27].

## Supplementary Display Items

**Table S4.** Qualitative comparison of biotic vs. abiotic *in situ* (bio)manufacturing approaches across different destinations in the Solar-system (excluding cislunar, which can be considered as an in-between of Earth Orbit and destination Moon).

| Destinations | | abiotic | biological |
|---|---|---|---|
| Earth Orbit[28] | advantage | in certain cases manufacturing in microgravity may yield a premium product | bioprinting without structural stabilization and scaffold-free tissue engineering |
| | | re-use/-purposing of infrastructure on-orbit for strategic reduction of up-mass | more extensive recycling allows for tighter loop-closure |
| | drawback | no *in situ* resource utilization possible | no *in situ* resource utilization possible |
| | | in many cases ability to re-supply outweighs infrastructure-investment | in many cases ability to re-supply outweighs infrastructure-investment |
| | | microgravity makes certain processes more difficult | microgravity makes aqueous processes challenging |
| Lunar[29] | advantage | strategic outpost for infrastructure as stepping stone to the solar system | allows resources to be exploit that are not accessible otherwise |
| | | gravity, may allow certain processes to be adopted more readily | gravity, allows gas/liquid separation → operation of aqueous processes |
| | | may in some cases save mass/cost of re-supply | may in some cases expand mission capabilities |
| | drawback | limited portfolio and amount/density of available resources | resources are limited and processes are largely dependent on abiotic ISRU |
| | | ability to re-supply and delivery may often outweigh infrastructure investment | ability to re-supply and delivery may outweigh infrastructure investment |
| Interplanetary[30] | advantage | re-supply not feasible → recycling and loop-closure compulsory | increased redundancy through flexibility: can allow *ad hoc* solution of complex incidental problems |
| | | systems proven in LEO are readily transferable/adaptable | may allow more complete loop-closure and recycling |
| | drawback | no *in situ* resources available (only recycling/production from stock) | no *in situ* resources available (only recycling/production from stock) |
| | | microgravity makes certain processes more difficult | microgravity makes aqueous processes challenging |
| Martian[31] | advantage | no supply-chain, just-in-time response not feasible → ISRU, LC and ISM compulsory | especially suited to leverage the available *in situ* resources to expand capabilities |
| | | | allows resources to be exploit that are not accessible otherwise |
| | | gravity, may allow certain processes to be adopted more readily | gravity, allows gas/liquid separation → operation of aqueous processes |
| | drawback | high infrastructure investment | high maintenance |
| | | not as resilient | more susceptible to drift |

**a**

| Scenario | A | B | C | D | E |
|---|---|---|---|---|---|
| Length [days] | 180 | 540 | 180 | 540 | 5400 |
| Loc | Moon | Mars | Moon | Mars | Mars |
| N [trips] | 1 | 1 | 30 | 10 | 1 |
| $V_{Eq}$ [kg/m³] | 126 | 117 | 126 | 117 | 117 |
| $P_{Eq}$ [kg/kW] | 136 | 162 | 136 | 162 | 162 |
| $C_{Eq}$ [kg/kW] | 55.4 | 96 | 55.4 | 96 | 96 |
| $CT_{Eq}$ [kg/hr] | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 |
| $L_{Eq}$ [kg/kg] | 7.2 | 30 | 7.2 | 30 | 30 |

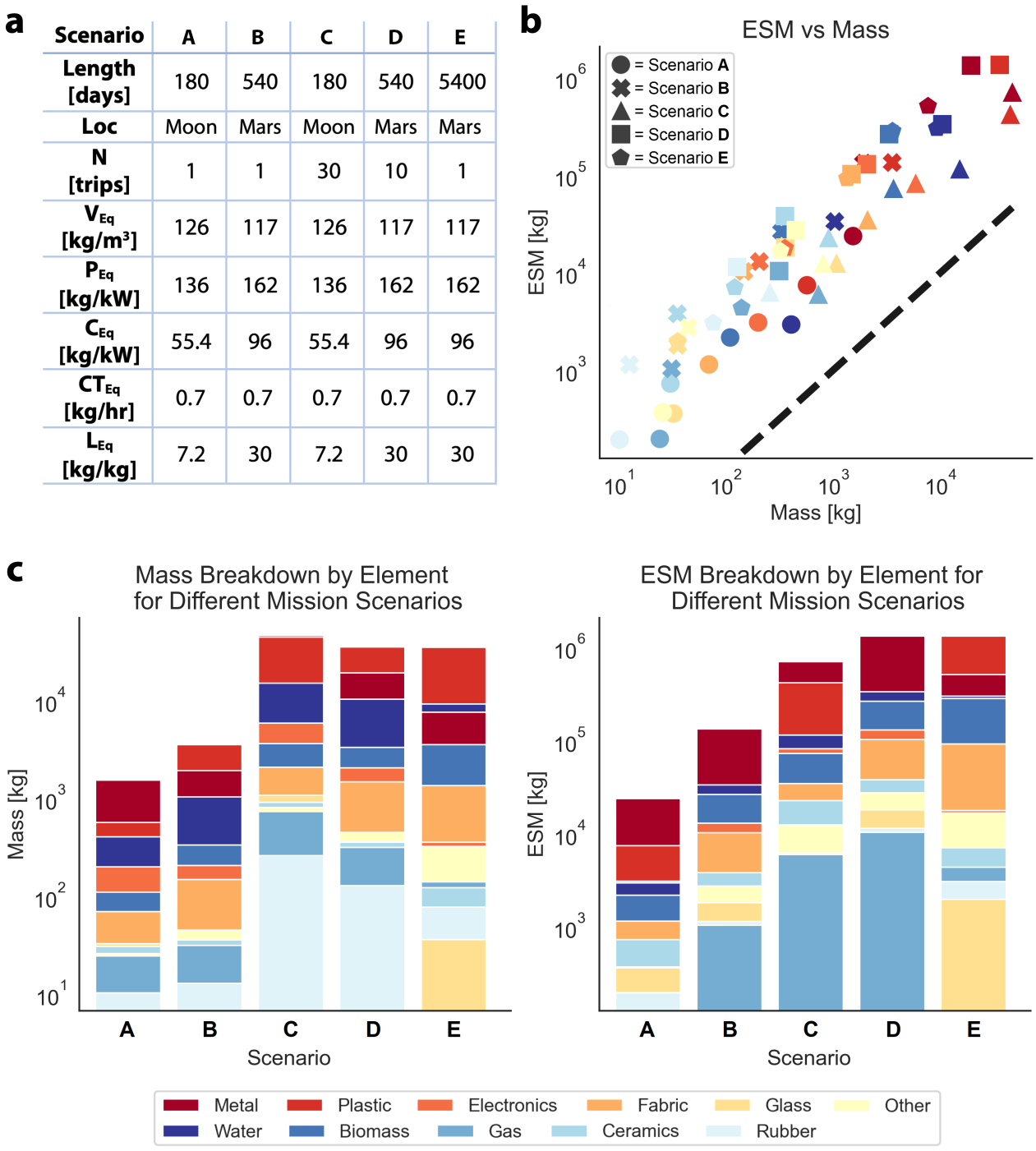


**Figure S1. Alternate visualization of scenario-dependent inventory-breakdown.** The parameter description of exemplar mission-design scenarios is given in panel **a**: scenarios 'A' and 'B' correspond to single sorties ($N$) to the Moon and Mars respectively using standard surface-operation duration[4], while scenarios 'C' and 'D' correspond to multi-sortie campaigns with the same (total) 5,400 days of surface operation as for scenario 'E'. These parameters can be used to calculate the ESM cost and include equivalency factors for Volume ($V_{eq}$), Power ($P_{eq}$), Cooling ($C_{eq}$), Crew-Time ($CT_{eq}$), and Location ($L_{eq}$). A comparison of ESM and carry-along mass (both in kg) is presented in the scatter-plot **b**; the dotted line represents a 1:1 correspondence between ESM and carry-along mass to show the trade-offs in systems grouped by element in terms of non-standard mass components (volume, power, etc.) contributing to cost as compared to only mass. Color-coding of **b** corresponds to the bar-charts in **c**, where the carry-along and ESM are broken down by material-composition. Note that the carry-along and/or ESM for each scenario are plotted on a log scale. The maximum visible edge of each bar in a stack represents the corresponding component's carry-along or ESM value.

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