Benchmarking ALSSAT with ALiSSE : Aligning Life Support System Optimization with Ecosystem Efficiency

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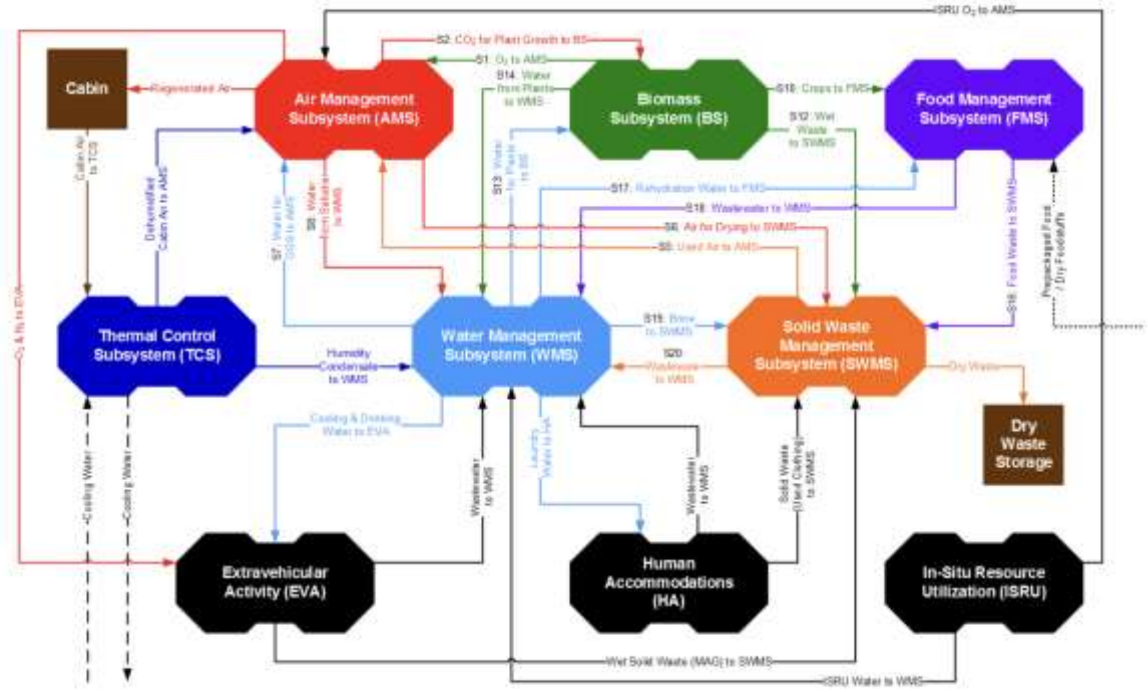
Overview

- What is NASA's Advanced Life Support Sizing Analysis Tool?
- Use of Advanced Life Support System Evaluator Evaluation Criteria
- Hypothesis
- Methodology
- Findings / Results
- Analysis / Conclusions
- Open Questions & Next Steps

NASA ALSSAT

- First developed by the Crew and Thermal Systems Division (CTSD) of Johnson Space Center (JSC) in 1997
- Updated by Lockheed Martin in 2005 and then by Barrios Technology and Hamilton Sundstrand (now part of Collins Aerospace) again in 2012.
- Helpful for preliminary ECLSS design, developing trade studies, and analyzing system tradeoffs.



Overall ALSSAT Mass Balance — From User's Guide for the ALSSAT (NASA/TM-2017-219287)

1997
CTSD initial Development

2005
Lockheed Martin adds food, solid waste, and thermal control subsystems

2012
Barrios & HS upgrade entire ALS database, CO2 calculations, and cabin air & and food subsystem.

ALiSSE Criteria

- Advanced Life Support System Evaluator (ALiSSE) defines seven key metrics to evaluate and compare life support system designs.
- Metrics capture the technical, operational, and ecological performance of closed-loop habitats, guiding trade-offs between resource use, safety, and autonomy.

ALiSSE Criteria

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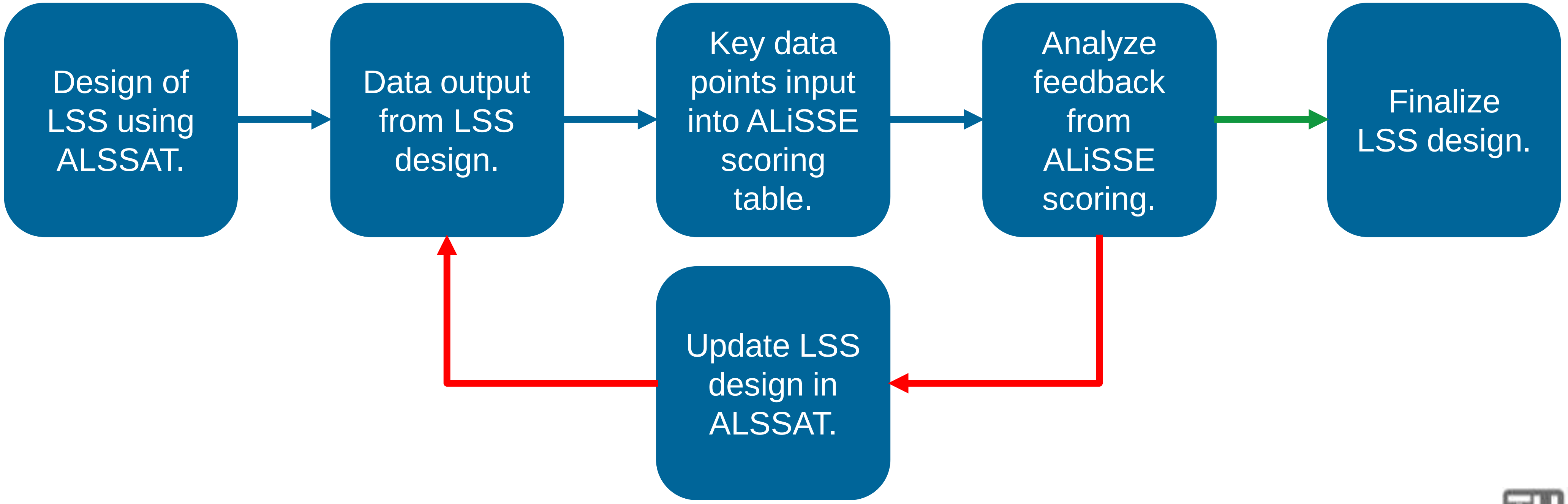
- Metrics capture the technical, operational, and ecological performance of closed-loop habitats, guiding trade-offs between resource use, safety, and autonomy.
- **Three values directly measured by ALSSAT—two partially measured.**

Hypothesis

Incorporating the ALiSSE evaluation criteria as benchmarking metrics during conceptual mission design will yield measurably different optimization outcomes — favoring higher ecological closure and system resilience even when ESM increases slightly.

Methodology

- Designed a sample mission in ALSSAT.
- Nonplanetary; Crew of (4); Mission duration of (180) days
- No docking pressurization and (2) cabin repressurizations.
- Sized LSS based on criteria and evaluated with ALiSSE scoring table.



Findings – ALSSAT Snapshot

CDS		Case #1	Case 1		(Sample cas)			
ALS SUBSYSTEMS								
	Tech./Data	**Mass (kg)**	**Vol(m^3)**	**Power (W)**	**Cooling (W)**	**Crewtime, MMH/Dur**	**ESM (NCT), kg**	**ESM (CT), kg**
Air		1,139.87	2.38	2,769.84	2,213.93	6.51	3,334.38	3,338.94
Biomass		0.00	0.00	0.00	0.00	0.00	0.00	0.00
Food		1,269.68	3.49	10.00	10.00	0.00	1,510.46	1,510.46
Waste		318.11	3.21	783.84	643.55	209.59	1,113.84	1,260.56
SolWC	Urinal & Commode	216.24	1.75	241.00	241.00	29.59	526.02	546.73
SWPS		101.87	1.46	542.84	402.55	180.00	587.82	713.82
SWTP	PWMC+ALS_Store	101.87	1.46	542.84	402.55	180.00	587.82	713.82
SWPS_Tankage		0.00	0.00	0.00			0.00	0.00
MCV							0.00	0.00
Process_Control		0.00	0.00	0.00	0.00		0.00	0.00
PQM		0.00	0.00	0.00			0.00	0.00
SPD		0.00	0.00	0.00	0.00		0.00	0.00
Water		1,000.84	3.27	676.02	676.02	0.00	1,759.88	1,759.88
Thermal		397.75	0.90	3,156.69	3,156.69	0.99	2,982.54	2,983.23
Total 6 ALS Subsystems		4,126.24	13.25	7,396.38	6,700.19	217.09	10,701.11	10,853.07
EXTERNAL INTERFACES								
	Tech./Data	**Mass (kg)**	**Vol (m^3)**	**Power (W)**	**Cooling (W)**	**Crewtime, MMH/Dur**	**ESM (NCT), kg**	**ESM (CT), kg**
Extravehicular Activities		130.35	0.49	20.83	20.83	0.00	179.72	179.72
Human Accommodations		407.66	0.95	0.00	0.00	0.00	470.97	470.97
Total External Interfaces		538.01	1.44	20.83	20.83	0.00	650.69	650.69
ADDL. CONTINGENCY								
Total addl. contingency (not included above)		68.76	0.19	10.00	10.00	0.00	89.57	89.57
Total ALS Subsystems & Ext. Interfaces (w/Contingency)		4,733.01	14.88	7,427.22	6,731.03	217.09	11,441.36	11,593.32
Total ALS Subsystems & Ext. Interfaces (w/out Contingency)		4,664.25	14.69	7,417.22	6,721.03	217.09	11,351.80	11,503.76

Findings – ALiSSE Scorecard

- Applied a priority weighting towards directly measured values (e.g., Mass 30 %, Energy 25 %, Crew 25 %) and deprioritized value to partially measured values (e.g. Efficiency 10 %, Sustainability 10%)

Metric	Raw Value	Units	Lower Better?	Min (Baseline)	Max (Benchmark)	Weight	Normalized Value (0–1)	Weighted Score
Mass	4733.01	kg	Yes	3000	6000	0.3	0.422	0.127
Energy & Power	14.16	kW	Yes	8	18	0.25	0.384	0.096
Crew Time	217.09	hr	Yes	100	300	0.25	0.415	0.104
Efficiency	85	%	No	70	95	0.1	0.600	0.060
Sustainability	80	%	No	60	90	0.1	0.667	0.067
Composite Score	0.453003167						**AVG: 0.498**	

- N = (X - Min) / (Max - Min); (When a higher value is better)
- N = 1 - (X-Min) / (Max - Min); (When a lower value is better)
- Weighted score: $N_i \times w_i$
- Composite score: $\sum (N_i \times w_i)$ = 0.50

Findings – ALSSAT Snapshot II

CDS		Case #1	Case 1		(Sample cas)			
ALS SUBSYSTEMS								
	Tech./Data	Mass (kg)	Vol(m^3)	Power (W)	Cooling (W)	Crewtime, MMH/Dur	ESM (NCT), kg	ESM (CT), kg
Air		1,139.87	2.38	2,769.84	2,213.93	6.51	3,334.38	3,338.94
Biomass		0.00	0.00	0.00	0.00	0.00	0.00	0.00
Food		1,269.68	3.49	10.00	10.00	0.00	1,510.46	1,510.46
Waste		318.11	3.21	783.84	643.55	209.59	1,113.84	1,260.56
SolWC	Urinal & Commode	216.24	1.75	241.00	241.00	29.59	526.02	546.73
SWPS		101.87	1.46	542.84	402.55	180.00	587.82	713.82
SWTP	PWMC+ALS_Store	101.87	1.46	542.84	402.55	180.00	587.82	713.82
SWPS_Tankage		0.00	0.00	0.00			0.00	0.00
MCV							0.00	0.00
Process_Control		0.00	0.00	0.00	0.00		0.00	0.00
PQM		0.00	0.00	0.00			0.00	0.00
SPD		0.00	0.00	0.00	0.00		0.00	0.00
Water		1,000.84	3.27	676.02	676.02	0.00	1,759.88	1,759.88
Thermal		397.75	0.90	3,156.69	3,156.69	0.99	2,982.54	2,983.23
Total 6 ALS Subsystems		3,300.99	10.60	5,917.11	5,360.15	288.72	8,560.89	8,682.45
EXTERNAL INTERFACES								
	Tech./Data	Mass (kg)	Vol (m^3)	Power (W)	Cooling (W)	Crewtime, MMH/Dur	ESM (NCT), kg	ESM (CT), kg
Extravehicular Activities		130.35	0.49	20.83	20.83	0.00	179.72	179.72
Human Accommodations		407.66	0.95	0.00	0.00	0.00	470.97	470.97
Total External Interfaces		538.01	1.44	20.83	20.83	0.00	650.69	650.69
ADDL. CONTINGENCY								
Total addl. contingency (not included above)		68.76	0.19	10.00	10.00	0.00	89.57	89.57
Total ALS Subsystems & Ext. Interfaces (w/Contingency)		3,907.76	12.23	5,947.94	5,390.99	288.72	9,301.14	9,422.71
Total ALS Subsystems & Ext. Interfaces (w/out Contingency)		3,839.00	12.04	5,937.94	5,380.99	288.72	9,211.58	9,333.15

Findings – ALiSSE Scorecard II

- Reduction of crew from 4 to 3; mission days from 180 to 240.
- Energy and mass savings closer to 20%.
- Crew time increase tradeoff with less ESM and energy requirement.

Metric	Raw Value	Units	Lower Better?	Min (Baseline)	Max (Benchmark)	Weight	Normalized Value (0–1)	Weighted Score
Mass	3300.99	kg	Yes	3000	6000	0.3	0.700	0.210
Energy & Power	11.34	kW	Yes	8	18	0.25	0.670	0.168
Crew Time	288.72	hr	Yes	100	300	0.25	0.060	0.015
Efficiency	85	%	No	70	95	0.1	0.600	0.060
Sustainability	80	%	No	60	90	0.1	0.667	0.067
Composite Score	0.453003167						**AVG: 0.539**	

- N = (X - Min) / (Max - Min); (When a higher value is better)
- N = 1 - (X-Min) / (Max - Min); (When a lower value is better)
- Weighted score: $N_i \times w_i$
- Composite score: $\sum (N_i \times w_i) = 0.50$

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Analysis / Conclusions

- ALiSSE evaluation criteria can yield measurably different optimization outcomes. Very reliant on scoring mechanism used, mission priorities, and availability of confirmable data.
- While the updated mission would be less ideal from ESM benchmark, ALiSSE helped to highlight areas of optimization.
- Mass and Energy carried more weight for nonplanetary mission. Could vary for planetary missions (e.g. Risk and Efficiency).
- Missions where crew number less flexible may require other optimization techniques.
- ALSSAT used in early-stage mission design. Ideal time to evaluate alternative benchmarks for LSS design.

Open Questions

- Dynamic modeling & resource utilization.
- In-situ resource utilization.
- Mars Missions (longer travel distance, increased risk, what are changeable variables).

Thank You!

Questions?

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