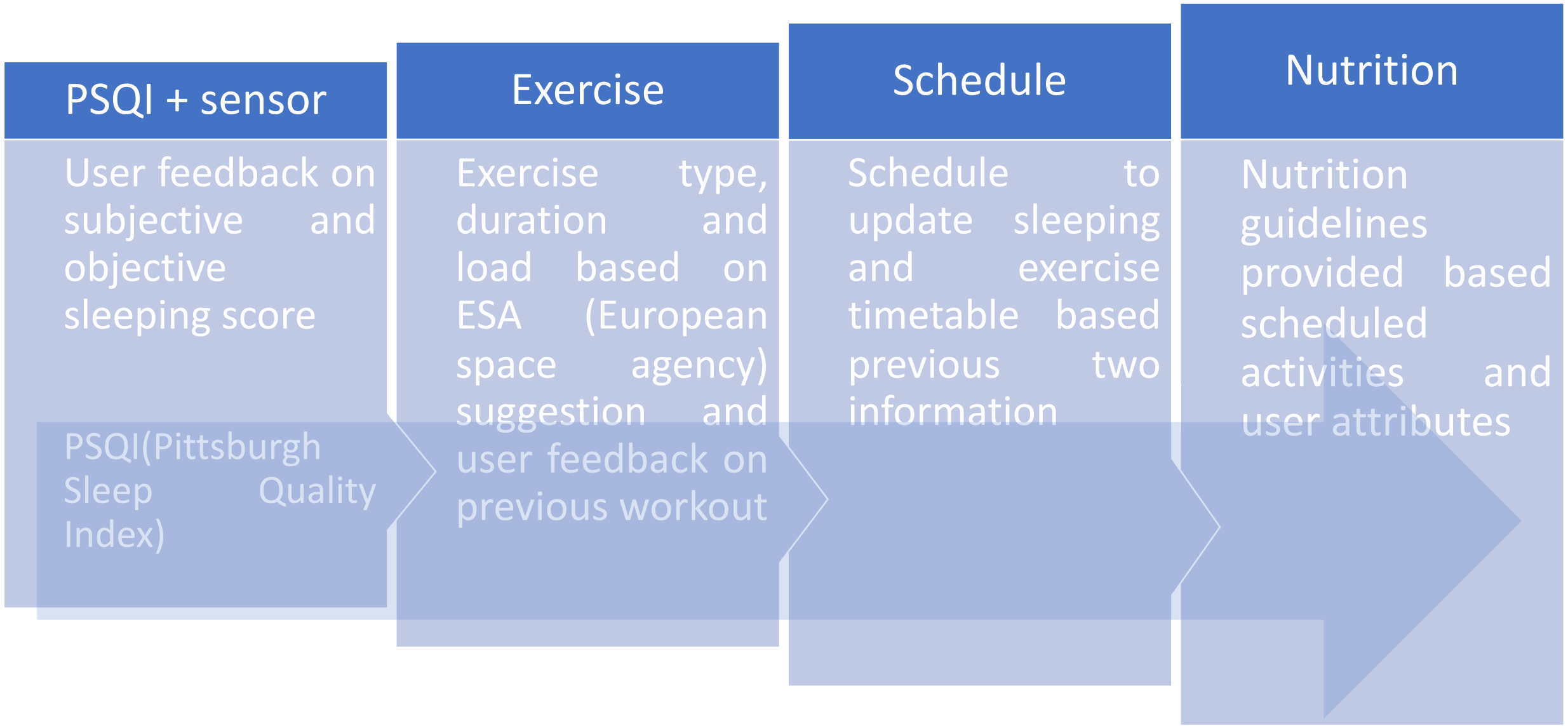
Summary of logics

Team Legacy

04.October.2020

Summary of logic flow



Sleep

- Aim: Make sure astronauts have enough rest and slept well both objectively and subjectively.
- To do:
  1. Objective sleep scoring system
  2. Subjective sleep scoring system – based on Pittsburgh Sleep Quality Index

Sleep – Objective sleep scoring

- Considering the type of data NASA has:

  Total sleep time, start and end times, date of data period, sleep onset, sleep latency, sleep efficiency, wake after sleep onset, light (white, blue, red and green) illumination, FMS plans to also include sleep phases: light, deep, rapid eye movement, and wake.

Sleep – Subjective sleep scoring

- Subjective sleep scoring system is developed based on gold standard Pittsburgh Sleep Quality Index (PSQI) questionnaire.

Buysse et al. 1988

1. During the past month, what time have you usually gone to bed at night? _____
2. During the past month, how long (in minutes) has it usually taken you to fall asleep each night? _____
3. During the past month, what time have you usually gotten up in the morning? _____
4. During the past month, how many hours of actual sleep did you get at night? (This may be different than the number of hours you spent in bed.) _____

5. During the past month, how often have you had trouble sleeping because you…	Not during the past month	Less than once a week	Once or twice a week	Three or more times a week
a. Cannot get to sleep within 30 minutes				
b. Wake up in the middle of the night or early morning				
c. Have to get up to use the bathroom				
d. Cannot breathe comfortably				
e. Cough or snore loudly				
f. Feel too cold				
g. Feel too hot				
h. Have bad dreams				
i. Have pain				
j. Other reason(s), please describe:				
6. During the past month, how often have you taken medicine to help you sleep (prescribed or "over the counter")?				
7. During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?				
	No problem at all	Only a very slight problem	Somewhat of a problem	A very big problem
8. During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?				
	Very good	Fairly good	Fairly bad	Very bad
9. During the past month, how would you rate				

Sleep – Combination

- Based on the objective and subjective scores the schedule planner app would then suggest actions to be taken.

- For instance, if the objective score is good (e.g. 80 out of 100), but subjectively astronaut feels tiresome (subjective score), the planar would suggest actions such as mediation (proven to be effective in improving PSQI score; Black et al., 2015).

- Another example would be advice to take melatonin if sleep latency was too high (may be effective, shown DIJK et al., 2001)

Nutrition

- Aim: replenish astronaut with suitable calories according to gold standard guidance published by WHO and FAO.
- To do:
  1. Calculate amount of calories astronaut needs per day
  2. Convert amount of calories to amount (gram) of nutrition to intake per day

Nutrition – Calories Needed

- **Baseline** suitable energy intake per day is suggested by FAO (Food and Agriculture Organization of the United Nations) given in the following equations

Age *Years*	No.	BMR: MJ/day	see	BMR: kcal/day	see
Males					
< 3	162	0.249kg - 0.127	0.292	59.512kg - 30.4	70
3-10	338	0.095kg + 2.110	0.280	22.706kg + 504.3	67
10-18	734	0.074kg + 2.754	0.441	17.686kg + 658.2	105
18-30	2879	0.063kg + 2.896	0.641	15.057kg + 692.2	153
30-60	646	0.048kg + 3.653	0.700	11.472kg + 873.1	167
³ 60	50	0.049kg + 2.459	0.686	11.711kg + 587.7	164
Females					
< 3	137	0.244kg - 0.130	0.246	58.317kg - 31.1	59
3-10	413	0.085kg + 2.033	0.292	20.315kg + 485.9	70
10-18	575	0.056kg + 2.898	0.466	13.384kg + 692.6	111
18-30	829	0.062kg + 2.036	0.497	14.818kg + 486.6	119
30-60	372	0.034kg + 3.538	0.465	8.126kg + 845.6	111
³ 60	38	0.038kg + 2.755	0.451	9.082kg + 658.5	108

Human energy requirements Report of a Joint FAO/WHO/UNU Expert Consultation, 2001

Note: baseline assume lowest possible energy consumption, i.e. sleeping

Nutrition – Calories Needed

- PAL (physical activity level) adjustment to calories needed, where mean PAL can be calculated from sum of energy cost or basal metabolic rate (PAR) of activity multiplied by time of activity

$$\mathrm{PAL} = \frac{\sum\left(PAR_{activity} * time\ of\ activity\right)}{24}$$

Human energy requirements Report of a Joint FAO/WHO/UNU Expert Consultation, 2001

PAR was published on annex 5, Human energy requirements Report of a Joint FAO/WHO/UNU Expert Consultation, 2001

Nutrition – what to eat

- **Protein**

- Minimum protein intake per day is 0.83 g/kg$_{\text{human weight}}$

  "Protein and Amino Acid Requirements in Human Nutrition" WHO, 2002

- Suggested protein intake 1.2-2.0 g/kg$_{\text{human weight}}$

  American College of Sports Medicine

We therefore propose astronaut to have 1.2g/kg of protein if no exercises on the day and 1.6g/kg of protein if exercised on the day

Nutrition – what to eat

- **Fat**
- It is suggested to have greater than 15% but less than 30% of fat of total Calories intake per day

$$15\% \times Energy_{total} < Energy_{fat} < 30\% \times Energy_{total}$$

- It is suggested to have less than 10% of saturated fat of total Calories intake per day

$$Energy_{saturated\ fat} < 10\% \times Energy_{total}$$

"Healthy diet" WHO, 2018

Nutrition – what to eat

- **Carbohydrates**
- It is suggested to have between 50-75% of carbonhydrates of total Calories intake per day

FAO/WHO Scientific Update on carbohydrates in human nutrition: conclusions. 2007

- **Sugar**
- It is suggested to eat less than 5% of sugar of total Calories intake per day

“Healthy diet” WHO, 2018

Nutrition – what to eat

The suggested guidance priorities protein intake, making sure astronaut keeps muscle strength

We therefore propose astronaut to have (22.5/88) of remaining energy of fat.

$$Energy_{fat} = \frac{22.5}{88} \times (Energy_{total} - Energy_{protein})$$

In which are saturated:

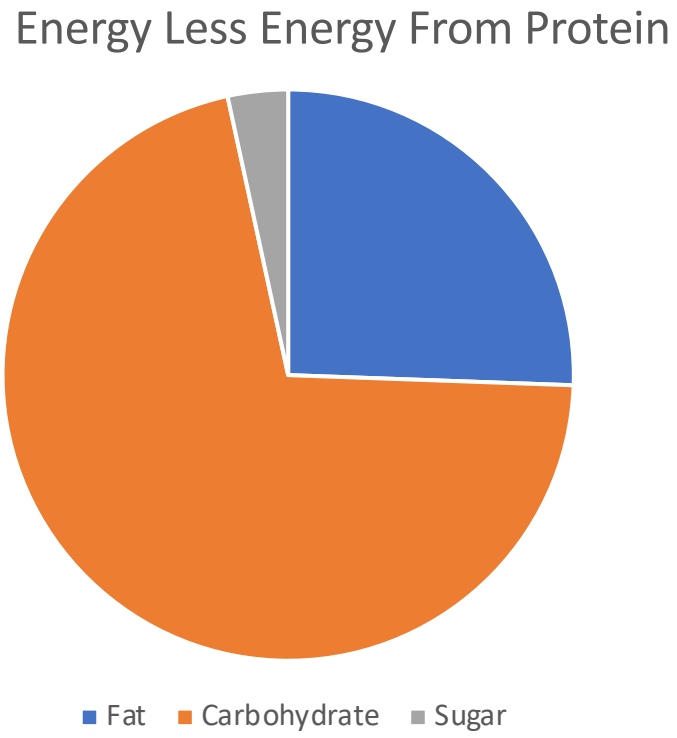
$$Energy_{saturated\_fat} = \frac{5}{88} \times (Energy_{total} - Energy_{protein})$$

Carbohydrates:

$$Energy_{carbohydrates} = \frac{62.5}{88} \times (Energy_{total} - Energy_{protein})$$

Sugar:

$$Energy_{sugrar} = \frac{3}{88} \times (Energy_{total} - Energy_{protein})$$



Nutrition – what to eat

- This can be converted to mass of nutrition with known nutrition energy per gram:

Fat contains 9 kcal (37 kJ) per gram
Protein contains 4 kcal (17 kJ) per gram
Carbohydrate contains 4 kcal (17 kJ) per gram

British nutrition foundation

$$mass_{fat} = \frac{Energy_{fat}}{9} \qquad mass_{saturated\ fat} = \frac{Energy_{saturated\ fat}}{9}$$

$$mass_{carbohydrates} = \frac{Energy_{carbohydrates}}{4}$$

$$mass_{sugar} = \frac{Energy_{sugar}}{4}$$

Nutrition – what to eat

- **Sodium**
- It is suggested to have less than 2g of sodium or 5g to table salt (sodium chloride) intake

- **Potassium**
- It is suggested to have 1:1 molar ratio of potassium to sodium intake

"Guideline: Sodium intake for adults and children" WHO, 2012
"Guideline: Potassium intake for adults and children" WHO, 2012

We therefore propose astronaut to have 4g of table salt intake per day
Potassium intake can be calculated by

$$\frac{\left[\frac{Molar\ \mathrm{Mass}_{sodium}}{Molar\ \mathrm{Mass}_{sodium\ Chloride}} \times 4(g)\right]}{Molar\ \mathrm{Mass}_{sodium}} \times Molar\ \mathrm{Mass}_{potassium} = 2.7g\ (1\ d.p.)$$

Exercise

- 3 phases
- 1. adaptation phase first 1-20 days of mission
- 2. main phase 130-150 days
- 3. preparation for reentry, final15-30 days of mission

Exercise

- **Phase 1**
- Start from 2nd day / 3rd day
- Cycle ergometer <= 1hr
- 1hr → 2.5hr
- Cycle ergometer (30), treadmill (30) and resistive exercise devices (60) balance use, 4-5 sessions per device each week in a **periodic order**.
- Intensity is relatively low (50-60% of pre-flight capacity)
- Note: setup takes ~ 1 hour

Exercise

- **Phase 2**
- 3-5% increment per week, goal 80% or higher of individual maximal capacity
- 6-7 resistance + 4-7 cardio sessions per week.
- Focus on lower limbs

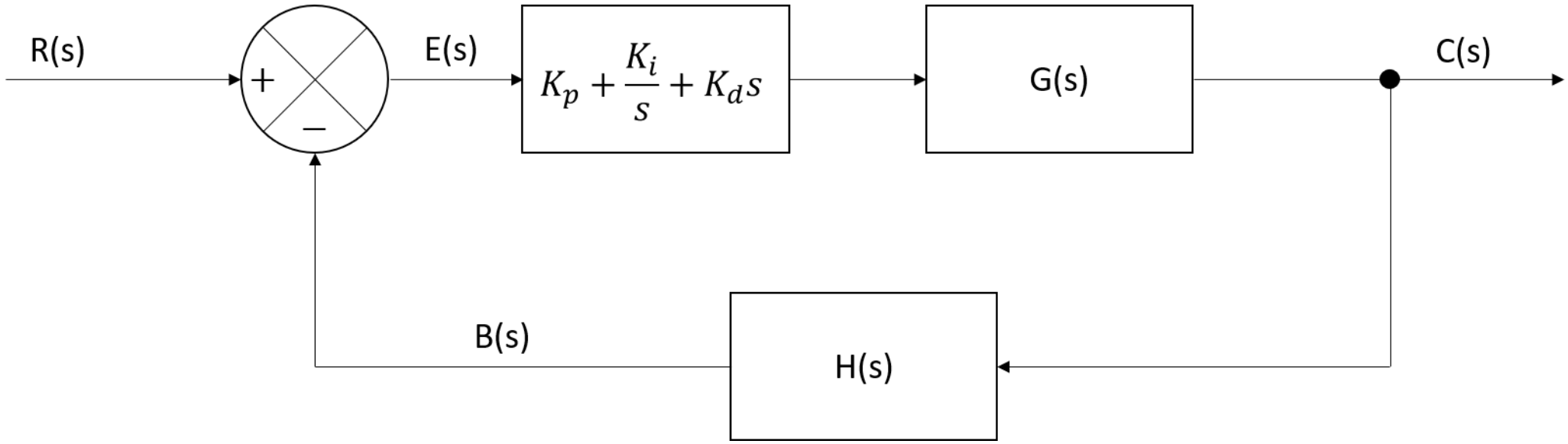
Exercise – code logic

Aim: schedule suitable workout for astronaut

1. Identify intensity of training based on
    I. Target
    II. Previous user feedback on training difficulties.
2. Identify workout to do, time length, and load

Exercise – Identify intensity of training

- Adopt PID controller



Where R(s) is target work load, B(s) is user feedback work load

Exercise - Identify workout to do, time length, and load – **phase 1**

- Workout can be separated into phase 1, adaptation phase, and phase 2, main phase.
- Phase 1 criteria:
  - ☐ Last for 21 days
  - ☐ No workout on day 1
  - ☐ Target load starts from 50-60% of max pre-flight workout load capacity

Exercise in space: the European Space Agency approach to in-flight exercise countermeasures for long-duration missions on ISS, 2016

- Phase 1 parameter used:
  - ✓ Last for 21 days
  - ✓ No workout on day 1
  - ✓ Total exercise time = setup time + actual workout time, where actual workout time is assumed to be 0.6*Total exercise time
  - ✓ Workout (total exercise) time: 1st week – 1 hr; 2nd week – 2 hrs; 3rd week – 2.5 hrs
  - ✓ Workout load (of max capacity): 1st week – 50% normally but 60% if astronaut found easy; 2nd week onwards decided by PID controller.

Exercise - Identify workout to do, time length, and load – **phase 2**

- Phase 2 criteria:
  - ☐ Days after 21st day
  - ☐ Target load starts from 80% of max pre-flight workout load capacity

Exercise in space: the European Space Agency approach to in-flight exercise countermeasures for long-duration missions on ISS, 2016

- Phase 2 parameter used:
  - ✓ Days after 21st day
  - ✓ Total exercise time = setup time + actual workout time, where actual workout time is assumed to be 0.6*Total exercise time
  - ✓ Workout (total exercise) time: 2.5 hrs
  - ✓ Workout load (of max capacity): decided by PID controller.