Towards Forecasting Resource Consumption In Mars Analog Simulations

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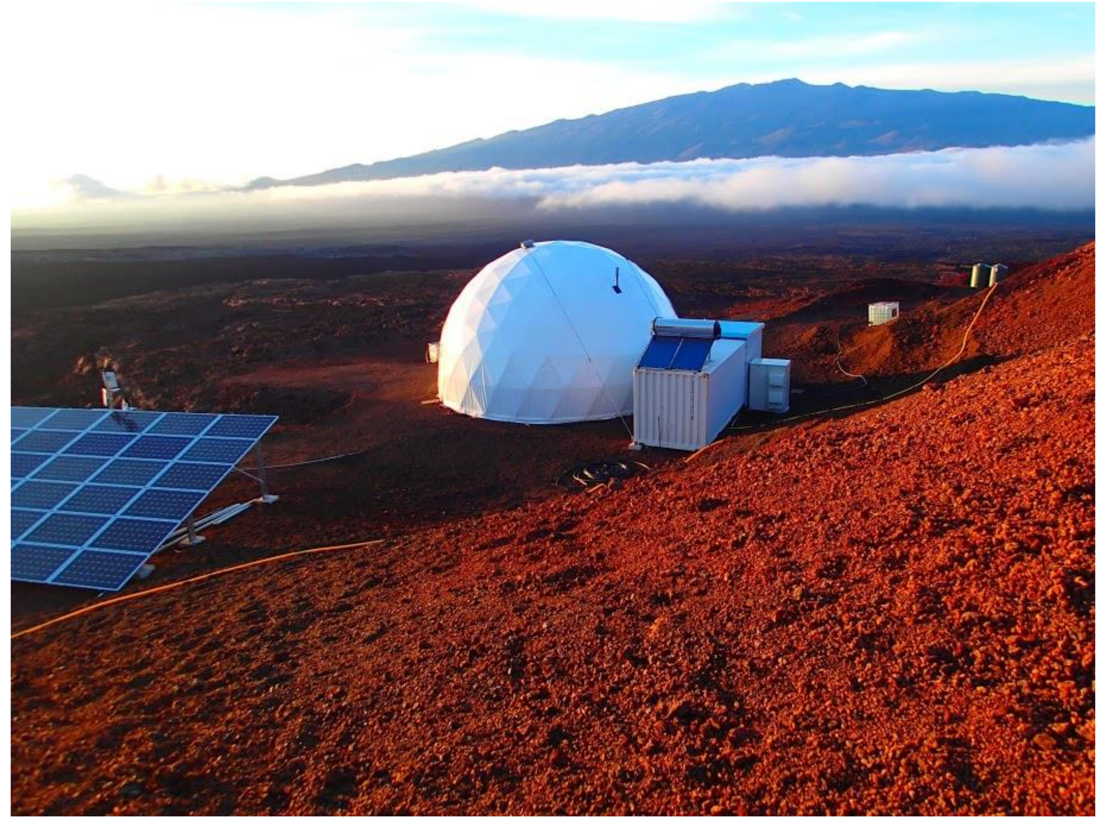
INTRODUCTION

The NASA funded Hawaii Space Exploration Analog and Simulation (HI-SEAS) is a planetary surface exploration analog site at ~8,500 feet on the Mauna Loa side of the saddle area on the Big Island of Hawaii. The second 120 day mission is currently underway with six astronaut-like crew members (in terms of education, experience, and attitude) living under Mars exploration conditions. Mission three and four will be 248 and 365 days, respectively, and will be carried out in the next two years. **[1]**



Above: The HI-SEAS Habitat at ~8,500ft elevation on the slopes of Mauna Loa, housing a six-person crew with ~1,000ft² of living space.

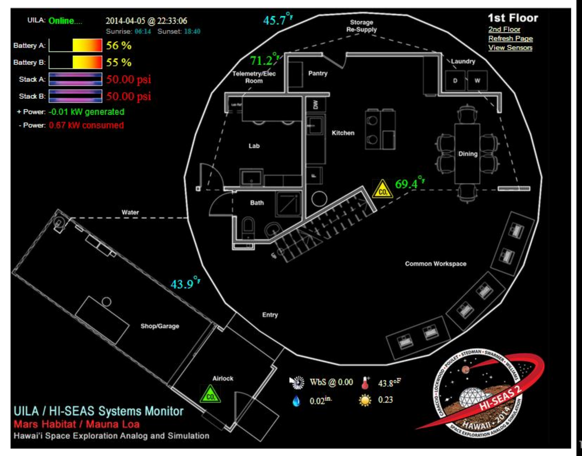
MONITORING HABITAT RESOURCES

Energy and water consumption is monitored during the analog mission and this data will give a picture of what resources may be required for exploration or colonization on other planetary bodies. Mars missions could last as long as 2-½ years with no potential for resupply. **[2]** Due to this restriction, consumption must be monitored, controlled, and forecasted with a degree of high accuracy. This research investigates data from current and previous Mars analog mission crew consumption rates to construct predictory models. These models are used to predict crew consumption rates and allow for changes in crew schedules and behavior. Utilizing machine learning, the habitat water and appliance usage was modeled with the frequency and power consumption of each system. This information will aide in forecasting consumption rates of future missions with great accuracy.

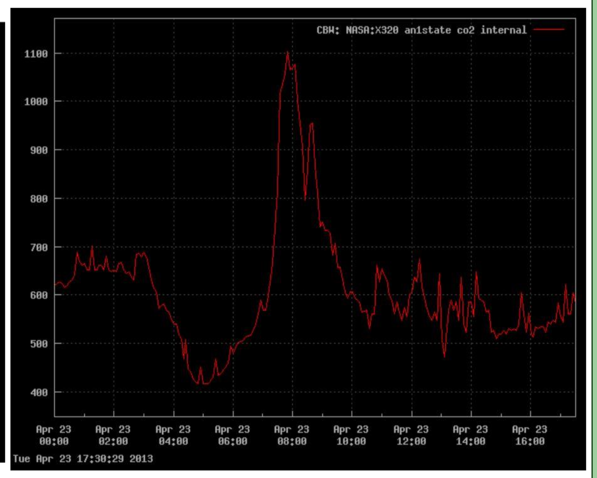
Above: Solar panels during HI-SEAS Mission 2.

HABITAT TELEMTRY SYSTEM

The HI-SEAS habitat system was outfitted with a sensor telemetry routing system. A ControlByWeb X-320 web interface was utilized to control and collect sensor information and distribute to a remote location. The X-319 is an Ethernet I/O module with four digital inputs that allows for support of up to four temperature and humidity sensors. Using this technology, the habitat power and utility consumption was monitored.



Left: Crew User Interface of the state of the habitat.



Right: 24-hour read out of CO2 level sensor in the habitat.

CREW CONSUMPTION RATES

The following table shows the average individual consumption rates for crew members over a four month mission. This data was collected on Flashline Mars Arctic Research Station (FMARS in 2009) where SOL is one day on Earth. **[3]**

	AVERAGE CREW PERSONAL WATER CONSUMPTION (mL)					
	Drinking	Food	Hand/Face	Shower	Oral	Shaving
Sol1	2113	983	1013	71	429	0
Sol2	5296	446	871	2633	608	0
Sol3	2588	650	604	504	567	0
Sol4	3013	596	679	1596	313	0
Sol5	3571	875	1008	975	300	75
S0l6	2917	1129	1063	1317	579	121
Sol7	2450	642	783	421	421	75
Sol8	3958	917	967	363	417	0
Sol9	3475	1375	1204	1571	646	0
Sol10	2758	883	688	513	483	0
Sol11	2546	896	667	1304	754	0
Sol12	3396	346	1058	863	729	17
Ave	3173	811	884	1011	520	24
Std Dev	855	290	195	717	151	42

Table 1: : Average crew personal water consumption collected over a period of 12 days on FMARS 2009. [3]

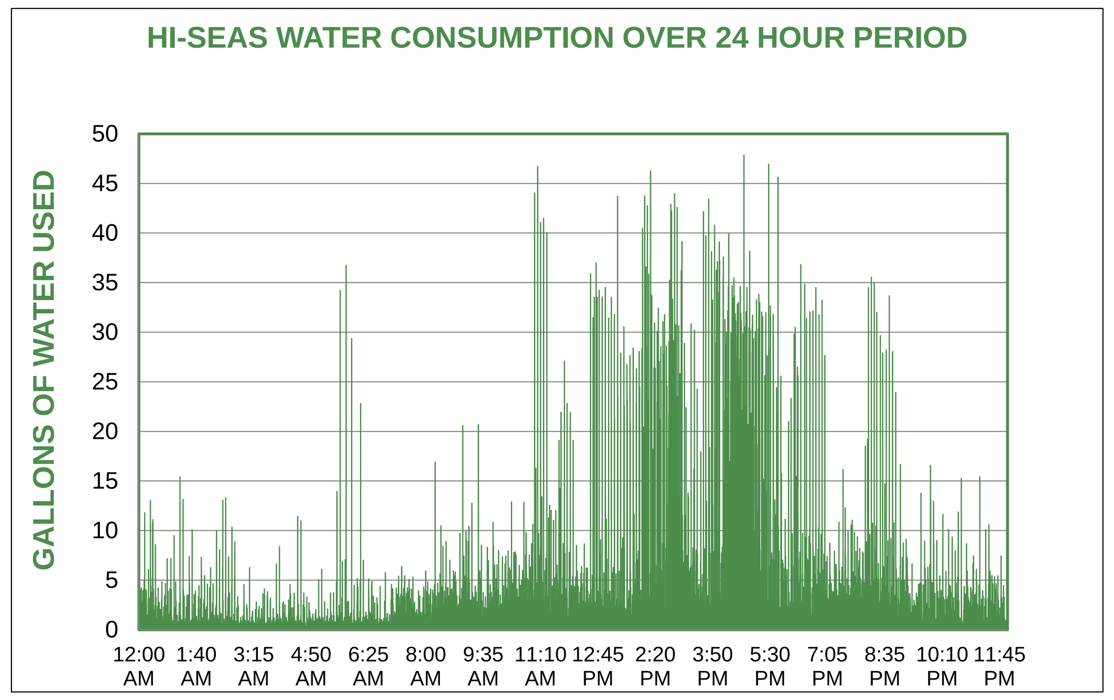
The following data shows the average time crew members spent using various electrical appliances during the analog simulation for a one week period. This translates into KW depending on the electrical efficiency of the appliance and time in operation.

	Minutes in Operation Per Day [min.sec]						
Appliance	M	T	W	R	F	Sat	Sun
Washing Machine	90	0	0	0	90	135	225
Dryer	30	0	0	0	60	30	60
Microwave	6.45	16.3	11.15	10	9	8	11.3
Induction Cooker	50	10	65	70	105	213	15
Hot water maker	30	36	42	48	42	30	3
Coffee Pot	10	10	10	10	10	10	1
Bread Maker	210	0	70	0	4	0	0
Rice Cooker	0	0	0	25	294	0	0
Yogurt Maker	0	0	0	0	0	0	0
Toaster	0	0	0	0	0	0	0
Electric mixer	15	0	0	0	5	0	0
Toaster Oven	60	30	38	0	50	0	0
Mini Fridge	24	24	24	24	24	24	24
	6/23/2014	6/24/2014	6/18/2014	6/19/2014	6/20/2014	6/21/2014	6/22/2014

Table 2: Crew appliance usage collected over one week on HI-SEAS 2 in 2014. .

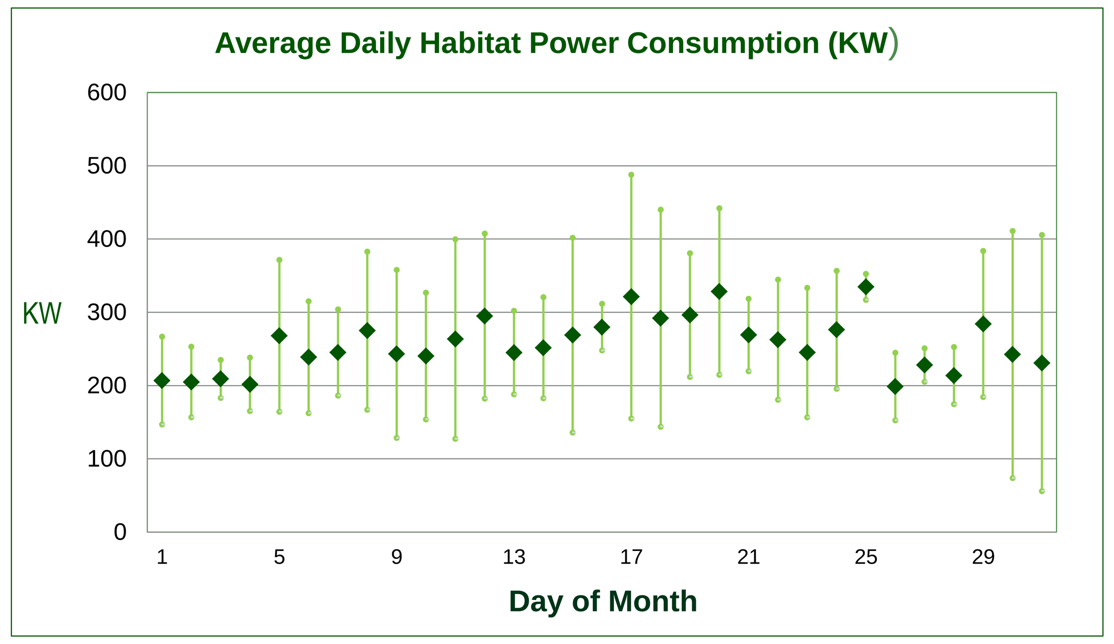
HABITAT DAILIY RESOURCE CONSUMPTION

The following tables show a 24-hour average consumption rate of the crew over a four month mission for both electrical and water resources.



Water consumption measured every 5 minutes over a 24 hour period during the HI-SEAS 1 Mission.

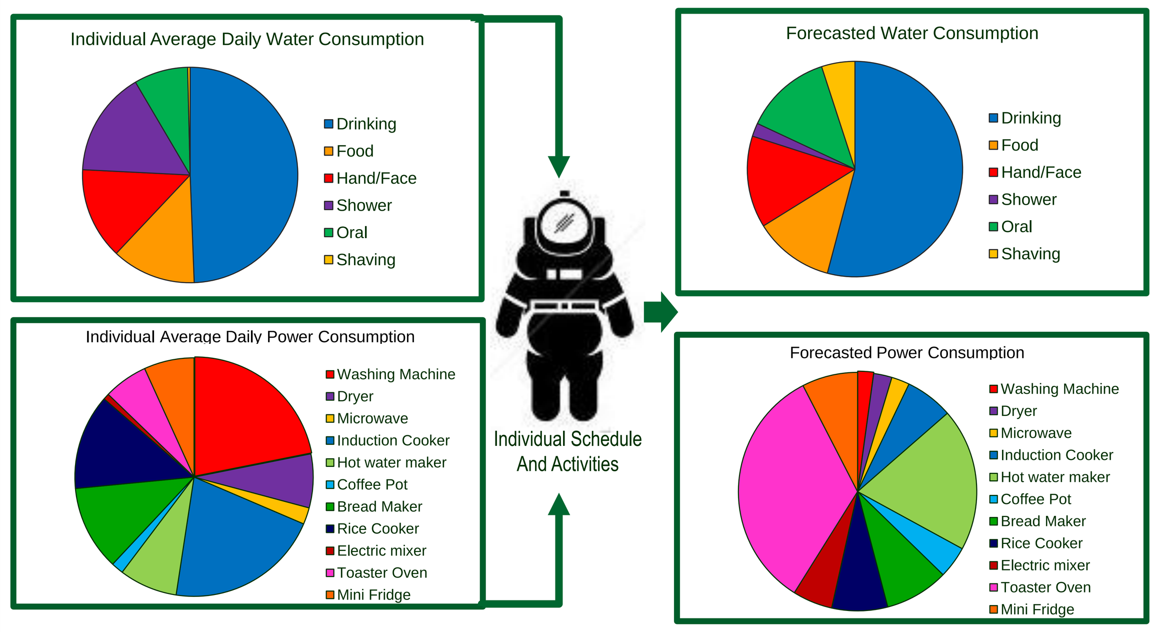
To support a Mars mission, we must be able to accurately forecast weeks to months in advance allowing for the crew to modify and adapt to new resource consumption situations.



Above: Average total power consumption in the habitat during HI-SEAS 1. Note the large standard deviation in daily consumption despite a routine living environment..

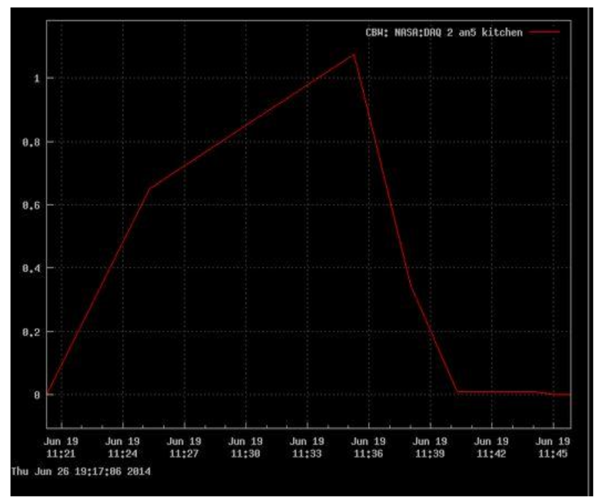
SIMULATION OF CREW CONSUMPTION

Utilizing data presented in Tables 1 and 2, a model of crew activities is constructed and used as information in the simulation. Additionally the crew schedule and personal activities are uploaded to the simulation on a daily basis. This allows the simulation to adapt for changes in activities. With such a small system, major changes in activities by just one crew member can have a major influence on resources for that day.



FAST UPDATING RESOURCES FOR FORECASTING

The habitat has six breakers that are monitored for power consumption in kilo-watts (KW). Using machine learning, crew activities can be identified through the KW profile of an appliance being used over time. To accomplish this, KW profiles of each appliance are captured and then taught to the computer. Non-intrusive appliance load monitoring (NIALM), break down readings of power usage of the habitat and identify individual appliances.**[4]** Given X observed data, and missing values Z with unknown values ϴ, the likelihood L is found iteratively by a conditional distribution ZX given X under the estimate of parameters. The parameter that maximizes this quantity is then found. **[4]**



$$L(\boldsymbol{\theta};\mathbf{X}) = p(\mathbf{X}|\boldsymbol{\theta}) = \sum_{\mathbf{Z}} p(\mathbf{X},\mathbf{Z}|\boldsymbol{\theta})$$

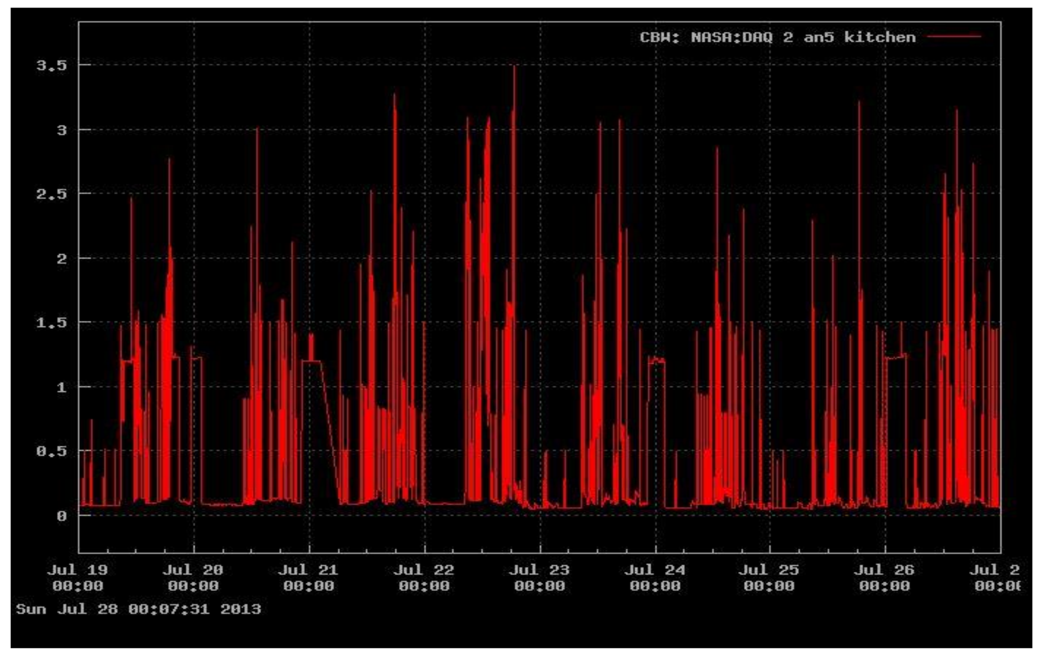
$$Q(\boldsymbol{\theta}|\boldsymbol{\theta}^{(t)}) = \operatorname{E}_{\mathbf{Z}|\mathbf{X},\boldsymbol{\theta}^{(t)}}\left[\log L(\boldsymbol{\theta};\mathbf{X},\mathbf{Z})\right]$$

$$\boldsymbol{\theta}^{(t+1)} = \underset{\boldsymbol{\theta}}{\arg\max}\ Q(\boldsymbol{\theta}|\boldsymbol{\theta}^{(t)})$$

Left: KW Profile of Induction burner turned on for a period of 15 minutes from HI-SEAS 2

Right: Maximum likelihood Estimate (MLE) algorithm

The usage and power consumption of each appliance can be identified within minutes of use and uploaded to the forecasting model. Allowing the forecasting model to adapt to developing changes in the habitat within minutes.



Kilowatt profile of Kitchen power over a 7 day period from HI-SEAS 2. Appliance KW profiles are extracted from this data and identified.

FUTURE WORK

The crew consumption simulation model, system will be implemented in the habitat to log the crew activities. Crew will be able to change and inform the computer of their intensions with ease. The crew simulation model will be combined with methods of monitoring and identifying appliances. The combination of these two models will be the foundation of the forecasting model, which will be the next stage of development.

REFERENCES

[1] Planetary Habitat Systems Monitoring On a Mars Analog Mission. Engler, S.T., Abrimov O., Leung H., Binsted K., Wiekling B. 100 Year Starship 2013 Public Symposium Conference Proceedings Pg. 537 – 552

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