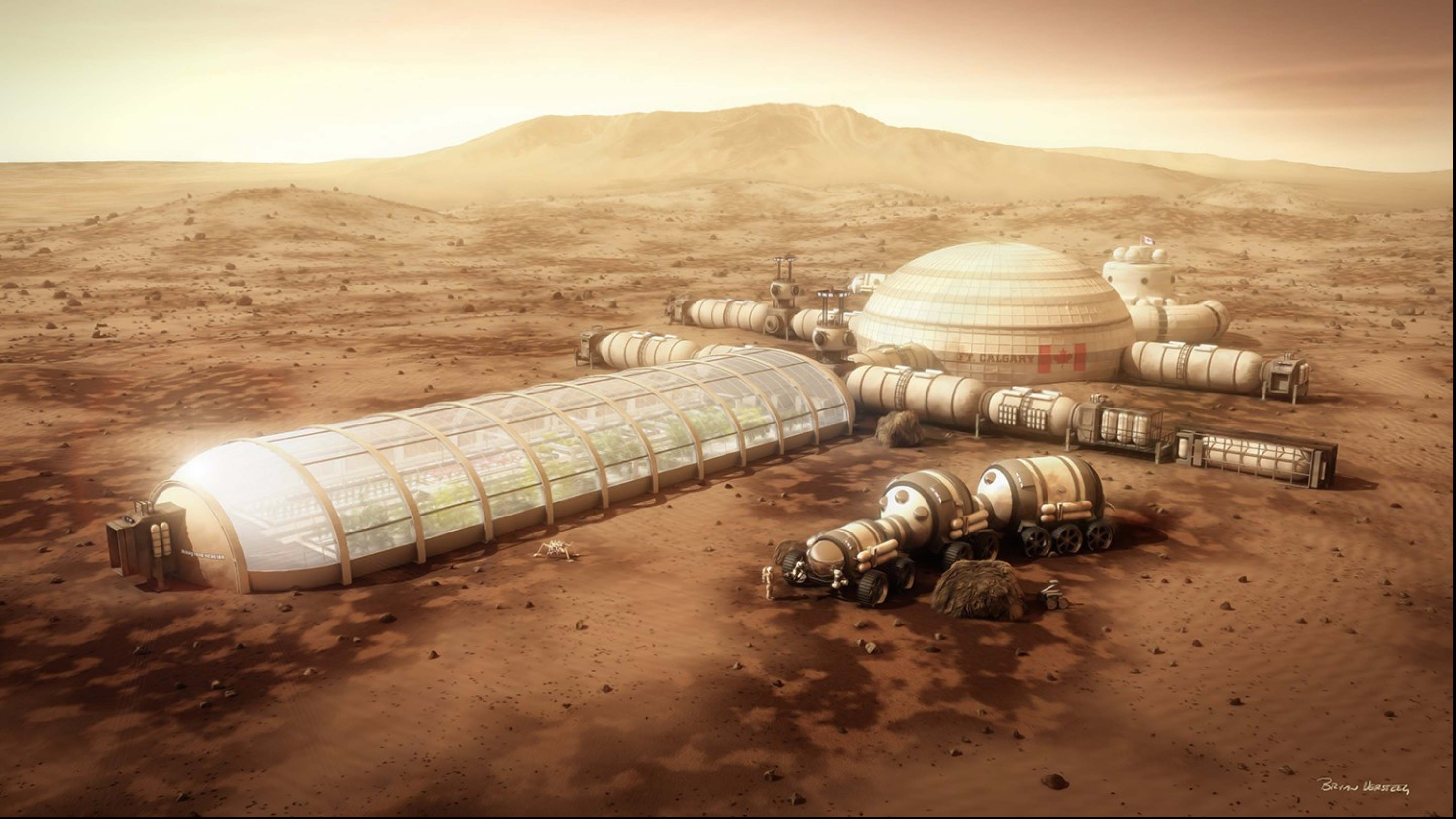
Becoming Interplanetary

An exploration of long-term, off-world habitation with SIMOC and SAM

Kai Staats, MSc

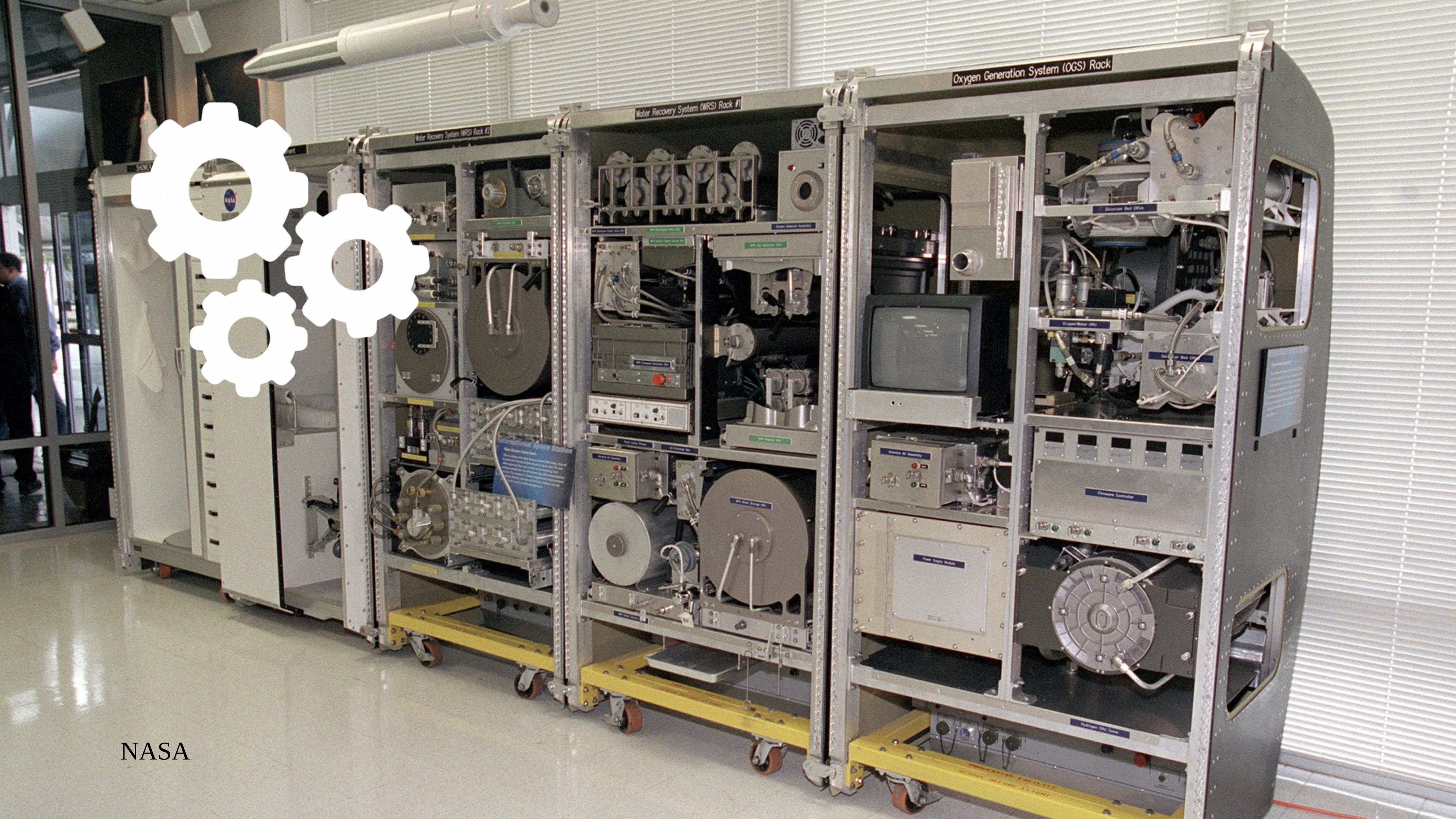
Mars Society Convention
October 17, 2020


FT. CALGARY
Bryan Versteeg

How do we sustain human life
in hostile, off-world environments?

ECLSS

Environmental Control and
Life Support System

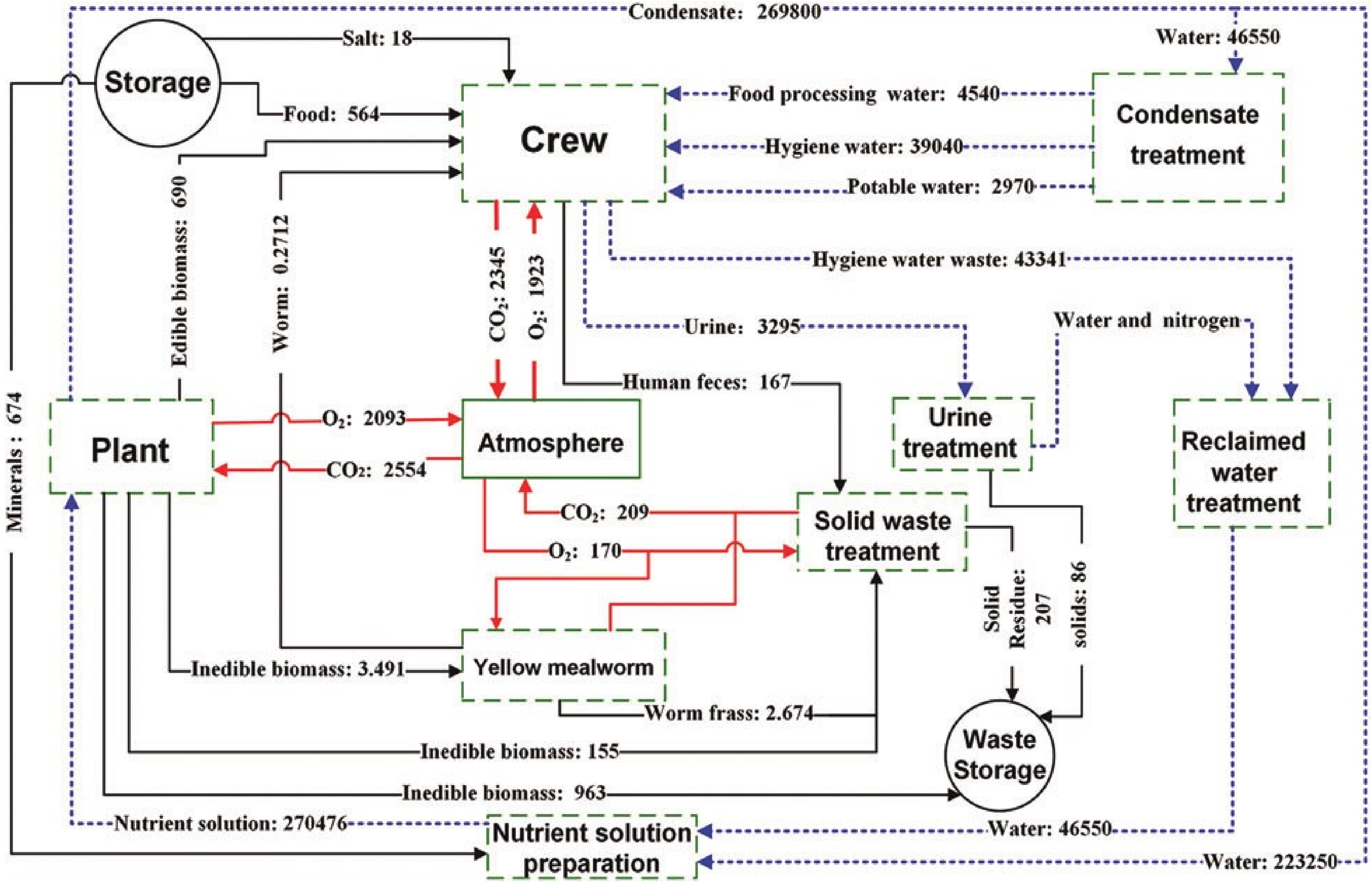

Oxygen Generation System (OGS) Rack
Water Recovery System (WRS) Rack #1
Water Recovery System (WRS) Rack #2

NASA


Biosphere 2


Lunar Palace

Lunar Palace System Flow



SIMOC

A scalable, interactive model of an off-world community

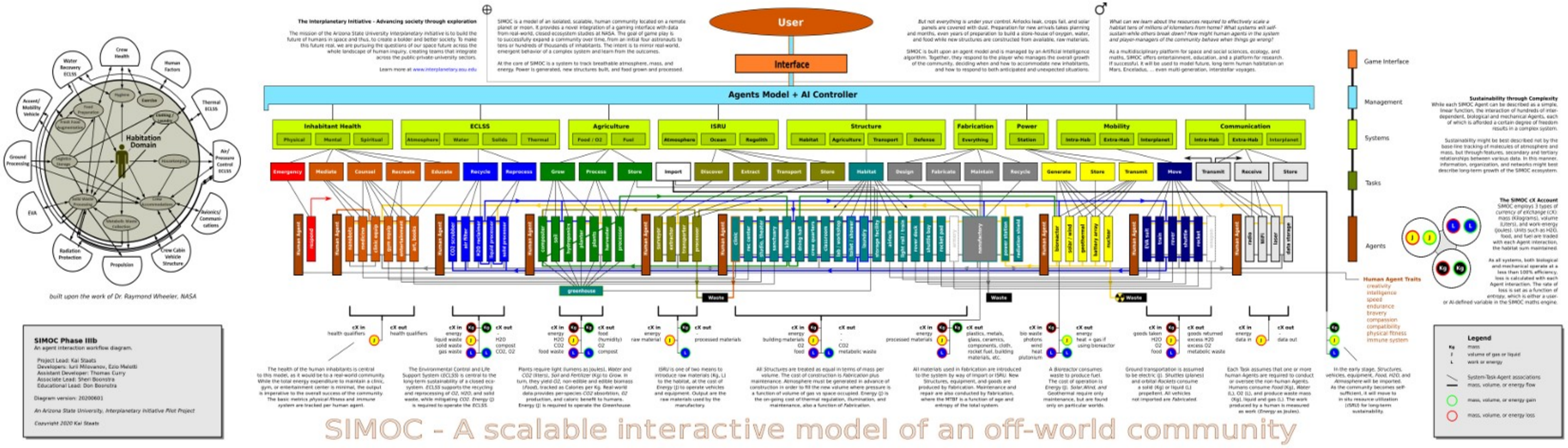
Agents

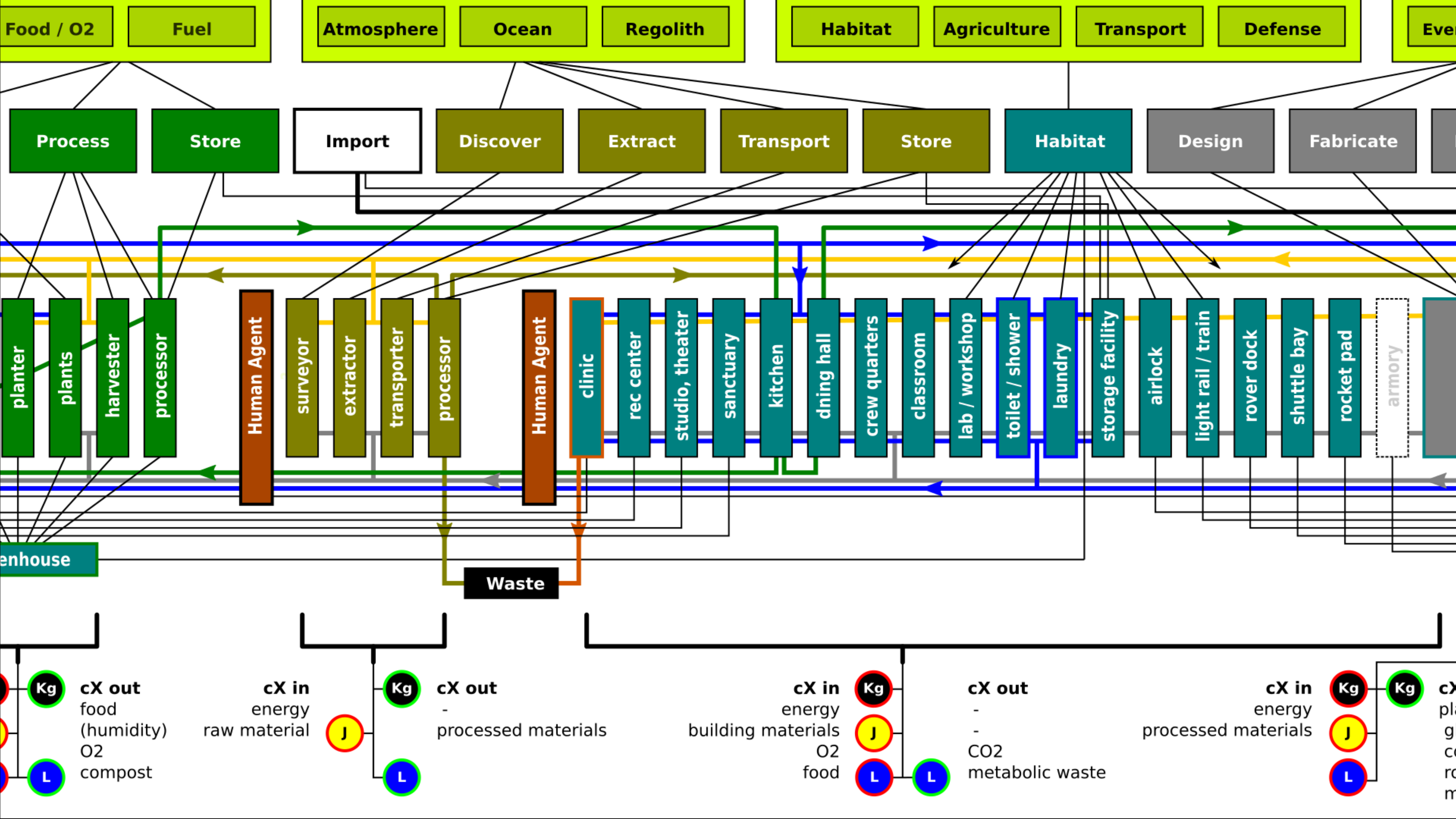
ECLSS systems, plants, humans, solar panels, habitat structures, equipment, vehicles, etc.

Currencies of Exchange

O_2, CO_2, HC_4, and H_2O vapor, potable, waste, and treated; edible and non-edible plant biomass; potassium, phosphorus, nitrogen, and kWh (power), etc. ...

SIMOC Agent Interaction Diagam





Food / O2
Fuel
Atmosphere
Ocean
Regolith
Habitat
Agriculture
Transport
Defense
Process
Store
Import
Discover
Extract
Transport
Store
Habitat
Design
Fabricate
planter
plants
harvester
processor
Human Agent
surveyor
extractor
transporter
processor
Human Agent
clinic
rec center
studio, theater
sanctuary
kitchen
dning hall
crew quarters
classroom
lab / workshop
toilet / shower
laundry
storage facility
airlock
light rail / train
rover dock
shuttle bay
rocket pad
armory
Waste
Kg
J
L
cX out
food
(humidity)
O2
compost
cX in
energy
raw material
cX out
-
processed materials
cX in
energy
building materials
O2
food
cX out
-
-
CO2
metabolic waste
cX in
energy
processed materials

HUMAN INHABITANTS

All values are per agent, built from NASA's *Human Integration and Design* handbook (2017)

In from Storage:

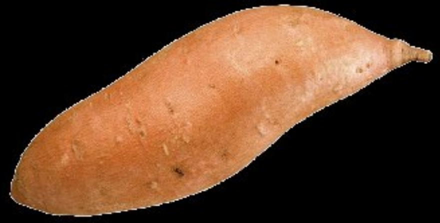
- + 0.021583 kg/hr atmo_o2* 21% nominal at 14.7 psi
- + 0.083333 kg/hr h2o_potb* 2.0 kg / day drink, plus (was 2.5 with food hydration)
- + 0.0825 kg/hr h2o_potb 1.98 kg / day hygiene + urine flush
- + 0.062917 kg/hr food_edbl 1.5 kg / day [includes rehydration; add nutrition in Phase IV]

* remove agent if it has not drank water in 3 days, or not eaten in 21 days

Out to Storage:

- - 0.025916 kg/hr atmo_co2 0.622 kg / day respiration
- - 0.079167 kg/hr atmo_h2o 1.9 kg / day respiration + perspiration
- - 0.0625 kg/hr h2o_urin** 1.5 kg urine
- - 0.087083 kg/hr h2o_wste 2.09 kg wastewater balances all inputs/outputs (was 2.59)
- - 120W per hour heat_cal [Phase IV thermal load]; temp value

** an agent will not urinate if it has not drank, nor defecate if it has not eaten



Safeway

Table of Plant Growth

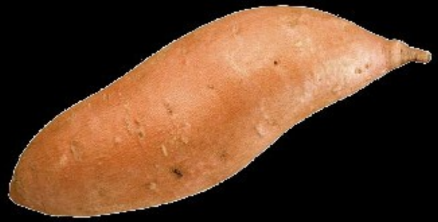
Crop	Category	Light *	Period	Growth **	Grams / hr	Total	Edible	sold_n	sold_p	sold_k	h2o_potb	atmo_o2	atmo_co2
Rice	cereal grain	0.2300870147	12	85	1.2595833333	2569.55	770.95	-0.0206755062	-0.0003270886	-0.002466768	-7.9341666667	1.1201294643	-1.5399905754
Wheat	cereal grain	0.8018183846	22	79	2.0833333333	3950	1580	-0.034197	-0.000541	-0.00408	-11.25	1.8526785714	-2.547123016
Cabbage	leafy green	0.1952253458	24	85	0.2804166667	572.05	515.1	-0.0098276438	-0.0003632356	-0.0027380959	-0.2529166667	0.2752949011	-0.3777302131
Chard	leafy green	0.1185296743	16	45	0.44875	484.65	315	-0.0157271507	-0.0002493329	-0.001878111	-1.4133333333	0.440553653	-0.6044805936
Celery	leafy green	0.1185296743	24	75	0.4783333333	861	774.75	-0.0167639452	-0.0002657699	-0.0020019233	-0.43	0.4695966514	-0.6443302892
Lettuce	leafy green	0.1185296743	16	28	0.3041666667	204.4	183.96	-0.01066	-0.000169	-0.001273	-0.27375	0.2986111111	-0.4097222222
Spinach	leafy green	0.1185296743	16	30	0.3041666667	219	197.1	-0.01066	-0.000169	-0.001273	-0.27375	0.2986111111	-0.4097222222
Dry Bean	legume	0.1673360107	18	85	1.0416666667	2125	850	-0.0300195313	-0.0005058594	-0.0038085938	-5.625	1.5010127315	-2.0616319444
Peanut	legume	0.188253012	12	104	0.9379166667	2341.04	585.52	-0.0270295859	-0.0004554758	-0.0034292578	-6.3258333333	1.3515118634	-1.8562934028
Soybean	legume	0.1952253458	12	97	0.5333333333	1241.6	582	-0.01537	-0.000259	-0.00195	-2.5516666667	0.7685185185	-1.0555555556
Strawberry	fruit	0.1533913432	12	85	0.9270833333	1891.25	662.15	-0.0184122632	-0.0002913426	-0.0021961615	-5.4183333333	0.5763666242	-0.7907178481
Tomato	fruit	0.188253012	12	85	0.9654166667	1969.45	886.55	-0.019173579	-0.000303389	-0.002286969	-4.77875	0.6001984127	-0.823412698
Green Onion	vegetable	0.1812806783	24	50	0.4166666667	500	450	-0.0146027397	-0.0002315068	-0.0017438356	-0.375	0.4090563166	-0.5612633181
Onion	vegetable	0.1185296743	24	50	0.46875	562.5	450	-0.0164280822	-0.0002604452	-0.0019618151	-0.84375	0.4601883562	-0.6314212329
Pea	vegetable	0.1673360107	24	75	1.1179166667	2012.25	804.75	-0.0391791507	-0.0006211329	-0.004678711	-6.0375	1.0974980974	-1.5058694825
Pepper	vegetable	0.188253012	24	85	0.9654166667	1969.45	886.55	-0.0338345479	-0.0005364014	-0.0040404671	-4.7775	0.9477834855	-1.3004471081
Snap Bean	vegetable	0.1673360107	18	85	1.2375	2524.5	1009.8	-0.043370137	-0.0006875753	-0.0051791918	-6.6825	1.2148972603	-1.6669520548
Radish	root vegetable	0.1812806783	16	25	0.4583333333	275	137.5	-0.0091026919	-0.0001440346	-0.0010857428	-2.0625	0.5393177194	-0.7452059028
Red Beet	root vegetable	0.1185296743	16	38	0.4166666667	380	247	-0.0082751745	-0.0001309405	-0.0009870389	-1.3125	0.4902888358	-0.6774599116
Carrot	root vegetable	0.1952253458	24	75	0.62375	1122.75	673.5	-0.0123879362	-0.0001960179	-0.0014775972	-2.245	[illegible]	[illegible]
Sweet Potato	root vegetable	0.1952253458	12	85	1.5625	3187.5	1275	-0.031031904	-0.000491027	-0.003701396	-8.437		
White Potato	root vegetable	0.1952253458	12	132	1.25375	3971.88	2779.9	-0.0249	-0.000394	-0.00297	-3.384166666		

Wheeler, NASA

Cabbage
Total: 572g
Edible: 515g
O_2: +0.275g
CO_2: -0.377g

Strawberry
Total: 1891g
Edible: 662g
O_2: +0.576g
CO_2: -0.790g

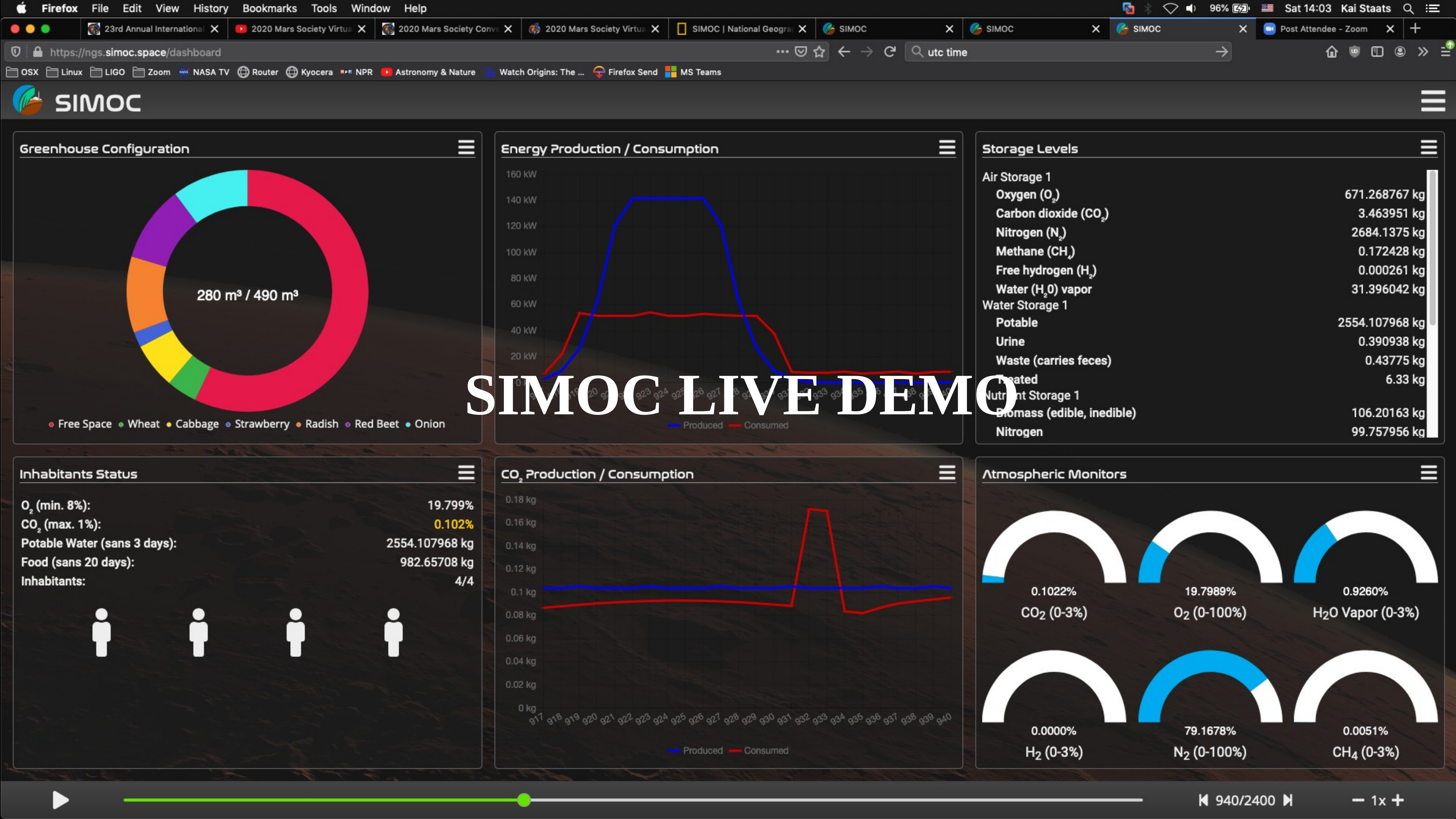
Wheat
Total: 3950g
Edible: 1580g
O_2: +1.852g
CO_2: -2.547g



Sweet Potato
Total: 3187g
Edible: 1275g
O_2: +1.838g
CO_2: -2.540g

Tomato
Total: 1969g
Edible: 886g
O_2: +0.600g
CO_2: -0.823g

Green Onion
Total: 500g
Edible: 450g
O_2: +0.409g
CO_2: -0.561g


SIMOC LIVE DEMO
https://ngs.simoc.space/dashboard
SIMOC
Greenhouse Configuration
280 m³ / 490 m³
Free Space
Wheat
Cabbage
Strawberry
Radish
Red Beet
Onion
Energy Production / Consumption
160 kW
140 kW
120 kW
100 kW
80 kW
60 kW
40 kW
20 kW
Produced
Consumed
Storage Levels
Air Storage 1
Oxygen (O2) 671.268767 kg
Carbon dioxide (CO2) 3.463951 kg
Nitrogen (N2) 2684.1375 kg
Methane (CH4) 0.172428 kg
Free hydrogen (H2) 0.000261 kg
Water (H20) vapor 31.396042 kg
Water Storage 1
Potable 2554.107968 kg
Urine 0.390938 kg
Waste (carries feces) 0.43775 kg
6.33 kg
Nutrient Storage 1
106.20163 kg
Nitrogen 99.757956 kg
Inhabitants Status
O2 (min. 8%): 19.799%
CO2 (max. 1%): 0.102%
Potable Water (sans 3 days): 2554.107968 kg
Food (sans 20 days): 982.65708 kg
Inhabitants: 4/4
CO2 Production / Consumption
0.18 kg
0.16 kg
0.14 kg
0.12 kg
0.1 kg
0.08 kg
0.06 kg
0.04 kg
0.02 kg
0 kg
Produced
Consumed
Atmospheric Monitors
0.1022%
CO2 (0-3%)
19.7989%
O2 (0-100%)
0.9260%
H2O Vapor (0-3%)
0.0000%
H2 (0-3%)
79.1678%
N2 (0-100%)
0.0051%
CH4 (0-3%)
940/2400
1x

SIMOC – Scalable, Interactive Model of an Off-world Community

Grades: 9 - 14 Prep Time: ~30 Minutes Lesson Time: Varies Based on Project

Teacher Guide

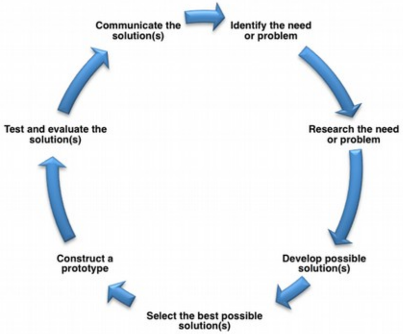
WHAT STUDENTS DO: Use the SIMOC model to develop a habitat to support life off-world.

Students work with a model using authentic data gathered from decades of NASA and other science research on life support systems to develop a habitat to support researchers on Mars or other off-world environments They will actively engage in creative critical thinking and iterative innovation through collaboration and persistence.

NGSS CORE & COMPONENT QUESTIONS	INSTRUCTIONAL OBJECTIVES
	Students will be able to:
How do engineers solve problems? *NGSS Core Question: ETS1: Engineering Design* What is a design for? What are the criteria and constraints of a successful solution? *NGSS ETS1.A: Defining & Delimiting an Engineering Problem* What is the process for developing potential design solutions? *NGSS ETS1.B: Developing Possible Solutions* How can the various proposed design solutions be compared and improved? *NGSS ETS1.C: Optimizing the Design Solution*	**IO1: Use and modify a model limited by criteria and constraints to solve a complex science and engineering problem**

(I) Engineering Design Cycle Defined

This diagram of the engineering cycle is a simplified version of what actually happens in an engineering task. The actual process is much more iterative, often going from later steps in the cycle and circling back to earlier steps as new information is gathered.



Identify the need or problem

- Specify and prioritize requirements and constraints to better define the need or problem

Research the need or problem

- Examine current state of the issue and current solutions
- Explore other options through resources (Ex: Internet, interviews, periodicals, etc.)
- Identify the constraints

Develop possible solution(s)

- Brainstorm possible solutions
- Draw on mathematics and science
- Explain or describe the possible solutions on paper, computer simulation, or 3D model
- Refine the possible solutions

Select the best possible solution(s)

- Determine, using simple analysis, which solution(s) best meet(s) the original requirements

Construct a prototype

- Model the selected solution(s) on paper, computer simulation, or 3D model

Test and evaluate the solution(s)

- Does it work?
- Does it meet the original design constraints?

Communicate the solution(s)

- Make an engineering presentation that includes a discussion of how the solution(s) best meet(s) the needs of the initial problem, opportunity, or need
- Discuss societal impact and tradeoffs of the solution(s)

Space Analog for the Moon and Mars

SAM @ Biosphere 2


NASA
HYGIENE MODUL
Segment B
Segment A
2
4

Wiki Biosphere 2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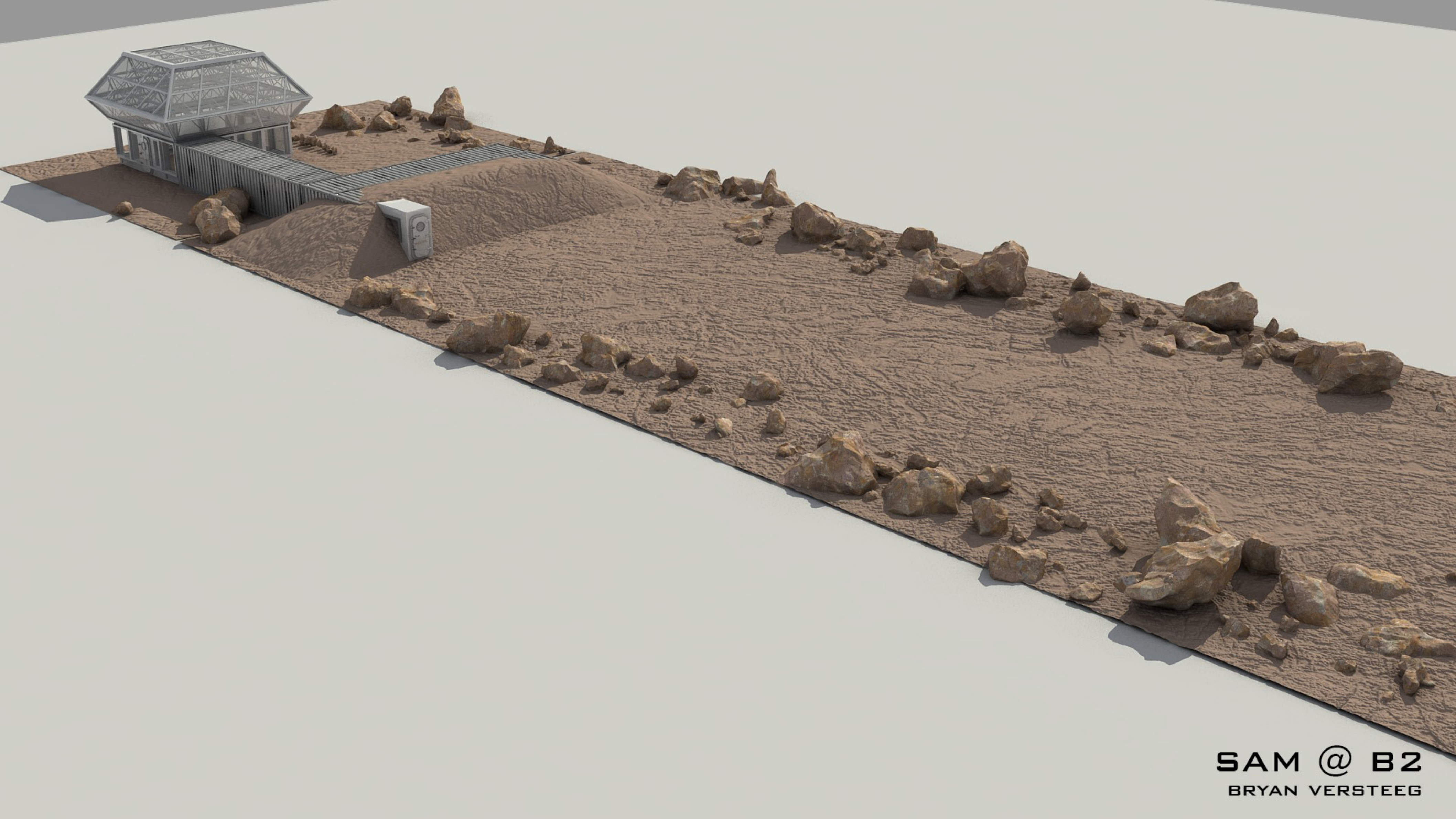

SAM @ B2
BRYAN VERSTEEG


SAM @ B2
BRYAN VERSTEEG

The principal **science** objectives at SAM:

1) Transition from **physicochemical** (machine-based) to **bioregeneration** (plant-based) life support systems.

2) Transform simulated **regolith to soil.**

3) A study of the **microbiome** of the built environment.

4) Test **pressurized suits** in entry, exit, and EVAs in a half-acre Mars yard complete with boulder field and lava tube.

5) Advanced computer models and **simulation.**

To **engage research** teams from around the world in hands-on **scientific discovery**, to **inspire** the next generation to be engaged **custodians** of this planet while **exploring** new worlds.


def repl_func():
print("Repl function")
return repl_func

Biosphere 2
THE UNIVERSITY OF ARIZONA

NATIONAL GEOGRAPHIC

NASA

CEAC
Controlled Environment Agriculture Center

PARAGON
SPACE DEVELOPMENT CORPORATION

ARIZONA
SCIENCE
CENTER

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