Planetary Exploration Habitat Energy Requirements and Forecasting

Simon Engler, *Prof. Kim Binsted, University of Hawaii*
Dr. Henry Leung, University of Calgary

Contact me: simon.engler@hawaii.edu

NEW AND UNIQUE CHALLENGES LONG TERM SPACE TRIPS

- MARS TRIP 2.5 YEARS MININUM
- RESUPPLY CANNOT BE REQUIRED IN CASE OF DELIVERY FAILURE
- RESOURCES MUST BE MONITORED CLOSELY TO ENSURE MISSION COMPLETION → **FORECASTING OF RESOURCES**

- SMALL ENVIRONMENT WITH LOW NUMBER PEOPLE
- EACH CREW MEMBER HAS **HUGE INFLUENCE** ON RESOURCE USAGE (20% - ALL THINGS BEING EQUAL IN 6 MAN CREW)
- SUDDEN CHANGES IN RESOURCE CONSUMPTION CAN CAUSE FORECAST MODELS TO BECOME **INACCURATE OR FAIL**

- GOAL IS TO CREATE FORECAST ACCOUNTING FOR THESE SUDDEN CHANGES

- Hawaii Space Exploration Analog and Simulation
- NASA funded long term isolation experiment focusing on crew cohesion and crew selection
- Five missions lasting 4-mon, 4-mon, 8-mon,1-yr,8-mon

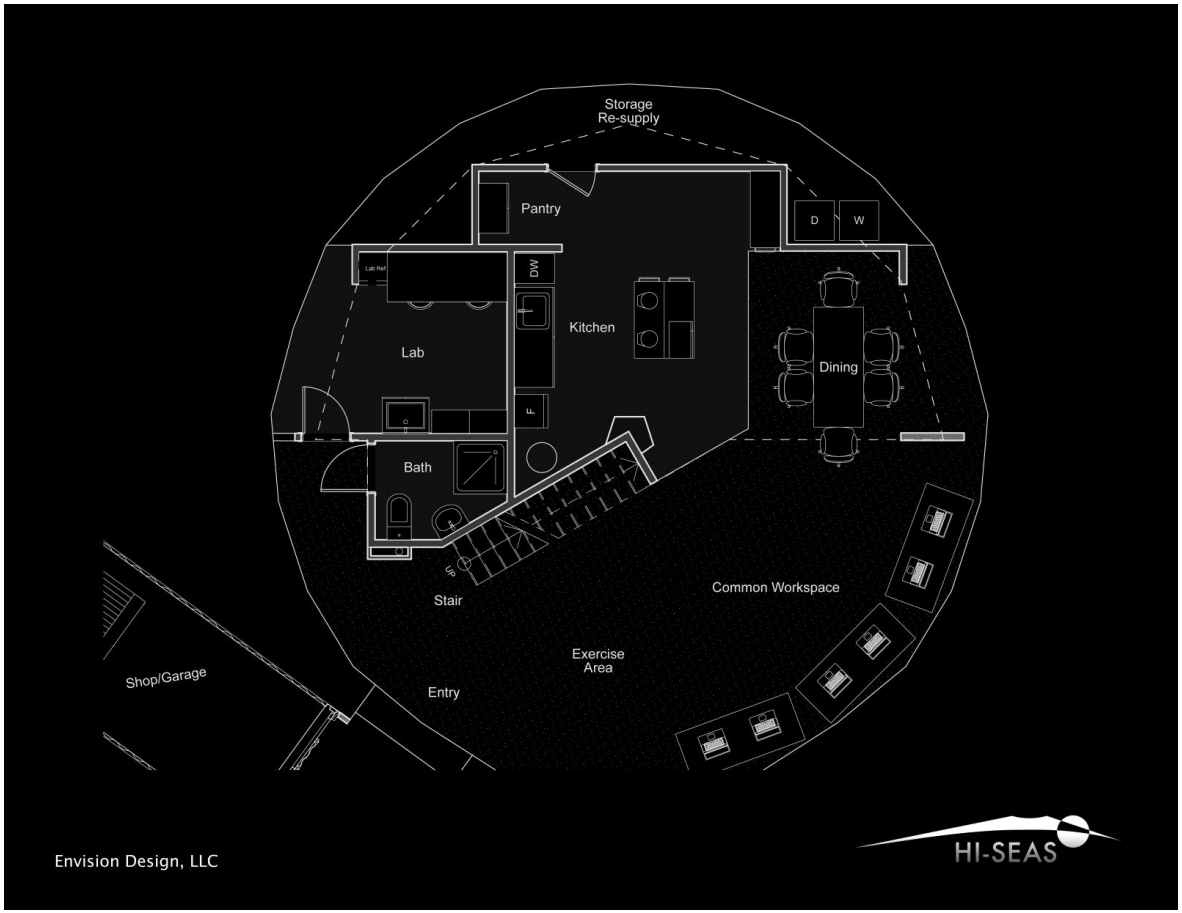
PRIMARY RESEARCH

- Team Processes and Team Effectiveness
- Self-Guided Stress Management and Resilience Training
- MENTALBLOCK
- Effectiveness of a Shared Social Behavioral Task as a Team-Building Exercise in Isolated, Confined, and Extreme Environments
- Crew Communication in Debriefs
- Autonomous Behavioral Countermeasures for Spaceflight
- Numerous **opportunistic research** projects

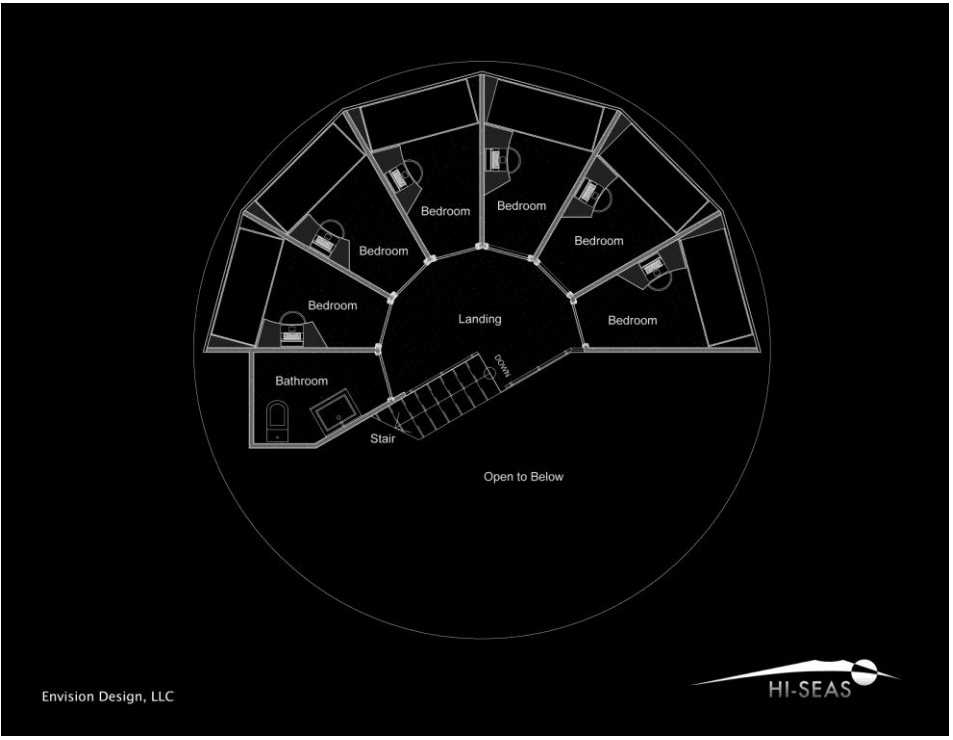
HI-SEAS HABITAT

- 32-foot Diameter Dome
- 6 Bedrooms
- Upstairs/Downstairs Bathroom
- Lab
- Airlock/Sea container
- Living area
- Dining Room
- Kitchen
- Washing Area

MAIN FLOOR HABITAT



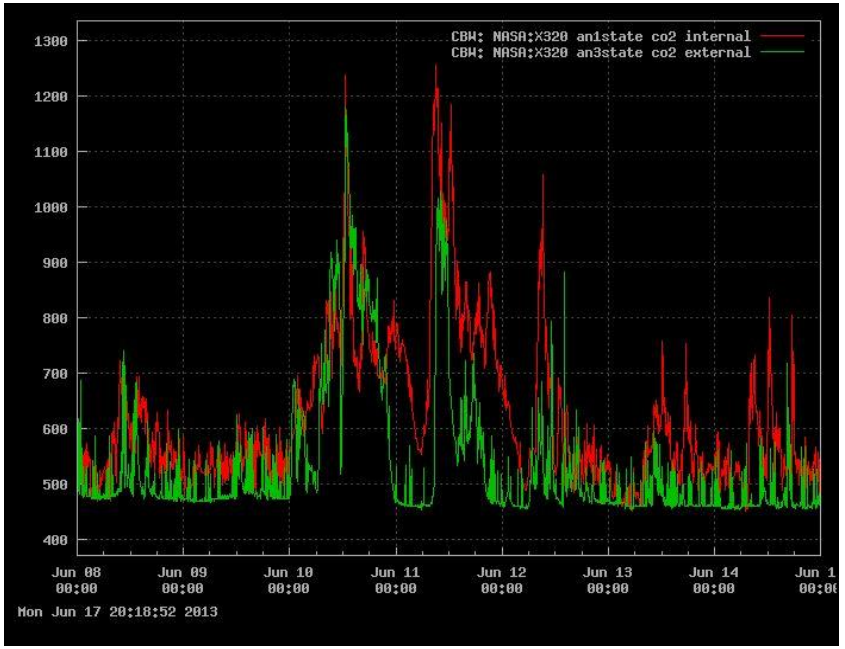
SECOND FLOOR HABITAT

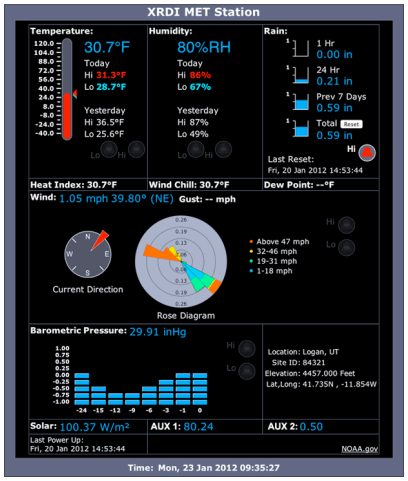


HI-SEAS POWER SYSTEMS

Sensor System

- Water level sensor
- CO2 /Humidity Sensors
- 3x Temperature Sensors
- Power consumption Sensors
- X320M Controllers updating data under 5 minute intervals





- Weather Station
- Wind Direction
- Humidity
- Solar Radiation
- Rain Water

MISSION POWER AND WATER CONSUMPTION

POWER

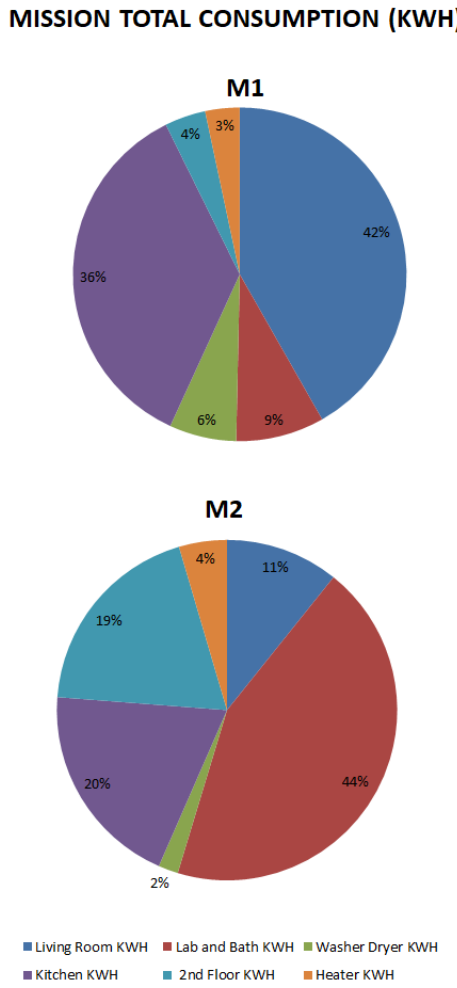
(KWH)	M1	M2	M3	M4	M5
Living Room	4129	524	2243	4037	2557
Lab and Bath	847	221	6463	10663	7819
Washer Dryer	642	95	28	48	37
Kitchen	3544	990	3732	4478	3582
2nd Floor	392	969	3460	5967	2228
Heater	329	230	511	1034	840
Total::	9887	5043	16437	26230	15219

WATER

Mission	Daily	Weekly	Month	Total
M2	53.4	449	1617	8088
M3	59.3	580	2240	15675
M4	61.7	299	1227	15256
M5	56.5	406	1659	14228

*- *All values are in gallons*

M1 AND M2 POWER USAGE DISTRIBUTION

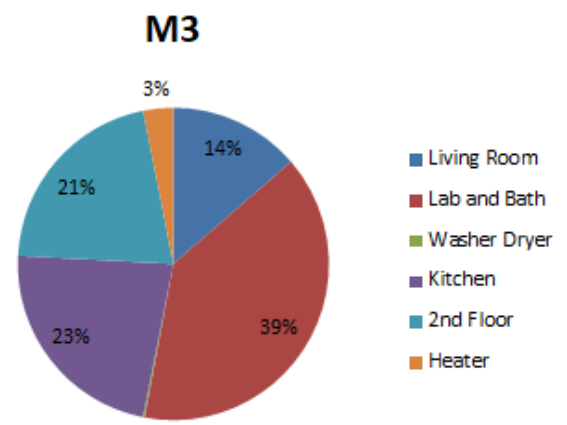


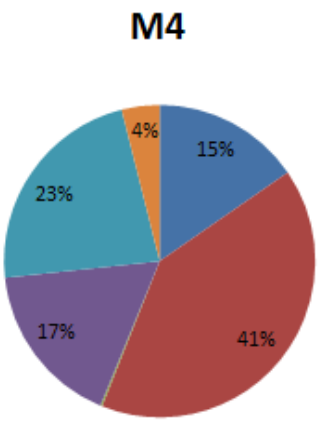
M3, M4, M5 POWER USEAGE DISTRIBUTION

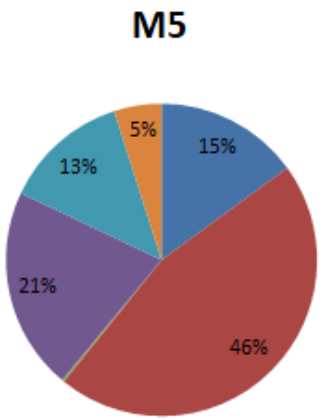
TAKE NOTE OF THE NEAR EQUAL DISTRIBUTION OF POWER USAGE ACROSS THREE MISSIONS

REPEATED AND COMPARABLE ENERGY DATA

PLEASE CONTACT US FOR DATA TO USE IN YOUR RESEACH

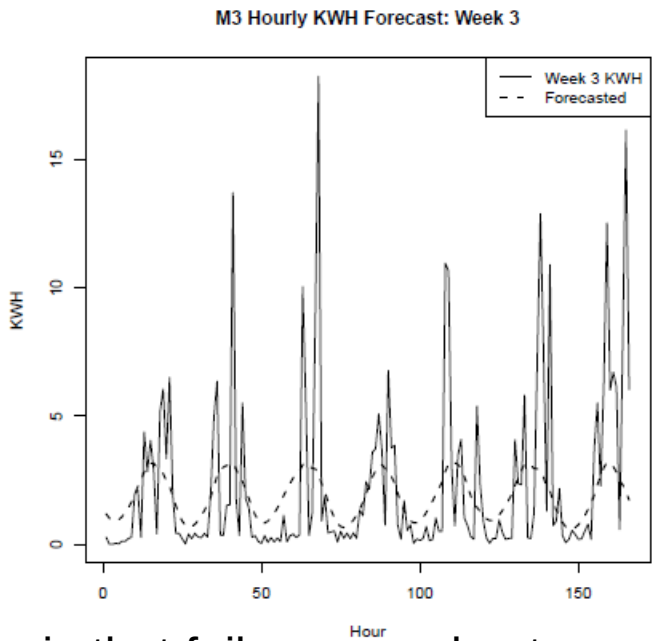


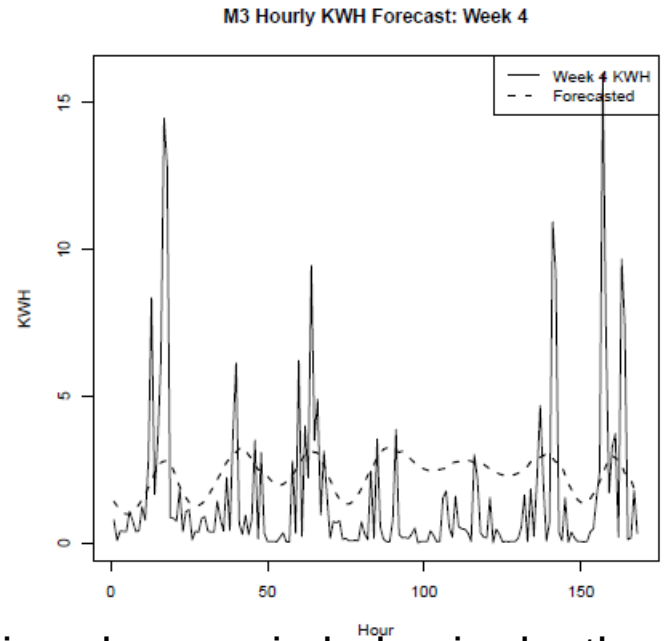




FORECASTING FAILURES

- Initial attempts to forecast using standard machine learning methods yielded reasonable forecasts accompanied by sudden **severe** to **catastrophic failures**





Hypothesis that failures are due to excessive changes in behavior by the crew due to an external influence denoted a **significant event** that in return has an **emotional impact** on crew members

IDENTIFYING SIGNIFICANT EVENTS

- Crew commanders daily report was used to identify a significant event on mission timeline

HI-SEAS MISSION 3 SIGNIFICANT EVENTS CALENDAR

		WEEK	SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
Comms Blackout		1	5	6	7	8	9	10	11
Comms Intermittant		2	12	13	14	15	16	17	18
Comms modification		3	19	20	21	22	23	24	25
Septic Malfunction		4	26	27	28	29	30	31	32
Septic Infestation		5	33	34	35	36	37	38	39
Septic Maintnance		6	40	41	42	43	44	45	46
Celebration Milestone		7	47	48	49	50	51	52	53
Celebration Birthday		8	54	55	56	57	58	59	60
Celebratrion Holiday		9	61	62	63	64	65	66	67
Severe Weather		10	68	69	70	71	72	73	74
Energy Ration		11	75	76	77	78	79	80	81
No Significant Event (NSE)		12	82	83	84	85	86	87	88
Water Ration		13	89	90	91	92	93	94	95
Multiple Events		14	96	97	98	99	100	101	102
Power Outage		15	103	104	105	106	107	108	109
Resupply		16	110	111	112	113	114	115	116
Water Refill		17	117	118	119	120	121	122	123
		18	124	125	126	127	128	129	130
		19	131	132	133	134	135	136	137
		20	138	139	140	141	142	143	144
		21	145	146	147	148		150	151
		22	152	153	154	155	156	157	158
		23	159	160	161	162	163	164	165
		24	166	167	168	169	170	171	172
		25	173	174	175	176	177	178	179
		26	180	181	182	183	184	185	186
		27	187	188	189	190	191	192	193
		28	194	195	196	197	198	199	200
		29	201	202	203	204	205	206	207
		30	208	209	210	211	212	213	214
		31	215	216	217	218	219	220	221
		32	222	223	224	225	226	227	228
		33	229	230	231	232	233	234	235
		34	235	237	238	239	240		

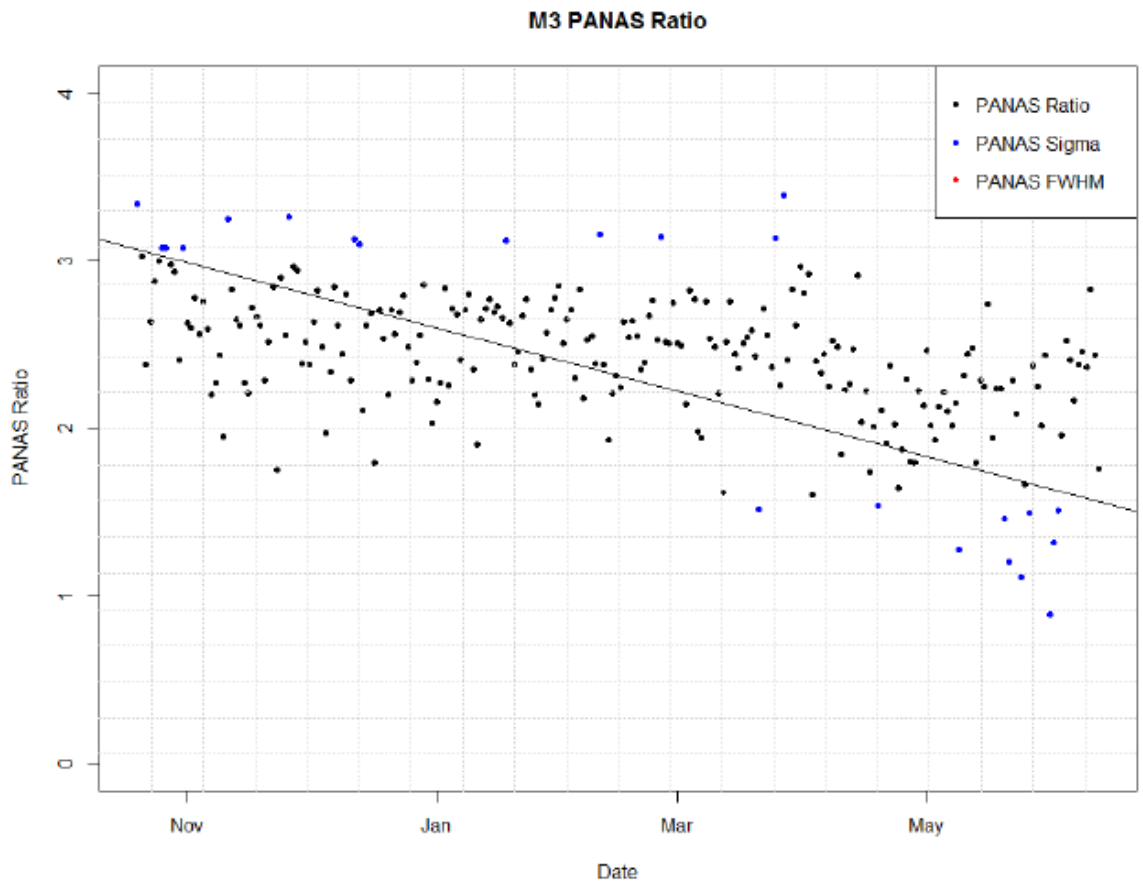
CREW PSYCOLOGICAL STATE

Positive and Negative Affect Schedule (PANAS).

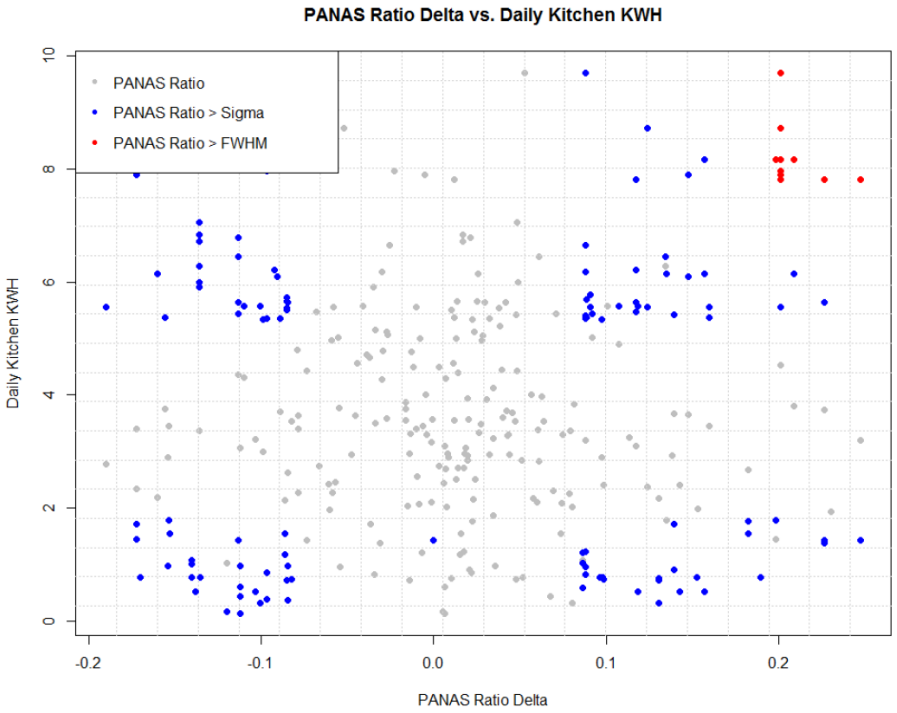
For non-clinical experiments, the PANAS is considered to be a reliable measure of the population. (D.Watson et. al.,1988)

- Daily survey rate emotional words on a five point scale
- Sum the crew's **positive** and **negative** PANAS values separately
- Ratio of P+ over P- give the PANAS Ratio
- The difference between the PANAS Ratio over 48 hours is the Delta PANAS Ratio (daily emotional change)

PANAS SCORES

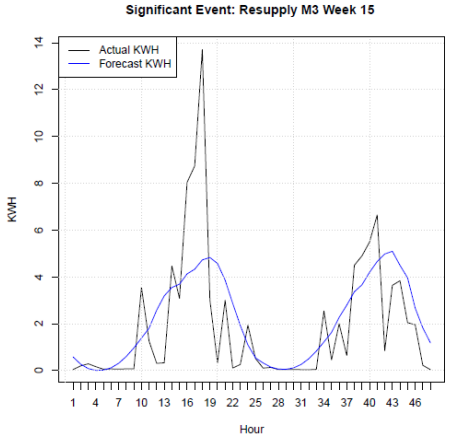


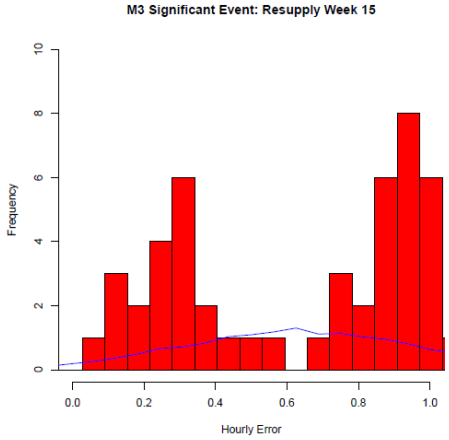
SIGNIFICANT EVENTS & PANAS

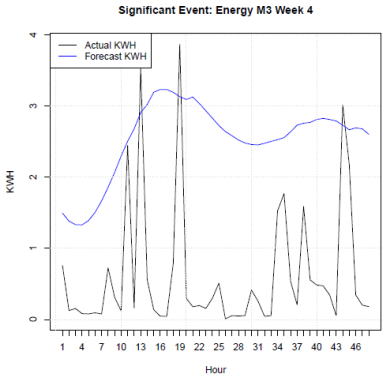


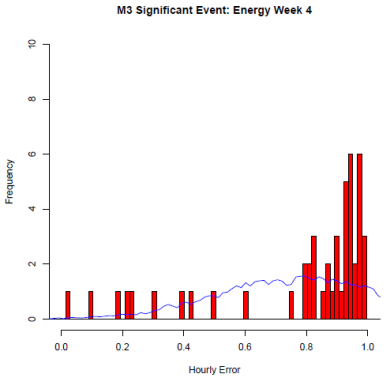
Datetime	SE	panas	energy
2014-11-10	WATER REFILL	1.149014366	5.4761420
2014-11-23	WATER REFILL	0.708595387	7.8152893
2014-11-24	ENERGY RESTRICTION	-0.510186757	5.6334124
2014-11-26	WATER REFILL	0.501764706	1.4315105
2014-12-05	TOILET MAINTNANCE, RESUPPLY, ENERGY RESTRICTION	-0.890625	5.7808534
2014-12-12	COMMS INTURRUPTION	0.464262295	5.5541108
2015-01-18	COMMS BLACKOUT	0.612903225	0.3903438
2015-02-10	RESUPPLY	-0.789209906	0.8575735
2015-03-06	TOILET MAINTANCE	-0.915594442	5.3536077
2015-03-12	EVA, ENERGY RESTRICTION	1.135400106	6.0959773
2015-03-21	RESUPPLY	-1.315934066	7.8969233
2015-03-12	EVA, ENERGY RESTRICTION	-0.642734455	5.6913059
2015-03-21	RESUPPLY	-0.482496195	5.3655196
2015-04-03	TOILET MAINTANCE	-0.470489553	5.5516951
2015-04-17	ONE-ON-ONE DEBRIEFS	-0.494828161	5.4045873
2015-05-09	WATER REFILL, CELEBRATION (END WWII)	-0.875653083	6.6420921
2015-05-13	ENERGY RESTRICTION	-0.684508492	1.2268424

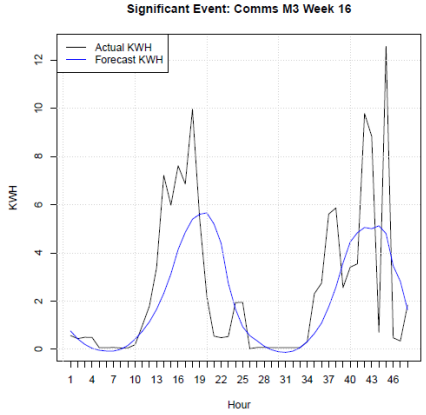
SIGNIFICANT EVENTS & PANAS CREATE FORECAST FAILURE

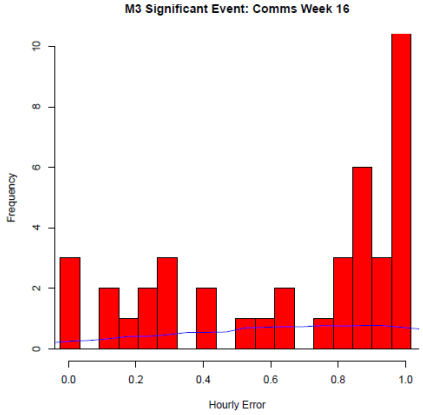


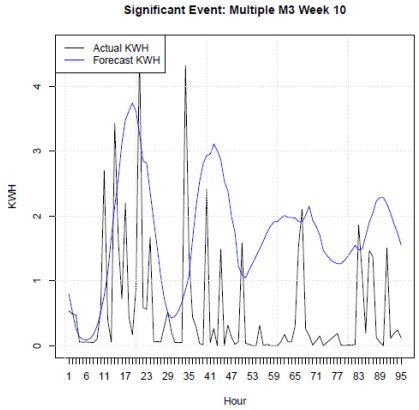


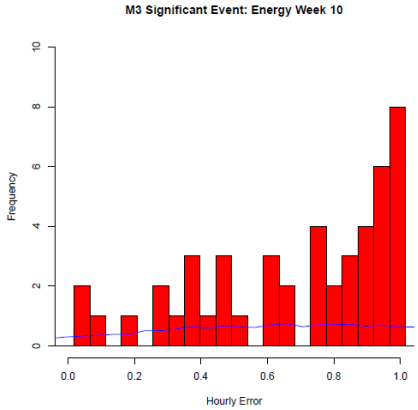










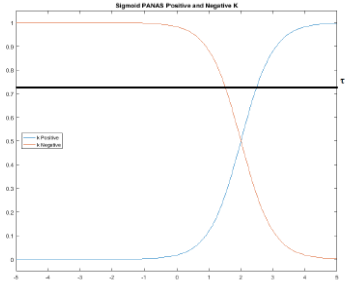


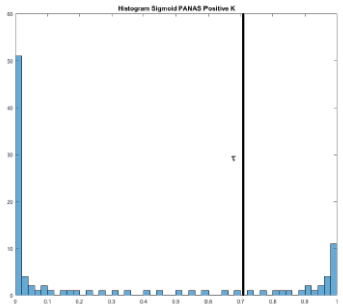
BRAIN NEURAL NETWORK

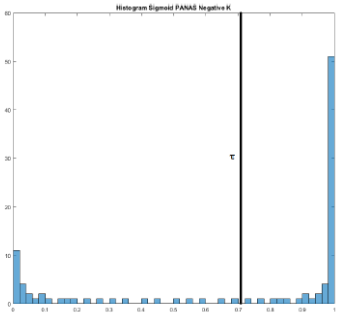
- Human brain neural nets are governed by synaptic responses which decide when a neuron will fire or not
- **Serotonin** is a chemical which decreases synaptic response and is associated with negative emotions/depression
- **Dopamine** and is neural enhancer and is associated with positive emotions/pleasure
- **Long term memories** associated with strong emotions

MODULATED NEURAL ACTIVATION METHOD

- Taking the sigmoid activation function and adding an exponential factor associated with the Delta PANAS Ratio
- Has the effect of changing the probability density such that positive Delta PANAS values increase the percentage of values to fire (slope of the sigmoid function changes)
- Negative values will invert the sigmoid function such that it acts as a neural inhibitor and inverts the probabilities such that previously low probabilities are now high

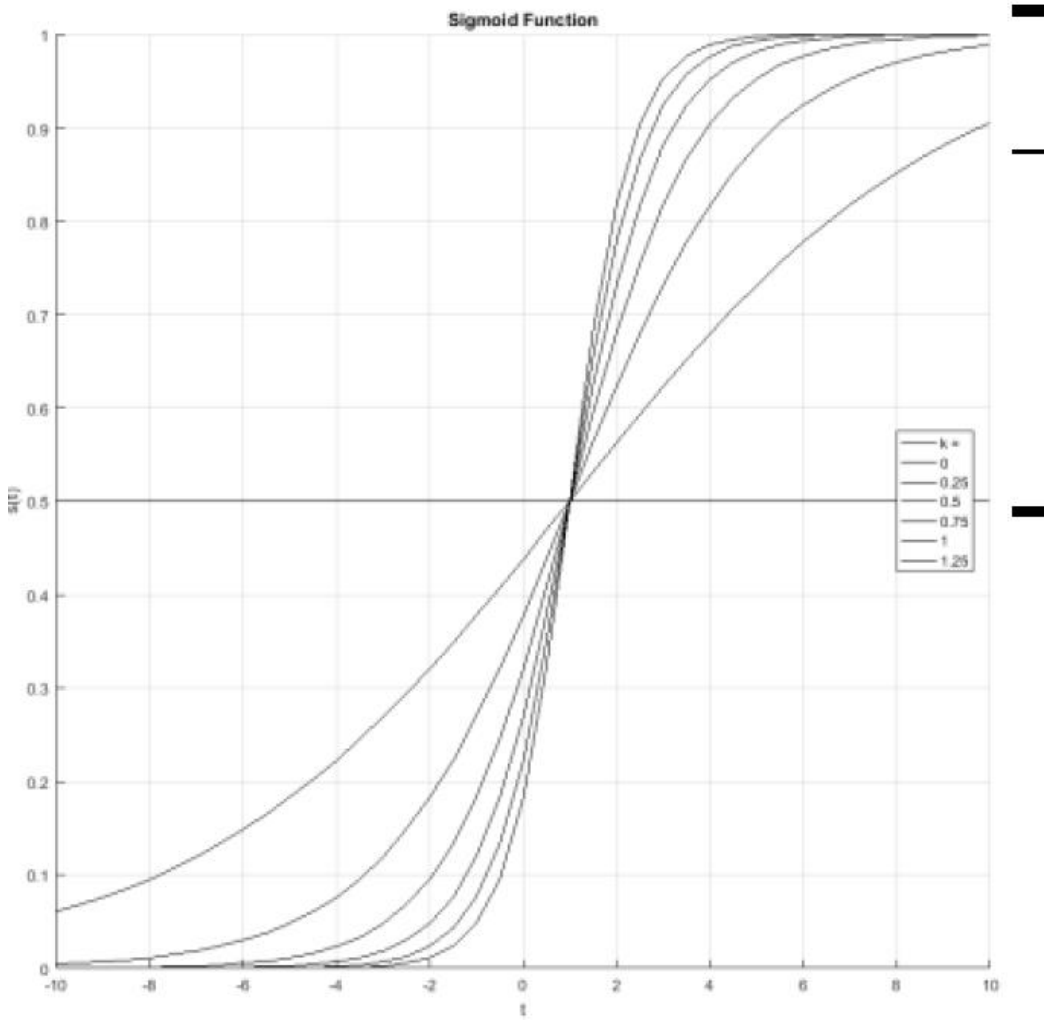






$$s(t) = \frac{1}{1 + e^{-\kappa t}}$$

PANAS MODIFIED SIGMOID FUNCTION



S2S LSTM-RNN

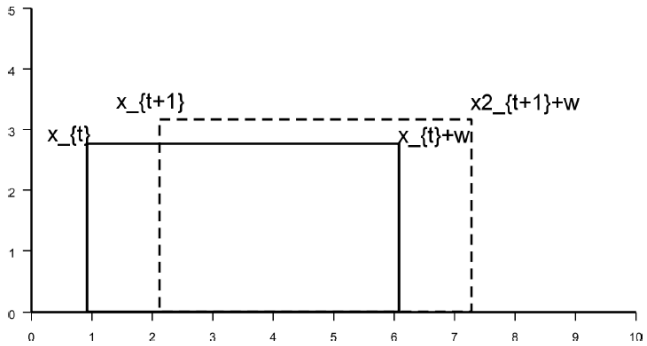


Figure 4.13: Siding window forecasting with a window of size w. The memory cells store the past time-step between x_t and $x_t + w$ as a sequence. The forecast sequence is in a window one time-step between x_{t+1} and $x_{t+1} + w$

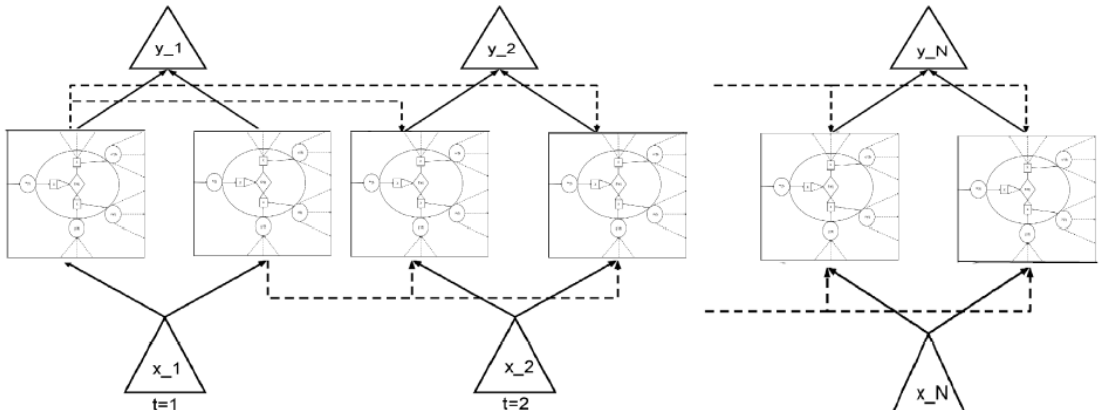
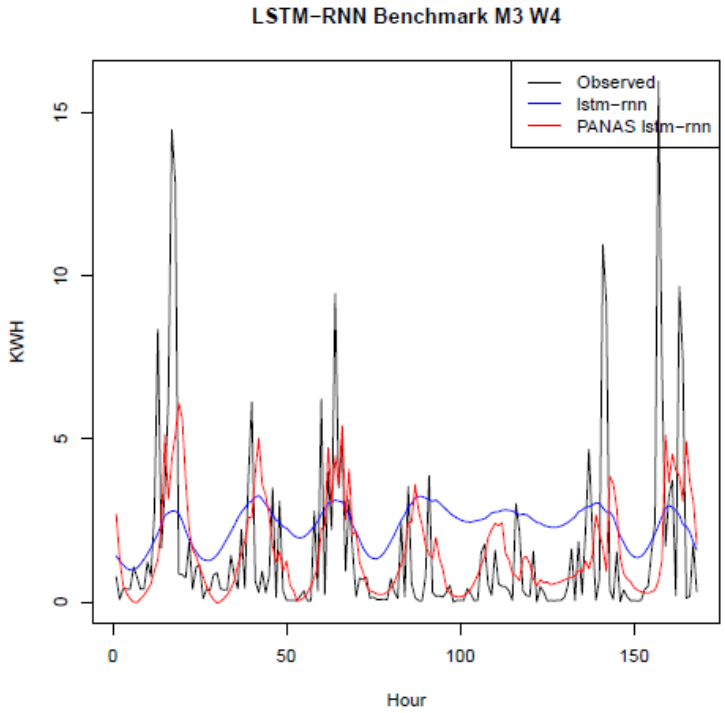


Figure 4.14: This figures depicts an RNN with two hidden LSTM memory cells. Each sequence is fed into the network as input sequences $(x_1, x_2, ..., x_n)$ and output sequences $(y_1, y_2, ..., y_n)$ using the sliding window as depicted in Fig. 4.13

FORECAST IMPROVEMENTS



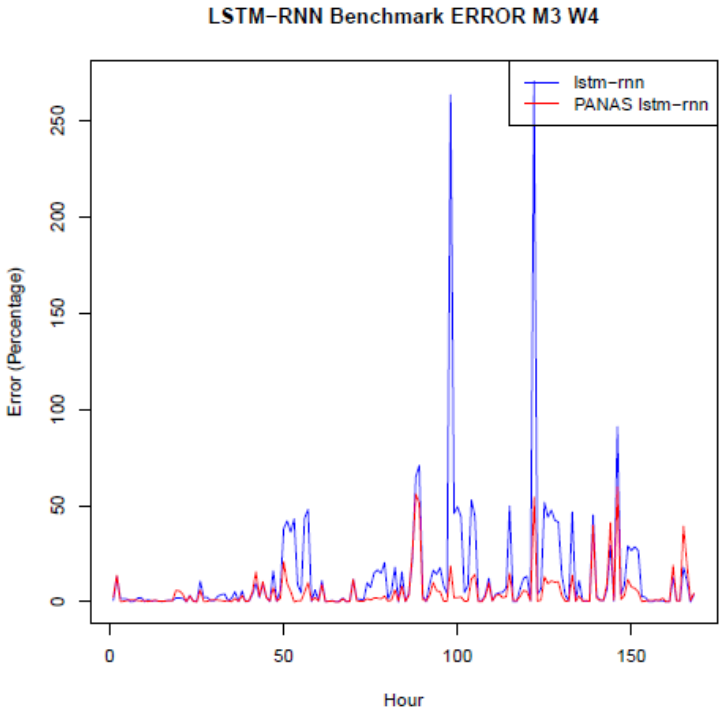
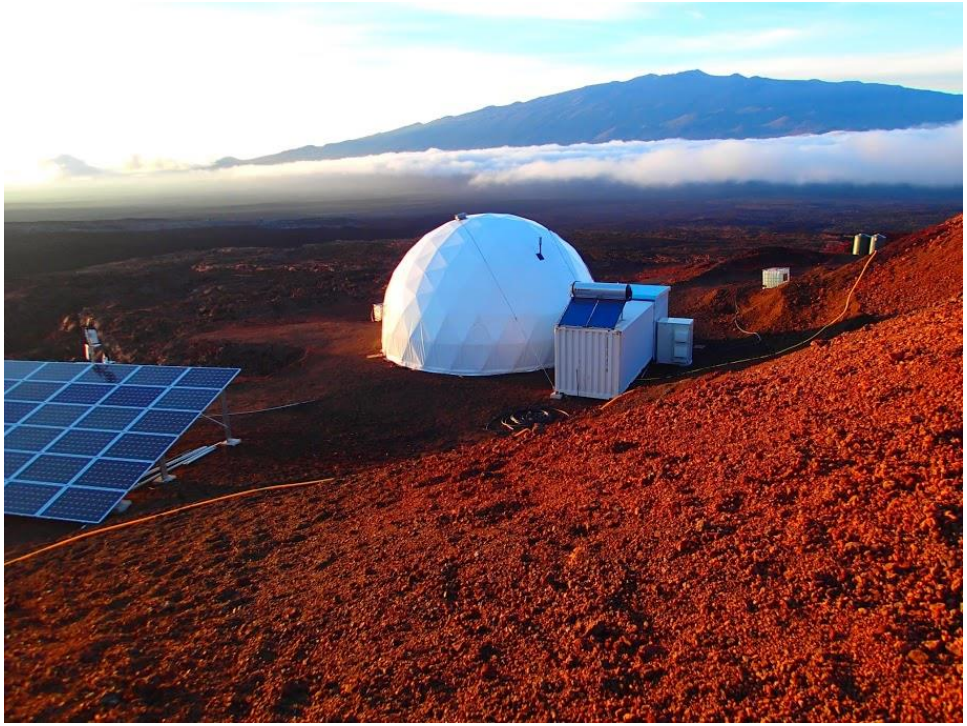
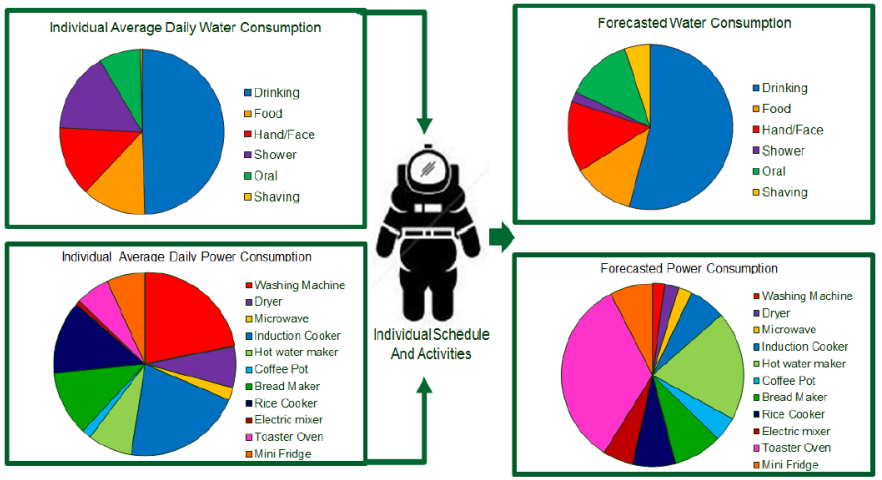


Figure 5.8: The benchmark is used on the LSTM-RNN and Neural Modulated LSTM-RNN method. The Observation data had a STD = 2.69, LSTM-RNN had an RMSE = 2.71, STD = 0.591, STD Error = 0.598, and a Mean Error = 14.13%. The Neural Modulated LSTM-RNN has a STD = 1.43, an RMSE = 2.57, with STD Error = 0.598, and a Mean Error of 5.39%.

FUTURE WORK




Individual Average Daily Water Consumption
Drinking
Food
Hand/Face
Shower
Oral
Shaving
Individual Average Daily Power Consumption
Washing Machine
Dryer
Microwave
Induction Cooker
Hot water maker
Coffee Pot
Bread Maker
Rice Cooker
Electric mixer
Toaster Oven
Mini Fridge
Individual Schedule And Activities
Forecasted Water Consumption
Drinking
Food
Hand/Face
Shower
Oral
Shaving
Forecasted Power Consumption
Washing Machine
Dryer
Microwave
Induction Cooker
Hot water maker
Coffee Pot
Bread Maker
Rice Cooker
Electric mixer
Toaster Oven
Mini Fridge

CONCLUSION

- Modified activation function method result is more accurate power consumption forecasts during significant events
- Memory activation functions within the LSTM memory cell increase in accuracy when the memory gate is governed by the modified activation method
- Modifying activation functions with emotional scores within this analogy hint at the possibility that emotional response may happen more naturally in behavior of real systems
- More direct experiments are required to draw further conclusions