Fuel Consumption Model for Tactical Operations Centers (TOCs)

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Background

- CERDEC conducted a power assessment in 2008
  - Three Command Posts (CPs): the Brigade Main, the Infantry Battalion CP and the MAIN Tactical CP.
  - Eight days of mission equipment operation.
- AMSAA requested SURVICE Engineering Company conduct a study to account for the fuel consumed.
- By then end of the study, SURVICE had accounted for 97% of the reported fuel used during TOCFEST.
- Resulting model can be used to predict fuel usage for TOCs – any weather conditions, shelters, shelter configuration, mission equipment layout, generators, and ECUs.

BCT Main CP
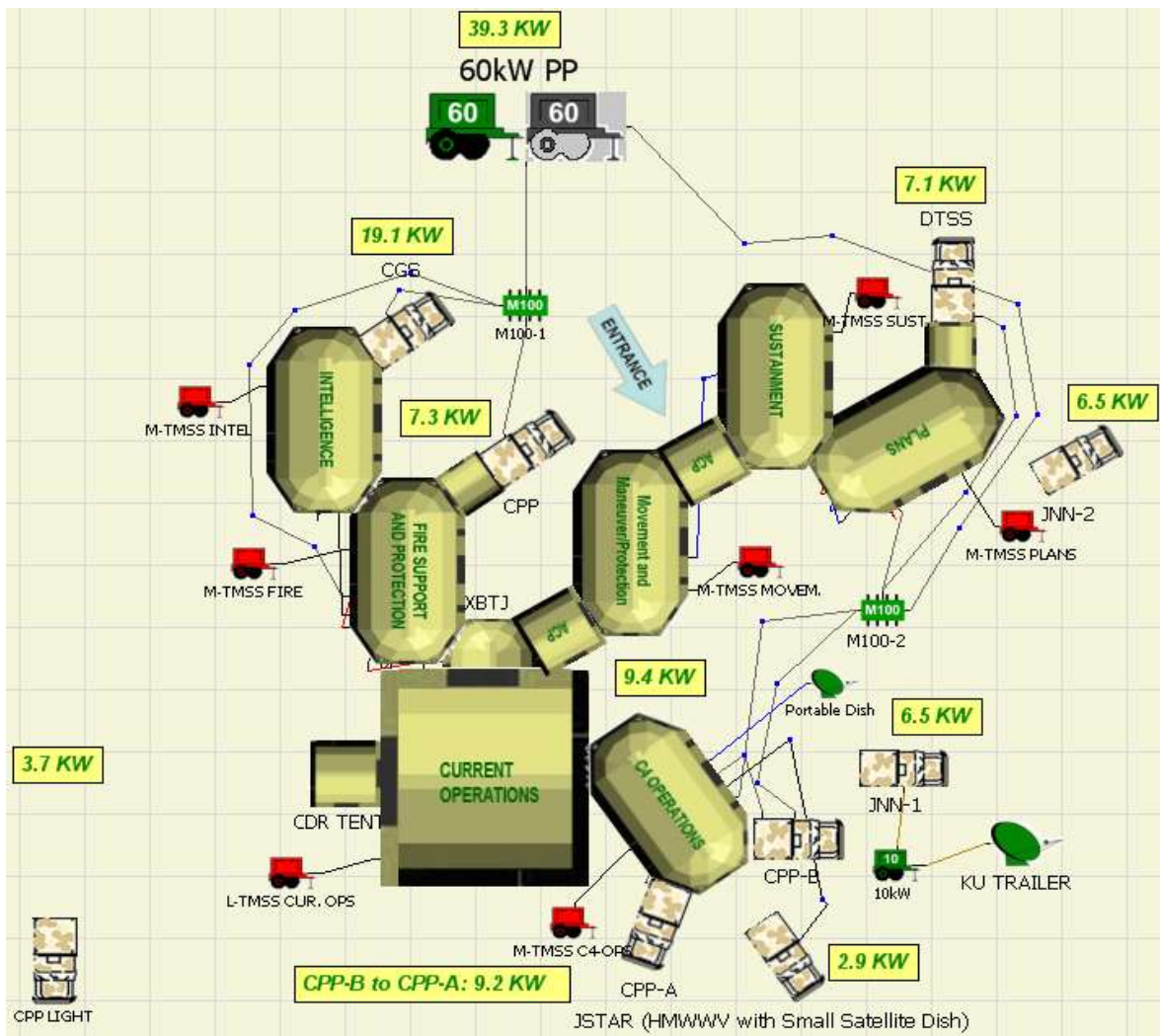
Problem Statement

Find: the fuel consumed by TMSSs during TOCFEST

Given:

- Total daily fuel usage & calculated fuel usage by power plants

- Shelter and mission equipment layouts

- Dates evaluated

- Weather conditions

- ECU capacities and TMSS fuel consumption rates

Tools:

- AutoDISE software

- HVAC Requirements calculator (part of AutoDISE)
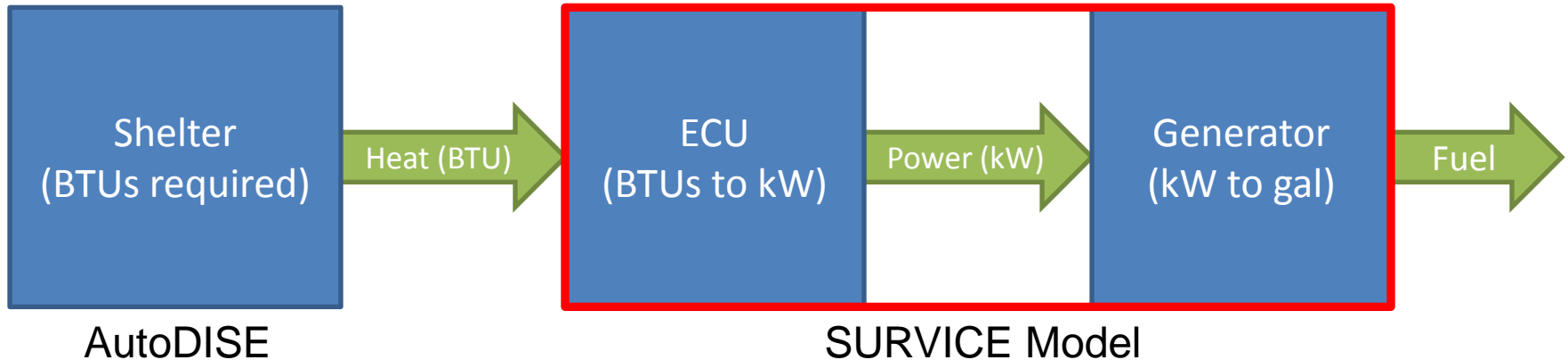
- SURVICE Fuel Consumption Model

Additional Input

- Assumptions made in the following areas:
  - ECU settings
  - TOC hours of operation
  - # personnel in each shelter
  - Conditions within shelters
  - Ground conditions
  - Solar and electrical contribution to heat load

Approach

Determine:

- Heating required (BTUs)
- Electrical Power to generate heating (BTU to kW)
- Fuel to produce total power (kW to gal)

HVAC Requirements Calculator

AutoDISE Input/Output

| Shelter: | Fire Support and Protection | | | | | | | | | | | | |

Inputs to AutoDISE

# of Personnel	12
Activity Level	moderate
Max Temp in shelter (°F)	80
Min Temp in shelter (°F)	70
Desired humidity inside (%)	50
Ventilation/Infiltration (CFM)	120

Color Codes:
- Enter into AutoDISE
- Values returned by AutoDISE
- TMSS used (note the ref. in the formulas to the Medium/Large TMSS)
- Not used - TMSS not running

Conditional Formatting
- Power to heat/cool …
- Power to heat/cool …
- Power to heat/cool …
- % Time ECU Running/NOT Runn
- % Time ECU Running/NOT Runn

- Cooling Required
- Heating Required
- No Heating/Cooling necessary
- Heating/Cooling not required for this setting, fuel calculated at no load
- Heating/Cooling required is more than ECU can provide, consider adjusting settings

		Inputs to AutoDISE					Calculated from AutoDISE					Power to heat/cool all connected
Date	Time	Ambient Temp	Ground Temp	Ambient Humidity	Wind Speed	Solar Load	Steady-State Temp	Electrical Equipment	Ventilation	Personnel	Structure	
(by hour)	(by hour)	(°F)	(°F)	(%)	(mph)	(BTU/hr/ft²)	(degrees F)	(BTU/hr)	(BTU/hr)	(BTU/hr)	(BTU/hr)	(BTU/hr)
3/27/2008	5:59 AM	36.32	36.32	77%	0.00	0	70.0	0	-4,435	0	-15,498	-26,703
3/27/2008	6:59 AM	33.62	33.62	85%	0.00	0	70.0	0	-4,790	0	-16,558	-28,625
3/27/2008	7:59 AM	33.62	33.62	85%	0.00	0	70.0	0	-4,790	0	-16,558	-28,625
3/27/2008	8:59 AM	33.62	33.62	88%	0.00	0	70.0	0	-4,790	0	-16,558	-28,625
3/27/2008	9:59 AM	33.8	33.8	86%	0.00	0	70.0	0	-4,767	0	-16,488	-28,498
3/27/2008	10:59 AM	35.96	35.96	83%	0.00	0	70.0	0	-4,482	0	-15,640	-26,960
3/27/2008	11:59 AM	36.14	36.14	85%	2.30	0	70.0	0	-4,458	0	-22,507	-36,455
3/27/2008	12:59 PM	38.48	38.48	82%	0.00	0	70.0	0	-4,150	0	-14,643	-25,154
3/27/2008	1:59 PM	43.16	43.16	67%	0.00	0	70.0	0	-3,534	0	-12,766	-21,768
3/27/2008	2:59 PM	42.62	42.62	78%	0.00	0	70.0	0	-3,605	0	-12,984	-22,161
3/27/2008	3:59 PM	42.8	42.8	87%	4.60	0	70.0	0	-3,582	0	-19,413	-31,046
3/27/2008	4:59 PM	46.4	46.4	73%	8.06	0	70.0	0	-3,107	0	-17,655	-28,002
3/27/2008	5:59 PM	45.5	45.5	73%	6.90	0	70.0	0	-3,226	0	-18,107	-28,780
3/29/2008	5:59 AM	35.42	35.42	53%	9.21	0	70.0	0	-4,553	0	-25,401	-40,575
3/29/2008	6:59 AM	34.34	34.34	53%	3.45	0	70.0	0	-4,695	0	-24,446	-39,442
3/29/2008	7:59 AM	33.62	33.62	53%	3.45	0	70.0	0	-4,790	0	-24,908	-40,203
3/29/2008	8:59 AM	33.08	33.08	57%	4.60	0	70.0	0	-4,861	0	-25,825	-41,561
3/29/2008	9:59 AM	32.36	32.36	58%	4.60	0	70.0	0	-4,956	0	-26,299	-42,339
3/29/2008	10:59 AM	32.18	32.18	59%	6.90	0	70.0	0	-4,980	0	-27,169	-43,571
3/29/2008	11:59 AM	33.26	33.26	46%	6.90	0	70.0	0	-4,838	0	-26,435	-42,373
3/29/2008	12:59 PM	34.34	34.34	45%	6.90	0	70.0	0	-4,695	0	-25,701	-41,174
3/29/2008	1:59 PM	35.24	35.24	40%	13.81	0	70.0	0	-4,577	0	-26,063	-41,519
3/29/2008	2:59 PM	37.22	37.22	38%	11.51	0	70.0	0	-4,316	0	-24,442	-38,943
3/29/2008	3:59 PM	38.66	38.66	38%	11.51	0	70.0	0	-4,127	0	-23,431	-37,302
3/29/2008	4:59 PM	40.64	40.64	36%	5.75	0	70.0	0	-3,866	0	-21,165	-33,834
3/29/2008	5:59 PM	43.16	43.16	33%	9.21	0	70.0	0	-3,534	0	-20,035	-31,842
3/30/2008	5:59 AM	28.94	28.94	51%	3.45	0	70.0	0	-5,407	0	-27,913	-45,153
3/30/2008	6:59 AM	28.04	28.04	52%	8.06	0	70.0	0	-5,525	0	-30,274	-48,566
3/30/2008	7:59 AM	27.68	27.68	50%	5.75	0	70.0	0	-5,572	0	-29,858	-48,053
3/30/2008	8:59 AM	26.24	26.24	45%	4.60	0	70.0	0	-5,762	0	-30,327	-48,949
3/30/2008	9:59 AM	24.44	24.44	49%	4.60	0	70.0	0	-5,999	0	-31,510	-50,890
3/30/2008	10:59 AM	24.26	24.26	50%	3.45	0	70.0	0	-6,023	0	-30,913	-50,097
3/30/2008	11:59 AM	27.32	27.32	47%	3.45	0	70.0	0	-5,620	0	-28,952	-46,865
3/30/2008	12:59 PM	29.48	29.48	42%	2.30	0	70.0	0	-5,335	0	-26,620	-43,273
3/30/2008	1:59 PM	33.62	33.62	40%	8.06	0	70.0	0	-4,790	0	-26,443	-42,321
3/30/2008	2:59 PM	35.6	35.6	35%	6.90	0	70.0	0	-4,530	0	-24,844	-39,777
3/30/2008	3:59 PM	39.92	39.92	33%	10.36	0	70.0	0	-3,861	0	-22,424	-35,695

Fuel Consumption Calculations

|	Medium TMSS								
	Low Heat (LowHeat on, only heating when too cold)				Total Low Heat Fuel (gal) 54.73	**High Heat** (High Heat on, only heating when too cold)				Total High Heat Fuel (gal) 101.20
Power to heat/cool all connected	% of time ECU Running (assume low setting)	% of time ECU NOT Running	Fuel Consumed (ECU Running) (assume low setting)	Fuel Consumed (ECU NOT Running) (assume no load)	Total Fuel (Running + No Load)	% of time ECU Running (assume high setting)	% of time ECU NOT Running	Fuel Consumed (ECU Running) (assume high setting)	Fuel Consumed (ECU NOT Running) (assume no load)	Total Fuel (Running + No Load)
(BTU/hr)	(%)	(%)	(gal/hr)	(gal/hr)	(gal/hr)	(%)	(%)	(gal/hr)	(gal/hr)	(gal/hr)
-26,703	89%	11%	0.48	0.04	0.52	45%	55%	0.65	0.21	0.86
-28,625	95%	5%	0.52	0.02	0.53	48%	52%	0.70	0.20	0.90
-28,625	95%	5%	0.52	0.02	0.53	48%	52%	0.70	0.20	0.90
-28,625	95%	5%	0.52	0.02	0.53	48%	52%	0.70	0.20	0.90
-28,498	95%	5%	0.51	0.02	0.53	47%	53%	0.69	0.20	0.89
-26,960	90%	10%	0.49	0.04	0.52	45%	55%	0.66	0.21	0.87
-36,455	122%	-22%	0.54	0.00	0.54	61%	39%	0.89	0.15	1.04
-25,154	84%	16%	0.45	0.06	0.51	42%	58%	0.61	0.22	0.83
-21,768	73%	27%	0.39	0.10	0.50	36%	64%	0.53	0.24	0.77
-22,161	74%	26%	0.40	0.10	0.50	37%	63%	0.54	0.24	0.78
-31,046	103%	-3%	0.54	0.00	0.54	52%	48%	0.76	0.18	0.94
-28,002	93%	7%	0.50	0.03	0.53	47%	53%	0.68	0.20	0.88
-28,780	96%	4%	0.52	0.02	0.53	48%	52%	0.70	0.20	0.90
-40,575	135%	-35%	0.54	0.00	0.54	68%	32%	0.99	0.12	1.11
-39,442	131%	-31%	0.54	0.00	0.54	66%	34%	0.96	0.13	1.09
-40,203	134%	-34%	0.54	0.00	0.54	67%	33%	0.98	0.13	1.10
-41,561	139%	-39%	0.54	0.00	0.54	69%	31%	1.01	0.12	1.13
-42,339	141%	-41%	0.54	0.00	0.54	71%	29%	1.03	0.11	1.14
-43,571	145%	-45%	0.54	0.00	0.54	73%	27%	1.06	0.10	1.16
-42,373	141%	-41%	0.54	0.00	0.54	71%	29%	1.03	0.11	1.14
-41,174	137%	-37%	0.54	0.00	0.54	69%	31%	1.00	0.12	1.12
-41,519	138%	-38%	0.54	0.00	0.54	69%	31%	1.01	0.12	1.13
-38,943	130%	-30%	0.54	0.00	0.54	65%	35%	0.95	0.13	1.08
-37,302	124%	-24%	0.54	0.00	0.54	62%	38%	0.91	0.14	1.05
-33,834	113%	-13%	0.54	0.00	0.54	56%	44%	0.82	0.17	0.99
-31,842	106%	-6%	0.54	0.00	0.54	53%	47%	0.77	0.18	0.95
-45,153	151%	-51%	0.54	0.00	0.54	75%	25%	1.10	0.09	1.19
-48,566	162%	-62%	0.54	0.00	0.54	81%	19%	1.18	0.07	1.25
-48,053	160%	-60%	0.54	0.00	0.54	80%	20%	1.17	0.08	1.24
-48,949	163%	-63%	0.54	0.00	0.54	82%	18%	1.19	0.07	1.26
-50,890	170%	-70%	0.54	0.00	0.54	85%	15%	1.24	0.06	1.30
-50,097	167%	-67%	0.54	0.00	0.54	83%	17%	1.22	0.06	1.28
-46,865	156%	-56%	0.54	0.00	0.54	78%	22%	1.14	0.08	1.22
-43,273	144%	-44%	0.54	0.00	0.54	72%	28%	1.05	0.11	1.16
-42,321	141%	-41%	0.54	0.00	0.54	71%	29%	1.03	0.11	1.14
-39,777	133%	-33%	0.54	0.00	0.54	66%	34%	0.97	0.13	1.10
-35,695	119%	-19%	0.54	0.00	0.54	59%	41%	0.87	0.15	1.02
-32,845	109%	-9%	0.54	0.00	0.54	55%	45%	0.80	0.17	0.97
-29,483	98%	2%	0.53	0.01	0.54	49%	51%	0.72	0.19	0.91

Common Conditions

- TMSS ECU COP = 1 (Resistance heating)
- Fuel for HMMWV's not included in analysis
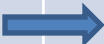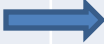- Distribution of Connector tent heat load
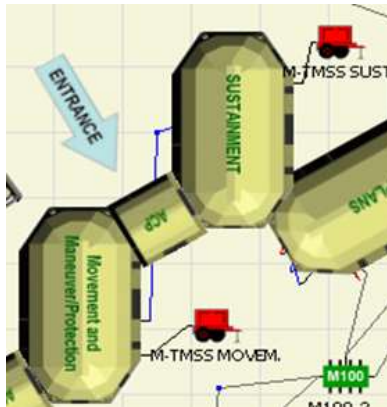
Actual Layout
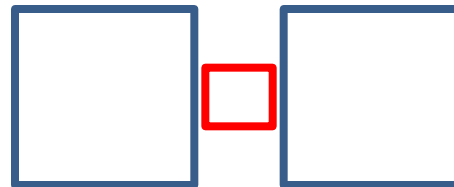
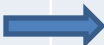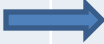Heat load calculated separately
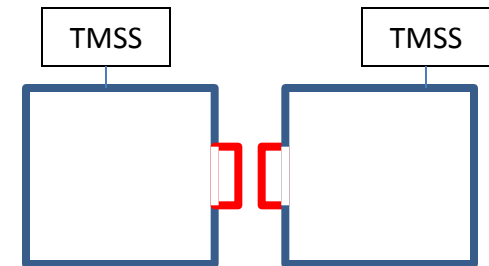
Heat Load Distributed

# Study Conditions

|	Scenario 1 (Original Assumptions)	Scenario 2	Scenario 3
Heat Setting	Low	Low →	High
Hours of Operation	0600-1800 →	0600-1900	0600-1900
# Personnel	# laptop stations →	0	0
Internal Temperature	65-80°F →	70-80°F	70-80°F
Desired Humidity	50%	50%	50%
Ventilation/Infiltration	# laptop stations	# laptop stations	# laptop stations
Ground Type	Dirt/grass	Dirt/grass	Dirt/grass
Ground Temperature	Air temperature	Air temperature	Air Temperature
Solar Load	0 BTU/hr	0 BTU/hr	0 BTU/hr
Conversion of Electrical Load to Heat Load	100% →	0%	0%

Scenario 1 Fuel Consumption
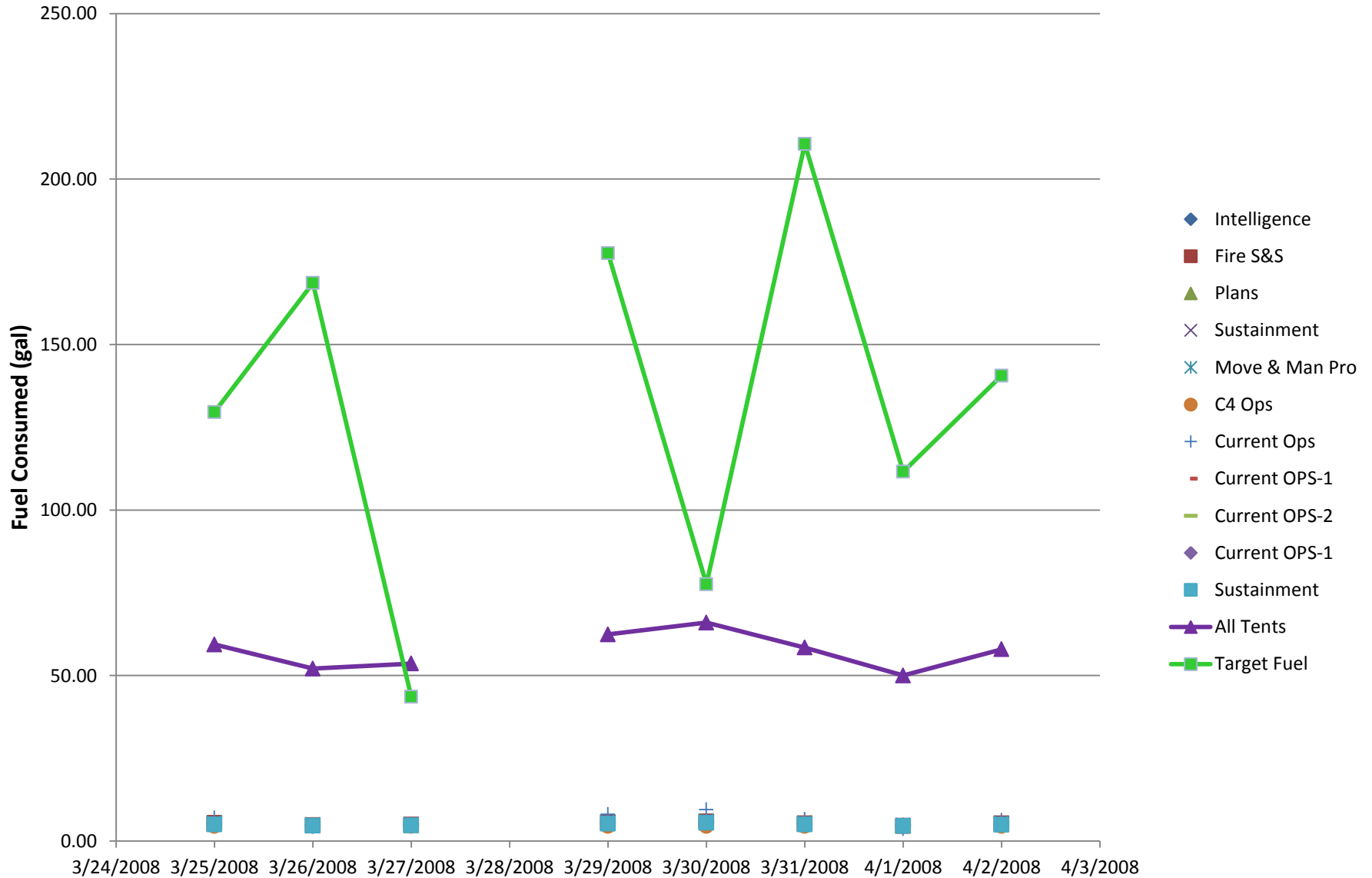
Scenario 2 Fuel Consumption
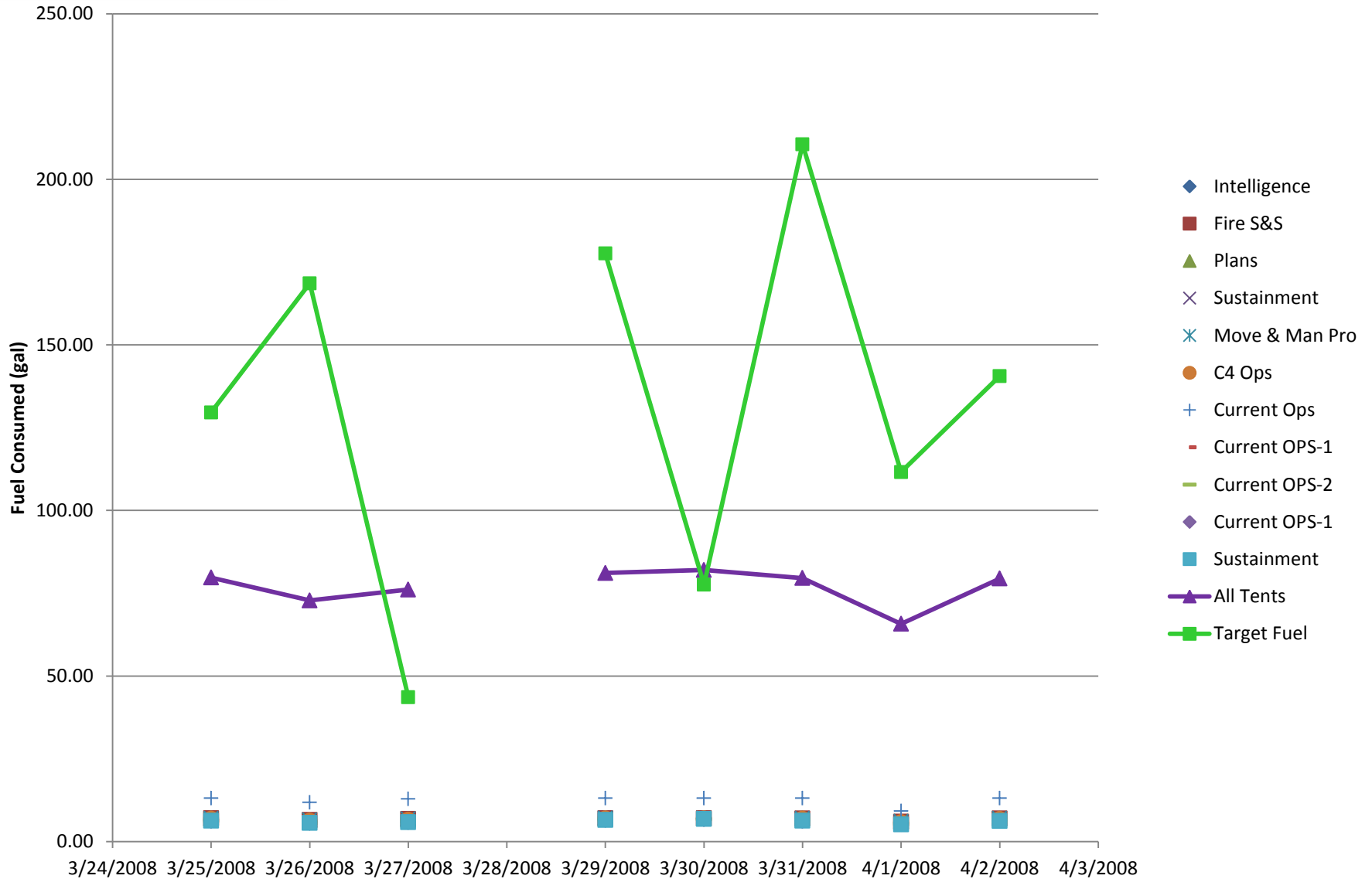
Scenario 3 Fuel Consumption
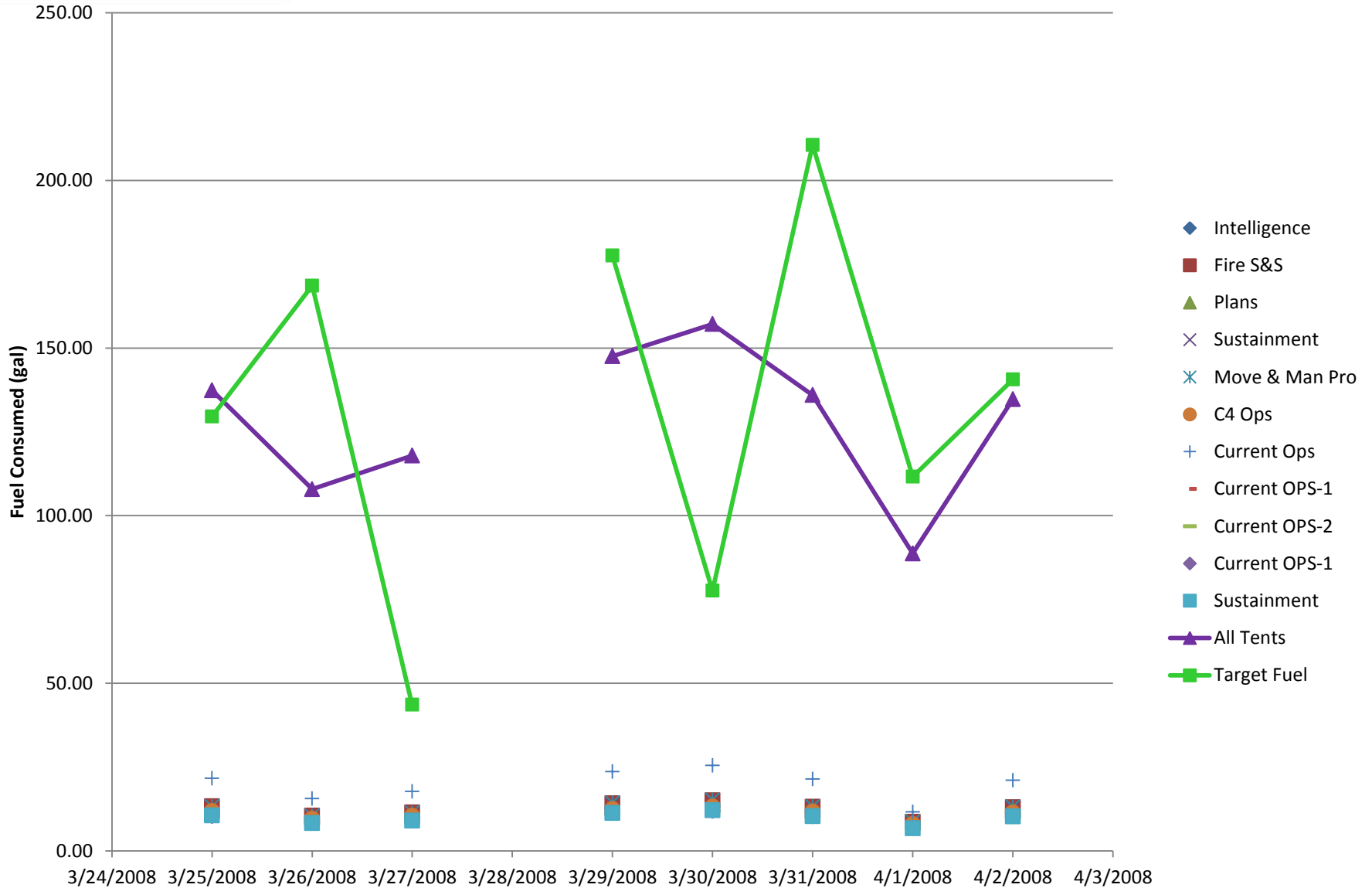
Fuel Consumption (gals)

Date	Scenario 1	Scenario 2	Scenario 3	Consumed by TMSSs
3/25/2008	61.40	79.74	137.37	129.6
3/26/2008	52.75	72.80	107.88	168.6
3/27/2008	54.53	76.10	117.88	43.6
3/28/2008				
3/29/2008	64.99	81.13	147.54	177.6
3/30/2008	69.25	82.00	157.13	77.6
3/31/2008	60.22	79.58	135.95	210.6
4/1/2008	50.40	65.77	88.71	111.6
4/2/2008	59.61	79.45	134.73	140.6
Total	473.15	616.58	1027.18	1059.8

Conclusion

- SURVICE model had accounted for 97% of the reported fuel used during TOCFEST.

- Resulting model can be used to predict fuel usage for TOCs – any weather conditions, shelters, shelter configuration, mission equipment layout, generators, and ECUs.

- The model shows what factors can significantly affect fuel usage.

BACKUP

Potential Fuel Consumption
based on Fuel Consumption Data from CERDEC

Generator Operating Conditions	TMSS Size	Fuel Consumption	Daily Fuel Consumption (12 hrs/day)	8-day total Fuel Consumption	Qty of TMSS size in TOC	Fuel Consumed per TMSS size (8-day total)	Potential Fuel Usage for TOCFEST
		(gal/hr)	(gal/day)	(gal)		(gal)	(gal)
Full Load	Medium	1.46	17.52	140.16	10	1401.6	1629.12
	Large	2.37	28.44	227.52	1	227.52	
Half Load	Medium	0.54	6.48	51.84	10	518.4	615.36
	Large	1.01	12.12	96.96	1	96.96	
No Load	Medium	0.38	4.56	36.48	10	364.8	388.8
	Large	0.25	3	24	1	24	

Recorded fuel used during TOCFEST	1231	
Report estimated fuel consumption by PP	171.2	14%
Report estimated fuel consumption by TMSS's	1059.8	86%