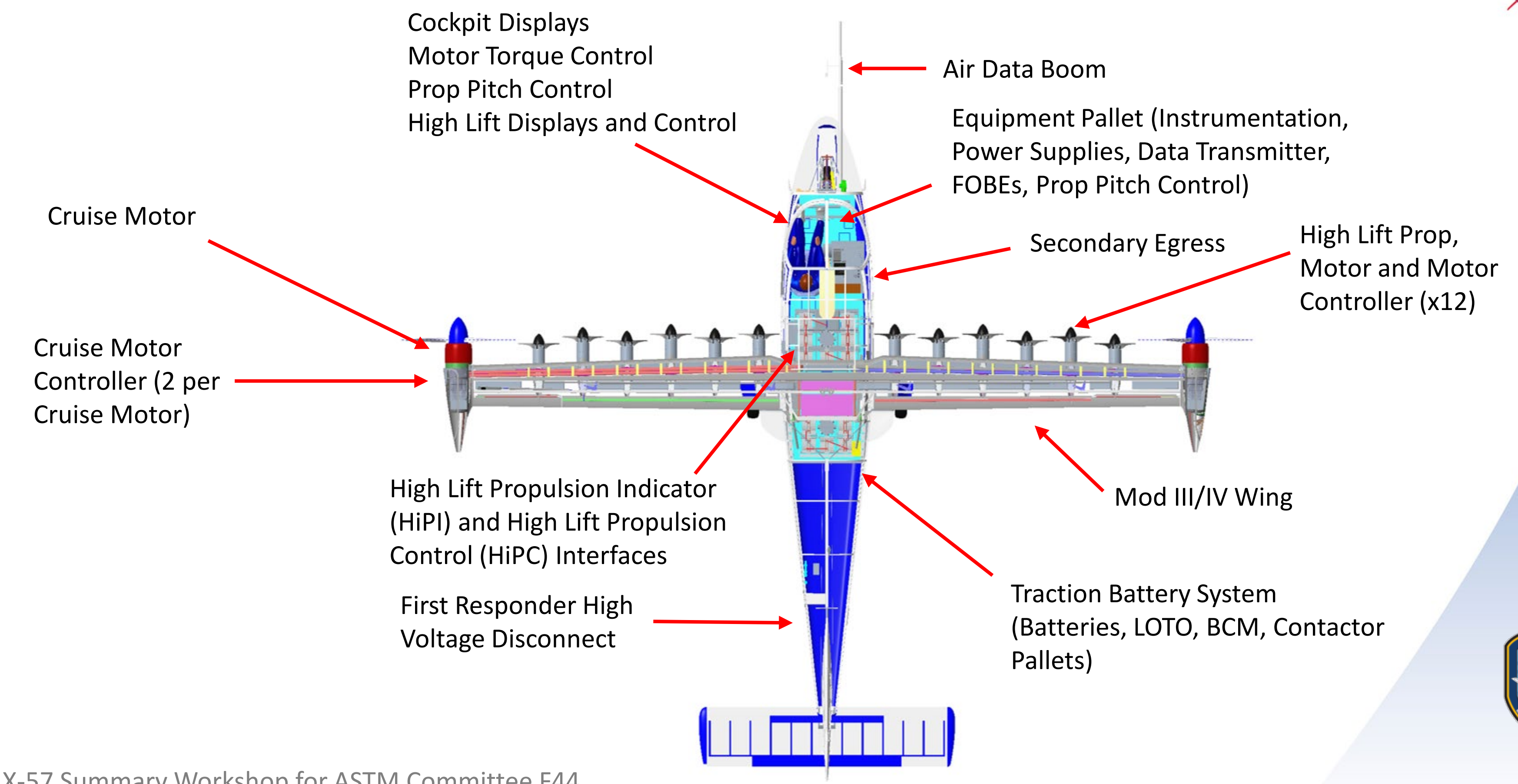
X-57 Avionics Architecture

Sean Clarke, X-57 Principal Investigator

Presented on behalf of

Keith Harris, X-57 Vehicle Team Lead (Retired)

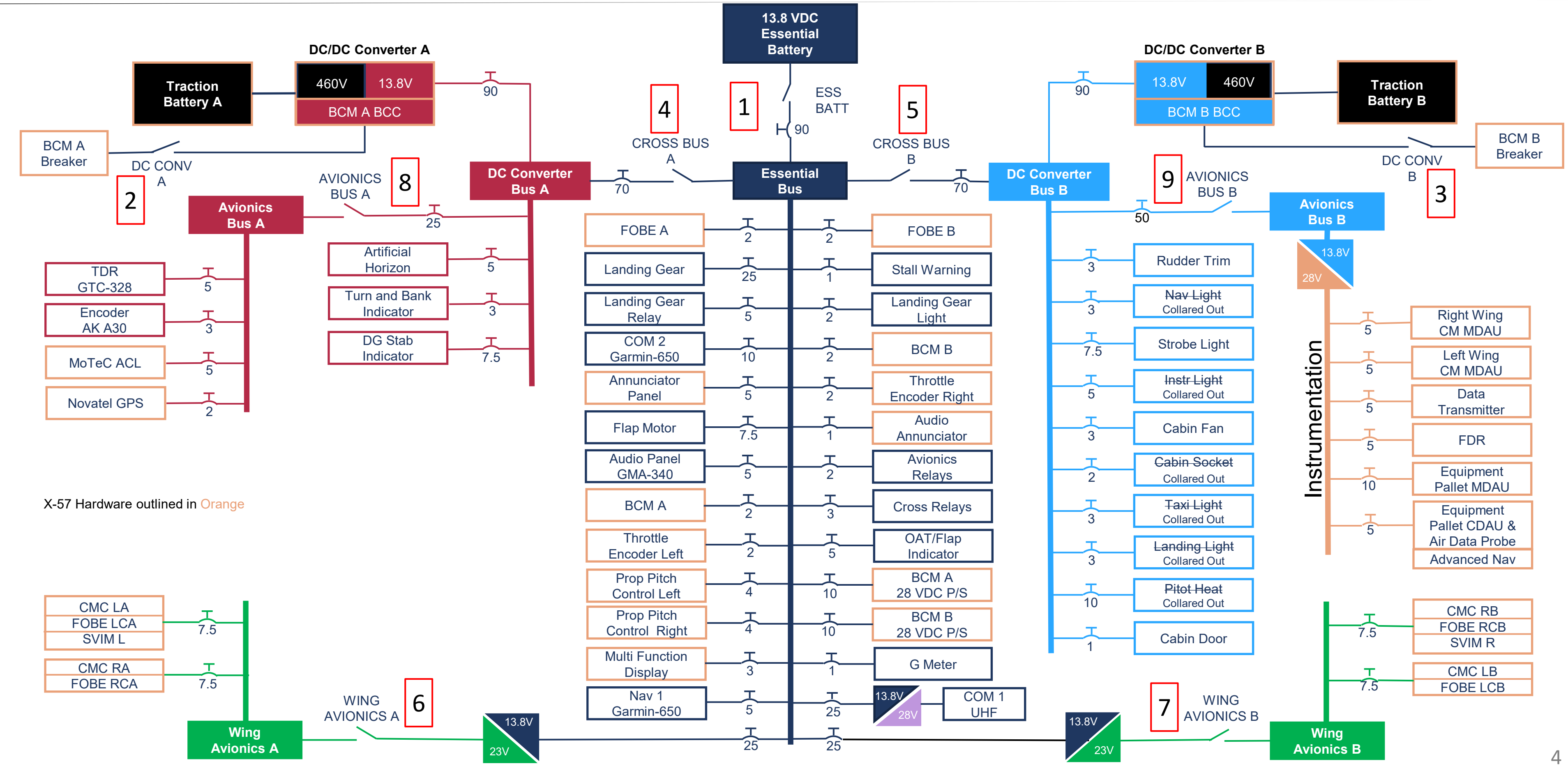
Mod III/IV High Lift Hardware



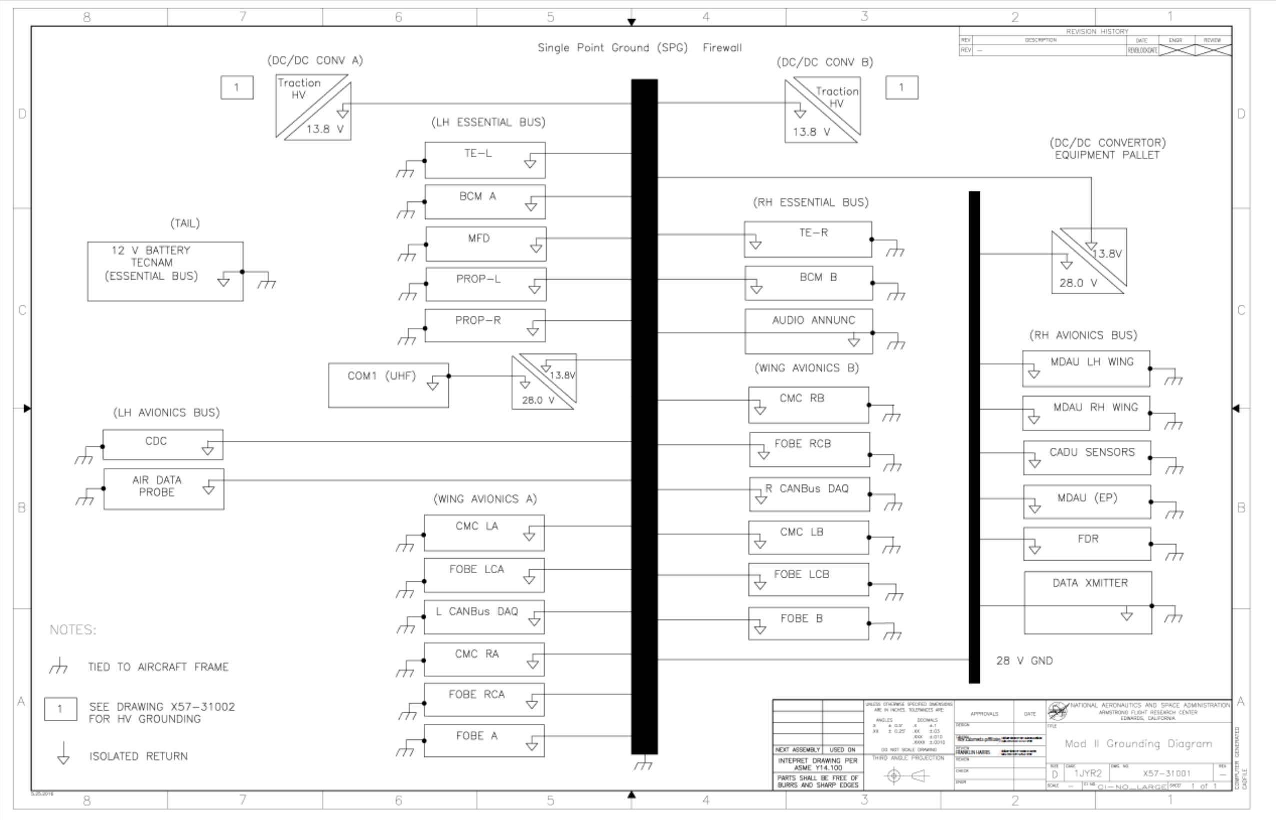
Avionics Architecture

- The X-57 avionics system consists of stock Tecnam avionics hardware, Commercial Off the Shelf (COTS) hardware, Modified Commercial Off the Shelf (MOTS) hardware and X-57 Custom hardware
- Hardware voltage requirements
  - 13.8 VDC (Primary)
  - 28 VDC
  - 23 VDC
- The X-57 avionics power design uses the stock Tecnam avionics power architecture as a baseline
  - The stock Tecnam power system utilizes three 13.8 VDC power sources (battery and two alternators) to provide redundant avionics power
  - This redundancy was preserved in the X-57 avionics power architecture

Mod II Avionics Power Architecture

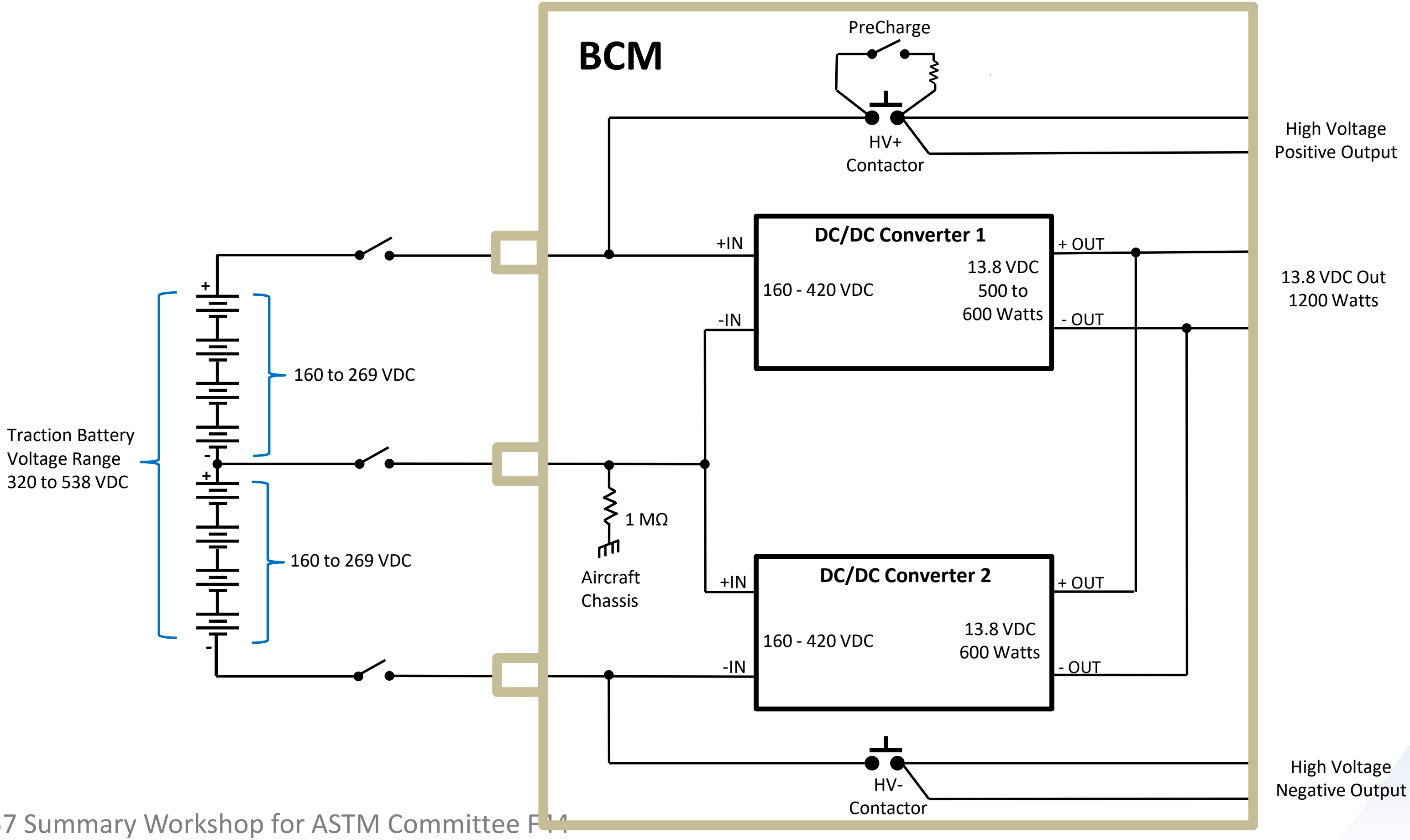


Grounding Diagram



Eliminate Ground Loops to reduce noise on system

Avionics 13.8 VDC DC/DC Converters



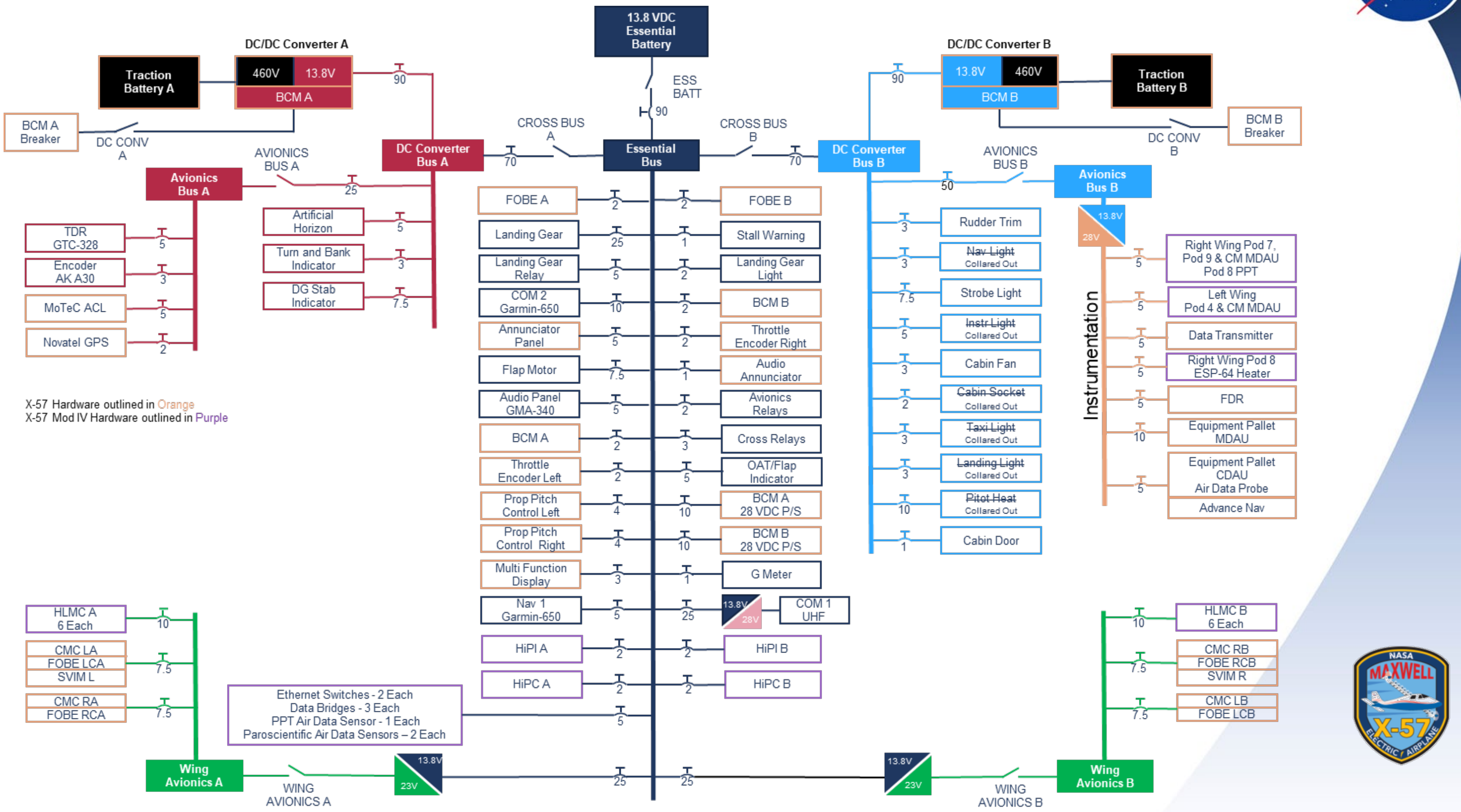
Mod II Avionics Power Analysis

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

Mod II Avionics 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	40.5	81.1	NA	NA	NA	NA
DC Converter A (13.8 VDC)	90	7.6	9.2	40.8	64.2	563.6	885.7
DC Converter B (13.8 VDC)	90	33.6	38.0	40.8	64.2	563.6	885.7
Totals		**81.7**	**128.4**	**81.7**	**128.4**	**1127.3**	**1771.5**
				Remaining Power Available (%)		**53.0%**	**26.2%**

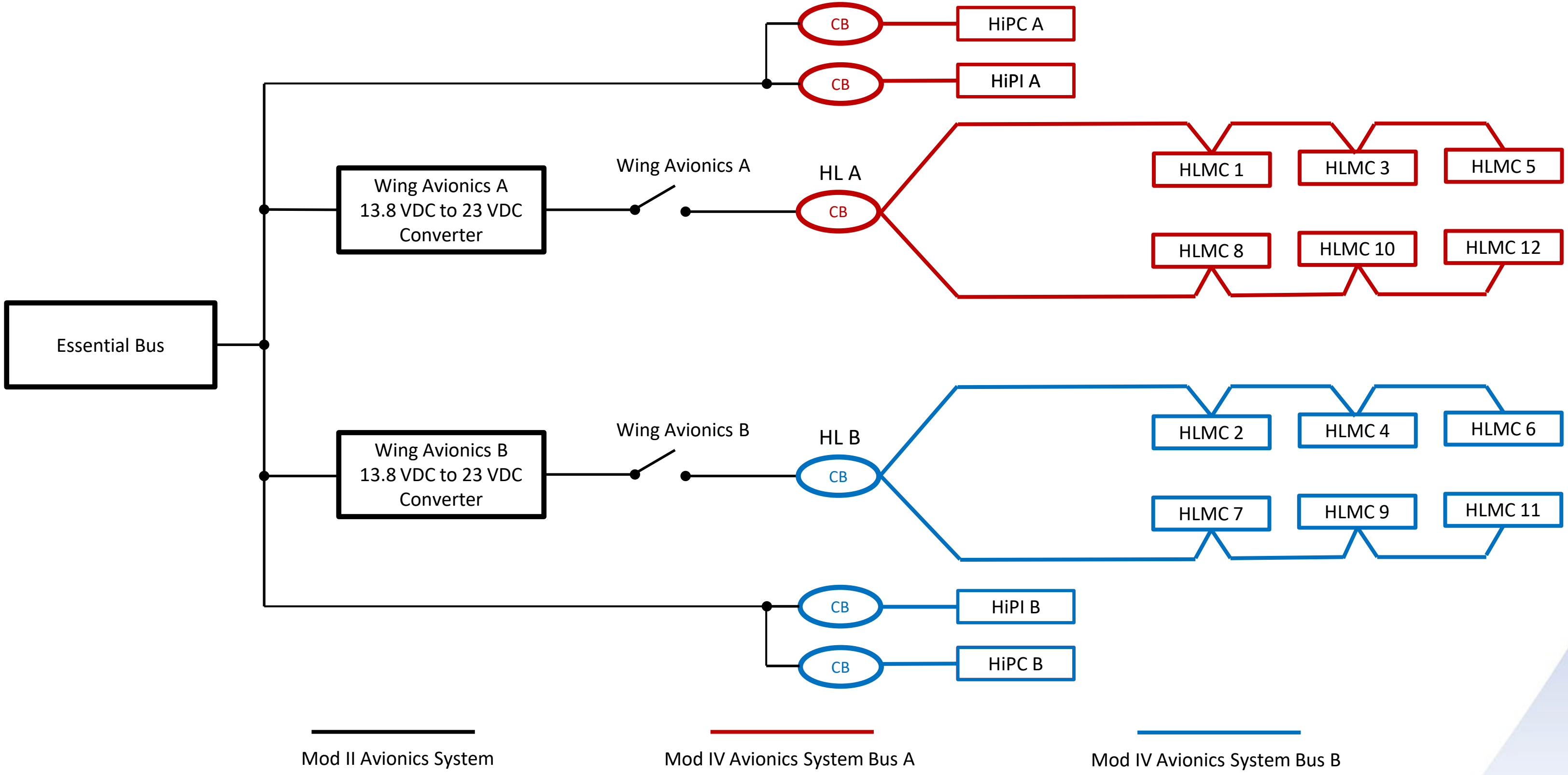
X57 Mod II uses half of available avionics power
Provides redundancy in the event of a DC Converter failure

Mod IV High Lift Avionics Power Architecture



Mod IV High Lift Motor Numbering

High Lift Avionics Power Distribution



Loss of avionics 23 VDC A or B would result in a symmetric loss of high lift

Avionics Architecture

Lessons Learned and Recommendations

Lessons Learned

- If using DC/DC Converters to generate avionics power from the traction battery…….
  - Consider using 28 VDC instead of 13.8 VDC for avionics primary power
    - Higher voltages and lower currents reduced the effects of voltage drops caused by inrush current during power-up and long cable runs for components located in nacelles
    - Noise spikes are more tolerable on a higher voltage power system
      - A negative noise spike of 3-5 volts can turn off a 13.8 VDC system
    - Lower currents due to higher voltage will reduce wire size and weight
    - Most of the avionics components have a range of 11 to 32 VDC
  - The DC/DC Converter input voltage range should match the traction battery operational range
  - If Lock Out Tag Outs (LOTOs) are used on HV system, make sure the DC/DC Converter design can accept the input voltage slew rate caused by closing and opening the LOTO
  - Implement a power design for operating the avionics system without the traction battery in the loop for ground operations
- Redundancy and Load Shedding
  - Have redundant power sources and a load shedding strategy
  - Utilize an essential bus and backup battery for safety of flight systems

Lessons Learned

- Grounding, shielding and cabling
  - Avionics power designer must be proficient in grounding, shielding and cabling techniques to reduce the effects of EMI/EMC caused by the high voltage propulsion system
  - Cannot use the same techniques to wire an electric propulsion vehicle as a combustion propulsion vehicle
    - Examples
      - Ship's chassis should not be used for a signal or power return
      - Use twisted or twisted shielded cable wherever possible
      - Terminate shields properly
      - Develop a grounding tree (diagram) for all hardware and use a single point ground for returns
      - May need to add chokes on input power for avionics subsystems
- Workmanship
  - Use technicians certified and experienced in cabling, crimping and soldering (J Standards)
- Electrostatic Discharge (ESD)
  - Use ESD protection when handling ESD sensitive components

Recommendations

- Utilize an EMI/EMC expert early in the design phase
- Avionics power designer must be proficient in grounding, shielding and cabling techniques
- If possible, use fiber optic cables for signals to minimize effect from EMI
- If using DC/DC Converters to generate avionics power from the traction battery, consider using 28 VDC instead of 13.8 VDC for avionics primary power
  - This is especially critical for components that have long cable runs
- The DC/DC Converter input voltage range should match the traction battery operational range

Recommendations

- Utilize an essential bus and backup battery for safety critical systems
- Develop a load shedding strategy for off nominal conditions (X-57 Pilot's Checklist PCL-CEPT-019 available upon request)
- Incorporate a First Responder Disconnect to allow emergency personnel to quickly remove high voltage form aircraft
- If possible, don't fly prototype/engineering units
  - Budget for flight units
- Use technicians certified and experienced in cabling, crimping and soldering (J Standards)