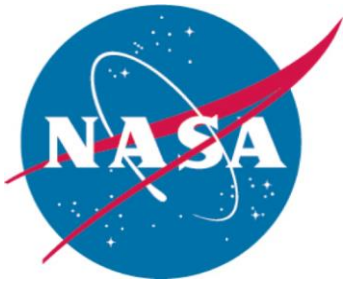

National Aeronautics and

Space Administration

Armstrong Flight Research Center
Edwards, CA 93523-0273

X-57

Maxwell

X-57 Mod IV Avionics Power Analysis

ANLYS-CEPT-032

Revision: **B** **Date:** 10/2/23

Prepared By:

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X-57 Mod IV Avionics Power Analysis (ANLYS-CEPT-032)

Scope

The X-57 Mod IV Avionics Power Analysis was developed to provide the design requirements for the X-57 Mod IV Avionics Power System. In the Mod IV configuration, twelve 13kW high lift motors and motor controllers are distributed along the leading edge of the Mod III carbon fiber wing to assist with lift during takeoff and landing. These motors are turned off during the cruise phase of the flight. A high voltage traction battery (460 VDC nominal) supplies power for the high lift motors. The Mod IV avionics power design uses the Mod II and Mod III power architecture as a baseline. Please see the Mod II Avionics Power Analysis (ANLYS-CEPT-020) for a description of the Mod II and Mod III avionics power design.

Power requirement estimates for each subsystem used in this analysis were provided by manufacturer specifications, measured in the laboratory or provided by the subsystem design engineer. Typical power requirements and maximum power requirements were provided for each subsystem.

The Mod II, Mod III and Mod IV Avionics Power Systems consists of seven 13.8 VDC buses, two 28 VDC Buses and two 23 VDC buses.

13.8 VDC Buses

Essential Bus – Power for the essential bus is provided by a Lithium Iron Phosphate (LiFePO4) battery. This battery is called the essential battery. The essential bus provides power to enable two 13.8V DC Converters and essential bus avionics subsystems. If both 13.8V DC Converters were to fail in flight, the essential battery will continue to provide power the essential subsystems and allow the pilot to safely land the aircraft. The essential bus also provides power to the Mod IV high lift subsystems. Essential bus power requirements for an essential bus only landing can be found in the "Mod IV Essential Bus Energy Requirements" worksheet of this document.

DC Converter Bus A and DC Converter Bus B – These buses are the primary source of avionics power to the aircraft. They provide 13.8 VDC to the aircraft's avionic systems via the two 13.8V DC Converters. These buses also charge the essential battery in flight. The outputs of these two DC Converters are electrically connected when the Cross Bus relays are closed during startup. Closing the Cross Bus relays allow these DC Converters to share the avionics system load. The "Mod IV Summary" worksheet provides the total estimated power required for the Mod IV avionics system.

Avionics Bus A – This bus provides 13.8 VDC from DC Converter "A" to non-essential avionics subsystems. These subsystems can be turned off if "power shedding" is required in flight without affecting the pilot's ability to safely land the aircraft.

Avionics Bus B – This bus provides 13.8 VDC from DC Converter "B" to the input of the instrumentation 13.8 VDC to 28V DC Converter. The instrumentation system requires 28 VDC. The instrumentation system can be turned off if "power shedding" is required in flight without affecting the pilot's ability to safely land the aircraft.

Wing Avionics Bus A – This bus provides 13.8 VDC from the Essential Bus to the input of the Wing Avionics "A" 13.8 VDC to 23V DC Converter. This DC Converter provides 23 VDC to Bus A avionics subsystems located in the left and right wing nacelles.

Wing Avionics Bus B – This bus provides 13.8 VDC from the Essential Bus to the input of the Wing Avionics "B" 13.8 VDC to 23V DC Converter. This DC Converter provides 23 VDC to Bus B avionics subsystems located in the left and right wing nacelles.

28 VDC Buses

28 VDC Bus A and 28 VDC Bus B – The Essential Bus provides input power to two 13.8 VDC to 28V DC Converters located in Battery Control Module (BCM) A and Battery Control Module (BCM) B. These DC Converters supply 28 VDC to enable the high voltage contactors which provide high voltage to the traction system. These DC converters also provide power to traction system displays and sensors. A block diagram of the 28 VDC Buses can be found in the "Mod IV BCM 28 VDC Power Estimate" worksheet of this documents.

Explanation of Mods

Mod I – Flight testing of a Stock Tecnam P2006T

Mod II - Retrofit a Tecnam P2006T with an electric propulsion system

Mod III - Modify the configuration with a cruise-optimized wing and electric propulsion system

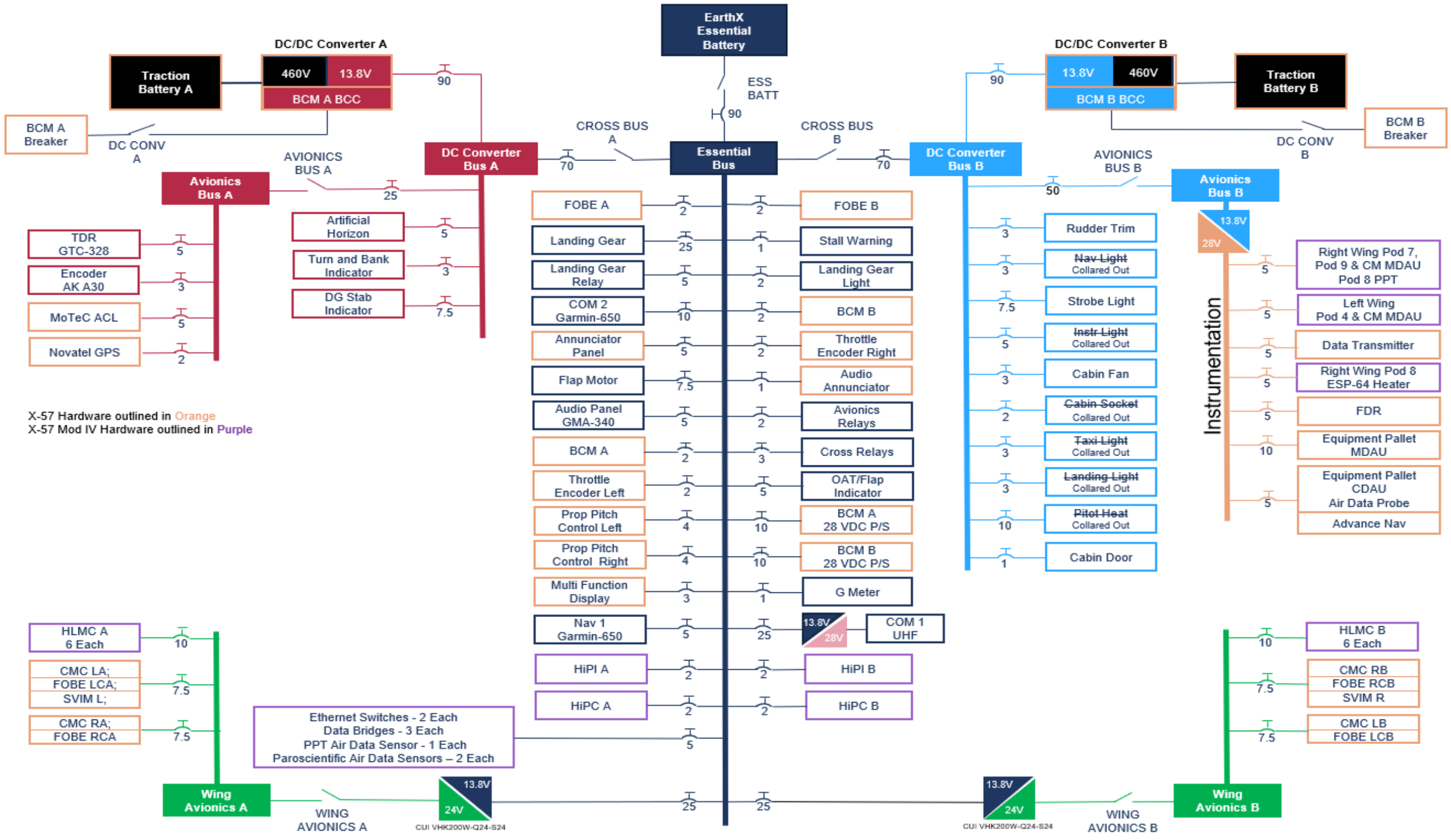
Mod IV - Design for low-speed takeoff and landing characteristics with an integrated Distributed Electric Propulsion (DEP) system.

X-57 Mod IV Avionics Power Analysis

Revision History

REV	DATE	DESCRIPTION
-	10/26/20	Original Release
A	6/24/21	Included Mod II Analysis Updates from ANALYS-CEPT-020 Rev B Removed ALS Updated BCM 28VDC Power Distribution Drawing Updated Architecture Drawing
B	10/2/23	Added changes for the from the Mod II Avionics Power analysis (ANLYS-CEPT-020) Rev C and Rev D. This includes the following: •Updated “Mod IV Architecture” worksheet to capture changes from the Mod II Avionics Power Analysis Rev C and Rev D •Updated “Mod IV Power Summary” worksheet to capture changes from the Mod II Avionics Power Analysis Rev C and Rev D •Moved Cockpit FOBEs from the Wing Avionics Bus to the Essential Bus in the “Mod IV Individual Loads” worksheet and the “Mod IV Essential Bus Energy Req” worksheet •Removed Airdata Probe transducers from Avionics Bus B in the “Mod IV Individual Loads” worksheet . Airdata Probe transducers will receive power (0.9 watts) from TTC Data System and are captured in the “Mod IV Inst 28VDC Pwr Est” worksheet •Removed BCM Fan power from the “Mod IV BCM 28 VDC Pwr Est” worksheet and added a sperate worksheet, Mod IV 23 VDC BCM Fan PWR EST, for the new 23 VDC power supplies providing power to the BCM fans. The load for the new BCM FAN power supplies was added to the 28V A and 28V B Breaker loads in the “Mod IV Individual Loads” worksheet and the “Mod IV Essential Bus Energy Req” worksheet •Increased the max current for the Landing Gear from 12 amps to 21 amps in the “Mod IV Individual Loads” worksheet and the “Mod IV Essential Bus Energy Req” worksheet as per email from Brennan dated 8/18/2022 •Changed breaker on Landing Gear from 20 amps to 25 amps on Mod IV Architecture drawing and the "Mod IV Individual Loads" worksheet •Changed NAV-1 Garmin Breaker from 3 amps to 5 amps on Architecture Drawing and the "Mod IV Individual Loads" worksheet •Decreased CMC Load from 40 watts to 23 watts as per email from Sean dated 11/1/22 •Update the maximum power for the BCM 28VDC Power Estimate

Mod IV Avionics Power Architecture



X-57 Hardware outlined in Orange
X-57 Mod IV Hardware outlined in Purple

Avionics Power Available With Traction Battery at 400 VDC or Greater (Watts)	2400

Mod IV Avioincs Power Summary[1]							
Bus	Breaker Size	Typical Current Load with Both Cross Buses Open (Amps[3])	Max Current Load[2] with Both Cross Buses Open (Amps[3])	Typical Current Load with Both Cross Buses Closed (Amps[3])	Max Current Load[2] with Both Cross Buses Closed (Amps[3])	Typical Power Load with Both Cross Buses Closed (Watts)	Max Power Load[2] with Both Cross Buses Closed (Watts)
Essential Bus (13.8 VDC)	90	68.3	107.7	NA	NA	NA	NA
DC Converter A (13.8 VDC)	90	7.6	9.2	61.5	84.2	848.2	1161.6
DC Converter B (13.8 VDC)	90	47.1	51.5	61.5	84.2	848.2	1161.6
Totals		**122.9**	**168.4**	**122.9**	**168.4**	**1696.3**	**2323.3**
				Remaining Power Available (%)		**29.3%**	**3.2%**

Notes

1 - Assumes a fully charged Essential Battery and changing not required during flight operations. Also assumes Essential Battery does not provide any power to avionics system

2 - Max Current Load and Max Power Load assumes typical current load for all subsystems except for the Flaps, UHF radios, Prop Pitch, Landing Gear, Mode S Transponder, Rudder Trim and Strobe Lights. For these subsystems, the analysis assumes these subsystems are simultaneously operating at maximum current and power

3 - Assumes voltage is 13.8 VDC

Mod IV Avionics Load Sheet[1]

Bus	Tecnam or Mod II	Breaker Panel	Breaker Label	Subsystem	Breaker Rating (Amps)	Operating Voltage	Typical Current (Amps)	Max Current (Amps)	Steady-State Power (Watts)	Peak Power (Watts)	Verification Method	Comments
ESSENTIAL BUS	**Tecnam**	**LH**	**ESS BATT**	**ESSENTIAL BUS TOTALS**	**90.0**	**13.8**	**68.3**	**144.7**	**942.1**	**1996.7**		
	Tecnam	LH	AUDIO PANEL	GMA 340 Audio Panel	5.0	13.8	2.2	2.2	30.4	30.4	Data Sheet	https://www8.garmin.com/specs/gma340.pdf
	Tecnam	LH	COM 2	Garmin GTN 650 GPS	10.0	13.8	0.5	5.7	6.2	78.1	Estimated	http://static.garmin.com/pumac/190-01007-A1_10.pdf http://www.vansairforce.com/community/showthread.php?t=74683 Based on 16 Watt transmit power, current = 4.02A for 10 Watt transmit. Source is unverified. Source also lists Main connector 1.6A typical, 2.8A Max. - maybe wired together with NAV1
	Tecnam	LH	NAV 1	Garmin GTN 650 GPS	5.0	13.8	0.6	1.2	8.3	16.0	Estimated	
	Tecnam	LH	LANDING GEAR		25.0	13.8	0.1	21.0	1.4	289.8	Measured	Measured by Scaled 9/10/18
	Tecnam	LH	RELAY LAND GEAR		5.0	13.8	0.1	0.1	1.4	1.4	Measured	Measured by Scaled 9/10/18
	Tecnam	LH	FLAP MOTOR		15.0	13.8	10.0	10.0	138.0	138.0	Data Sheet	Estimate from Ultramotion datasheet
	Tecnam	LH	ANNUNC PANEL	Annunciator Panel and Cabin Lite	5.0	13.8	1.3	1.3	17.3	17.3	Estimated	1/4 breaker size (changed to LEDs), Includes blue logic control box (can disconnect cabin light)
	Tecnam	LH	OAT/FLAP IND	OAT and Flap Indicator	5.0	13.8	2.5	2.5	34.5	34.5	Estimated	Need Update. Assume 1/2 of Breaker Size
	Mod II	LH	TE-L	Throttle Encoder Left	2.0	13.8	0.1	0.1	1.4	1.4	Data Sheet	Baumer Spec
	Mod II	LH	BMS-A	Battery Management System A	2.0	13.8	0.3	0.3	4.1	4.1	Estimated	Email from Randy Dunn on 9/17/2018
	Mod II	LH	MFD	MoTEC Display	3.0	13.8	0.4	0.4	5.2	5.2	Data Sheet	MoTEC Manual
	Mod II	LH	PROP-L	Prop Pitch Controller Left	4.0	13.8	0.2	1.5	2.8	20.7	Measured	Measured by Matt Redifer on 9/19/2018 with prop pitch changing
	Mod II	LH	PROP-R	Prop Pitch Controller Right	4.0	13.8	0.2	1.5	2.8	20.7	Measured	Measured by Matt Redifer on 9/19/2018 with prop pitch changing
	Tecnam	RH	CROSS RELAYS		3.0	13.8	0.2	0.3	2.8	4.1	Measured	Current Draw is .2A each (2 in aircraft). Measured by Scaled 9/10/18.
	Tecnam	RH	LIGHT LAND GEAR		2.0	13.8	0.1	0.1	1.4	1.4	Measured	Measured by Scaled 9/10/18
	Tecnam	RH	STALL WARNING		1.0	13.8	0.9	0.9	12.6	12.6	Measured	Measured by Scaled 9/10/18
	Tecnam	RH	AVIONICS RELAYS		2.0	13.8	0.2	0.3	2.8	4.1	Estimated	Assumed to be the same as the Cross relays
	Mod II	RH	TE-R	Throttle Encoder Right	2.0	13.8	0.1	0.1	1.4	1.4	Data Sheet	Baumer Spec
	Mod II	RH	BMS-B	Battery Management System B	2.0	13.8	0.3	0.3	4.1	4.1	Estimated	Email from Randy Dunn on 9/17/2018
	Mod II	RH	AUDIO ANNUNC	Audio Annunciator	1.0	13.8	0.8	0.8	10.4	10.4	Data Sheet	PS Engineering Manual Max
	Mod II	RH	COM 1	UHF	25.0	13.8	3.0	18.9	41.4	260.7	Measured	Measured by Scaled (8.5A @ 28V * 2 / 90%)
	Mod II	LH	28 A	BCM A 28 VDC Power Supply	10.0	13.8	7.5	22.9	103.0	316.6	Estimated	Mod IV BCM 28 VDC Power Estimate Worksheet
	Mod II	RH	28 B	BCM B 28 VDC Power Supply	10.0	13.8	7.5	22.9	103.0	316.6	Estimated	Mod IV BCM 28 VDC Power Estimate Worksheet
	Mod II	RH	G Meter	G Meter	1.0	13.8	0.1	0.1	1.4	1.4	Data Sheet	Manual Spec
	Mod II	LH	FOBE A	FOBE A	2.0	13.8	0.1	0.1	1.7	1.7	Data Sheet	FOBE Manual
	Mod II	RH	FOBE B	FOBE B	2.0	13.8	0.1	0.1	1.7	1.7	Data Sheet	FOBE Manual
				Ethernet Switches (2 Each)			3.0	3.0	41.4	41.4	Data Sheet	Manual Spec
				Data Bridge (3 Each)			0.7	0.7	9.7	9.7	Data Sheet	Manual Spec
				PPT-2 (Data Boom)			0.1	0.1	1.4	1.4	Data Sheet	Manual Spec
	Mod IV		HL DATA	Paroscientific Sensors (Data Boom)	5.0	13.8	0.1	0.1	1.4	1.4	Data Sheet	0.032 for two transducers; Email form Phil H on 9/17/2018
	Mod IV		HiPI A	High Lift Indicator System A	2.0	13.8	1.0	1.0	13.8	13.8	Estimated	Requirements Document
	Mod IV		HiPI B	High Lift Indicator System B	2.0	13.8	1.0	1.0	13.8	13.8	Estimated	Requirements Document
			HiPC A	High Lift Control A	2.0	13.8	1.0	1.0	13.8	13.8	Estimated	Requirements Document
	Mod IV		HiPC B	High Lift Control B	2.0	13.8	1.0	1.0	13.8	13.8	Estimated	Requirements Document
WING AVIONICS BUS A		**LH**	**WING AVIONICS A**	**WING AVIONICS A TOTALS**	**25.0**	**13.8**	**10.6**	**10.6**	**146.0**	**146.6**		
	Mod II	NA	NA	Wing Avionics Relay A	NA	13.8	0.1	0.2	1.4	2.1	Estimated	Relay coil is wired directly to 25 amp Wing Avionics B Breaker
	Mod II			CMC LA			2.1	2.1	28.8	28.8	Estimated	Estimate (40 Watts) provided by Dave A for the XM3 CMCs
	Mod II			FOBE LCA			0.1	0.1	1.7	1.7	Data Sheet	FOBE Manual
	Mod II	LH	CMC LA, FOBE LCA	L CANBus DAQ	7.5 (24 VDC)	13.8	0.6	0.6	8.6	8.6	Data Sheet	SVIM Data Sheet
	Mod II			CMC RA			2.1	2.1	28.8	28.8	Estimated	Estimate (40 Watts) provided by Dave A for the XM3 CMCs
	Mod II	LH	CMC RA, FOBE RCA	FOBE RCA	7.5 (24 VDC)	13.8	0.1	0.1	1.7	1.7	Data Sheet	FOBE Manual
	Mod IV		HL A	HLMC A Bus (6 Each HLMC)	10 (24 VDC)	13.8	5.4	5.4	75.0	75.0	Estimated	10 Watts HLMC requirement/.0.8 efficiency of 23 VDC power supply/13.8 x 6
WING AVIONICS BUS B		**RH**	**WING AVIONICS B**	**WING AVIONICS B TOTALS**	**25.0**	**13.8**	**10.6**	**10.6**	**146.0**	**146.6**		
	Mod II	NA	NA	Wing Avionics Relay B	NA	13.8	0.1	0.2	1.4	2.1	Estimated	Relay coil is wired directly to 25 amp Wing Avionics B Breaker
	Mod II			CMC RB			2.1	2.1	28.8	28.8	Estimated	Estimate (40 Watts) provided by Dave A for the XM3 CMCs
	Mod II			FOBE RCB			0.1	0.1	1.7	1.7	Data Sheet	FOBE Manual
	Mod II	RH	CMC RB, FOBE RCB	R CANBus DAQ	7.5 (24 VDC)	13.8	0.6	0.6	8.6	8.6	Data Sheet	SVIM Data Sheet
	Mod II			CMC LB			2.1	2.1	28.8	28.8	Estimated	Estimate (40 Watts) provided by Dave A for the XM3 CMCs
	Mod II	RH	CMC LB, FOBE LCB	FOBE LCB	7.5 (24 VDC)	13.8	0.1	0.1	1.7	1.7	Data Sheet	FOBE Manual
	Mod IV		HL B	HLMC B Bus (6 Each HLMC)	10 (24 VDC)	13.8	5.4	5.4	75.0	75.0	Estimated	10 Watts HLMC requirement/.0.8 efficiency of 23 VDC power supply/13.8 x 6
DC CONVERTER A		**LH**	**DC CONV A**	**DC/DC CONVERTER A TOTALS**	**90.0**	**13.8**	**3.7**	**4.4**	**51.3**	**60.7**		
	Tecnam	LH	HORZ-LH	Artificial Horizon	5.0	13.8	1.4	1.7	18.8	23.5	Measured	Measured by Scaled 9/10/18
	Tecnam	LH	TURN & BANK	Turn and Bank Indicator	3.0	13.8	1.4	1.7	18.8	23.5	Measured	Measured by Scaled 9/10/18 (Seems odd that AH & T&B are exactly the same draw).
	Tecnam	LH	DG/STAB IND	DG/Stab Indicator	7.5	13.8	1.0	1.0	13.8	13.8	Estimated	Estimate
AVIONICS BUS A		**LH**	**AVIONICS BUS A**	**AVIONICS BUS A TOTALS**	**25.0**	**13.8**	**3.9**	**5.5**	**53.5**	**76.2**		
	Tecnam	LH	TDR	Garmin GTX 328 Mode S Transponder	5.0	13.8	1.6	3.2	21.8	44.4	Data Sheet	http://static.garmin.com/pumac/GTX328Transponder_MaintenanceManual.pdf
	Tecnam	LH	ENCODER	Amery King A30	3.0	13.8	1.0	1.0	13.8	13.8	Estimated	1/3 breaker size
	Mod II	LH	MOTEC ACL	MoTEC ACL	5.0	13.8	0.2	0.2	2.8	2.8	Data Sheet	MoTEC Manual
	Mod II	LH	AIR DATA PROBE	Novatel GPS	2.0	13.8	1.1	1.1	15.2	15.2	Data Sheet	Novatel Manual; Air data probe is powered by the instrumentation system for Mod II
DC CONVERTER B		**RH**	**DC CONV B**	**DC/DC CONVERTER B TOTALS**	**90.0**	**13.8**	**7.2**	**11.6**	**99.4**	**160.4**		
	Tecnam	RH	RUDDER TRIM	Rudder Trim	3.0	13.8	1.1	1.5	15.2	20.7	Measured	Measured by Scaled 9/10/18
	Tecnam	RH	NAV LIGHT (Collared)	~~Navigation Light~~	3.0	13.8	0.0	0.0	0.0	0.0	Measured	Functionality exist but system not required for X57 flights at AFRC (1.6 amps Measured at Scaled)
	Tecnam	RH	STROBE LIGHT	Strobe Light	7.5	13.8	4.0	8.0	55.2	110.4	Measured	Measured by Scaled on 9/10/2018. Peak is likely higher than 8A but equipment wouldn't capture this
	Tecnam	RH	INST LIGHT (Collared)	~~Instrument Lights~~	5.0	13.8	0.0	0.0	0.0	0.0	Measured	Functionality exist but system not required for X57 flights at AFRC (0.1 amps Measured at Scaled)
	Tecnam	RH	CABIN FAN	Cabin Fan	3.0	13.8	2.0	2.0	27.6	27.9	Measured	Measured by Scaled 9/10/18
	Tecnam	RH	CABIN SOCKETS (Collared)	~~Cabin Elec Sockets~~	2.0	13.8	0.0	0.0	0.0	0.0	Measured	Functionality exist but system not required for X57 flights at AFRC
	Tecnam	RH	LANDING LIGHT (Collared)	~~Landing Light~~	3.0	13.8	0.0	0.0	0.0	0.0	Measured	Functionality exist but system not required for X57 flights at AFRC (0.1 amps Measured at Scaled)
	Tecnam	RH	PITOT HEAT (Collared)	~~Pitot Heat~~	10.0	13.8	0.0	0.0	0.0	0.0	Measured	Functionality exist but system not required for X57 flights at AFRC (5 amps Measured at Scaled)
	Tecnam	RH	TAXI LIGHT (Collared	~~Taxi Light~~	3.0	13.8	0.0	0.0	0.0	0.0	Measured	Functionality exist but system not required for X57 flights at AFRC (1.2 amps Measured at Scaled)
	Tecnam	RH	CABIN DOOR	Cabin Door Open Indicator	1.0	13.8	0.1	0.1	1.4	1.4	Estimated	
AVIONICS BUS B		**RH**	**AVIONICS BUS B**	**AVIONICS BUS B TOTALS**	**50.0**	**13.8**	**39.9**	**39.9**	**550.0**	**550.0**		
	Mod II			Advanced Nav								
	Mod II	LH	CDAU	CDAU (Equipment Pallet)	5.0 (28 VDC)	13.8						
	Mod II	LH	FDR	FDR (Equipment Pallet)	5.0 (28 VDC)	13.8	10.9	10.9	150.8	150.8	Measured	Only have a combined current for this hardware
	Mod II	LH	MDAU	MDAU (Equipment Pallet)	10.0 (28 VDC)	13.8	3.8	3.8	53.1	53.1	Estimated	
	Mod II	LH	DATA XMIT	Data Transmitter ((Equipment Pallet)	5.0 (28 VDC)	13.8	5.5	5.5	75.8	75.8	Estimated	
	Mod IV			MDAU LH (Cruise Nacelle)		13.8	3.3	3.3	45.9	45.9	Estimated	
	Mod IV	LH	LEFT MDAU	MDAU LH (HL Pod 4)	5.0 (28 VDC)	13.8	3.3	3.3	45.9	45.9	Estimated	
	Mod IV			MDAU RH (Cruise Nacelle)		13.8	3.3	3.3	45.9	45.9	Estimated	
	Mod IV			MDAU RH (HL Pod 7)		13.8	2.7	2.7	36.8	36.8	Estimated	
	Mod IV			MDAU RH (HL Pod 9)		13.8	3.1	3.1	42.2	42.2	Estimated	
	Mod IV	LH	RIGHT MDAU	PPT-2 (ESP Module)	5.0 (28 VDC)	13.8	0.0	0.0	0.4	0.4	Estimated	
	Mod IV	LH	ESP HEATER	ESP Heater	5.0 (28 VDC)	13.8	3.9	3.9	53.2	53.2	Estimated	

Notes

1 - Includes loads from "Mod IV BCM 28VDC Pwr Est" worksheet and the "Mod IV Inst 28VDC Pwr Est" worksheet

Mod II Essential Bus Energy Estimates for Essential Bus only Landing

Bus	Tecnam or Mod II	Breaker Panel	Breaker Label	Description	Breaker Rating (Amps)	Operating Voltage	Typical Current (Amps)	Steady-State Power (Watts)	Time (Minutes)	Energy (Watt Hour)	Verification Method	Comments
		LH	**ESS BATT**	**ESSENTIAL BUS TOTALS**	**90.0**	13.8	**88.9**	**1268.0**	**20.0**			
	Tecnam	LH	AUDIO PANEL	GMA 340 Audio Panel	5.0	13.8	2.2	30.4	20.0	10.12	Data Sheet	https://www8.garmin.com/specs/gma340.pdf
				Garmin GTN 650 GPS Transmit			0.0	0.0	0.0	0.00	Estimated	
	Tecnam	LH	COM 2	Garmin GTN 650 GPS Standby	10.0	13.8	0.5	6.2	20.0	2.07	Estimated	Will not transmit on COM 2 when on Essential Bus only. COM 1 is Primary
	Tecnam	LH	NAV 1	Garmin GTN 650 GPS	5.0	13.8	0.6	8.3	20.0	2.76	Estimated	
	Tecnam	LH	LANDING GEAR	Hydraulic Pump On	25.0	13.8	21.0	289.8	0.2	0.97	Measured	Measured by Scaled 9/10/18
	Tecnam	LH	RELAY LAND GEAR	Landing Gear Relay	5.0	13.8	0.1	1.4	0.2	0.00	Measured	Measured by Scaled 9/10/18
	Tecnam	LH	FLAP MOTOR	Flap Motor On	15.0	13.8	10.0	138.0	0.2	0.46	Data Sheet	Estimate from Ultramotion datasheet
	Tecnam	LH	ANNUNC PANEL	Annunciator Panel and Cabin Lite	5.0	13.8	1.3	17.3	20.0	5.75	Estimated	1/4 breaker size (changed to LEDs), Includes blue logic control box (can disconnect cabin light)
	Tecnam	LH	OAT/FLAP IND	OAT and Flap Indicator	5.0	13.8	2.5	34.5	20.0	11.50	Estimated	Need Update. Assume 1/2 of Breaker Size
	Mod II	LH	TE-L	Throttle Encoder Left	2.0	13.8	0.1	1.4	20.0	0.46	Data Sheet	Baumer Spec
	Mod II	LH	BMS-A	Battery Management System A	2.0	13.8	0.3	4.1	20.0	1.38	Estimated	Email from Randy Dunn on 9/17/2018
	Mod II	LH	MFD	MoTEC Display	3.0	13.8	0.4	5.2	20.0	1.75	Data Sheet	MoTEC Manual
	Mod II	LH	PROP-L	Prop Pitch Controller Left Changing Pitch	4.0	13.8	1.5	20.7	2.0	0.69	Measured	Measured by Matt Redifer on 9/19/2018 with prop pitch changing
ESSENTIAL BUS (13.8 VDC)	Mod II	LH	PROP-R	Prop Pitch Controller Right Changing Pitch	4.0	13.8	1.5	20.7	2.0	0.69	Measured	Measured by Matt Redifer on 9/19/2018 with prop pitch changing
	Tecnam	RH	CROSS RELAYS		3.0	13.8	0.2	2.8	0.0	0.00	Measured	Current Draw is .2A each (2 in aircraft). Measured by Scaled 9/10/18.
	Tecnam	RH	LIGHT LAND GEAR		2.0	13.8	0.1	1.4	20.0	0.46	Measured	Measured by Scaled 9/10/18
	Tecnam	RH	STALL WARNING		1.0	13.8	0.9	12.6	20.0	4.19	Measured	Measured by Scaled 9/10/18
	Tecnam	RH	AVIONICS RELAYS		2.0	13.8	0.2	2.8	0.0	0.00	Estimated	Assumed to be the same as the Cross relays
	Mod II	RH	TE-R	Throttle Encoder Right	2.0	13.8	0.1	1.4	20.0	0.46	Data Sheet	Baumer Spec
	Mod II	RH	BMS-B	Battery Management System B	2.0	13.8	0.3	4.1	20.0	1.38	Estimated	Email from Randy Dunn on 9/17/2018
	Mod II	RH	AUDIO ANNUNC	Audio Annunciator	1.0	13.8	0.8	10.4	20.0	3.45	Data Sheet	PS Engineering Manual Max
				UHF Transmit			18.9	260.7	4.0	17.38	Measured	
	Mod II	LH	COM 1	UHF Standby	25.0	13.8	3.0	41.4	16.0	11.04	Measured	COM 1 is Primary
	Mod II	LH	28 A	BCM A 28 VDC Power Supply	10.0	13.8	7.5	103.0	20.0	34.32	Estimated	Mod IV BCM 28 VDC Power Estimate Worksheet
	Mod II	RH	28 B	BCM B 28 VDC Power Supply	10.0	13.8	7.5	103.0	20.0	34.32	Estimated	Mod IV BCM 28 VDC Power Estimate Worksheet
	Mod II	RH	G Meter	G Meter	1.0	13.8	0.1	1.4	20.0	0.46	Data Sheet	Manual Spec
	Mod II	LH	FOBE A	FOBE A	2	13.8	0.1	1.7	20.0	0.58	Data Sheet	FOBE Manual
	Mod II	RH	FOBE B	FOBE B	2	13.8	0.1	1.7	20.0	0.58	Data Sheet	FOBE Manual
	Mod II	NA	NA	Wing Avionics Relay A	NA	13.8	0.1	1.4	20.0	0.46	Estimated	Relay coil is wired directly to 25 amp Wing Avionics B Breaker
	Mod II			CMC LA		13.8	2.1	28.8	20.0	9.58	Estimated	Estimate (40 Watts) provided by Dave A for the XM3 CMCs
	Mod II			FOBE LCA		13.8	0.1	1.7	20.0	0.58	Data Sheet	FOBE Manual
WING AVIONICS BUS A (24 VDC)	Mod II	LH	CMC LA, FOBE LCA	L CANBus DAQ	7.5 (24 VDC)	13.8	0.6	8.6	20.0	2.88	Data Sheet	SVIM Data Sheet
	Mod II			CMC RA		13.8	2.1	28.8	20.0	9.58	Estimated	Estimate (40 Watts) provided by Dave A for the XM3 CMCs
	Mod II	LH	CMC RA, FOBE RCA	FOBE RCA	7.5 (24 VDC)	13.8	0.1	1.7	20.0	0.58	Data Sheet	FOBE Manual
ESSENTIAL BUS 13.8 VDC	Mod II	NA	NA	Wing Avionics Relay B	NA	13.8	0.1	1.4	20.0	0.46	Estimated	Relay coil is wired directly to 25 amp Wing Avionics B Breaker
	Mod II			CMC RB		13.8	2.1	28.8	20.0	9.58	Estimated	Estimate (40 Watts) provided by Dave A for the XM3 CMCs
	Mod II			FOBE RCB		13.8	0.1	1.7	20.0	0.58	Data Sheet	FOBE Manual
WING AVIONICS BUS B (24 VDC)	Mod II	RH	CMC RB, FOBE RCB	R CANBus DAQ	7.5 (24 VDC)	13.8	0.6	8.6	20.0	2.88	Data Sheet	SVIM Data Sheet
	Mod II			CMC LB		13.8	2.1	28.8	20.0	9.58	Estimated	Estimate (40 Watts) provided by Dave A for the XM3 CMCs
	Mod II	RH	CMC LB, FOBE LCB	FOBE LCB	7.5 (24 VDC)	13.8	0.1	1.7	20.0	0.58	Data Sheet	FOBE Manual
	Mod IV			Ethernet Switches (2 Each)			3.0	41.4	20.0	13.80	Data Sheet	Manual Spec
	Mod IV			Data Bridge (3 Each)			0.7	9.7	20.0	3.22	Data Sheet	Manual Spec
	Mod IV			PPT-2 (Data Boom)			0.1	1.4	20.0	0.46	Data Sheet	Manual Spec
ESSENTIAL BUS 13.8 VDC	Mod IV		HL DATA	Paroscientific Sensors (Data Boom)	5.0	13.8	0.1	1.4	20.0	0.46	Data Sheet	0.032 for two transducers; Email form Phil H on 9/17/2018
	Mod IV		HiPI A	High Lift Indicator System A	2.0	13.8	1.0	13.8	20.0	4.60	Estimated	Requirements Document
	Mod IV		HiPI B	High Lift Indicator System B	2.0	13.8	1.0	13.8	20.0	4.60	Estimated	Requirements Document
	Mod IV		HiPC A	High Lift Control A	2.0	13.8	1.0	13.8	20.0	4.60	Estimated	Requirements Document
	Mod IV		HiPC B	High Lift Control B	2.0	13.8	1.0	13.8	20.0	4.60	Estimated	Requirements Document
WING AVIONICS BUS A (24 VDC)	Mod IV		HL A	HLMC A Bus (6 Each HLMC)	10 (24 VDC)	13.8	5.4	75.0	20.0	25.00	Estimated	10 Watts HLMC requirement/.0.8 efficiency of 23 VDC power supply/13.8 x 6
WING AVIONICS BUS B (24 VDC)	Mod IV		HL B	HLMC B Bus (6 Each HLMC)	10 (24 VDC)	13.8	5.4	75.0	20.0	25.00	Estimated	10 Watts HLMC requirement/.0.8 efficiency of 23 VDC power supply/13.8 x 6

Total Watt Hours	**280.85**
Amp Hours @ 13.8 VDC	**20.35**
Amp Hours @ 12 VDC	**23.40**

White boxes are time inputs and have margin added
Grey boxes are referenced to the Mod II Load Sheet
Gold boxes a re populated by formulas
Loads in red are momentary
Assumes UHF Operations Only

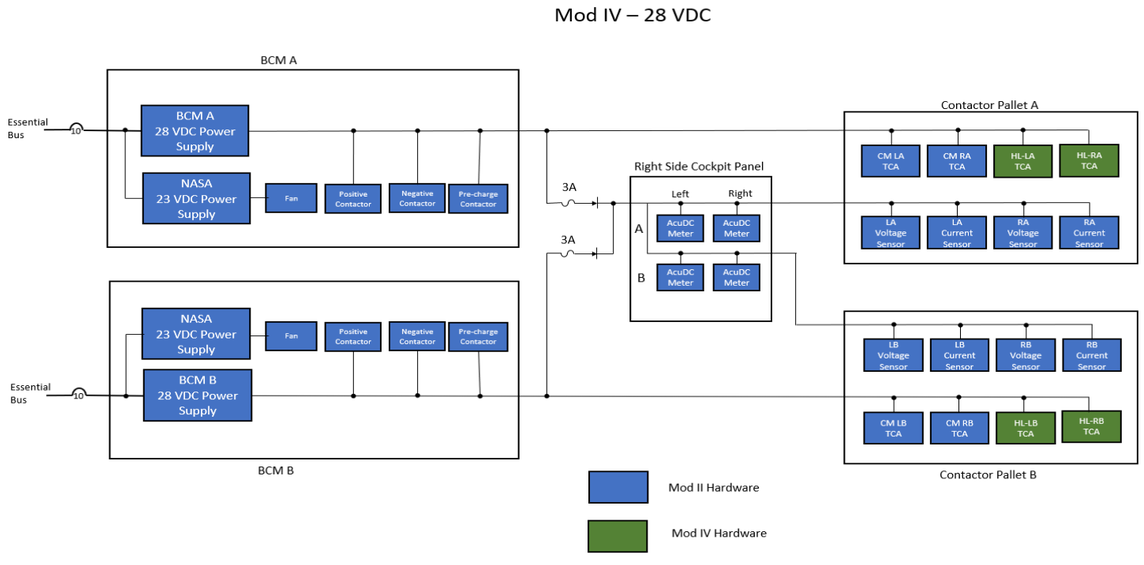
	Mod IV BCM 28 VDC Power Estimates							
		BCM 28 VDC Estimates				13.8 VDC Estimates			
	Item	Steady State Current (Amps)	Maximum Current (Amps)	Steady State Power (Watts)	Maximum Power (Watts)	Steady State Current (Amps)	Maximum Current (Amps)	Steady State Power (Watts)	Maximum Power (Watts)
BCM A 28 VDC Power Supply	TE KHR500KSANL + Side; 4.5A inrush for 100 ms[1] (BCM A)	0.35	4.5	9.8	126	0.9	11.6	12.4	159.5
	TE KHR500KSANL - Side; 4.5A inrush for 100 ms[1] (BCM A)	0.35	4.5	9.8	126	0.9	11.6	12.4	159.5
	TCA - Kilovac CAP120; 4.5A inrush for 100 ms[1] (Contactor Pallet A)	0.15	4.5	4.2	126	0.4	11.6	5.3	159.5
	TCA - Kilovac CAP120; 4.5A inrush for 100 ms[1] (Contactor Pallet A)	0.15	4.5	4.2	126	0.4	11.6	5.3	159.5
	TCA - Kilovac CAP120; 4.5A inrush for 100 ms[3,4] (Contactor Pallet A)	0.15	4.5	4.2	126	0.4	11.6	5.3	159.5
	TCA - Kilovac CAP120; 4.5A inrush for 100 ms[3,4] (Contactor Pallet A)	0.15	4.5	4.2	126	0.4	11.6	5.3	159.5
BCM B 28 VDC Power Supply	TE KHR500KSANL + Side; 4.5A inrush for 100 ms[1] (BCM B)	0.35	4.5	9.8	126	0.9	11.6	12.4	159.5
	TE KHR500KSANL - Side; 4.5A inrush for 100 ms[1] (BCM B)	0.35	4.5	9.8	126	0.9	11.6	12.4	159.5
	TCA - Kilovac CAP120; 4.5A inrush for 100 ms[1] (Contactor Pallet B)	0.15	4.5	4.2	126	0.4	11.6	5.3	159.5
	TCA - Kilovac CAP120; 4.5A inrush for 100 ms[1] (Contactor Pallet B)	0.15	4.5	4.2	126	0.4	11.6	5.3	159.5
	TCA - Kilovac CAP120; 4.5A inrush for 100 ms[3,4] (Contactor Pallet B)	0.15	4.5	4.2	126	0.4	11.6	5.3	159.5
	TCA - Kilovac CAP120; 4.5A inrush for 100 ms[3,4] (Contactor Pallet B)	0.15	4.5	4.2	126	0.4	11.6	5.3	159.5
Shared Power Between BCM A and BCM B 28 VDC Power Supplies	700-S874-NASA Current Sensor (Contactor Pallet A)[2]	0.02	0.02	0.56	0.56	0.1	0.1	0.7	0.7
	700-S874-NASA Current Sensor (Contactor Pallet A)[2]	0.02	0.02	0.56	0.56	0.1	0.1	0.7	0.7
	700-S1060 Voltage Sensor (Contactor Pallet A)[2]	0.017	0.017	0.476	0.476	0.0	0.0	0.6	0.6
	700-S1060 Voltage Sensor (Contactor Pallet A)[2]	0.017	0.017	0.476	0.476	0.0	0.0	0.6	0.6
	700-S874-NASA Current Sensor (Contactor Pallet B)[2]	0.02	0.02	0.56	0.56	0.1	0.1	0.7	0.7
	700-S874-NASA Current Sensor (Contactor Pallet B)[2]	0.02	0.02	0.56	0.56	0.1	0.1	0.7	0.7
	700-S1060 Voltage Sensor (Contactor Pallet B)[2]	0.017	0.017	0.476	0.476	0.0	0.0	0.6	0.6
	700-S1060 Voltage Sensor (Contactor Pallet B)[2]	0.017	0.017	0.476	0.476	0.0	0.0	0.6	0.6
	Accuenergy Meter LA (RH Panel)[2]	0.10	0.10	2.8	2.8	0.3	0.3	3.5	3.5
	Accuenergy Meter RA (RH Panel)[2]	0.10	0.10	2.8	2.8	0.3	0.3	3.5	3.5
	Accuenergy Meter LB (RH Panel)[2]	0.10	0.10	2.8	2.8	0.3	0.3	3.5	3.5
	Accuenergy Meter RB (RH Panel)[2]	0.10	0.10	2.8	2.8	0.3	0.3	3.5	3.5
	Totals	3.15	9.55	88.1	267.3	8.09	24.52	111.6	338.4

1-The two traction contactors inside the BCM will close sequentially. The traction contactors in the Contactor Pallet also close sequentially using separate switches in the cockpit. The inrush current of 4.5 amps for 100 ms for the traction contactor closure will occur sequentially for the four traction contactors on one 28 VDC power supply and not all at once.

2- The BCM A and BCM B 28 VDC power supplies are connected to AcuDC Meters A and B and Contactor Pallets A and B sensors through OR'ing diodes. One BCM 28 VDC power supply must be able to supply power all of this hardware.

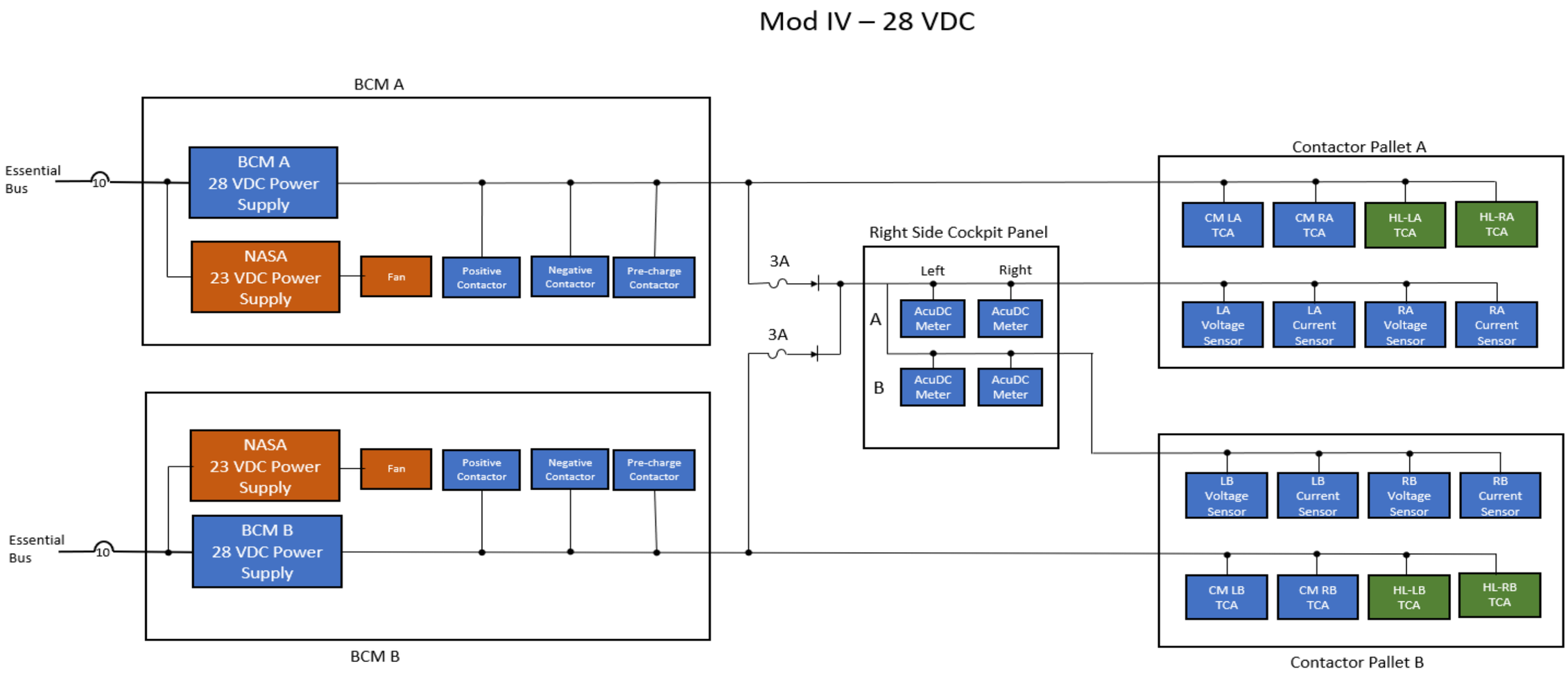
3 - Mod IV Equipment

4 - The High Lift Contactors in Contactor Pallet A are wired to one enable switch in the cockpit which means they will turn on at the same time creating an inrush of current of 9 amps for 100 ms. The same is true for the High Lift Contactors in Contactor Pallet B. The High Lift switches for Contactor A and Contactor B are sequential. The 9 amps generated during the High Lift Contactor closure is used for the maximum current calculation.



	Mod IV 23 VDC BCM Fan Power Estimates								
		BCM Fan 23 VDC Estimates				13.8 VDC Estimates			
	Item	Steady State Current (Amps)	Maximum Current (Amps)	Steady State Power (Watts)	Maximum Power (Watts)	Steady State Current (Amps)	Maximum Current (Amps)	Steady State Power (Watts)	Maximum Power (Watts)
BCM A 23 VDC Power Supply	BCM A Fan (Model VXR250-2828S)	1.6	5	36.8	115	3.4	10.7	47.2	147.4
BCM B 23 VDC Power Supply	BCM B Fan (Model VXR250-2828S)	1.6	5	36.8	115	3.4	10.7	47.2	147.4
	Totals	3.2	10.0	73.6	230.0	6.8	21.4	94.4	294.9

Power Supply and Fan shown in orange below



Mod IV Instrumentation 28 VDC Power Estimates				
	28 VDC		13.8 VDC	
Instrumentation	Steady State Power (Watts)	Steady State Current (Amps)	Steady State Power (Watts)	Steady State Current (Amps)
CDAU (Equipment Pallet)	119.168	4.256	150.846	10.931
FDR (Equipment Pallet)				
MDAU (Equipment Pallet)	41.972	1.499	53.129	3.850
Data Xmit Cband 10 Watts (Equipment Pallet)	59.920	2.140	75.848	5.496
MDAU LH (Cruise Nacelle)	36.260	1.295	45.899	3.326
MDAU RH (Cruise Nacelle)	36.260	1.295	45.899	3.326
MDAU LH (HL Pod 4)[1]	36.260	1.295	45.899	3.326
MDAU RH (HL Pod 7)[1]	29.064	1.038	36.790	2.666
MDAU RH (HL Pod 9)[1]	33.348	1.191	42.213	3.059
ESP Heater (Pod 8)[1]	42.000	1.500	53.165	3.853
PPT-2 (ESP Module Pod 8)[1]	0.280	0.010	0.354	0.026
Estimated Input Power Total	**550.0**			
Estimated Input Current Total				**39.9**

Power estimates provide by Joe H. in an email on 9/21/20

Initial data has DC/DC Converters at 79% efficient

1 - Mod IV Equipment