National Aeronautics and Space Administration

Armstrong Flight Research Center

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X-57

Maxwell

X-57 Cruise Motor and High-Lift Motor Mission Profile Power Analysis

ANLYS-CEPT-018

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X-57 Mission Profile Power Analysis (ANLYS-CEPT-018)

Scope

The X-57 Mission Profile Power Analysis was developed to evaluate the X-57 traction battery's performance against Mod II, Mod III and Mod IV generic flight mission profiles. Traction battery system performance acceptance testing requirements were developed using data generated by this analysis. This analysis was also used to define the maximum power requirements for the traction system components.

Mod IV Standard Energy Profile

The Mod IV Standard Energy Profile is not intended to be used as an actual flight profile. It is a combination of several Mod IV maneuvers and will not be flown in any single flight. The purpose of the Mod IV Standard Energy Profile is to provide the maximum operating requirements for the Mod IV traction system

Mod III/IV High Lift Motor Airspeed, Power and RPM Modes

High lift motor RPM in the "Airspeed" mode is dependent on the vehicle's equivalent airspeed (KEAS). High lift motor RPM in the "Fixed" mode is set to 4800 RPM. Airspeed, Power and RPM Schedules for the high lift motors in the Mod III and Mod IV Profiles can be found in X-57 High-Lift Propeller Operating Conditions Analysis Document (ANLYS-CEPT-023).

DisTributed Thrust Take Offs (DiTTO)

Mod III and Mod IV Flight Profiles include DisTributed Thrust Take Offs (DiTTO) that engage the high lift system in the Fixed RPM mode during takeoff. Since the primary propulsion motors were moved to the wingtips in the Mod III and Mod IV configuration, having the high lift motors engaged in the fixed mode will assist with mitigating the effects associated with asymmetric thrust from the primary propulsion motors during takeoff.

Simulate Battery Performance Plots

The battery performance plots located at the bottom of each page were generated using an X-57 traction battery model developed by Glenn Research Center. All measurements from the battery model are at the battery pack level (8 modules). The thermal plots assume the battery pack is at 10°C before the start of the profile. Data generated from the battery model were compared to acceptance test data of the battery system using the Mod II flight profile defined in this document.

Airspeed and Altitude Reference Atmosphere

Airspeed and altitude data are included in the profiles to assist with the thermal analysis. Referenced atmospheric conditions are provided by the X-57 Maxwell Project Reference Atmospheres Guide (GUIDE-CEPT-002). The power levels included in this document assume a standard day reference atmosphere.

Explanation of Mods

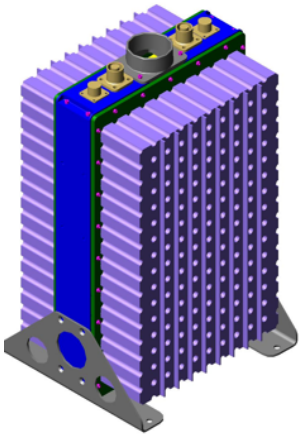
Mod I – Flight testing of stock Tecnam P2006T

Mod I – Retrofit a Tecnam P2006T with an electric propulsion system

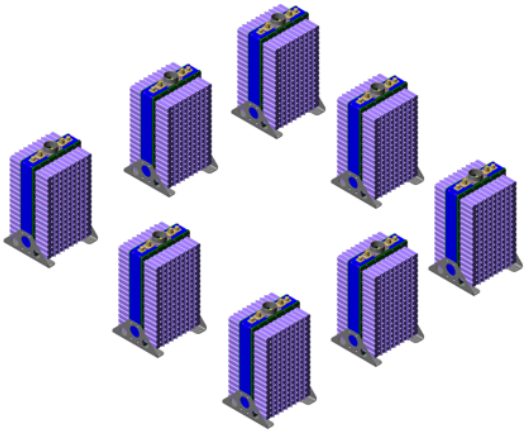
Mod III/IV – Remove the stock Tecnam wing and install a carbon fiber wing optimize for cruise conditions. This wing also includes an integrated Distributed Electric Propulsion (DEP) system designed to supplement lift for low-speed takeoffs and landing

Traction Battery Nomenclature

Battery Module 20P-16S
320 Cells
57.6 Volts
60 Ah - 3,456 Wh



Battery Pack 20P-128S
8 Modules
2560 Cells
461 Volts
60 Ah - 27,648 Wh



X-57 Cruise Motor and High-Lift Motor Mission Profile Power Analysis

Revision History

REV	DATE	DESCRIPTION	APPROVAL
-	2018-04-18	Baseline	FKH
A	2020-02-05	Removed Thermal Profiles Increased Mod II Takeoff Power from 60 kW to 72 kW Increased Mod II Cruise Power from 45 kW to 55 kW Increased Mod II Climb Durations Added Approximate Battery Energy Available Added separate Worksheet for Mod III Standard Energy Profile Updated Mod IV Standard Energy Profile with latest estimates Added Worksheets (Blue) for Mod IV Flight Maneuvers	FKH
B	2020-05-19	Increased Mod IV HL Motor Shaft Power Requirements to account for the 10-degree partial fold of the props: - HLP runup (fixed): From 8.6 kW to 9.9 kW - Ground roll (fixed): From 8.6 kW to 9.4 kW - Climb to 500' AGL (fixed): From 7.0 kW to 7.3 kW - Decel to 63 KCAS: From 4.5 kW to 5.1 kW - Hold at 63 KCAS: From 9.5 kW to 10.5 kW - Decel to 58 KCAS: From 10.5 kW to 11.1 kW - Hold at 58 KCAS: From 11.5 kW to 12.4 kW - Accelerate to Recovery: From 4.5 kW to 6.2 kW - Pattern (airspeed): From 2.1 kW to 2.5 kW - Final approach (airspeed): From 5.1 kW to 5.4 kW	FKH
C	2020-07-20	- Added DiTTO Takeoff Worksheet	FKH
D	2021-04-09	Added DiTTO Take OFF to the Mod III Standard Energy Profile, Mod IV Slow Flight HQ, Mod IV Slow Speed HQ, Mod IV Simulated Land-TO Added a READ ME worksheet Added Battery Model Plots Removed DiTTO Profile since it is incorporated into the Mod III and Mod IV Profiles Decresed desend to pattern times	FKH

Scope
Mission Profile Power Analysis The purpose of this power analysis is to assess the traction battery performance against Mod II, III and Mod IV flight generic mission profiles. The flight profiles were generated through analysis by the Performance and Sizing IPT. These profiles, along with the fight simulator data, will be used to developed detailed mission profiles using the flight planning tool.
Notes
Simulated Battery Performance Plots All outputs are at the A/B pack level, one set of 8 modules. Voltage under load must be above 340 V. Battery temperature starting point was set to 10 degC to represent thermal conditioning of batteries before flight Mod-IV total current split into Cruise and High Lift. Cruise/high lift currents do not include the load estimate for avionics system. Avionics system estimate is 0.8 kW/pack for Mod II, 1 kW/pack for Mods III/IV.
Battery Energy Remaining Estimates Battery enegery remaining estimates in each of the worksheets are based on general assumptions that do not include temperature effects and should not be used for detailed battery energy analysis. These battery energy estimates are used to develop the mission profile and provide an initial "rough cut" of the profile's energy requirements. The X57 Traction Battery Model shall be used to provide a detailed analysis of the flight profiles. The plots associated with each flight profile in this document are generated using the X57 Traction Battery Model and should be used for detailed battery energy analysis and traction system component design
Margin Energy margin is contained in the duration of the flight segments. See Notes 1 and Note 2 on each profile for an explanation of the duration margin
Mod IV Standard Energy Profile The Mod IV Standard Energy Profile is not intended to be used as a flight profile. It is a combination of several Mod IV maneuvers and will not be flown in any single flight. The purpose of the Mod IV Standard Energy Profile is to provide the maximum predicted power requirements for the Mod IV traction system
Airspeed and Altitude Reference Atmosphere Airspeed and altitude data are included in the energy profiles to assist with the thermal analysis of the propulsion system. Referenced atmospheric conditions are provided by the X-57 Maxwell Project Reference Atmospheres Guide (GUIDE-CEPT-002). The power levels included in this document assume a standard day reference atmosphere.
High Lift Motor Airspeed, Power and RPM Schedules Airspeed, Power and RPM Schedules for the high lift motors can be found in X-57 High-Lift Propeller Operating Conditions Analysis Document (ANLYS-CEPT-023).
DisTributed Thrust Take Offs (DiTTO) Mod III and Mod IV Flight Profiles include DisTributed Thrust Take Offs (DiTTO) that engage the High Lift System propulsion system in the Fixed RPM mode to mitigate hazards associated with cruise motor asymmetric thrust during takeoff and cruise nacelle thermal loads.

Mod II Standard Energy Profile

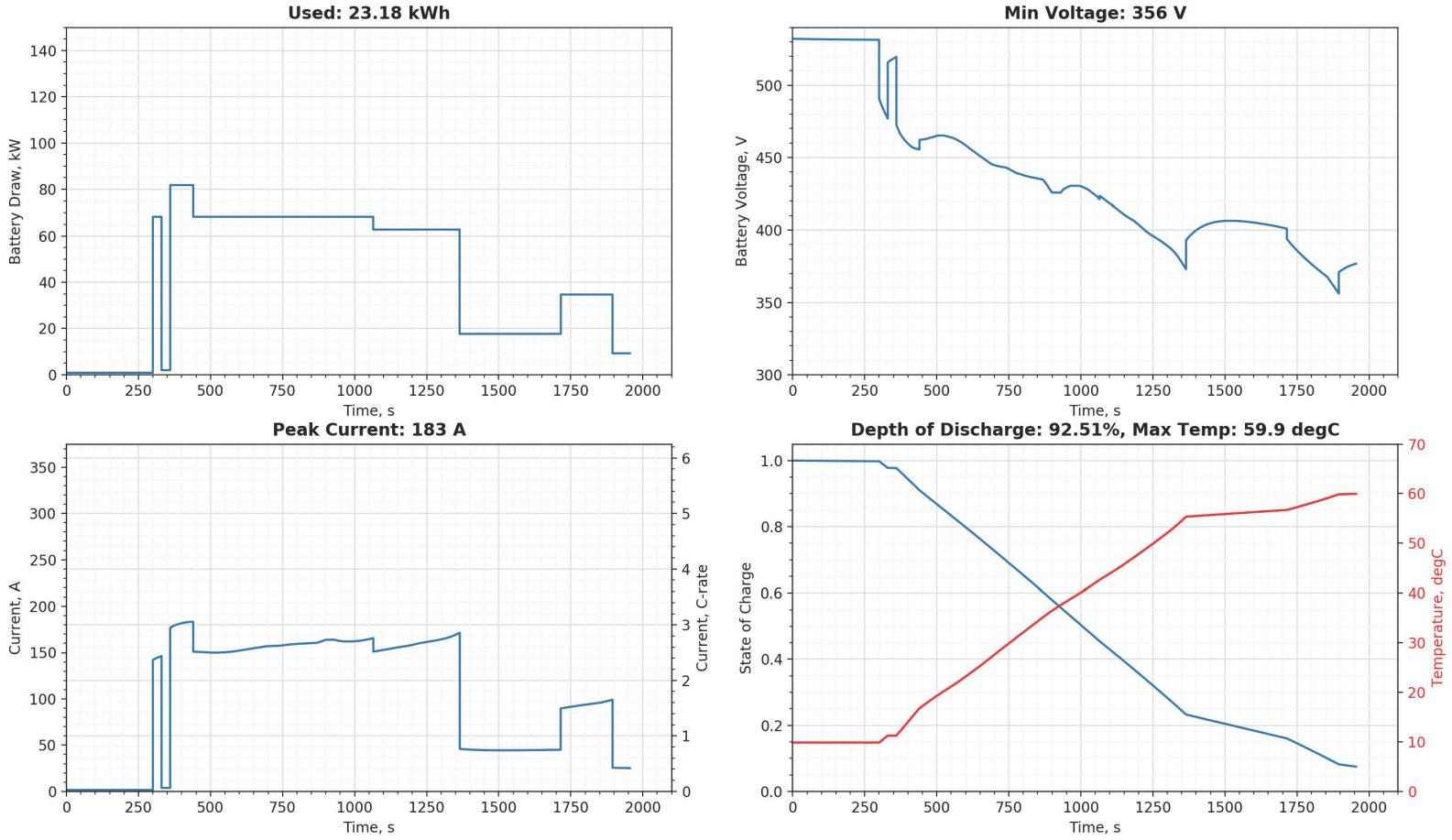
Phase	Maneuver	Initial Pressure Altitude (ft)	Initial Velocity (KCAS)	Duration (Seconds)	Cruise Motor Shaft Power (kW)		Cruise Motor Input Power (kW) 92.0% Efficiency		Cruise Controller Input Power (kW) 97.0% Efficiency		Avionics Power (kW)		Traction Bus Input Power (Battery Out) (kW) 99.5% Efficiency					Traction Bus Energy (kWh/Phase)
					1 Motor	2 Motors	1 Motor	2 Motors	1 Motor	2 Motors	1 side	2 sides	cell (W)	brick (W)	module	pack	system	
Taxi	Taxi from NASA	2300	0	0	5.0	10.0	5.4	10.9	5.6	11.2	0.8	1.6	2.5	50.3	0.8	6.4	12.9	0.0
Preflight	TO Checklist	2300	0	300	-						0.8	1.6	0.3	6.3	0.1	0.8	1.6	
	Cruise Runup	2300	0	30	60.0	120.0	65.2	130.4	67.2	134.5	0.8	1.6	26.7	534.2	8.5	68.4	136.8	
	Flight go/no-go	2300	0	30	1.0	2.0	1.1	2.2	1.1	2.2	0.8	1.6	0.8	15.1	0.2	1.9	3.9	1.3
Mod II Takeoff and Climb	Ground Roll	2300	0	10	72.0	144.0	78.3	156.5	80.7	161.4	0.8	1.6	32.0	639.8	10.2	81.9	163.8	
	Climb to 500' AGL[1]	2300	70	70	72.0	144.0	78.3	156.5	80.7	161.4	0.8	1.6	32.0	639.8	10.2	81.9	163.8	
	Cruise Climb to 8000' MSL[2]	2800	85	625	60.0	120.0	65.2	130.4	67.2	134.5	0.8	1.6	26.7	534.2	8.5	68.4	136.8	27.4
Maneuvers	Cruise/Maneuver (8000 MSL)[3]	8000	120	300	55.0	110.0	59.8	119.6	61.6	123.3	0.8	1.6	24.5	490.2	7.8	62.7	125.5	10.5
Mod II Descent and Landing	Descent to Pattern[4]	8000	110	350	15.0	30.0	16.3	32.6	16.8	33.6	0.8	1.6	6.9	138.3	2.2	17.7	35.4	
	Pattern (1500 AGL)	3800	95	120	30.0	60.0	32.6	65.2	33.6	67.2	0.8	1.6	13.5	270.2	4.3	34.6	69.2	
	Final Approach	2800	75	60	30.0	60.0	32.6	65.2	33.6	67.2	0.8	1.6	13.5	270.2	4.3	34.6	69.2	
	Rollout and turnoff	2300	75	60	7.5	15.0	8.2	16.3	8.4	16.8	0.8	1.6	3.6	72.3	1.2	9.3	18.5	7.2
Taxi	Taxi to NASA	2300	10	0	5.0	10.0	5.4	10.9	5.6	11.2	0.8	1.6	2.5	50.3	0.8	6.4	12.9	0.0
	Mission Total (s, Wh, kWh)			1955	20.2	40.4	21.9	43.9	22.6	45.3	0.4	0.9	9.1	181.1	2.9	23.2	46.4	
													Approximate Battery Energy Available[5] (Wh, kWh)					
													10	200	3.2	25.6	51.2	

% Battery Energy Remaining[5]	9.5%

Notes:

1. Assumes 425 ft/min climb, while current performance estimates are ~550 ft/min in this configuration. This results in ~15 seconds of time (30% energy) margin for this segment.
2. Assumes 500 ft/min climb from 2800 ft MSL, while current performance estimates are ~620 ft/min in this configuration. This results in ~120 seconds of time (25% energy) margin for this segment.
3. Increased Cruise Motor Power for Mod II from 45 kW to 55 kW since we need more power to cruise at faster speeds in the Mod II configuration. May need to limit duration.
4. Descent rate of 750 ft/min
5. Approximate Battery Energy calculated at a 10A/Cell (3.3C) discharge rate. Detailed battery estimates should use the X-57 Battery Model.

Tan boxes are populated by formulas from white boxes.
Blue rows are cruise system only
Green rows indicate Avionics Power is the only load


Used: 23.18 kWh
Battery Draw, kW
Time, s
Min Voltage: 356 V
Battery Voltage, V
Time, s
Peak Current: 183 A
Current, A
Current, C-rate
Time, s
Depth of Discharge: 92.51%, Max Temp: 59.9 degC
State of Charge
Temperature, degC
Time, s

Mod III Standard Energy Profile

DITTO Takeoff

Phase	Maneuver	High-Lift Mode	Initial Pressure Altitude (ft)	Initial Velocity (KCAS)	Duration (Seconds)	Cruise Motor Shaft Power (kW)		Cruise Motor Input Power (kW) 92.0% Efficiency		Cruise Controller Input Power (kW) 97.0% Efficiency		High Lift Motor Shaft Power (kW)		High Lift Motor Input Power (kW) 93.0% Efficiency		High Lift Controller Input Power (kW) 98.0% Efficiency		Avionics Power (kW)		Traction Bus Input Power (Battery Out) 99.5% Efficiency		High Lift Controller Input Power (kW) 97.0% Efficiency			Traction Bus Energy (kWh/Phase)
						1 Motor	2 Motors	1 Motor	2 Motors	1 Motor	2 Motors	1 Motor	12 Motors	1 Motor	12 Motors	1 Motor	12 Motors	1 side	2 sides	cell (W)	brick (W)	module	pack	system	
Taxi	Taxi from NASA		2300	0	0	5.0	10.0	5.4	10.9	5.6	11.2							1.0	2.0	2.6	51.8	0.8	6.6	13.3	0.0
Preflight	TO Checklist		2300	0	300	-	-	-	-	-	-							1.0	2.0	0.4	7.9	0.1	1.0	2.0	
	Cruise Runup		2300	0	30	60.0	120.0	65.2	130.4	67.2	134.5							1.0	2.0	26.8	535.8	8.6	68.6	137.2	
	HL Runup	Airspeed	2300		10	1.0	2.0	1.1	2.2	1.1	2.2	0.3	3.6	0.3	3.9	0.3	3.9	1.0	2.0	1.6	32.2	0.5	4.1	8.2	
	HL Runup	Fixed	2300	0	10	1.0	2.0	1.1	2.2	1.1	2.2	10.0	120.0	10.8	129.0	11.0	131.7	1.0	2.0	26.7	533.6	8.5	68.3	136.6	
	Flight go/no-go	Airspeed	2300		30	1.0	2.0	1.1	2.2	1.1	2.2	0.3	3.6	0.3	3.9	0.3	3.9	1.0	2.0	1.6	32.2	0.5	4.1	8.2	1.8
Mod III DiTTO Takeoff and Climb	Ground Roll	Fixed	2300		20	48.0	96.0	52.2	104.3	53.8	107.6	9.0	108.0	9.7	116.1	9.9	118.5	1.0	2.0	44.8	895.4	14.3	114.6	229.2	
	Climb to 500' AGL[1]	Fixed	2300	96	90	48.0	96.0	52.2	104.3	53.8	107.6	5.6	67.2	6.0	72.3	6.1	73.7	1.0	2.0	36.0	719.6	11.5	92.1	184.2	
	Cruise Climb[2]		2800	100	625	60.0	120.0	65.2	130.4	67.2	134.5							1.0	2.0	26.8	535.8	8.6	68.6	137.2	29.7
Manuevers	Cruise (8000 MSL)		8000	120	120	45.0	90.0	48.9	97.8	50.4	100.9							1.0	2.0	20.2	403.8	6.5	51.7	103.4	3.4
Mod III Descent and Landing	Desend to Pattern[3]		8000	120	350	15.0	30.0	16.3	32.6	16.8	33.6							1.0	2.0	7.0	139.8	2.2	17.9	35.8	
	Pattern (1500 AGL)		3800	105	120	30.0	60.0	32.6	65.2	33.6	67.2							1.0	2.0	13.6	271.8	4.3	34.8	69.6	
	Final Approach		2800	95	60	30.0	60.0	32.6	65.2	33.6	67.2							1.0	2.0	13.6	271.8	4.3	34.8	69.6	
	Rollout and turnoff		2300	75	60	7.5	15.0	8.2	16.3	8.4	16.8							1.0	2.0	3.7	73.8	1.2	9.5	18.9	7.3
Taxi	Taxi to NASA		2300	10	0	5.0	10.0	5.4	10.9	5.6	11.2							1.0	2.0	2.6	51.8	0.8	6.6	13.3	0.0
	Mission Total (s, Wh, kWh)				1825	17.0	34.0	18.5	36.9	19.0	38.1	0.2	2.7	0.2	2.9	0.2	2.9	0.5	1.0	8.2	164.8	2.6	21.1	42.2	
																				10	200	3.2	25.6	51.2	

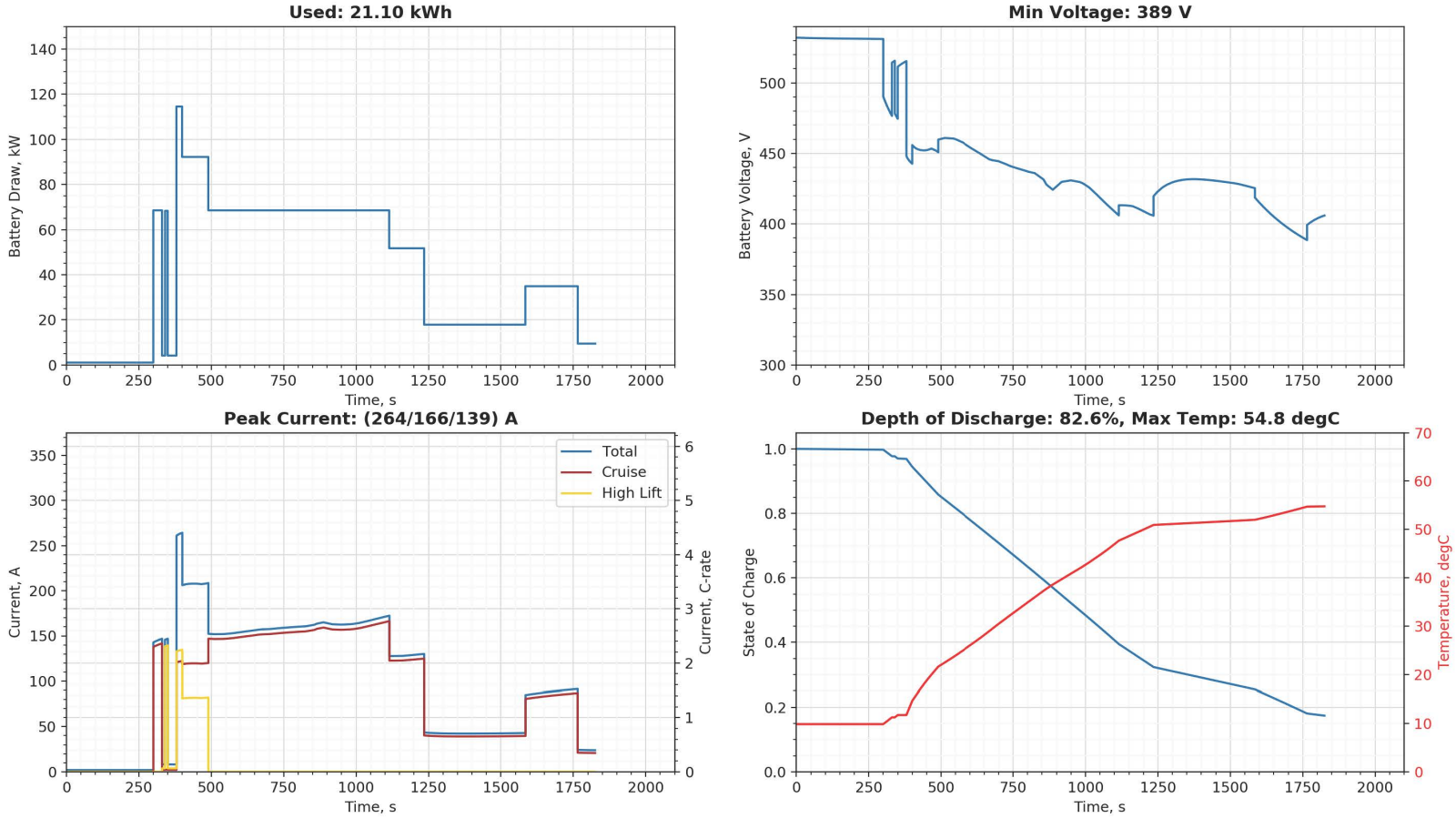
Approximate Battery Energy Available[4] (Wh, kWh)

% Battery Energy Remaining[4]	17.6%

Notes:

1. Assumes 333 ft/min climb, while current performance estimates are ~390 ft/min in this configuration. This results in ~13 seconds of time (17% energy) margin for this segment.
2. Assumes 500 ft/min climb from 2800 ft MSL, while current performance estimates are ~700+ ft/min in this configuration. This result sin ~180 seconds of time (40% energy) margin for this segment.
3. Descent rate of 750 ft/min
4. Approximate Battery Energy calculated at a 10A/Cell (3.3C) discharge rate. Detailed battery estimates should use the X-57 Battery Model.

Tan boxes are populated by formulas from white boxes.
Blue rows are cruise system only
Red rows indicate high-lift system active
Green rows indicate Avionics Power is the only load


Used: 21.10 kWh
Battery Draw, kW
Time, s
Min Voltage: 389 V
Battery Voltage, V
Time, s
Peak Current: (264/166/139) A
Total
Cruise
High Lift
Current, A
Current, C-rate
Time, s
Depth of Discharge: 82.6%, Max Temp: 54.8 degC
State of Charge
Temperature, degC
Time, s

Mod IV Standard Energy Profile

The Mod IV Standard Energy Profile is not intended to be a flight profile. It is a combination of several Mod IV maneuvers and will not be flown in a single flight

The purpose of the Mod IV Standard Energy Profile is to provide the maximum predicted power requirements for the Mod IV traction system.

Phase	Maneuver	High-Lift Mode	Initial Pressure Altitude (ft.)	Initial Velocity (KCAS)	Duration (Seconds)	Cruise Motor Shaft Power (kW)		Cruise Motor Input Power (kW) 92.0% Efficiency		Cruise Controller Input Power (kW) 97.0% Efficiency		High Lift Motor Shaft Power (kW)		High Lift Motor Input Power (kW) 93.0% Efficiency		High Lift Controller Input Power (kW) 98.0% Efficiency		Avionics Power (kW)		Traction Bus Input Power (Battery Out) (kW) 99.5% Efficiency					Traction Bus Energy (kWh/Phase)
						1 Motor	2 Motors	1 Motor	2 Motors	1 Motor	2 Motors	1 Motor	12 Motors	1 Motor	12 Motors	1 Motor	12 Motors	1 side	2 sides	cell (W)	brick (W)	module	pack	system	
Taxi	Taxi from NASA		2300	0	0	5.0	10.0	5.4	10.9	5.6	11.2							1.0	2.0	2.6	51.8	0.8	6.6	13.3	0.0
Preflight	TO Checklist		2300	0	300													1.0	2.0	0.4	7.9	0.1	1.0	2.0	
	Cruise Runup		2300	0	30	60.0	120.0	65.2	130.4	67.2	134.5							1.0	2.0	26.8	535.8	8.6	68.6	137.2	
	HL Runup	Airspeed	2300	0	10	1.0	2.0	1.1	2.2	1.1	2.2	0.3	3.6	0.3	3.9	0.3	3.9	1.0	2.0	1.6	32.2	0.5	4.1	8.2	
	HL Runup	Fixed	2300	0	10	1.0	2.0	1.1	2.2	1.1	2.2	10.0	120.0	10.8	129.0	11.0	131.7	1.0	2.0	26.7	533.6	8.5	68.3	136.6	
	Flight go/no-go	Airspeed	2300	0	30	1.0	2.0	1.1	2.2	1.1	2.2	0.3	3.6	0.3	3.9	0.3	3.9	1.0	2.0	1.6	32.2	0.5	4.1	8.2	1.8
Mod IV Fixed Mode Takeoff and Climb	Ground Roll	Fixed	2300	0	10	72.0	144.0	78.3	156.5	80.7	161.4	9.3	111.6	10.0	120.0	10.2	122.4	1.0	2.0	56.1	1,122.1	18.0	143.6	287.2	
	Climb to 500' AGL[1]	Fixed	2300	85	30	72.0	144.0	78.3	156.5	80.7	161.4	6.9	82.8	7.4	89.0	7.6	90.8	1.0	2.0	49.9	998.0	16.0	127.7	255.5	
	Cruise Climb to 6300' MSL[2]		2800	100	420	60.0	120.0	65.2	130.4	67.2	134.5							1.0	2.0	26.8	535.8	8.6	68.6	137.2	18.9
Mod IV Low Speed Maneuvers at Altitude	Setup for Maneuver		6300	120	60	45.0	90.0	48.9	97.8	50.4	100.9							1.0	2.0	20.2	403.8	6.5	51.7	103.4	
	Decel to 63 KCAS	Airspeed	6300	110	50	5.0	10.0	5.4	10.9	5.6	11.2	4.0	48.0	4.3	51.6	4.4	52.7	1.0	2.0	12.9	258.6	4.1	33.1	66.2	
	Hold at 63 KCAS	Airspeed	6300	63	180	5.0	10.0	5.4	10.9	5.6	11.2	9.6	115.2	10.3	123.9	10.5	126.4	1.0	2.0	27.4	548.1	8.8	70.2	140.3	
	Decel to 58 KCAS	Airspeed	6300	63	10	5.0	10.0	5.4	10.9	5.6	11.2	10.2	122.4	11.0	131.6	11.2	134.3	1.0	2.0	29.0	579.1	9.3	74.1	148.2	
	Hold at 58 KCAS	Airspeed	6300	58	10	5.0	10.0	5.4	10.9	5.6	11.2	11.4	136.8	12.3	147.1	12.5	150.1	1.0	2.0	32.1	641.1	10.3	82.1	164.1	
	Accelerate to Recovery	Airspeed	6300	58	60	60.0	120.0	65.2	130.4	67.2	134.5	4.9	58.8	5.3	63.2	5.4	64.5	1.0	2.0	39.5	789.0	12.6	101.0	202.0	13.9
Mod IV Airspeed Mode Landing	Setup for Landing		6300	120	60	45.0	90.0	48.9	97.8	50.4	100.9							1.0	2.0	20.2	403.8	6.5	51.7	103.4	
	Descent to Pattern[3]		6300	120	200	15.0	30.0	16.3	32.6	16.8	33.6							1.0	2.0	7.0	139.8	2.2	17.9	35.8	
	Pattern	Airspeed	3800	105	120	30.0	60.0	32.6	65.2	33.6	67.2	1.3	15.6	1.4	16.8	1.4	17.1	1.0	2.0	17.0	339.0	5.4	43.4	86.8	
	Final Approach	Airspeed	2800	75	60	30.0	60.0	32.6	65.2	33.6	67.2	5.0	60.0	5.4	64.5	5.5	65.8	1.0	2.0	26.5	530.3	8.5	67.9	135.7	
	Rollout and turnoff		2300	75	60	7.5	15.0	8.2	16.3	8.4	16.8							1.0	2.0	3.7	73.8	1.2	9.5	18.9	9.2
Taxi	Taxi to NASA		2300	10	0	5.0	10.0	5.4	10.9	5.6	11.2							1.0	2.0	2.6	51.8	0.8	6.6	13.3	0.0
	Mission Total (s, Wh, kWh)				1710	13.6	27.2	14.8	29.6	15.3	30.5	0.9	11.0	1.0	11.8	1.0	12.1	0.5	1.0	8.6	171.0	2.7	21.9	43.8	
																				10	200	3.2	25.6	51.2	

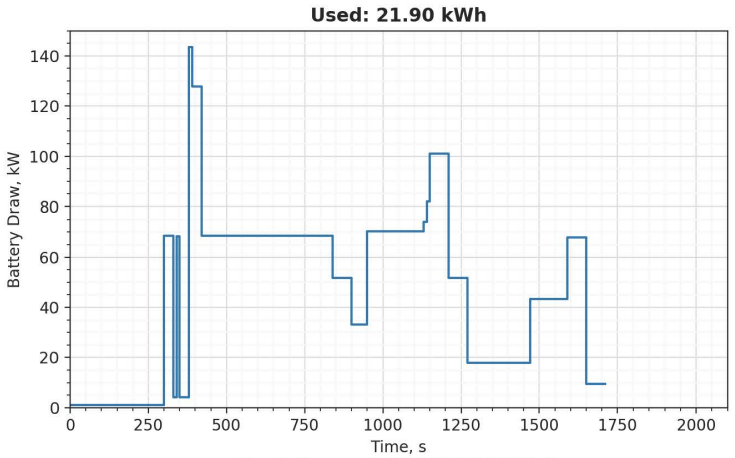
Approximate Battery Energy Available[4] (Wh, kWh)

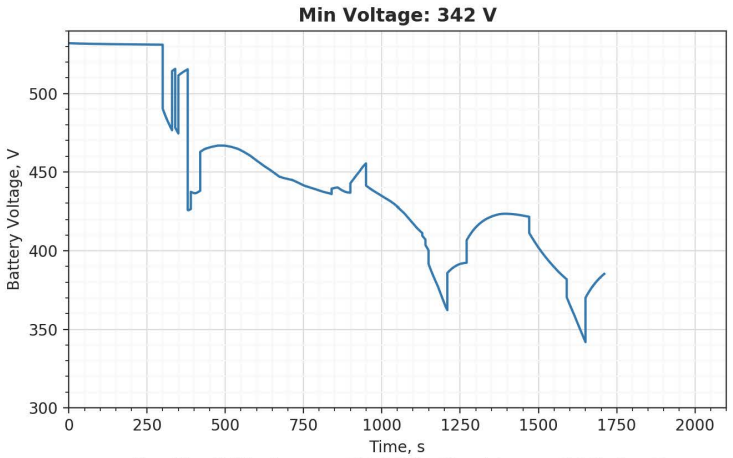
% Battery Energy Remaining[4]	14.5%

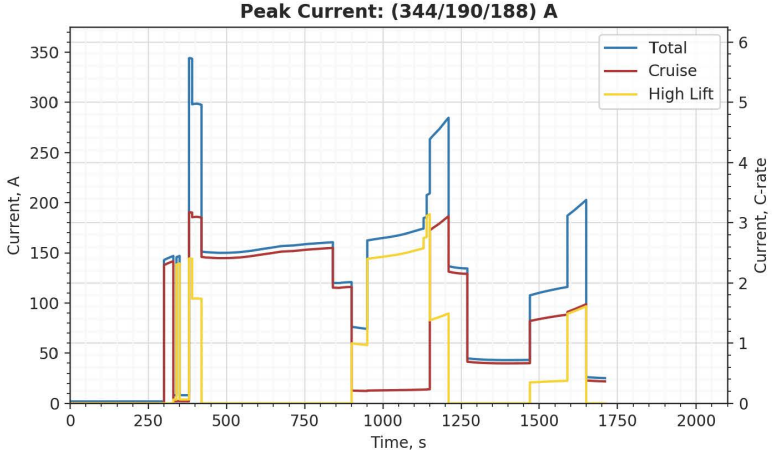
Notes:

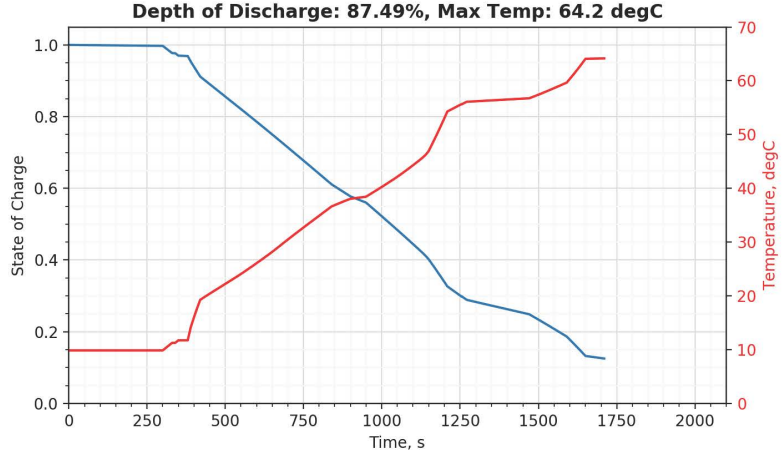
1. Assumes 1000 ft/min climb, while current performance estimates are ~1500 ft/min in this configuration. This results in ~10 seconds of time (50% energy) margin for this segment.
2. Assumes 500 ft/min climb from 2800 ft MSL, while current perfomance estimates are ~700+ ft/min in this configuration. This results in ~120 seconds of time (40% energy) margin for this segment.
3. Descent rate of 750 ft/min
4. Approximate Battery Energy calculated at a 10A/Cell (3.3C) discharge rate. Detailed battery estimates should use the X-57 Battery Model.

Tan boxes are populated by formulas from white boxes.
Blue rows are cruise system only
Red rows indicate high-lift system active
Green rows indicate Avionics Power is the only load


Used: 21.90 kWh
Battery Draw, kW
Time, s


Min Voltage: 342 V
Battery Voltage, V
Time, s


Peak Current: (344/190/188) A
Total
Cruise
High Lift
Current, A
Current, C-rate
Time, s


Depth of Discharge: 87.49%, Max Temp: 64.2 degC
State of Charge
Temperature, degC
Time, s

Mod IV Slow Flight HQ

Flight for low-speed handling qualities: sizing case for approach config, 63 KCAS

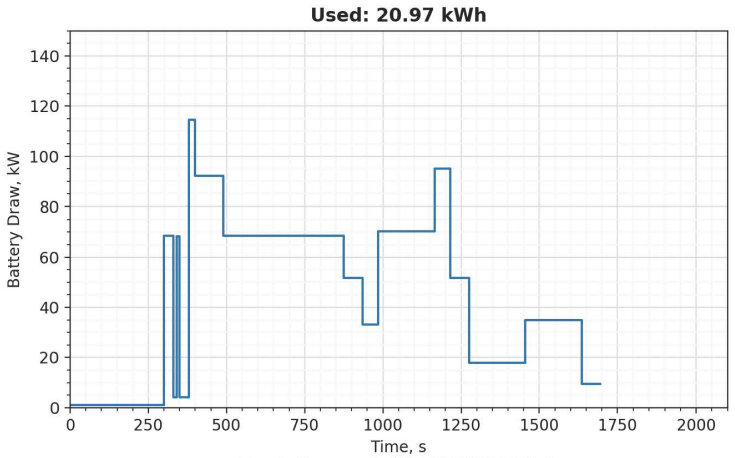
Phase	Maneuver	High-Lift Mode	Initial Pressure Altitude (ft)	Initial Velocity (KCAS)	Duration (Seconds)	Cruise Motor Shaft Power (kW)		Cruise Motor Input Power (kW) 92.0% Efficiency		Cruise Controller Input Power (kW) 97.0% Efficiency		High Lift Motor Shaft Power (kW)		High Lift Motor Input Power (kW) 93.0% Efficiency		High Lift Controller Input Power (kW) 98.0% Efficiency		Avionics Power (kW)		Traction Bus Input Power (Battery Out) (kW) 99.5% Efficiency					Traction Bus Energy (kWh/Phase)
						1 Motor	2 Motors	1 Motor	2 Motors	1 Motor	2 Motors	1 Motor	12 Motors	1 Motor	12 Motors	1 Motor	12 Motors	1 side	2 sides	cell (W)	brick (W)	module	pack	system	
Taxi	Taxi from NASA		2300	0	0	5.0	10.0	5.4	10.9	5.6	11.2							1.0	2.0	2.6	51.8	0.8	6.6	13.1	0.0
Preflight	TO Checklist		2300	0	300													1.0	2.0	0.4	7.9	0.1	1.0	2.0	
	Cruise Runup		2300	0	30	60.0	120.0	65.2	130.4	67.2	134.5							1.0	2.0	26.8	535.8	8.6	68.6	137.2	
	HL Runup	Airspeed	2300	0	10	1.0	2.0	1.1	2.2	1.1	2.2	0.3	3.6	0.3	3.9	0.3	3.9	1.0	2.0	1.6	32.2	0.5	4.1	8.2	
	HL Runup	Fixed	2300	0	10	1.0	2.0	1.1	2.2	1.1	2.2	10.0	120.0	10.8	129.0	11.0	131.7	1.0	2.0	26.7	533.6	8.5	68.3	136.6	
	Flight go/no-go	Airspeed	2300	0	30	1.0	2.0	1.1	2.2	1.1	2.2	0.3	3.6	0.3	3.9	0.3	3.9	1.0	2.0	1.6	32.2	0.5	4.1	8.2	1.8
Mod III DiTTO Takeoff and Climb	Ground Roll	Fixed	2300	0	20	48.0	96.0	52.2	104.3	53.8	107.6	9.0	108.0	9.7	116.1	9.9	118.5	1.0	2.0	44.8	895.4	14.3	114.6	229.2	
	Climb to 500' AGL[1]	Fixed	2300	96	90	48.0	96.0	52.2	104.3	53.8	107.6	5.6	67.2	6.0	72.3	6.1	73.7	1.0	2.0	36.0	719.6	11.5	92.1	184.2	
	Cruise Climb to 6000' MSL[2]		2800	100	385	60.0	120.0	65.2	130.4	67.2	134.5							1.0	2.0	26.8	535.8	8.6	68.6	137.2	20.5
Mod IV Low Speed Handling Quality Maneuver	Setup for Maneuver		6000	120	60	45.0	90.0	48.9	97.8	50.4	100.9							1.0	2.0	20.2	403.8	6.5	51.7	103.4	
	Decel to 63 KCAS	Airspeed	6000	110	50	5.0	10.0	5.4	10.9	5.6	11.2	4.0	48.0	4.3	51.6	4.4	52.7	1.0	2.0	12.9	258.6	4.1	33.1	66.2	
	Hold at 63 KCAS	Airspeed	6000	63	180	5.0	10.0	5.4	10.9	5.6	11.2	9.6	115.2	10.3	123.9	10.5	126.4	1.0	2.0	27.4	548.1	8.8	70.2	140.3	
	Accelerate to Recovery	Airspeed	6000	63	50	60.0	120.0	65.2	130.4	67.2	134.5	4.0	48.0	4.3	51.6	4.4	52.7	1.0	2.0	37.1	742.5	11.9	95.0	190.1	12.3
Mod III Descent and Landing	Setup for Landing		6000	120	60	45.0	90.0	48.9	97.8	50.4	100.9							1.0	2.0	20.2	403.8	6.5	51.7	103.4	
	Descent to Pattern[3]		6000	120	180	15.0	30.0	16.3	32.6	16.8	33.6							1.0	2.0	7.0	139.8	2.2	17.9	35.8	
	Pattern		3800	105	120	30.0	60.0	32.6	65.2	33.6	67.2							1.0	2.0	13.6	271.8	4.3	34.8	69.6	
	Final Approach		2800	95	60	30.0	60.0	32.6	65.2	33.6	67.2							1.0	2.0	13.6	271.8	4.3	34.8	69.6	
	Rollout and turnoff		2300	95	60	7.5	15.0	8.2	16.3	8.4	16.8							1.0	2.0	3.7	73.8	1.2	9.5	18.9	7.3
Taxi	Taxi to NASA		2300	10	0	5.0	10.0	5.4	10.9	5.6	11.2							1.0	2.0	2.6	51.8	0.8	6.6	13.1	0.0
	Mission Total (s, Wh, kWh)				1695	13.4	26.9	14.6	29.2	15.0	30.1	0.8	9.7	0.9	10.5	0.9	10.7	0.5	0.9	8.2	163.8	2.6	21.0	41.9	
												Approximate Battery Energy Available[4] (Wh, kWh)								10	200	3.2	25.6	51.2	

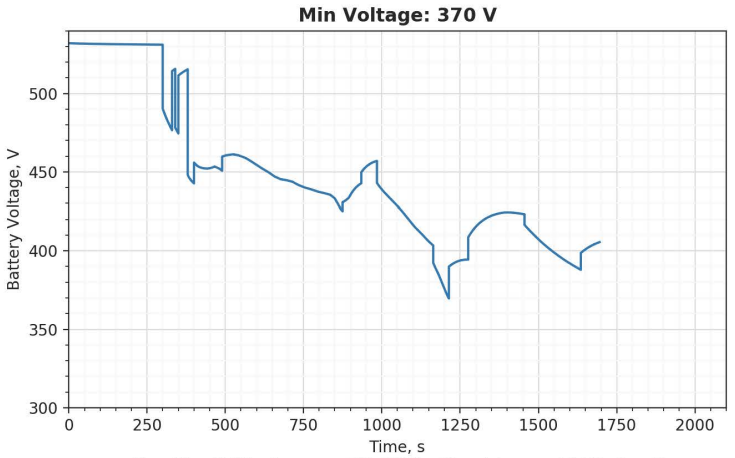
% Battery Energy Remaining[4]	18.1%

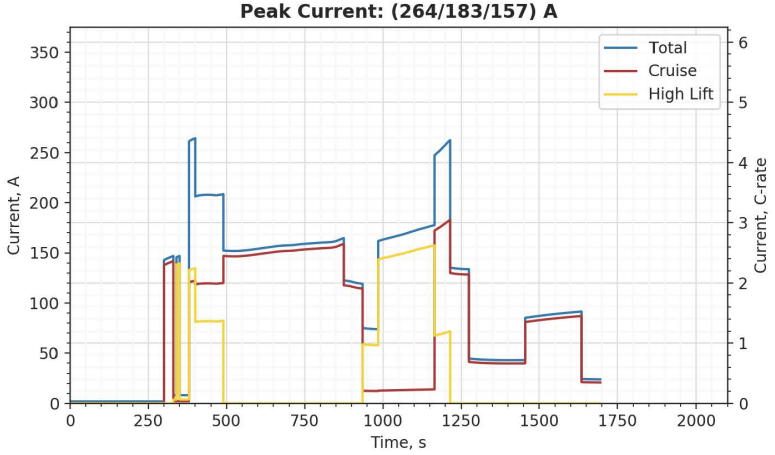
Notes:

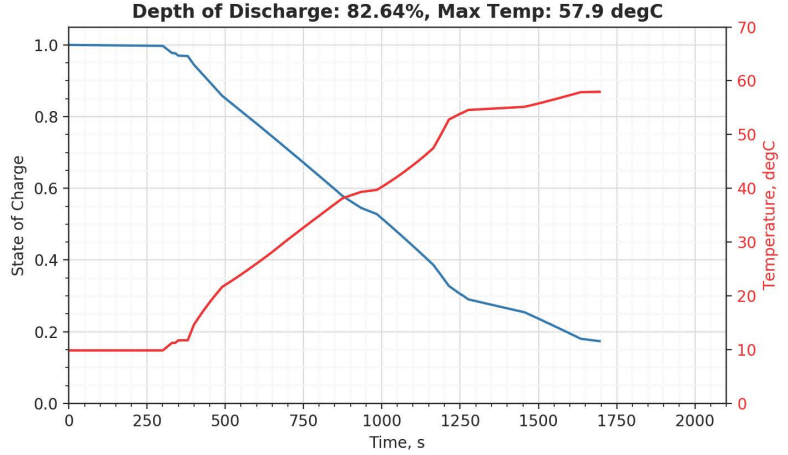
1. Assumes 350 ft/min climb, while current performance estimates are ~500 ft/min in this configuration. This results in ~25 seconds of time (40% energy) margin for this segment.
2. Assumes 500 ft/min climb from 2800 ft MSL, while current perfomance estimates are ~700+ ft/min in this configuration. This results in ~110 seconds of time (40% energy) margin for this segment.
3. Descent rate of 750 ft/min
4. Approximate Battery Energy calculated at a 10A/Cell (3.3C) discharge rate. Detailed battery estimates should use the X-57 Battery Model.

Tan boxes are populated by formulas from white boxes.
Blue rows are cruise system only
Red rows indicate high-lift system active
Green rows indicate Avionics Power is the only load


Used: 20.97 kWh
Battery Draw, kW
Time, s


Min Voltage: 370 V
Battery Voltage, V
Time, s


Peak Current: (264/183/157) A
Total
Cruise
High Lift
Current, A
Current, C-rate
Time, s


Depth of Discharge: 82.64%, Max Temp: 57.9 degC
State of Charge
Temperature, degC
Time, s

Mod IV LowSpeed Flight Obj

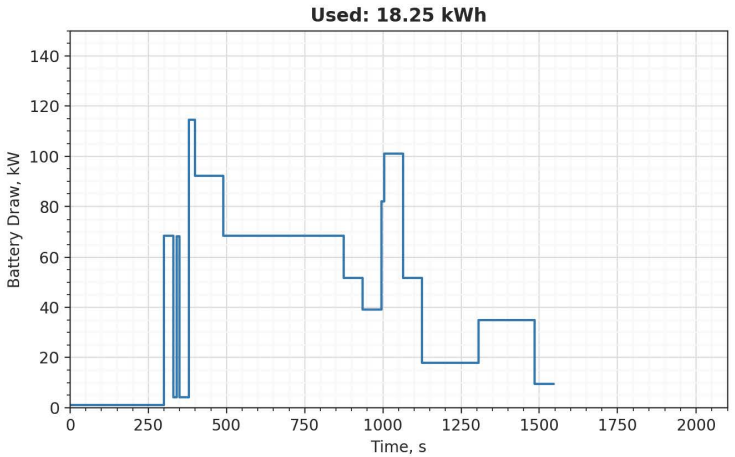
Flight to test minimum speed objective

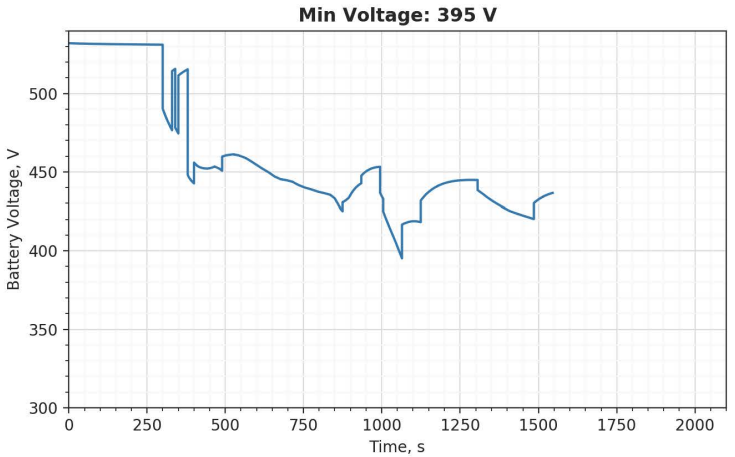
Phase	Maneuver	High-Lift Mode	Initial Pressure Altitude (ft)	Initial Velocity (KCAS)	Duration (Seconds)	Cruise Motor Shaft Power (kW)		Cruise Motor Input Power (kW) 92.0% Efficiency		Cruise Controller Input Power (kW) 97.0% Efficiency		High Lift Motor Shaft Power (kW)		High Lift Motor Input Power (kW) 93.0% Efficiency		High Lift Controller Input Power (kW) 98.0% Efficiency		Avionics Power (kW)		Traction Bus Input Power (Battery Out) (kW) 99.5% Efficiency					Traction Bus Energy (kWh/Phase)
						1 Motor	2 Motors	1 Motor	2 Motors	1 Motor	2 Motors	1 Motor	12 Motors	1 Motor	12 Motors	1 Motor	12 Motors	1 side	2 sides	cell (W)	brick (W)	module	pack	system	
Taxi	Taxi from NASA		2300	0	0	5.0	10.0	5.4	10.9	5.6	11.2							1.0	2.0	2.6	51.8	0.8	6.6	13.3	0.0
Preflight	TO Checklist		2300	0	300													1.0	2.0	0.4	7.9	0.1	1.0	2.0	
	Cruise Runup		2300	0	30	60.0	120.0	65.2	130.4	67.2	134.5							1.0	2.0	26.8	535.8	8.6	68.6	137.2	
	HL Runup	Airspeed	2300	0	10	1.0	2.0	1.1	2.2	1.1	2.2	0.3	3.6	0.3	3.9	0.3	3.9	1.0	2.0	1.6	32.2	0.5	4.1	8.2	
	HL Runup	Fixed	2300	0	10	1.0	2.0	1.1	2.2	1.1	2.2	10.0	120.0	10.8	129.0	11.0	131.7	1.0	2.0	26.7	533.6	8.5	68.3	136.6	
	Flight go/no-go	Airspeed	2300	0	30	1.0	2.0	1.1	2.2	1.1	2.2	0.3	3.6	0.3	3.9	0.3	3.9	1.0	2.0	1.6	32.2	0.5	4.1	8.2	1.8
Mod III DiTTO Takeoff and Climb	Ground Roll	Fixed	2300	0	20	48.0	96.0	52.2	104.3	53.8	107.6	9.0	108.0	9.7	116.1	9.9	118.5	1.0	2.0	44.8	895.4	14.3	114.6	229.2	
	Climb to 500' AGL[1]	Fixed	2300	96	90	48.0	96.0	52.2	104.3	53.8	107.6	5.6	67.2	6.0	72.3	6.1	73.7	1.0	2.0	36.0	719.6	11.5	92.1	184.2	
	Cruise Climb to 6000' MSL[2]		2800	100	385	60.0	120.0	65.2	130.4	67.2	134.5							1.0	2.0	26.8	535.8	8.6	68.6	137.2	20.5
Mod IV Minimum Speed Maneuver	Setup for Maneuver		6000	120	60	45.0	90.0	48.9	97.8	50.4	100.9							1.0	2.0	20.2	403.8	6.5	51.7	103.4	
	Decel to 58 KCAS	Airspeed	6000	110	60	5.0	10.0	5.4	10.9	5.6	11.2	4.9	58.8	5.3	63.2	5.4	64.5	1.0	2.0	15.3	305.1	4.9	39.1	78.1	
	Hold at 58 KCAS	Airspeed	6000	58	10	5.0	10.0	5.4	10.9	5.6	11.2	11.4	136.8	12.3	147.1	12.5	150.1	1.0	2.0	32.1	641.1	10.3	82.1	164.1	
	Accelerate to Recovery	Airspeed	6000	58	60	60.0	120.0	65.2	130.4	67.2	134.5	4.9	58.8	5.3	63.2	5.4	64.5	1.0	2.0	39.5	789.0	12.6	101.0	202.0	6.8
Mod III Descent and Landing	Setup for Landing		6000	120	60	45.0	90.0	48.9	97.8	50.4	100.9							1.0	2.0	20.2	403.8	6.5	51.7	103.4	
	Descent to Pattern[3]		6000	120	180	15.0	30.0	16.3	32.6	16.8	33.6							1.0	2.0	7.0	139.8	2.2	17.9	35.8	
	Pattern		3800	105	120	30.0	60.0	32.6	65.2	33.6	67.2							1.0	2.0	13.6	271.8	4.3	34.8	69.6	
	Final Approach		2800	95	60	30.0	60.0	32.6	65.2	33.6	67.2							1.0	2.0	13.6	271.8	4.3	34.8	69.6	
	Rollout and turnoff		2300	95	60	7.5	15.0	8.2	16.3	8.4	16.8							1.0	2.0	3.7	73.8	1.2	9.5	18.9	7.3
Taxi	Taxi to NASA		2300	10	0	5.0	10.0	5.4	10.9	5.6	11.2							1.0	2.0	2.6	51.8	0.8	6.6	13.3	0.0
	Mission Total (s, Wh, kWh)				1545	13.4	26.7	14.5	29.1	15.0	30.0	0.4	5.0	0.4	5.4	0.5	5.5	0.4	0.9	7.1	142.5	2.3	18.2	36.5	
												Approximate Battery Energy Available[4] (Wh, kWh)								10	200	3.2	25.6	51.2	
																				% Battery Energy Remaining[4]				28.7%	

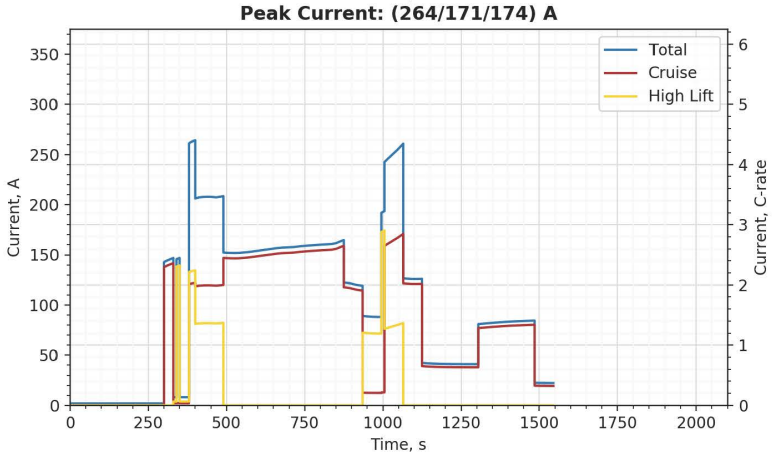
Notes:

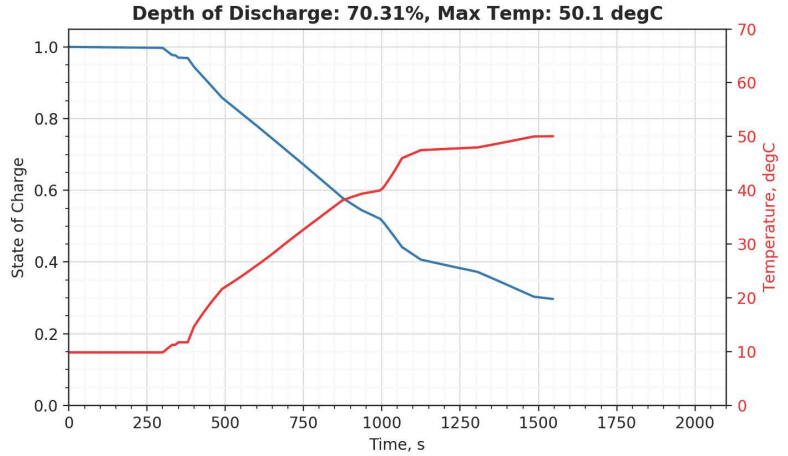
1. Assumes 350 ft/min climb, while current performance estimates are ~500 ft/min in this configuration. This results in ~25 seconds of time (40% energy) margin for this segment.
2. Assumes 500 ft/min climb from 2800 ft MSL, while current performance estimates are ~700+ ft/min in this configuration. This results in ~110 seconds of time (40% energy) margin for this segment.
3. Descent rate of 750 ft/min
4. Approximate Battery Energy calculated at a 10A/Cell (3.3C) discharge rate. Detailed battery estimates should use the X-57 Battery Model.

Tan boxes are populated by formulas from white boxes.
Blue rows are cruise system only
Red rows indicate high-lift system active
Green rows indicate Avionics Power is the only load


Used: 18.25 kWh
Battery Draw, kW
Time, s


Min Voltage: 395 V
Battery Voltage, V
Time, s


Peak Current: (264/171/174) A
Total
Cruise
High Lift
Current, A
Current, C-rate
Time, s


Depth of Discharge: 70.31%, Max Temp: 50.1 degC
State of Charge
Temperature, degC
Time, s

Mod IV TO-Land

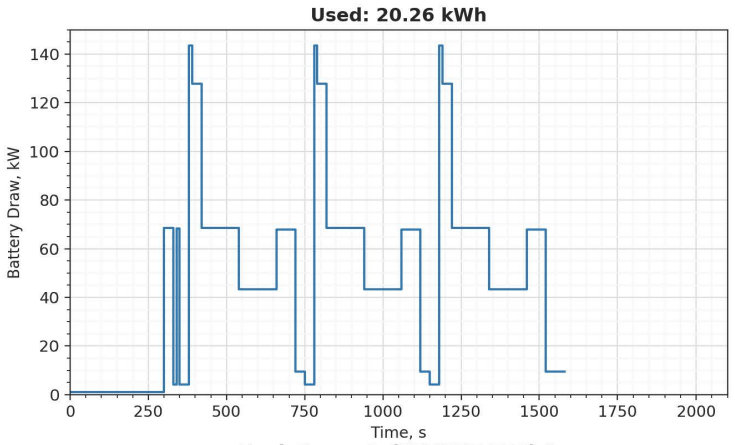
Mod IV TO and Landing at Ground Level

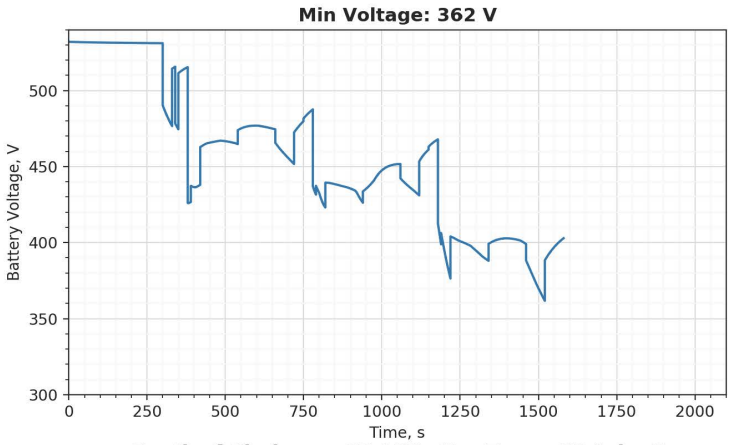
Phase	Maneuver	High-Lift Mode	Initial Pressure Altitude (ft)	Initial Velocity (KCAS)	Duration (Seconds)	Cruise Motor Shaft Power (kW)		Cruise Motor Input Power (kW) 92.0% Efficiency		Cruise Controller Input Power (kW) 97.0% Efficiency		High Lift Motor Shaft Power (kW)		High Lift Motor Input Power (kW) 93.0% Efficiency		High Lift Controller Input Power (kW) 98.0% Efficiency		Avionics Power (kW)		Traction Bus Input Power (Battery Out) (kW) 99.5% Efficiency					Traction Bus Energy (kWh/Phase)
						1 Motor	2 Motors	1 Motor	2 Motors	1 Motor	2 Motors	1 Motor	12 Motors	1 Motor	12 Motors	1 Motor	12 Motors	1 side	2 sides	cell (W)	brick (W)	module	pack	system	
Taxi	Taxi from NASA		2300	0	0	5.0	10.0	5.4	10.9	5.6	11.2							1.0	2.0	2.6	51.5	0.8	6.6	13.1	0.0
Preflight	TO Checklist		2300	0	300													1.0	2.0	0.4	7.9	0.1	1.0	2.0	
	Cruise Runup		2300	0	30	60.0	120.0	65.2	130.4	67.2	134.5							1.0	2.0	26.8	535.8	8.6	68.6	137.2	
	HL Runup	Airspeed	2300	0	10	1.0	2.0	1.1	2.2	1.1	2.2	0.3	3.6	0.3	3.9	0.3	3.9	1.0	2.0	1.6	32.2	0.5	4.1	8.2	
	HL Runup	Fixed	2300	0	10	1.0	2.0	1.1	2.2	1.1	2.2	10.0	120.0	10.8	129.0	11.0	131.7	1.0	2.0	26.7	533.6	8.5	68.3	136.6	
	Flight go/no-go	Airspeed	2300	0	30	1.0	2.0	1.1	2.2	1.1	2.2	0.3	3.6	0.3	3.9	0.3	3.9	1.0	2.0	1.6	32.2	0.5	4.1	8.2	1.8
Mod IV Fixed Mode Takeoff and Airspeed Mode Landing-1	Ground Roll	Fixed	2300	0	10	72.0	144.0	78.3	156.5	80.7	161.4	9.3	111.6	10.0	120.0	10.2	122.4	1.0	2.0	56.1	1,122.1	18.0	143.6	287.2	
	Climb to 500' AGL[1]	Fixed	2300	85	30	72.0	144.0	78.3	156.5	80.7	161.4	6.9	82.8	7.4	89.0	7.6	90.8	1.0	2.0	49.9	998.0	16.0	127.7	255.5	
	Cruise Climb to Pattern[2]		2800	100	120	60.0	120.0	65.2	130.4	67.2	134.5							1.0	2.0	26.8	535.8	8.6	68.6	137.2	
	Pattern (1500 AGL)[3]	Airspeed	3800	105	120	30.0	60.0	32.6	65.2	33.6	67.2	1.3	15.6	1.4	16.8	1.4	17.1	1.0	2.0	17.0	339.0	5.4	43.4	86.8	
	Final Approach	Airspeed	2800	75	60	30.0	60.0	32.6	65.2	33.6	67.2	5.0	60.0	5.4	64.5	5.5	65.8	1.0	2.0	26.5	530.3	8.5	67.9	135.7	
	Rollout and Stop		2300	75	30	7.5	15.0	8.2	16.3	8.4	16.8							1.0	2.0	3.7	73.8	1.2	9.5	18.9	12.9
Mod IV Fixed Mode Takeoff and Airspeed Mode Landing-2	Flight go/no-go	Airspeed	2300	0	30	1.0	2.0	1.1	2.2	1.1	2.2	0.3	3.6	0.3	3.9	0.3	3.9	1.0	2.0	1.6	32.2	0.5	4.1	8.2	
	Ground Roll	Fixed	2300	0	10	72.0	144.0	78.3	156.5	80.7	161.4	9.3	111.6	10.0	120.0	10.2	122.4	1.0	2.0	56.1	1,122.1	18.0	143.6	287.2	
	Climb to 500' AGL[1]	Fixed	2300	85	30	72.0	144.0	78.3	156.5	80.7	161.4	6.9	82.8	7.4	89.0	7.6	90.8	1.0	2.0	49.9	998.0	16.0	127.7	255.5	
	Cruise Climb to Pattern[2]		2800	100	120	60.0	120.0	65.2	130.4	67.2	134.5							1.0	2.0	26.8	535.8	8.6	68.6	137.2	
	Pattern (1500 AGL)[3]	Airspeed	3800	105	120	30.0	60.0	32.6	65.2	33.6	67.2	1.3	15.6	1.4	16.8	1.4	17.1	1.0	2.0	17.0	339.0	5.4	43.4	86.8	
	Final Approach	Airspeed	2800	75	60	30.0	60.0	32.6	65.2	33.6	67.2	5.0	60.0	5.4	64.5	5.5	65.8	1.0	2.0	26.5	530.3	8.5	67.9	135.7	
	Rollout and Stop		2300	75	30	7.5	15.0	8.2	16.3	8.4	16.8							1.0	2.0	3.7	73.8	1.2	9.5	18.9	12.9
Mod IV Fixed Mode Takeoff and Airspeed Mode Landing-3	Flight go/no-go	Airspeed	2300	0	30	1.0	2.0	1.1	2.2	1.1	2.2	0.3	3.6	0.3	3.9	0.3	3.9	1.0	2.0	1.6	32.2	0.5	4.1	8.2	
	Ground Roll	Fixed	2300	0	10	72.0	144.0	78.3	156.5	80.7	161.4	9.3	111.6	10.0	120.0	10.2	122.4	1.0	2.0	56.1	1,122.1	18.0	143.6	287.2	
	Climb to 500' AGL[1]	Fixed	2300	85	30	72.0	144.0	78.3	156.5	80.7	161.4	6.9	82.8	7.4	89.0	7.6	90.8	1.0	2.0	49.9	998.0	16.0	127.7	255.5	
	Cruise Climb to Pattern[2]		2800	100	120	60.0	120.0	65.2	130.4	67.2	134.5							1.0	2.0	26.8	535.8	8.6	68.6	137.2	
	Pattern (1500 AGL)[3]	Airspeed	3800	105	120	30.0	60.0	32.6	65.2	33.6	67.2	1.3	15.6	1.4	16.8	1.4	17.1	1.0	2.0	17.0	339.0	5.4	43.4	86.8	
	Final Approach	Airspeed	2800	75	60	30.0	60.0	32.6	65.2	33.6	67.2	5.0	60.0	5.4	64.5	5.5	65.8	1.0	2.0	26.5	530.3	8.5	67.9	135.7	
	Rollout and turnoff		2300	75	60	7.5	15.0	8.2	16.3	8.4	16.8							1.0	2.0	3.7	73.8	1.2	9.5	18.9	13.0
Taxi	Taxi to NASA		2300	10	0	5.0	10.0	5.4	10.9	5.6	11.2							1.0	2.0	2.6	51.5	0.8	6.6	13.1	0.0
	Mission Total (s, Wh, kWh)				1580	13.7	27.4	14.9	29.7	15.3	30.7	0.7	8.0	0.7	8.6	0.7	8.8	0.4	0.9	7.9	158.2	2.5	20.3	40.5	
												Approximate Battery Energy Available[4] (Wh, kWh)								10	200	3.2	25.6	51.2	
																				% Battery Energy Remaining[4]				20.9%	

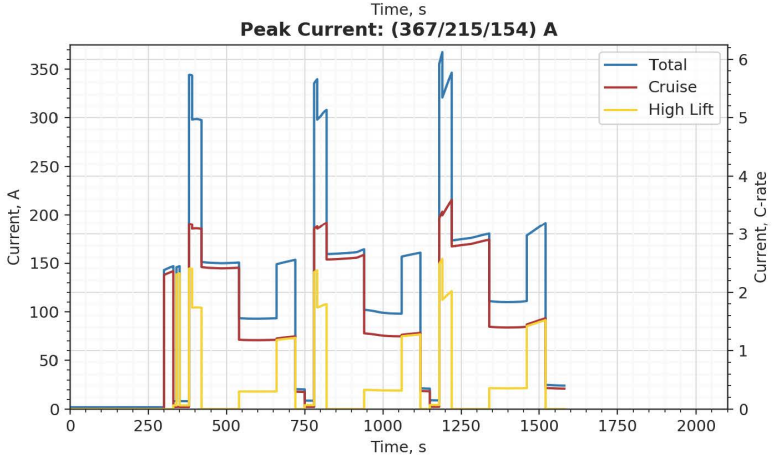
Notes:

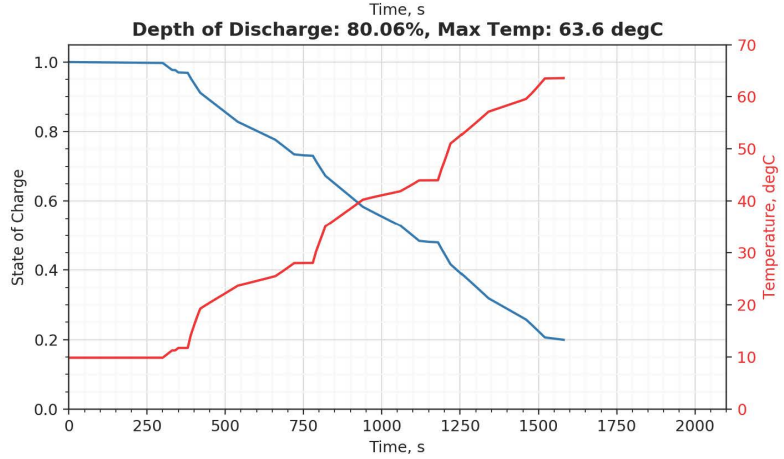
1. Assumes 1000 ft/min climb, while current performance estimates are ~1500 ft/min in this configuration. This results in ~10 seconds of time (50% energy) margin for this segment.
2. Assumes 500 ft/min climb from 2800 ft MSL, while current performance estimates are ~700+ ft/min in this configuration. This results in ~35 seconds of time (40% energy) margin for this segment.
3. Descent rate of 1000 ft/min
4. Approximate Battery Energy calculated at a 10A/Cell (3.3C) discharge rate. Detailed battery estimates should use the X-57 Battery Model.

Tan boxes are populated by formulas from white boxes.
Blue rows are cruise system only
Red rows indicate high-lift system active
Green rows indicate Avionics Power is the only load


Used: 20.26 kWh
Battery Draw, kW
Time, s


Min Voltage: 362 V
Battery Voltage, V
Time, s


Peak Current: (367/215/154) A
Total
Cruise
High Lift
Current, A
Current, C-rate
Time, s


Depth of Discharge: 80.06%, Max Temp: 63.6 degC
State of Charge
Temperature, degC
Time, s

Mod IV Simulated Land-TO

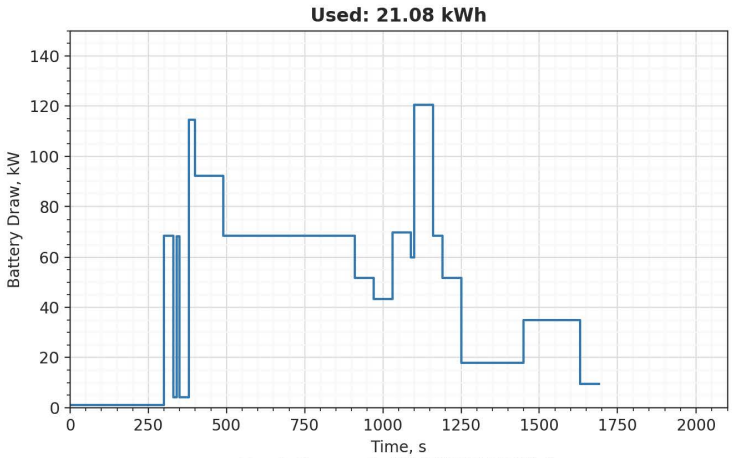
Simulated landing and takeoff at altitude.

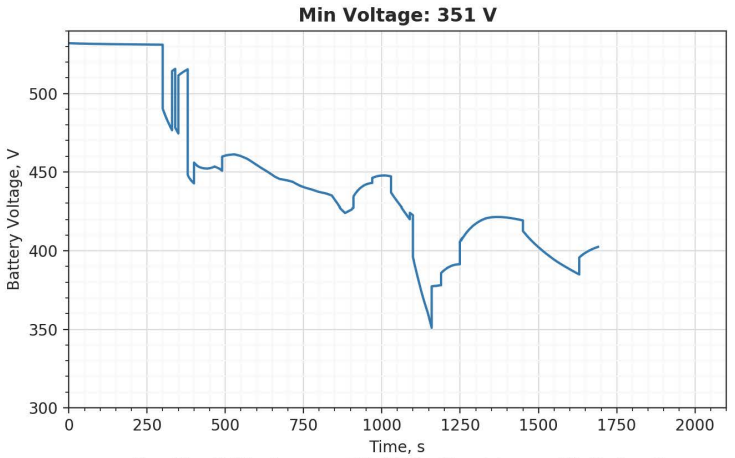
Phase	Maneuver	High-Lift Mode	Initial Pressure Altitude (ft)	Initial Velocity (KCAS)	Duration (Seconds)	Cruise Motor Shaft Power (kW)		Cruise Motor Input Power (kW) 92.0% Efficiency		Cruise Controller Input Power (kW) 97.0% Efficiency		High Lift Motor Shaft Power (kW)		High Lift Motor Input Power (kW) 93.0% Efficiency		High Lift Controller Input Power (kW) 98.0% Efficiency		Avionics Power (kW)		Traction Bus Input Power (Battery Out) (kW) 99.5% Efficiency					Traction Bus Energy (kWh/Phase)
						1 Motor	2 Motors	1 Motor	2 Motors	1 Motor	2 Motors	1 Motor	12 Motors	1 Motor	12 Motors	1 Motor	12 Motors	1 side	2 sides	cell (W)	brick (W)	module	pack	system	
Taxi	Taxi from NASA		2300	0	0	5.0	10.0	5.4	10.9	5.6	11.2							1.0	2.0	2.6	51.5	0.8	6.6	13.2	0.0
Preflight	TO Checklist		2300	0	300													1.0	2.0	0.4	7.9	0.1	1.0	2.0	
	Cruise Runup		2300	0	30	60.0	120.0	65.2	130.4	67.2	134.5							1.0	2.0	26.8	535.8	8.6	68.6	137.2	
	HL Runup	Airspeed	2300	0	10	1.0	2.0	1.1	2.2	1.1	2.2	0.3	3.6	0.3	3.9	0.3	3.9	1.0	2.0	1.6	32.2	0.5	4.1	8.2	
	HL Runup	Fixed	2300	0	10	1.0	2.0	1.1	2.2	1.1	2.2	10.0	120.0	10.8	129.0	11.0	131.7	1.0	2.0	26.7	533.6	8.5	68.3	136.6	
	Flight go/no-go	Airspeed	2300	0	30	1.0	2.0	1.1	2.2	1.1	2.2	0.3	3.6	0.3	3.9	0.3	3.9	1.0	2.0	1.6	32.2	0.5	4.1	8.2	1.8
Mod III DiTTO Takeoff and Climb	Ground Roll	Fixed	2300	0	20	48.0	96.0	52.2	104.3	53.8	107.6	9.0	108.0	9.7	116.1	9.9	118.5	1.0	2.0	44.8	895.4	14.3	114.6	229.2	
	Climb to 500' AGL[1]	Fixed	2300	96	90	48.0	96.0	52.2	104.3	53.8	107.6	5.6	67.2	6.0	72.3	6.1	73.7	1.0	2.0	36.0	719.6	11.5	92.1	184.2	
	Cruise Climb to 6300' MSL[2]		2800	100	420	60.0	120.0	65.2	130.4	67.2	134.5							1.0	2.0	26.8	535.8	8.6	68.6	137.2	21.9
Mod IV Simulated Takeoff and Landing at Altitude	Setup for Maneuver		6300	120	60	45.0	90.0	48.9	97.8	50.4	100.9							1.0	2.0	20.2	403.8	6.5	51.7	103.4	
	Sim Pattern	Airspeed	6300	105	60	30.0	60.0	32.6	65.2	33.6	67.2	1.3	15.6	1.4	16.8	1.4	17.1	1.0	2.0	17.0	339.0	5.4	43.4	86.8	
	Sim Final Approach	Airspeed	5800	75	60	30.0	60.0	32.6	65.2	33.6	67.2	5.3	63.6	5.7	68.4	5.8	69.8	1.0	2.0	27.3	545.8	8.7	69.9	139.7	
	Configure for Takeoff	Airspeed	5300	80	10	30.0	60.0	32.6	65.2	33.6	67.2	3.8	45.6	4.1	49.0	4.2	50.0	1.0	2.0	23.4	468.2	7.5	59.9	119.9	
	Sim Takeoff Climb	Fixed	5300	85	60	72.0	144.0	78.3	156.5	80.7	161.4	5.8	69.6	6.2	74.8	6.4	76.4	1.0	2.0	47.1	941.1	15.1	120.5	240.9	
	Sim Cruise Climb		5700	100	30	60.0	120.0	65.2	130.4	67.2	134.5							1.0	2.0	26.8	535.8	8.6	68.6	137.2	11.0
Mod III Descent and Landing	Setup for Landing		6300	120	60	45.0	90.0	48.9	97.8	50.4	100.9							1.0	2.0	20.2	403.8	6.5	51.7	103.4	
	Descent to Pattern[3]		6300	120	200	15.0	30.0	16.3	32.6	16.8	33.6							1.0	2.0	7.0	139.8	2.2	17.9	35.8	
	Pattern		3800	105	120	30.0	60.0	32.6	65.2	33.6	67.2							1.0	2.0	13.6	271.8	4.3	34.8	69.6	
	Final Approach		2800	95	60	30.0	60.0	32.6	65.2	33.6	67.2							1.0	2.0	13.6	271.8	4.3	34.8	69.6	
	Rollout and turnoff		2300	95	60	7.5	15.0	8.2	16.3	8.4	16.8							1.0	2.0	3.7	73.8	1.2	9.5	18.9	7.5
Taxi	Taxi to NASA		2300	10	0	5.0	10.0	5.4	10.9	5.6	11.2							1.0	2.0	2.6	51.5	0.8	6.6	13.2	0.0
	Mission Total (s, Wh, kWh)				1690	15.7	31.4	17.1	34.2	17.6	35.2	0.4	5.3	0.5	5.7	0.5	5.8	0.5	0.9	8.2	164.7	2.6	21.1	42.2	
																				10	200	3.2	25.6	51.2	
																				% Battery Energy Remaining[4]				17.7%	

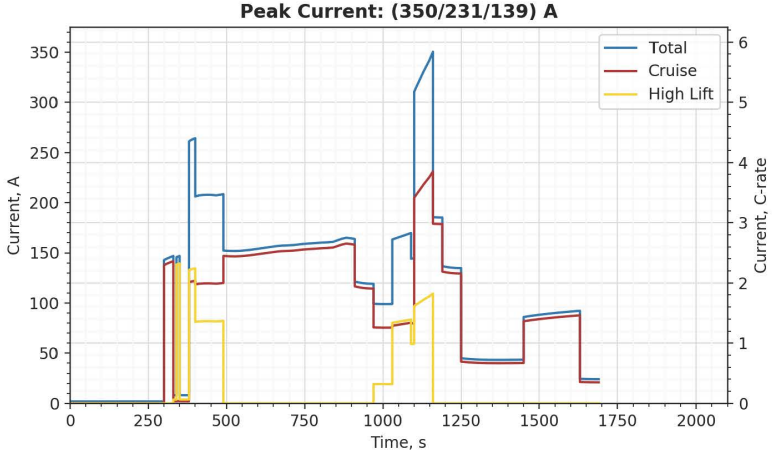
Notes:

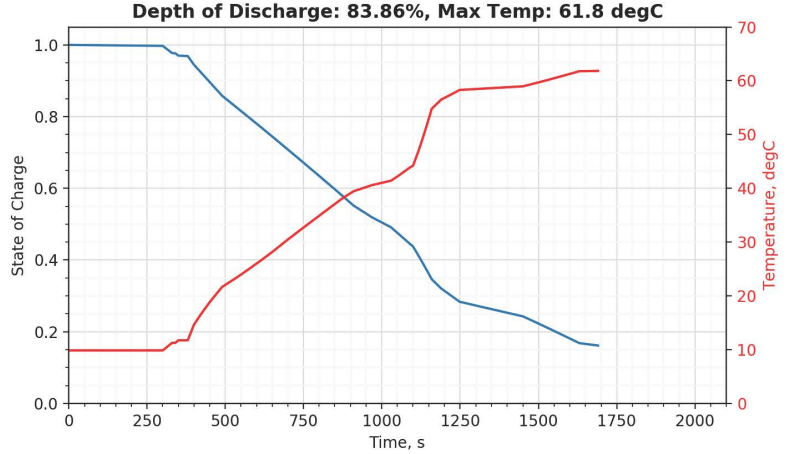
1. Assumes 350 ft/min climb, while current performance estimates are ~500 ft/min in this configuration. This results in ~25 seconds of time (40% energy) margin for this segment.
2. Assumes 500 ft/min climb from 2800 ft MSL, while current performance estimates are ~700+ ft/min in this configuration. This results in ~120 seconds of time (40% energy) margin for this segment.
3. Descent rate of 750 ft/min
4. Approximate Battery Energy calculated at a 10A/Cell (3.3C) discharge rate. Detailed battery estimates should use the X-57 Battery Model.

Tan boxes are populated by formulas from white boxes.
Blue rows are cruise system only
Red rows indicate high-lift system active
Green rows indicate Avionics Power is the only load


Used: 21.08 kWh
Battery Draw, kW
Time, s


Min Voltage: 351 V
Battery Voltage, V
Time, s


Peak Current: (350/231/139) A
Total
Cruise
High Lift
Current, A
Current, C-rate
Time, s


Depth of Discharge: 83.86%, Max Temp: 61.8 degC
State of Charge
Temperature, degC
Time, s