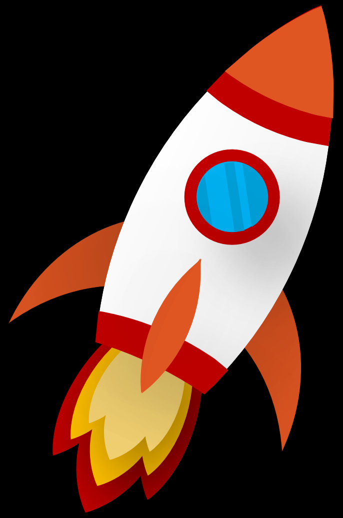
CHALLENGE 4:

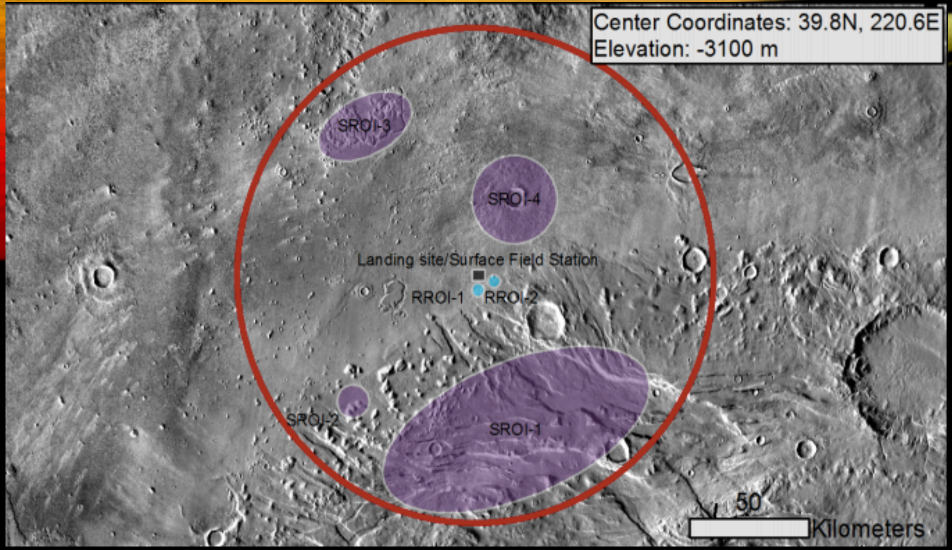
What if we lived on Mars?



OUTLINE

1. Introduction: Settling Assumptions
2. Initial Water Budget: Based on Research
3. Our Solution: Simulation
4. Simulation Results
5. Smart Water Management System: Enforcing the Water Budget

1 Introduction: Settling Assumptions



Map of Landing Site [1]

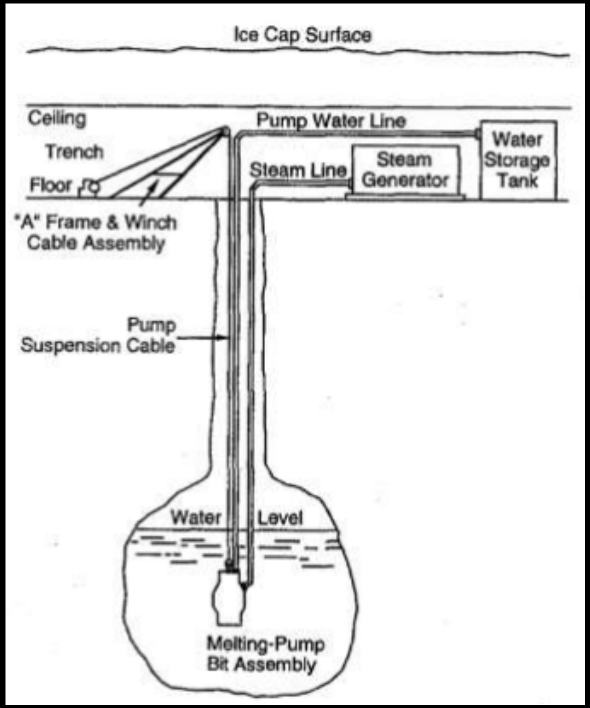
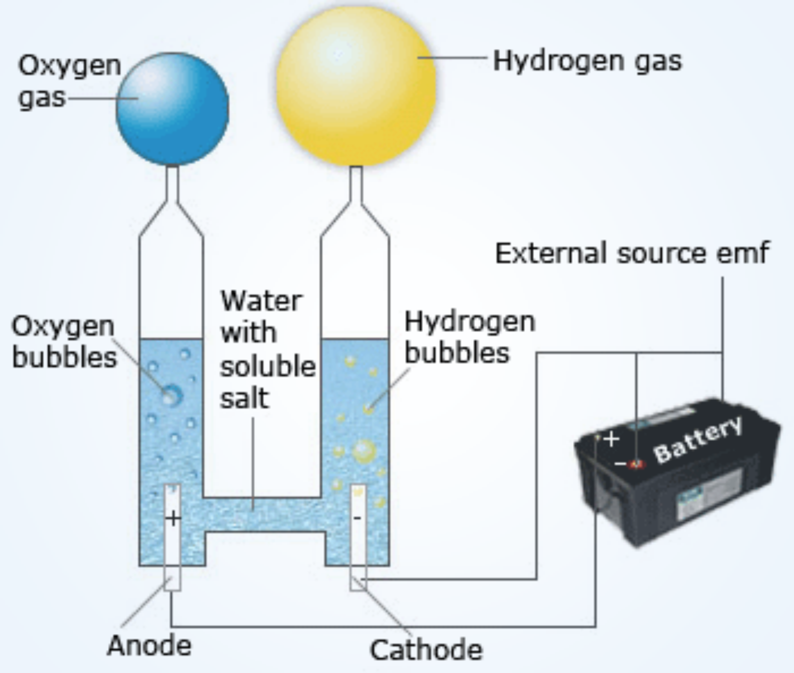
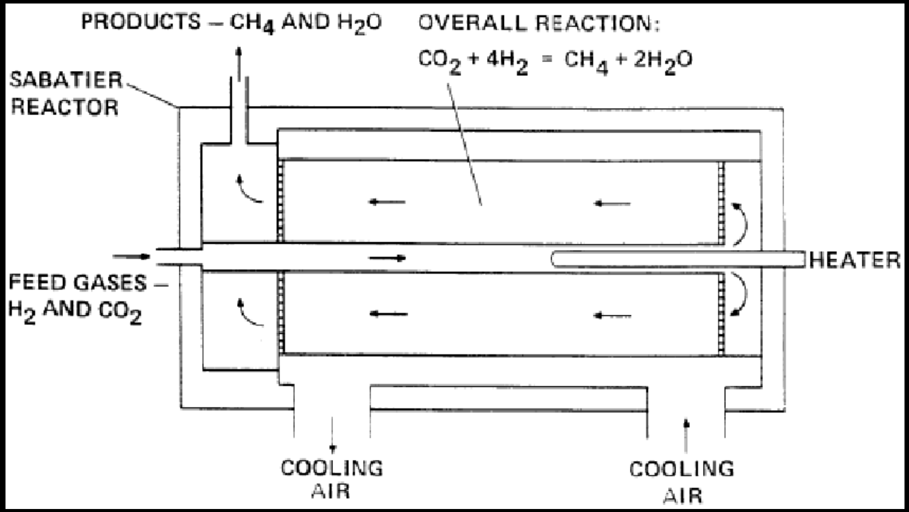


Diagram of Rodriguez Well [2]

- **Landing site:** 39.8N, 220.6E, Arcadia Planitia
- **Water Extraction Points:** RROI-1 and RROI-2 (Less than 3km away)
- **Method of Water Extraction**: Rodriguez Well
  - ➢ Water extracted only when required
  - ➢ Transported via heated pipeline to base
- **Initial Water Amount:** 84,000L
  - ➢ 14 months of drinking supply for 100 colonists (2kg per colonist per day [3])
- **Reserve Tank:** 4,860L stored at base
  - ➢ 30 days of drinking supply for 100 colonists [4]



Electrolysis of Water [5]

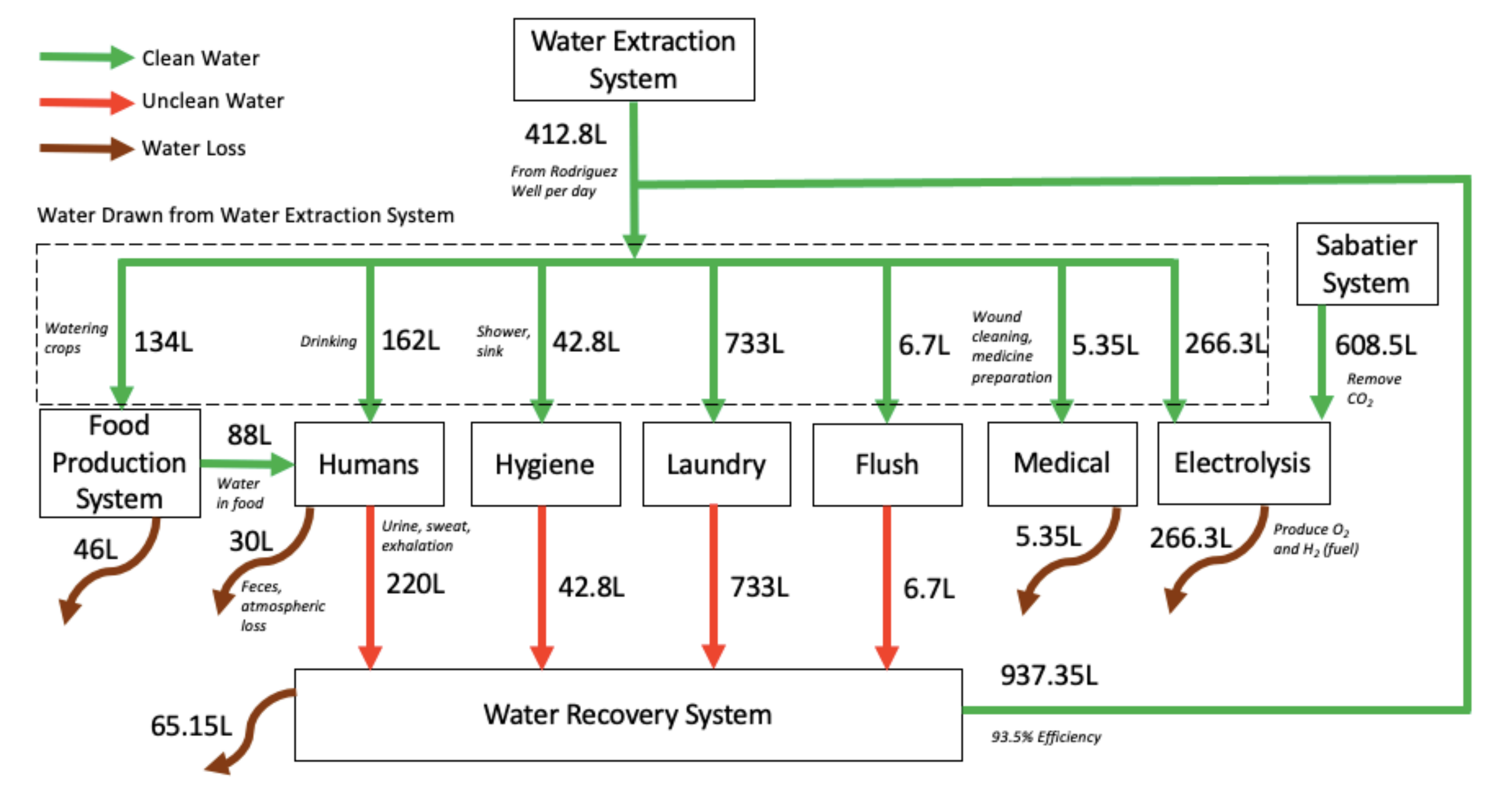


Sabatier System Diagram [6]

1 Introduction: Settling Assumptions

- **Water Recovery System:** 93.5% efficiency [7]
  - ➢ Input: urine, condensate, shower & sink wastewater, flush & laundry wastewater
  - ➢ For simplicity, overall input considered
- **Atmosphere Management:**
  - ➢ Electrolysis of water used for O_2 production (and H_2 for fuel)
  - ➢ Sabatier System used for CO_2 removal
- **Timeline for Systems to be Functional:**
  - ➢ Water Extraction System: 6 months
  - ➢ Water Recovery System: 2 months
- **Electricity:** Generated via solar panels
  - ➢ Not a consideration in this project

2 Initial Water Budget: Based on Research

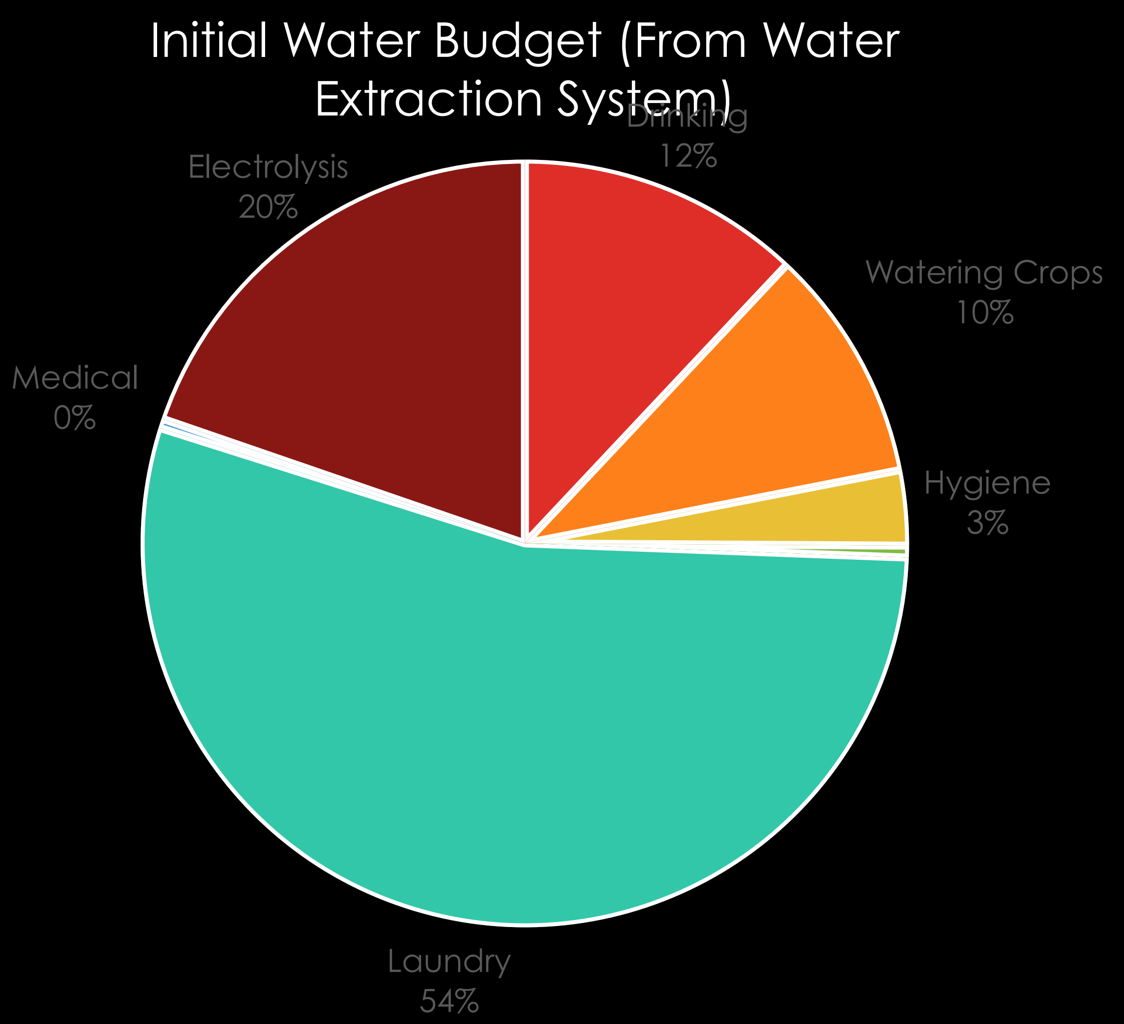


Flow of Water in Mars Habitat for 100 Colonists (per day)

② Initial Water Budget: Based on Research

Component	Water In (kg) per day	Water out (kg) per day	Net water gain of component (excluding recycled) (kg)
Humans	162 (Drinking) 88 (Crops)	220 (Urine, Sweat, Exhalation)	-30
Food Production System	134 (Water Crops)	88 (Ate by humans)	-46
Water Production System		412.8	+412.8
Hygiene	42.8 (Sink + Shower)	42.8 (Wastewater)	
Flush	6.7	6.7 (Wastewater)	
Laundry	733	733 (Wastewater)	
Medical	5.35		-5.35
Water Recycling System	1002.5	937.35	-65.15
Electrolysis	874.8		-874.8
CO2 Removal System		608.5	+608.5
TOTAL			0

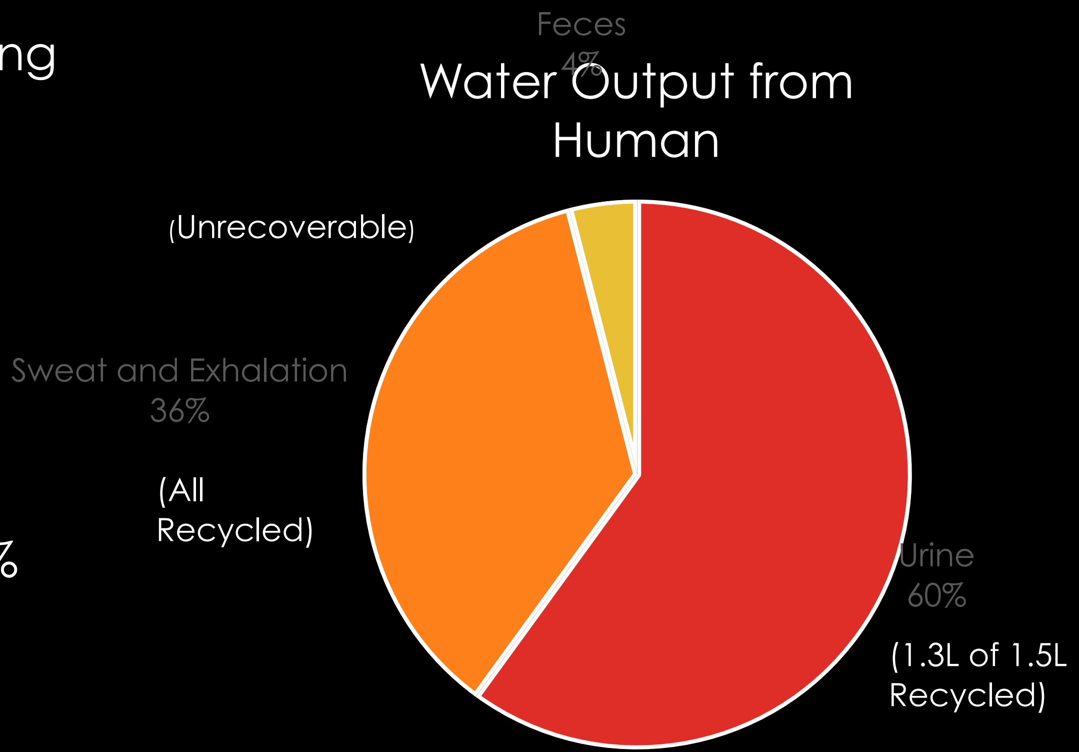
Initial Water Budget by Component



② Initial Water Budget: Based on Research

Components

- **Humans:**
  - ➢ For each person, 1.62L water consumed by drinking and 0.88L consumed through food per day [8]
  - ➢ Out of 2.5L input, 1.5L excreted in urine, 0.1L excreted in feces, 0.9L excreted via sweat and exhalation [9]
- **Food Production System:**
  - ➢ Vegetables have an average water footprint of 1.34L per kilocalorie [10]
  - ➢ Average adult require 2 kilocalories per day [11]
  - ➢ Hydroponic lettuce production have shown to utilize 75% less water [12], hence we assume a 50% reduction of water footprint for crop growing on Mars
  - ➢ Water required per day = 1.34*2*100*0.5 = 134L



2

Initial Water Budget: Based on Research

Components

- **Hygiene:**
  - ➢ Sink and shower
  - ➢ 42.8L per day for 100 colonists* [2]
- **Flush:**
  - ➢ 6.7L per day for 100 colonists* [2]
- **Laundry:**
  - ➢ 733L per day for 100 colonists* [2]

Wastewater Recycled

- **Medical:**
  - ➢ Wound cleaning and medicine preparation
  - ➢ 5.35L per day for 100 colonists* [2]

Unrecoverable

* Values were calculated based on extrapolation from a 500-day 4-crew Mars Mission [2]

2 Initial Water Budget: Based on Research

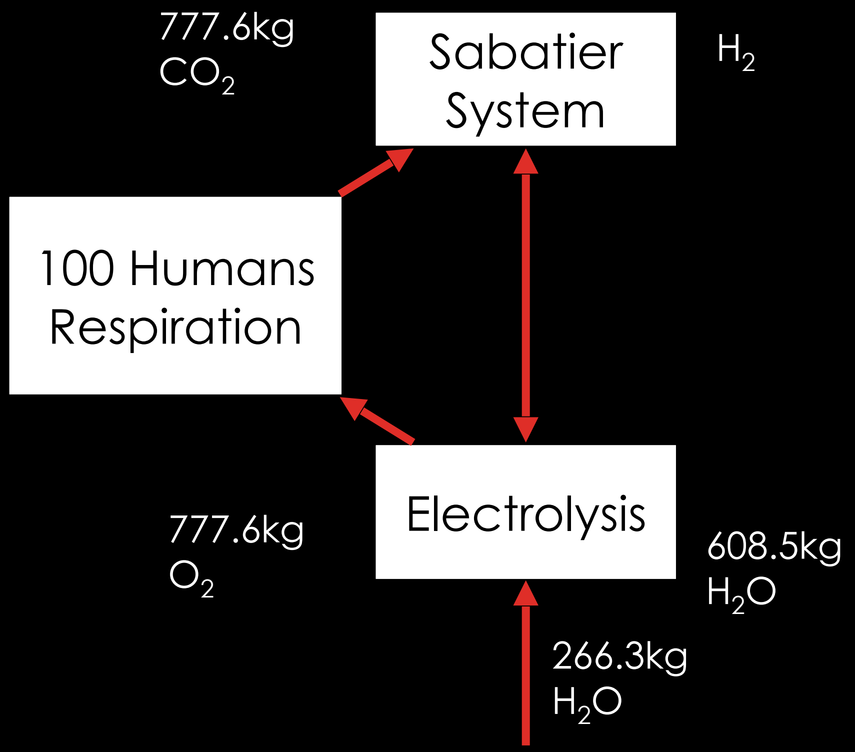
Components

- **Electrolysis:**
  - ➢ $H_2O \rightarrow H_2 + O_2$
  - ➢ H_2 used for fuel for vehicular expeditions/feed for Sabatier System
  - ➢ 5.4g* of O_2 allows 1 person to breathe for 10 minutes [13]
  - ➢ For 100 colonists, 777.6kg O_2 required per day which requires 874.8L water input feed
- **Sabatier System:**
  - ➢ $CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$
  - ➢ For 777.6kg CO_2 removed per day, 608.5L water produced per day
  - ➢ Water output feed directly connected to electrolysis input feed**

*g refers to weight on Earth

** In our simulation, Sabatier System not considered due to this reason

Simplified Interaction between Respiration, Sabatier System and Electrolysis



3 Our Solution: Simulation

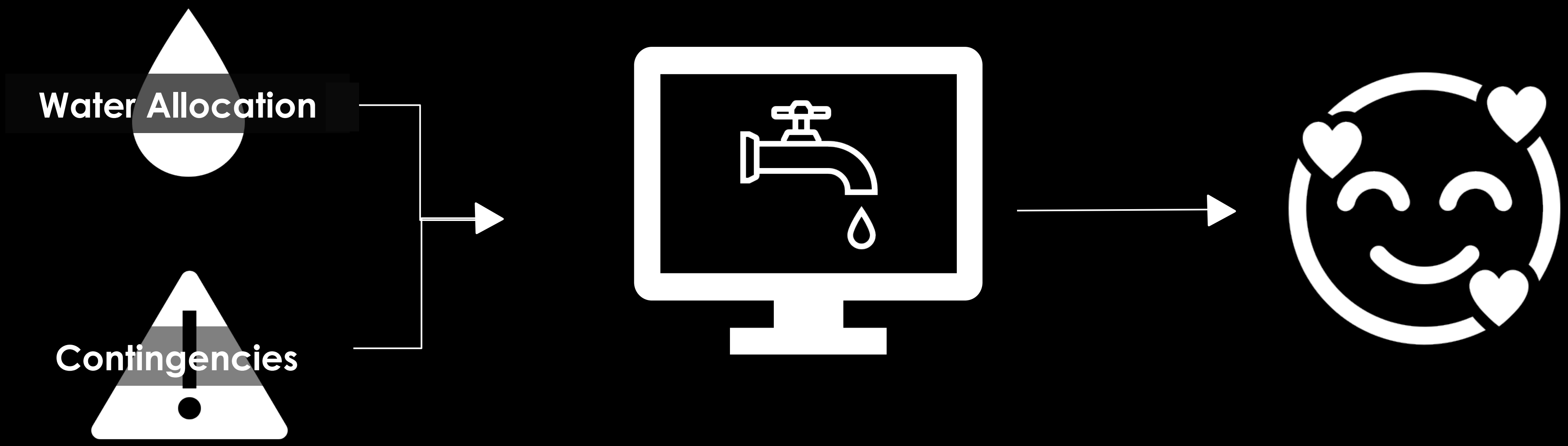
- **Simulation Modelling of Water Allocation and Consumption:**
  - ➢ Modelling of water distribution networks already established in various countries [14,15]
  - ➢ Create and run predictive models of the Martian colony's water system
  - ➢ Prospective rather than Retrospective
  - ➢ We will be generating the code for simulation from scratch, instead of relying on existing models

3 Our Solution: Simulation

Parameters

Predictive Model

Standard of Living Index



Water budget based on research used as reference

SOL is the metric used to determine how good the water allocation is

③ Our Solution: Simulation

https://www.youtube.com/watch?v=hknAcotCBeM

3 Our Solution: Simulation

Event etc. Drinking → 2, 5, 7, 8, 10, 14, 15, 18, 22, 23 → For each hour

(10 randomly generated numbers from 1-23)

(Represent the hours of day which it will attempt the event)

1. Not reached allocation for the event
2. Potable Water Tank still has water

≥ 1 criteria not fulfilled → Event Rejected → SOL reduced

Both criteria fulfilled → Event Approved → SOL maintained

All other drinking attempts approved → SOL increased at end of day

- All events run the above procedure each day
- Events and extent of SOL change listed on next slide

3 Our Solution: Simulation

Components	Type of Event	Event Frequency (per day)	Event Water Amount	Importance Factor	Effect of Rejected Consumption (- SOL) (1/Event Frequency * Importance Factor)	Effect of Achieving Allocated Consumption (+ SOL) (Importance Factor)
Watering Crops	Colony	2	67	NA	NA	NA
Drinking	Individual	10	0.162	0.95	0.095	0.95
Eating	Individual	10 (mirrors drinking)	0.088	0.75	0.075	0.75
Hygiene	Individual	2	0.214	0.4	0.2	0.4
Laundry	Colony	1	733	0.3	0.3	0.3
Flush	Individual	10	0.0067	0.35	0.035	0.35
Medical	Individual	1% chance	0.2 to 1 (Random number generated)	NA	SOL Drops to 0	NA
Electrolysis	Colony	24	11.09583333	1	0.041666667	1

Components	Type of Event	Time of Occurrence (once per day)	Input	Output
Water Extraction System	Colony	0th hour	NA	412.8L
Water Recycling System	Colony	0th hour	Input from daily wastewater output of human, hygiene, laundry, flush	0.935 * Input

- **Colony Events:**
  - ➢ Provide a global buff/ debuff of SOL for all 100 colonists
- **Individual Events:**
  - ➢ Provide a buff/debuff for each individual colonist
- **Importance Factor:**
  - ➢ Based on the importance of each activity to survival of humans
  - ➢ Relates this importance to the extent of effect on SOL of each activity
  - ➢ Forms basis of simulation

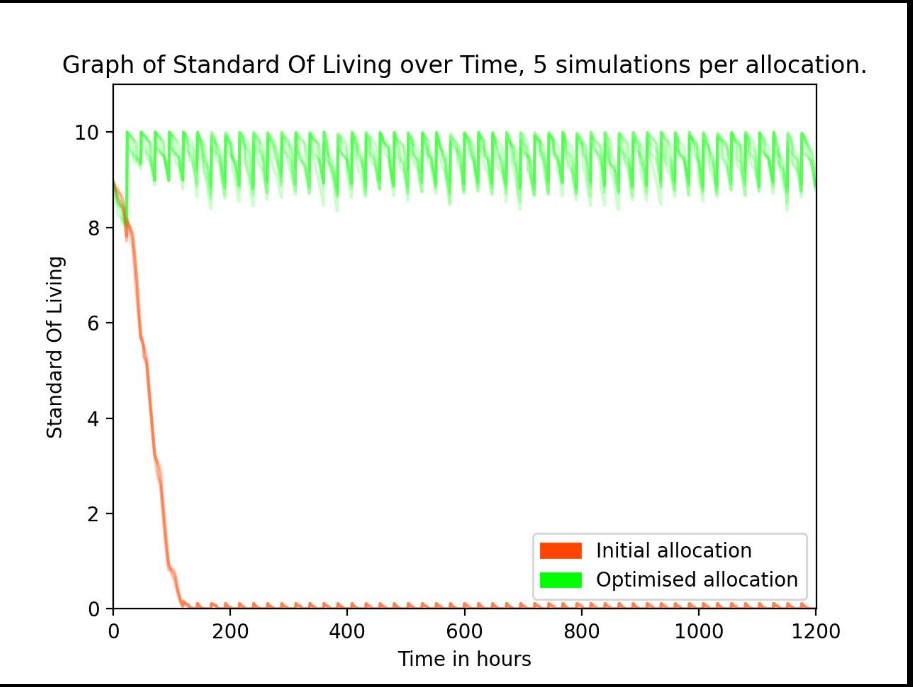
3 Our Solution: Simulation

- **Input:**
  - ➢ Percentage allocation for each component
- **Variables we can alter:**
  - ➢ Number of days simulation allowed to run
  - ➢ Efficiency of Water Recovery System
  - ➢ Water input by Water Extraction System per day
  - ➢ Deficit introduced
  - ➢ Importance factor for each component
  - ➢ And many more…
- **Output:**
  - ➢ Standard of Living (out of 10)
  - ➢ SOL can be plotted against number of days
- **Uses of Our Simulation:**
  - ➢ Determine optimum water budget for different scenarios
  - ➢ Allow system to swiftly adjust water allocation during contingencies (leaks, machine failure, etc.)

Khakimullin Aleksandr, Shutterstock.com

4 Simulation Results

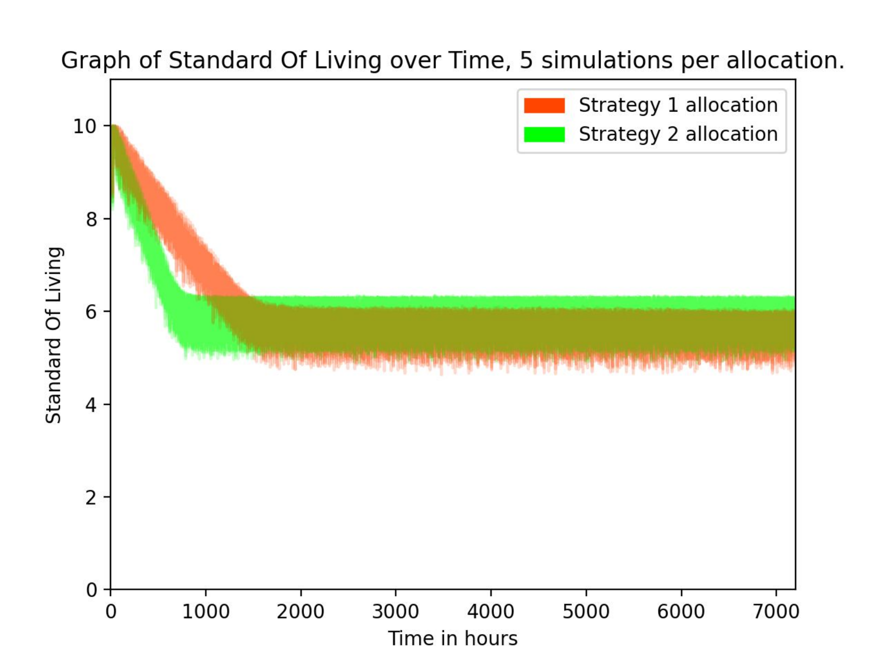
Component	Initial Water Budget (%)	Optimal Water Budget (%)
Watering Crops	9.92	20.79
Drinking	12.00	32.43
Hygiene	3.17	8.65
Laundry	54.29	0.32
Flush	0.50	0.35
Medical	0.40	2.88
Electrolysis	19.72	34.58



1. **Optimization**
   - ➢ Using a python script, we ran optimisers such as differential evolution and basin hopping in order to determine the best water allocation
   - ➢ Water deficit: 5L available out of 14L needed
   - ➢ Compared performance of optimized allocation with initial allocation based on research over 50 days
   - ➢ Observed that the optimal allocation maintained a steady SOL of around 9-10, while initial allocation dropped to 0 after 5 days
   - ➢ Observed that the optimal allocation allocated almost negligible water to laundry

4 Simulation Results

Component	Strategy 1 Water Budget (%)	Strategy 2 Water Budget (%)
Watering Crops	9.92	8.68
Drinking	12.00	10.50
Hygiene	3.17	2.78
Laundry	44.29	47.53
Flush	0.50	0.43
Medical	0.40	0.35
Electrolysis	29.72	29.723

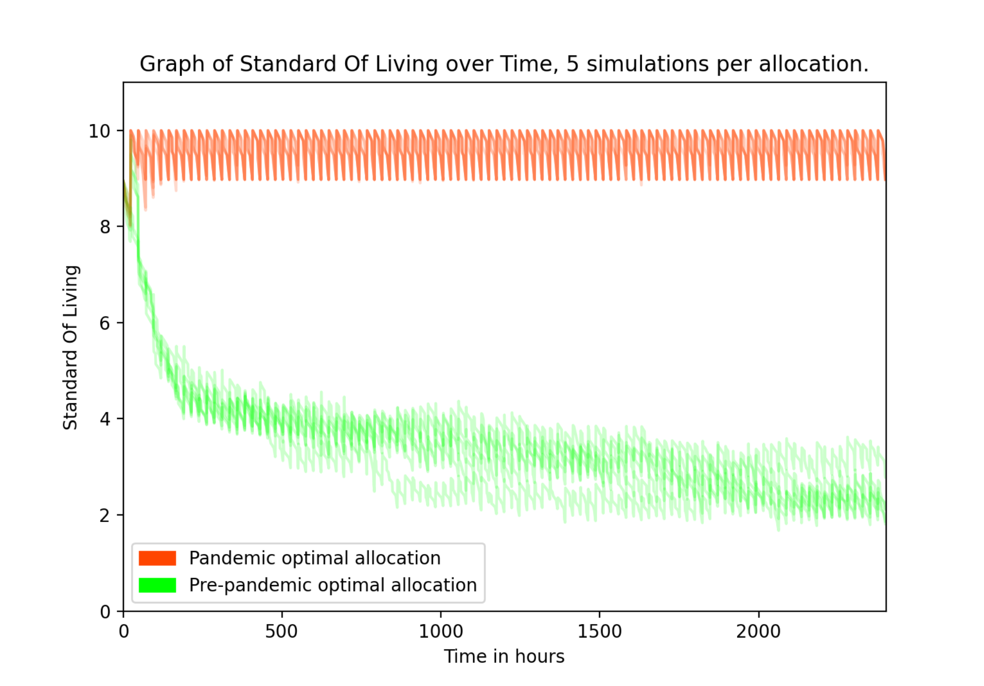


2(a) Scenario: Electrolysis System faulty, required additional water allocation of 10%

- Similar water deficit of 5L out of 14L
- Strategy 1: Take 10% from least important component (Laundry)
- Strategy 2: Take 10% equitably from each component based on their initial percentage
- Observed that Strategy 1 caused SOL to decrease at lower rate as compared to Strategy 2 => Strategy 1 better?
- However, both strategies cause SOL to stagnate at around 6/10

4 Simulation Results

Component	Pre-pandemic Water Budget (%)	Pandemic Water Budget (%)
Watering Crops	20.79	25.14
Drinking	32.43	29.24
Hygiene	8.65	10.56
Laundry	0.32	0.06
Flush	0.35	0.74
Medical	2.88	6.16
Electrolysis	34.58	28.10



2(b) Scenario: Pandemic Situation, probability of using water for medical use increased from 1% to 50%

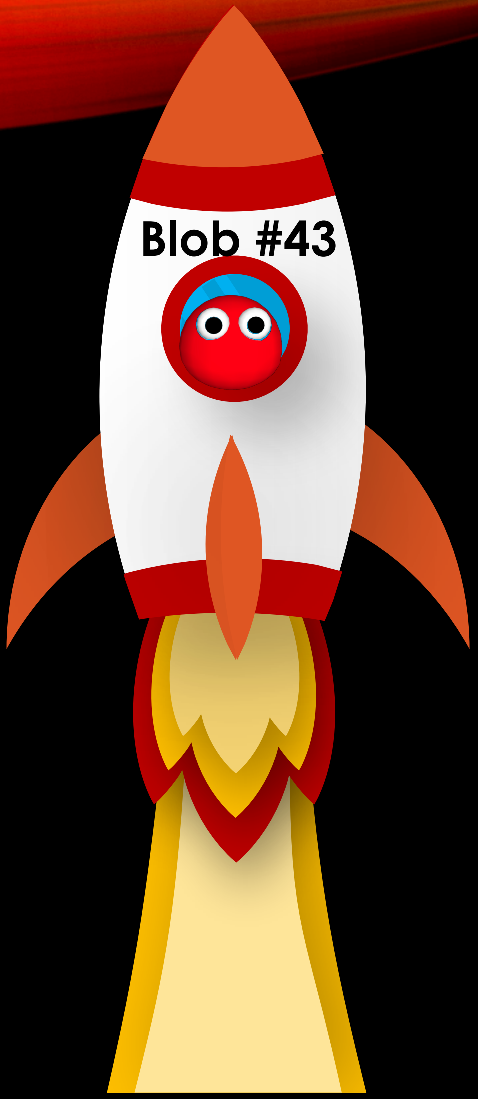
- Similar water deficit of 5L out of 14L
- Pre-pandemic allocation did not account for increase in medical water usage
- Performed much more poorly as compared to pandemic optimal allocation
- Pandemic optimal allocation was stable even after 50 days

Components

- **Wireless Sensor Networks**
  - ➢ Flowmeters placed at input/output of each component
- **Microcontroller**
  - ➢ Sensors transmit data on flow volume for each component to central microcontroller
  - ➢ Programmed with our code for the simulation
  - ➢ Colonists can view current water distribution and alter variables based on colony's condition

- **Functions:**
  - ➢ Ensure real water allocation follows that of the simulated model
  - ➢ Warns colonists if there are major deviations from water input/output of each component from simulated model (leaks, breakdowns etc.)
  - ➢ Automatically adjusts water allocation based on minor and major deviations

WHO WE ARE



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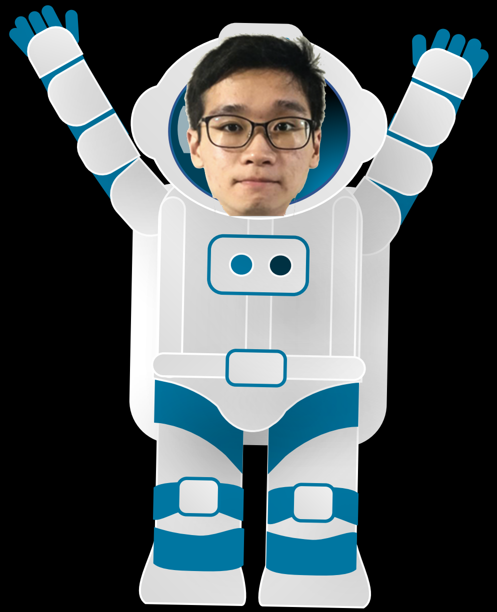

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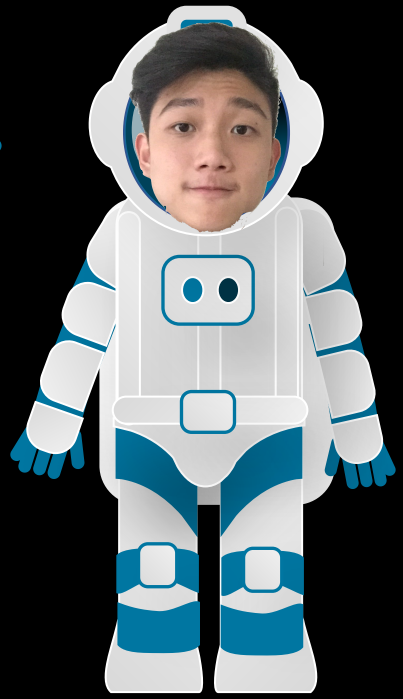

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