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Report Number MDC 91K0418

FINAL CRAD REPORT
EVALUATION OF ALL-ELECTRIC SECONDARY POWER FOR TRANSPORT AIRCRAFT

Contract Number NAS 3-25965

Document Control Number

Issue Date JANUARY 1992

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MCDONNELL DOUGLAS

PREFACE

This final report describes the two-part all-electric aircraft study conducted by Douglas Aircraft Company for NASA-Lewis Research Center (NASA-LeRC), in Cleveland, Ohio, under contract No. NAS3-25965, Task Order 1 with Amendment 1. The report provides a statement of objectives, gives the structure for the study as defined by the task flow breakdown, lists the assumptions made to initiate the study, describes the approach adopted to guide the study, and provides the program scope and schedule.

The Douglas program manager for this contract is James G. McComb. The NASA Technical Representative for Task Order No. 1 was David Renz and the Contracting Officer was Al Spence, both of NASA-Lewis Research Center.

This work was accomplished by personnel of the Douglas Advanced Aircraft Systems department with support from the Cost and Performance Analysis groups.

The organization chart for the departments of Douglas Aircraft Company that conducted this study is presented in the accompanying figure. The participants are listed below, with their areas of effort.

Aircraft Systems Engineering Staff Members:

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- G. Bell, Manufacturing Cost Analysis
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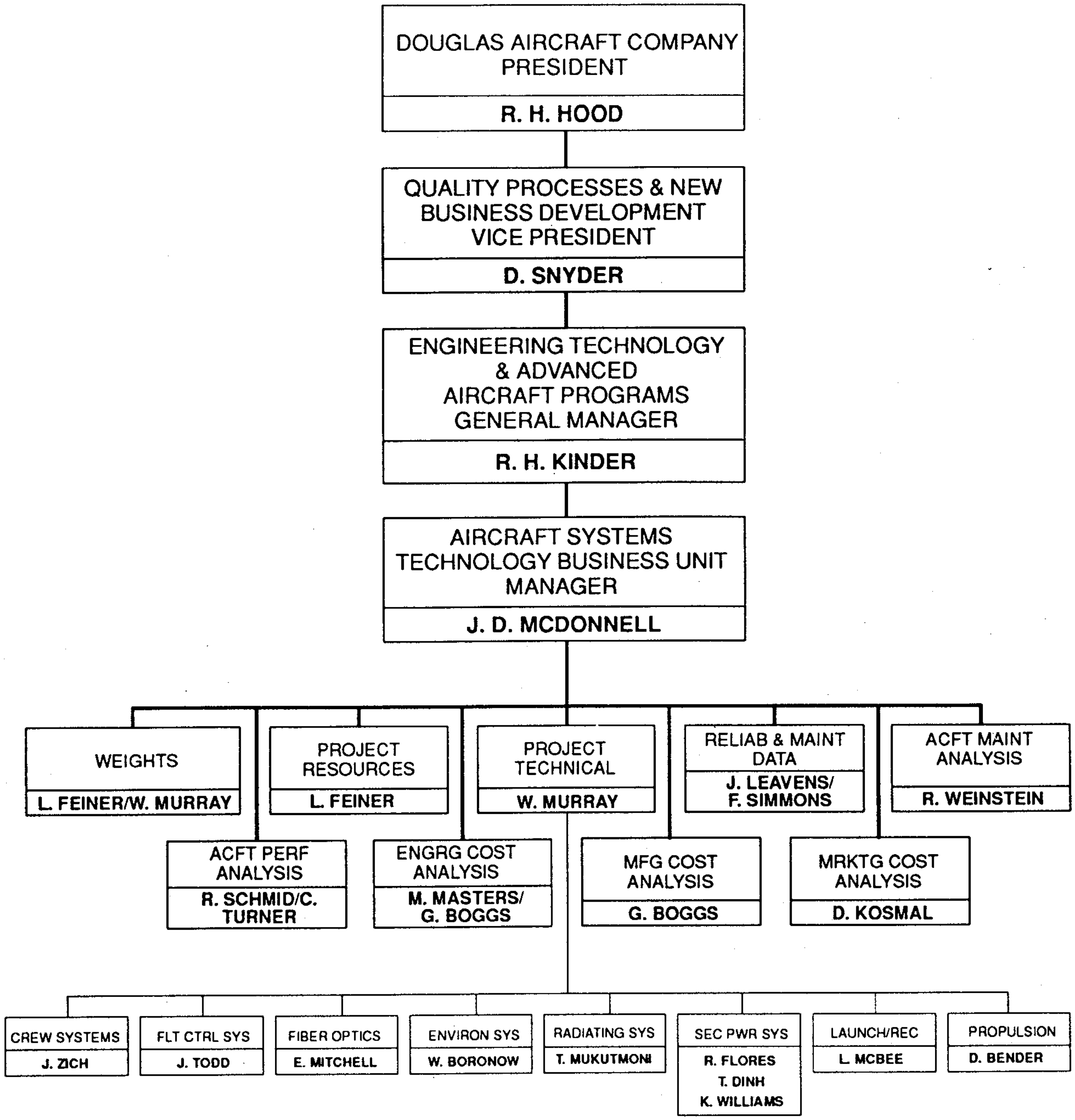
- F. Simmons, Reliability and Maintenance Analysis
- C. J. Turner, Advanced Aircraft Design and Performance Analysis
- R. I. Weinstein, Reliability and Maintenance Analysis

Douglas recognizes with appreciation the efforts of the engineering team from the AiResearch Division of Allied-Signal Company, who provided environmental control system concepts and technical reviews for this study free of charge. Other individuals who reviewed the study criteria and guidelines without NASA funding were:

Andrew Gordan, Analytical Engineering Corp.
T. T. Waugaman, Kilovac Corp.
D. M. Beauchaime, Eaton Corp. of Florida
T. J. Vallo, Westinghouse Electric Corp.
E. J. Schulze, McDonnell Douglas Electronic Systems Co.
M. J. Cronin, Advanced Aeronautical Systems, Inc.



ORGANIZATION

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FIGURES

FIGURES
(Continued)

TABLES

GLOSSARY

ac	alternating current
ADC	air data computer
ADG	air-driven generator
AL	aluminum (conductor material)
AN	annealed copper (conductor material)
APR	auxiliary power relay
APU	auxiliary power unit
APU-GCU	auxiliary power unit — generator control unit
ATA	Air Transport Association
AWG	American Wire Gage (conductor wire size)
BC	bus controller
BCU	bus control unit
BDCC	bidirectional converter and charge controller
BI	bus interrupter
BIT	built-in test
BTI	Bilinear Technologies, Inc.
Cat IIIb	Category IIIb (minimum visibility instrument landing condition)
cfm	cubic feet per minute
CPU	central processor unit (computer or microprocessor)
CSD	constant-speed drive
CUST	customer
CWS	control wheel steering
dc	direct current
DER	Designated Engineering Representative (certified by the FAA)
Des/Lnd	descent and land
DOC	direct operating cost
DP	differential protection (electrical)
EHA	electrohydraulic actuator
EIDI	electric impulse de-icing
ELOAD	electrical load
EM	electromagnetic
EMA	electromechanical actuator
EMC	electromagnetic compatibility
EME	electromagnetic effects

GLOSSARY
(Continued)

EPC	electric power center
EPCU	electric power control unit
°F	degrees Fahrenheit
FAA	Federal Aviation Administration
FADEC	full-authority digital electronic control (for main engine)
FAR	Federal Aviation Regulations
FBW	fly by wire
FCC	flight control computer
FHA	functional hazard analysis
FMEA	failure mode and effects analysis
FO/FO/FS	fail operational, fail operational, fail-safe
GE	General Electric Company
gpm	gallons per minute
HERF	high-energy radiation field
HIRF	high-intensity radiation field
hp	horsepower
Hz	Hertz (frequency)
IDG	integrated drive generator
IEEE	Institute of Electrical and Electronics Engineers
ILS	integrated logistics support
I/O	input/output
IRS	inertial reference system
kHz	kilohertz
kva	kilovolt ampere
kw	kilowatt
lb-ft	pound-feet (torque)
lb/hp	pounds per horsepower
lb/kft	pounds per thousand feet
LRU	line-replaceable unit
LVDT	linear voltage differential transducer
MB	multiple burst
MD-XX	McDonnell Douglas Advanced Aircraft Model XX
MD-11	McDonnell Douglas Aircraft Model 11
MS	multiple stroke

GLOSSARY
(Continued)

MTBF	mean time between failures
MTBUR	mean time between unscheduled removals
MTOGW	maximum takeoff gross weight
MTOW	maximum takeoff weight
NASA	National Aeronautics and Space Administration
NASA-LeRC	National Aeronautics and Space Administration — Lewis Research Center
OEW	operator empty weight
P&W	Pratt & Whitney Company
PBW	power by wire
PC	personal computer
PCIM	Power Conversion Intelligent Motion (technical magazine title)
PDM	pulse density modulation
PF	power factor
PFCC	primary flight control computer
PMAD	power management and distribution
POR	point of regulation
psi	pounds per square inch
psia	pounds per square inch, absolute
psig	pounds per square inch, gauge
RAM	random access memory
RDT&E	research, development, test, and evaluation
RGU	reference guidance unit
ROM	read-only memory
RPC	remote power controller
RPM	revolutions per minute
RR	Rolls-Royce Company
SFC	specific fuel consumption
SOW	Statement of Work
TR	transformer-rectifier
TRU	transformer rectifier unit
vac	volts alternating current
VSCF	variable-speed constant-frequency
WBS	Work Breakdown Structure

SECTION 1
SUMMARY

This report presents a study of advanced electrical power systems for transport aircraft based upon an all-electric design concept. It differs from present systems in the following respects:

1. Eliminates distributed hydraulic secondary power systems, for which the energy is obtained by main-engine gearbox-driven hydraulic pumps.
2. Eliminates distributed pneumatic secondary power systems, for which the energy is derived from high-temperature (400° to 475°F) and high-pressure air (33.5 to 100 psia) obtained by "bleed" from the compressor stages of the main aircraft engines.
3. Features expansion and redesign of the electrical secondary power system to supply electrical power to the loads conventionally supplied by either hydraulic or pneumatic secondary power.

The initial study was based upon an advanced 20-kHz electrical power transmission and distribution system, using a system architecture supplied by NASA-Lewis Research Center (NASA-LeRC) for a two-engine (twin-jet) air transport, with many advanced power conversion concepts. After the midterm technical review, NASA-LeRC requested Douglas Aircraft Company to retain the initial study results and refocus the study to pursue a more conventional all-electric air transport design with 400-Hz secondary electrical power transmission and distribution. Subsequent work was based upon a trijet MD-11 air transport, which was selected by Douglas in order to provide credible certified baseline system designs and to establish a firm data base for the comparative cost/benefit analyses.

The conclusions of the study are, in brief:

1. The 20-kHz conceptual design analyses produced a significant list of expected benefits, which suggests that further study of either a complete 20-kHz system or of selected sections and circuits would be desirable and cost-effective.
2. The all-electric trijet cost/benefit study, although carried out in a very conservative and nonoptimized fashion, revealed that there will be very valuable benefits: a weight reduction of 2,304 pounds from hardware redesign plus a 2.1-percent fuel reduction with aircraft resizing, to a total weight reduction of 11,000 pounds.
3. Cost reductions for a fleet of 800 aircraft in a 15-year production program are estimated as follows: RDT&E cost reduction of $76.71 million; $2.74 million saved per aircraft in production; $9.84 million saved in nonrecurring expenses; $120,000 per aircraft saved in product support expenses; and $300,000 saved each year in operating and maintaining each aircraft. Together, these represent a present value of $1.914 billion or a future value of $10.496 billion.

SECTION 2
INTRODUCTION

This report covers the evaluations conducted for NASA-LeRC: (1) 20-kHz electrical power distribution technology and the related conversion and control technologies applied to transport aircraft with all-electric secondary power (with no distributed hydraulic or pneumatic power, and without engine bleed air extraction), and (2) all-electric secondary power with a conventional distribution system, in response to the redirection and objectives contained in Amendment 1 to NAS3-25965.

The initial 20-kHz study is presented in Section 3 and the Redirected All-Electric Aircraft Study in Section 4. The conclusions are in Section 5 and the recommendations for future work are in Section 6.

2.1 OBJECTIVES

The objective of the original contract was to provide a realistic assessment of the strengths and weaknesses of a 20-kHz electrical power distribution system when fully integrated into a twin-engine transport aircraft. The 20-kHz system conceptual design was previously developed by NASA-LeRC and its subcontractors.

For the amended contract, the overall purpose was to provide an objective cost/benefit evaluation of an all-electric secondary power system when fully integrated into an advanced transport aircraft. The all-electric system conceptual design was to be defined by Douglas Aircraft Company. Both concepts involved redesign of a commercial transport study model from hybrid secondary power (electrical, hydraulic, and pneumatic) to a single form (electrical power) and a similar set of aircraft design criteria and guidelines to establish certifiable standards of quality for the electrical system designs.

2.2 TASK FLOW BREAKDOWN

The task flow breakdown for the original contract is shown in Figure 1. When the contract redirection was received on April 1, 1991, Work Breakdown Structure (WBS) Task 1, Detailed Plan; Task 2, Subcontractor Selections; Task 3, Criteria and Guidelines Selection; and Task 4.1.1, Aircraft Model Definition, were essentially completed. Task 4.1.2, All-Electric Load Definitions; Task 4.1.3, Power-by-Wire and Fly-by-Wire Concept Definitions; Task 4.1.4, Distributed Power System Definition; and Task 4.1.5, Electrical and Electronic Control Systems Definitions, were partially completed. These efforts were largely applicable to the amended (redirected) contract and required only review or reinterpretation for use in the final contract effort. The task flow breakdown for the redirected program is shown in Figure 2.

2.3 STUDY ASSUMPTIONS

The assumptions made for the original 20-kHz twin-jet study are shown in Table 1, while the assumptions made for the redirected trijet study are shown in Table 2. Many of these assumptions are common to both the twin-jet and the trijet study models.

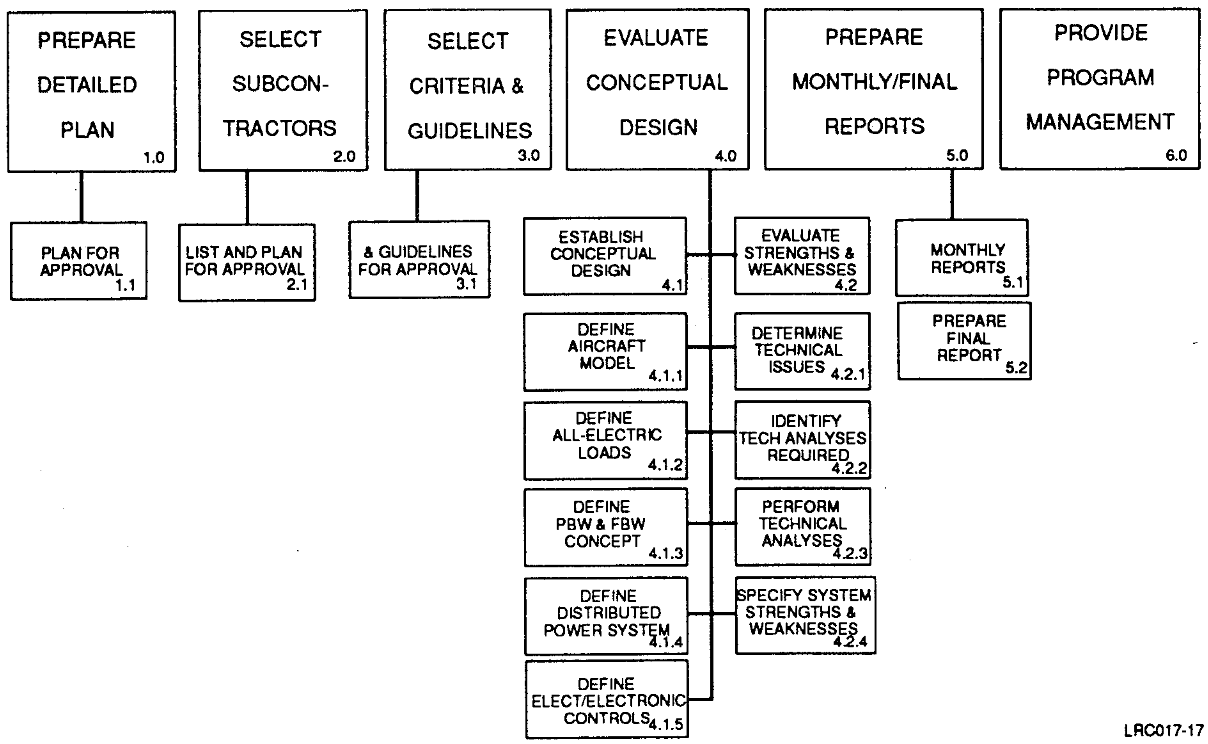


FIGURE 1. TASK FLOW BREAKDOWN

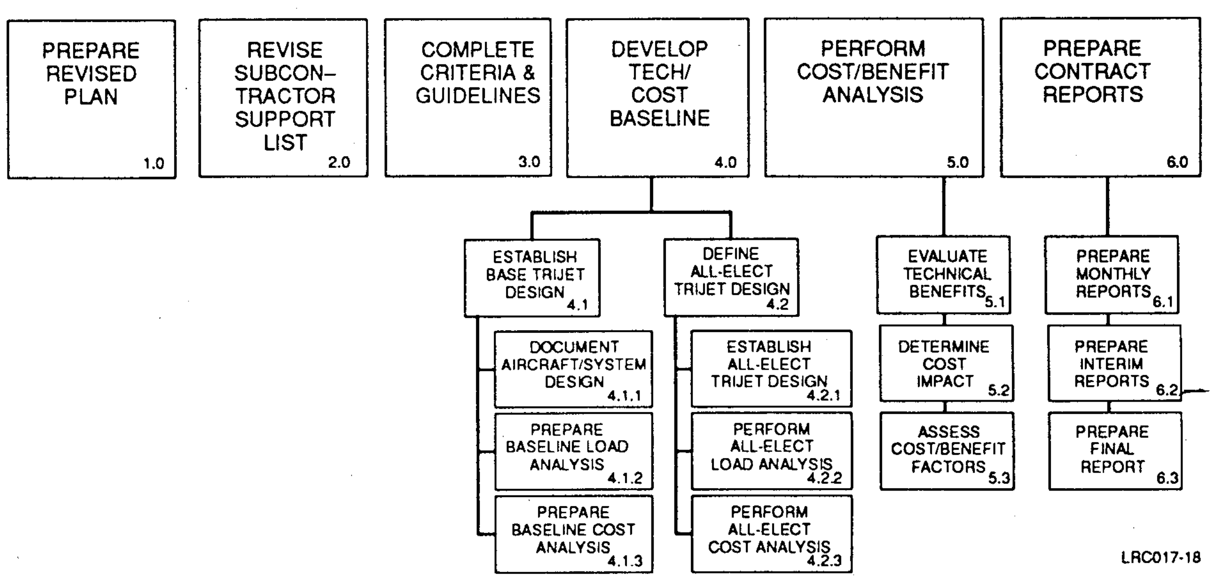


FIGURE 2. TASK FLOW BREAKDOWN FOR THE AMENDED CONTRACT

TABLE 1
STUDY ASSUMPTIONS FOR THE ORIGINAL CONTRACT

ITEM	COMMENT
ARCHITECTURE	LINKAGE WITH PAST NASA-LeRC 20-kHz PROGRAMS
MISSION AND AIRFRAME	COMMERCIAL AIRCRAFT WITH CREDIBLE/PRACTICAL/COST-EFFECTIVE APPLICATION
CERTIFICATION	STANDARD COMMERCIAL TRANSPORT DESIGN CRITERIA TO ASSURE VIABLE AND CERTIFIABLE SYSTEMS
SOURCES AND LOADS	LOADS AND 20-kHz POWER MANAGEMENT AND DISTRIBUTION ARE MUTUALLY TRANSPARENT
SECONDARY POWER	MAXIMUM USE OF 20-kHz AND RELATED TECHNOLOGY TO ELIMINATE DISTRIBUTED HYDRAULICS AND PNEUMATICS
FLIGHT CONTROLS	MAXIMUM USE OF FLY-BY-WIRE ADVANCED CONCEPTS ENHANCED BY ELIMINATION OF CENTRAL HYDRAULIC POWER
DISTRIBUTED POWER	DISTRIBUTED POWER CENTER DESIGN ENHANCES RELIABILITY WITH DUAL BUS ARCHITECTURE
AIR-CONDITIONING	VAPOR CYCLE AIR-CONDITIONING IMPROVES ENGINE EFFICIENCY BY ELIMINATING BLEED-AIR PNEUMATIC POWER
POWER CONTROL	DIGITAL RPC IS APPROPRIATE ADVANCED TECHNOLOGY FOR PBW, FBW, AND DISTRIBUTED POWER CENTERS

TABLE 2
STUDY ASSUMPTIONS FOR THE REDIRECTED CONTRACT

ITEM	COMMENT
AIRCRAFT MODEL	DOUGLAS SELECTED MD-11 COMMERCIAL TRIJET TRANSPORT
AIRCRAFT MISSION	3,000 N MI WITH FULL PASSENGER LOAD (323), STD COND
ARCHITECTURE	DERIVATIVE OF EXISTING MD-11 SECONDARY POWER SYSTEM
CERTIFICATION	ASSURANCE BY EXTENSION OF MD-11 DESIGN STANDARDS
DESIGN CRIT/GUIDELINES	DERIVED IN INITIAL PHASE OF THIS CONTRACT
SOURCES AND LOADS	ADD SOURCES/LOADS FOR ALL-ELECTRIC SECONDARY POWER
SECONDARY POWER	ELIMINATE ENGINE BLEED AIR, CENTRAL HYDRAULICS, AND PNEUMATIC POWER DISTRIBUTION
FLIGHT CONTROLS	MAXIMUM USE OF FLY-BY-WIRE ADVANCED CONCEPTS ENHANCED BY ELIMINATION OF CENTRAL HYDRAULIC POWER
DISTRIBUTED POWER	PARTIALLY DISTRIBUTED POWER CENTER DESIGN TO ENHANCE RELIABILITY
AIR-CONDITIONING	VAPOR CYCLE AIR-CONDITIONING IMPROVES ENGINE EFFICIENCY BY ELIMINATING BLEED-AIR PNEUMATIC POWER
POWER CONTROL	DIGITAL RPC IS APPROPRIATE ADVANCED TECHNOLOGY FOR PBW, FBW, AND DISTRIBUTED POWER CENTERS

2.4 APPROACH

2.4.1 Initial 20-kHz Study Approach

The approach followed for the initial study was to establish a twin-jet aircraft model for the study and then provide descriptions to define the evaluation criteria (Table 3), derived from the Statement of Work. The program drivers of the study were next determined. These were:

1. Make maximum use of electrical energy.
2. Use real transport aircraft system data for credibility.
3. Use traceable design data.
4. Assure certifiable and reliable system design.
5. Do not allow electrical energy transmission to adversely affect aircraft loads and operations.

Criteria and guidelines were then developed to measure the quality of the design effort. It should be noted that criteria are a mandatory statement ("shall be" or "must be"), while guidelines are advisory ("should be" or "may be"). The design was to be derived from MD-11 aircraft design technical specification (Reference 1). The initial list of 634 items was reduced to 156 by screening, peer review, specialists' review, and transfer of 175 design-specific items to a preliminary design requirements specification. The reviews were based on relevance to the 20-kHz all-electric design.

The data base was then organized as shown in Table 4.

TABLE 3
EVALUATION CRITERIA

ITEM	COMMENT
CERTIFIABILITY	COMPLIANCE WITH FAA REGULATION/CRITERIA/GUIDELINES
SATISFIES LOAD REQUIREMENTS	PMAD ARCHITECTURE AND SIZING FOR POWER FLOW REQUIREMENTS
DISPATCH RELIABILITY	SATISFIES AIRLINE OPERATION NEEDS
ADEQUATE REDUNDANCY	SATISFIES FO/FO/FS CRITERIA
EASE OF MAINTENANCE	REDUCES AIRLINE OPERATIONAL COST
IMPACT ON OTHER AIRCRAFT SYSTEMS	HAS NO UNFAVORABLE OPERATIONAL MODES
EFFECT ON MFG COSTS	MINIMIZES AIRCRAFT INITIAL COST
EASE OF INSTALLATION	MINIMIZES INITIAL MFG AND AIRLINE MAINTENANCE COST
SAFETY	DOMINANT DESIGN CRITERION
COST	ACQUISITION, OWNERSHIP, OPERATION, MAINTENANCE
OPERATION IN AUTOMATIC MODES	ACCEPTABLE FOR 2-PERSON FLIGHT DECK
PERFORMANCE	EFFICIENCY, REGULATION
CONTROLLABILITY	INTRODUCES NO UNUSUAL OR MARGINAL CONTROL MODES
ELECTROMECHANICAL CHARACTER	WEIGHT, FAULT TOLERANCE, INTEGRITY

Next, an objective process was developed for applying the criteria and guidelines. The focal areas were identified for objective evaluations of strength and weakness of the 20-kHz design concepts (Table 5), and locations determined for the sources and major loads. Using the 440-volt, single-phase, 20-kHz system architecture provided by NASA-LeRC, this architecture was expanded as necessary for the selected twin-jet aircraft model and design architectures were defined for the electrical power processing required to accomplish the following advanced design concepts: resonant power conversion, bidirectional power conversion/control, pulse density modulation for motor and frequency control, electrical engine-starting, and 1-phase transmission and phase-control for voltage regulation.

TABLE 4
STRENGTH AND WEAKNESS DATA BASE

SUBJECT	NO. CRITERIA/GUIDELINES
INSTALLATION	37
PERFORMANCE	17
REDUNDANCY	17
PROTECTION	14
CREW INTERFACE	13
MAINTENANCE	10
RELIABILITY	8
EMERGENCY PROVISIONS	7
CERTIFIABILITY	6
FAULT-TOLERANCE	6
OTHER SYS IMPACT	6
LOGISTICS	5
LOADS	4
OWNERSHIP COST	3
VALIDATION	2
COST, MANUFACTURER	1

TABLE 5
STRENGTH AND WEAKNESS ASSESSMENT

ITEM	COMMENT
DISTRIBUTION	DISTRIBUTION DESIGN PHILOSOPHY
ENGINE START	POWER FLOW AND SEQUENCING USED FOR ENGINE-STARTING
MOTORS	MOTOR LOAD CONTROL
FAILURE PROTECTION	PRIMARY PROTECTION USING LOAD CONTROLLERS
SYSTEM RECONFIGURATION	USE OF POWER INTERRUPT FOR SECONDARY FAILURE PROTECTION AND SYSTEM RECONFIGURATION
GENERATION AND CONTROL	METHOD OF PRIMARY GENERATION AND CONTROL
VOLTAGE REGULATION	METHOD OF VOLTAGE REGULATION ON MAIN DISTRIBUTION BUS
LOAD SHEDDING	METHOD OF LOAD SHEDDING

2.4.2 All-Electric Power System Study Approach

The approach taken for the redirected study was: (1) prepare a revised detailed study plan; (2) review the initial subcontractor support list; (3) review and confirm the criteria and guidelines list; (4) establish an objective process for applying the criteria and guidelines to evaluate the quality of the all-electric design; (5) establish an aircraft model for the revised study; (6) develop a baseline design using a well-established, firm data base; (7) determine locations for the electrical power sources, electrical power centers, and major loads in the new study model; (8) develop an integrated electrical system architecture for the all-electric aircraft; (9) redesign the modules which now use hydraulic or pneumatic power in order to use electrical power with equal or greater reliability; (10) determine the weights and weight changes for the new designs; (11) resize the aircraft to take advantage of reduced weight and fuel; (12) determine the electrical loading imposed by the new loads; (13) develop the new cost and performance values for the all-electric aircraft design and the resized all-electric aircraft; (14) identify the benefits which will accrue to the all-electric design relative to the conventional hybrid secondary power system design; and (15) develop the cost/benefit analyses and values relative to the aircraft manufacturer and the airline operator.

2.5 PROGRAM SCOPE AND SCHEDULE

The program scope and schedule are summarized in Figure 3. The detailed schedules and tasks are shown in Appendix A.

The original contract was dated October 9, 1990, with work to commence on October 29 and to be completed by July 1, 1991.

The scope of work was changed by Amendment No. 1, dated March 20, 1991, with the revised work to start on April 1, 1991. This was to be completed by October 1, 1991. The scope of work was changed to provide new designs, analyses, and data needed by NASA to evaluate the cost and benefits of an all-electric aircraft. These data were to be based upon conventional three-phase 400-Hz electrical power distribution rather than single-phase 20-kHz electrical power distribution. In addition, the effort was to be based upon a "hard" data base derived from a Douglas state-of-the-art certified aircraft.

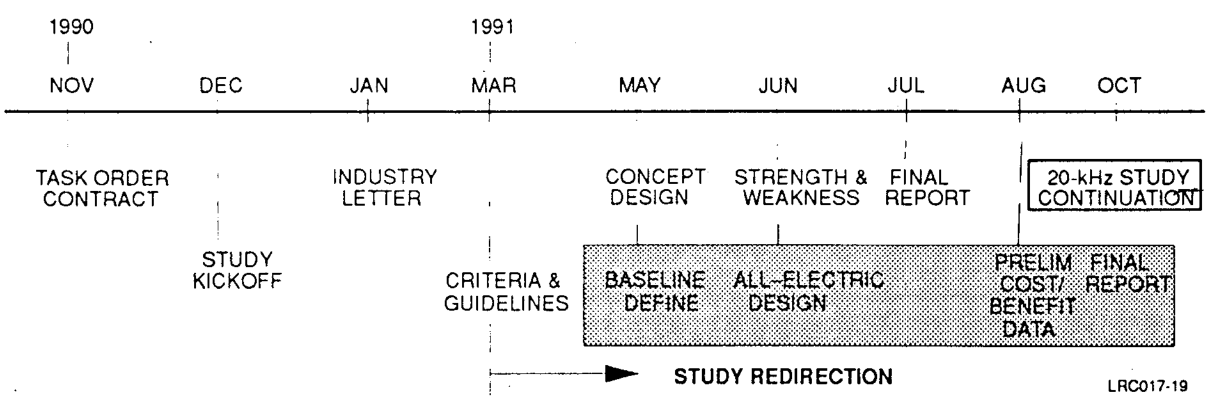


FIGURE 3. STUDY MILESTONES

SECTION 3
INITIAL 20 kHz STUDY

This section describes the work performed; the designs, data, and evaluations; the conclusions, and the expected benefits of a preliminary study of an advanced twin-jet air transport with 20-kHz electrical power distribution and many advanced-technology concepts.

3.1 SUBCONTRACTOR SELECTION

Industry support was considered essential in creating a viable all-electric 20-kHz aircraft study model. Aerospace companies and academic institutions associated with electrical power systems and, especially, 20-kHz technology were contacted. Power system specialists were identified by reviewing the roster and personally contacting other power system specialists. Fifty-nine individuals were contacted and asked to provide data and commentary in exchange for sharing the 20-kHz study results. After eliminating multiple points of contact within the same company and those unable to support the study, the list was reduced to 18 individuals who agreed to apply their expertise to the study. Table 6 shows those who were willing to participate in the study. The original mailing list and the letter requesting participation in the 20-kHz study are provided in Appendix B.

3.2 CRITERIA AND GUIDELINES SELECTION

The design criteria and guidelines were derived from the MD-11 aircraft design technical specification (Reference 1), supplemented by items provided by the study technical staff. The initial list included 634 items arranged by subject and topic, which were placed in a comprehensive data base. These items were screened to eliminate duplications, redundancies, and data that had insufficient relevance or value to the 20-kHz study. Design-specific items were then removed from the remaining 331 items and these were placed in a preliminary design requirements specification. The screening was performed by specialists within Douglas, and then reviewed by the unfunded subcontractors who responded to the Douglas request letter. The remaining list consisted of 156 items, organized by 16 subjects. This final list and the design requirements specification are presented in Appendix C. The list was selected for relevance to the 20-kHz technology, but after the design-specific items were removed, the remaining items were found to be virtually unaffected by the selected type of electrical system, and then could be used for the redirected program with conventional 400-Hz electrical power distribution.

3.3 SYSTEM EVALUATION APPROACH

The method established for system and design evaluation was outlined in the Statement of Work for this program, which is included in Appendix C. This evaluation was an item-by-item assessment based upon how well the system design would meet the criterion or the design guideline. A numerical grading would be given by each evaluator and the results would be accumulated into a composite score. The evaluators were to be the study staff members, peer group specialists, outside support subcontractors, and FAA-Designated Engineering Representatives (DERs). Later, by NASA request, a list of airline engineering managers was solicited. The review process was further refined, as shown in Appendix C. Since this evaluation had not been performed by the time of contract redirection, it was postponed for application to the all-electric design study.

3.4 BASELINE AIRCRAFT CONFIGURATION

The baseline aircraft used for this study was a 192-passenger twin jet. The features of the baseline model are shown in Figure 4. The twin-jet aircraft has two aisles with two-class seating, five-abreast

TABLE 6
VOLUNTARY SUPPORTING COMPANIES

COMPANY	DIVISION	CITY AND STATE	NAME	TITLE
AMP INC.	ADVANCED DEVELOPMENT LABS	PHOENIX, AZ	E. R. KREINBERG	SR. DEV ENGR
ANALYTICAL ENGG CORP.		N. OLMSTEAD, OH	DR. A. GORDAN	SR. ENGR
GENERAL ELECTRIC CO.	AEROSPACE DIVISION	BINGHAMTON, NY	R. VAN NOCKER	SR SYSTEM ENGR
INVERTACON CORP	POWER REX ASSOC.	TEMPE, AZ	E. R. WRIGHT, JR	GEN MGR
LEACH CORP.	LEACH POWER MANAGEMENT	BUENA PARK, CA	F. TOFIGH	PROJECT MGR
LUCAS AEROSPACE	POWER EQUIPMENT CORP.	AURORA, OH	F. HEUSER	PRODUCT MGR
MCDONNELL DOUGLAS (MDEC)	ELECTRONIC SYSTEMS CO.	ST. CHARLES, MO	E. J. SCHULZE	LEAD ENGR ELECTRONICS
PARKER HANNIFIN AEROSPACE	PARKER BERTEA AEROSPACE	IRVINE, CA	G. NELSON	REGIONAL MGR
TEXAS INSTRUMENTS, INC.	CONTROL PRODUCTS DIV.	ATTLEBORO, MA	J. M. McCORMICK	PRODUCT SPECIALIST
TRW, INC.	SPACE/TECH PWR SYS INTEG	REDONDO BEACH, CA	K. DECKER	STAFF ENGINEER
UNIVERSITY OF WISCONSIN	ELECTRICAL ENGG DEPT	MADISON, WI	T. LIPO	PROFESSOR
WESTINGHOUSE ELECTRIC CORP.	ELECTRICAL SYSTEMS	LIMA, OH	T. J. VALLO	–
SIMMONDS PRECISION PRODUCTS	–	GOLETA, CA	A. WILLIAMS	–
SUNDSTRAND CORP.	ADVANCED TECHNOLOGY GROUP	ROCKFORD, IL	G. SMITH	–
B.F. GOODRICH	FORMERLY SIMMONDS PRECISION	VISTA, CA	R. JOHNSON	PRODUCT APP MGR
KILOVAC CORP.	–	SANTA BARBARA, CA	R. T. WAUGANAN	SR. PRODUCT MKTG MGR
RAYCHEM CORP.		NEWPORT BEACH, CA	B. ERICKSON	MGR
EATON CORP. OF FLORIDA	AEROSPACE & COMM CTRL	SARASOTA, FL	D. M. BEAUCHAINE	MKTG MGR

in first class and seven-abreast in coach. The maximum takeoff gross weight (MTOGW) is 180,000 pounds. The aircraft systems and their functions are presented in Table 7. The particular twin-jet configuration was mandated by NASA in order to maintain baseline commonality with previous all-electric aircraft studies (Reference 2).

Aircraft size, engine thrust, payload, and performance for the baseline aircraft model were developed by Douglas for the new commercial MD-XX program.

ENGINE	TYPE – STSP43–2A THRUST – 23,200 LB	
PERFORMANCE	RANGE – 3,000 N MI TAKEOFF FIELD LENGTH – 7,100 FT LANDING SPEED – 126 KNOTS	
SIZE	WING AREA – 1,400 FT^2 WING SPAN/FUSELAGE LENGTH/DIAMETER – 130/152/16 FT	
PAYLOAD/FUEL	MTOGW – 180,000 LB MLW – 162,000 LB MZFW – 153,000 LB OEW – 104,400 LB	FUEL CAPACITY – 63,800 LB PASSENGER PAYLOAD – 38,400 LB PASSENGERS – 192 CARGO VOLUME – 1,680 FT^3

LRC017-1

FIGURE 4. BASELINE TWIN-JET FEATURES

TABLE 7
AIRCRAFT SYSTEMS

PRIMARY	
TYPE	**FUNCTION**
SECONDARY POWER	ELECTRICAL, MECHANICAL, PNEUMATIC
FLIGHT CONTROL	FLY-BY-WIRE/LIGHT SURFACE CONTROL
ENVIRONMENTAL	AIR PRESSURE/CONDITION, LIGHTING, DE-/ANTI-ICING
LANDING GEAR	EXTEND/RETRACT, STEERING, BRAKING
ENGINE SUBSYSTEMS	ENGINE START, FUEL MANAGEMENT, PROPULSION CONTROL
SECONDARY	
TYPE	**FUNCTION**
CREW SYSTEMS	DISPLAY AND CONTROL
RADIATING SYSTEMS	EMI/EMC, HIGH-ENERGY RADIATION FIELD
SUPPORTING TECHNOLOGIES	RELIABILITY, SAFETY, COST, PRODUCTION/MANUFACTURING, INSTALLATION
FIBER-OPTICS/PHOTONICS	OPTICAL SENSORS, CONVERSION, AND DATA LINKS

3.5 ELECTRICAL POWER SOURCES AND MAJOR LOAD LOCATIONS

Initially, the all-electric aircraft study focused on establishing conceptual 20-kHz electrical designs for secondary power functions currently provided by hydraulic fluids, pneumatic (air) cycles, or mechanical subsystems. The major electric power sources and the flight control, environmental control, and landing gear electrical load locations are shown in Figure 5 for the twin-jet baseline.

The electrical power system uses four 150-kva generators, two on each engine, with each generator sending power to separate dedicated power centers near the wing root. Each power center contains a power converter and the necessary switching and protection components for managing the generators and for connecting the generators to the dual 20-kHz distribution buses. Each center also distributes power to equipment in the wing and center fuselage areas. Four additional centers, two in the nose area and two in the empennage area, distribute power to equipment in the forward and aft fuselage areas. The eight load centers are networked together by the 440-volt, single-phase, 20-kHz power distribution and tie buses. Bus fault isolators and relays in the power centers enable any equipment to receive power from any generator, yet provide a highly fault-tolerant power distribution system.

The major electrical components for converting the hydraulic and pneumatic powered functions to electrically powered functions are also shown in Figure 5. The two vapor cycle units and four electric heaters are slightly aft of the nose area. The cabin air recirculation fans are shown along the left side of the aircraft. The landing gear is configured to operate using conventional hydraulic

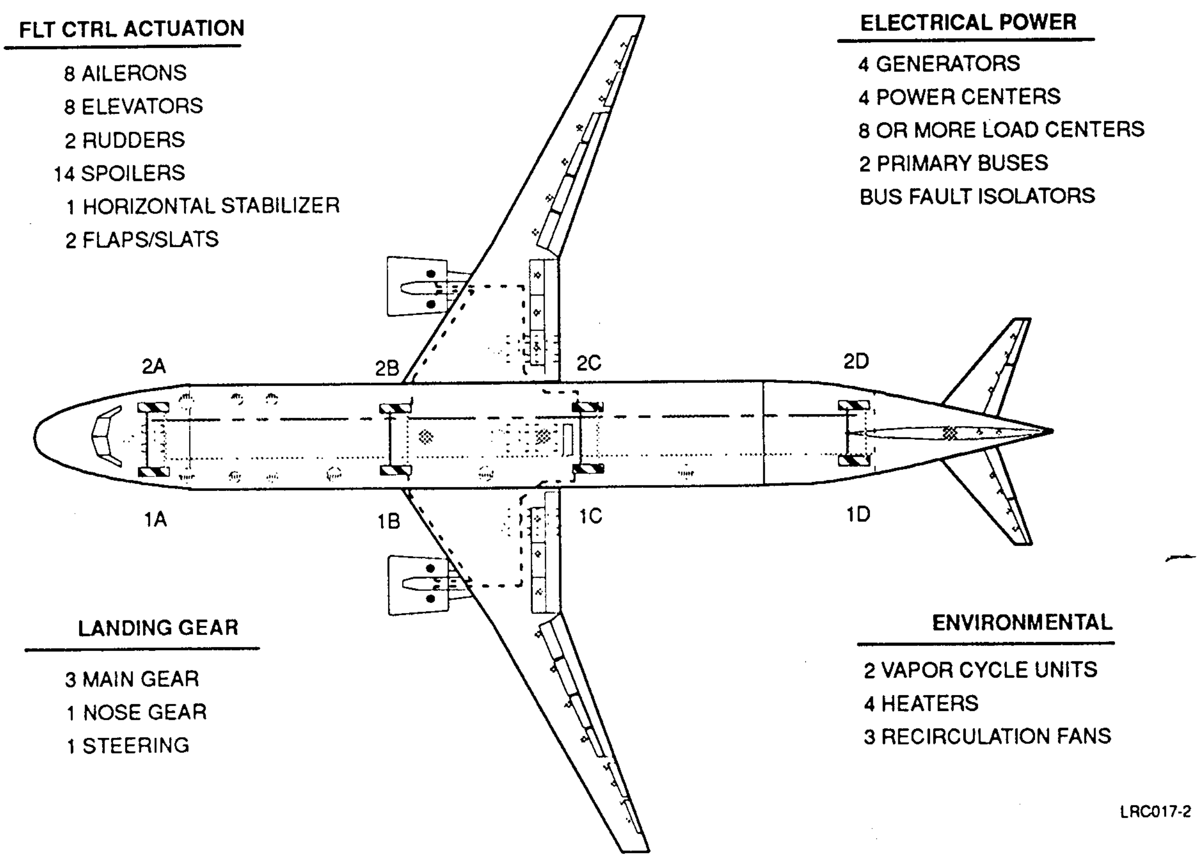


FIGURE 5. BASELINE TWIN-JET EQUIPMENT LOCATIONS

components powered by five electrically driven hydraulic pumps, three in the main gear area and two in the nose gear area. Flight control surface actuation is accomplished with a combination of electrically powered servo pump actuators (ESPAs), electromechanical actuators (EMAs), and electrohydraulic actuators (EHA). Eighteen ESPAs, two per aileron, two per elevator, and one per rudder, are used for primary flight control. Fourteen EMAs are used for spoiler control. One dual EHA is used for horizontal stabilizer control and two EHAs are used to drive torque tubes for extending and retracting the flaps and slats.

The aircraft secondary power system configuration described in this section represents the extent of definition reached for an all-electric 20-kHz twin jet at the time of NASA's contract redirection. Some of the system changes made during the cost/benefit study should also be incorporated into future 20-kHz twin-jet studies. For example, the torque tubes for slat and flap actuation were deleted and individual actuators were used to power each slat and flap surface independently. These refinements, as well as others yet to be fully defined, should be incorporated into future all-electric studies.

3.6 20-kHz ELECTRICAL POWER SYSTEM ARCHITECTURE

The electrical power system architecture for the 20-kHz system study, provided by NASA-LeRC, is shown in Figure 6. Douglas modified this architecture to provide solid-state bus controllers (BCs) and bus interrupters (BIs), as shown in Figure 7. Because current switching and interruption requirements are very high (up to 400 amperes at 440 volts, single-phase, 20 kHz) and total main bus isolation is very desirable, the BIs and BCs may be designed as hybrid switches with remote control. This concept uses electromagnetic power relays in parallel and in series with solid-state

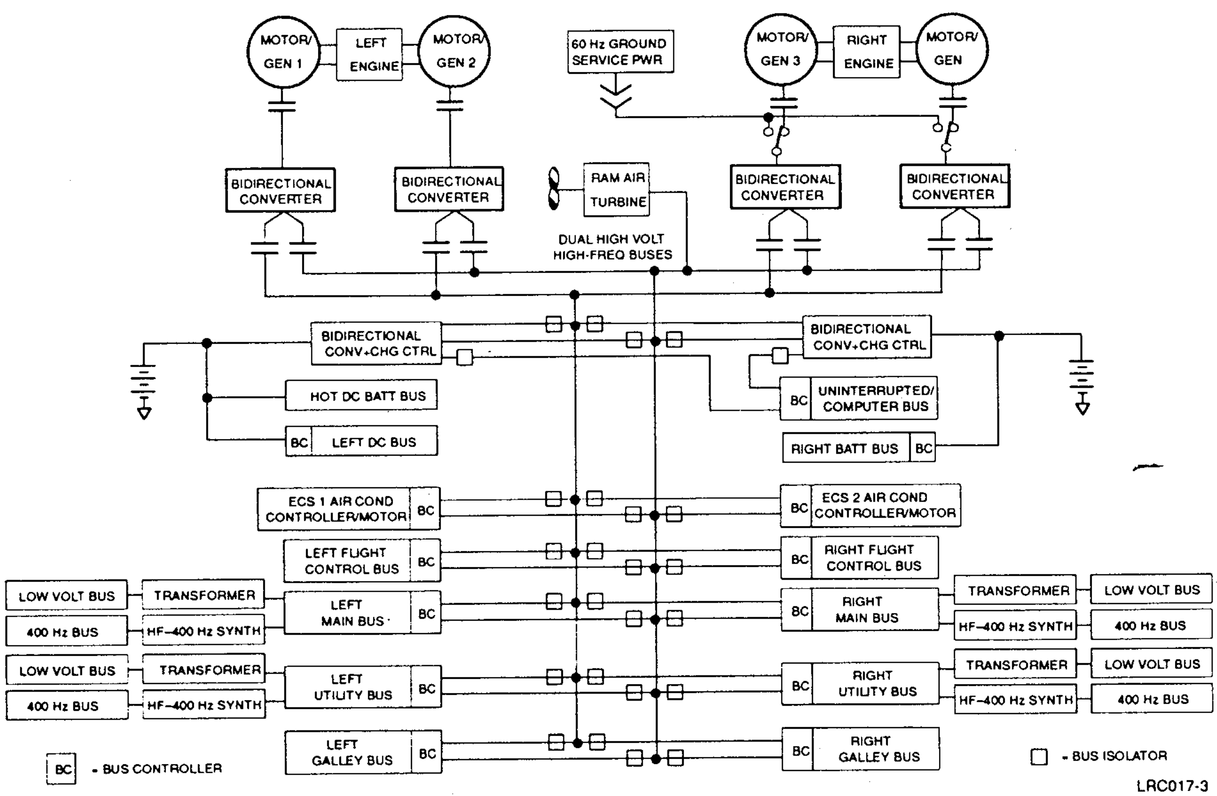


FIGURE 6. NASA-PROVIDED 20-kHz ARCHITECTURE

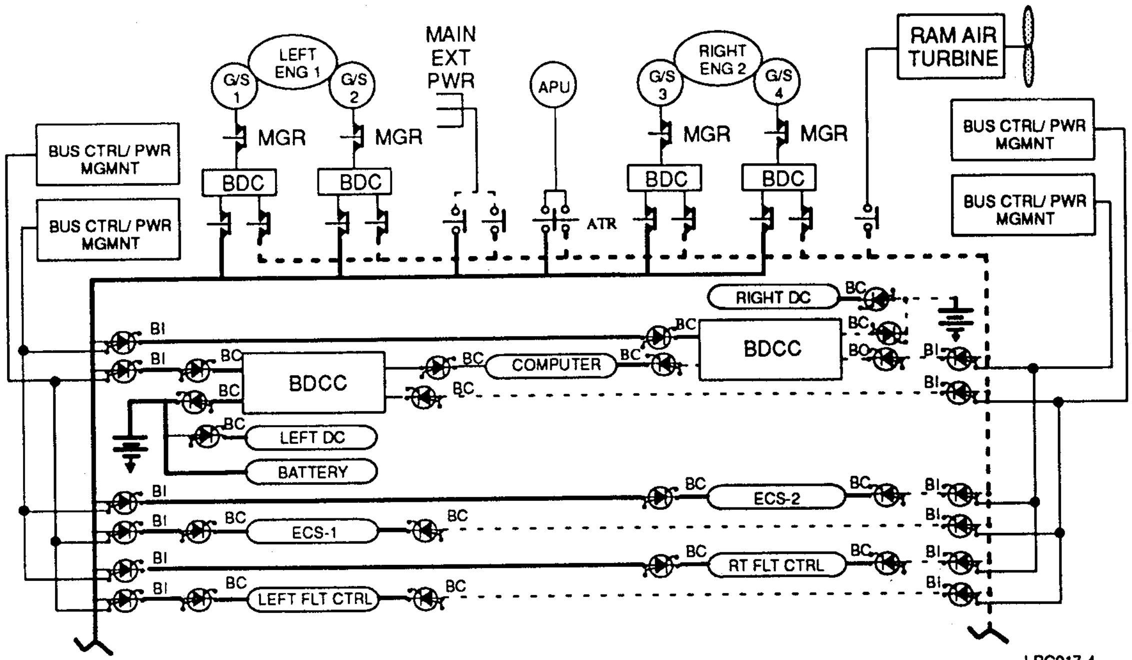


FIGURE 7. 20-kHz POWER DISTRIBUTION

remote power controllers (RPCs) in a time-integrated, sequenced mode of operation. The RPC would carry high current for a very short time, just long enough for the paralleled power relay to close on energizing the circuit or to open on de-energizing the circuit, both operations with only about a 1.2-volt drop across the contacts. Although the series power relay is not required for this dynamic BC operation, it would serve to totally isolate the circuit from RPC leakage voltage and current. Both the power relays do not need to be rated for full-circuit current interruption, but only for full current-carrying capacity; yet, as a backup interruption mode, the series unit (BI) might be fully rated for bus interruption current capacity.

The bidirectional converters shown in Figures 6 and 7 use the 20-kHz configuration originated by NASA-LeRC in prior study programs (Reference 2) in which a Mapham design of resonant converter supplies the load circuit in a voltage-fed mode across the series resonant capacitor. The output of the generators would be "wild frequency" in a 2-to-1 range, perhaps up to 1,800 Hz. The frequency was not selected during this study, but it would be based upon a balance between minimum weight, maximum efficiency (considering windage, friction, magnetization, and other electrical losses), mechanical winding stability, and maximum bearing life projections. The bidirectional converter would be supplied by moderately high voltage direct current (perhaps 270 vdc) derived from in-line full-wave rectifiers. This type of converter with high-frequency rectification results in electromagnetic compatibility issues, as described in Appendix D.

The bidirectional converter design permits full four-quadrant electrical phase-controlled operation. Power can flow to the generators from the main transmission system, thereby supplying the power at controlled frequency and proportional voltage to the generators to operate them as variable-speed, high-torque motors for engine-starting. Several converter architectures are possible to provide the bidirectional power control function, with phase, frequency, voltage, and power-directional control. Concepts for the preliminary design assessment are discussed further in Section 3.7. In-depth study was postponed by NASA-LeRC for budgetary reasons. There is no technical obstacle to this concept, and NASA has previously funded major studies on the subject. Similarly, the pulse density modulation (PDM) approach to providing variable-frequency and proportional variable-voltage power from a 20-kHz single-phase transmission bus is well defined and well understood from prior studies funded by NASA-LeRC. These techniques would be used for the 400-Hz loads where the high-frequency to 400-Hz synthesizer is labeled in Figure 6 as HF-400HZ SYNTH.

The bidirectional converter and charge controller (BDCC) modules shown in Figures 6 and 7 would rectify 20-kHz power to direct current after transformation to the proper voltage for battery charging. It would also produce 20-kHz power by series resonance from the batteries for emergency power to the computers and/or special ac emergency loads. The BDCCs would also provide controlled normal power to the computers and to the left and right dc buses. The bus control and power management modules are quadruply redundant. These would use digital data buses to the BCs and BIs for control and to sense their operational status.

3.7 ELECTRICAL POWER PROCESSING CONCEPTS

The advanced design concepts listed in Section 2.4.1 are implemented in the proposed conceptual 20-kHz designs. The key 20-kHz components are shown in Figure 8. The form of the electrical power is shown for each modular interface to present a clear picture of the power-processing functions performed. In the normal operating mode, the generator provides three-phase power at engine

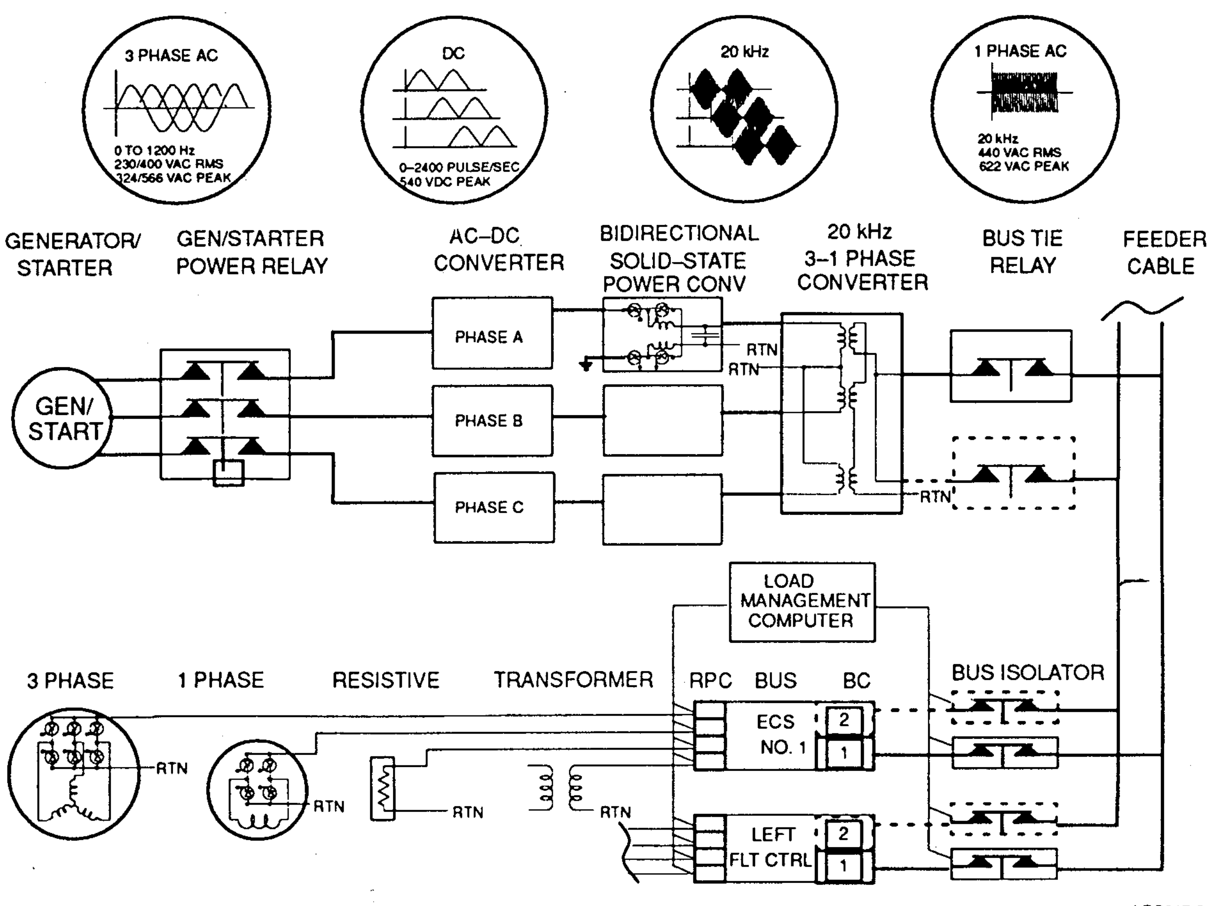


FIGURE 8. KEY 20-kHz COMPONENTS

idle speed at a frequency up to 1,200 Hz, as shown, or perhaps up to 1,800 Hz. The voltage is suggested to be 230/400 volts at the converter input and 240/416 volts at the alternator (generator) terminals in order to reduce generator feeder weight to the converters, which may be located in the wing root area or the wheel well area, with access to fuel and ram air for cooling. Each phase is next separately rectified, then converted to a single-phase, 20-kHz, 440-volt wave in the bidirectional solid-state resonant power converters. The relative time-phase angles of these three 20-kHz waves are 120 electrical degrees apart. One phase is then reversed in a three-phase to single-phase transformer and the three phases are added vectorially to form single-phase, 440-volt, 20-kHz output for the transmission buses. The output voltage can be regulated by changing the switching phase control of the solid-state switches in the bidirectional solid-state power converter module.

Two power transmission feeder cables are shown in Figure 8, with a bus tie power relay to connect the 440-volt, single-phase, 20-kHz output of the converter to the feeders for transmission of electrical power to the power distribution centers. A preliminary technical investigation of the characteristics of 20-kHz distribution cables was performed by Bilinear Technologies, Inc. (BTI) under subcontract. The study results are in the final report on Agreement for Services AS-25529-C, prepared by Dr. Ken James of Bilinear Technologies, Inc. This report is presented in Appendix E. The study covered two major areas of research: an analysis of the change from 400-Hz to 20-kHz power distribution, and an initial effort to model and synthesize a power converter to change from direct current to 20 kHz.

Some conclusions of the transmission line study are given in the following text. Others are provided in Appendix E.

1. An electromagnetic shield is very effective and must be provided to reduce electromagnetic interference (EMI) and to improve the operating characteristics of the transmission line. Even if it is very thin and lightweight, it can be very effective. A braided metal shield is recommended to provide greater physical flexibility and ease of installation.
2. Fuselage current return is not an acceptable design for high-frequency transmission energy, and a more controlled and confined path is required to reduce EMI, to reduce line impedance, and to improve electrical performance. A two-wire shielded design is preferred as a basis for the transmission line model. A coaxial design or a stack of braided strap conductors has been recommended in past studies. These are actually physical variants of the shielded two-wire design, which was retained for its ease of modeling and analysis.
3. Three-phase transmission was considered impractical at 20 kHz, although it can be generated by electronic converters. This is largely because phase load balance and identical characteristics would be very difficult to achieve over a significant power transmission distance, and the residual current in the neutral or ground conductor could become excessive.
4. A shield around the twin wire conductors reduces the characteristic impedance, Z_c or Z_o, and increases the surge impedance loading, or power which can be propagated in the transmission line.
5. The power which can be transmitted is equal to the vector line voltage squared, then divided by the vector characteristic impedance. However, not all the power accepted by the line will appear at the load or receiving end of the line because shunt capacitance will allow power to be shunted to the return wire, the shield, or both.
6. Making the wire conductor radius larger reduces both series resistance and Z_c, as shown in Appendix E, while making the shield inner diameter larger increases Z_c because the shunt

capacitance is reduced. The latter is a mixed benefit because it also reduces the maximum power capability. Separating the wires in the shield has very little effect on the value of Z_c. The shield consistently lowers the values of Z_c below those for unshielded transmission lines.

It is recommended that shielding be used for any two-wire configuration, but of sufficient inside diameter so as to avoid increasing the shunt capacitance and thus causing shunt current to flow which does not provide power to the electrical loads. Thin strip conductors are preferable to round conductors because of their lower inductance and resistance characteristics.

The bus isolators are shown in Figure 8 in a typical connection to two types of loads, environmental control and flight control, through bus controllers. The individual loads and the branch circuits which supply them are controlled and protected by remote power controllers (RPCs). These RPCs are under control of the load management computer by means of dual digital and status indication circuits. This conceptual design will later be used to permit full-time active load management and load leveling techniques to minimize the peak power loading in accordance with the generator power available at any given time. Four typical load types are shown: (1) a three-phase converter to derive three-phase PDM-synthesized frequency and proportional voltage for motors or for three-phase transformers to supply lower-voltage, lower-frequency three-phase loads or load buses, (2) a single-phase converter to derive single-phase, full-wave, PDM-synthesized frequency and proportional voltage for single-phase power at variable or reduced frequency (e.g., 400-Hz single-phase), (3) resistive 20-kHz heaters or other resistance loads, and (4) a lightweight transformer to convert voltage for 20-kHz, single-phase, low-voltage loads such as lighting loads.

Figure 9 shows the bidirectional converter in block diagram form. The same power processing channel is used as in Figure 8, but control modules have been added. A central processing unit (CPU) provides operational control functions. Random-access memory (RAM) and read-only

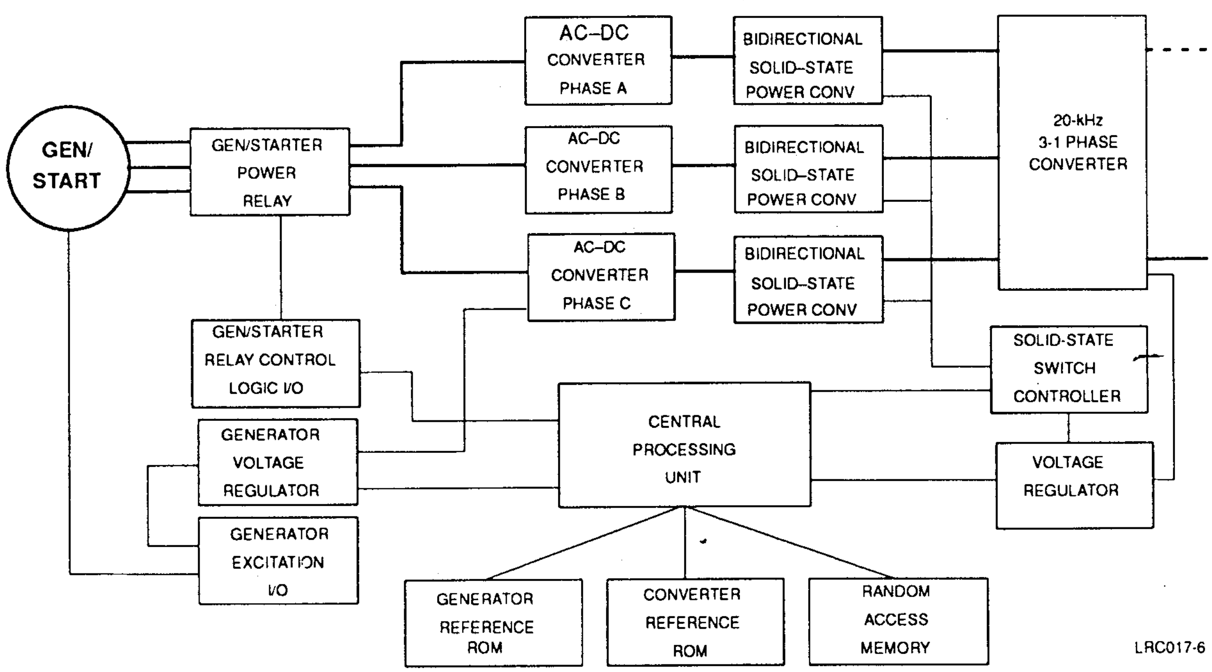


FIGURE 9. BIDIRECTIONAL CONVERTER

memory (ROM) modules are included, with control reference data for both the generator and the converter. The output voltage is sensed and compared with the stored voltage reference in the voltage regulator module. The resulting error signal is used to modulate the solid-state switch controller to vary the time-phase signals to switches in the three channel converters. When added vectorially in the three-to-one phase converter, the total output voltage can be varied from zero to three times the phase voltage (220 volts), giving a range from zero to 660 volts at 20 kHz, single-phase, with a normal line voltage of 440 volts, single-phase, two-wire circuit. Shielding and filtering are provided as determined necessary for EMI control to protect other aircraft systems.

The voltage input to the ac-dc converter set is sensed and compared with the reference voltage in the generator voltage regulator. The error signal produced drives the generator excitation I/O to control the excitation to the generator/starter, which then determines the generator output voltage. The CPU also controls the generator/starter power relay to energize or de-energize the channel converters. In addition, a channel differential protection system loop will operate to trip the generator/starter power relay in the event of a fault in the channel feeder.

3.8 POWER-BY-WIRE/FLY-BY-LIGHT FLIGHT CONTROL SYSTEMS

The conceptual system architecture is shown in Figure 10 for the two-channel configuration for a future power-by-wire/fly-by-light flight control system. Two starter/generators are driven by each engine to provide one power system channel. The two channels can be cross-tied to provide for

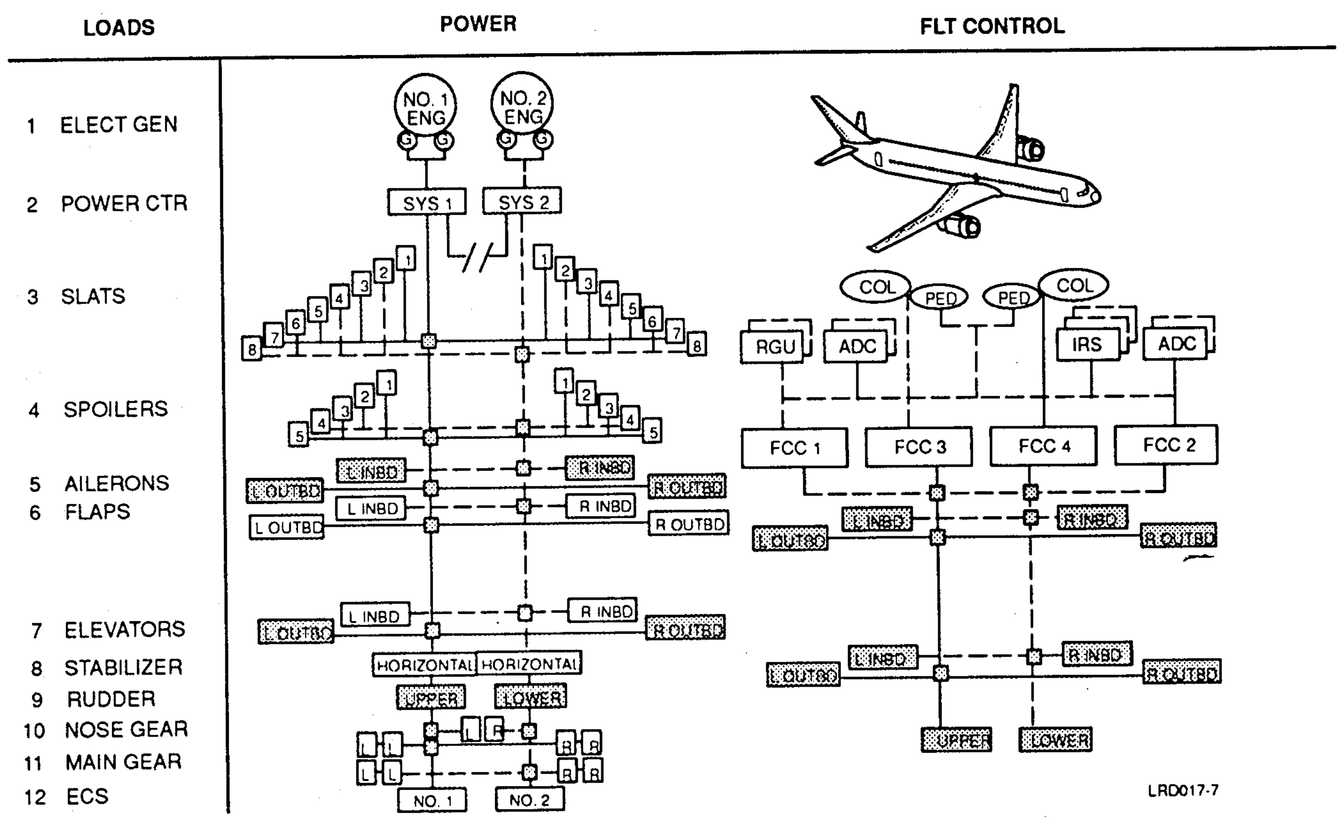
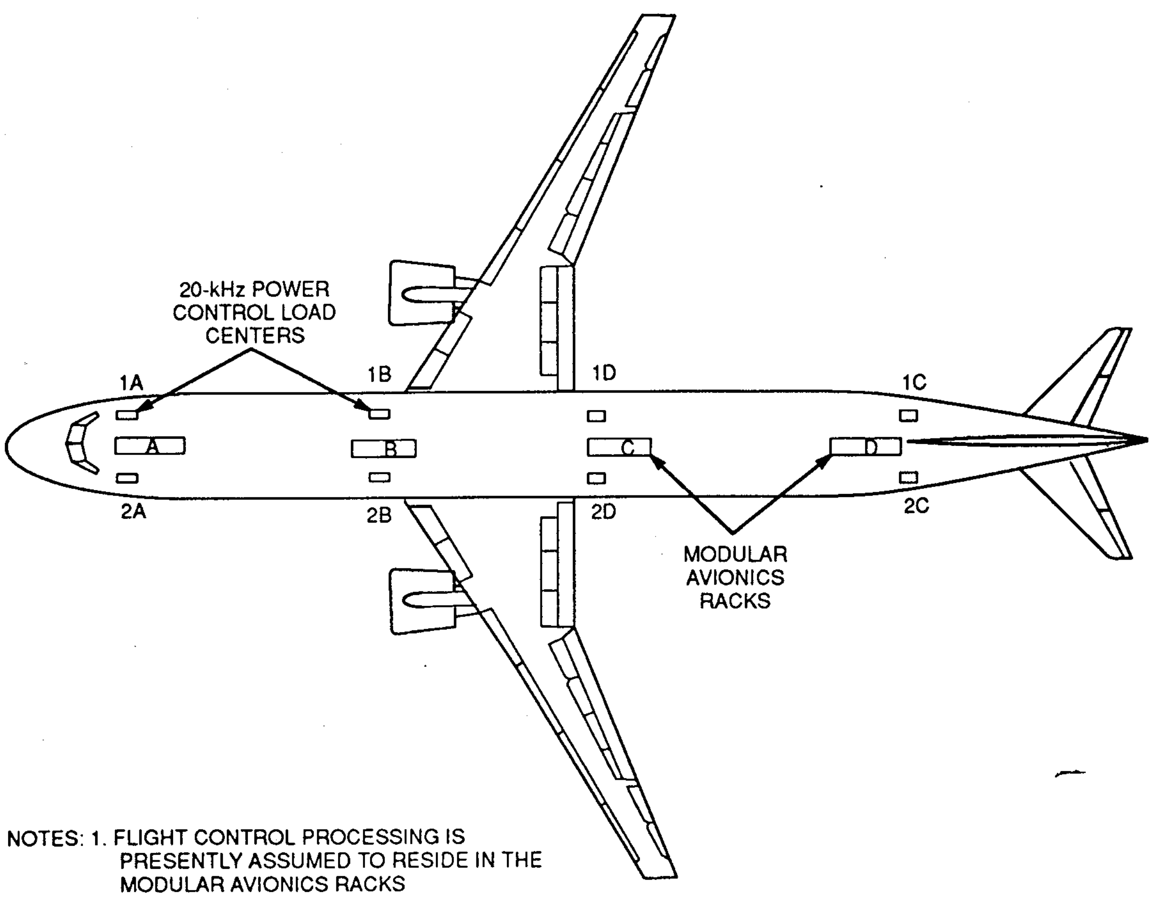


FIGURE 10. FUTURE TWIN-JET POWER-BY-WIRE/FLY-BY-LIGHT SYSTEMS

either backup or parallel operating modes. As shown in the figure, the loads are supplied in a manner that provides the most redundant control modes and minimizes the loss of function and performance from interruption of one channel. This concept provides an electrical equivalent of the existing hydraulically powered flight control systems.

Further information developed on fly-by-light and fly-by-wire systems during the all-electric trijet study is presented in Section 4.5.2.

Preliminary conceptual designs for modular avionics and power control racks and their locations are shown in Figures 11 and 12, with modules for flight control surface actuators. Table 8 lists the number of actuators and flight surface segments, the functions of the surface segments, and the flight phases during which the segments are active. Figure 13 shows 32 modules: each is 2 inches wide, for a total width of 64 inches, and each is 7.64 inches high and 12.52 inches deep.



NOTES: 1. FLIGHT CONTROL PROCESSING IS PRESENTLY ASSUMED TO RESIDE IN THE MODULAR AVIONICS RACKS

2. THE MODULAR AVIONICS RACKS AND 20-kHz POWER CONTROL RACKS ARE SHOWN SEPARATELY FOR DIFFERENTIATION OF FUNCTIONS AND REDUNDANCY, NOT NECESSARILY PHYSICAL IMPLEMENTATION

FIGURE 11. 20-kHz MODULAR AVIONICS AND POWER CONTROL RACKS

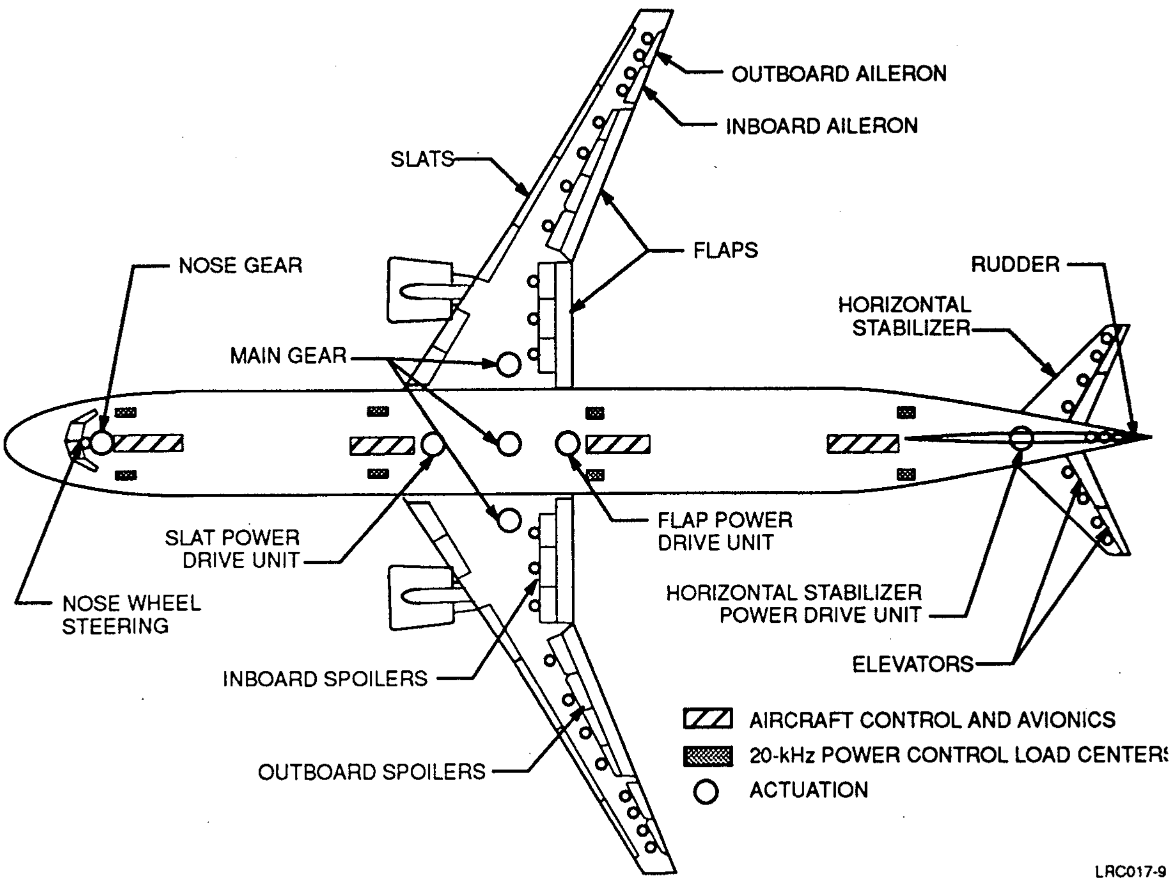


FIGURE 12. 20-kHz CONTROL AND POWER ACTUATION LOCATIONS

3.9 ENVIRONMENTAL SYSTEMS

The environmental systems include the cabin pressurization, ventilation, cooling, and heating systems. These are major systems that are presently supplied by pneumatic power derived from the engine bleed air taps. The pneumatic system is also the normal energy source for the de-icing/anti-icing systems, the leading edges of the wings, the horizontal stabilizers, and the engine nacelle inlet ducts.

The all-electric aircraft design uses electrical power for all of these systems except for engine inlet anti-icing which, due to its proximity to the engine heat source and its small energy demand, would be powered by a limited amount of engine bleed air. In the General Electric engine, the thrust reversers are also operated by bleed air, and this design would be retained for the same reasons. In addition, the reversers are used infrequently and only after landing.

The baseline design for the 20-kHz study aircraft was the MD-XX twin transport now in advanced design. A design assessment was made of the MD-XX air-conditioning and pressurization systems. A summary of these redesigned systems, a conceptual system schematic, and estimates of the airflow requirements for these systems are shown in Figure 14.

TABLE 8
ACTUATION FOR MAJOR FLIGHT PHASES

CONTROL/SURFACES	NO. ACTUATORS TOTAL	NO. SEGMENTS	FUNCTION	MAJOR FLIGHT PHASES*
PRIMARY			ROLL, WLA	ALL (EXCEPT TAXI)
AILERONS	8	4	ROLL, WLA	ALL (EXCEPT TAXI)
LOW-SPEED (OUTBOARD)	4	2	ROLL	TAKEOFF, CLIMB, LANDING, GO-AROUND, DESCENT APPROACH
ALL-SPEED (INBOARD)	4	2	ROLL, WLA	ALL (EXCEPT TAXI)
ELEVATORS	8	4	PITCH, WLA	ALL (EXCEPT TAXI)
RUDDER	3	1	YAW, YAW DAMPER	ALL (EXCEPT TAXI)
SPOILERS	14	14	ROLL, WLA, SPEEDBRAKE	ALL (EXCEPT TAXI)
OUTBOARD	8	8	ROLL, WLA, SPEEDBRAKE	ALL (EXCEPT TAXI)
INBOARD	6	6	SPEEDBRAKE, GROUND	ALL (EXCEPT TAXI)
HORIZONTAL STABILIZER	1 MOTOR	1	PITCH TRIM, PITCH	ALL (EXCEPT TAXI)
SECONDARY	4 MOTORS	16	HIGH LIFT	TAKEOFF, CLIMB, LANDING, GO-AROUND, APPROACH
FLAPS (TORQUE TUBE DRIVE)	2 MOTORS	4	HIGH LIFT	TAKEOFF, CLIMB, LANDING, GO-AROUND, APPROACH
SLATS (TORQUE TUBE DRIVE)	2 MOTORS	12	HIGH LIFT	TAKEOFF, CLIMB, LANDING, GO-AROUND, APPROACH
NOSEWHEEL STEERING	1 SET	—	GROUND STEERING	TAXI, TAKEOFF
LANDING GEAR	4 SETS	—	LANDING GEAR UP AND DOWN	TAKEOFF, LANDING, GO-AROUND
NOSE	1 SET	—	NOSE GEAR UP AND DOWN	TAKEOFF, LANDING, GO-AROUND
MAIN	3 SETS	—	NOSE GEAR UP AND DOWN	TAKEOFF, LANDING, GO-AROUND

*MAJOR FLIGHT PHASES: TAXI, TAKEOFF, GO-AROUND, CLIMB, CRUISE, DESCENT, APPROACH, AND LANDING

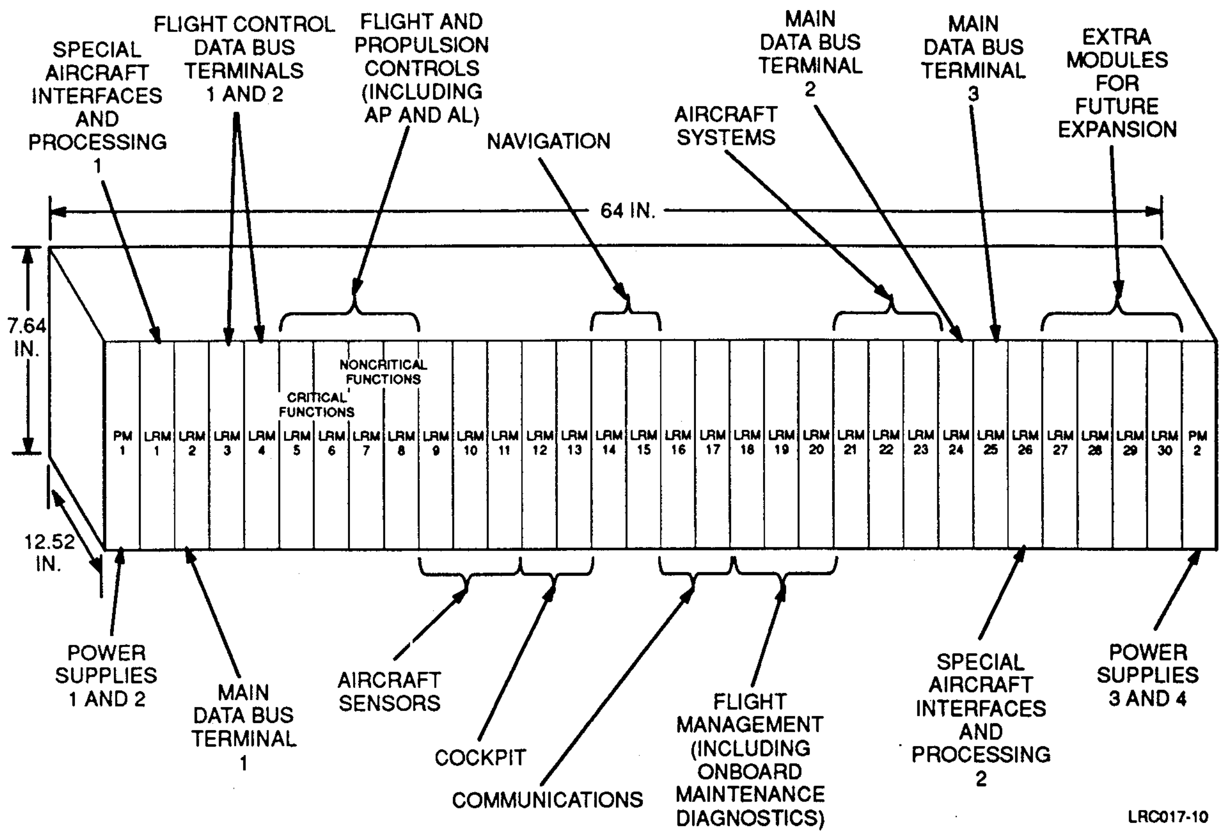


FIGURE 13. TWIN-JET MODULAR AVIONICS RACK CONCEPT

PRESSURIZATION	RAM AIR USING SHAFT–DRIVEN COMPRESSOR
COOLING	VAPOR–CYCLE USING FUEL HEAT SINK–GROUND/RAM AIR–FLT
HEATING	ELECTRIC HEATER FOR CABIN WARMUP AND TRIM

PRESSURIZATION AIR SUPPLY REQUIRED (FLT IDLE)

	NORMAL	ONE COMPRESSOR INOP
FLT DECK	300 CFM	200 CFM
CABIN	2,494 CFM	1,664 CFM
LEAKAGE	56 CFM	56 CFM
TOTAL	2,850 CFM	1,920 CFM

MINIMUM AIRFLOW (2 VAP CYC + 2 RECIR FAN)

	NORMAL	ONE VAPOR CYCLE UNIT
FLT DECK	300 CFM	300 CFM
CABIN	4,156 CFM	2,494 CFM
TOTAL	4,456 CFM	2,794 CFM

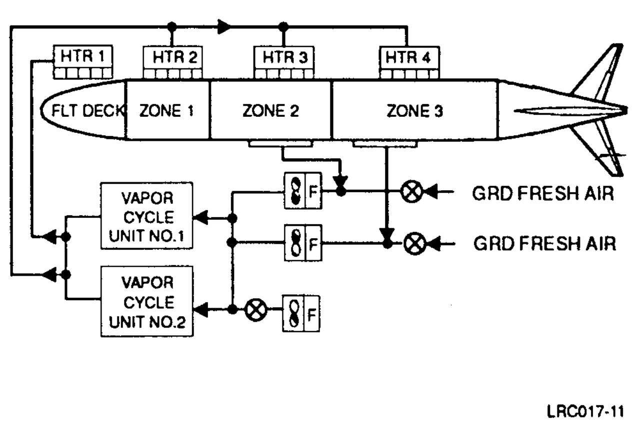
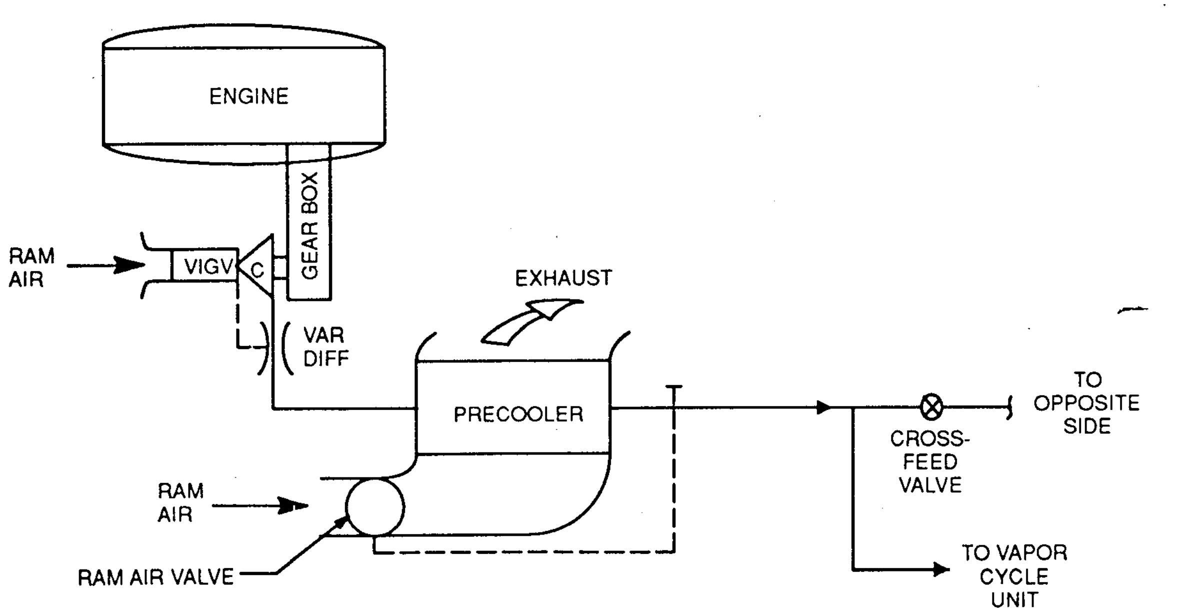


FIGURE 14. TWIN-JET AIR-CONDITIONING CONCEPT

The preliminary environmental control system design for an all-electric twin jet based on the MD-XX model produced the following features:

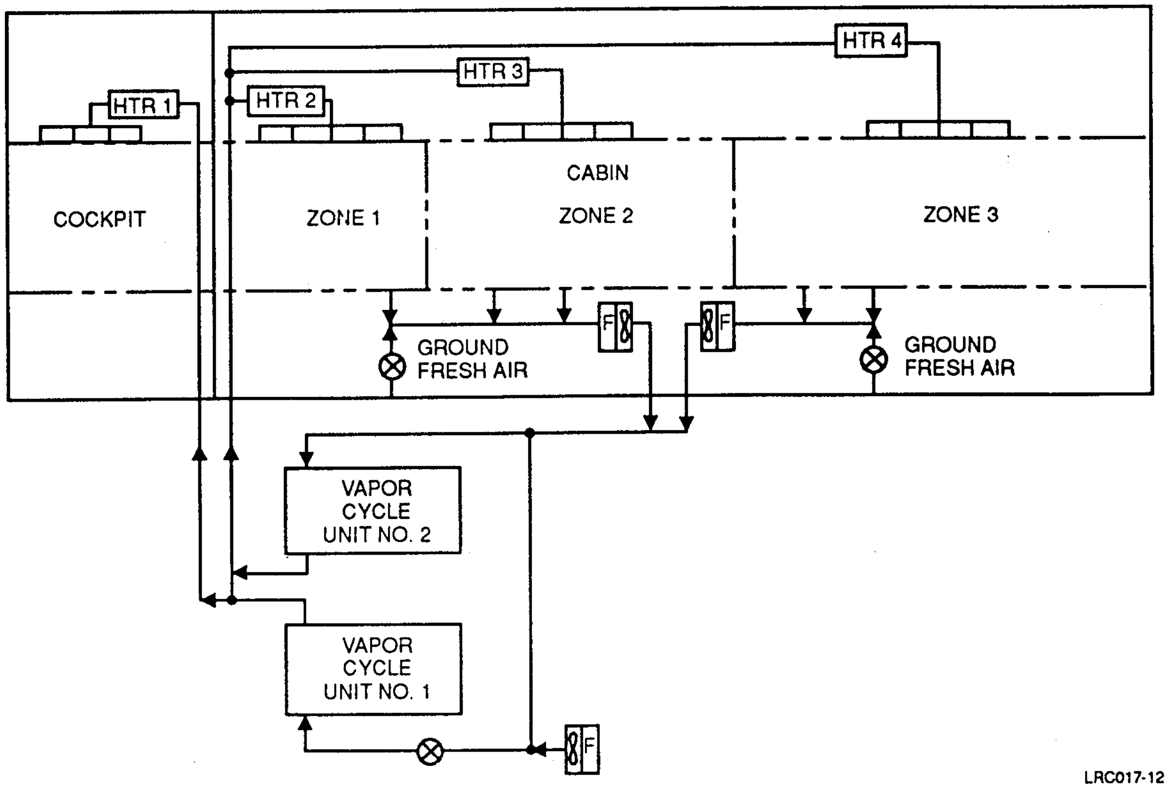
- Engine shaft-driven compressor (C)
  - — Variable-inlet guide vanes (VIGV)
  - — Variable diffuser
  - — Variable speed
- Cabin air recirculation (50 percent of total)
  - — Two 4-kw fans for normal operation
  - — One 4-kw fan for warmup
- Four zone heaters for warmup and trim
- Heaters for cargo compartments
- Two vapor cycle units
- Electro-impulse de-icing systems

Major new elements are: compressors driven by each engine shaft gearbox, with adaptable operating features; vapor-cycle air-conditioning units instead of the conventional high-pressure, high-temperature air cycle units; and electro-impulse de-icing (EIDI) systems. EIDI systems are still in the developmental stage and alternative methods were later adopted, as described in Section 4.5.3. The conceptual designs for 20-kHz power systems are illustrated in Figures 14 through 17.



A. PRESSURIZATION AND FRESH AIR SUPPLY

FIGURE 15. ADVANCED ENVIRONMENTAL SYSTEM CONCEPTS



B. AIR CONDITIONING

FIGURE 15. ADVANCED ENVIRONMENTAL SYSTEM CONCEPTS

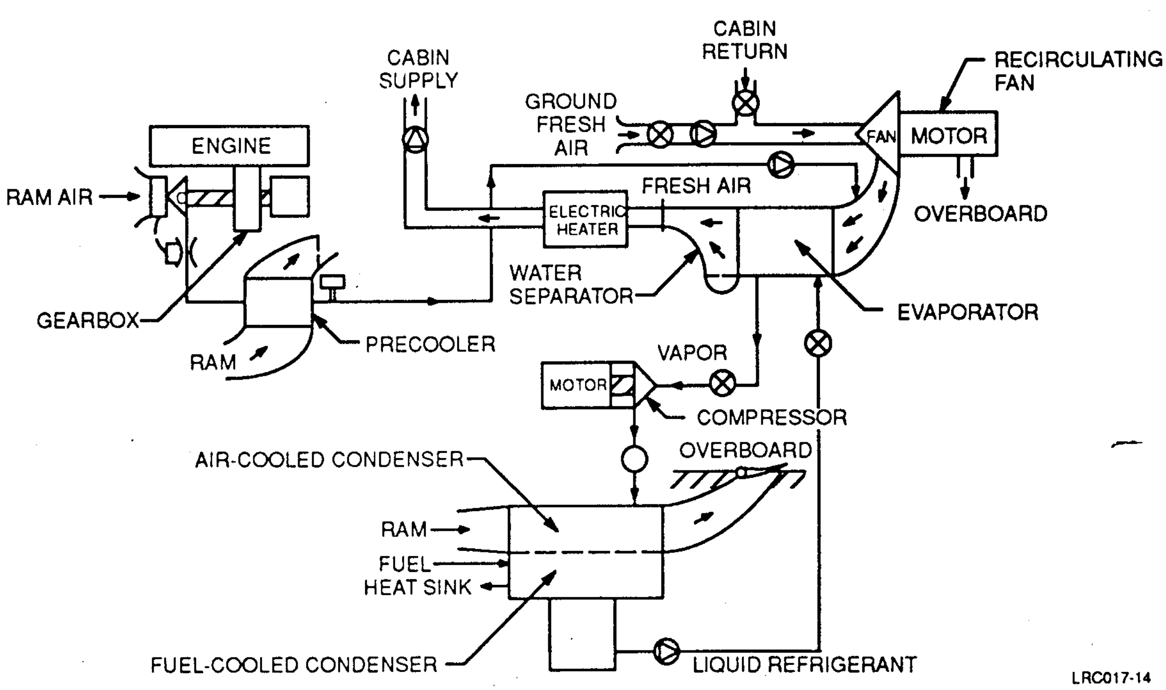


FIGURE 16. VAPOR-CYCLE ENVIRONMENTAL CONTROL SYSTEM

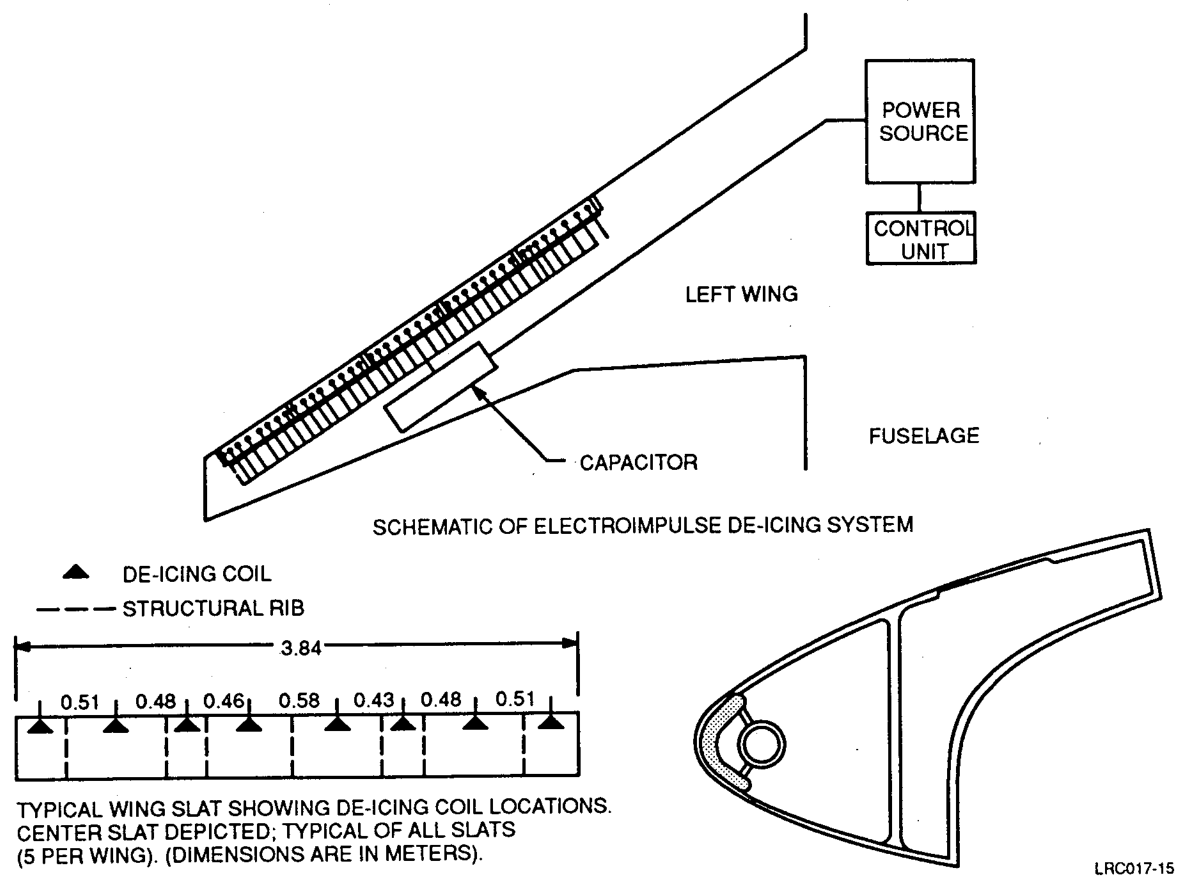


FIGURE 17. TYPICAL ELECTRO-IMPULSE DE-ICING COIL INSTALLATION

3.10 OTHER SYSTEMS AND TECHNOLOGIES

3.10.1 Electromagnetic Compatibility

Use of 20-kHz energy for main power transmission systems and converters to derive a variety of other frequency/speed profiles for motors suggests strongly that a new spectrum of frequencies, harmonics, and bandwidths may be encountered. Provisions to deal with these should be made at the outset and pursued concurrently with the system design and development.

In developing a viable 20-kHz power processing concept, it must be ensured that the hardware based on the concept has the potential for compliance with applicable industry specifications pertaining to aircraft electromagnetic environments (EME). The specifications in common use for aircraft EME compliance are presented in Appendix D.

Generally speaking, the "unconventional elements" of the 20-kHz power distribution conceptual design are: conversion equipment, both source- and receiver-end equipment, and a transmission/distribution network. There are basically two EME considerations against which these unconventional elements must be evaluated:

1. Self-generated electromagnetic emissions: The emissions from the new elements might be at a much higher level than the conventional ones and thus might have an impact upon industry practices for shielding, filtering, grounding, and bonding of airborne equipment.

2. Electromagnetic susceptibility: The newly introduced equipment for the distribution systems must be immune to the "accepted" electromagnetic environments encountered by aircraft. These environments can have external or internal origins. The external origins are in high-intensity radiated fields, and lightning-induced effects, including those due to multiple stroke (MS) and multiple burst (MB), while the internal environments arise from normal or abnormal system transients, such as switching or current/voltage spikes due to equipment malfunction or energy dissipation.

A number of documents pertaining to aircraft EME provide guidelines, specifications, and standards for evaluating airborne systems and equipment with respect to their airworthiness and certifiability. The documents used by the aircraft industry to define limits and test requirements are included in Appendix D.

3.10.2 Crew System Technology

The objectives of a crew system technology study for the 20-kHz twin-jet all-electric air transport were determined and an approach defined. The objectives and approach proved equally applicable to the redirected study, which was completed.

The objectives were: (1) ensure compatibility with human capabilities and limitations; (2) ensure optimal allocation of functions between humans and equipment; (3) ensure an efficient arrangement of crew station, equipment, controls, and displays; (4) maximize personnel safety and minimize the potential for human error; and (5) minimize personnel skills and training requirements.

The approach taken was to develop human engineering guidelines and criteria, first reviewing the general standards for human engineering and then selecting the appropriate guidelines and criteria for the specific design. The technical design efforts were then reviewed and inputs provided to the technical analyses (e.g., for flight controls or electrical systems as necessary). The crew system design concepts and interfaces were modified after assessing the impact of the crew on cockpit layout, system control panel layouts, and system summary CRT display formats.

3.10.3 Reliability, Maintainability, and Safety

Reliability, maintainability, and safety must be addressed early in the design of any electrical power system. It is of particular concern when dealing with new design concepts and hardware. Reliability is designed into the architecture, hardware, and operation of the system. Maintainability must be designed into the installations, the hardware integration, the sensors, and the status and operating condition displays to enhance an airline's ability to maintain the systems. Safety is closely related to the inherent reliability of all system elements, but is also closely related to the automatic protection system design, the philosophy adopted to select the displayed parameters, the manual and automatic operation schemes, and the computer software and control algorithms. Some features of an acceptable reliability design are described below:

Dispatch Reliability — The percentage of takeoffs that are not delayed 15 minutes or more due to equipment or system failures, an item of great concern to airline operators. This is partially controllable by designing for high system reliability and for simple, modular replacements of line-replaceable units (LRUs).

The fully functional and partially functional operating capabilities and characteristics are established by redundancy studies. This is part of the overall reliability study.

The MTBF is a major quantitative and measurable element for determining first, the reliability of the LRU, then the individual system or subsystem, and finally, the overall electrical power system reliability.

Reliability trade studies are conducted to establish the quality of the electrical power system and its parts in terms of a statistical probability of survival. Data are used from past programs on the basis of similarity of form, fit, and function. Then, any significant stress factors due to operation, application, or environment are applied to modify the data for the specific program.

Maintainability is very broad and involves the following considerations.

1. Ease of maintenance as affected by the maintenance built-in test (BIT) functions provided, the operational parameters, accessibility, tools, skills, product support facilities, spares inventory and logistics, to name a few significant factors.
2. For the airline operator, the time required for repair or replacement is a very important cost factor.
3. The mean time between unscheduled removals (MTBUR) is also a very important cost factor and is related directly to the MTBF, but it also includes removals that are later determined to have been unwarranted, perhaps due to inadequate or incorrect BIT indications or to unsatisfactory levels of skills and training.
4. Maintainability trade studies, although tedious and time-consuming, can save a great deal of cost by anticipating problems and guiding the redesign of marginal system elements.

Safety is a mandatory requirement for aircraft certification and is the dominant factor in all aircraft and system designs. The FAA establishes the certification requirements in the Federal Aviation Requirements (FARs), Chapter 25, Part 25.1309. The requirements are succinctly stated as follows:

"Occurrence of any failure condition which would prevent the continued safe flight and landing of the airplane is [shall be] extremely improbable. . . . Occurrence of any other failure condition which would reduce the capability of the airplane or the ability of the crew to cope with adverse operating conditions is [shall be] improbable."

Advisory Circular 25.1309-1, defines "extremely improbable" as equal to or less than one event in 1 billion flight hours (10E-09), and improbable as equal to or less than one event in 100,000 flight hours (10E-05).

The evaluation of safety and related quality issues must be accompanied by a functional hazard analysis (FHA), and this must be followed by a failure mode and effects analysis (FMEA).

The system diagnosis and testability assessment should provide an in-depth view of the total system in terms of the following factors: ease of maintenance, fault detection, fault isolation, aircraft condition monitoring, and a cost-effective, user-friendly means of aircraft maintenance.

3.10.4 Propulsion Systems and Auxiliary Power System

The propulsion systems generally include the engines and engine accessories and the fuel management systems. This study also included the auxiliary power unit (APU) and the air-driven generator (ADG) which is used to generate emergency power for extended flight periods in lieu of the time-limited battery power source. The propulsion elements are the generator, engine starter, ground power, engine controls and full-authority digital electronic controls (FADEC), engine instruments, engine ignition, fuel quantity indication, fuel management system, fuel pumping system, fire detection system, engine thrust reversers, and the ADG emergency power system.

The 20-kHz All-Electric Airplane features a generator drive with direct gearing to the engine and with higher than conventional speeds, generators with higher power ratings and without constant-speed drive (CSD), hydraulic pumps, and air-driven engine-starters.

The generators will serve as motors for starting the main engines, using 20-kHz aircraft power. The engine-cranking requirements must be established in terms of torque versus engine speed.

The APU is not required for dispatch of an airplane. However, its benefits have been accepted by all airlines for all Douglas air transports to date, even though its cost is significant. The reasons for the high level of acceptance include the following:

The aircraft can be independent of the airport ground power facilities and therefore does not require an advance gate assignment.

The aircraft can "hold" indefinitely on the ramp before moving to an available gate.

The APU can be used as a full-time backup or emergency power source if its design allows high-altitude operation. The battery used to start an APU then provides power to crank-start an inoperative engine, with "windmilling" assistance in flight, thereby enhancing flight safety during extraordinary engine incidents in flight.

The aircraft can be pushed back to clear a gate, then be held indefinitely for ground service, check-outs, or maintenance before departure, while providing air heating, cooling, and ventilation, electrical power, and lighting for all ground cockpit and cabin services.

In flight, the number of acceptable conditions for a split power configuration for "dual land" in Cat IIIb weather conditions is greatly increased (e.g., from 4 to 12 in a trijet aircraft configuration).

Flight operations are greatly enhanced after an engine shutdown, especially after an allowable dispatch with one generator inoperative.

Any study of the reliability required for extended twin-engine operations over water must consider the number of electrical power generators required for dispatch of the aircraft. The 20 kHz twin-jet model would have a total of four engine-driven generators, not including the APU. Dispatch with any of these generators inoperative would be acceptable for overland flights, but would be questionable for overwater flights of moderate range (1.5 to 2 hours). The study must consider the inherent safety factors, the services which might reasonably be curtailed or discontinued, whether the flight is in daylight or nighttime, and the weather conditions at the destination and alternate airports.

The ability to air-start an engine in flight is very significant for the operational safety of any aircraft. For a twin jet, it is even more important because extended flight with one inoperative engine is always undesirable. Two engines of a trijet give greater inherent safety. The investigation of in-flight restarts must address the greater difficulty of crank-starting the new high-bypass engines, the level of "windmilling" assistance in level flight or in a glide mode, the amount of power available from the other engine's generators, the amount of power available from the APU, the aircraft power demands with and without load-shedding, and the power available from the battery to start the APU, if necessary. These matters are even more critical if both engines are inoperative and prudent management requires restoration of propulsion power by all available means. Load-shedding in this event is virtually mandatory on the basis of priorities, with flight control and computer power as minimum loads. The emergency load analysis will provide the necessary minima for both alternating current and battery dc power loading.

3.11 EXPECTED 20-kHz POWER SYSTEM BENEFITS

The expected benefits of the initial 20-kHz system are presented in Table 9. A detailed analysis was not made to quantify these benefits because of the redirection of this contract. In general, the higher frequency makes electrical components and magnetic structures smaller and lighter in weight. Using the pulse density modulation concept, it also encourages the application of variable-speed/variable-frequency to motors in very flexible control and operating modes. In addition, the resonant converter concept is more efficient than other phase-controlled converter designs, and the circuit implementations encourage the use of bidirectional power and reversed power flow for electric engine-starting.

TABLE 9
EXPECTED 20-kHz POWER BENEFITS

TECHNOLOGY	PROPERTIES
LIGHTWEIGHT MAGNETICS	SMALLER TRANSFORMERS SMALLER CAPACITIVE/INDUCTIVE ELEMENTS SMALLER MOTORS/GENERATORS
ADAPTABLE POWER CONTROL/CONVERSION	BIDIRECTIONAL POWER FOR STARTING CONVERTED POWER QUALITY AS REQUIRED
CONTROLLED ENERGY DISTRIBUTION	LIGHTWEIGHT ISOLATORS LIGHTWEIGHT RECONFIGURATION SWITCHES SYNCHRONIZED SWITCHING
SYNTHESIZED POWER	CONSTANT V/F RATIO CONTROLLED ENGINE START CONTROLLED ECS DRIVE MOTOR

SECTION 4
REDIRECTED ALL-ELECTRIC AIRCRAFT STUDY
(Contract Revision 1.1)

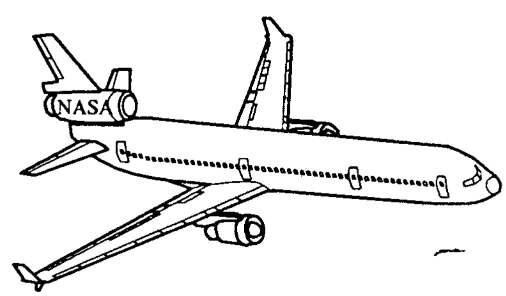
This section covers the work done and the results of the redirected program, which uses conventional 400-Hz electrical power distribution and defines an all-electric secondary power system, with no distributed hydraulic or pneumatic secondary power. Much of the effort expended and results obtained during the original contract were useful for the redirected contract. The advanced design concepts and technologies retained in the redirected contract include: the design criteria and guidelines; electrical power for engine starting using the main generators; bidirectional power converters; Mapham series resonant power converters operating at 20 kHz, with load power taken from the resonance capacitors; and PDM modules to synthesize 400-Hz electrical power for distribution and other variable frequencies for motors.

The headings of the following sections include the corresponding Work Breakdown Structure numbers to aid in correlating the work performed with the redirected contract Statement of Work.

4.1 BASELINE TRIJET DESIGN (WBS 4.1)

The baseline trijet configuration used for this study was a 323-passenger trijet. Douglas and NASA-LeRC agreed to use this as a baseline aircraft because of Douglas' ready access to detailed product data and because it could be easily reconfigured from a conventionally powered to an all-electric derivative aircraft.

Baseline trijet weights, engine thrust, payload, and performance provided a sound reference for the cost/benefit comparisons of alternative all-electric configurations. The features of the baseline model are shown in Figure 18. The aircraft has two aisles with two-class seating, 34 in first class and 289 in coach. The maximum takeoff gross weight is 602,500 pounds.



ENGINE	TYPE – CF6–80–C2 THRUST – 61,500 LB	
PERFORMANCE	PASSENGER & BAG RANGE – 6,600 N MI TAKEOFF FIELD LENGTH – 10,550 FT LANDING SPEED – 139 KNOTS	
SIZE	WING AREA – 3,648 FT^2 WING SPAN/FUSELAGE LENGTH/DIA – 170/201/20 FT	
PAYLOAD/FUEL	MTOGW – 602,500 LB MLW – 430,000 LB MZFW – 400,000 LB OEW – 278,400 LB	FUEL CAPACITY – 259,000 LB SPACE-LIMITED PAYLOAD – 102,835 LB PASSENGERS – 323 (MIXED: 34,289) CARGO VOLUME – 4,954 FT^3

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FIGURE 18. BASELINE TRIJET FEATURES

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4.2 BASELINE AIRCRAFT/SYSTEM DESIGNS (WBS 4.1.1)

Information for the baseline aircraft and system designs was obtained from Reference 3, which is generally known as the MD-11 Lamm Schematics Book. It is of particular value because it allows very specific hardware identifications for both removals and electrical replacements. Extracts will be shown later to illustrate its use. The electrical, mechanical, hydraulic, pneumatic, and bleed air systems are presented in the document. The baseline trijet air transport data came from Reference 4, which describes every component of the MD-11 to an accuracy of 0.01 pound and provides the exact location of each of these components within the aircraft.

4.2.1 Baseline Secondary Power Systems

The secondary power systems for the baseline aircraft are described in Table 10.

A key objective of this study was to develop new configurations to replace hydraulic, mechanical, and pneumatic systems with electrical equivalents. Table 11 provides a matrix overview of baseline power capacities of the hydraulic, pneumatic, and electrical systems for the reference trijet air transport. The total aircraft secondary power capability of nearly 1.6 megawatts includes a conversion of hydraulic and pneumatic power capabilities to electrical units.

4.2.1.1 Baseline Trijet Hydraulic Power — The baseline trijet hydraulic system, from which we derived an alternative electrically powered equivalent design, is functionally shown in Figure 19. Three separate 3,000-psi hydraulic systems operate continuously in parallel to supply hydraulic power for flight controls, the landing gear, steering, and braking. Each of the three systems is powered by a set of two 35-gpm variable-displacement pumps attached to and driven by an aircraft engine. Each system is independent of the other, so that the loss of one will not affect the others. Two reversible motor pumps are provided in case both engine pumps are lost in any one system or an engine is shut down. With this motor pump configuration, it is possible to pressurize System 1 and 2 from System 3 or to power System 3 from System 1 or 2. Auxiliary hydraulic power is available from two electrically driven pumps rated at 8 gpm each. These pumps are normally used to supply hydraulic power to System 3 for ground maintenance. In an emergency, an air-driven generator would be used to drive one of the auxiliary motor pumps.

TABLE 10
BASELINE SECONDARY POWER SYSTEMS

TYPE	FUNCTION
HYDRAULICS	PROVIDES "MUSCLE" POWER FOR ALL FLIGHT CONTROL SURFACES, LANDING GEAR DEPLOYMENT/RETRACTION, BRAKING SYSTEMS, WITH MODULATED POWER FOR ANTI-SKID BRAKING
MECHANICAL	MANUALLY OPERATED CABLE "BACKUP" SYSTEM PROVIDES MECHANICAL POWER FOR CONTROL AND OPERATION OF MAIN HYDRAULIC VALVES TO MOVE THE FLIGHT CONTROL SURFACES
PNEUMATIC	MAIN ENGINE BLEED AIR PROVIDES PNEUMATIC ENERGY FOR AIR CYCLE AIR-CONDITIONING AND PRESSURIZATION, HOT AIR FOR ANTI-ICING AND DE-ICING, AND MAIN-ENGINE STARTING
ELECTRIC	MAIN ENGINE-GENERATORS (IDG), APU, ADG, AND BATTERY SOURCES PROVIDE ELECTRIC POWER FOR SYSTEM CONTROLS, SENSORS, DISPLAYS, LIGHTING, AND COMPUTER POWER FOR AUTOMATIC OPERATION OF ALL SYSTEMS AND POWER FOR WINDSHIELD ANTI-FOG/ANTI-ICING/DE-ICING, AVIONICS AND NAVIGATION, COMMUNICATIONS, AND ENGINE CONTROLS

TABLE 11
BASELINE SECONDARY POWER SOURCES

TRIJET CAPACITY

	CAPACITY	P2 PSI	P1 PSI	HP	WATTS	AMPS/ PH.
ONE ENGINE						
ELECTRICAL	120,000 VA			161	120,000	348
HYDRAULIC	70 GPM	3,000.0	0.0	123	91,400	265
PNEUMATIC	2,227 CFM	10.9	1.4	277	207,014	600
ONE ENGINE TOTAL				561	418,415	1,213
THREE ENGINES TOTAL				1,683	1,255,244	
APU						
ELECTRICAL	90,000 VA			121	90,000	261
HYDRAULIC	0 GPM	3,000.0	0.0	0	0	0
PNEUMATIC	2,227 CFM	10.9	1.4	277	207,014	600
TOTAL				398	297,014	861
ADG						
ELECTRICAL	20,000 VA				0	0
HYDRAULIC	8 GPM	3,000.0	0.0	14	10,446	30
PNEUMATIC	0 CFM	10.9	1.4	0	0	0
TOTAL				14	10,446	30
BATTERY						
ELECTRICAL	1,400 VA			2	1,400	50
HYDRAULIC	0 GPM	3,000.0	0.0	0	0	0
PNEUMATIC	0 CFM	10.9	1.4	0	0	0
TOTAL				2	1,400	50
TOTAL AIRCRAFT				**2,097**	**1,564,104**	

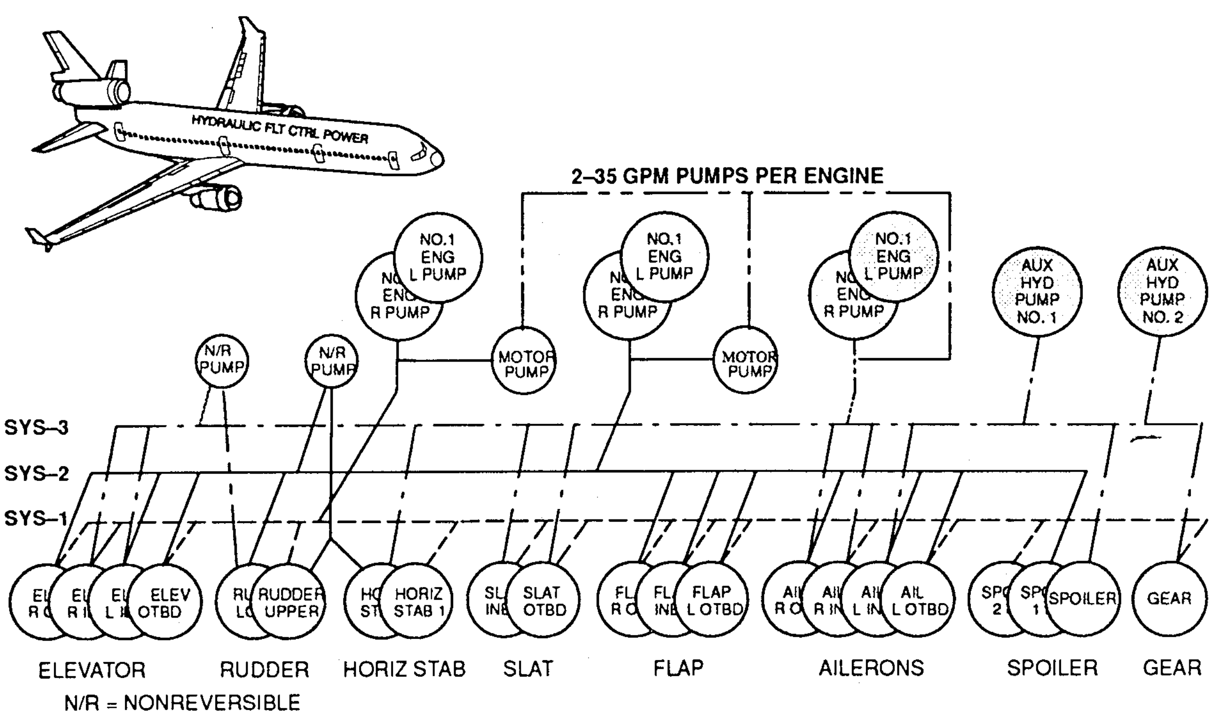


FIGURE 19. BASELINE HYDRAULIC ACTUATION POWER

4.2.1.2 Baseline Trijet Pneumatic Power — The pneumatic power supplied by the baseline trijet system is shown in Figure 20. The air for the pneumatic support system is obtained by bleeding compressed air from each of the trijet engines. The bleed air from each engine is pressure- and temperature-controlled and is distributed for ice protection, air-conditioning, thrust reversers, and cargo heat. Each manifold is isolated to limit the consequences in the event a pneumatic duct bursts. Opening the isolation valve provides engine-starting capability by pressurized air from another engine, from a ground "air cart," or from the onboard APU.

4.2.1.3 Baseline Trijet Electrical Power — The baseline trijet electrical power system architecture is shown by the simplified functional schematic as the boxed part of Figure 21. The ac generating system for the baseline trijet aircraft consists of three 110/120 kva, 3-phase, 400-Hz, 120/208-volt integrated-drive generators (IDGs), one on each engine, and one auxiliary power generator rated in flight at 90 kva, 3 phase, 400 Hz, 120/208 volts, mounted on an APU engine at the rear of the aircraft. Two external (ground) power sources, each rated at 90 kva minimum, are needed for main and galley power. Emergency ac power is supplied by a battery-powered static inverter rated at 2.4 kva, 1 phase, 400 Hz, 115 volts and an air-driven generator rated at 20/25 kva, 3 phase, 400 Hz, 115/208 volts. The power distribution system is designed so that each generator is connected by a power relay to its assigned bus, with auxiliary contacts as required for control and sensing signals. Each generator is connected to the ac tie bus through an assigned bus-tie relay to provide either parallel or isolated operation.

The APU power distribution subsystem is connected by auxiliary power relays at each main ac bus. The present APU cannot provide sustained parallel operation with the main generators or with main external (ground) power. Ground service power is available from ac generator bus 2, from the APU, or from main external power (EP). The left and right emergency buses are powered by generators 1 and 3, the APU, external power, the single-phase static inverter, or the ADG. Distribution of

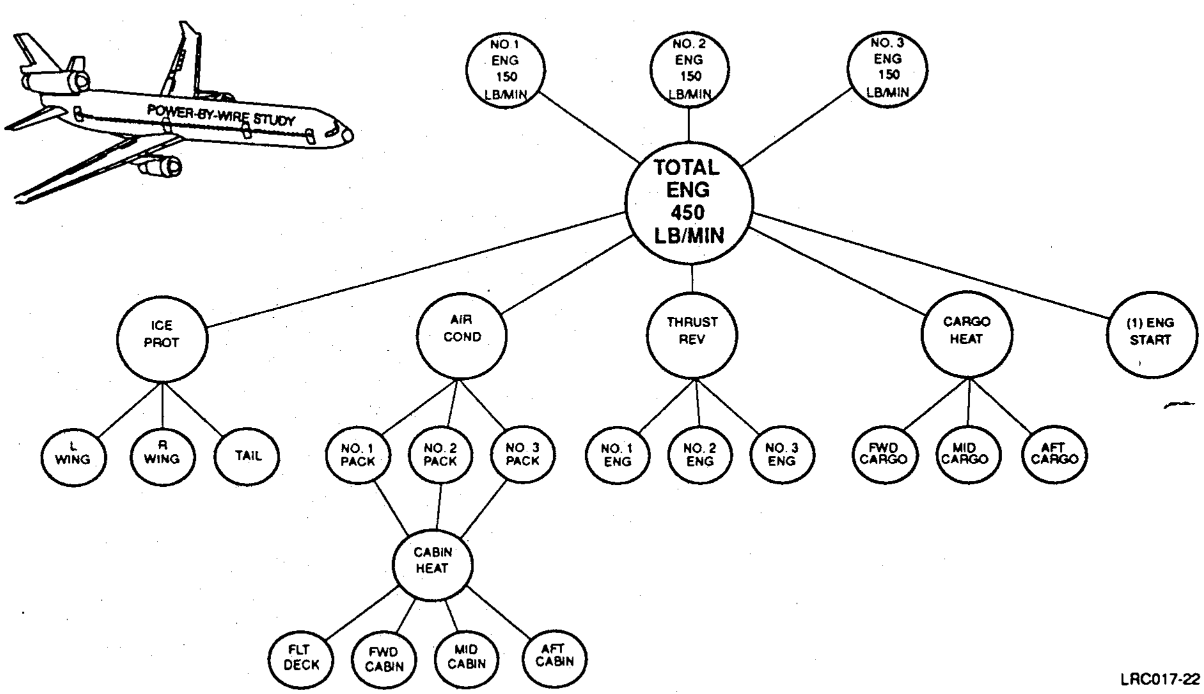


FIGURE 20. BASELINE BLEED AIR REQUIREMENTS

power is automatically controlled by the electrical power control unit (EPCU not shown) in conjunction with the generator control unit for each IDG and the APU generator control unit. In case of a failure of the automatic control system or to permit manual override control, an overhead electrical system control panel in the flight compartment (Figure 22) will provide the necessary control devices and indications.

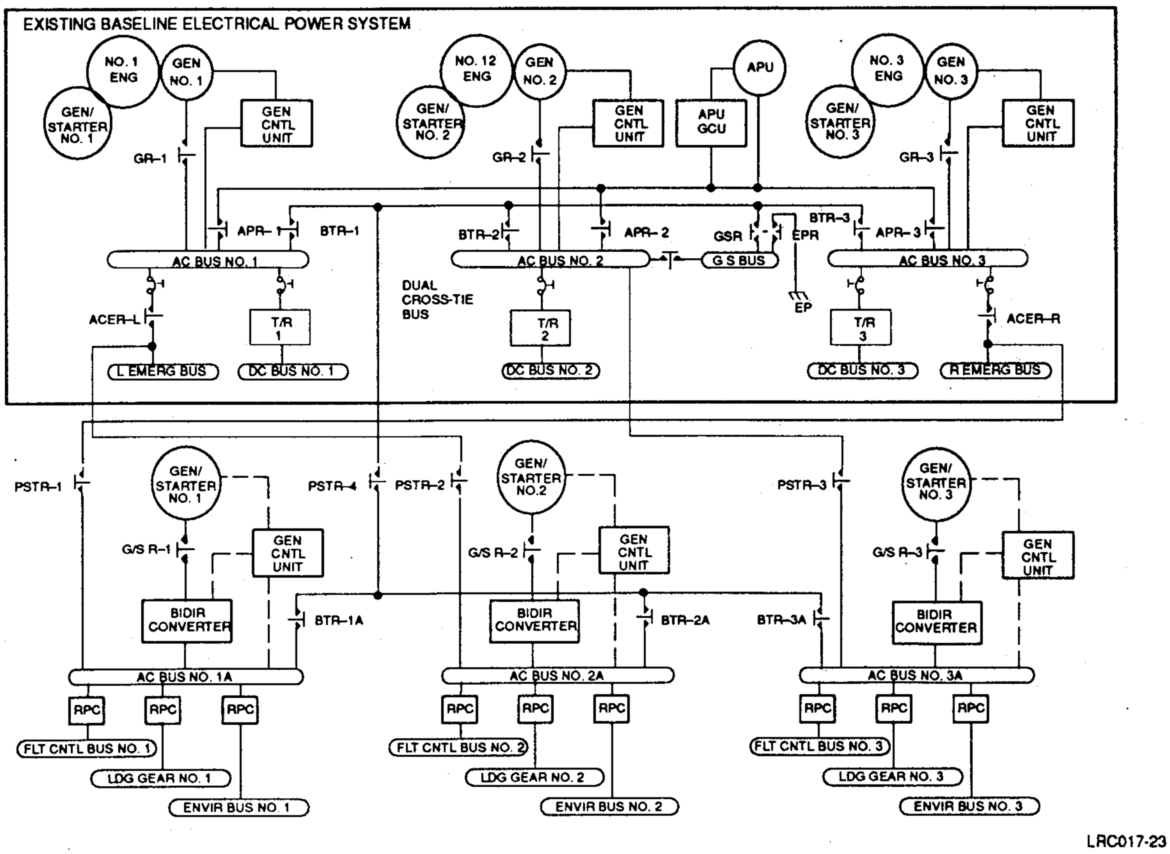


FIGURE 21. ALL-ELECTRICAL POWER SYSTEM ARCHITECTURE

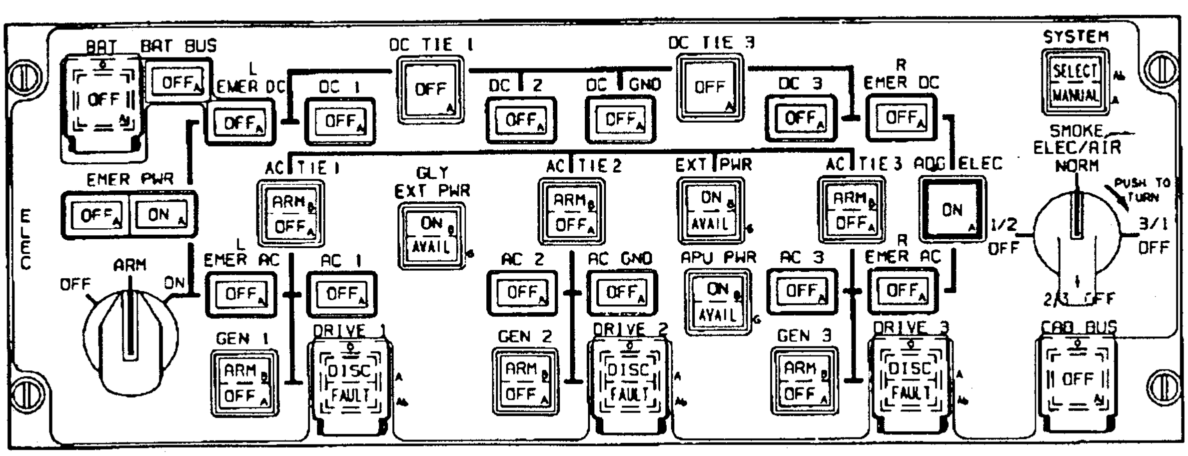


FIGURE 22. ELECTRICAL SYSTEM CONTROL PANEL

The primary direct current electrical power system consists of four transformer-rectifier (TR) units that convert 115-vac 3-phase 400-Hz power to a nominal 28-vdc 75-ampere output. The TR units supply power to their respective buses and can operate in parallel as common supply sources through the dc tie bus. Battery power consists of two series-connected 14-volt nickel-cadmium batteries, each rated at 50 ampere-hours. The batteries supply power to either a relay-controlled battery bus or a bus tied directly to the batteries. The batteries supply dc power if the TR units are not in operation. They also supply power for single-phase static inverter operation, for an emergency ac bus, and for starting the auxiliary power unit. The battery charger converts 3-phase 115/200-vac 400-Hz input into a controlled dc output to keep the batteries fully charged. The battery charger operates whenever ac power is available on the ac generator ground service bus or the right emergency ac bus.

4.2.2 Baseline Flight Control System

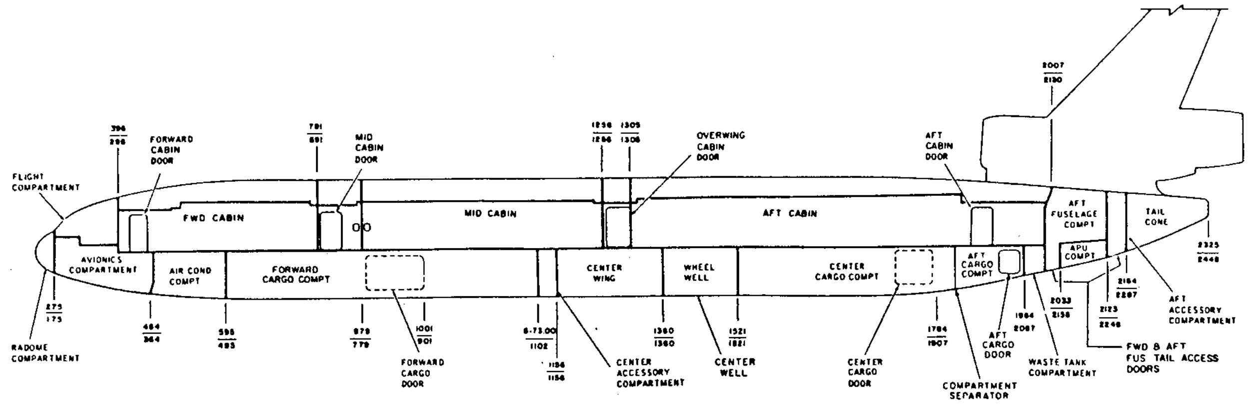
The flight control system for the baseline trijet aircraft is a conventional type. It uses distributed hydraulic secondary power for the "muscle" power to operate the very large flight control surfaces and hard-wired electrical control for the hydraulic valves and valve control modulators, monitors, and LVDTs. It has mechanical cables and associated devices with mechanical "load feel" as manually powered backup control links to the hydraulic valves. The dual-redundant flight control computers provide autopilot control to the hydraulic valves. The flight control system is further described in Section 4.5.2 for the all-electric aircraft.

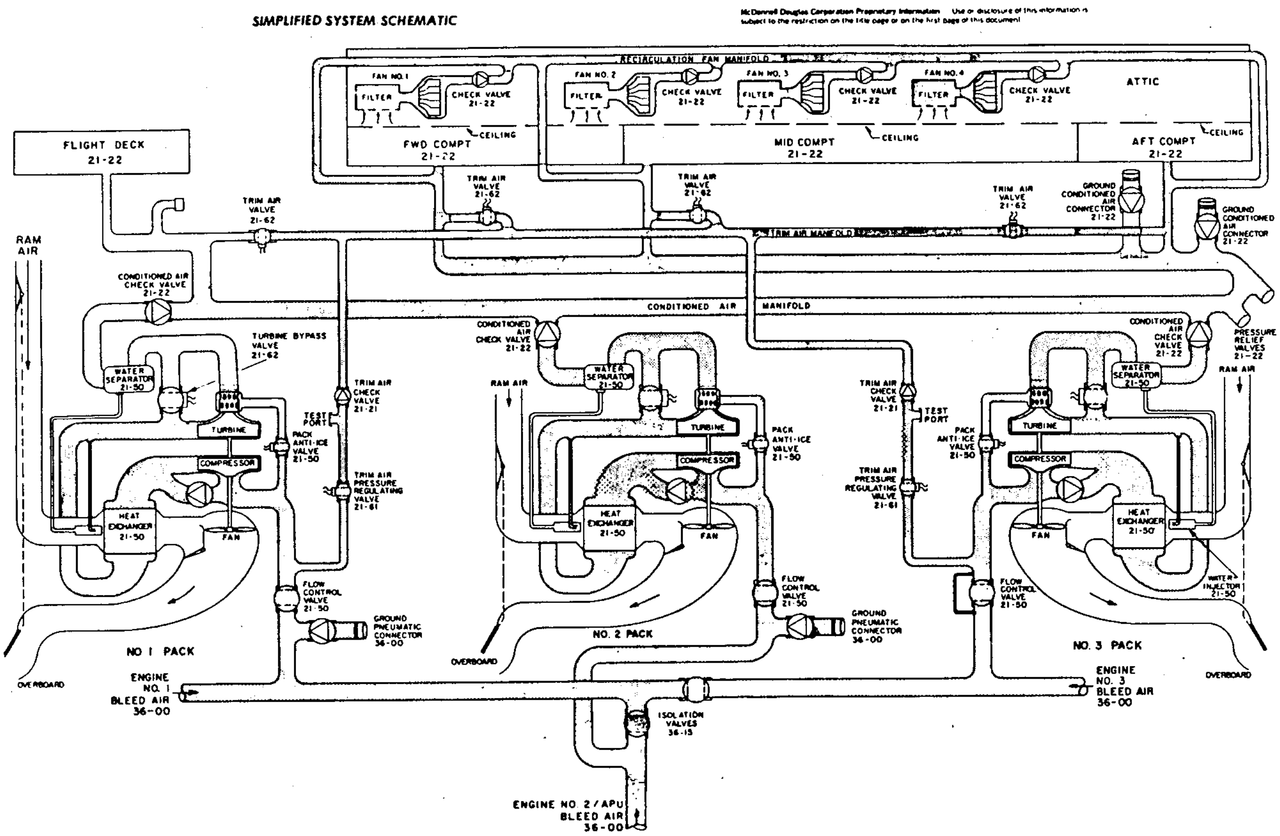
4.2.3 Baseline Environmental System

The environmental system for the baseline aircraft utilizes bleed air from three engines distributed through pneumatic manifolds to drive three air-cycle air-conditioning packs for controlling pressure and temperature inside the fuselage. The system includes four recirculation fans that improve system efficiency by achieving a uniform mix of cabin air with the standard proportion of fresh air. The system is designed so that two of the three air-conditioning packs have adequate capacity to maintain pressurization and passenger comfort without operational restrictions. The air-conditioning and pressurization air supply distribution is shown in Figure 23 and the cabin conditioned air distribution is shown in Figure 24. The baseline system is designed to maintain a pressure altitude of 8,000 feet or lower, using 50 percent new and 50 percent recirculated air. The system will maintain cabin temperature at 70°F on a 103°F day on the ground and throughout the flight envelope.

4.2.4 Baseline Ice Protection Systems

The baseline trijet utilizes a thermal-pneumatic anti-icing system, which is composed of four subsystems: engine cowl, two wings, and tail. The hot air for cowl de-icing is obtained through a dedicated cowl anti-icing shutoff valve on each engine. The ducting for this function is contained in the engine pod. The wing and tail anti-icing subsystems utilize hot bleed air from the pneumatic system, and each is controlled by an anti-ice shutoff valve. Hot air at temperatures up to 400°F is blown against the leading-edge surfaces using "piccolo tubes" or double skins to prevent the formation of ice. The design airflow rates for anti-icing are 1.5 lb/sec for each wing and 1.0 lb/sec for the tail. The flight deck control/annunciation and the system controllers for the wings and tail anti-icing shutoff valves are shown in Figures 25 and 26. The engine cowl de-icing is not shown because the existing configuration is retained for the all-electric trijet design.





ALL CUSTOMERS EXCEPT FREIGHTERS

21-00
CODE 100

TITLE				
AIR CONDITIONING	DOUGLAS	88277	MD-11	21-00
P BORISY	D BHAT	U MARTINO	04-27-90	

NOTE: $\frac{\text{MFG STA}}{\text{LINE STA}}$, INCHES

EXAMPLE: $\frac{791}{691}$ IF APPROPRIATE

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FIGURE 23. BASELINE AIR SUPPLY DISTRIBUTION

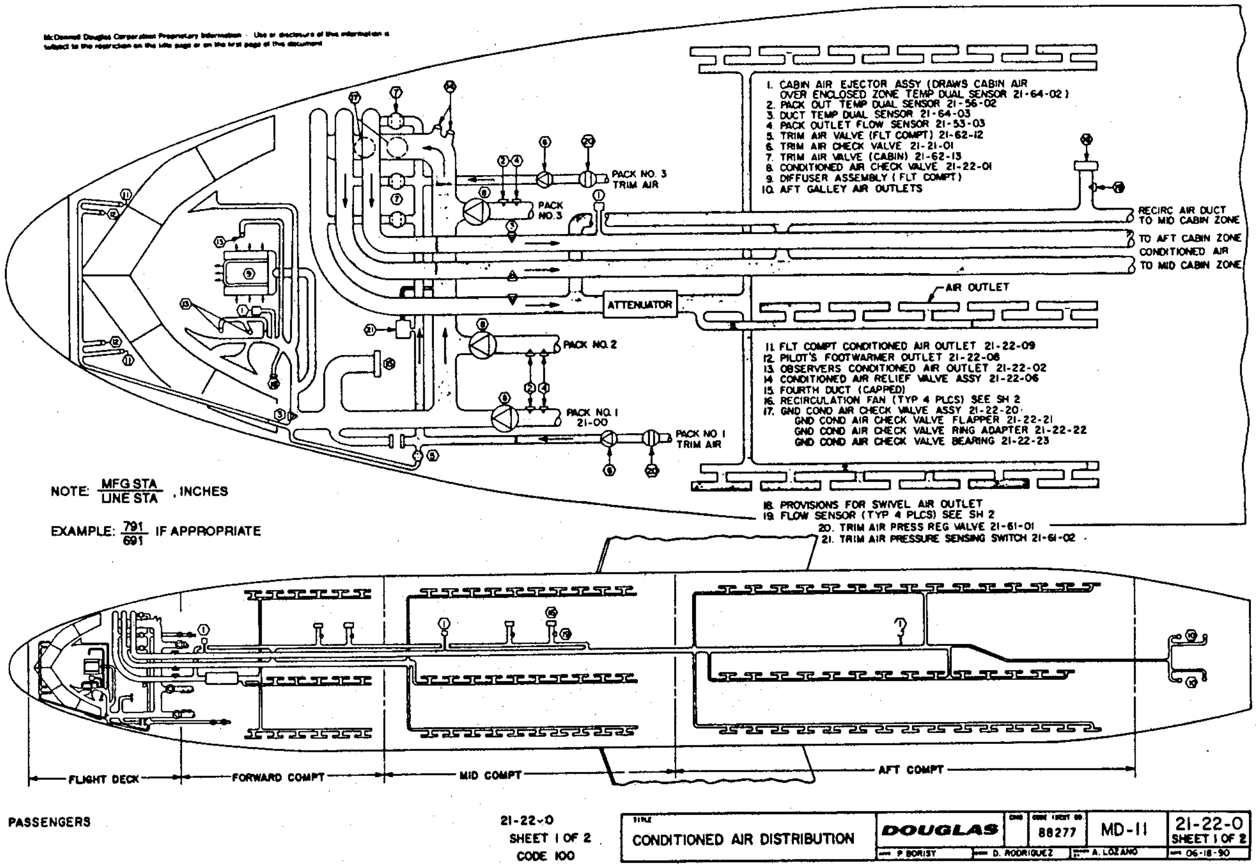

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FIGURE 24. BASELINE CABIN CONDITIONED AIR DISTRIBUTION

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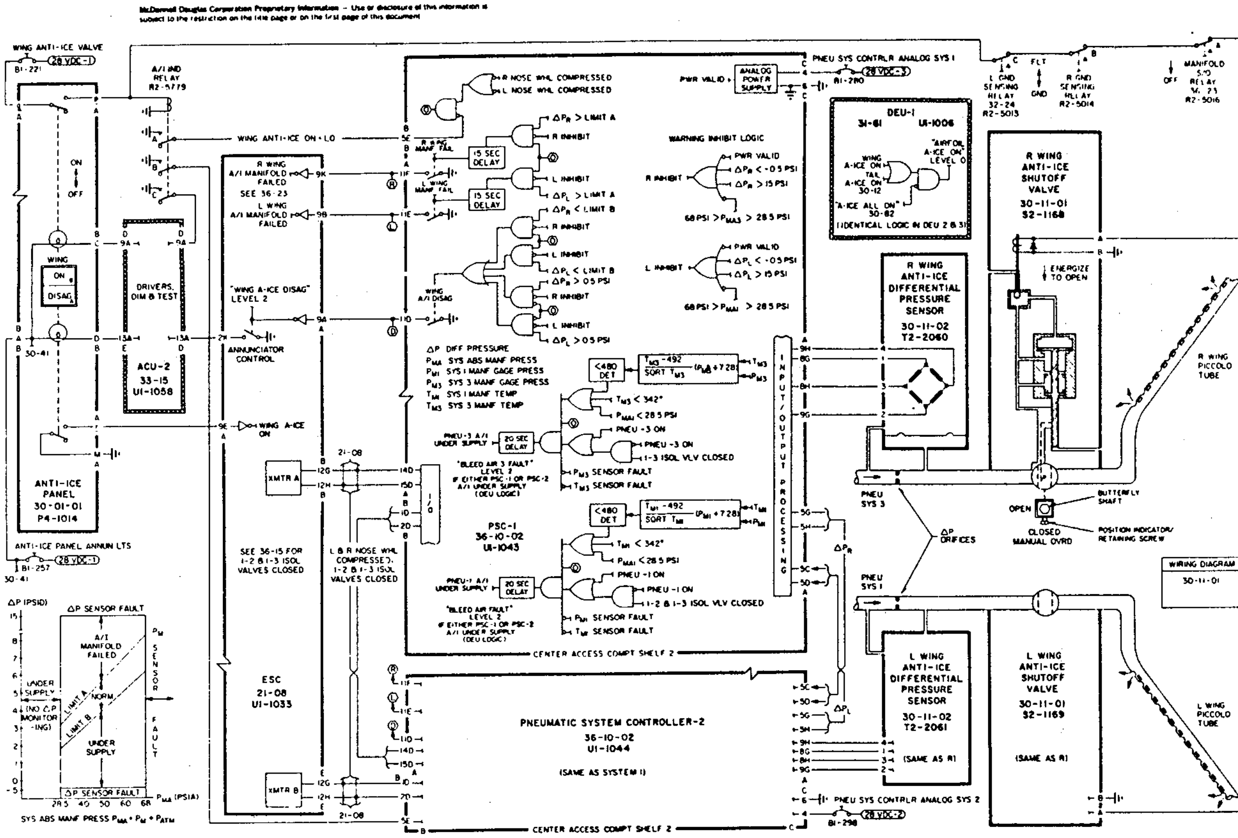

FIGURE 25. BASELINE WING ANTI-ICE

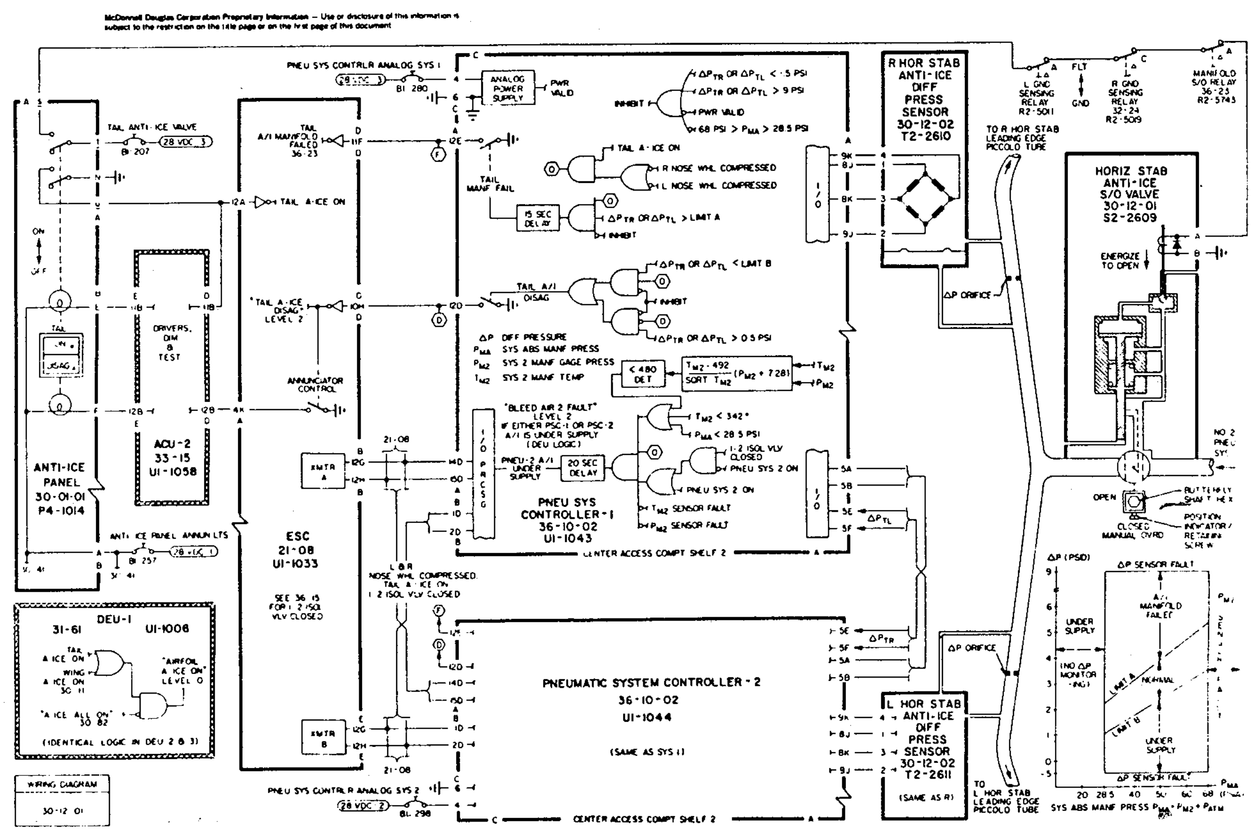

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FIGURE 26. BASELINE TAIL ANTI-ICE

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4.2.5 Baseline Propulsion and APU Systems

The general requirements and provisions for propulsion engine technology and the justification for an APU are provided in Section 3.10.4.

The baseline trijet airplane has a pneumatic air-driven starter on each engine. It has neither the generators nor the frequency converters which could provide the bidirectional power necessary for engine-starting with electrical power. The APU includes a 90/110-kva generator and a compressor capable of providing 320 to 340 lb/min of pneumatic power for either engine-starting or environmental control through the air cycle air-conditioning packs. The cooling mode is estimated to take 117 kva of pneumatic power for the air-conditioning packs and 45 kva for air circulating fans on a hot day. It also provides electrical power for 96 kw of space heaters and 45 kva of fan power for the environmental heating system, in addition to electrical power for all other aircraft systems on the ground when the main engines are not operating.

The all-electric airplane will be designed for significantly different methods of extraction of energy from the main engines, as described in Section 4.5.5.

4.2.6 Other Baseline Aircraft Systems

The baseline trijet airplane was certified for airline service after satisfying the electromagnetic compatibility (EMC) criteria described in Section 3.10.1. These requirements are not affected by the type of electrical power distribution and are therefore equally applicable to an airplane based upon 400-Hz or 20-kHz electrical power distribution.

The crew systems design criteria and philosophy which were applied during the baseline trijet transport design are described in Section 3.10.2. These are also not affected by the form of electrical power distribution and are therefore equally applicable to an airplane based upon 400-Hz or 20-kHz electrical power distribution. The cockpit overhead panel affords either manual or automatic control and system status indications for the crew. This panel and the all-electric design are shown in Section 4.5.6.

The certification was accomplished under the stringent criteria and requirements for reliability, maintainability, and safety described in Section 3.10.3. These are general requirements which are independent of the specific type of electrical power distribution. Therefore, they are equally applicable to the baseline or all-electric trijet air transport designs.

4.2.7 Baseline Weight Analysis

The "empty" weights for the baseline trijet are shown in Figure 27. These weights are derived from a computer report generated by the trijet Weights Analysis group (Reference 4). The report assigns an alpha code function to each system and to each major aircraft component, using letters A through W. The system or component is then subdivided alphabetically by its detailed parts, from which specific weight values are derived. An example of the weight list is provided in Appendix F.

4.3 BASELINE ELECTRICAL LOAD ANALYSIS (WBS 4.1.2)

The baseline electrical load profile shown in Figure 28 was derived from a Douglas computer program-ELOAD (Reference 5). This source tabulates the electrical power consumption of each system and produces the total kva loading for various phases of aircraft operation, using periods of

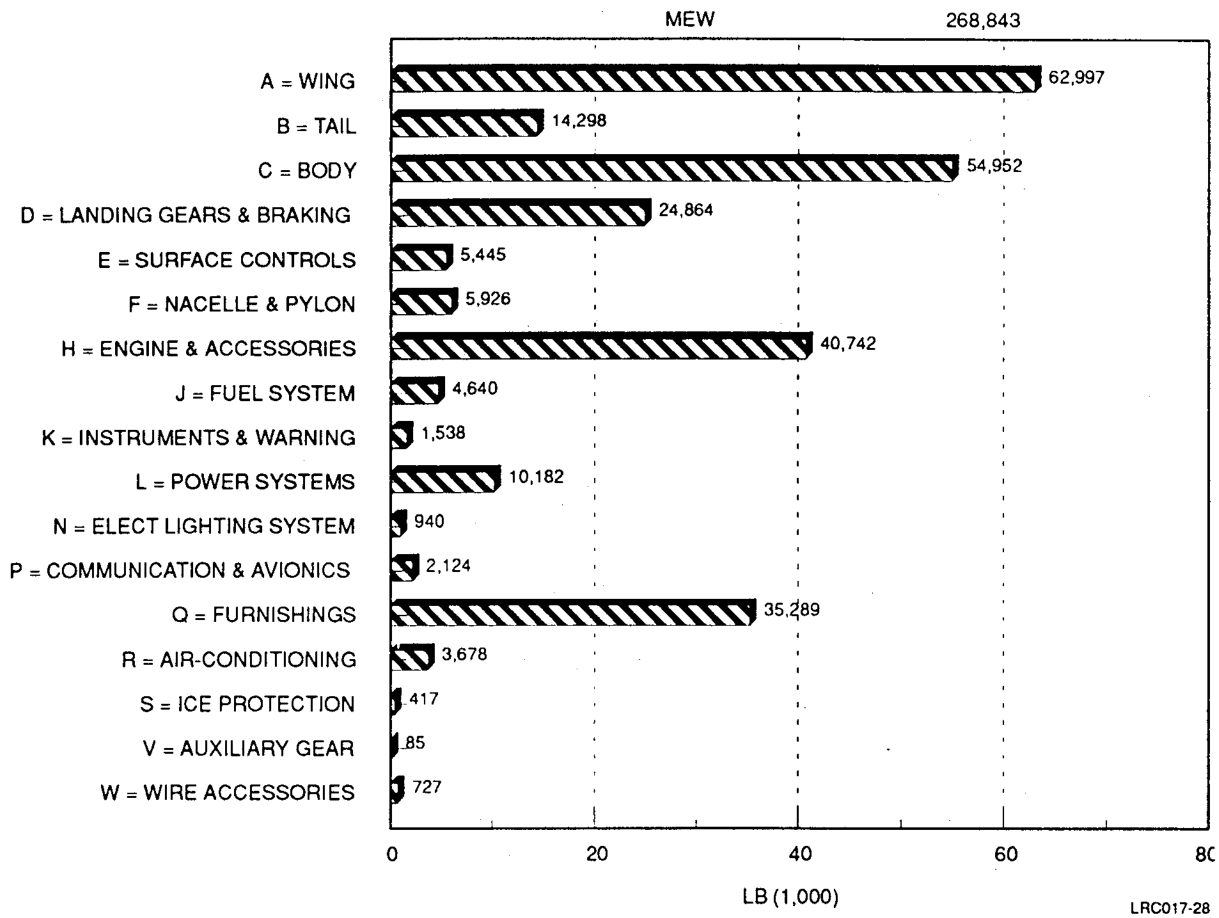


FIGURE 27. BASELINE EMPTY WEIGHT

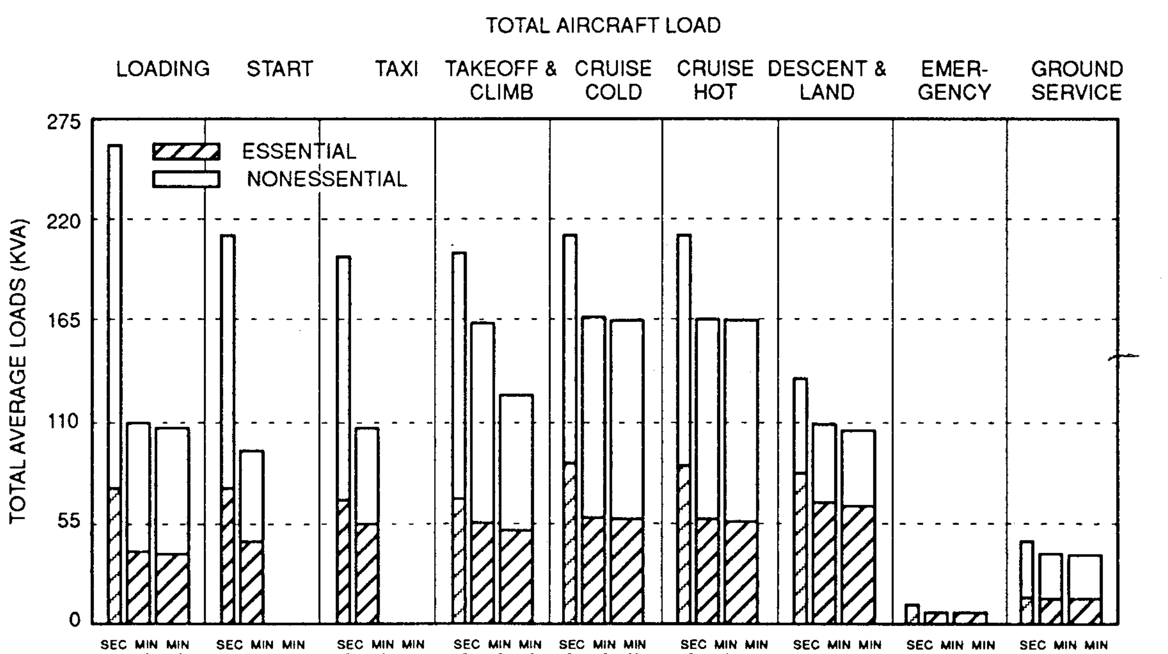


FIGURE 28. ALTERNATING CURRENT BASELINE AIRCRAFT LOAD ANALYSIS

5 seconds, 2 to 5 minutes, and 15 to 30 minutes. The loads in these analyses are based on a night flight with 65 percent of the reading lights on, with a full fuel load, and with the galleys operating. The analyses assume a nonstop flight with the aircraft on the ground only long enough to load and unload passengers. Sample data applicable to this study are provided in Appendix G.

4.4 BASELINE COST ANALYSIS (WBS 4.1.3)

The cost analysis for this study utilized three alternative configurations to demonstrate the effects of an all-electric design. These were a baseline trijet, a trijet with all-electric secondary power, and an all-electric trijet with resized engines and wings. Parametric computer models were used to quantify costs for these configurations. The cost data comparison for the three-configuration study is presented in Section 4.7.

A top-level cost comparison was made with various Douglas cost models in these major categories: development and test cost, flyaway unit cost, product support cost, and operations and maintenance cost.

The cost analysis process involves breaking down major cost categories into lower level cost elements that facilitate compilation of cost data and then recombining them to arrive at high-level cost categories. The cost analysis process used for the baseline and later for the all-electric aircraft configurations is described in the following sections.

4.4.1 Cost Elements

Four high-level cost categories (development and test, flyaway, product support, and operations and maintenance) were divided into 10 cost elements to facilitate gathering and managing costing information.

The following 10 elements were cost-quantified in order to run the Douglas parametric cost analysis models:

- Aircraft weights by system technology and hardware location
- Gross takeoff weight
- Specific fuel consumption
- System failure rates
- System maintenance hours per flight hour
- System material cost per flight hour
- Fuel price per gallon
- Crew cost per trip
- Navigation and landing fees per trip
- Aircraft utilization hours per year

Some elements are a function of product design, development, and manufacturing, while others depend primarily on airline operating factors.

The first three cost items are closely related to the aircraft's physical design characteristics while the second three are related to the aircraft functional design and the airline's maintenance practices. The last four items include labor costs, fuel costs, and transportation facilities fees.

4.4.2 Cost Analysis Ground Rules and Assumptions

The parametric cost estimates for the baseline trijet were prepared according to the following ground rules and assumptions that were also applied to the all-electric and resized aircraft configurations:

1. The cost analyses are based upon a baseline trijet weight of 268,000 pounds, as defined in the weight report (Reference 4), which represents an FAA-certifiable configuration.
2. The costs of development and production for the alternative trijet study configurations are estimated using four production lots, 200 aircraft each, for a total of 800 aircraft in a span of 15 years.
3. All costs are expressed in 1990 calendar year dollars.
4. Douglas Aircraft is to design, develop, and produce all structures and system provisions in McDonnell Douglas facilities, except for nacelles, which are to be purchased as part of the engine package.
5. Costs are based upon reasonable and continuous production and delivery schedules. The cost impact of compressed or stretched schedules has not been considered.
6. Costs for airborne systems and equipment are included in the flyaway costs; buyer-furnished interior and galley systems are also included.
7. The estimates are success-oriented in that cost-estimating relationships are based upon samples of successful programs. No allowance is included for growth or engineering changes. The estimates assume that a single aircraft configuration for each alternative is developed, with provision for GE, P&W, and RR engines. The aircraft is designed in an environment where requirements are stable and well understood.
8. Production improvement due to a learning curve is progressively incorporated into the cost model for each of the four production lots.
9. Ground testing includes static tests on elements of the airframe, fatigue tests on full-scale wing and fuselage, an iron bird test for flight-control laws and software, and 2,500 hours of wind-tunnel testing.
10. Flight test time of 2,010 hours includes development and FAA certification tests.
11. Power plants are procured from engine manufacturers and include nacelles and thrust reversers as well as the bare power plant. Douglas now furnishes the engine-mounted accessories such as integrated drive generators and hydraulic pumps; however, it should be noted that the hydraulic pumps will be eliminated for the all-electric configuration.
12. The estimate for specific fuel consumption improvement includes the effect of removing the bleed air required for pressurization, ventilation, and anti-icing. The net shaft horsepower change for removing hydraulic pumps and adding generators is also included.
13. Fuel, crew, maintenance, navigation, and landing costs represent the market conditions used in the Douglas Marketing department pricing model on August 1, 1991.
14. No aircraft sales price was used in the operating cost analysis because sales pricing is confidential and only changes in operating cost are needed for the cost/benefit analysis.
15. Values for failure rates, maintenance hours per flight hour, and maintenance material cost per flight hour represent the performance of a mature trijet program.

The aircraft utilization rate applied in the pricing model represents the nominal performance values which airlines are currently experiencing.

These assumptions and ground rules, when applied to the baseline aircraft configuration, provide the data point-of-reference for comparing the changes required for the all-electric and resized all-electric configurations.

The baseline aircraft costs in Table 12 are provided here for reference only. They are discussed in Section 4.7.

TABLE 12
BASELINE TRIJET COSTS

OPERATING COST – DOLLARS/TRIP
1990 ESTIMATES – 3,000 N MI

	BASE
SEATS	323
PASSENGERS	323
REVENUE CARGO (LB)	0
STUDY PAYLOAD (LB)	67,830
STUDY PRICE ($ M)	0
MTOW (LB)	602,500
FUEL CAPACITY (LB)	258,966
OEW (LB)	278,400
BLOCK TIME (HR)	6.775
UTILIZATION (BLOCK HR/YR)	4,234
TRIP COSTS ($/TRIP)	
FLIGHT CREW	5,056
CABIN CREW	6,674
MAINTENANCE	8,608
NAVIGATION	1,227
LANDING FEE	2,350
FUEL 0.60 $/GAL	8,211
TOTAL CASH COST ($/TRIP)	32,126
($/SEAT)	99.46

DEVELOPMENT/PRODUCTION/SUPPORT
COSTS IN 1990 MILLIONS OF DOLLARS

	BASE
RDT&E	
ENGINEERING	1,199
TEST & DEVELOPMENT	671
INITIAL TOOLING	818
SUPPLIER NONRECURRING	907
FSD ILS	58
PROJECT MANAGEMENT	118
TOTAL RDT&E	3,771
PRODUCTION	
TOTAL (800 AIRCRAFT)	68,662
UNIT AVERAGE	86
PRODUCT SUPPORT	
NONRECURRING	309
RECURRING	2,972
TOTAL PRODUCT SUPPORT	3,281

4.5 ALL-ELECTRIC TRIJET DESIGN (WBS 4.2.1)

The all-electric trijet design affected all the systems shown in Figure 29. Bleed air and hydraulic power, in the form of distributed systems, were removed in entirety. Only local derivatives were retained which could operate the function directly and/or with electrical energy as the power source. Among these derivatives were the hydraulic rams, the LVDTs, and the FCC interface servos and modulators.

The removal of bleed air pneumatic power required electrical power designs for the environmental system, engine starting, and ice protection. The removal of hydraulic power required new electrical power designs for the landing gear and the seven flight control functions shown in Figure 29: the spoiler, aileron, slat, flap, rudder, elevator, and horizontal stabilizer.

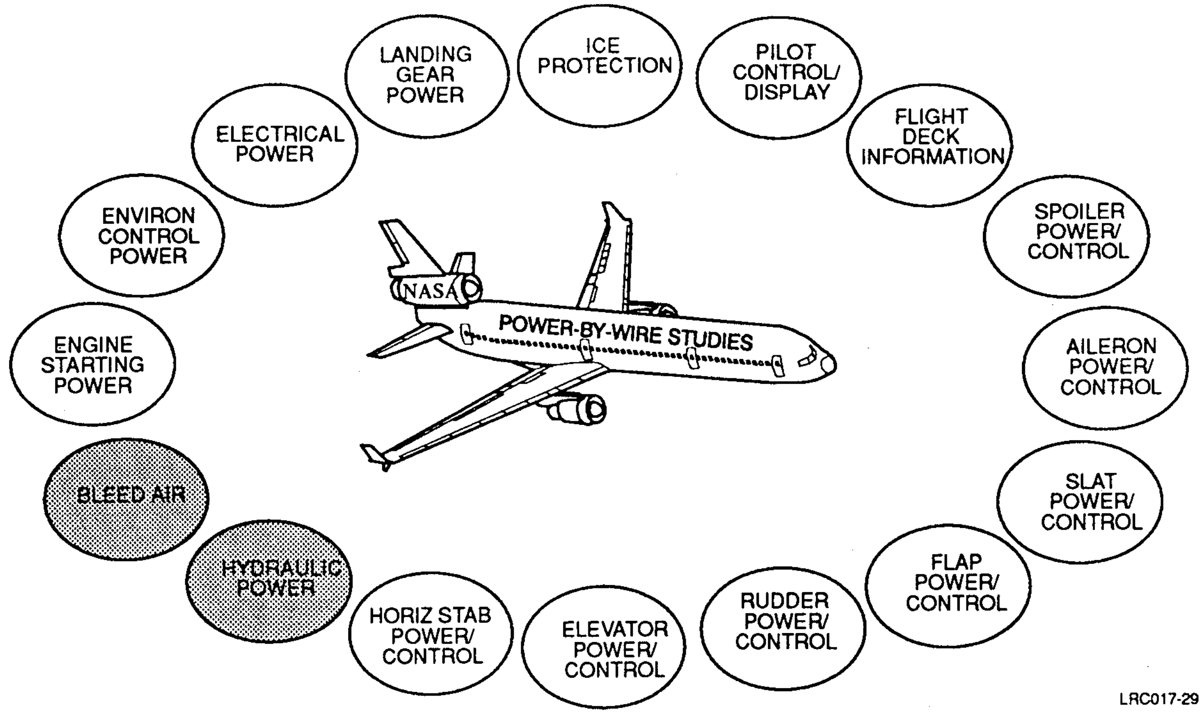


FIGURE 29. SYSTEMS IMPACTED

Key features of the conceptual design approach include: (1) eliminating distributed hydraulic and pneumatic systems; (2) minimizing the impact on other systems; (3) eliminating mechanical controls; (4) retaining 400-Hz power distribution; (5) maintaining power source equivalency; and (6) using available or soon to be available technology. This approach is conservative and credible. The operational characteristics of the existing trijet were retained to minimize impacts on or between systems. Mechanical controls were removed and their redundancy functions were replaced by quad-redundant primary flight control computers, with servo feedback signals to provide normal pilot "feel." Power source equivalency was retained by a one-for-one substitution of an electrical servo pump actuator, an electromechanical actuator, or an integrated actuator package (IAP) to replace the conventional hydraulically powered actuator. To retain a minimum-risk design, only components and technologies that are now available and can be certified in the near term were selected for the system redesigns.

4.5.1 All-Electric Secondary Power Systems

The secondary power system defined for the all-electric trijet aircraft was redesigned from the baseline trijet to be an electrical power system capable of providing all the functions now provided by the hydraulic and pneumatic systems. It retained intact the electrical power system for the baseline trijet to continue service to the unchanged baseline electrical circuits and loads. This was a very pragmatic decision, based upon several factors:

1. The study resources would not support redesign of the existing electrical system.
2. The degree of MD-11 power design, qualification, and certification made it extremely unlikely that any further weight reduction could be realized.

3. The electrical power center and the central accessory compartment are physically unable to accommodate any more equipment.
4. Maintainability would be seriously impaired if physical integration of new equipment with the existing MD-11 should be attempted in the central accessory compartment in front of the wing.

Key design features of the redesigned secondary power systems are briefly described in Table 13. The major loads which will be powered by electrical secondary power in the all-electrical design are shown in Figure 30. This figure also shows the locations of existing trijet power sources, the new all-electric power sources, the new distributed power and load centers, and the main power feeders from the sources to the power centers.

4.5.1.1 All-Electric Power System Architecture — The architecture chosen for the trijet all-electric power system is shown in Figure 31. The existing trijet architecture is shown in the boxed area while the architecture for the new loads is shown in the remaining area. A similar form was selected to maintain commonality with the proven, FAA-certified baseline design. The three new starter-generators are cross-tied by a tie bus, similar to three existing IDG sets. Each new starter-generator supplies power to a generator bus, which supplies a subbus for each of the new secondary power system load groups — flight control, landing gear, and environmental loads. A dual cross-tie bus between the generator tie-buses provides all load buses access to all generators.

An enhanced all-electric system architecture is presented in Figure 31. The landing gear loads, environmental system loads, all of the flight control system loads, the primary flight control com-

TABLE 13
ALL-ELECTRIC AIRCRAFT SECONDARY POWER SYSTEMS

SYSTEM	DIFFERENCES FROM BASELINE
HYDRAULICS	CENTRAL HYDRAULIC SYSTEM, PLUMBING/PIPING AND FLUIDS ARE ELIMINATED
	NO ENGINE-DRIVEN PUMPS ARE PROVIDED
	LOCAL DEDICATED HYDRAULIC LINKS ARE PROVIDED IN ACTUATOR ASSEMBLIES BETWEEN MOTOR PUMP AND MECHANICAL OPERATORS
PNEUMATIC	CENTRAL PNEUMATIC SYSTEM AND DISTRIBUTION DUCTS ARE ELIMINATED
	NO BLEED AIR IS EXTRACTED FROM THE MAIN ENGINE OR THE APU
ELECTRIC	ALL ELECTRIC SERVICES NOW PROVIDED ON THE BASELINE REMAIN INTACT
	REVERSED POWER FLOW IS PROVIDED BY THE BIDIRECTIONAL POWER CONVERTERS FOR ENGINE-STARTING
	APU IS STARTED WITH MAIN BATTERY POWER
	VOLTAGE AND FREQUENCY CONTROL ARE PROVIDED BY PULSE DENSITY MODULATION (PDM) FOR STARTER-GENERATORS AND MOTORS
	VAPOR-CYCLE AIR-CONDITIONING PACKS ARE ELECTRICALLY DRIVEN
	ANTI-ICING AND DE-ICING ARE PROVIDED BY A HYBRID SYSTEM OF ELECTROMECHANICAL DEVICES (TBD) AND ELECTRICAL HEATING FOR LIMITED AREAS (e.g., WINDSHIELDS)
	MANUALLY OPERATED SERVO LINKS ARE PROVIDED AS "BACKUP" FLIGHT CONTROLLERS IN PLACE OF THE CONTROL COMPUTERS IN THE AUTOPILOT SYSTEMS. THESE OPERATE MAIN HYDRAULIC VALVES, AND ALSO PROVIDE SIMULATED LOAD "FEEL" TO THE CONTROL COLUMNS AND PEDALS

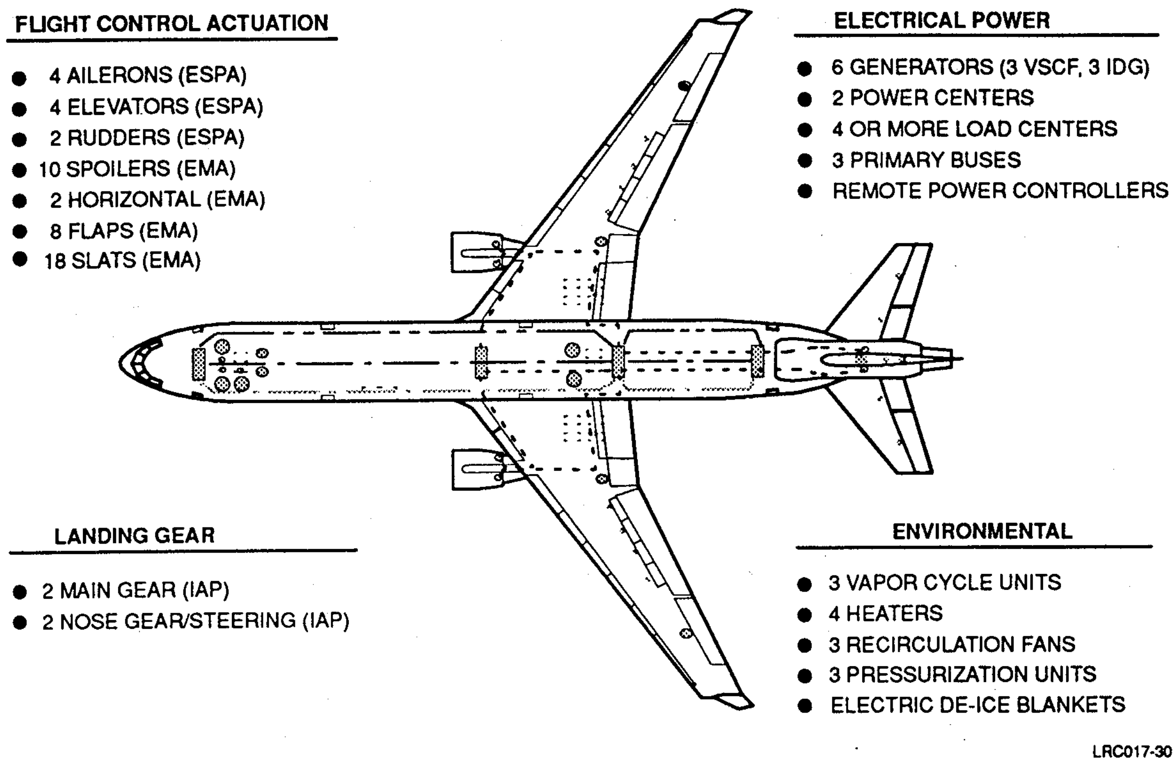


FIGURE 30. ALL-ELECTRIC SYSTEM FEATURES

puters (PFCCs), and the quad-redundant advanced-design ARINC-629 digital data buses are shown in the figure. The electrical source buses for the loads are assigned for proper redundancy in flight control. The bus number assignments match the hydraulic system bus number assignments in the reference trijet transport, thereby retaining the same potential for reliability.

4.5.1.2 All-Electric Power System Architecture — The advanced design concepts that are accommodated by the new all-electric secondary power system designs include resonant power conversion, bidirectional power conversion and control, pulse density modulation for motor and frequency control, electrical engine-starting, and three-phase transmission and frequency control for voltage regulation.

The all-electric model is the same as the 20-kHz design except that it uses three-phase power transmission and frequency control for voltage regulation, while the 20-kHz design used single-phase power transmission and phase control for voltage regulation. This design difference is illustrated by the key components in Figure 32 and by the bidirectional converter design shown in Figure 33 (compare with Figures 8 and 9).

4.5.1.3 All-Electric Power System Architecture — The new system architectures for the redesigned systems are shown in summary form in Figure 34. The electrical power schematic features six generators. Three are existing 120-kva IDGs and three are 180-kva starter-generators, all with a tie bus to accommodate parallel operation. A cross-tie bus permits parallel operation or power-sharing between all buses and generators. A bidirectional converter (BDC) permits power to flow to the load buses or it supports engine-starting with controlled voltage and frequency from the generator buses to the generators.

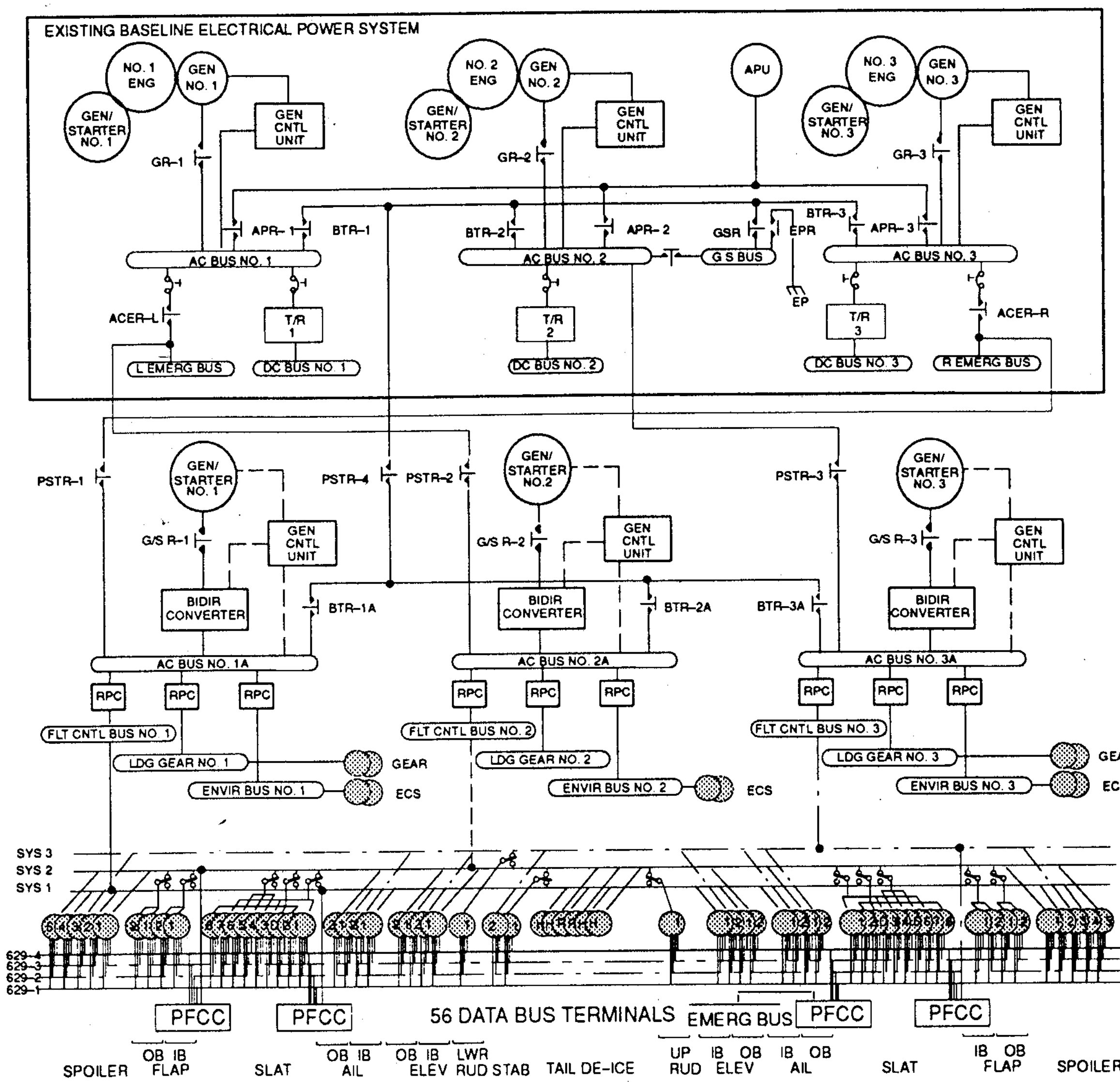


FIGURE 31. ALL-ELECTRIC OVERALL SYSTEM ARCHITECTURE

The environmental system power supply shown in Figure 34 has three 39-kw vapor-cycle air-conditioning packs (V), one from each of the new main generator buses in the new EPC-2 aft of the aircraft wing box. It also shows three 125-kw compressor motors (P) supplied by the three new electrical power buses. Six fans are shown, three to distribute conditioned air and three to provide outside air while on the ground. Four heaters of 16 kw each are provided, one each in the flight deck, forward cabin, mid-cabin, and aft cabin zones. The design is based on 50-percent recirculated and 50 percent new air.

The left spoiler power and control system is also shown in Figure 34. The right side is a mirror image. It provides 6.3 kw of power to drive each electromechanical actuator which can be used because of the low bandwidth and infrequent operation. The bus assignments allow no more than two out of five spoilers on each side to be inoperative upon the loss of any electrical power bus.

The ice protection and slat actuation power design in the figure shows eight slat elements and one drooped leading edge (DLE) slat on the left side, with a mirror image design on the right. Each slat

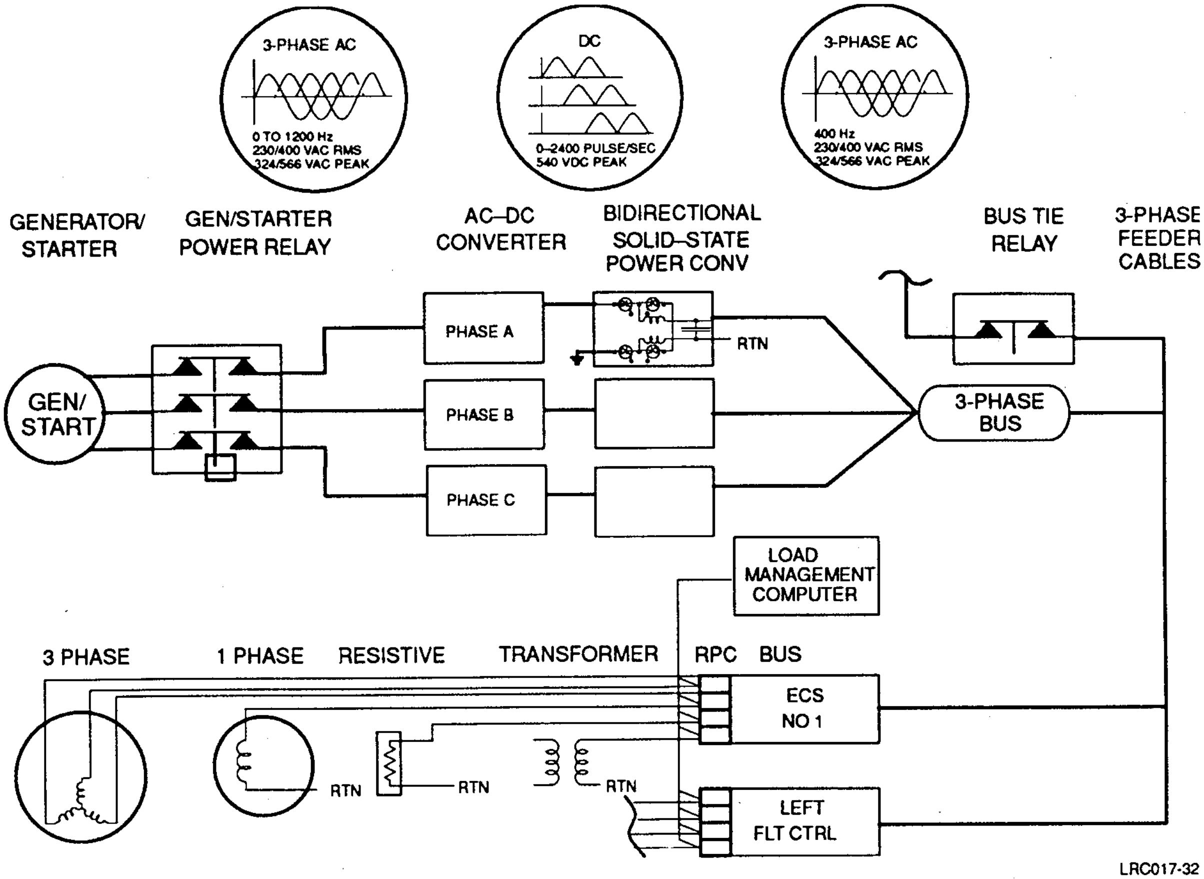


FIGURE 32. KEY COMPONENTS

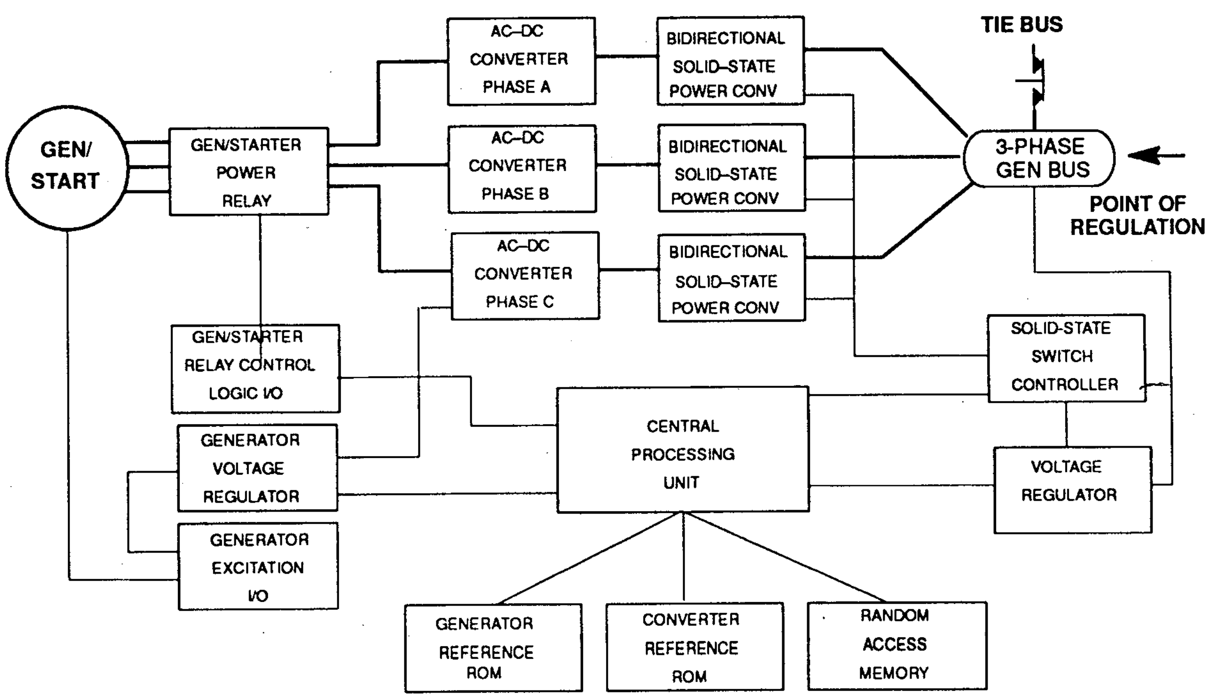
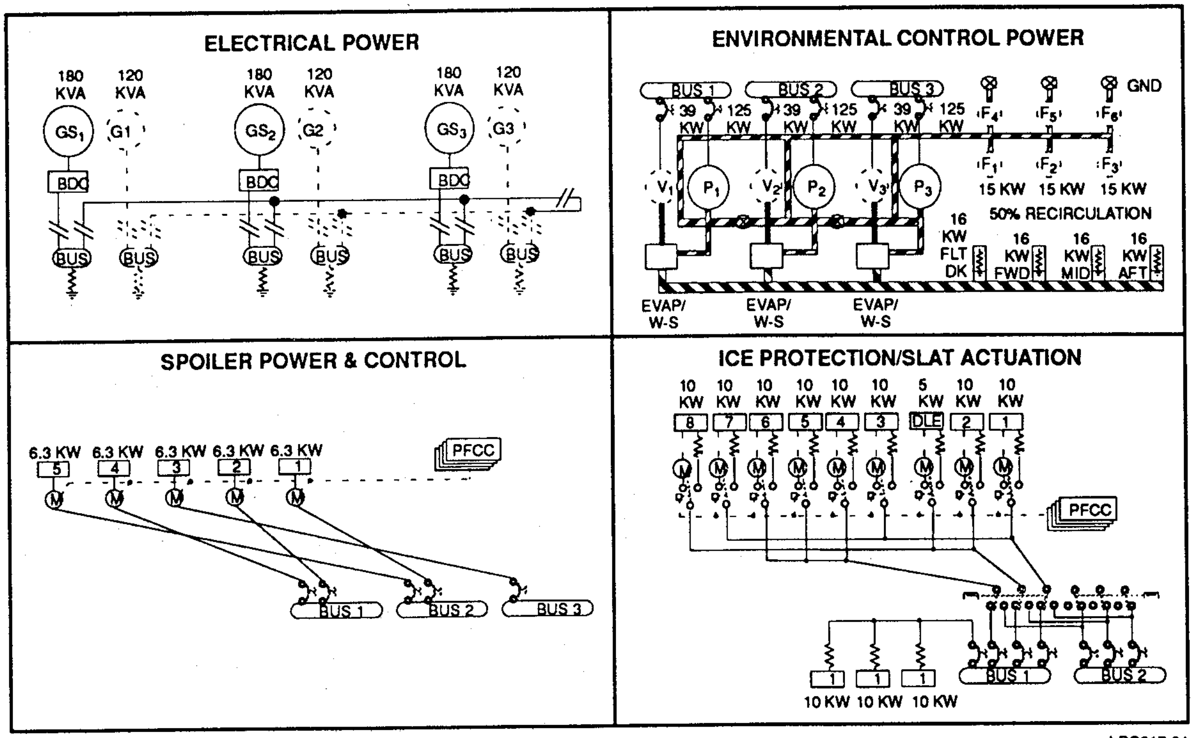


FIGURE 33. BIDIRECTIONAL CONVERTER



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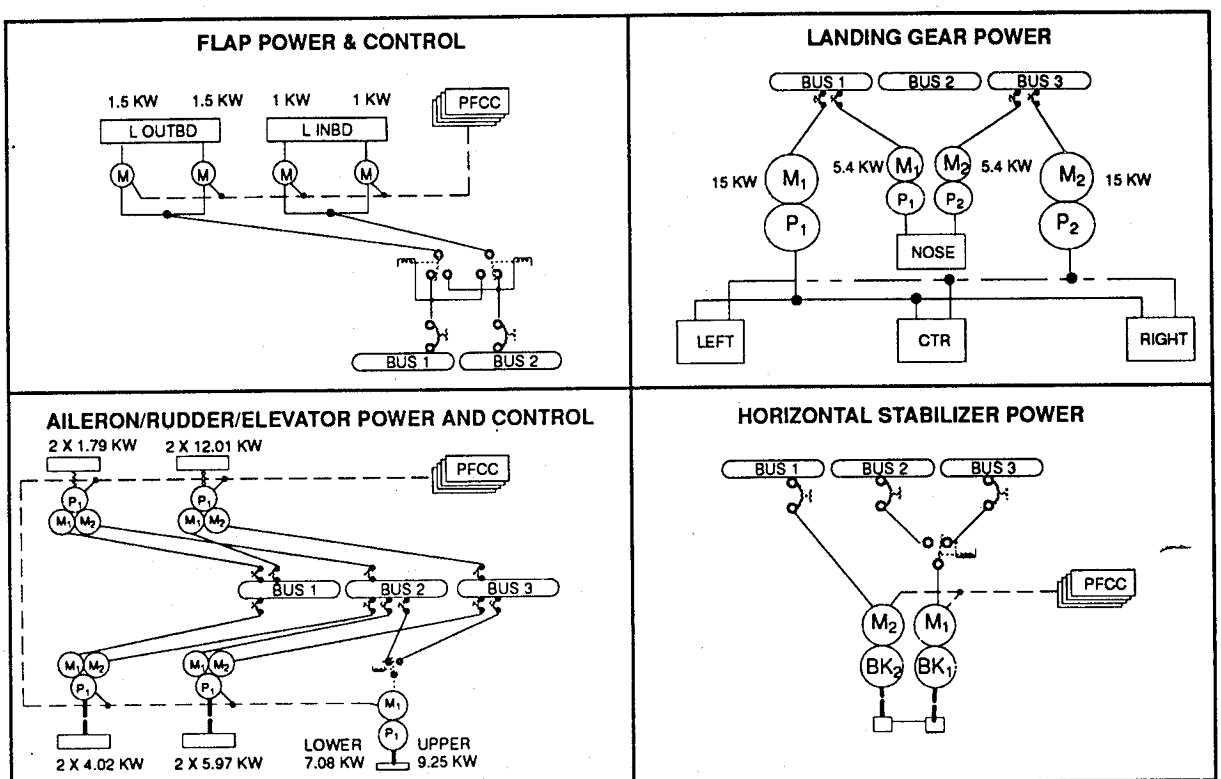

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FIGURE 34. NEW SYSTEM ARCHITECTURES

is driven by a 2-kw motor in the EMA design. During de-icing, each power supply circuit is relay-transferred to a blanket heater, 10 kw for each slat and 5 kw for each DLE. Each of the three main feeders on each wing is transferred to an alternate bus upon loss of its normal feeder power. Each tail leading edge (two horizontal stabilizers and one rudder) is de-iced by a 10-kw blanket heater. All blanket heaters are temperature-monitored, and temperature gradients are controlled by power densities from 1 to 15 w/in.^{3}, with an average of 4.63 w/in.^{2}.

The flap power and control schematic in Figure 34 shows two 1.5-kw EMA drives for each of the two flaps on the left side, with two identical flap drives on the right wing. Either motor can drive each flap, and relay transfer will occur if the normal electrical power source is inoperative.

The landing gear power system schematic in the figure shows a 15-kw integral actuator package (IAP) powered from two electrical main buses for the main landing gear. These pressurize local hydraulic reservoirs, which have sufficient capacity for retracting and deploying the landing gear, and for supplying antiskid braking power for all main and center landing gears. Two of the electrical buses provide 5.4 kw each to the two nose wheel IAPs for retraction, deployment, and steering by local hydraulic power.

The aileron, rudder, and elevator power and control schematic specifies higher bandwidth (up to 100 Hz) for rapid and responsive flight maneuvering and smooth flight control characteristics. Each surface has a dual motor-driven electrical servo-pump actuator with two different electric power buses for redundancy. One exception is the rudder power supply, which has a single 9.25-kw ESPA for the upper rudder and a 7.08-kw ESPA for the lower rudder.

The horizontal stabilizer moves infrequently, in small angular position changes. Both sides are coordinated through dual chain drives and jackscrews, with electromagnetic brakes on the jackscrews. Either motor brake drive assembly can operate both stabilizer sides through the EMA drive differential unit. Access is provided to redundant electrical power from any of the three electrical buses shown in the figure, so the system will not be inoperative upon loss of a main electrical bus.

In general, the electrical power buses described in this section are also served by tie-buses so that the probability of losing all electrical power to any bus is very low. The four primary flight control computers and the dual-redundant flight control computers operating in the autopilot mode together provide a high level of control redundancy.

4.5.2 All-Electric Fly-by-Wire Flight Control System

The flight control system defined for the all-electric trijet air transport utilizes three electrical power channels derived from the three new starter-generator power buses. The systems are summarized in Section 4.5.1. The conceptual fly-by-wire system power schematic and the signal (control) schematic are shown in Figure 35. The dual reference guidance units, dual-dual or quad-redundant air data computers, and triple-redundant inertial reference systems are shown to be digitally linked to the quad-redundant primary flight control computers. The dual-redundant, mechanically parallel cockpit control columns and pedals provide normal flight crew manual control inputs, while the autopilot functions are generated in the dual-redundant FCCs.

The flight control system concept is illustrated in Figure 36. The upper diagram shows the flight control system of the MD-11, a conventional trijet. The dual control wheels and pedals (not shown)

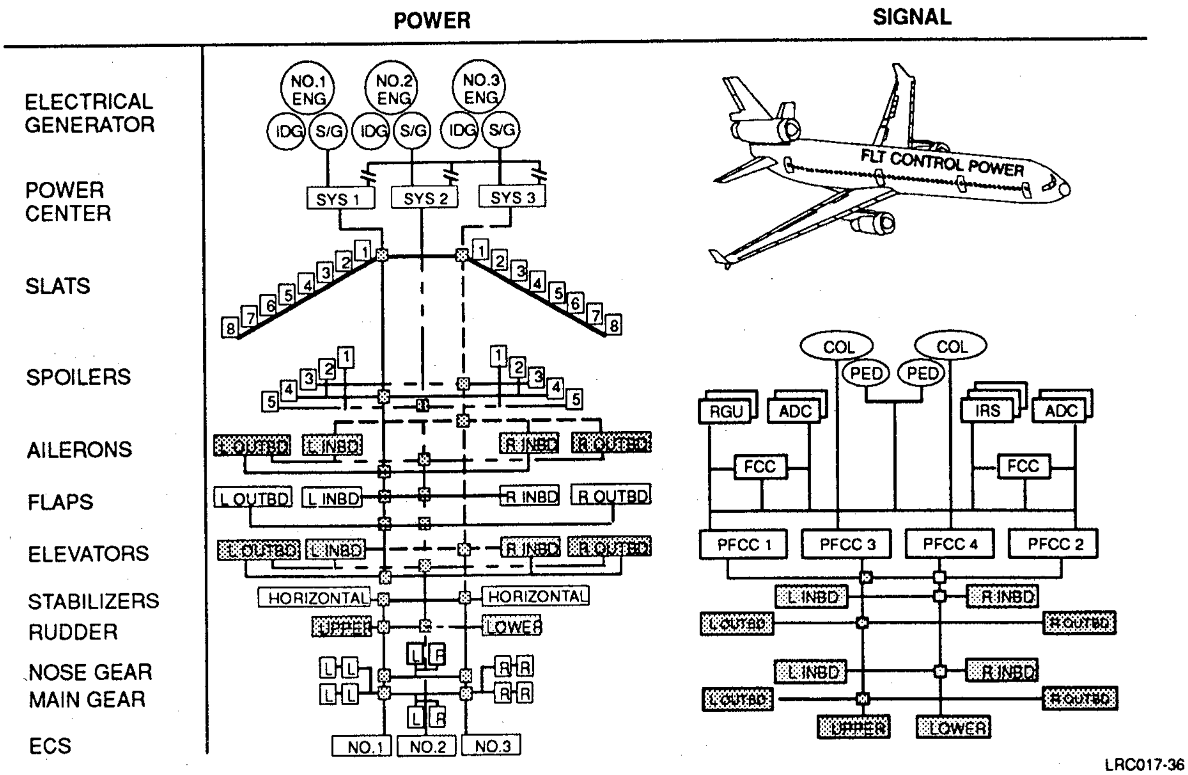


FIGURE 35. POWER-BY-WIRE/FLY-BY-WIRE SYSTEMS

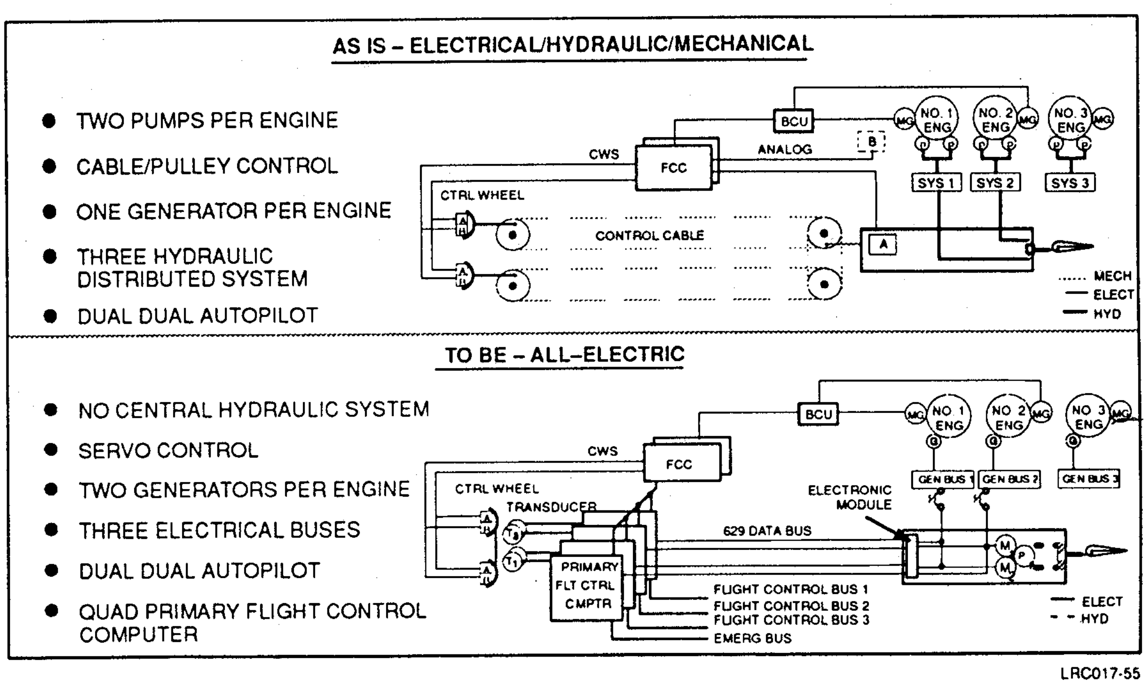


FIGURE 36. FLIGHT CONTROL SYSTEM CONCEPT

provide direct mechanical cable forces to analog elements and hydraulic fluid flow valves for the hydraulic rams that drive the control surfaces. In addition, dual force sensor analog signals (A and B) provide a control wheel steering (CWS) mode in conjunction with the flight control computers where the FCCs command the actuators and the mechanical control cables then move with the flight control surfaces to provide "load feel" to the flight crew. The FCC is fed by the appropriate electrical power source bus, as determined by the bus control unit. The FCC can operate in an autopilot mode with manual trim signals from the cockpit. Figure 36 shows a combination of mechanical, electrical, and hydraulic energy/power transfer media used in the conventional aircraft.

The all-electric schematic is illustrated in the lower half of Figure 36. The control wheels and pedals (not shown), CWS, FCCs, and bus control unit function in the same manner as described above. However, the control wheels and pedals operate through dual-dual redundant servo transmitters (T) to activate control algorithms in the new quad-redundant primary flight control computers. These computers also generate proportional "load feel" torques back to the servo transmitters to provide the flight crew with familiar sensory feedbacks. The computers send the appropriate ARINC-629 data bus command signals to the dual-dual redundant actuator control (servo) electronics modules in the flight control actuators. These receivers then control the ESPAs, EMAs, or IAPs to operate the control surfaces with local hydraulic, electrical, or mechanical energy. The only medium of distributed energy/power for the all-electric trijet aircraft is electrical, while the local mechanical actuator packages utilize the hydraulic, mechanical, or electrical media, generally in their present form.

The term ESPA, for electrical servo pump actuator, has been used to describe a high-bandwidth (at least 100 Hz), responsive, controllable local converter of electrical power to deliver hydraulic and mechanical forces. The ESPA shown in Figure 37 is a servo pump manufactured by Lucas Aerospace, Inc. It is typical for this type of actuator. It contains a high-pressure hydraulic pump

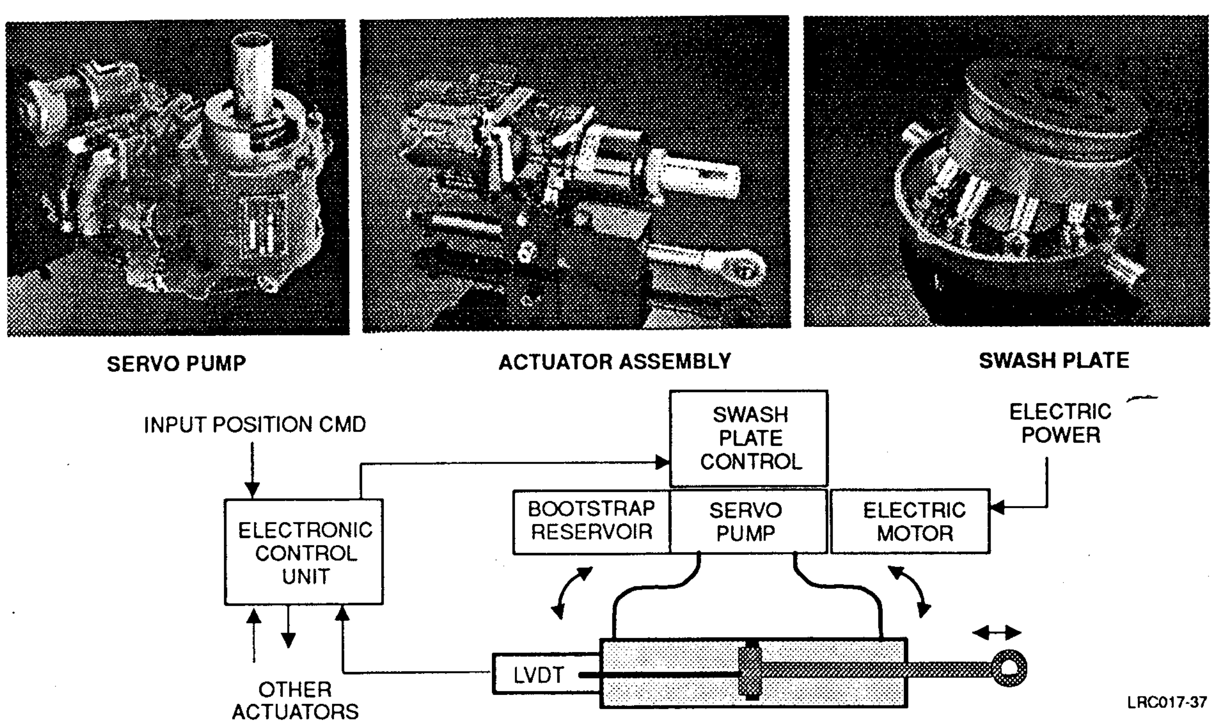


FIGURE 37. LUCAS SERVO PUMP

(3,000 psig or higher) driven by an electrical motor through a modulated swash plate. The swash plate is tilted by its control to modulate the flow rate and direction of the pumped hydraulic fluid to the cavities in the hydraulic ram-actuator. The electric motor runs at constant speed and direction, thereby avoiding the wear and tear, time delay, motor-heating, and switch/control complexities of a rapidly reversing electric motor drive used in such an application. This design is appropriate for a modern flight control autopilot system, which needs high bandwidths to provide smooth flight characteristics at all times; positive control during air turbulence, maneuvering, and landing operations; and active wing load alleviation. The LVDT senses the ram position for the electronic control unit, which receives input position commands and coordinates controls with other actuators.

The study of all-electric flight control systems included trades of alternative designs for electrical equivalences, or "duals," of the present trijet controls and actuators. The driving parameter was the weight, and the second design parameter was reliability. The results of the study are summarized in Figures 38 and 39.

The elevators, located on the aft horizontal section of the tail, are major control surfaces. Each side has an inboard and an outboard surface. The weight estimates for the all-electric versions are shown in the right column of Figure 38 for each of the options studied. The options are described by their redundancy characteristics in the left column. Box 1 shows the present hydraulic system architecture for which the "dual" is being studied.

The primary differences are shown to be in the independence of the motor pump channels and the number of electrical feeders provided to serve those channels. In some instances, electrical transfer

ELEVATOR ACTUATION POWER ALTERNATIVES

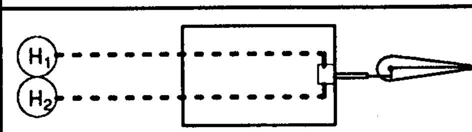
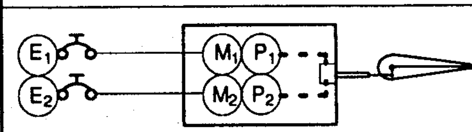
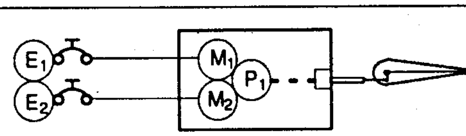
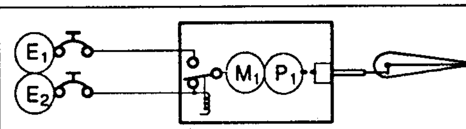
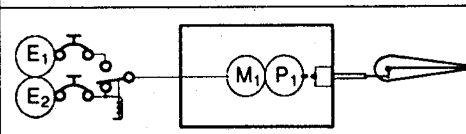
DESCRIPTION	ALTERNATIVE	RELIABILITY (1,000 HR)	WEIGHT (LB)
EXISTING TRIJET DUAL HYDRAULIC DUAL FEED		?	304.0 INBD 276.3 OUTBD
DUAL ELECTRIC DUAL FEED DUAL ELECTRIC/ HYDRAULIC		0.9709	211.5 INBD 164.2 OUTBD
DUAL ELECTRIC DUAL FEED DUAL ELECTRIC/ SINGLE HYDRAULIC		0.9640	193.5 INBD 152.0 OUTBD
DUAL ELECTRIC DUAL FEED SINGLE ELECTRIC/ HYDRAULIC		0.8548	190.3 INBD 150.6 OUTBD
DUAL ELECTRIC SINGLE FEED SINGLE ELECTRIC/ HYDRAULIC		0.8212	187.1 INBD 145.6 OUTBD

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FIGURE 38. ELEVATOR ACTUATION POWER ALTERNATIVES

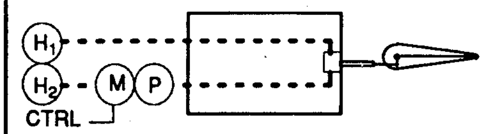
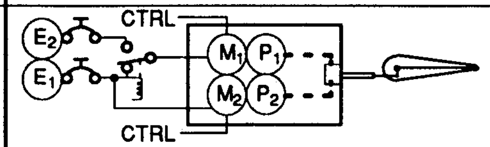
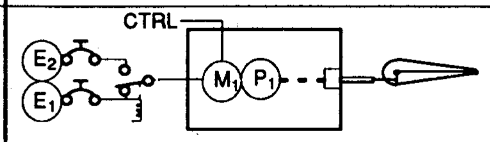
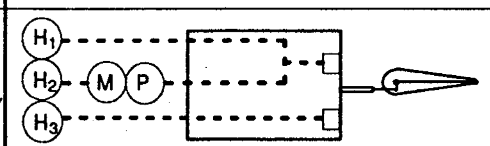
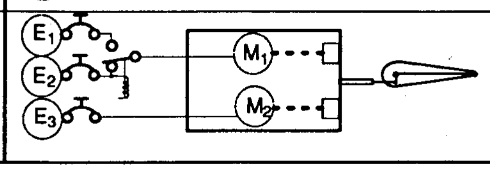
DESCRIPTION	ALTERNATIVE	RELIABILITY (1,000 HR)	WEIGHT (LB)
EXISTING RUDDER DUAL HYDRAULIC DUAL FEED STANDBY		?	205.7 UPPER 207.7 LOWER
DUAL ELECTRIC RUDDER, DUAL FEED DUAL ELECTRIC/ HYDRAULIC STANDBY		0.9635	178.6 UPPER 199.5 LOWER
DUAL ELECTRIC RUDDER, SINGLE FEED SINGLE ELECTRIC/ HYDRAULIC		0.9378	147.8 UPPER 159.2 LOWER
EXISTING HORIZ STAB TRIPLE HYDRAULIC TRIPLE FEED, STANDBY		?	679.6 L & R
TRIPLE ELECTRIC HORIZ STAB, DUAL FEED, DUAL ELECTRIC/ HYDRAULIC		0.9894	760.2 L & R

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FIGURE 39. RUDDER AND HORIZONTAL STABILIZER ACTUATION POWER ALTERNATIVES

relays are used to give alternative electrical feeders or sources. Reliability assessments are shown on a 1,000-hour operational basis. The more familiar 1-hour basis is a little more difficult to read because it contains more 9s. For example, a 1,000-hour reliability of 0.9709 is equivalent to a 1-hour reliability of 0.9999709, yet both represent a mean time between failures (MTBF) of 33,862 hours. A sample calculation is shown in Appendix H.

The reliability value is not shown for the present hydraulic design, nor was it computed. It is not significant and would require consideration of an entire distributed hydraulic channel, which could fail as a whole if fittings or valves fail. By contrast, the electrical system is protected, paralleled, and switchable at many points to obtain a higher inherent channel reliability. For these reasons, all-electric reliability was only computed back to the three-channel electrical buses. These buses are estimated to have a 1 million-hour MTBF (1-hour reliability of 0.999999 or 1,000-hour reliability of 0.999) and their impact upon the flight control circuit reliability is trivial, assuming that the electrical power supply to the bus is of equivalent reliability. The results shown in Figure 38 for elevator actuation boxes 2 and 3 indicate only a 0.0069 difference in reliabilities (27,274 hours vs. 33,862 hours MTBF), yet the weight differences are 18 pounds for inboard and 12.2 pounds for outboard actuation.

The four elevators in the all-electric, digitally controlled system each have two remote power controllers (RPCs), and each elevator can be used independently for partial control authority. This additional operational redundancy has an enormous effect upon the overall flight control system reliability. For example, a 1,000-hour reliability of 0.9640 for each elevator produces a 1,000-hour system reliability of 0.99999832 or a 1-hour reliability of 0.99999999832 (0.832 x 10E-08) with four surfaces. The equivalent MTBF is more than 500 million hours for loss of power to all four elevator surfaces.

The same method of evaluation applies to Figure 39 for rudder and horizontal stabilizer actuation power. The existing rudder and horizontal stabilizer architectures are in boxes 1 and 4, where the M represents the hydraulic motor presently used to isolate two distributed hydraulic systems.

An interesting weight estimate is shown in Figure 39. The horizontal stabilizers powered with ESPA dual circuits are shown to be 80.6 pounds heavier than the existing design. It was later recognized that the existing dual mechanical chain drives, with screw jacks and a differential transmission and mechanical holding brakes, could be replaced by EMAs on each side driving the same mechanical system with electrical motors and simple electrical solenoid brakes. The weight reduction was significant, resulting in nearly equal weights for the existing and all-electric designs.

A preliminary study was made of the merits of fly-by-wire and fly-by-light options which may be applied to either the conventional or the all-electric trijet air transports. The results of this study are summarized in Appendix I. The program funding was not sufficient for a full study of this subject, and the program statement of work indicated that the study technologies would include only fly-by-wire and fly-by-light system interfaces. The weight conclusions of the preliminary study are shown in Figure 40. Each option is shown in terms of its contribution to the total weight of a flight control system based upon the noted combination of technologies. For example, the existing conventional trijet flight control system weight is 5,445 pounds. The design defined by this all-electric

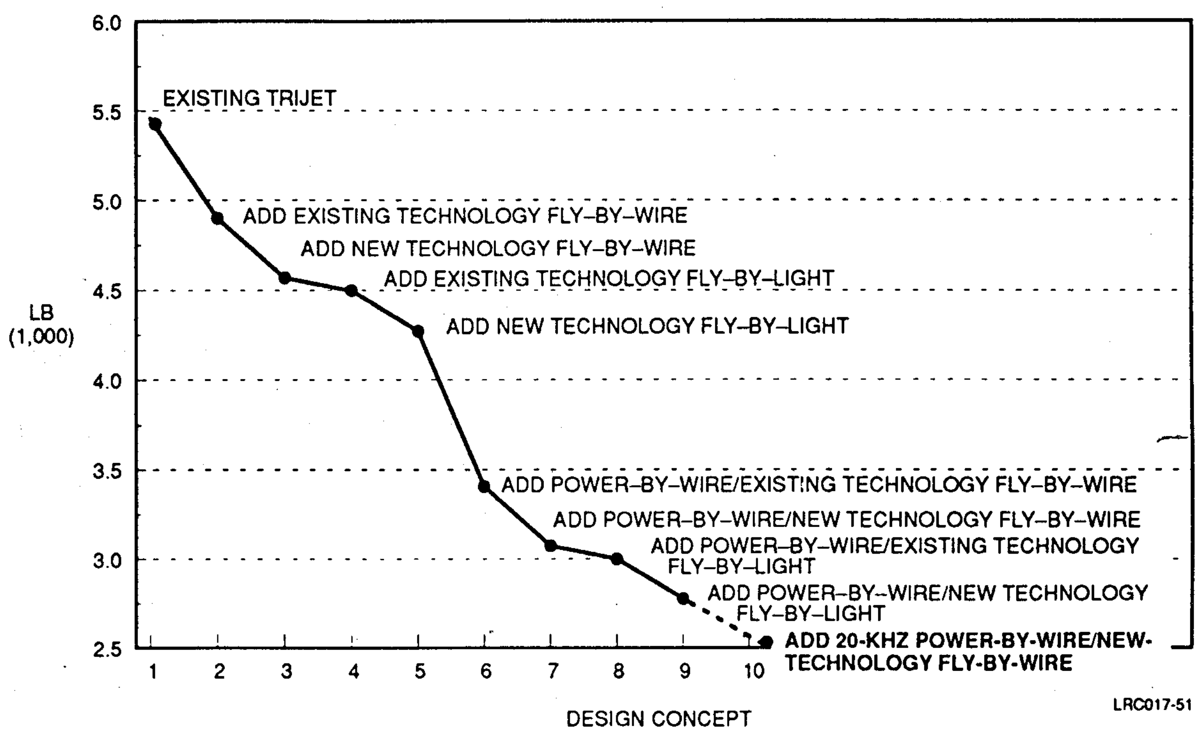

FIGURE 40. FLIGHT CONTROL SYSTEM – ADVANCED DESIGN WEIGHT IMPACTS

study program has all-electric power-by-wire technology and existing ARINC-429 fly-by-wire technology. The system weight is 3,408 pounds, which represents a system weight saving of 2,037 pounds or 37.4 percent. Figure 40 shows that a change in advanced ARINC-629 fly-by-wire technology would reduce the weight to 3,100 pounds and a change in the existing fly-by-light technology should reduce the weight to 3,000 pounds. Further weight reductions of 250 pounds were estimated if the advanced fly-by-light technology is adopted. A general observation has also been made that a 20-kHz power-by-wire system, either complete or selective in scope, would further reduce the weight of any of the options.

4.5.3 All-Electric Environmental System

The all-electric environmental system was defined in conjunction with the AiResearch division of Allied-Signal Aerospace Company. It was sized to meet the capacity of the baseline environmental system, which accommodates 400 passengers. The features of the system are presented in the following text:

- Three motor-driven compressors
- Three vapor-cycle air-conditioning packs
- Three cabin recirculation fans
- Three ground-operated air intake fans
- Electric heaters, distributed within the fuselage
- 50-percent fresh and 50-percent recirculated air supply
- 450 lb/min of air at 40°F for cooling
- Fuel heat-sink for the heat exchangers

The all-electric aircraft environmental system is shown in Figure 41. Three motor-driven compressors, each with a ram air intake, maintain pressure and provide the 50-percent fresh air supply during flight. The vapor-cycle air-conditioning packs cool and dehumidify the fresh and recirculated air supplied to the flight deck and cabin. The power consumption and weight for the three systems are shown below:

Weight	(lb)
Pressurization and cooling	1,429
Recirculation fans and heaters	257
Total for 3 systems	1,686
Power	(kw)
Compressors	375
Vapor-cycle units	117
Recirculation fans & heaters	186
Total for 3 systems	678

The weight and power estimates include the compressors, electric motors, valves, sensors, controllers, heat exchangers, and other minor components.

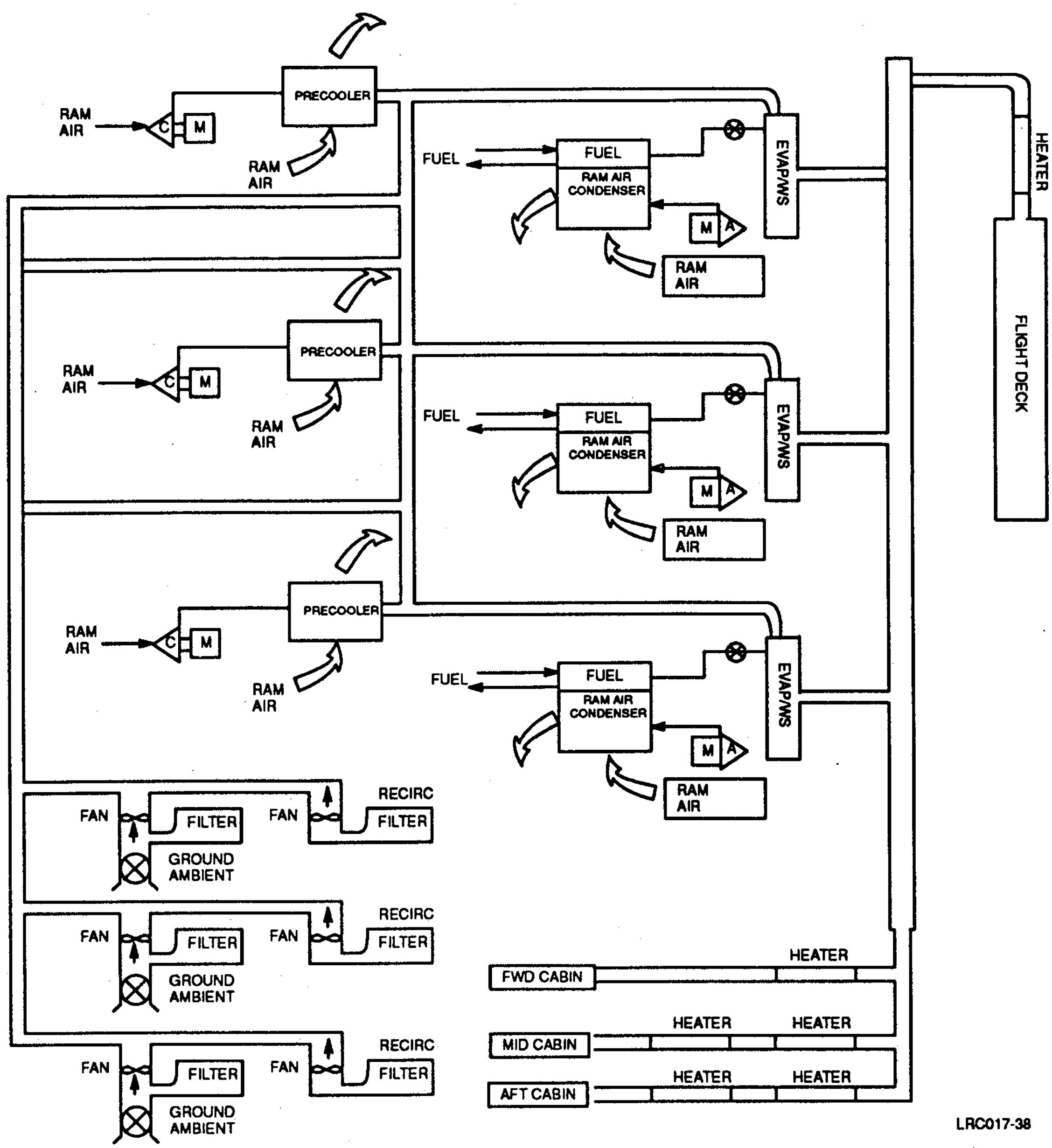

FIGURE 41. ALL-ELECTRIC ENVIRONMENTAL CONTROL SYSEM

The compressor for cabin pressurization is driven by a variable-speed electric motor/controller that is modulated to meet the environmental system air supply demand. The ram-air precooler dimensions are 20 by 22 by 6 inches, and it weighs 30 pounds. The vapor-cycle compressor is a high-speed (up to 40,000 rpm) integrated motor/compressor assembly. The coolant temperature is 173°F at the condenser and 35°F at the evaporator/water separator. The recirculation fans are conventional three-phase 400-Hz 115/200-vac induction motors driving aluminum alloy blades inside a housing. The fans operate at 7,800 rpm and provide a flow rate of 1,200 cfm at sea level with a pressure rise of 14 inches of water.

The system definition provided by AiResearch is sized as a replacement for the baseline trijet environmental system. The use of fuel as a heat sink for the vapor-cycle condenser requires fuel lines to be routed to the nose area of the trijet, where the air-conditioning compartments are located. Installation of fuel lines forward of the wing area is undesirable for numerous reasons. Alternative approaches for heat-sinking should be evaluated in future system optimization efforts.

The 678-kw peak power consumption estimate for the three environmental systems was used in the electrical load analysis with little consideration given to power management. Cooling and heating sequences need to be monitored and controlled to avoid energy waste. Methods for recovery of energy from exhaust air need to be defined and evaluated. More effective load management and refinement of the environmental system design are likely to reduce the system peak power demand by 50 percent, which will bring the overall electrical load in line with the total electrical generator capacity used in this study.

4.5.4 All-Electric Ice Protection Systems

A thermal electric ice-protection concept was developed based upon the anticipated system weight and cost savings and upon the time and budget constraints for the study. The system chosen for the cost/benefit study was selected without a detailed comparison of alternative methods, such as electroimpulse (EIDI), chemical, thermal pneumatic, or pneumatic boots. It was believed that thermal electric ice protection would allow time-sharing of power distribution cables with the leading edge slat actuators.

It was recognized that the all-electric aircraft would have a de-icing system for removal of ice that must be equivalent to the anti-icing system on the baseline trijet.

The thermal electric system design concept was based upon using independent integral thermal electric blankets on the leading edge of each slat and on the leading edge of the vertical and horizontal stabilizers. The engine nacelle ice protection was to remain the responsibility of the engine manufacturer and was retained in its present thermal pneumatic configuration for this study.

The thermal electric system architecture for the left wing and half of the empennage is shown in Figure 42. The concept is also shown in Figure 34.

The total power required for half the system is 115 kw. Each slat was allocated 10 kw except for the smaller drooped leading edge over the wing pylon, which was 5 kw. Each of the tail surfaces was allocated two thermal electric segments with 10 kw each.

The configuration of each 10-kw thermal electric surface is as follows:

Width	~ 1.5 ft
Length	~ 10 ft
Area	15 ft^2
	2,160 $in.^2$
Thickness	0.040 in.
Total power	10 kw
Heat density	4.63 $w/in.^2$, average

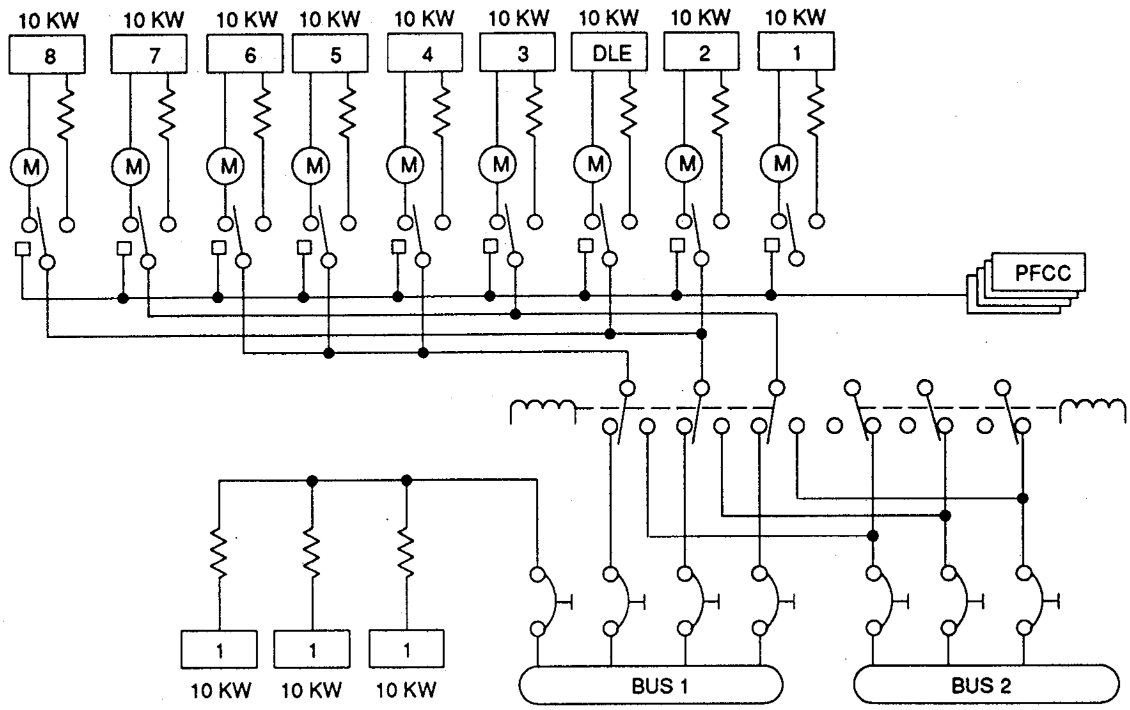

FIGURE 42. ICE PROTECTION/SLAT ACTUATION

The overall aircraft electrical ice-protection requirements are summarized below:

	(kw)
Left wing	85 kw
Right wing	85 kw
Left horizontal stabilizer	20 kw
Right horizontal stabilizer	20 kw
Vertical stabilizer	20 kw
Total	230 kw

The ice-protection power required for the wing leading edge was substantially more than the power needed for the extension and retraction of the slats. Accordingly, a decision was made to time-share the feeder cables with the slat-actuation function. This approach would interrupt the ice-protection power during slat actuation, which occurs for a maximum of 30 seconds only a few times per flight. The shared feeder idea required a switching relay with an intelligent control module and power source.

The primary flight control computer using redundant ARINC-629 data buses was designated as the control source. A solid-state switching device with internal circuit protection for each slat heater and actuator power feeder wire was located on the front spar near the center slat track. Each center slat track requires redesign to incorporate an EMA jackscrew and a telescoping electrical cable in order to supply power to the thermal electric leading edge surface heater. The shared power feeder cable uses a three-feeder configuration rather than a single feeder because a weight analysis showed it to be lighter. A detailed design of the entire system was not within the scope of this study. However, weight impacts were estimated. The weight for each of the 10-kw thermal blankets was estimated at 12 pounds, giving a total of 276 pounds for all surfaces. Other weights for cabling and components can be found in Appendix F.

A thermal electric ice protection system may appear to be heavy and to utilize more power than other methods. However, as shown in Figure 42, it can be easily integrated with other electrically powered functions. A more optimum overall design will be produced when alternative electrical thermal de-icing configurations are evaluated concurrently with an electrical power management system. After the conceptual design and the data analysis were completed, it was discovered that there was no need for thermal electric de-icing of the vertical stabilizer. Elimination of this item would save 20 kw and 24 pounds, and should be included in the refinement of the all-electric design.

4.5.5 All-Electric Propulsion and APU Systems

The general requirements and characteristics for an advanced propulsion power system and the justification for an APU are provided in Section 3.10.4 while the baseline trijet propulsion system and APU are described briefly in Section 4.2.5. The all-electric airplane system design eliminates the pneumatic engine air starters and provides bidirectional power from the main electrical system power buses through the main electrical power converters to the new starter/generators. This power is controlled to drive the new starter/generators as synchronized induction motors. The frequency of the power supplied to the starter/generator is synchronized to the speed of the engine, and the voltage is made proportional to both frequency and engine speed. This design approach maintains both the electrical current and the engine cranking torque at near their constant maximum sustainable values throughout the starting cycle.

The starting performance and profile derived for the General Electric CF6-80C2 engine are described in the starter torque characteristics in Appendix J. The performance depends upon the torque margin available at the peak point. This is where the sum of the drag torque and the accelerating torque is exceeded by the starter/generator motoring torque by the value of the margin selected for the analysis. The margin provides extra torque for degraded performance during the operating life of the engine and the generator, or added drag torque at very low temperatures, and it will reduce the starting time under any given set of conditions. For example, as shown in Appendix J, the starter/generator needs to be only 160.4 kva if the margin is zero (lowest power limit); and it would need to be 191.5-kva for a torque margin of 70 ft-lb. However, the generator size selected to meet the aircraft electrical power demands is 180 kva continuous, giving an available torque margin of 45 ft-lb. It has been calculated that a 70 ft-lb margin at peak torque demand would provide a 35-second starting time on a standard 59°F day, with a longer period at low temperatures. This performance estimate includes the drag torque from a cold (–40°F) 120-kva Sundstrand IDGS driven by the power gearbox of the engine being started, but running with no connected electrical load. The overload rating of the generator (225 kva for 5 minutes) would give much greater torque margins for engine starting.

The specific fuel consumption (SFC) for the engine is an important weight, performance, and economic parameter for the airplane. An analysis showed that elimination of all the bleed air would reduce the baseline SFC by 1.26 percent.*

*The actual baseline trijet SFC value is proprietary.

Table 14 shows the effects of removing the two hydraulic pumps and adding the fully loaded 180-kva starter/generator. With this load, the overall reduction in the baseline SFC is 0.67 percent.

TABLE 14
SPECIFIC FUEL CONSUMPTION CHANGES

NO BLEED BASELINE SFC SAVINGS		−1.26%
SHAFT HORSEPOWER PENALTY		
HYDRAULIC PUMP REMOVAL	−123	
180-KVA GEN/STARTER ADDITION	+241	
NET HORSEPOWER CHANGE	+118	
SFC PENALTY PER 100 HORSEPOWER	+0.50%	
NET SHAFT HORSEPOWER SFC PENALTY	+0.59%	
SHAFT HORSEPOWER SFC PENALTY		+0.59%
NET CHANGE IN SFC		−0.67%

4.5.6 Other All-Electric Aircraft Systems

4.5.6.1 Other All-Electric Aircraft Systems — The landing gear and braking systems operate for very short periods, but they have high energy and power demands. The present local hydraulic systems were determined to be most cost-effective for support of one cycle per flight. Electric motor pumps will be used to pressurize the existing hydraulic reservoirs and to maintain normal pressure during gear retraction, deployment, and antiskid braking operation. This concept is described as an integrated actuator package design. The antiskid braking operation requires a significant average electrical power demand. The present hydraulic reservoir will be retained to store energy from the electrical motor-driven hydraulic pump in order to eliminate high peak power demands.

4.5.6.2 Other All-Electric Aircraft Systems — The electromagnetic environment considerations for aircraft design will be essentially the same for the baseline and the all-electric design of aircraft; these are similar to issues discussed in Section 3.10.1. However, as more electrical services are provided in the all-electric design and more critical systems use the common electrical utility, the possibilities for EMI are increased and the consequences of uncontrolled EMI become more significant. The use of high-frequency conversion and more electronic energy processing does not, of itself, yield greater problems, but possible interactions and corrective action for EMI are of greater concern.

However, the shielding and RF suppression requirements for the self-generated electromagnetic-emission from conversion equipment for 400-Hz power distribution are expected to be less demanding than they would be for 20-kHz power distribution (see Section 3.10.1).

Further, the present systems and functions that are based on nonelectrical actuation mechanisms (e.g., hydraulic, mechanical, or pneumatic) are not included in the EME certification. If these are modified to be either partially or fully electrical-based designs, they would have to be designed and tested for compliance with industry EME standards (see Appendix D).

4.5.6.3 Crew System Technology — The crew system design approach was derived from the preliminary assessments decribed in Section 4.10.2. These were conducted to ensure that all design changes incorporate good human engineering practices. A general guideline followed by all disciplines because of study program time and cost constraints was to limit design changes to those required by an all-electric aircraft.

Following this guideline, where system design changes did not affect the aircrew, no changes were made in their interfaces. For example, a fly-by-wire flight control system did not require changes in the cockpit layout; therefore, none were undertaken. Moreover, where design changes required modification of aircrew interfaces, major efforts were made to retain viable features from the original panels and to incorporate them into the new panels. For example, the elimination of bleed air required extensive redesign of the air panel, but the temperature controls on the original panel needed no change.

This strategy was pursued during redesign of the electrical panel. Most of the original panel was retained, but the elimination of the hydraulic panel required that the electrical panel be expanded to incorporate functions formerly performed by the hydraulic system. During the redesign, every effort was made to keep the changes consistent with the baseline design philosophy to ensure that an integrated crew station would result.

Figures 43 and 44 show the baseline design and the all-electric design views of the overhead panels for the baseline and modified aircraft systems studied during this conceptual design effort.

The approach to system operation is the same as on the original baseline trijet. These systems are fully automated and require no pilot intervention during normal, abnormal, or emergency operations. In case of malfunctions, corrections are made automatically. However, the systems can be placed in a manual operation mode and operated directly by the aircrew should the need arise. The status of these systems is provided to the aircrew on the front instrument panel display units, thus relieving them of any need to directly monitor the overhead panel. These features greatly reduce aircrew workload and allowed the baseline designers to eliminate the flight engineer's position, while permitting the two pilots to concentrate on flying the aircraft.

4.5.7 Weight Analysis

The weight values and the weight comparisons were the most critical data of the study. The cost and performance analyses were conducted with algorithms that used weight as their principal independent variable. Accordingly, major efforts of this study were devoted to careful redesigns that would produce accurate absolute and comparative weights.

4.5.7.1 Weight Analysis Approach — The approach adopted for the all-electric weight analyses was as follows:

1. Determine from the new all-electric system designs which areas of the baseline aircraft would be affected in terms of aircraft weight.
2. Analyze each affected baseline system using the MD-11 Lamm schematic (Reference 3) for replacement of mechanical, hydraulic, and pneumatic systems by electrical system technologies.

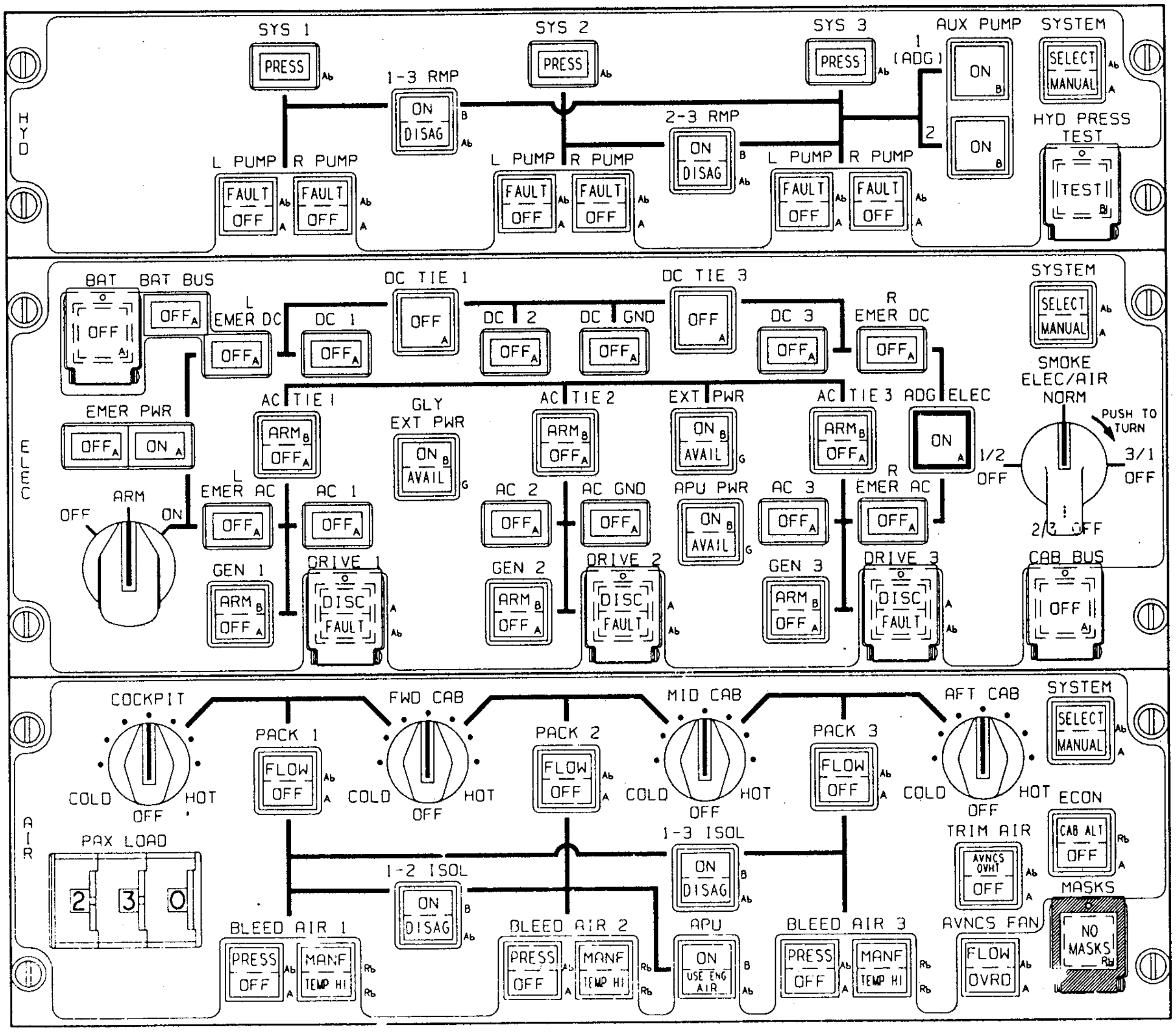

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FIGURE 43. BASELINE OVERHEAD CONTROL PANEL

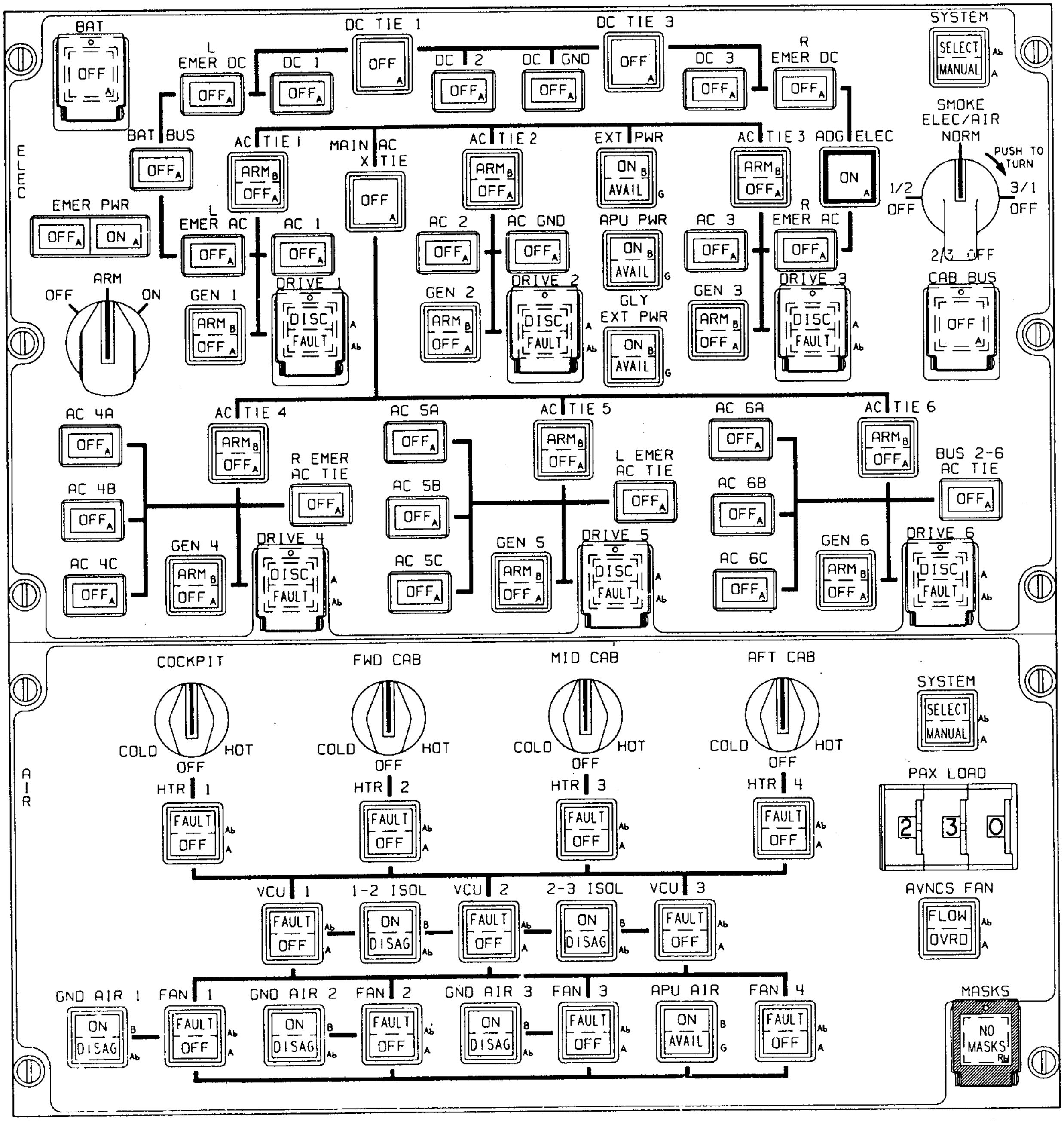

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FIGURE 44. ALL-ELECTRIC OVERHEAD CONTROL PANEL

3. Evaluate each system for weight impact, using the baseline weight data base as described in Section 5.2.7. Then, add, delete, and revise the individual component weight figures.
4. Create a new data base for the changes only, then document it on a personal computer spreadsheet (see Appendix F).

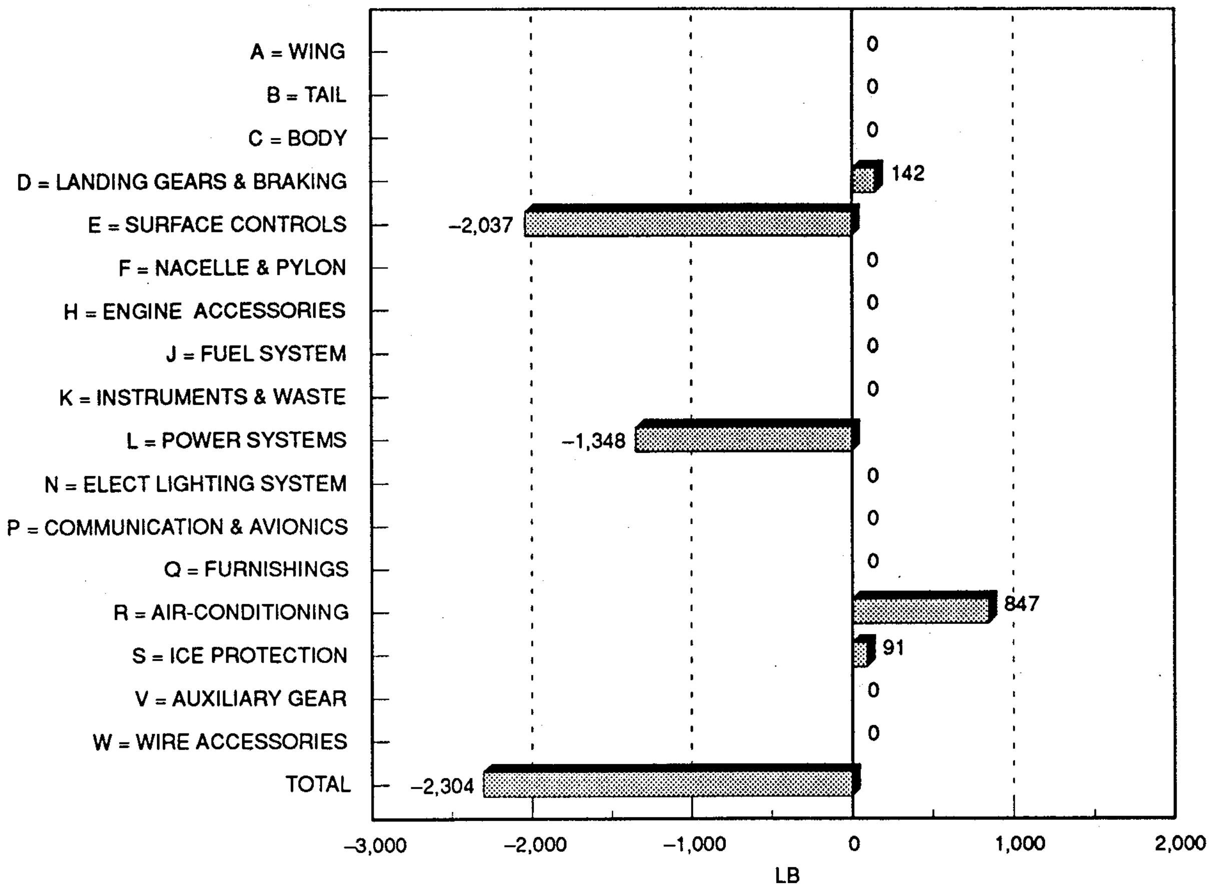
The incremental weight change from the baseline for each system is shown in Table 15. The total weight changes for the entire aircraft are shown in Figure 45. The total weight reduction of 2,304 pounds is composed of weight reductions in surface controls and power systems, and weight increases in the landing gear, air-conditioning, and ice protection systems. The weight differences derived from this analysis were used as drivers for other parametric studies such as performance, reliability, and costs.

4.5.7.2 Main Electrical Power Hardware Weights — Major weight elements for the electrical power system include the new generators, converters, control modules (GCUs and the EPCU/BCU), and the main feeders from the generators to the new electrical power center (EPC-2) located immediately aft of the wing box. The existing trijet EPC (EPC-1) is located immediately forward of the wing box, in the center accessory compartment. The weight estimates were based upon extrapolations from advanced VSCF weight data and on scaling rules derived from reports in the transactions of the IEEE Power Electronics Society, in the Power Conversion Intelligent Motion (PCIM) technical magazines, in the proceedings of the Power Electronics Specialists Conferences, and in related textbooks and research reports.

TABLE 15
SYSTEM WEIGHT ANALYSIS

ITEM CODE	EXISTING (LB)	ALL-EL (LB)	CHANGE (LB)
DA* = MAIN LANDING GEAR	0	130	130
DB* = NOSE LANDING GER	63	75	12
EE* = MISC NEW EQUIPMENT	0	34	34
EF* = AILERON	584	382	−202
EH* = ELEVATOR	816	719	−96
EJ* = RUDDER	378	322	−56
EL* = FLAPS	575	274	−301
EN* = SPOILERS	639	433	−206
EP* = HORIZONTAL STABILIZER	692	597	−95
ET* = GENERAL PLUMBING-SURFACE CONTROL	81	0	−81
EV* = SLATS	1,700	667	−1,033
LA* = AC POWER SYSTEM	5,534	8,276	2,824
LH* = HYD POWER SYSTEM	2,277	0	−2,277
LP* = PNEUMATIC POWER SYSTEM	1,932	37	−1,896
RN* = COOLING AIR SYSTEM	1,263	2,110	847
SA* = WING ICE PROTECTION	183	243	60
SB* = TAIL ICE PROTECTION	111	141	31
TOTAL	16,826	14,440	−2,304

*THIS SUMMARY REPRESENTS ONLY NEW OR CHANGED WEIGHTS AND SHOULD NOT BE MISTAKEN AS TOTAL WEIGHT FOR EACH CATEGORY



NOTE: ENGINE ACCESSORY WEIGHT CHANGES ARE INCLUDED WITH THE PARTICULAR SYSTEM.

FIGURE 45. WEIGHT CHANGES

The length of the main feeders was scaled from the actual trijet configuration. The conductor size was selected from several paralleling options where single conductors per phase had inadequate current capacity, or ampacity. The voltage drop criterion of 5 volts per phase between the generator terminals and the point of regulation located in EPC-2 was used to verify that the ampacity was the limiting parameter rather than the line voltage drop. Copper conductors were used in the engine nacelle, through the pylons, and to wing leading-edge connector blocks for paralleled aluminum conductor connections. The feeder segment lengths are listed in Table 16 and the feeder routing is shown in Figure 46. Selection data are shown in Table 17 for single, dual, and triple conductor feeders in parallel per phase. The feeder alternatives are listed in Table 18. The consolidated main power system weight estimates are shown in the table for channel capacities of 120 kva, 150 kva, and 180 kva.

If additional power is later required, it is suggested that two 120-kva starter/generators be installed on the two unused hydraulic pump pads rather than one 180-kva starter/generator on each engine. This would provide 240 kva per engine of new power rather than 180 kva. It would increase the generator redundancy and system reliability, with nine generators total, and it would increase the main engine-starting torque and power, with two generators per engine. The total electrical power derived from the aircraft engines would be increased from 900 kva in the present design to

TABLE 16
FEEDER LENGTHS

LENGTH (FEET)	TYPE	FROM	TO	EXIST OR NEW
11.0	AN	WING ENGINE GEN	WING FIREWALL	EXIST
15.0	AN	WING FIREWALL	PARALLEL FEEDER CONN.	EXIST
31.7	AL	P.F. CONN.	EPC-1	EXIST
1.0	AN	EPC-1	GEN RELAY	EXIST
11.0	AN	WING ENGINE GEN	WING FIREWALL	NEW
15.0	AN	WING FIREWALL	P.F. CONN. (WING L/E)	NEW
20.0	AL	P.F. (WING L/E)	WING T/E	NEW
23.0	AL	WING T/E	EPC-2	NEW
1.0	AN	EPC-2	STARTER/GEN RELAY	NEW
11.0	AN	TAIL ENG GEN	TAIL FIREWALL	EXIST
13.0	AN	TAIL FIREWALL	PARALLEL FEEDER CONN.	EXIST
126.7	AL	P.F. CONN	EPC-1	EXIST
1.0	AN	EPC-1	GEN RELAY	EXIST
11.0	AN	TAIL ENG GEN	TAIL FIREWALL	NEW
13.0	AN	TAIL FIREWALL	PARALLEL FEEDER CONN.	NEW
91.7	AL	P.F. CONN	EPC-2	NEW
1.0	AN	EPC-2	STARTER/GEN RELAY	NEW

NOTE: L/E IS THE LEADING EDGE OF THE WING; T/E IS THE TRAILING EDGE OF THE WING; AND P.F. IS THE PARALLEL FEEDER SECTION WITH TWO OR MORE CONDUCTORS IN PARALLEL PER PHASE TO CARRY THE HIGHER FEEDER CURRENTS.

1,080 kva, and the weight for the main power system (see Table 19) would increase by 427.5 pounds from 1,447.7 to 1,875.2 pounds.

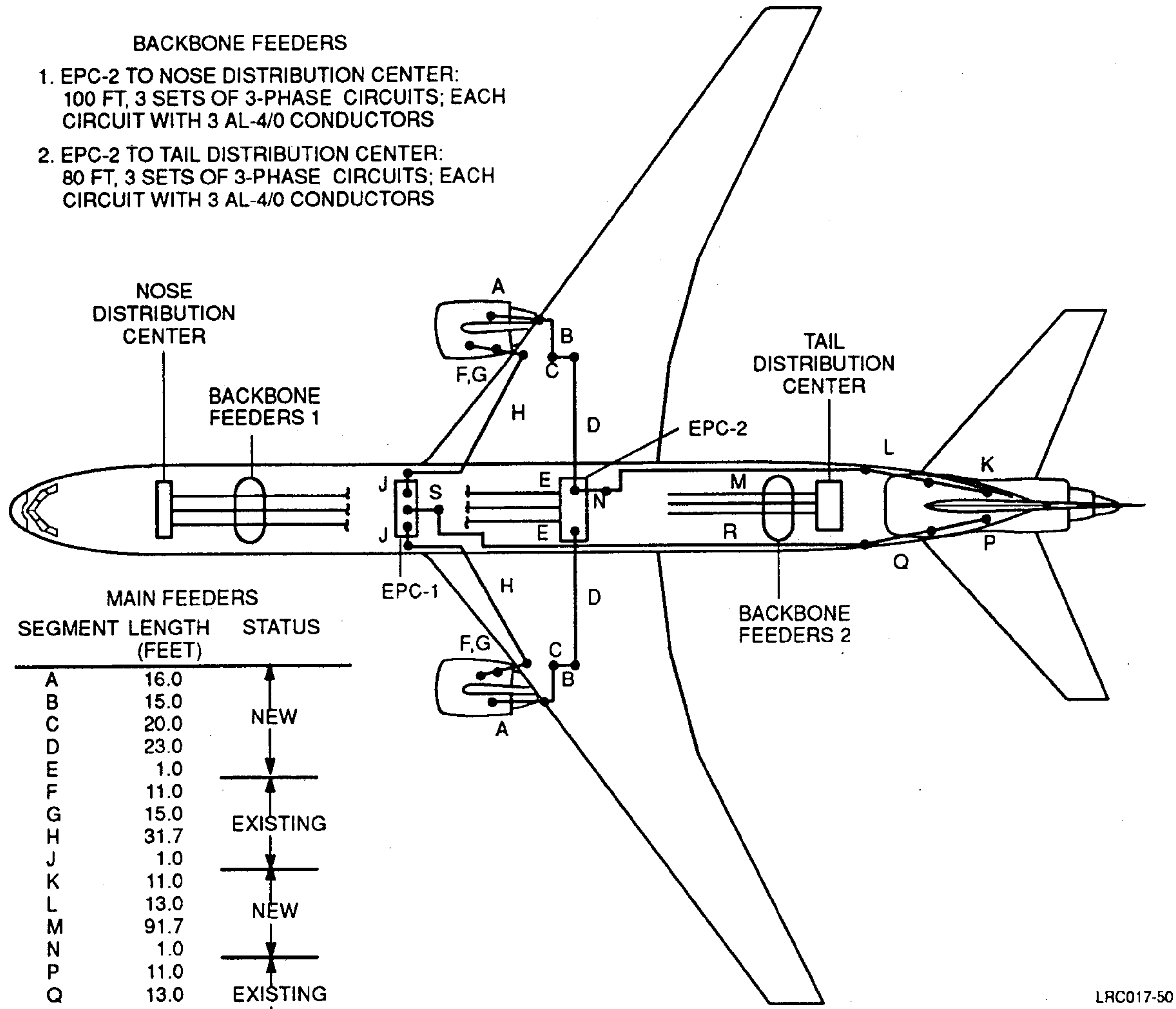
The generators, converters, and related hardware weights were extrapolated from data on conventional Douglas trijets, accumulated proposals, and briefings for dc-link converters with switching-mode inverters rated 90 kva. The generators are assumed to be of conventional design and synchronous, but driven as variable-speed, variable-frequency, proportional-voltage induction motors for engine-starting, with the control logic provided to the converters. Conventional VSCF converters are estimated to be 1.9 lb/kva per channel, of which 0.7 lb/kva is in the generator operated at a nominal 1,000-Hz frequency and 1.2 lb/kva are in the converter/filter/transformer assembly. The GCU weight for 90 kva is 12.8 pounds per channel; the EPCU/BCU weight for 90 kva is 13.8 pounds per channel. Power relays are sized for 120 kva (346 amperes per phase at 115/200 volts). These are to be used at 90 kva (260 amperes per phase), but the actual weight will depend upon the number and type of auxiliary contacts provided.

4.6 ALL-ELECTRIC LOAD ANALYSIS (WBS 4.2.2)

The same approach was followed for the all-electric load analysis as for the baseline analysis. The steps taken were: (1) use baseline load analysis program; (2) identify added loads; (3) estimate efficiency and power factors; (4) establish functional criticality and assign to buses; (5) estimate load duty cycles; and (6) accumulate loads. The analysis was generated and documented using a personal computer spreadsheet which is included in Appendix G. Because the new electrical power system would be added to the baseline power system, it was determined that the new all-electric loads should be analyzed using the same criteria applied for the baseline load analysis.

BACKBONE FEEDERS

1. EPC-2 TO NOSE DISTRIBUTION CENTER: 100 FT, 3 SETS OF 3-PHASE CIRCUITS; EACH CIRCUIT WITH 3 AL-4/0 CONDUCTORS
2. EPC-2 TO TAIL DISTRIBUTION CENTER: 80 FT, 3 SETS OF 3-PHASE CIRCUITS; EACH CIRCUIT WITH 3 AL-4/0 CONDUCTORS



MAIN FEEDERS

SEGMENT	LENGTH (FEET)	STATUS
A	16.0	NEW
B	15.0	NEW
C	20.0	NEW
D	23.0	NEW
E	1.0	NEW
F	11.0	EXISTING
G	15.0	EXISTING
H	31.7	EXISTING
J	1.0	EXISTING
K	11.0	NEW
L	13.0	NEW
M	91.7	NEW
N	1.0	NEW
P	11.0	EXISTING
Q	13.0	EXISTING
R.	126.7	EXISTING
S	1.0	EXISTING

FIGURE 46. MAIN POWER FEEDER PLAN

TABLE 17
FEEDER SELECTION DATA

FEEDER CONDUCTOR TYPE AND SIZE	CIRCUIT WEIGHT FACTOR (LB/KVA/1,000 FT)	CIRCUIT LENGTH LIMIT (FT)	POWER LIMIT		
			SINGLE (KVA)	DUAL (KVA)	TRIPLE (KVA)
AN-1/0	22.14	133.9	51.75	103.50	155.25
AN-2/0	23.95	129.3	60.38	120.76	181.14
AN-3/0	26.96	121.4	69.00	138.00	207.00
AN-4/0	29.76	110.9	77.63	155.26	232.89
AL-1/0	11.73	148.4	42.44	84.88	127.32
AL-2/0	12.23	133.9	50.03	100.06	150.09
AL-3/0	13.42	144.9	55.89	111.78	167.67
AL-4/0	13.87	131.1	65.55	131.10	196.65

TABLE 18
FEEDER SELECTION ALTERNATIVES

CHANNEL POWER (KVA)	FEEDER OPTIONS	FEEDER WEIGHT (3-WIRE)	
		(LB/1,000 FT)	(LB/100 FT)
120	3 x AL-1/0	502	50.2
	2 x AL-4/0	592	59.2
	2 x AN-2/0	1,050	105.0
150	3 x AL-2/0	609	60.9
	3 x AN-1/0	1,245	124.5
180	3 x AL-4/0	888	88.8

TABLE 19
NEW MAIN ELECTRICAL POWER SYSTEM WEIGHT ANALYSIS

SYSTEM COMPONENTS	OPTION 1	OPTION 2	OPTION 3
CHANNEL RATING	120 KVA	150 KVA	180 KVA
CHANNEL CURRENT	348 AMP	435 AMP	522 AMP
STARTER/GEN (0.7 LB/KVA)	84 LB	105 LB	126 LB
BIDIRECT CONVERTER RESONANT WITH FILTERS (40% CONVENTIONAL AT 0.48 LB/KVA)	57.6	72.0	86.4
PDM SYNTHESIZER (TO 400 Hz; 25% CONVENTIONAL AT 0.30 LB/KVA)	36.0	45.0	54.0
CHANNEL SUBTOTAL	177.6 LB	222.0 LB	266.4 LB
THREE CHANNELS (SUBTOTAL)	532.8	666.0	799.2
POWER FEEDERS			
ST/GEN CHANNEL 1 (50 FT x 3-WIRE)*	102.2 LB (3 x AL-1/0)	118.2 LB (3 x AL-2/0)	157.9 LB 3 x AL-4/0)
ST/GEN CHANNEL 2 (116 FT x 3-WIRE)*	200.4 (3 x AL-1/0)	237.6 (3 x AL-2/0)	332.7 (3 x AL-4/0)
ST/GEN CHANNEL 3 (50 FT x 3-WIRE)*	102.2 (3 x AL-1/0)	118.2 (3 x AL-2/0)	157.9 (3 x AL-4/0)
THREE CHANNEL FEEDERS (SUBTOTAL)	404.8 LB**	474.0 LB	648.5 LB
TOTAL MAIN POWER	937.6 LB	1,140.0 LB	1,447.7 LB

* INCLUDES 11.0 FT OF 4-WIRE WITH GROUND FROM GENERATOR TO FIREWALL AND COPPER CABLE SEGMENTS (NOT LISTED).
**THE ALTERNATIVE (2 x AL-4/0) WOULD WEIGH 400 LB,BUT WOULD BE MUCH HARDER TO INSTALL.

For this analysis, the following assumptions and methods were utilized:

- The flight profile is based on a night flight with 65 percent of the reading lights on, a full load of fuel, and the galleys operating.

- The flight is nonstop and the aircraft will be on the ground only long enough to load and unload passengers.
- Where multiple power sources are required, such as in the case of standby power for flight controls, only the actual power requirement is listed.
- The operation time for each load was derived from actual data where available, existing operation times for components related to the converted system, and subjective evaluations by cognizant personnel. Notes are included in Appendix G to further define the operation times.
- Hydraulic, pneumatic, and environmental loads were converted to equivalent electrical loads. Where new electrically driven equipment was required (e.g., flight control computers), data from similar existing equipment were used.
- Efficiencies and power factors were estimated based on existing technologies available at this time.

Each load was evaluated for functional criticality and was determined to be an essential, nonessential, or monitored load. Essential loads are required to maintain controlled flight; nonessential loads may be disconnected under conditions of limited power but can be recovered; and monitored loads are automatically disconnected during limited power availability, but can also be recovered.

Three analyses were made for each operating condition; a 5-second, a 2- or 5-minute, and a 15- or 30-minute interval.

The operating conditions were defined as follows:

Loading — The condition between securing the aircraft and preparing to start the engine. Typical loading operations consist of hoisting, fueling, lighting, radio communications, heating, and cooking. Power is supplied by the APU, the batteries, or external (ground) power.

Start — The condition from preparation for engine starting to initiation of aircraft taxiing.

Taxi — The condition from the aircraft's first movement on the ground to the start of the takeoff run.

Takeoff and Climb — The condition commencing with the takeoff run and ending with the aircraft leveled-off and set (trimmed) for cruise.

Cruise Cold Day — The condition in which the aircraft is in level flight and the ice protection and heating equipment are operating.

Cruise Hot Day — The condition in which the aircraft is in level flight and the ice protection and heating equipment are not operating.

Descent and Landing — The condition in which the aircraft reduces altitude, enters the base leg of an airport approach, lands, taxis, and is secured with engines shut down.

Emergency — Any period of the flight in which the required normal sources of power are inoperative. During this time, the essential loads required for safety of flight are powered by the emergency power system.

Ground Service — Performance of maintenance, service, and cleaning operations. During this condition, only the ground service buses are powered.

The new all-electric loads were identified in the areas of flight control, landing gear, and environmental and ice protection. Each load was given a detailed analysis, as shown in Appendix G. The loads were accumulated and categorized by the equipment name and a modified reference designator.

Horsepower ratings were included in the analysis primarily for hydraulic, mechanical, and pneumatic requirements. These horsepower ratings allow for conversion to electrical requirements using the mathematical formulas shown in Appendix G. To remain consistent throughout the analysis, horsepower ratings are included for nonhydraulic, nonmechanical, and nonpneumatic devices such as flight computers or relays.

Figure 47 shows the connected load totals derived for horsepower, kilowatts, and kilovoltamperes for the newly established all-electric loads. The higher load requirements in the area of environmental and ice protection are readily apparent. As shown in Appendix G, the connected load "on-times" were applied to the relevant operating conditions using intervals of 5 seconds, 2 or minutes, and 15 or 30 minutes. For the operation times that were determined to be less than the interval of the specific column heading, a percentage of operation time is given. For continuous load, the applied time is 100 percent of the time interval. Figure 48 shows the total averaged loading for the new

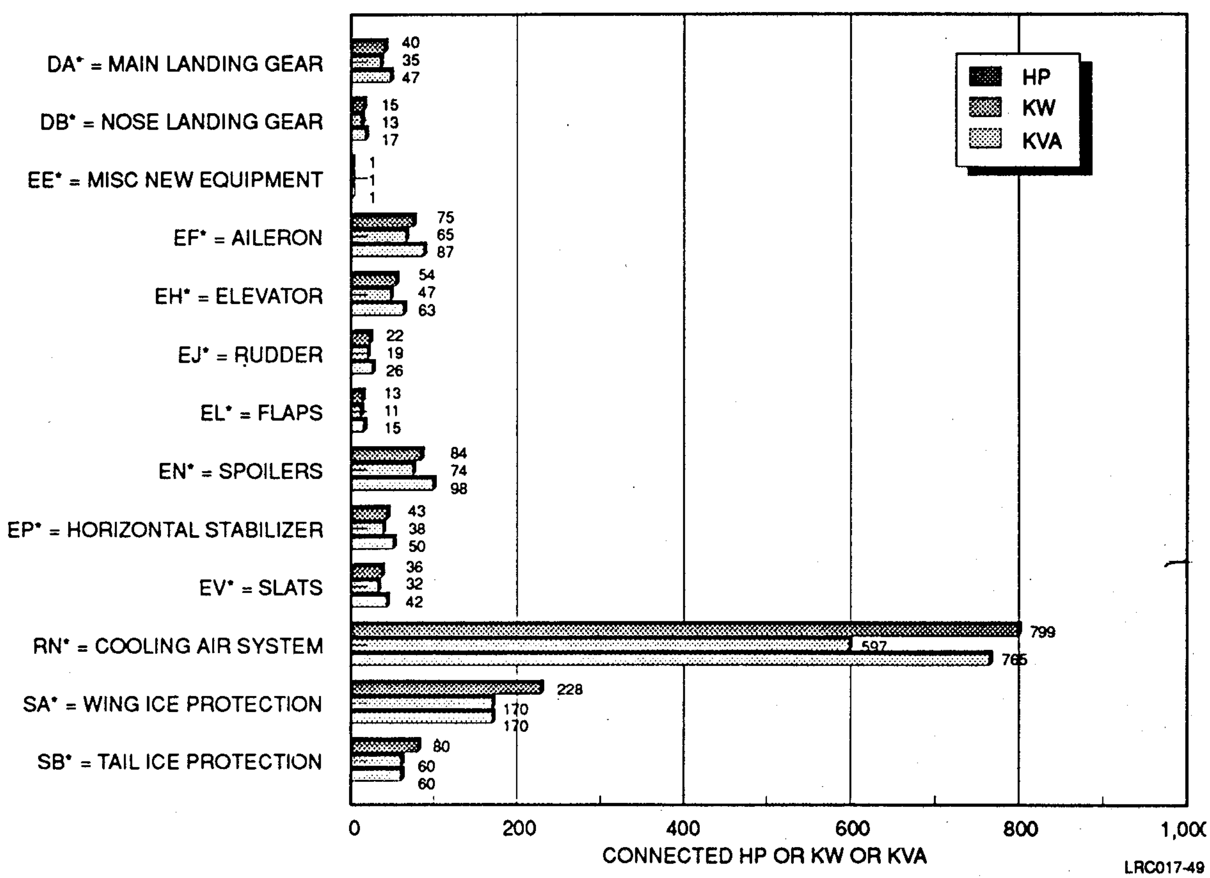


FIGURE 47. ADDED ALL-ELECTRIC ALTERNATING CURRENT LOADS BY SYSTEM

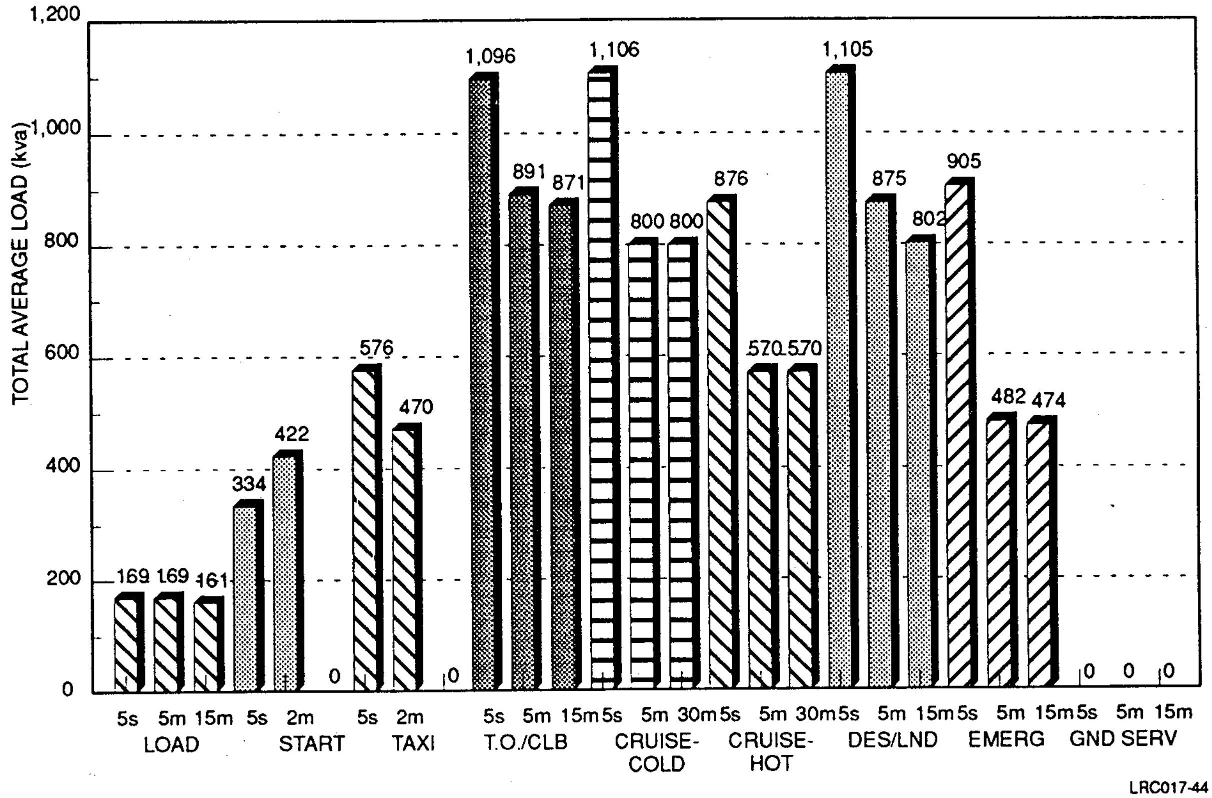


FIGURE 48. LOAD ANALYSIS FOR ADDED ALL-ELECTRIC SYSTEMS

all-electric ac loads, for each operating condition and time interval. The bar graph was derived from the section of the load analysis with column headings LD1-5S through GS3-15M. The kva rating for each connected load was used to compute the average load for each condition and interval. Each connected load was subjected to the following formula to obtain its average load power value:

Average kva = (total kva per load x operating time) divided by the appropriate time interval

The averaged loads in each of the time-interval columns were then totaled to give the values shown above each bar in Figure 48. The graph shows that the peak conditions occur during all phases of flight. This is due to simultaneous operation of landing gear, flight control, and environmental equipment. To minimize these peak requirements, power management should be considered in future analysis of the all-electric loads. Engine starting power is not included in Figure 48 (see Section 4.5.5 and Appendix J).

4.7 ALL-ELECTRIC COST ANALYSIS (WBS 4.2.3)

The all-electric trijet cost analysis used the same methodology and computer models as described for the baseline in Section 4.4. The methodology can be summarized as follows:

- Determine the all-electric design weight and SFC changes
- Run the all-electric and resized performance computer models
- Analyze new all-electric system reliability and maintainability characteristics

- Run the all-electric and resized airline operating cost model
- Run the engineering/manufacturing/logistics cost model
- Compare the baseline, all-electric, and resized costs

The following analyses were conducted to quantify the cost/benefits for an all-electric aircraft: weights, electrical load, aircraft performance, reliability, aircraft maintainability, engineering, manufacturing, integrated logistics support (ILS), and market analyses.

The following section presents the results of each analysis, except for the weight analysis (Sections 4.2.7 and 4.5.7) and electrical load analysis (Sections 4.3 and 4.6).

4.7.1 Aircraft Performance Analysis

The performance data for the baseline trijet configuration were modified to reflect the 2,304-pound system weight saving and the 0.67-percent SFC improvement defined in Sections 4.5.5 and 4.5.7. The all-electric configuration was resized using the scaling methodology of the Douglas Advanced Aircraft Design group to synthesize a new configuration. The new configuration has smaller wings and a smaller engine, which produces the lower thrust requirement. The new wing and engine were both lighter, but the aircraft mission parameters were unchanged. The results of this analysis are shown in Table 20.

Passenger capacity, payload, thrust, wing area, and range parameters were initially held constant for the all-electric configuration to ensure that the resulting cost/benefits would contain only the impacts of the all-electric design changes. When the operating empty weight was reduced by the system weight savings, the performance analysis showed that the aircraft could use a slightly slower approach speed and a shorter takeoff field length and that the fuel consumption would be reduced by 1.2 percent.

For the resized configuration, the approach speed and takeoff field length were kept the same as for the baseline, while the wing size and the engine thrust were scaled downward to match the

TABLE 20
AIRCRAFT PERFORMANCE DATA

	BASELINE	ALL-ELECTRIC	RESIZED
ENGINE	GE	GE	GE
MTOGW (LB)	602,500	596,500	591,500
OEW (LB)	278,400	276,100	273,000
PASSENGERS	323	323	323
PAYLOAD (LB)	67,830	67,830	67,830
THRUST/ENGINE (LB)	61,500	61,500	60,225
WING AREA (FT^2)	3,648	3,648	3,589
RANGE (N MI)	6,600	6,600	6,600
APPROACH SPEED (keas)	139	138	139
T.O. FIELD LENGTH (FT)	10,550	10,200	10,550
BLOCK FUEL (LB)	91,692	90,588	89,750

reduced lift requirements. The resized all-electric configuration then resulted in a reduction in maximum takeoff gross weight of 11,000 pounds and a 2.12 percent reduction in total fuel consumption. This information is shown in Figure 49. The benfit ratio is 4.77 pounds of total weight reduction for each pound of hardware weight eliminated.

Engines designed for no bleed-air or very little bleed-air requirements are expected to show additional SFC improvement.

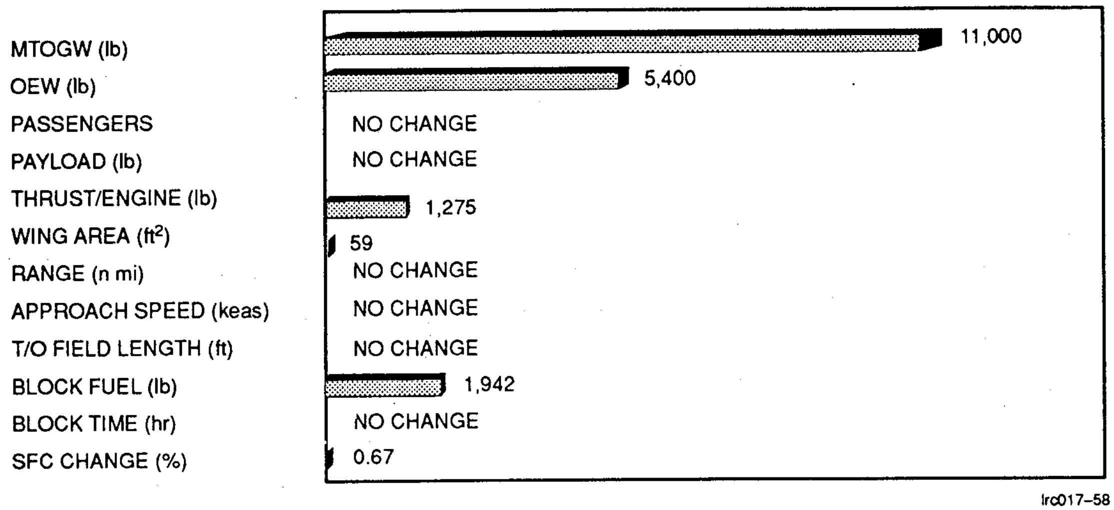


FIGURE 49. RESIZED ALL-ELECTRIC PERFORMANCE IMPROVEMENTS

4.7.2 Reliability Analysis

The reliability analyses were essentially the same for the all-electric and the resized configurations because there were no system changes made when going from the all-electric to the resized aircraft. Reliability data were established for each of the aircraft systems affected by the change in an all-electric airplane. Methodology accepted by the Air Transport Association (ATA) was used to quantify the expected failure rate per flight hour according to major ATA system chapter numbers. The weight/component change listings (Appendix F) and the new all-electric system block diagrams served as the basis for estimating the failure rates of the all-electric configuration. The resulting failure rates per flight hour and mean time between failures are shown in Table 21. As expected, the hydraulic system showed significant improvement because it was virtually eliminated, while the electrical power system was degraded by adding more hardware and a second electrical power center.

Reliability of the ice-protection system was degraded due to the greater complexity of the thermal electric de-icing configuration than the present pneumatic anti-icing system. However, the net improvement for those systems affected by the change to all-electric was a reduction in failure rate per flight hour of 15.9 percent. Figure 50 shows the changes from the baseline to the all-electric aircraft in failure rates per flight hour for each system. The ATA system failure rate changes were used as input to the maintainability analysis.

4.7.3 Aircraft Maintainability Analysis

An aircraft maintainability analysis was conducted to quantify input parameters for the operating cost model. Maintenance man-hours per flight hour and material cost per flight hour were quanti-

TABLE 21
FAILURE RATES FOR BASELINE AND ALL-ELECTRIC SYSTEMS

ATA	CHAPTER	BASELINE TRIJET (FAILURES/ FLT HR)	ALL-ELECTRIC (FAILURES/ FLT HR)	IMPROVEMENT (%)	TRIJET MTBF (HR)	ALL-ELECTRIC MTBF (HR)	MTBF CHANGE (HR)
21	AIR-CONDITIONING	0.0061	0.0057	5.8	163.93	175.44	−11.5
22	AUTOFLIGHT	0.0030	0.0025	17.3	333.33	400.00	−66.7
24	ELECTRICAL POWER	0.0031	0.0040	−30.0	322.58	250.00	72.6
27	FLIGHT CONTROLS	0.0033	0.0028	16.3	303.03	357.14	−54.1
29	HYDRAULIC POWER	0.0023	0.0000	100.0	434.78	0.00	434.8
30	ICE AND RAIN PROTECTION	0.0015	0.0019	−22.9	666.67	526.32	140.4
36	PNEUMATIC	0.0027	0.0003	88.1	370.37	3,333.33	−2,963.0
38	MISC (WATER/WASTE)	0.0090	0.0089	0.6	111.11	112.36	−1.2
49	APU	0.0028	0.0023	17.1	357.14	434.78	−77.6
	TOTAL	0.0337	0.0284	15.9	29.67	35.21	−5.5

MTFB = MEAN VALUE OF FLIGHT HOURS BETWEEN FAILURES

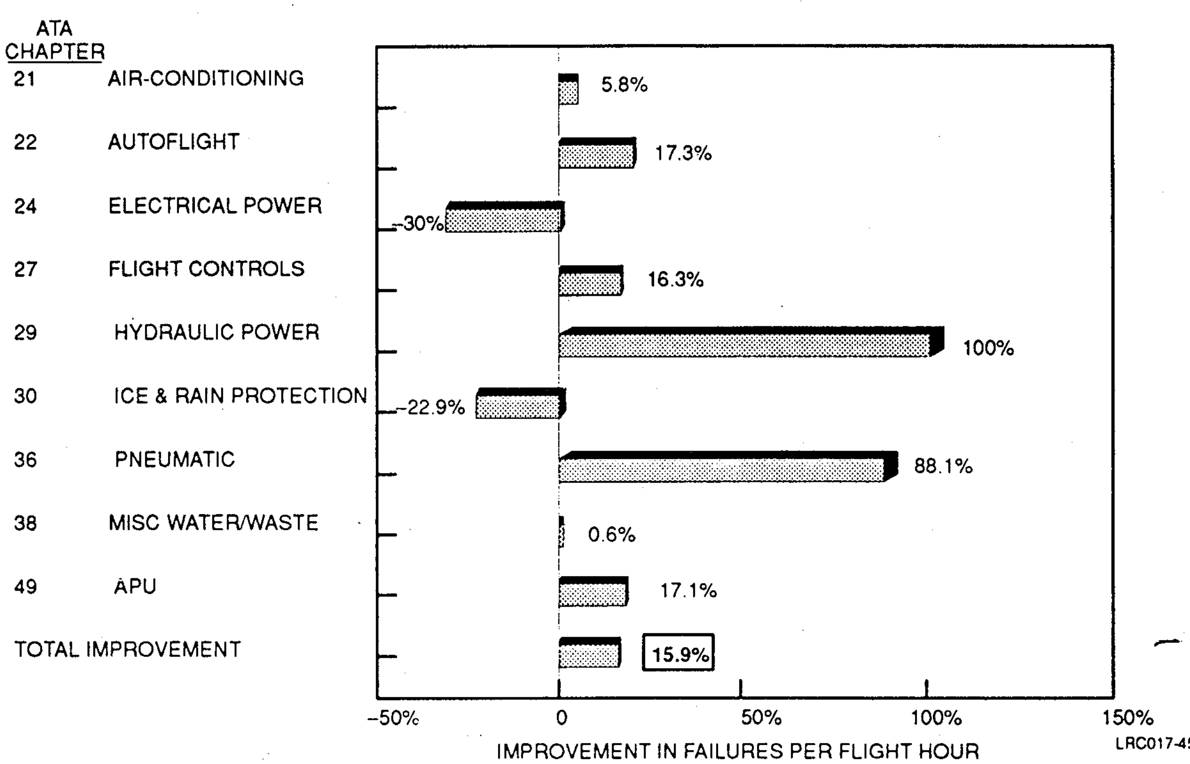


FIGURE 50. TRIJET ALL-ELECTRIC RELIABILITY CHANGES

fied pursuant to each major ATA system chapter. Table 22 shows both labor and material maintenance changes per flight hour for the categories in each ATA system chapter. The overall systems impacted by this study showed a 21.9 percent labor reduction and a 15.6 percent material cost reduction for maintenance for each flight hour.

TABLE 22
DIRECT MAINTENANCE FOR BASELINE AND ALL-ELECTRIC SYSTEMS

		BASELINE				ALL-ELECTRIC			
ATA	CHAPTER	L1 MH/FH	L2 MH/FLT	M1 MATL/FH ($)	M2 MATL/FLT ($)	L1 MH/FH	L2 MH/FLT	M1 MATL/FH ($)	M2 MATL/FLT ($)
21	AIR-CONDITIONING	0.1729	0.0091	3.6763	0.0049	0.1625	0.0086	3.4557	0.0046
22	AUTOFLIGHT	0.1246	0.0191	0.6800	0.0298	0.1184	0.0181	0.6460	0.0283
24	ELECTRICAL POWER	0.1132	0.0005	3.9742	0.0046	0.1868	0.0008	6.5574	0.0076
27	FLIGHT CONTROLS	0.1043	0.2581	5.6265	1.4028	0.0980	0.2426	5.2889	1.3186
29	HYDRAULIC POWER	0.0854	0.1254	4.6382	1.1107	0.0000	0.0000	0.0000	0.0000
30	ICE AND RAIN PROTECTION	0.0484	0.0000	1.1853	0.0000	0.0537	0.0000	1.3157	0.0000
32	LANDING GEAR	0.0021	0.8122	0.2520	149.7112	0.0021	0.8244	0.2558	151.9569
36	PNEUMATIC	0.1606	0.0000	1.3795	0.0000	0.0032	0.0000	0.0276	0.0000
38	WATER/WASTE	0.0480	0.1707	4.2329	2.8372	0.0466	0.1657	4.1059	2.7521
49	AUXILIARY POWER	0.0000	0.6039	0.0000	36.6554	0.0000	0.5828	0.0000	35.3725
57	WINGS	0.0000	0.4504	0.0000	15.7809	0.0000	0.4414	0.0000	15.4653
TOTAL		0.8595	2.4494	25.6449	207.5375	0.6713	2.2844	21.6530	206.9059

NOTE: FH = FLIGHT HOURS, MH = MAN-HOURS, FLT = FLIGHT; L1, L2 ARE LABOR HOURS; M1, M2 ARE MATERIAL COSTS.

4.7.4 Engineering Analysis

The engineering, manufacturing, and integrated logistics support cost entities were derived using a Douglas parametric cost-estimating model. The guidelines and assumptions used for this model are described in Section 4.4.2. The estimating model output report showing work complexity factors, cost weighting factors, and labor rates is Douglas proprietary and will not be provided as part of this report. However, cost summaries for the baseline, all-electric, and resized aircraft can be found in Appendix K.

For the purpose of this study, engineering cost includes the product design and certification effort. In the cost model, these were identified as research, development, test, and evaluation (RDT&E); these are virtually all the costs experienced through certification, excluding production costs. The RDT&E cost is subdivided into the following elements: engineering, test and evaluation, initial tooling, supplier nonrecurring, full-scale development, and project management.

The values of each RDT&E cost element for the baseline, all-electric, and resized aircraft are shown in Table 23. Analysis showed that the design and certification cost for a new trijet can be reduced by 2 percent if the all-electric secondary power systems defined in this report are incorporated.

TABLE 23
ALL-ELECTRIC TRIJET PRODUCT COST COMPARISON

	$ MILLION – 1990		
	BASE	ALL-ELECTRIC	RESIZED
RDT&E			
ENGINEERING	1,199	1,124	1,116
TEST & DEVELOPMENT	671	654	651
INITIAL TOOLING	818	823	816
SUPPLIER NONRECURRING	907	956	942
FSD ILS	58	55	55
PROJECT MANAGEMENT	118	115	114
TOTAL RDT&E	3,771	3,728	3,694
PRODUCTION			
TOTAL (800 AIRCRAFT)	68,662	67,031	66,475
UNIT AVERAGE	86	84	83
PRODUCT SUPPORT			
NONRECURRING	309	302	299
RECURRING	2,972	2,902	2,878
TOTAL PRODUCT SUPPORT	3,281	3,203	3,177

4.7.5 Manufacturing Analysis

The manufacturing unit costs were established for four production lots of 200 aircraft each and then averaged to give a single flyaway unit cost for each of the study configurations. The parametric cost model provides cost subtotals for tooling, production, and project management. A breakdown of these costs can be found in Appendix K. The average flyaway unit cost for each aircraft study configuration is shown in Table 23. Analysis showed that the average aircraft unit cost can be reduced by 3.2 percent if an all-electric secondary power system is utilized.

4.7.6 Integrated Logistics Support Analysis

ILS costs are defined by three major entities in the parametric cost model: airframer nonrecurring; airframer support investment, and airline support investment. Airframer nonrecurring cost covers the RDT&E for those ground-support equipment, training equipment and services, and product support activities which are peculiar to this airplane. Airframer support investment is the cost of the airframer-furnished product support equipment, training, services, support activities, initial spares inventory, field service, and maintenance site activation. Airline support investment is the cost of airline-furnished product support for the same cost elements defined for the airframers. The ILS costs for the aircraft study configurations are shown in Table 23. The savings potential is 5.2 percent for ILS if all-electric secondary power systems are utilized.

4.7.7 Market Analysis

Airline DOC comparisons for the baseline, all-electric, and resized aircraft were made with the Douglas Marketing department's cost model. This model utilizes a methodology which is accepted by the air transport industry to compare alternative aircraft configurations for various mission operating ranges and payloads. The alternative trijet operating costs for a 3,000-n-mi range, using 1990 dollars, are shown in Table 24. The number of passengers, payload, and fuel capacity are held as constants for the analysis; whereas, the maximum takeoff weight (MTOW) and the OEW are reduced by the 2,304-pound all-electric system weight savings and by the wing and engine weight savings due to aircraft resizing. The aircraft block time (i.e., engine start to engine shutdown time) and the aircraft utilization per year increased very slightly due to performance changes. The change in utilization time has a very minor effect on crew trip costs. Navigation and landing fees are also reduced only slightly. However, as indicated in Table 24, maintenance and fuel costs show the most significant improvements for the resized all-electric aircraft. The 1.48-percent reduction in trip cost equates to an annual savings of $298,125 in direct operating costs for each aircraft. Other airline product support cost savings, as shown in Appendix K, are realized on aircraft-peculiar ground support equipment, training equipment and services, support data, initial spares, site activation, and field service. These savings amount to $197 million, or 3.2 percent of the total airline support investment for the 15-year, 800-aircraft program.

4.8 TECHNICAL BENEFITS (WBS 5.1)

The technical benefits of the all-electric air transport concept are generally related to the weight reductions possible with the system redesigns for electrical power. Figure 51 illustrates this weight-sensitivity. When weight is reduced, for whatever reason, the fuel required for a given mission or commercial route segment is reduced in an exponential manner by the loop shown to the upper left of Figure 50. Reduced fuel burn reduces fuel load, which in turn reduces weight. This is reiterated through the loop shown in the figure for further weight reduction.

Other benefits are shown with the improved use of energy by load-sharing and attaining higher efficiency of system components or their applications. These reduce the amount of energy to be dissipated in heat exchangers or in the pressurized volume. Smaller heat exchangers or fans or ram air coolers then reduce the aerodynamic drag, which, in turn, reduces the main engine effort and fuel consumption and enters the exponential fuel equation. Better engine performance by improved SFC or by reduced or eliminated engine bleed air also improves the fuel burn efficiency. The use of six electrical power generators with cross-tie busing allows maximum opportunities for

TABLE 24
ALL-ELECTRIC DIRECT OPERATING COST COMPARISON

	BASE	ALL-ELECTRIC	RESIZED
SEATS	323	323	323
PASSENGERS	323	323	323
REVENUE CARGO (LB)	0	0	0
STUDY PAYLOAD (LB)	67,830	67,830	67,830
STUDY PRICE ($ M)	0	0	0
MTOW (LB)	602,500	596,500	591,500
FUEL CAPACITY (LB)	258,966	258,966	258,966
OEW (LB)	278,400	276,100	273,000
BLOCK TIME (HR)	6.775	6.776	6.779
UTILIZATION (BLOCK HR/YR)	4,234	4,235	4,237
TRIP COSTS ($/TRIP)			
FLIGHT CREW	5,056	5,036	5,020
CABIN CREW	6,674	6,675	6,678
MAINTENANCE	8,608	8,386	8,391
NAVIGATION	1,227	1,221	1,216
LANDING FEE	2,350	2,326	2,307
FUEL $0.60/GAL	8,211	8,112	8,037
TOTAL CASH COST ($/TRIP)	32,126	31,.756	31,649
($/SEAT)	99.46	98.32	97.98
(PERCENT)	0	−1.15	−1.48
YEARLY SAVINGS ($)		**231,250**	**298,125**

NOTE: DOLLARS/3,000-N-MI TRIP, 1990 ESTIMATES

load-sharing. Although a load-sharing study was outside the scope of the contract, such a study is desirable along with other forms of design optimization recommended in Section 6.

The benefits identified during this study are given in Table 25. These benefits are self-explanatory and cover a spectrum of technical and economic features — cost, maintenance, operation, corrosive fluids, material deterioration, high temperature and safety, engine performance, mechanical problems, flight control philosophy and designs, and electrical hardware utilization. Other benefits are expected to surface during the recommended system optimization study.

4.9 COST IMPACTS (WBS 5.2)

The cost impacts that directly affect the operator have been quantified in this study. However, early in the study, many other intangible costs affecting public and government interests were acknowledged. Figure 52 shows the various global cost issues to consider in a change to all-electric secondary power systems. Those cost issues in the figure which are referenced to the public and government are outside the scope of this study. However, the cost issues in the figure which are referenced to the operator and manufacturer, although not directly correlated by parameter name with the study results, are covered in the cost parameters quantified by this study. Tables 26 and 27 show that nearly $10.5 billion can be accumulated throughout the 15-year program if all-electric technology is applied to the entire fleet of 800 new trijets delivered at a constant rate of about one per week. The recurring cost-avoidance for each new aircraft would be $2.85 million, while the nonrecurring

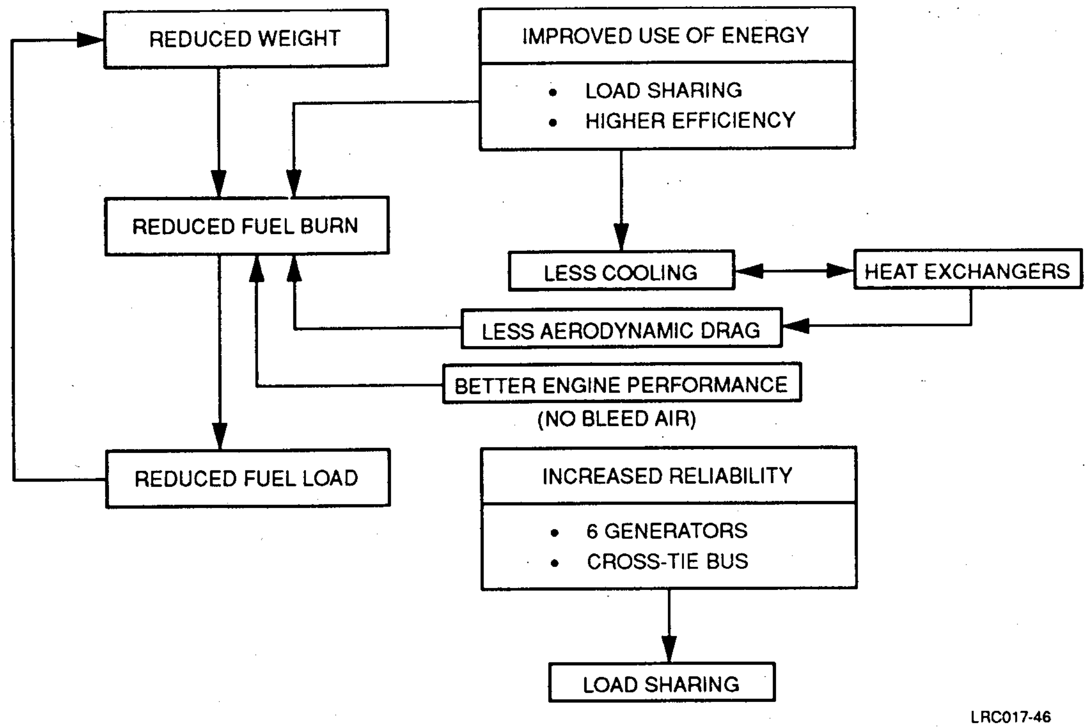


FIGURE 51. ALL-ELECTRIC AIRCRAFT RELATIONSHIPS

cost-avoidance for development and test and product support would be $87 million. Airline cost-avoidance would be $298,125 for each year the aircraft is in service. An additional $197 million of cost-avoidance, shown in Appendix K but not included in the capital accumulation (future value) estimate of $10.5 billion, would be realized in the airline's product support investment.

The equivalent present value for launching a trijet program that uses all-electric secondary power rather than conventional secondary power is nearly $2 billion. It is interesting to note that $6.9 billion, or about two-thirds of the savings, will be related to RDT&E and production, while $3.6 billion, or one-third of the savings, will be related to 15-year service and operation by the airline operators. Moreover, the incremental change in the present value of the entire program for each pound of hardware removed per aircraft is $830,700.

4.10 COST/BENEFIT FACTORS (WBS 5.3)

The very significant cost savings are discussed in Section 4.7. Many tangible and intangible benefits are identified in Table 25. Although not quantified, they are clearly such as to enhance the quality, safety, maintainability, operational factors, and performance of the aircraft; hence, they will make such an all-electric aircraft more desirable for the airline operators. At the request of NASA, as discussed in Section 6, Douglas has established an Airline Advisory Committee to review and evaluate the all-electric airplane designs from this study. The present committee members are also shown in Section 6. It is anticipated that the committee will make a thorough evaluation of the airline operator's views of the all-electric air transport concept and of the designs defined by this study.

TABLE 25
ALL-ELECTRIC STUDY BENEFITS

DESIGN CHANGE	RESULT
REDUCED WEIGHT	LESS FUEL CONSUMPTION/ENVIRONMENTAL IMPACT LOWER INITIAL OWNERSHIP COST LOWER OPERATING/MAINTENANCE COST
USED SINGLE TYPE SEC PWR	REDUCED MAINTENANCE INVENTORY SIMPLIFIED CREW OPERATING PROCEDURES SIMPLIFIED MAINTENANCE AND TRAINING
ELIMINATED HYDRAULICS	EASIER MODULE (LRU) REPLACEMENT AND REPAIR ELIMINATED DISTRIBUTED CORROSIVE FLUIDS AVOIDS ON-AIRCRAFT SPILL AND CLEANUP PROBLEMS ELIMINATES FLUID PURGING/REFILLING/CLEAN-UP PROCESSES REDUCES ENVIRONMENTAL IMPACTS OF HYDRAULIC FLUIDS AVOIDS COMPONENT (SEALS, INSERTS, DUCTS) MATERIAL DETERIORATION
ELIMINATED PNEUMATICS	ELIMINATES HIGH-TEMPERATURE (450°F) DUCTS REMOVES THE NEED FOR BURST DUCT PROTECTION SYSTEM
ELIMINATED ENGINE BLEED	IMPROVED ENGINE PERFORMANCE (SFC AND THRUST) PERMITS REFINEMENT OF COMPRESSOR/CORE DESIGN FOR BETTER SFC
ELIMINATED MECHANICAL CABLES	ELIMINATED MECHANICAL LOCKUP MODES SIMPLIFIED RIGGING ADJUSTMENTS (ELECTRONIC)
USED FULL-AUTHORITY FBW	SIMPLIFIED FLIGHT CONTROL ALGORITHMS PROVIDED INDIVIDUAL SURFACE CONTROL AUTHORITY IMPROVED EMERGENCY AND BACKUP CONTROL ENHANCED AUTOMATIC PILOT OPERATION
USED ELECTRICAL ENGINE START	ELIMINATES HOT DUCT AIR VALVES UTILIZES ELECTRICAL POWER CABLES FOR DUAL FUNCTION ALLOWS SINGLE FUNCTION FOR APU (ELECTRICAL POWER)

4.11 SYSTEM DESIGN EVALUATIONS

The system design evaluation process described in Appendix C was applied by the engineering staff to the systems and designs presented in this report. The evaluations were based on subjective experience, and the results were within a reasonable range, 60 percent to 80 percent, with an overall average of 66.7 percent. The composite, averaged percentage scores for each evaluation category are given in Figure 53. Recommendations for design improvements for the lower scores are provided in Appendix C. These can be considered in future optimization studies.

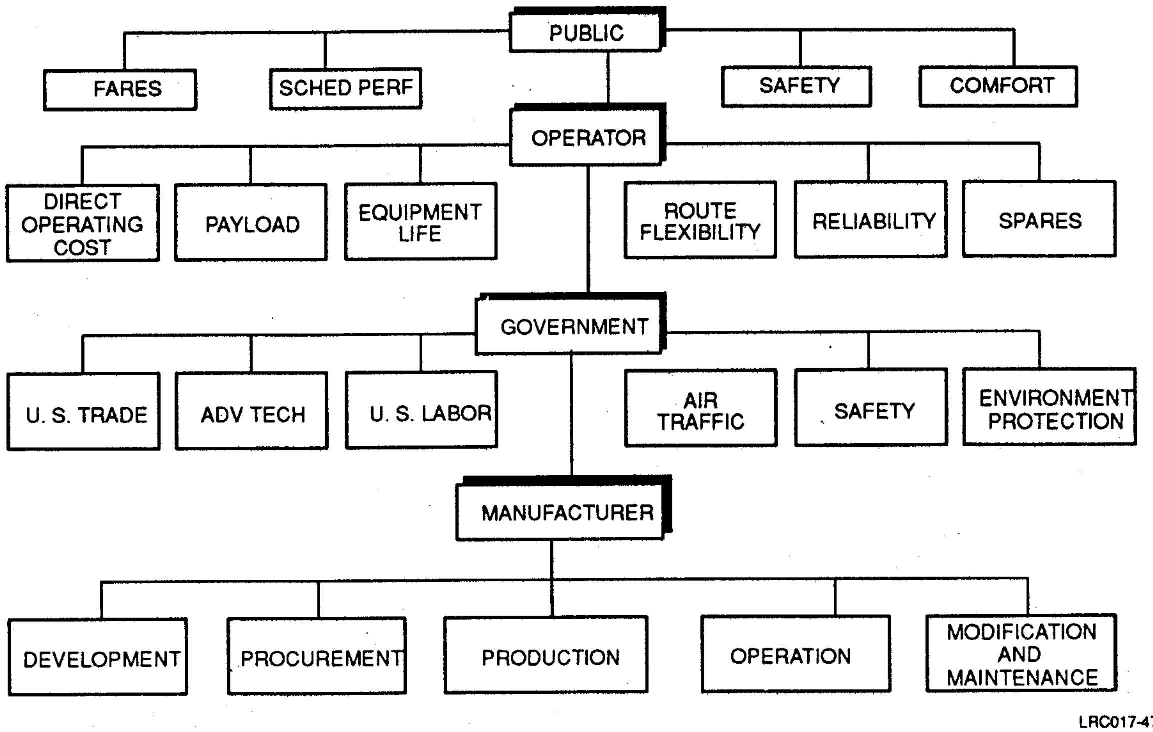


FIGURE 52. GLOBAL COST ISSUES

TABLE 26
COST SUMMARY

	BASE		ALL-ELECTRIC		RESIZED	
	RECURRING	NONRECURRING	RECURRING	NONRECURRING	RECURRING	NONRECURRING
DEVELOPMENT AND TEST		3,770.73		3,727.96		3,694.02
FLYAWAY UNIT COST	85.83		83.79		83.09	
PRODUCT SUPPORT (ILS)	3.72	308.98	3.63	301.64	3.60	299.14
IN-SERVICE OPERATIONS/ MAINTENANCE			0.23		0.30	

NOTE: BECAUSE SOME BASELINE COSTS ARE PROPRIETARY, ONLY THE DIFFERENTIALS ARE SHOWN.
DOLLARS (1990) IN MILLIONS BASED ON 800 AIRCRAFT

[redacted]

TABLE 27
COST IMPACT

	PRODUCTION	SERVICE
PROGRAM LENGTH (YR)	15	15
AIRCRAFT PER YEAR	53.3	53.3
SAVINGS PER AIRCRAFT	2.85	0.30
NONRECURRING SAVINGS	86.55	
RATE OF RETURN	12%	12%
FUTURE VALUE	6,909	3,587
TOTAL PRESENT VALUE	**$1.914 BILLION**	
TOTAL FUTURE VALUE	**$10.496 BILLION**	

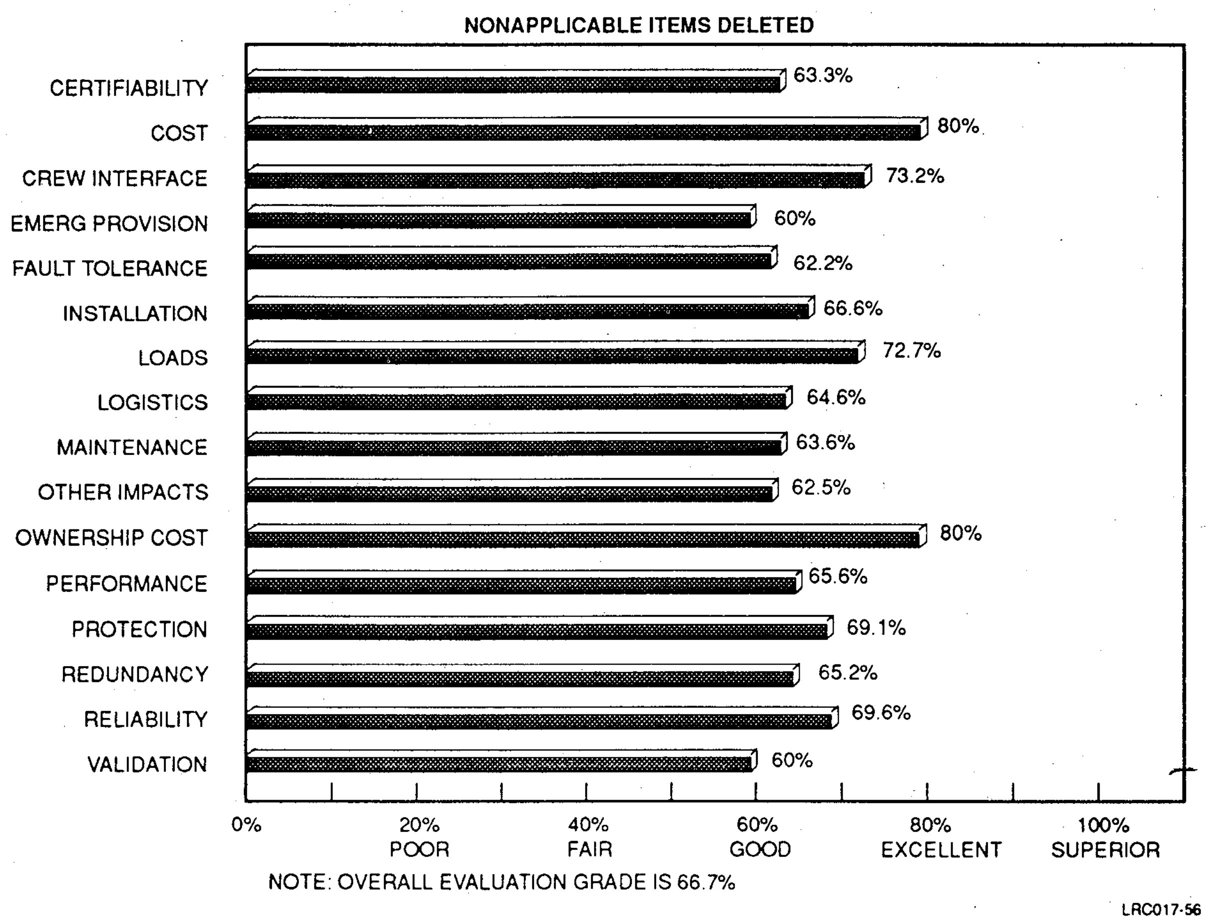


FIGURE 53. EVALUATION RESULTS

SECTION 5
CONCLUSIONS

The conclusions reached as the result of this study are briefly summarized as follows:

1. The benefits listed in Table 9 should be verified by continuing the 20-kHz study for part or all of the all-electric airplane systems. This work should be done for a trijet rather than for a twin jet to permit a direct comparison with the results of this study. Figure 54 illustrates the major milestones accomplished in this study. The shaded area of the figure shows the 20-kHz milestones which were not accomplished. It indicates, in a box enclosed by solid lines, the proposed continuation of the 20-kHz study subsequent to October 1991.

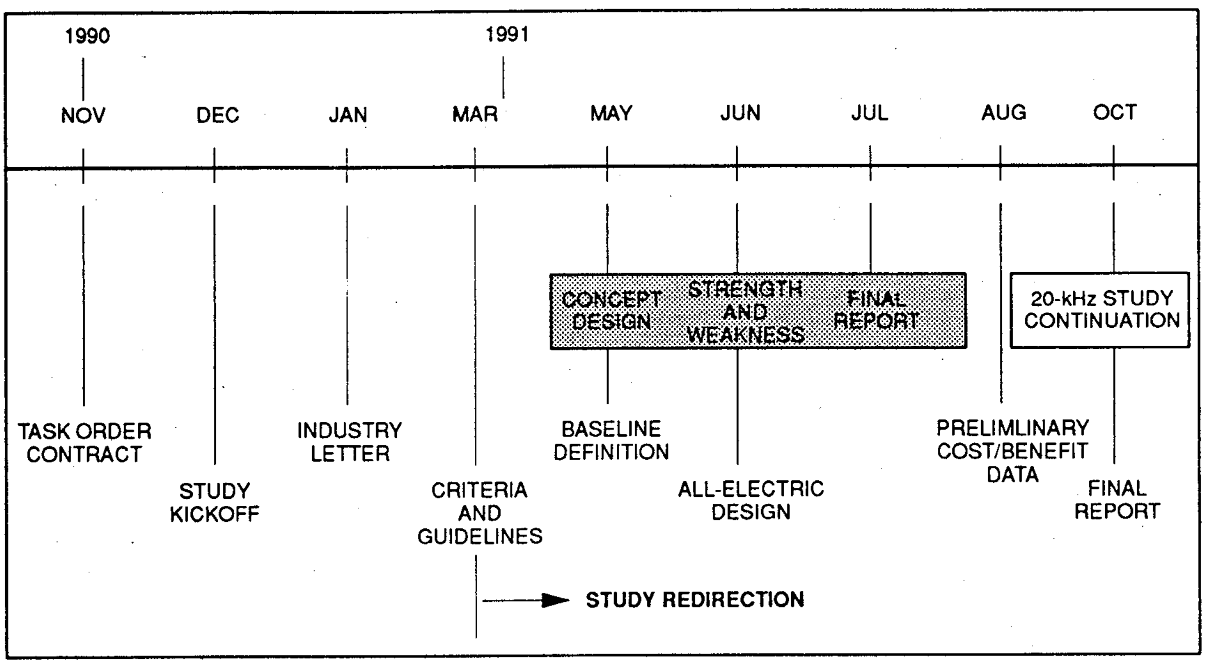


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FIGURE 54. STUDY MILESTONES

2. The benefits of the all-electric design concepts are not generally the result of major single cost savings or weight savings. As this study progressed, it became apparent that rather small incremental savings accrued to individual system redesigns for use of electrical secondary power in place of hydraulic or pneumatic secondary power. However, these accumulate to produce a large value of 2,304 pounds, even after the weight of new electrical hardware is added.

3. Major technical advancements confirmed by this study are:

   a. An all-electric airplane design without distributed hydraulic or pneumatic secondary power or main-engine compressor bleed air is both feasible and economically desirable, using present-day hardware and technologies.

   b. The desirable properties and dynamics of hydraulic "muscle" are available in high-bandwidth electrical servo pump actuators.

C-2.

c. The low bandwidths of electromechanical and electrohydraulic actuators need not be used except for applications in which they operate infrequently or unidirectionally.

d. The concepts of high-frequency switched-mode electronic converters with bidirectional power capabilities for main-engine starting and pulse density modulation for lower-frequency synthesis are all feasible technical advancements. These should be defined sufficiently for hardware development in a later study.

Other tasks are identified for future work in the following section.

SECTION 6
RECOMMENDATIONS

In-depth analyses and optimization studies were beyond the scope of this study. It was designed to provide realistic conceptual designs sufficient to permit a cost/benefit analysis. That analysis showed significant savings in cost and fuel that warranted a recommendation for further work to improve the designs by optimization and additional system study, syntheses, hardware development, and testing.

Major studies are recommended for the following as future work packages:

- System optimization
- Load-sharing (time-lining)*
- Active load management*
- Computer automation (loads, automatic operation)*
- Multiplexed information/control systems, including BITE and artificial intelligence
- Double-voltage power transmission
- Windmilling engine power for emergency loads
- Environmental control power through dual main converters
- Electromagnetic braking

These are proposed to use the electrical energy from the generators more efficiently and to study the identified system design improvements.

The Aeronautical Analysis Division of NASA-LeRC requested Douglas to form an advisory committee composed of commercial airlines' engineers, FAA specialists such as the Designated Engineering Representatives at Douglas, and members of the NASA-LeRC and Douglas Study Team. Members of the initial Advisory Committee are presented in Table 28.

*These could be investigated in a single work package.

TABLE 28
ADVISORY COMMITTEE

AIRLINE ADVISORS	NAME	PHONE NUMBER
AMERICAN	JACK GRAEFF MANAGER, ACFT PROGRAM & DEVL ENGG	(918) 292-3742
FEDERAL EXPRESS	LESLIE L. SPENGLER MANAGER, ACFT DEVELOPMENT & OP ENGG	(901) 369-3055
DELTA	CHARLES BAUTZ MANAGER, PERFORMANCE & ANALYSIS	(404) 765-3280
UNITED	EDWARD MARSEY MANAGER, FLIGHT SAFETY	(708) 952-4557
USAIR	ROBERT E. MATSON MANAGER, POWER PLANT ENGG	(412) 472-7085
FAA DER ADVISORS (DOUGLAS)		
ELECTRICAL POWER	J. CREAGER R. BILES	(310) 593-9604 (310) 593-1374
FLIGHT CONTROLS	P. LIEN C. WESTLUND	(310) 593-7681 (310) 593-6531
AUTOPILOT	J. QUINN E. PIPER	(310) 593-8781 (310) 593-1029
ENVIRONMENTAL	G. STOFFEL	(RETIRED)
LANDING GEAR	C. WESTLUND	(310) 593-6531
ALL-ELECTRIC STUDY		
NASA — PROJECT MANAGER	D. RENZ	(216) 433-5321
DOUGLAS — SECONDARY POWER	L. FEINER	(310) 593-5040
DOUGLAS — ELECTRICAL POWER	W. MURRAY	(310) 593-8724

DER = DESIGNATED ENGINEERING REPRESENTATIVE

REFERENCES

1. MD-11 Aircraft Design Technical Specification, Douglas Aircraft Company, No. DTS1100C, 1990. (Douglas Aircraft Company Proprietary Data)
2. Advanced Secondary Power System for Transport Aircraft, NASA Technical Paper 2463, May 1985.
3. MD-11 System Design Document (Lamm Schematic Book), Douglas Aircraft Company Code Identification No. 88277, October 1, 1987. (Douglas Aircraft Co. Proprietary Data)
4. MD-11 Weights Document, Douglas Aircraft Company, No. DS 1100D, April 17, 1991 (Douglas Aircraft Company Proprietary Data).
5. ELOAD Reports, Douglas Aircraft Company, WXS7030-A; Baseline – Load Analysis – Electrical – AC, May 1990; WXS7031-A; Baseline – Load Analysis – Electrical – DC, June 1990 (Douglas Aircraft Company Proprietary Data).

APPENDIX A
SCHEDULES

SCHEDULE – ORIGINAL CONTRACT

SCHEDULE/MANLOA D – EVALUATION OF 20 kHz SECONDARY POWER SYSTEM

s = start; f = finish; m = meeting; r = report
a = customer approval

11/10/90

WBS	TASK	YEAR / MO / DAY / HR/MO / HOURS										
		YEAR	1990			1991						
		MO	10	11 11 11 11	12 12 12 12 12	1 1 1 1	2 2 2 2	3 3 3 3	4 4 4 4 4	5 5 5 5	6 6 6 6	7 7 7 7 7
		DAY	29	5 12 19 26	3 10 17 24 31	7 14 21 28	4 11 18 25	4 11 18 25	1 8 15 22 29	6 13 20 27	3 10 17 24	1 8 15 22 29
		HR/MO	160	184	120	144	160	200	152	160	192	152
		HOURS										
1.0	PREPARE DETAILED PLAN (NASA 1.0)	100		s f								
1.1	SUBMIT PLAN FOR NASA APPROVAL			100 r	a							
2.0	SELECT SUBCONTRACTORS (NASA 2.0)	100		s	f							
2.1	SUBMIT LIST AND PLAN FOR NASA APPROVAL			100	r a							
3.0	SELECT STUDY CRITERIA AND GUIDELINES (NASA 3.0)	480		s		f						
3.1	SUBMIT CRITERIA & GUIDELINES FOR NASA APPROVAL			50	280	150 r a						
4.0	EVALUATE ACFT EPS CONCEPTUAL DESIGN (NASA 4.0)											
4.1	ESTABLISH CONCEPTUAL DESIGN											
4.1.1	DEFINE AIRCRAFT MODEL	250			s 50	150	50	f				
4.1.2	DEFINE ALL-ELECTRIC LOADS	400				s 150	150	100	f			
4.1.3	DEFINE POWER/FLY-BY-WIRE CONCEPT	200				s 100	100	f				
4.1.4	DEFINE DISTRIBUTED POWER SYSTEM	300					s 150	150	f			
4.1.5	DEFINE ELECTRONIC/ELECTRICAL CONTROLS	300						s 100	200 f			
4.2	EVALUATE STRENGTHS AND WEAKNESSES											
4.2.1	DETERMINE TECHNICAL ISSUES	200					s 100	100	f			
4.2.2	IDENTIFY TECHNICAL ANALYSES REQUIRED	150					s 50	50	50 f			
4.2.3	PERFORM TECHNICAL ANALYSES	700						s 100	200	225	175	f
4.2.4	SPECIFY SYSTEM STRENGTHS AND WEAKNESSES	700							s 100	300	300	f
5.0	REPORTING											
5.1	MONTHLY TECHNICAL PROGRESS	80			r 10	r 10	r 10	r 10	r 10	r 10	r 10	r 10 draft r final r
5.2	FINAL REPORT	300										300
6.0	PROGRAM MANAGEMENT	240		26	26	26 m	26	26	26 m	28	28	28 m
				NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL
	TOTAL HOURS	4500		276	366	586	636	636	586	563	513	338
	EQUIV MEN			1.5	3.05	4.06	3.97	3.18	3.85	3.51	2.67	2.22
	CUM HOURS	4500		276	642	1228	1864	2500	3086	3649	4162	4500
	LABOR $K	$262.9		$15	$20	$35	$38	$38	$35	$33	$30	$20
	CONSULTANT EXPENSE $K	$10.0						$5				$5
	TRAVEL $K	$10.8				$3.6			$3.6			$3.6
	COMPUTING $K	$15.0			$1.5	$1.5	$2.0	$2.0	$2.0	$2.0	$2.0	$2.0
	TOTAL MONTHLY $K	$298.7		$15	$22	$40	$40	$45	$40	$35	$32	$31
	TOTAL CUM $K	$298.7		$15	$37	$76	$116	$161	$201	$236	$268	$299

SCHEDULE – AMENDED CONTRACT

(revised) - SCHEDULE/MANLOAD - EVALUATION OF ALL-ELECTRIC AIRCRAFT COST/BENEFIT

04/16/91

s = start; f = finish; m = meeting; r = report
a = customer approval

WBS	TASK	YEAR 1991 / MO / DAY / HR/MO / HOURS	3: 18, 25	4: 1, 8, 15, 22, 29 (152)	5: 6, 13, 20, 27 (160)	6: 3, 10, 17, 24 (200)	7: 1, 8, 15, 22, 29 (152)	8: 5, 12, 19, 26 (160)	9: 2, 9, 16, 23, 30 (192)	10: 7, 14, 21, 28 (160)
1.0	REVISE DETAILED PLAN	50	s	f						
1.1	SUBMIT PLAN FOR NASA APPROVAL			50 r a						
2.0	REVALIDATE SUBCONTRACTOR LIST	50		s f						
2.1	SUBMIT LIST AND PLAN FOR NASA APPROVAL			50 r	a					
3.0	COMPLETE STUDY CRITERIA AND GUIDELINES	100	(CONT)		f					
3.1	SUBMIT CRITERIA & GUIDELINES FOR NASA APPROVAL			100	r a					
4.0	DEFINE AIRCRAFT STUDY MODELS									
4.1	ESTABLISH BASELINE DESIGN									
4.1.1	DOCUMENT AIRCRAFT/SYSTEM DESIGNS	125		s f 125						
4.1.2	ESTABLISH BASELINE LOAD ANALYSIS	100		s 100	f					
4.1.3	ESTABLISH BASELINE COST ANALYSIS	250		s 100	f 150					
4.2	ESTABLISH ALL-ELECTRIC DESIGN									
4.2.1	ESTABLISH AIRCRAFT/SYSTEM DESIGN	425			s 225	f 200				
4.2.2	PERFORM ALL-ELECTRIC LOAD ANALYSIS	180			s 80	f 100				
4.2.3	PERFORM ALL-ELECTRIC COST ANALYSIS	228			s 78	f 150				
5.0	PERFORM COST/BENEFIT ANALYSIS									
5.1	EVALUATE RELATIVE TECHNICAL BENEFITS	225				s 100	f 125			
5.2	DETERMINE DIFERENTIAL COSTS	225				s 50	f 175			
5.3	ASSESS COST/BENEFIT FACTORS	225					s f 225			
6.0	REPORTING									
6.1	MONTHLY TECHNICAL PROGRESS	50		r 10	r 10	r 10	r 10	r 10	prelim	final
6.2	FINAL REPORT	400						s 200	p 200	f
7.0	PROGRAM MANAGEMENT	164	USED AS	26	26	m 28	28 m	28	28 m	
			OF MAR 31	APR	MAY	JUN	JUL	AUG	SEP	OCT
	TOTAL HOURS	4500	1703	561	569	638	563	238	228	
	EQUIV MEN			3.69	3.55	3.19	3.70	1.48	1.18	
	CUM HOURS	4500	1703	2264	2833	3471	4034	4272	4500	
	LABOR $K	$265.5	$100	$33	$34	$38	$33	$14	$13	
	CONSULTANT EXPENSE $K	$10.0	$0		$5				$5	
	TRAVEL $K	$10.8	$0			$3.6		$3.6	$3.6	
	COMPUTING $K	$15.0	$0	$2.0	$2.0	$3.0	$3.0	$3.0	$2.0	
	TOTAL $K	$301.3	$100.5	$35	$41	$44	$36	$21	$24	
	TOTAL CUM $K	$301.3		$136	$176	$220	$257	$277	$301	

APPENDIX B
SUPPORTING SUBCONTRACTORS

MCDONNELL DOUGLAS

Douglas Aircraft Company

FORM LETTER —
SEE LIST OF ADDRESSEES
ATTACHED

December 14, 1990
C1-AS-1X6-90-038-53

Douglas has recently been awarded a task order contract from the National Aeronautics and Space Administration to evaluate the application of a 20 kHz, 440V ac, single phase, electrical power system for an advanced, twin-engined transport aircraft. The objective of this NASA initiative is to establish the viability of such a system in a representative aircraft application.

Douglas is embarked upon a 9 month, 3 man level-of-effort that will perform an analytical evaluation of a responsive system design against a twin-engined aircraft configuration, utilizing developed ground rules and evaluation criteria. To facilitate this effort, it is desired to obtain engineering input from informed industry and related academic sources.

This letter is therefore sent to you to determine your interest in providing technical commentary and data. It will assist Douglas to define a system architecture and to prepare a physical and functional representation of a 20kHz electrical power system for an advanced twin engined transport aircraft. Although, initially, we are unable to provide funding for such involvement, we believe a modest investment by your R&D personnel would prove beneficial both to you and to Douglas. It would provide us with your informed input and give you insight into an airframe manufacturer's future electrical power, distribution and control concepts, and keep you informed of our progress in this important area of technological advancement.

This opportunity is being offered to a number of organizations or individuals active in this field and we have attached a list of those solicited to participate. The information obtained will be combined to form an averaged data base for statistical purposes, while maintaining the confidentiality of the individual inputs. The final results of the study will, of course, be in the public domain. However, current NASA policy allows proprietary data to be held and controlled by the NASA subcontractor, with only summary data being published in the final report issued by NASA.

We enclose a program statement of work, with a schedule showing the envisaged sub-tasks for this project. Also attached is a draft of a form we propose to utilize for acquisition of data for definition of the system components.

We believe, by this award to Douglas, NASA has initiated an exciting program with significant potential that may lead to substantial support with a commensurate level of funding from NASA and the USAF. An all-electric-aircraft laboratory demonstration is a possible stepping stone toward a 1996 go-ahead for a new twin engined transport aircraft. We shall welcome your participation!

Please provide your response by January 22, 1991 to:

Douglas Aircraft Company,
L. Feiner M/C 1X6 18-61,
3855 Lakewood Blvd,
Long Beach, CA. 90846.

If you should require any additional information or if someone else in your organization should have received this request, please do not hesitate to contact:

L. (Lou) Feiner (213) 593-5040 or
W. (Bill) Murray (213) 593-8724.

Soon after we are able to count you as a participant we shall encourage you to visit Douglas here in Long Beach, CA. to more fully discuss the program. We shall always welcome your comments and suggestions on how this project may be pursued in the most effective manner possible.

Sincerely,

J. McDonnell
Business Unit Mgr
Aircraft Sys

W. E. Murray
W. Murray
Principal Specialist
Secondary Pwr Sys

L. Feiner
L. Feiner
Group Leader
Secondary Pwr Sys

Attachments:
1) Requirements-Sample Form
2) Response-Sample Form
3) List of Invited Participants

Enclosures:
1) Statement of Work-20kHz Sec Pwr Sys
(NOT IN FINAL REPORT)

20 kHz SECONDARY POWER SYSTEM

DOUGLAS AIRCRAFT CO. TWIN TRANSPORT APPLICATION DEVELOPMENT STUDY

COMPANY NAME: McDonnell Douglas — DIVISION: Douglas Aircraft
LOCATION: 3855 Lakewood Blvd LB, Ca. — MAIL CODE: Dept 1X6 MC 18-61
PREPARED BY: L. Feiner — PHONE NO: 213 593-5040

PART NAME: Bus Isolator- AC — DAC REF NO: B1-1

DESCRIPTION:

The bus isolator is a solid state overload protection device that limits the fault current that can be drawn from the 20kHz, 440 vac, power feeder bus and physically opens the feeder circuit. It also has a power management input that enables commanded open and closure from a central processor via a time shared bi-directional data bus. The device contains current and voltage limit sensing for the electrical load.

REQUIREMENTS

EXAMPLE

THERMAL
HIGH TEMP: 85 deg C — LOW TEMP: -55 deg C

COOLING
NATURAL CONVECTION: from external case — NONE:
FORCED AIR: — LIQUID:

PRESSURE
MAX ALTITUDE: 50,000 Ft

MECHANICAL
SHOCK: 3.5g — VIBRATION:

PHYSICAL
LENGTH: 12 inches — WIDTH: 3 inches max
HEIGHT: 8 inches

PACKAGING
CLOSED VENTED: — ARINC 600:
CLOSED SEALED: Unpressurized usage — ARINC 650:

WEIGHT
LBS: 10 [illegible]

ELECT CONNECTION
RACK & PANEL: — STUD: for 8ga and larger
RECTANGULAR: — CIRCULAR: for control & 10ga & up

ELECT POWER-INPUT
CONSUMPTION: 0.5% of thruput power — VOLTAGE: 440 vac
PHASES: single — FREQUENCY: 20 kHz

ELECT POWER-OUTPUT
RATING: part family, 5 to 50 amps — VOLTAGE: 440 vac
PHASES: single — FREQUENCY: 20 kHz

RELIABILITY
MTBF: 50,000 hr

SPS-1

20 kHz SECONDARY POWER SYSTEM

DOUGLAS AIRCRAFT CO. TWIN TRANSPORT APPLICATION DEVELOPMENT STUDY

RESPONSE

COMPANY NAME: ____________ DIVISION: ____________

LOCATION: ____________ MAIL CODE: ____________

PREPARED BY: ____________ PHONE NO: ____________

PART NAME: ____________ DAC REF NO: ____________

DESCRIPTION:

PHYSICAL

LENGTH: ____________ WIDTH: ____________

HEIGHT: ____________

WEIGHT

LBS: ____________

PRODUCT STATUS (CHECK AS APPLICABLE)

CONCEPTUAL	______	DELIVERY LEAD TIME: 1 YR	______
INITIAL DSGN	______	2 YR	______
DEVELOPMENT	______	3 YR	______
PROTOTYPE	______	4 YR	______
PRODUCTION	______	5 YR	______

RELATIVE COST (CHECK ONE)

COMPARED TO CONVENTIONAL 400Hz AIRCRAFT TECHNOLOGY:

EQUAL ______

DOUBLE ______

TRIPLE ______

OTHER ____________

ADDITIONAL INFORMATION AND COMMENTS:

SPS-2

Company Name	Division	St No	Street Name	City	State/ZIP	PHONE-#	Title	Last Name	First Name	Mail Code
1 Acme Electric Corp	Aerospace	5225	Wiley Post Way Ste 180	Salt Lake	UT 84116	801 596-0075	Mktg Mgr	Brown	Gary E.	
2 Allied Signal Inc	Bendix Electric Power Div	HWY 35		Eatontown	NJ 07724	201 389-1764	Sr Mktg Rep Staff	Sarpolus	R. W.	
3 Allied Signal Research	Garrett Airesearch	2525	W. 190th St	Torrance	CA 90504	213 512-4409	Engrg Superv-motors	Wuertz	Kenneth	
4 Allied-Signal Inc	Bendix Elec Pwr Div	118	State HWY 35	Eatontown	NJ 07724		Engr Mgr	Anderson	Donald E.	
5 AMP Inc	Advd Dev Labs	21220	N 19th St	Phoenix	AZ 85027	602 242-3730	Sr Dev Engr	Kreinberg	Earl R.	
6 Analytical Engrg Corp		25111	Country Club Blvd Ste216	N. Olmstead	OH 44070	216 779-0282	Sr Engr	Gordan	Andy	
7 Avtech Corp	Power & Lighting	3400	N. Wallingford	Seattle	WA 98103	206 634-2540	Engrg Supervisor	Rector	Mark W.	
8 Avtron Mfg Inc		10409	Meech Ave	Cleveland	OH 44105	216 641-8310	Pres	Fritz	Dwain E.	
9 Eaton Corp	Corporate R & D	4201	N 27th St	Milwaukee	WI 53216	414 449-6592	Sr Engr	Rutchik	Walter L.	
10 Eldec Corp	Monitor & Ctrl Div	16700	13th W. PO Box 100	Lynnwood	WA 98046	206 743-6821	Sales Mgr	Blackbourn	Steven R.	MS15
11 Figgie International Mfg	Hartman Elect Mftg	175	N. Diamond St	Mansfield	OH 44902	419 524-1411	Engrg Mgr	Boyce	Jeffery W.	
12 General Dynamics	Space Systems	PO Box	85990	San Diego	CA 92138	619 547-5372	Prog Chf Engr	Mildice	James W.	MC248680
13 General Electric Co	Aerospace Division	PO Box	5000	Binghamton	NY 13902	607 770-2916	Sr System Engr	Van Nocker	Richard	MC 786B
14 Harris Corp	Harris Power R & D	1	River Rd PO Box 804	Schenectady	NY 12301	518 387-6529	Director	Temple	Dr. Victor	
15 HR Textron	HR Division	25200	W. Rye Canyon Rd	Valencia	CA 91355	605 253-5471		Shaw	Edward D.	
16 ILC Data Divice Corp		105	Wilbur Place	Bohemia	NY 11716	516 563-5212	VP Engrg	Jarecki	Herb	
17 Induction General Corp	GM Industrial Court	3253	Old Franhstown Rd	Pittsburg	PA 15239		Pres	Patel	Mikund R.	
18 Inland Motors Co	Inland Technology	501	First St	Radford	VA 24141	703 639-9045	Product Manager	Ward	David	
19 Invertacon Corp	Power Rex Assoc	3115	S Fairfield PO Box 27929	Tempe	AZ 85282	602 967-4866	Pres	Wright Jr	Erniest R.	
20 ITT Aerospace Ctrls Div		1200	S. Flower St	Burbank	CA 91502	818 953-2196	Dir Engr	Aldrich	Allyn M.	
21 Kilovac Corp		PO Box	4422	Santa Barbara	CA 93140	805 684-4560	VP Prod Devel	Smith	Philip L.	
22 Leach Corp	Leach Power Management	6820	Orangethorpe Ste E/Box 5032	Buena Park	CA 90622	714 739-0770	Program Manager	Tofigh	Farshid	
23 Leach Corp	Relay Div	6900	Orangethorpe Ave	Buena Park	CA 90620	714 739-0770	Director	Tryon	Ritchie	
24 Leland	Aerospace Electrical Sys	PO Box	5000	Binghamton	NY 13902	607 770-2700	Director Mktg/Program	Jennings	Graig N.	
25 Leland Electricity		470	East National Road	Vandalia	OH 45377	512 898-5881	President	Fahringer	Gerald	
26 Lucas Aerospace Inc		17600	Broadway Ave	Maple Heights	OH 44137	216 662-1000	Engrg Mgr	Pabich	Frank	
27 Marathon Battery Co	PMG	PO Box	8232	Waco	TX 76710	817 776-0650	Mgr Product Engr	Ulrich	Robert C.	
28 McDonnell Douglas Corp	McDonnell Aircraft	PO Box	516	St Louis	MO 63166	314 232-0232	Mgr Elect Equip	Curtis	Arlo C.	MC0341240
29 McDonnell Douglas Corp	Electronic Systems Co	PO Box	426	St Charles	MO 63302	314 925-5148	Lead Engr Electronics	Schulze	Eric J.	MC500 4244
30 McDonnell Douglas Corp	MDC Helicopter Co	5000	E. McDowell Rd	Mesa	AZ 85205	602 891-2279		Tilus	Darrell D.	
31 Mechanical Products Inc		1824	River St PO Box 729	Jackson	MI 49204	517 782-0391	Pres	Matzen	Lynn	
32 MPC Products		7426	N. Linder	Skokie	IL 60077	312 673-8300	Sales Mgr	Howski	Glenn	
33 Pacific Scientific	Electro Kinetics Div	402	E. Gutierrez St PO Box 1500	Santa Barbara	CA 93102	805 963-2055		Bhargava	Brij	
34 Parker Hannifin Aerospace	Parker Bertea Aerospace	14300	Alton Pkwy	Irvine	CA 92718	714 837-0566	Regional Manager	Nelson	George	
35 Plessy Dynamics Corp		110	Algonquin Pkwy	Whippany	NJ 07981	201 428-9898	Dir of Rsch & Dev	Barba	Valentin	
36 Purdue University	School of Electrical Engrg			W. Laffayette	IN 47906	317 494-3481	Proffessor	Krause	Paul	
37 Purdue University	School of Electrical Engrg			W. Laffayette	IN 47908	317 494-3481	Proffessor	Wasynczuk	Oleg	
38 Raychem Corp	Defense Systems	300	Constitution Dr	Menlo Park	CA 94025	415 361-3311	Govt Liaison Mgr	Cinibulk	Walter	
39 Simmonds Precision Prods Inc		Norwich	Oxford Rd	Norwich	NY 13815	607 335-5193	VP Mktg	Bartlon	John A.	
40 Sundstrand Corp		4747	Harrison Ave	Rockford	IL 61125			Lynch	Leo	
41 Sundstrand Corp	Advance Technology Group	4747	Harrison Ave PO Box 7002	Rockford	IL 61109	815 394-2993	Engr Mgr Elec Res	Messenger	Lawrence	740 E6
42 Sundstrand Corp	Electric Power Systems	4747	Harrison Ave	Rockford	IL 61125	815 226-6411	Sys Mktg Mgr	Pierce	Gary	
43 Sundstrand Corp	Advance Technology Group	4747	Harrison Ave	Rockford	IL 61125	815 394-7230	Director Elect Rsch	Thollot	Pierre	Dept 995-6
44 Texas Instruments Inc	Control Prod Div	34	Forest St	Attleboro	MA 02703	508 699-3008	Elect Dsgn engr	LeComte	Norman	MS 12 32
45 TRW Inc	Space/Tech Pwr Sys Integ	Bldg	M2 2341	Redondo Beach	CA 90287	213 813-5290	Staff Engr	Beiss	John J.	
46 University of Wisconsin		1513	University Ave	Madison	WI 53706	608 262-5343	Professor	Laurentz	Bob	
47 University of Wisconsin		1415	Johnson Dr	Madison	WI 53706	608 262-0287	Professor	Lipo	Tom	
48 Utah Res & Dev Co		PO Box	10	W. Jordan	UT 84084	801 561-9385	VP Engrg	Coleman	Leland	
49 W L Gore & Associates	Electronics	4747	E. Beautiful Lane	Phoenix	AZ 85044	602 431-0077	Product Dev Mgr	Dukes	Robert D.	
50 Western Gear Corp	Corporate Mktg	11150	Sunrise Valley Dr	Reston	VA 22091			Corradi	C.	
51 Westinghouse Electric Corp	Electrical Systems	PO Box	989	Lima	OH 45802	419 221-6075	Fellow Engr	Fox	David A.	
52 WestingHouse Electric Corp	Aerospace Electrical Div	PO Box	989	Lima	OH 45802	419 221-6258	Mgr Sys & Adv Tech	King	Alan E.	

APPENDIX C

CRITERIA AND GUIDELINES — EXPANDED DATA BASE

CONTENTS

CRITERIA AND GROUND RULES
FOR
EVALUATION OF 20-kHz TWIN TRANSPORT
FEBRUARY 27, 1991

This is the first draft of the ground rules and criteria for evaluation of 20-kHz power distribution for a 200-passenger twin transport (Ref: NAS3-26965).

Keep in mind that the Douglas task is to implement the NASA-provided 20-kHz baseline system concept in a 200-passenger transport and then identify the strengths and weaknesses of the 20-kHz design approach.

Comments on the draft material are requested. Please provide your comments to W. Murray or L. Feiner by the end of March 1991.

You are encouraged to comment on those items for which you feel you have knowledge or can give an opinion that will contribute to the selection of evaluation criteria for a 20-kHz power distribution system.

A data base has been established for managing individual criteria records according to a subject, category, and other selected fields. The first few sheets in the attachment list the subjects, and pages C-5 through C-29 contain the records. Please circle the appropriate relevance classification for those records you choose and ignore all others unless you have comments or wish to add new records. (See the footnote for a definition of the relevance number.)

SUBJECT	Recno	CATEGORY
7754150	99	PERFORMANCE
A111317	100	PERFORMANCE
ABNORMAL OPERATION	28	FAULT TOLERANCE
AIR CONDITION	71	LOADS
AIR SOURCE RELIABILITY	130	REDUNDANCY
AIRCRAFT MODEL	34	INSTALLATION
AUTOLAND	147	RELIABILITY
AUTOMATIC PROTECTIVE DEVICE	116	PROTECTION
AUTOMATIC RESTART	21	EMERG PROVISION
AVIONICS COOLING	131	REDUNDANCY
BACKUP CONTROL	22	EMERG PROVISION
BACKUP POWER	132	REDUNDANCY
BACKUP REVERSION	23	EMERG PROVISION
BLEED AIR SYSTEM	90	OTHER IMPACTS
BUILT-IN TEST	80	MAINTENANCE
BUS, FEEDER AND BRANCH CKT ROUTE PLANNING	133	REDUNDANCY
CABIN AIR TEMPERATURE RESPONSE RATE	101	PERFORMANCE
CABIN PRESSURE CONTROL	102	PERFORMANCE
CABIN PRESSURIZATION	134	REDUNDANCY
CABIN TEMPERATURE CONTROL	24	EMERG PROVISION
CARGO HEATING	103	PERFORMANCE
CIRCUIT AMBIGUITY	8	CREW INTERFACE
CIRCUIT BREAKER AUTOMATIC RESET	117	PROTECTION
CIRCUIT BREAKER RESET	118	PROTECTION
CIRCUIT REDUNDANCY	135	REDUNDANCY
COLD AIR	104	PERFORMANCE
COMPONENT AVAILABILITY	75	LOGISTICS
COMPONENT INTERCHANGEABILITY	81	MAINTENANCE
CONTROL COMPUTERS	148	RELIABILITY
CONTROL ELECTRICAL POWER	105	PERFORMANCE
CONTROL ISOLATION	119	PROTECTION
CONTROL POWER	136	REDUNDANCY
CONTROL SOFTWARE	155	VALIDATION COMP
COOLING	35	INSTALLATION
CREW INFORMATION PROCESSING	9	CREW INTERFACE
CREW INTERFACE	10	CREW INTERFACE
CREW INTERVENTION	11	CREW INTERFACE
CREW STATION ARRANGEMENT	12	CREW INTERFACE
CREW WORKLOAD	13	CREW INTERFACE
DETAILED SYSTEM DESIGN	36	INSTALLATION
DIGITAL FLY-BY-WIRE SYSTEM	37	INSTALLATION
DISPATCH LIMITS	137	REDUNDANCY
DISPATCH RELIABILITY	149	RELIABILITY
DISPATCHABILITY	82	MAINTENANCE
DISPLAY FAILURE	14	CREW INTERFACE
DISPLAYED INFORMATION	15	CREW INTERFACE
EFFICIENCY	106	PERFORMANCE
EIDI	83	MAINTENANCE
EIDI FAILURE IDENTIFICATION	84	MAINTENANCE
ELECTRICAL LOAD ANALYSIS	72	LOADS
ELECTRICAL SYSTEM CONFIGURATION	38	INSTALLATION
ELECTROMAGNETIC INTERFERENCE SUPPRESSION	107	PERFORMANCE
EMC CONTROL	39	INSTALLATION
EMC SPECIFICATIONS	40	INSTALLATION
EMC TESTING	156	VALIDATION COMP

1. CERTIFICABILITY, GENERAL REQUIREMENTS

The system shall conform with general requirements, including: no significant technology risk; no system single failure mode; accomplishment of a safety evaluation of design, performance, hazards, failure modes/rates & system degradation.

CIRCLE ONE:..1..2..3..4..5

2. CERTIFICABILITY, PARTICULAR REQUIREMENTS

The system shall be in conformance with certain particular requirements, which include: the effects of residual ice on lift and drag shall be accommodated.

CIRCLE ONE:..1..2..3..4..5

3. CERTIFICABILITY, SPECIFICATIONS-INDUSTRIAL

The system shall conform with all relevant requirements of applicable industry specifications, including: ISO-7137, RTCA DO 160.

CIRCLE ONE:..1..2..3..4..5

4. CERTIFICABILITY, SPECIFICATIONS-MILITARY

The system shall conform with all relevant requirements of applicable military specifications/standards, including: MIL-G-21480, MIL-G-6099, MIL-STD-704.

CIRCLE ONE:..1..2..3..4..5

5. CERTIFICABILITY, SPECIFICATIONS-REGULATORY

The system must conform with regulatory requirements,including FAR 25/1309/1351/1353/1355/1359/1363, NPRM 89-31 (fuel as heat sink, air/min/occupant-1.0 lbs gnd/0.6lbs flt), and applicable CAA and JAA regulations.

CIRCLE ONE:..1..2..3..4..5

6. CERTIFICABILITY, SPECIFICATION-MDC

The system shall comply with all relevant requirements of applicable MDC specifications, including: DS 1100C (APR 1988), WZZ7000, WZZ7001, WZZ7002, WZZ7364, WZZ7442.

CIRCLE ONE:..1..2..3..4..5

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

7. COST, MANUFACTURING COST

Effects on cost of manufacturing, procurement, installation, design and development, certification, maintenance and operation must be assessed and minimized.

CIRCLE ONE:..1..2..3..4..5

8. CREW INTERFACE, CIRCUIT AMBIGUITY

The electrical system shall be designed to avoid ambiguities in switching networks and/or sneak circuits while operating in any system configuration.

CIRCLE ONE:..1..2..3..4..5

9. CREW INTERFACE, CREW INFORMATION PROCESSING

The design shall ensure compatibility with human information processing capability, and shall minimize personnel skills and training requirements, thus minimizing the potential for human error.

CIRCLE ONE:..1..2..3..4..5

10. CREW INTERFACE, CREW INTERFACE

The design shall allocate functions to personnel, and to equipment interfaces to achieve optimal crew system performance.

CIRCLE ONE:..1..2..3..4..5

11. CREW INTERFACE, CREW INTERVENTION

Manual intervention and override actions by the aircraft crew should be facilitated.

CIRCLE ONE:..1..2..3..4..5

12. CREW INTERFACE, CREW STATION ARRANGEMENT

The design shall provide efficient arrangement of crew stations, equipment, controls and displays to support normal and emergency task performance.

CIRCLE ONE:..1..2..3..4..5

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

13. CREW INTERFACE, CREW WORKLOAD

The design shall be such that crew workload, accuracy, time constraints, mental processing and communication requirements do not exceed operator capabilities.

CIRCLE ONE:..1..2..3..4..5

14. CREW INTERFACE, DISPLAY FAILURE

Failure of a display or its circuit shall be immediately apparent to the operator.

CIRCLE ONE:..1..2..3..4..5

15. CREW INTERFACE, DISPLAYED INFORMATION

The displayed information shall be sufficient for but limited to that required to make decisions and take actions that are within the required limits and precision of the operator with no requirement for transposing or computing.

CIRCLE ONE:..1..2..3..4..5

16. CREW INTERFACE, FAILURE ANNUNCIATION

Failures shall be clearly and unequivocably annunciated.

CIRCLE ONE:..1..2..3..4..5

17. CREW INTERFACE, FLIGHT CRITICAL CIRCUIT CONTROLS

All circuit protection control essential to flight shall be located in the flight compartment within reach of either seated crew member.

CIRCLE ONE:..1..2..3..4..5

18. CREW INTERFACE, FLIGHT DECK CREW

The aircraft shall designed for operation by a flight deck crew of two.

CIRCLE ONE:..1..2..3..4..5

19. CREW INTERFACE, GENERATOR CONTROL SWITCHES

Switches to control generator operation (On-Off-Reset) shall be

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

provided on the electrical power system panel.

CIRCLE ONE:..1..2..3..4..5

20. CREW INTERFACE, SOFTWARE ERRORS

Software errors/faults should be easily discernible by pre-flight checks and by continuous in-flight self-check routines.

CIRCLE ONE:..1..2..3..4..5

21. EMERG PROVISION, AUTOMATIC RESTART

Fly-by-wire/light computers will provide automatic restart without power recycling for any and all transient-induced failures up to 6 seconds.

CIRCLE ONE:..1..2..3..4..5

22. EMERG PROVISION, BACKUP CONTROL

A partial single-thread optical or electrical stick-to-surface backup channel will be provided for "minimum safe control" in the event of complete computer failure.

CIRCLE ONE:..1..2..3..4..5

23. EMERG PROVISION, BACKUP REVERSION

Provisions will be made to preclude accidental reversion to backup mode.

CIRCLE ONE:..1..2..3..4..5

24. EMERG PROVISION, CABIN TEMPERATURE CONTROL

Maintain adequate (possibly degraded) cabin temperature control after any probable failure(s).

CIRCLE ONE:..1..2..3..4..5

25. EMERG PROVISION, FIRE PROCEDURES

Fire procedures should be direct and effective.

CIRCLE ONE:..1..2..3..4..5

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

26. EMERG PROVISION, GEN EQUIP SELECTION

The generator equipment must provide the engine start function for normal and emergency operation.

CIRCLE ONE:..1..2..3..4..5

27. EMERG PROVISION, INDEPENDENT CABIN AIR SOURCES

Provisions should be made for two completely independent air sources for pressurization, ventilation and air conditioning.

CIRCLE ONE:..1..2..3..4..5

28. FAULT TOLERANCE, ABNORMAL OPERATION

Failures or abnormal operation of the air supply or air conditioning systems that result in abnormal cabin pressures must be indicated for corrective action or maintenance purposes.

CIRCLE ONE:..1..2..3..4..5

29. FAULT TOLERANCE, FAULT TOLERANCE

The installed systems should be highly fault tolerant.

CIRCLE ONE:..1..2..3..4..5

30. FAULT TOLERANCE, FAULT TOLERANCE

The control technique must assure that the EPS is fault-tolerant and can operate in programmed modes even during degraded conditions.

CIRCLE ONE:..1..2..3..4..5

31. FAULT TOLERANCE, PARTS STRESS LEVEL

The stress level of the parts employed should be sufficiently low (derated) as to afford longevity and high reliability.

CIRCLE ONE:..1..2..3..4..5

32. FAULT TOLERANCE, SINGLE FAULT VULNERABILITY

The system shall not be vulnerable to single fault failure.

CIRCLE ONE:..1..2..3..4..5

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

33. FAULT TOLERANCE, TOLERANCE FOR DEGRADED POWER

Versatility, reliability and tolerance for degraded power operational modes shall be provided for flight-critical systems in the all-electric airplane.

CIRCLE ONE:..1..2..3..4..5

34. INSTALLATION, AIRCRAFT MODEL

The most advanced aircraft available should be used as a model for this study (MD_11, MD-90, MD-12 or advanced twin).

CIRCLE ONE:..1..2..3..4..5

35. INSTALLATION, COOLING

Hardware shall be designed and installed for heat dissipation such that temperature rise will not present a problem.

CIRCLE ONE:..1..2..3..4..5

36. INSTALLATION, DETAILED SYSTEM DESIGN

The system architecture shall utilize a distributed equipment philosophy that performs power conditioning and control signal processing as close to the utilization equipment as practical.

CIRCLE ONE:..1..2..3..4..5

37. INSTALLATION, DIGITAL FLY-BY-WIRE SYSTEM

A digital fly-by-wire system shall be considered for sensing, data collection and control of flight control systems, in either "hard-wire" or fibre-optic circuits.

CIRCLE ONE:..1..2..3..4..5

38. INSTALLATION, ELECTRICAL SYSTEM CONFIGURATION

The electrical system configuration will conform to the NASA supplied baseline block diagram. Significant modifications to the baseline must be approved by NASA.

CIRCLE ONE:..1..2..3..4..5

39. INSTALLATION, EMC CONTROL

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

Wire and cable installations shall be controlled for the purpose of achieving maximum electromagnetic compatibility within the aircraft environment.

CIRCLE ONE:..1..2..3..4..5

40. INSTALLATION, EMC SPECIFICATIONS

The design installations and materials shall comply with Aircraft Wiring Installations Classification Specification WZZ7002 on each aircraft.

CIRCLE ONE:..1..2..3..4..5

41. INSTALLATION, EMI REDUCTION

Ground circuits and bonding shall be designed to provide for the reduction of electromagnetic interference.

CIRCLE ONE:..1..2..3..4..5

42. INSTALLATION, ENGINE GENERATORS

Two generators shall be installed on each engine.

CIRCLE ONE:..1..2..3..4..5

43. INSTALLATION, ENVIRONMENTAL CONSTRAINTS

The elements of the system should be commensurate with the environmental constraints of the aircraft, such as : The vibration spectrum; The temperature spectrum; The electro-magnetic spectrum; Shock loading, both Normal and Emergency.

CIRCLE ONE:..1..2..3..4..5

44. INSTALLATION, ENVIRONMENTAL CONSTRAINTS

The elements of the system should be commensurate with the environmental constraints of the aircraft, such as: Decompression (thermal shock); Lightning; Humidity; Explosive atmosphere; Heat soak.

CIRCLE ONE:..1..2..3..4..5

45. INSTALLATION, GROUNDING FOR LIGHTNING PROTECTION

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

The generator and electrical power system installations shall be grounded such that the effect of surges caused by lightning strikes on the aircraft skin will be minimized.

CIRCLE ONE:..1..2..3..4..5

46. INSTALLATION, HIGH TEMPERATURE WIRING

Nonwicking wire (not more than 1 percent increase in weight) shall be used in high temperature areas.

CIRCLE ONE:..1..2..3..4..5

47. INSTALLATION, INSTALLATION

Installation of components and wiring (other than power feeders) must be compatible with other electrical equipment installations.

CIRCLE ONE:..1..2..3..4..5

48. INSTALLATION, MAIN ELECTRICAL POWER CONVERTERS

One bi-directional 20 kHz converter shall be provided for each main generator to convert power from 400-1200 Hz (or higher) generator frequency to 20 kHz power transmission frequency.

CIRCLE ONE:..1..2..3..4..5

49. INSTALLATION, MATERIALS

The use of dissimilar metals should be appropriately controlled to avoid deterioration.

CIRCLE ONE:..1..2..3..4..5

50. INSTALLATION, MINIMUM WIRE SIZE - 18 ga

No wire smaller than No. 18 gage shall be used in the demountable power plant except No. 20 gauge wire may be used provided it is a high-strength alloy conductor (PD135).

CIRCLE ONE:..1..2..3..4..5

51. INSTALLATION, MINIMUM WIRE SIZE - 20 ga

No wire smaller than No. 20 gage shall be used in areas where high vibration or extreme environmetal conditions normally exits.

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

CIRCLE ONE:..1..2..3..4..5

52. INSTALLATION, OIL SYSTEM

A complete oil and filtration system shall be integral with the generator drive and the converter, if these are of integral design.

CIRCLE ONE:..1..2..3..4..5

53. INSTALLATION, OPEN WIRING

Open wiring shall be routed to minimize the possibility of a broken wire contacting control cables, actuating rods, oxygen lines, fluid lines or tanks containing any fluids.

CIRCLE ONE:..1..2..3..4..5

54. INSTALLATION, PACKAGING

The system should lend itself to being readily: packaged, sealed, and cooled.

CIRCLE ONE:..1..2..3..4..5

55. INSTALLATION, PACKAGING TECHNOLOGY

Packaging techniques must be adapted for higher voltages and frequencies than are currently used for solid-state control modules, transformers, capacitors, motor, and lighting loads.

CIRCLE ONE:..1..2..3..4..5

56. INSTALLATION, PHYSICAL INSTALLATION CONSTRAINTS

The elements of the system should be commensurate with the physical constraints of the aircraft, such as: overhung moment; attitude; direction of rotation; interconnection; mounting provisions.

CIRCLE ONE:..1..2..3..4..5

57. INSTALLATION, PRIMARY CONTROL

Digital data busses, optical, electrical, or both will be used between control computers and actuators to minimize control system weight and provide optimum reliability.

CIRCLE ONE:..1..2..3..4..5

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

58. INSTALLATION, PROTECTION AGAINST FLUIDS

Wiring, conduits, junction boxes, connectors and disconnects shall be installed so as to avoid fluids and fluid drainage

CIRCLE ONE:..1..2..3..4..5

59. INSTALLATION, SEGREGATED CRITICAL LOADS/EMERG BUSES

Elements which provide for critical loads or emergency buses shall be segregated to avoid common damage/failure modes and to retain their redundancy and system integrity.

CIRCLE ONE:..1..2..3..4..5

60. INSTALLATION, THERMAL MANAGEMENT

Thermal integration and thermal management are major requirements for the all-electric 20 kHz power system to acccommodate high-power semiconductor switches and converter electronics.

CIRCLE ONE:..1..2..3..4..5

61. INSTALLATION, WIRE AND BUS SIZE SELECTION

Wire and bus sizes shall be selected for the maximum operating currents in accordance with the cited design specifications.

CIRCLE ONE:..1..2..3..4..5

62. INSTALLATION, WIRE BUNDLE INSTALLATION

Serrated clamps shall be used for installation of wire bundles in the air conditioning pack compartments and in high vibration areas, except for the propulsion system areas.

CIRCLE ONE:..1..2..3..4..5

63. INSTALLATION, WIRE BUNDLE INSTALLATION

Serrated clamps shall be used for installation of wire bundles in the air conditioning pack compartments and in high vibration areas, except for the propulsion system areas.

CIRCLE ONE:..1..2..3..4..5

64. INSTALLATION, WIRE HARNESSES

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

Wiring shall be run in open harnesses, except where it is not readily accessible, not adequately protected by the aircraft components or where the use of open harnesses is impratical.

CIRCLE ONE:..1..2..3..4..5

65. INSTALLATION, WIRE INSULATION

A hard insulating material shall be used where wiring goes through cutouts in the structure.

CIRCLE ONE:..1..2..3..4..5

66. INSTALLATION, WIRE MOISTURE PREVENTION

Wiring routed under the lavatories or galley areas shall be protected from mositure damage.

CIRCLE ONE:..1..2..3..4..5

67. INSTALLATION, WIRE ROUTING

Wiring shall be routed in conduit, or heavy duty cable shall be used, where subjected to foreign object damage.

CIRCLE ONE:..1..2..3..4..5

68. INSTALLATION, WIRE SIZE SELECTION

Wire sizes shall be determined from the maximum currrent-carrying capacity of the wire except where the voltage drop criterion limitation requires larger sizes for satisfactory operation.

CIRCLE ONE:..1..2..3..4..5

69. INSTALLATION, WIRING IN CONDUITS

All wiring routed in conduit shall be free of ties.

CIRCLE ONE:..1..2..3..4..5

70. INSTALLATION, WIRING INSTALLATION

Wires shall be installed in accordance with the applicable ARINC characteristic, unless designated as future spares or specified otherwise.

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

CIRCLE ONE:..1..2..3..4..5

71. LOADS, AIR CONDITION

Provide temperature control, ventilation and air for pressurization.

CIRCLE ONE:..1..2..3..4..5

72. LOADS, ELECTRICAL LOAD ANALYSIS

The electrical load analysis shall conform to the format required for FAA certification and shall identify loads that are candidates for peak power load management.

CIRCLE ONE:..1..2..3..4..5

73. LOADS, POWER CLASSIFICATION FOR EQUIPMENT

CIRCLE ONE:..1..2..3..4..5

74. LOADS, VOLTAGE AND FREQUENCY REGULATION

The system voltage and frequency at the terminals of all essential load equipment shall be maintained within the limits for which the equipment is designed during any probable operatiing condition.

CIRCLE ONE:..1..2..3..4..5

75. LOGISTICS, COMPONENT AVAILABILITY

Aircraft-qualified components must be available for the highest power operating conditions.

CIRCLE ONE:..1..2..3..4..5

76. LOGISTICS, EXOTIC MATERIALS

The materials employed should not be excessively exotic.

CIRCLE ONE:..1..2..3..4..5

77. LOGISTICS, MATERIALS

New and unique material/methods of shielding, clamping, terminating, sleeving, etc. should be confined to power cables (feeders and

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

buses).

CIRCLE ONE:..1..2..3..4..5

78. LOGISTICS, TECHNOLOGY COMPLEXITY

The technology employed should not be excessively sophisticated or complex.

CIRCLE ONE:..1..2..3..4..5

79. LOGISTICS, TOXIC MATERIAL

Toxic materials should not be employed.

CIRCLE ONE:..1..2..3..4..5

80. MAINTENANCE, BUILT-IN TEST

Built-in test facilities should be facilitated wherever pratical.

CIRCLE ONE:..1..2..3..4..5

81. MAINTENANCE, COMPONENT INTERCHANGEABILITY

The elements of the system should be readily interchangeable.

CIRCLE ONE:..1..2..3..4..5

82. MAINTENANCE, DISPATCHABILITY

Extended availability should be provided for in the fly-by-wire/light computer system to optimize dispatchability and reduce maintenance.

CIRCLE ONE:..1..2..3..4..5

83. MAINTENANCE, EIDI

The EIDI system if adopted should use a standard module for wing and cowl mounted equipment.

CIRCLE ONE:..1..2..3..4..5

84. MAINTENANCE, EIDI FAILURE IDENTIFICATION

Provide a means of indicating EIDI failure and isolate to an LRU.

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

CIRCLE ONE:..1..2..3..4..5

85. MAINTENANCE, FAULT REPORTING

The environmental control system should use central fault reporting.

CIRCLE ONE:..1..2..3..4..5

86. MAINTENANCE, MAINTAINABILITY

Accessibility to and difficulty for replacement of equipment and component should be equivalent to other avionics equipment.

CIRCLE ONE:..1..2..3..4..5

87. MAINTENANCE, MOUNTING PAD

The starter/generator mounting provisions shall be compatible with other engine/generator interface designs.

CIRCLE ONE:..1..2..3..4..5

88. MAINTENANCE, VAPOR CYCLE REFRIGERATION

The vapor cycle units should be modular for ease of maintenance.

CIRCLE ONE:..1..2..3..4..5

89. MAINTENANCE, VAPOR CYCLE SYSTEM PACKAGING

The vapor cycle system LRUs should be replaceable within 15 minutes for ease of maintenance.

CIRCLE ONE:..1..2..3..4..5

90. OTHER IMPACTS, BLEED AIR SYSTEM

Alternative means must be devised to provide functions currently porvided by the engine bleed air system.

CIRCLE ONE:..1..2..3..4..5

91. OTHER IMPACTS, GROUND SERVICE

Provide means of ground cart attachment for conditioned and pneumatic air.

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

CIRCLE ONE:..1..2..3..4..5

92. OTHER IMPACTS, GROUND SUPPORT EQUIPMENT

The requirements for ground support equipment shall be kept to a minimum.

CIRCLE ONE:..1..2..3..4..5

93. OTHER IMPACTS, ICE PROTECTION

Wing and engine inlet ice protection will be provided by electro-impulse de-icing (EIDI) if possible which will be based generally on NASA CR4175 dated September 1988.

CIRCLE ONE:..1..2..3..4..5

94. OTHER IMPACTS, INTERACTION SENSITIVITY

If any system interactions exist, these shall not degrade the performance, safety, nor other essential criteria for the EPS.

CIRCLE ONE:..1..2..3..4..5

95. OTHER IMPACTS, WATER EXTRACTION

Provisions shall be made to extract water from the air to avoid freezing in the evaporator of the vapor cycle system.

CIRCLE ONE:..1..2..3..4..5

96. OWNERSHIP COST, MAINTENANCE HOUR/FLIGHT HOUR

The maintenance hours per flight hour should be low.

CIRCLE ONE:..1..2..3..4..5

97. OWNERSHIP COST, MTBUR/MTBF

The MTBUR and MTBF should be high.

CIRCLE ONE:..1..2..3..4..5

98. OWNERSHIP COST, OWNERSHIP COST

Effect on cost of ownership for procurement, installation, design

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

and development, certification, maintenance and operation must be assessed and should be relatively low.

CIRCLE ONE:..1..2..3..4..5

99. PERFORMANCE, 7754150

CIRCLE ONE:..1..2..3..4..5

100. PERFORMANCE, A111317

CIRCLE ONE:..1..2..3..4..5

101. PERFORMANCE, CABIN AIR TEMPERATURE RESPONSE RATE

Provide cabin temperature pull-down and warm-up per the MD-11 DTS.

CIRCLE ONE:..1..2..3..4..5

102. PERFORMANCE, CABIN PRESSURE CONTROL

Maintain normal cabin pressure control operation during any normal flight operation (including descent at flight idle power) after any probable failure(s).

CIRCLE ONE:..1..2..3..4..5

103. PERFORMANCE, CARGO HEATING

Provide adequate heat to maintain 40 degrees F in cargo compartment(s).

CIRCLE ONE:..1..2..3..4..5

104. PERFORMANCE, COLD AIR

Provide cold air (<70 degrees F) for "eyeballs" (300 fpm @ head level)

CIRCLE ONE:..1..2..3..4..5

105. PERFORMANCE, CONTROL ELECTRICAL POWER

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

Low voltage clean electrical power will be provided to the fly-by-wire/light computers and actuator electronics.

CIRCLE ONE:..1..2..3..4..5

106. PERFORMANCE, EFFICIENCY

The EPS shall provide full rated power with a minimum efficiency of 80% at 20 kHz source buses and 70% at loads (overall).

CIRCLE ONE:..1..2..3..4..5

107. PERFORMANCE, ELECTROMAGNETIC INTERFERENCE SUPPRESSION

Conducted and radiated interference at 20 kHz and its' harmonics must be compatible with equipment susceptibility standards specified in WZZ7000.

CIRCLE ONE:..1..2..3..4..5

108. PERFORMANCE, EME/HIRF

All full or part time critical functions will be fully operational in electromagnetic environments as specified in the latest revision of RTCA DO-160C.

CIRCLE ONE:..1..2..3..4..5

109. PERFORMANCE, ENVIRONMENTAL SYSTEM CONFIGURATION

The pneumatic and airconditioning systems will be designed to conform to figure 33 of NASA TP-2463 dated May 1985.

CIRCLE ONE:..1..2..3..4..5

110. PERFORMANCE, FIBER OPTIC COMPONENTS

Fiber optic technology shall be applied to signal/data transmission only, utilizing multimode fibers, and should not extend to optical sensors

CIRCLE ONE:..1..2..3..4..5

111. PERFORMANCE, FIBER OPTIC UTILIZATION

Fiber optics technology may be applied to flight control data bus and/or power system management bus and miscellaneous control bus application.

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

CIRCLE ONE:..1..2..3..4..5

112. PERFORMANCE, SMOKE REMOVAL

Conditioned air rate with one air conditioning pack inoperative shall be adequate to clear smoke.

CIRCLE ONE:..1..2..3..4..5

113. PERFORMANCE, SWITCHING TRANSIENTS

System transients due to switching, fault clearing or other causes shall not make essential loads inoperative and shall not cause a smoke or fire hazard.

CIRCLE ONE:..1..2..3..4..5

114. PERFORMANCE, SYSTEM AUTOMATION

The all-electric design shall support a high level of system automation and sophisticated electronics and provide spare capacity to facilitate new function and system growth.

CIRCLE ONE:..1..2..3..4..5

115. PERFORMANCE, TRIM AIR

Provide adequate trim heating to all cabin zones under all ambient conditions and with severe mismatch of passenger loading.

CIRCLE ONE:..1..2..3..4..5

116. PROTECTION, AUTOMATIC PROTECTIVE DEVICE

Automatic protective devices must be used to minimize distress to the electrical system and hazard to the airplane in the event of wiring faults or serious malfunction of the system or connected equipment.

CIRCLE ONE:..1..2..3..4..5

117. PROTECTION, CIRCUIT BREAKER AUTOMATIC RESET

Automatic reset circuit breakers may be used as integral protectors for electrical equipment (such as thermal cut-outs) if there is circuit protection to protect the cable to the equipment.

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

CIRCLE ONE:..1..2..3..4..5

118. PROTECTION, CIRCUIT BREAKER RESET

If the ability to reset a circuit breaker or replace a fuse is essential to safety in flight, that circuit breaker or fuse must be located and identified so that it can be readily reset or replaced in flight.

CIRCLE ONE:..1..2..3..4..5

119. PROTECTION, CONTROL ISOLATION

Voltage and current isolation shall be provided for all flight control system logic modules.

CIRCLE ONE:..1..2..3..4..5

120. PROTECTION, ESSENTIAL LOAD PROTECTION

Each circuit for essential loads must have individual circuit protection. However, individual protection for each circuit in an essential load system (such as each position light circuit in a system) is not required.

CIRCLE ONE:..1..2..3..4..5

121. PROTECTION, FAULT PROTECTION

Generic, random and transient software and hardware fault protection will be provided for the fly-by-wire/light computer system critical functions.

CIRCLE ONE:..1..2..3..4..5

122. PROTECTION, FIBER OPTIC DATA RATES

Fiber optic technology may be used for all data rates, but are preferred for data rates over 2 MHz.

CIRCLE ONE:..1..2..3..4..5

123. PROTECTION, FIBER OPTIC EMI IMMUNITY

Fiber optic installations should be used to enhance aircraft immunity to EMI, HIRF and lightning.

CIRCLE ONE:..1..2..3..4..5

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

124. PROTECTION, FLIGHT CRITICAL CIRCUIT PROTECTION

Circuit division and protection shall be provided to prevent interruption to circuits critically affecting the safety of flight, and redundancy for flight safety shall not be compromised.

CIRCLE ONE:..1..2..3..4..5

125. PROTECTION, LOCAL DC SYSTEMS

Local 28V DC systems may be considered for use when supplied by 20 kHz sources with short distribution conductor lengths.

CIRCLE ONE:..1..2..3..4..5

126. PROTECTION, PASSIVE CIRCUIT CHECKS

A system of passive checks (tests) shall be provided to support pre-flight checkout and post-flight maintenance operations.

CIRCLE ONE:..1..2..3..4..5

127. PROTECTION, PHASE SEQUENCE PROTECTION

Protection shall be provided for the generator AC output circuits to avoided incorrect phase rotation/sequence.

CIRCLE ONE:..1..2..3..4..5

128. PROTECTION, PROTECTIVE AND CONTROL DEVICES

The protective & control devices must be designed to de-energize & disconnect faulty sources & transmission equipment from their associated buses with sufficient rapidity to protect from hazardous over-voltage & other malfunctioning.

CIRCLE ONE:..1..2..3..4..5

129. PROTECTION, RESETTABLE CIRCUIT PORTECTIVE DEVICES

Each resettable circuit protective device must be designed so that, when an overload or circuit fault exists, it will open the circuit irrespective of the position of the operating control.

CIRCLE ONE:..1..2..3..4..5

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

130. REDUNDANCY, AIR SOURCE RELIABILITY

Two air sources must be operative for normal dispatch above 25,000 ft.

CIRCLE ONE:..1..2..3..4..5

131. REDUNDANCY, AVIONICS COOLING

The avionics cooling system must provide redundancy for dispatch, adequate cooling for new electrical loads and shall not overheat cargo (animal carrying) areas during this operating condition.

CIRCLE ONE:..1..2..3..4..5

132. REDUNDANCY, BACKUP POWER

Digital data systems shall be provided with backup power from dissimilar sources; i.e., batteries or RAT's in addition to the multipule redundant engine driven generators.

CIRCLE ONE:..1..2..3..4..5

133. REDUNDANCY, BUS, FEEDER AND BRANCH CKT ROUTE PLANNING

The redundancy, separation, isolation of buses, power feeders and load paths must provide circuit separation and isolation to avoid common failure modes between redundant systems.

CIRCLE ONE:..1..2..3..4..5

134. REDUNDANCY, CABIN PRESSURIZATION

With one pack inoperative, provide sufficient air for maximum cabin leakage plus repressurization at 300 fpm cabin rate of descent plus excess for cabin pressure control.

CIRCLE ONE:..1..2..3..4..5

135. REDUNDANCY, CIRCUIT REDUNDANCY

Separate (redundant) distribution cirucits shall be used to supply power to redundant load systems.

CIRCLE ONE:..1..2..3..4..5

136. REDUNDANCY, CONTROL POWER

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

Digital data systems used for control and aircraft systems management shall be powered by at least dual redundant sources separate from all operating power circuits.

CIRCLE ONE:..1..2..3..4..5

137. REDUNDANCY, DISPATCH LIMITS

Dispatch shall be acceptable with one generator inoperative.

CIRCLE ONE:..1..2..3..4..5

138. REDUNDANCY, FLY-BY-WIRE SYSTEM REDUNDANCY

Digital fly-by-wire circuits must be, at least, dual redundant and use multiplexing technology.

CIRCLE ONE:..1..2..3..4..5

139. REDUNDANCY, ICE PROTECTION FAILURE

Redundant air sources must be provided for trim air, avionics cooling, cabin ventilation, and ice protection.

CIRCLE ONE:..1..2..3..4..5

140. REDUNDANCY, OPERATIONAL DEGRADATION

Operational degradation to final backup control will be provided for compilation of fly-by-wire/light computer system critical functions.

CIRCLE ONE:..1..2..3..4..5

141. REDUNDANCY, POST FAILURE ICE PROTECTION

Provide complete ice protection after any probable failures including protection for the wing, engine cowl, air inlets and air data sensors.

CIRCLE ONE:..1..2..3..4..5

142. REDUNDANCY, PRIMARY ACTUATORS

Primary actuators, (Aileron, Spoilers, Elevators, and Rudder) should be of common sizes to the extent possible, based on dual redundancy on split ailerons, elevators, and rudder.

CIRCLE ONE:..1..2..3..4..5

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

143. REDUNDANCY, REDUNDANCY

The installed system must afford adequate redundancy to meet reliability criteria.

CIRCLE ONE:..1..2..3..4..5

144. REDUNDANCY, REDUNDANCY - COMPONENTS

Alternate parts, redundant sources and redundant loads may be used to satisfy critical load operational requirements.

CIRCLE ONE:..1..2..3..4..5

145. REDUNDANCY, SECONDAY ACTUATORS

Secondary actuators (Flaps and Slats) should be of common sizes to the extent possible.

CIRCLE ONE:..1..2..3..4..5

146. REDUNDANCY, SOURCE INDEPENDENCE

Redundant sources, distribution, control and monitoring elements shall be separated to the greatest extent possible to enhance reliability and to avoid common failure modes.

CIRCLE ONE:..1..2..3..4..5

147. RELIABILITY, AUTOLAND

The Auto-land mode must be highly reliable.

CIRCLE ONE:..1..2..3..4..5

148. RELIABILITY, CONTROL COMPUTERS

Fly-by-wire/light control computer system shall meet the operational requirement of 1 failure in one (1) failure in one (1) billion flt hours with one LRU inop for dispatch (extremely improbable failure).

CIRCLE ONE:..1..2..3..4..5

149. RELIABILITY, DISPATCH RELIABILITY

Dispatch of the aircraft with inoperative electrical components

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

should be equivalent to the MD80 or any comperable twin-transport.

CIRCLE ONE:..1..2..3..4..5

150. RELIABILITY, FAIL OPERATIONAL/SAFE

The electrical circuits shall provide FO/FO/FS reliability charateristics to all flight critical systems.

CIRCLE ONE:..1..2..3..4..5

151. RELIABILITY, FAILURE PROBABILITY

The electrical system supporting flight critical loads (Those which determine aircraft safety of flight) shall, together with the critical loads, provide a failure probability no greater than one (1) in one (1) billion fight hours.

CIRCLE ONE:..1..2..3..4..5

152. RELIABILITY, RELIABILITY

No failure or malfunction of any power source shall create a hazard or impair the ability of remaining sources to supply essential loads.

CIRCLE ONE:..1..2..3..4..5

153. RELIABILITY, SYSTEM AND COMPONENT ADVERSE OPERATING

The occurrence of any other failure condition which would reduce the capability of the airplane or the ability of the crew to cope with adverse operating conditions shall be improbable.

CIRCLE ONE:..1..2..3..4..5

154. RELIABILITY, SYSTEM/ASSOCIATED COMPONENT RELIABILITY

The occurrence of any failure condition which would prevent the continued safe flight and landing of the airplane shall be extremely improbable.

CIRCLE ONE:..1..2..3..4..5

155. VALIDATION COMP, CONTROL SOFTWARE

All fly-by-wire/light and autoflight software will meet and be tested to critical and essential standards as defined in the latest

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

revision of RTCA DO-178A.

CIRCLE ONE:..1..2..3..4..5

156. VALIDATION COMP, EMC TESTING

The system shall be acceptable as determined by an EMC testing program in accordance with the (TBD) specifications.

CIRCLE ONE:..1..2..3..4..5

**REQUIREMENTS SPECIFICATION
FOR A
20-kHz ELECTRICAL POWER SYSTEM ON A TWIN TRANSPORT
FEBRUARY 27, 1991**

This is the first draft of the 20-kHz electrical power system requirements specification for a 200-passenger twin transport (Ref: NAS3-26965).

Keep in mind that the Douglas task is to implement the NASA-provided 20-kHz baseline system concept in a 200-passenger transport and then identify the strengths and weaknesses of the 20-kHz design approach.

Comments on the draft material are requested. Please provide your comments to W. Murray or L. Feiner by the end of March 1991.

You are encouraged to comment on those items for which you feel you have knowledge or can give an opinion that will contribute to the definition of a 20-kHz power system.

A data base has been established for managing individual requirements records according to a subject, category, and other selected fields. The first few sheets in the attachment list the subjects, and pages C35 through C62 contain the records. Please circle the appropriate relevance classification for those records you choose and ignore all others unless you have comments or wish to add new records. (See the footnote for a definition of the relevance number.)

1. LOADS, 60 HZ POWER SUPPLIES

60 and 50 Hz power must be provided for aero medical equipment and for passenger shavers. The aero medical 60 Hz power must be a good quality sine wave. A square wave is adequate for shavers.

CIRCLE ONE:..1..2..3..4..5

2. FAULT TOLERANCE, ABNORMAL CONDITIONS

The system should be able to safely accommodate: Engine Speed Variations; Short Circuits; Overspeed Conditions.

CIRCLE ONE:..1..2..3..4..5

3. CREW INTERFACE, AC TIE SWITCHES

AC tie switches shall be included on the electrical system control panel to provide individual manual control of the bus tie relays when the electrical system is in the manual mode.

CIRCLE ONE:..1..2..3..4..5

4. LOADS, AFT CABIN GALLEY

A maximum combined service load of TBD KVA shall be provided for the aft cabin galley complex.

CIRCLE ONE:..1..2..3..4..5

5. INSTALLATION, AIRCRAFT EXTERNAL GROUNDING

A grounding lug (Appleton Electric P/N TGP9385 or equivalent) shall be installed in the vacinity of each main gear.

CIRCLE ONE:..1..2..3..4..5

6. INSTALLATION, AIRCRAFT STRUCTURAL GROUNDING

The aircraft structure may be the normal negative, common or neutral for the load cirucits, except for the primary 20 kHz power transmission system.

CIRCLE ONE:..1..2..3..4..5

7. CREW INTERFACE, ANNUNCIATION

Annunciation shall be provided on the electrical control panel to

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

indicate abnormalities.

CIRCLE ONE:..1..2..3..4..5

8. CREW INTERFACE, AUTOMATIC CONTROL

Remote monitoring and control shall be provided for management of the electrical power system elements and loads by the automatic EPS control system or by the crew.

CIRCLE ONE:..1..2..3..4..5

9. PROTECTION, AUTOMATIC LANDING DUAL-LAND

Intiation of automatic landing shall automatically open the appropriate remote control circuit breakers to isolate the left DC bus from the right battery bus.

CIRCLE ONE:..1..2..3..4..5

10. PROTECTION, AUTOMATIC LANDING (DUAL LAND)

Initiation of automatic landing shall automatically unparallel the main generator buses and the 20 kHz transmission lines.

CIRCLE ONE:..1..2..3..4..5

11. PROTECTION, AUTOMATIC MODES

The automatic mode of operation shall take into account the phase of flight and shall preclude any undesireable changes in the system configuration.

CIRCLE ONE:..1..2..3..4..5

12. PROTECTION, AUTOMATIC/MANUAL CONTROL

The electrical system shall be controlled automatically with a manual backup mode of operation.

CIRCLE ONE:..1..2..3..4..5

13. CREW INTERFACE, AUTOMATIC/MANUAL CONTROL SWITCH

A system master selection/control switch shall control whether the electrical system is in the automatic or manual mode.

CIRCLE ONE:..1..2..3..4..5

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

14. EMERG PROVISION, AUXILARY POWER RELAYS

Two auxilary power relays, one to connect the RAT generator to each 20 kHz main bus, shall be installed.

CIRCLE ONE:..1..2..3..4..5

15. EMERG PROVISION, BACKUP ELECTRICAL POWER

Emergency electrical power will be provided to all flight control electronics and actuation in the event of main power bus failures or total engine failure.

CIRCLE ONE:..1..2..3..4..5

16. EMERG PROVISION, BATTERY BUS REGULATION

Battery bus regulation to 28 volt DC, nominal, is required during battery charging (42 volts DC nominal)

CIRCLE ONE:..1..2..3..4..5

17. EMERG PROVISION, BATTERY BUSES

A 28 volt DC battery bus shall be installed for each battery to distribute the DC power at 28 volt DC nominal.

CIRCLE ONE:..1..2..3..4..5

18. EMERG PROVISION, BATTERY CAPACITY

When fully charged, each battery shall be capable of providing electrical power for approximately 15 minutes for all loads essential for safe operation of the aircraft.

CIRCLE ONE:..1..2..3..4..5

19. INSTALLATION, BATTERY CASE VENTILATION

In flight, battery case ventilation shall be by venturi action, and on the ground, by a non-forced astmospheric vent through the flight venturi system.

CIRCLE ONE:..1..2..3..4..5

20. EMERG PROVISION, BATTERY CHARGER

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

A current-limiting battery charger shall be incorporated in each battery/DC bi-directional converter and it shall be protected by inhibiting circuitry to insure proper operation and temperature.

CIRCLE ONE:..1..2..3..4..5

21. EMERG PROVISION, BATTERY DIRECT BUS

The battery shall supply power directly to the battery direct bus which shall supply only those loads which can tolerate 42 volt charging voltage.

CIRCLE ONE:..1..2..3..4..5

22. EMERG PROVISION, BATTERY DISCHARGE POWER

If the associated converter is not producing power, the battery shall provide power to the Battery Bus.

CIRCLE ONE:..1..2..3..4..5

23. INSTALLATION, BATTERY DISCONNECTS

The battery electrical connectors shall be of the quick-disconnect type.

CIRCLE ONE:..1..2..3..4..5

24. EMERG PROVISION, BATTERY EMERGENCY POWER

Emergency power shall be adapted to the 20 kHz/DC battery bus and bi-directional battery charger design concept.

CIRCLE ONE:..1..2..3..4..5

25. INSTALLATION, BATTERY VENTILATION

Battery ventilation shall be provided to vent the batteries to accommodate a specified maximum gassing rate.

CIRCLE ONE:..1..2..3..4..5

26. INSTALLATION, BATTERY VOLTAGE

Two 11-cell battery assemblies shall be connected in series to provide a nominal 28 volt DC power source for each of the two main batteries.

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

CIRCLE ONE:..1..2..3..4..5

27. REDUNDANCY, BUS TIE RELAYS

Bus tie relays shall be installed to connect each generator/converter bus to each of the 20 kHz AC tie buses.

CIRCLE ONE:..1..2..3..4..5

28. INSTALLATION, CABIN UTILITY BUSES

Cabin utility power buses shall be installed to distribute power for passenger lighting and other service equipment in the cabin(s).

CIRCLE ONE:..1..2..3..4..5

29. LOADS, CABIN UTILITY POWER

Cabin utility power buses shall receive 20 kHz, 440 volt AC, single phase power from either the left or right 20 kHz main or power transmission buses.

CIRCLE ONE:..1..2..3..4..5

30. FAULT TOLERANCE, COMMON MODE IMPEDANCE

System design should provide minimum common mode impedances for loads having power or currents which are of relatively large magnitudes.

CIRCLE ONE:..1..2..3..4..5

31. CREW INTERFACE, CONTROL AND MONITORING SYS SELECTION

Electrical power system control, monitoring and display systems shall be integrated with the flight deck control/display systems and control shall rely on remotely controlled/programmable circuit protection devices.

CIRCLE ONE:..1..2..3..4..5

32. PERFORMANCE, CONTROL POWER

Control power must be adequately and reliably provided.

CIRCLE ONE:..1..2..3..4..5

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

33. EMERG PROVISION, CONVERTER CHARGING POWER

The battery bus shall receive power from the bi-directional converter with battery charge control.

CIRCLE ONE:..1..2..3..4..5

34. CREW INTERFACE, CREW DISCONNECT

Means shall be provided which are accessible in flight to appropriate crew members for individual and collective disconnection of the electrical power sources from the system.

CIRCLE ONE:..1..2..3..4..5

35. PERFORMANCE, DC BIAS

The system should not give rise to significant DC content.

CIRCLE ONE:..1..2..3..4..5

36. LOADS, DC TO AC CONVERSION

Power-limited 28V DC conversion to 20 kHz may be considered for special purposes.

CIRCLE ONE:..1..2..3..4..5

37. INSTALLATION, DISTRIBUTED POWER CONTROL

Distributed system controls and distributed power centers should be defined to obtain the greatest potential weight reduction and to utilze the most advanced electronics.

CIRCLE ONE:..1..2..3..4..5

38. INSTALLATION, DISTRIBUTED POWER CONTROL

Distributed system controls and distributed power centers should be defined to obtain the greatest potential weight reduction and to utilze the most advanced electronics.

CIRCLE ONE:..1..2..3..4..5

39. PERFORMANCE, ELECTRICAL POWER - 20 kHz

Electrical power shall be provided, wherever possible, at 20 kHz,

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

440 volt, single phase to all loads and load buses.

CIRCLE ONE:..1..2..3..4..5

40. PERFORMANCE, ELECTRICAL POWERR CHARACTERISTICS

The aircraft electrical circuits shall be capable of receiving 115/200 volt, 3 phase power at 400 Hz, 60 Hz, or 50 Hz through the external power receptacle and external power relays.

CIRCLE ONE:..1..2..3..4..5

41. LOADS, ELECTRICAL POWER-400 Hz

Where low frequency (400 Hz) power is necessary, power converters shall be installed to convert from 20 kHz to either 115/200 volt three phase or 115 volt single phase power, for selected load groups.

CIRCLE ONE:..1..2..3..4..5

42. LOADS, ELECTRICAL POWER-HVDC

Where high voltage direct current power is necessary, power converters shall be installed to convert from 20 kHz to 270 volt DC power.

CIRCLE ONE:..1..2..3..4..5

43. INSTALLATION, ELECTRICAL SYSTEM CONTROLLERS

Electrical system controllers shall be installed in the main power control center.

CIRCLE ONE:..1..2..3..4..5

44. CREW INTERFACE, ELECTRICAL SYSTEM DISPLAY

All electrical system parameters which are required for system monitoring shall be presented on the system display.

CIRCLE ONE:..1..2..3..4..5

45. EMERG PROVISION, EMERGENCY AC POWER

Two bi-directional converters shall be installed to provide 440 volt 20 Khz single phase emergency power, one each for the left and right emergency 20 kHz AC bus when the normal power source and RAT

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

electrical power are not available.

CIRCLE ONE:..1..2..3..4..5

46. EMERG PROVISION, EMERGENCY BATTERY CHARGER

Each battery converter shall have a charge controller to charge the associated main battery and to provide power to the uninterrupted computer bus.

CIRCLE ONE:..1..2..3..4..5

47. EMERG PROVISION, EMERGENCY BUS POWER

The left AC emergency bus and the right AC emergency bus shall normally receive power from either the left or the right 20 kHz power transmission bus and these emergency buses are normally supplied by different 20 kHz buses.

CIRCLE ONE:..1..2..3..4..5

48. EMERG PROVISION, EMERGENCY BUSES

A 115 VAC, 400 Hz, 1 phase left emergency bus and 3 phase right emergency bus shall be installed for equipment which cannot accept 20 khz directly or for which individual converters (synthesizers) would not be cost effective.

CIRCLE ONE:..1..2..3..4..5

49. EMERG PROVISION, EMERGENCY POWER

Reliable emergency power shall be provided during abnormal operating conditions.

CIRCLE ONE:..1..2..3..4..5

50. CREW INTERFACE, EMERGENCY POWER SELECTION

Both automatic and manual selection shall be provided for emergency power system elements.

CIRCLE ONE:..1..2..3..4..5

51. EMERG PROVISION, EMERGENCY STATIC CONVERTER

TBD KVA static converters shall be installed to provide single phase 115 volt 400 Hz power to the left and right emergency 400 Hz AC

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

buses.

CIRCLE ONE:..1..2..3..4..5

52. PERFORMANCE, ENGINE STARTING POWER

The main bi-directional power converter shall enable aircraft engine starting by runing the main generators as motors using any power source(s) available to the 20 kHz main buses.

CIRCLE ONE:..1..2..3..4..5

53. CREW INTERFACE, EPS CONTROL PANEL

An electrical system control panel shall be installed in the flight deck (cockpit).

CIRCLE ONE:..1..2..3..4..5

54. CREW INTERFACE, EPS CONTROL POWER DESIGN

The electrical system control switches and annunciator lights shall be arranged to provide a schematic presentation of the electrical systems.

CIRCLE ONE:..1..2..3..4..5

55. INSTALLATION, EPS CONTROL UNIT

An electrical power system control unit shall be installed in a location TBD to control 20 khz and 28 volt DC bus ties and to provide automatic control functions.

CIRCLE ONE:..1..2..3..4..5

56. PROTECTION, EPS FAULT PROTECTION

The aircraft electrical power system shall be protected against shorts and grounds, open circuits, over and under voltage, frequency and excitation for the generators, unbalanced currents and incorrect phase sequence.

CIRCLE ONE:..1..2..3..4..5

57. PROTECTION, EPS OVERLOAD PROTECTION

Circuitry interlock protection shall prevent the connection of large power loads to a single bus or generator, or combination of

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

generators, where such loads will seriously overload the bus, generators, or system.

CIRCLE ONE:..1..2..3..4..5

58. PROTECTION, EPS PROTECTION

A fully coordinated electrical protection system shall be provided to minimize loss of service and to reduce the potential for damage to equipment and/or the aircraft.

CIRCLE ONE:..1..2..3..4..5

59. PROTECTION, EPS PROTECTION OPERATION

The protective equipment shall discriminate between faulted and unfaulted components and shall isolate the faulted components from the system without interrupting service from the remaining components in so far as is practicable.

CIRCLE ONE:..1..2..3..4..5

60. INSTALLATION, EXTERNAL POWER

Means must be provided to ensure that no external power supply having a reverse polarity or a reverse phase sequence can supply power to the airplane's electrical system.

CIRCLE ONE:..1..2..3..4..5

61. PERFORMANCE, EXTERNAL POWER CONTROL

The electrical power control unit shall provide 28 volt DC battery or rectified external power at pin F of the external power receptacle.

CIRCLE ONE:..1..2..3..4..5

62. PERFORMANCE, EXTERNAL POWER CONVERSION

Conversion to 20 kHz shall be accomplished within the aircraft.

CIRCLE ONE:..1..2..3..4..5

63. PERFORMANCE, EXTERNAL POWER ENABLING CURRENT

The maximum DC current available from pin F for use in applying external power to the aircraft shall be 0.5 ampere.

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

CIRCLE ONE:..1..2..3..4..5

64. PERFORMANCE, EXTERNAL POWER ENABLING VOLTAGE

28 volt DC power must be applied to pin E (via the external power plug) in order for the aircraft external power relay to close.

CIRCLE ONE:..1..2..3..4..5

65. CREW INTERFACE, EXTERNAL POWER PANEL

An external power panel shall be installed near the external power receptacle.

CIRCLE ONE:..1..2..3..4..5

66. PERFORMANCE, EXTERNAL POWER PRIORITY

Whenever external power is available and selected, it shall have priority to supply the 20 kHz tie buses.

CIRCLE ONE:..1..2..3..4..5

67. PROTECTION, EXTERNAL POWER PROTECTION

With power from the main external power source, the electrical system shall be protected against over and under voltage/frequency, shorts, grounds and incorrect phase sequence.

CIRCLE ONE:..1..2..3..4..5

68. PERFORMANCE, EXTERNAL POWER RELAY

An external power relay shall be installed to provide external power the two right hand main 20 kHz power converters.

CIRCLE ONE:..1..2..3..4..5

69. CREW INTERFACE, EXTERNAL POWER STATUS DISPLAY

Main external power annunciator lights (AVAILABLE and ON) shall be installed on the electrical system control panel, the external power panel and the cabin service panel.

CIRCLE ONE:..1..2..3..4..5

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

70. CREW INTERFACE, EXTERNAL POWER SWITCH

The main external power switch shall be located on the electrical system control panel to control the application of external power to the external power bus and to the associated main 20 kHz power converters.

CIRCLE ONE:..1..2..3..4..5

71. CREW INTERFACE, EXTERNAL POWER SWITCHES

Two external power switches shall be installed, one on the ground panel and one on the cabin service panel, to control the application of external power to the external power bus and the two right-hand main 20 kHz power converters.

CIRCLE ONE:..1..2..3..4..5

72. CREW INTERFACE, EXTERNAL POWER UNAVAILABLE LIGHT

A Main External Power Not On annuciator light shall be installed on the external power panel.

CIRCLE ONE:..1..2..3..4..5

73. WEIGHT, FLY-BY-WIRE/LIGHT

Fly-by-wire/light flight controls will be implemented to provide optimum aircraft performance and to reduce system weight.

CIRCLE ONE:..1..2..3..4..5

74. LOADS, FORWARD CABIN GALLEY

A maximum combined service load of TBD KVA shall be provided for the forward cabin galley complex.

CIRCLE ONE:..1..2..3..4..5

75. CREW INTERFACE, GALLEY BUS POWER RESET

Galley bus reset switches, one for each galley bus, shall be installed on the electrical power system panel.

CIRCLE ONE:..1..2..3..4..5

76. PROTECTION, GALLEY DIFFERENTIAL PROTECTION

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

Galley feeders shall be protected by differential protection circuit.

CIRCLE ONE:..1..2..3..4..5

77. CREW INTERFACE, GALLEY EXTERNAL POWER ANNUNCIATION LIGHT

Galley External Power Available and Power On annuciator lights shall be included on the electrical systems control panel and the ground power panel.

CIRCLE ONE:..1..2..3..4..5

78. PERFORMANCE, GALLEY EXTERNAL POWER CONVERSION

Conversion of 115/200 volt, 3 phase, 400 Hz or 60 Hz or 50 Hz external power to 20 kHz power shall be accomplished within the aircraft.

CIRCLE ONE:..1..2..3..4..5

79. PERFORMANCE, GALLEY EXTERNAL POWER ENABLING CURRENT

The maximum DC current available from pin F for use in applying galley external power to the aircraft shall be 0.5 ampere.

CIRCLE ONE:..1..2..3..4..5

80. PERFORMANCE, GALLEY EXTERNAL POWER ENABLING VOLTAGE

28 volt DC power must be applied to pin E (via the galley external power plug) in order for the aircraft galley transfer relays to close into the external power position.

CIRCLE ONE:..1..2..3..4..5

81. PROTECTION, GALLEY EXTERNAL POWER PROTECTION

With power from the external power source, the electrical system shall be protected against over and under voltage/frequency, shorts, grounds and incorrect phase sequence.

CIRCLE ONE:..1..2..3..4..5

82. PERFORMANCE, GALLEY EXTERNAL POWER SWITCH

A galley external power switch shall be located on the electrical system control panel to control the application of external power to

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

the 20 kHz galley power converters.

CIRCLE ONE:..1..2..3..4..5

83. CREW INTERFACE, GALLEY EXTERNAL POWER UNAVAILABLE LIGHT

A Galley External Power Not On annuciator light shall be installed on the ground power panel.

CIRCLE ONE:..1..2..3..4..5

84. PERFORMANCE, GALLEY EXTERNAL RECEPTACLE

A galley external power receptacle shall be installed aft of the nose landing gear wheel well near the aircraft external power receptacle.

CIRCLE ONE:..1..2..3..4..5

85. PERFORMANCE, GALLEY LOAD CONTROL

A galley load control unit shall be installed for each galley.

CIRCLE ONE:..1..2..3..4..5

86. PERFORMANCE, GALLEY LOAD CONTROL UNITS

Galley load control units shall be installed to connect each of the galley buses to either of the 20 kHz transmission lines and shall provide a galley load shedding function.

CIRCLE ONE:..1..2..3..4..5

87. PERFORMANCE, GALLEY LOAD POWER

Wiring shall be installed for each galley load of TBD KVA of 440 volt, single phase 20 kHz power.

CIRCLE ONE:..1..2..3..4..5

88. PROTECTION, GALLEY LOAD POWER SHEDDING

When an overload on the electrical system exists, power for galley service shall be automatically shut off.

CIRCLE ONE:..1..2..3..4..5

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

89. CREW INTERFACE, GALLEY LOAD RESTORATION

Restoration of power to the galley load shall require manual operation.

CIRCLE ONE:..1..2..3..4..5

90. PROTECTION, GALLEY LOAD SHEDDING

Power shall be removed by the protective circuit from all galley loads to eliminate overloads and such action shall be appropriately indicated.

CIRCLE ONE:..1..2..3..4..5

91. PERFORMANCE, GALLEY MAXIMUM EXTERNAL POWER

Galley power to a maximum of TBD KVA shall be provided from the external power source through the galley external power receptacle while main external power is received through the main external power receptacle.

CIRCLE ONE:..1..2..3..4..5

92. PERFORMANCE, GALLEY POWER

20 kHz 440 volt single phase heating power shall be provided for galleys if technically feasible and the control power shall be 28 DC derived from the same 20 kHz source bus.

CIRCLE ONE:..1..2..3..4..5

93. PERFORMANCE, GALLEY POWER CABLE RETENTION

A retension device shall be installed on the receptacle to protect against inadvertent disconnection of the galley external power cable.

CIRCLE ONE:..1..2..3..4..5

94. PERFORMANCE, GALLEY POWER CHARACTERISTICS

The AC galley loads shall be capable of receiving 440 volt, single phase 20 kHz power.

CIRCLE ONE:..1..2..3..4..5

95. PERFORMANCE, GALLEY POWER DISTRIBUTION

The galley power shall be distributed to meet the specified power level requirements.

CIRCLE ONE:..1..2..3..4..5

96. PERFORMANCE, GALLEY TRANSFER SWITCHES

Galley transfer relays shall be installed to connect each of the galley buses to the 20 kHz external power converter(s).

CIRCLE ONE:..1..2..3..4..5

97. CREW INTERFACE, GENERATOR BUS FAULT RESET

Bus fault reset switches, one for each generator bus shall be installed on the electrical power system panel.

CIRCLE ONE:..1..2..3..4..5

98. LOADS, GENERATOR BUS LOCATION/CONFIGURATION

No loads shall be connected directly to the generator output other than the bi-directional converter.

CIRCLE ONE:..1..2..3..4..5

99. PERFORMANCE, GENERATOR BUSES

Four AC generator buses, one for each engine generator, shall be installed as the main generator power source buses for 115/200 volt, 3 phase, 400-1200 Hz (or higher) variable frequency generator power.

CIRCLE ONE:..1..2..3..4..5

100. INSTALLATION, GENERATOR CONNECTIONS

Each generator shall incorporate a means for quick attachment and detachment.

CIRCLE ONE:..1..2..3..4..5

101. INSTALLATION, GENERATOR CONTROL UNITS

Generator control units, one for each generator/drive/converter channel, may be installed in the electrical power center.

CIRCLE ONE:..1..2..3..4..5

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

102. CREW INTERFACE, GENERATOR DISCONNECTS

Generator disconnect switches shall be included on the electrical system control panel, one for each generator, and re-engagement of a disconnect device shall be possible only on the ground with the engines not operating.

CIRCLE ONE:..1..2..3..4..5

103. PERFORMANCE, GENERATOR EXCITATION

The generator excitation system shall be capable of excitation for rated power over the full operating speed range.

CIRCLE ONE:..1..2..3..4..5

104. INSTALLATION, GENERATOR POWER RELAYS

Generator power relays, one for each generator/drive/converter channel, may be installed to connect each generator to the respective generator bus.

CIRCLE ONE:..1..2..3..4..5

105. PERFORMANCE, GENERATOR PRIORITY

Whenever a main AC generator/converter is capable of delivering power, all 20 kHz main buses may be connected to that source.

CIRCLE ONE:..1..2..3..4..5

106. INSTALLATION, GENERATORS

Each generator drive assembly should include a TBD KVA, 3 phase, 240/416 volt or 120/208 volt 400-1200 Hz (or higher) brushless generator as the primary source of electrical power for normal operation of the aircraft.

CIRCLE ONE:..1..2..3..4..5

107. PERFORMANCE, GENERATORS

Power sources must function properly when independent and when connected in combination/parallel.

CIRCLE ONE:..1..2..3..4..5

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

108. PERFORMANCE, GROUND OPERATION

The aircraft electrical power system shall be capable of full ground operation without power to the aircraft's main engine flight power buses.

CIRCLE ONE:..1..2..3..4..5

109. PERFORMANCE, GROUND POWER

Ground or external power shall be acceptable in the forms of 400 Hz, 50 Hz, 60 Hz, or 20 kHz, and shall be converted to 20 kHz power for distribution within the airplane.

CIRCLE ONE:..1..2..3..4..5

110. OTHER IMPACTS, GROUND SERVICE BUS

With only the ground service bus energized, either or both right hand bi-directional converters shall be powered to charge the batteries and all 20 kHz buses may be powered subject to the ground power limit.

CIRCLE ONE:..1..2..3..4..5

111. PERFORMANCE, GROWTH CAPABILITY

Components and distribution systems must be capable of safely accommodating moderate increase in bus loads.

CIRCLE ONE:..1..2..3..4..5

112. EMERG PROVISION, IMMEDIATE EMERGENCY POWER SOURCE

For immediate power to emergency flight-critical loads, one or more battery sources shall be provided.

CIRCLE ONE:..1..2..3..4..5

113. CREW INTERFACE, INDICATION

There shall be means to indicate the generating system quantities essential for safe operation of the system, such as the voltage and current supplied by each generator.

CIRCLE ONE:..1..2..3..4..5

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

114. LOADS, INSTRUMENT POWER BUSES

28 volt AC instrument power buses shall be installed on the flight deck to distribute 28 volt AC power to instruments and related loads.

CIRCLE ONE:..1..2..3..4..5

115. INSTALLATION, INSTRUMENT POWER TRANSFORMERS

28 volt AC instrument power transformers shall be installed to provide 28 volt AC, single phase, 400 Hz power on the flight deck.

CIRCLE ONE:..1..2..3..4..5

116. PROTECTION, INTERRUPT CAPABILITY

The system shall have adequate: Short circuit capability; Voltage post fault voltage recovery; Fault interrupt capability.

CIRCLE ONE:..1..2..3..4..5

117. PERFORMANCE, ISOLATED TRANSMISSION BUSES

The buses may be operated in an isolated mode and loads may be connected to either 20 kHz main power transmission bus.

CIRCLE ONE:..1..2..3..4..5

118. PROTECTION, ISOLATION FROM RAT/GROUND POWER

Means shall be provided to prevent continued paralleling of any main engine-driven generator/converter with either the RAT driven generator/converter or the external power converter.

CIRCLE ONE:..1..2..3..4..5

119. INSTALLATION, LOAD CONVERTER LOCATION

The 20 kHz load converter and synthesizers shall be located near the 400 Hz, 270 volt DC, or 28 volt DC buses or the loads which they serve.

CIRCLE ONE:..1..2..3..4..5

120. LOADS, LOAD POWER

Power shall be delivered to load centers, load groups and/or individual loads in the form and voltage best suited to the load(s).

CIRCLE ONE:..1..2..3..4..5

121. PROTECTION, LOAD SHEDDING-AUTOMATIC

Automatic load shedding shall be provided as necessary to sustain flight critical loads upon loss of system elements.

CIRCLE ONE:..1..2..3..4..5

122. PROTECTION, LOAD SHEDDING-MANUAL

Manual load shedding shall be provided to enhance power system management and reconfiguration.

CIRCLE ONE:..1..2..3..4..5

123. LOADS, LOAD/POWER COMPATIBLITY

The supplied power should be commensurate with: Motor Loads; Lamp Loads; Unbalanced Loads; Step Loads; Leading Power Factor Loads.

CIRCLE ONE:..1..2..3..4..5

124. LOADS, LOW FREQUENCY LOADS

Low frequency (400 Hz) power may be used for electrical/electronics equipment, conversion to 270 volt DC actuator power and 28 volt AC instrument power transformers.

CIRCLE ONE:..1..2..3..4..5

125. LOADS, LOW FREQUENCY POWER BUSES

Low frequency power to loads shall be minimized, and where possible, such loads shall be grouped and supplied by load buses.

CIRCLE ONE:..1..2..3..4..5

126. PERFORMANCE, MAIN ALL-ELECTRIC POWER SYSTEM

The main electrical power transmission system shall consist of a 20 kHz alternating current system.

CIRCLE ONE:..1..2..3..4..5

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

127. INSTALLATION, MAIN ELECTRICAL CONVERTER LOCATION

The main electrical power converters can be either separate or integral with the generator/drive assembly.

CIRCLE ONE:..1..2..3..4..5

128. INSTALLATION, MAIN EXTERNAL POWER RECEPTACLE

A main external power receptacle shall be installed aft of the nose landing gear wheel well just left of the aircraft center line.

CIRCLE ONE:..1..2..3..4..5

129. INSTALLATION, MAIN POWER CONVERTERS

Four main bi-directinal converters shall be installed, one for each generator, to convert variable frequency power to 20 kHz, 440 volt, single phase power.

CIRCLE ONE:..1..2..3..4..5

130. CREW INTERFACE, MASTER EPS CONTROL

System master switch is (Automatic/Manual Mode Switch, Battery Switches and Emergency Power switch) shall be included on the electrical system control panel.

CIRCLE ONE:..1..2..3..4..5

131. LOADS, MID CABIN GALLEY

A maximum combined service load of TBD KVA shall be provided for the mid cabin galley complex.

CIRCLE ONE:..1..2..3..4..5

132. PERFORMANCE, NO BREAK POWER

As subsequent main generator/converters become capable of delivering power, they shall automatically supply power to the associated 20 kHz bus without a power interruption occuring.

CIRCLE ONE:..1..2..3..4..5

133. LOADS, NON 20 kHz LOADS

28V DC and 400 Hz alternating current shall be provided for loads

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

and buses for which 20 kHz cannot practically be used.

CIRCLE ONE:..1..2..3..4..5

134. EMERG PROVISION, NORMAL BATTERY CHARGING

The battery chargers shall each charge the associated battery whenever power is present on either 20 kHz transmission line, the associated battery switch is ON and the associated emergency power relay is not energized.

CIRCLE ONE:..1..2..3..4..5

135. PERFORMANCE, NORMAL POWER SOURCE

The secondary power requirements shall be supplied by the aircraft engines during normal operation.

CIRCLE ONE:..1..2..3..4..5

136. PERFORMANCE, NO-BREAK POWER TRANSFER

The control system shall provide no-break power transfer between any two sources of main 440 VAC, single phase 20 kHz power (i.e., main converters, APU generator (if used), external power converters).

CIRCLE ONE:..1..2..3..4..5

137. INSTALLATION, OIL COOLING

A means shall be installed in each nacelle to cool the generator oil while on the ground or in flight.

CIRCLE ONE:..1..2..3..4..5

138. INSTALLATION, PACKAGING

Equipment and components packaging, except for high power connections, should conform to ARINC 600 or 650 packaging standards.

CIRCLE ONE:..1..2..3..4..5

139. PERFORMANCE, PARALLELING CONTROLS

Paralleling shall be controlled by an automatic control circuit through control of the bus tie relays and the generator/converter relays.

CIRCLE ONE:..1..2..3..4..5

140. PERFORMANCE, PARALLEL/ISOLATED OPERATION

The generator/converter system shall be designed so that all main engine driven generator/converter channels can be operated either isolated or paralleled.

CIRCLE ONE:..1..2..3..4..5

141. PERFORMANCE, POWER BUS SOURCE PRIORITY

Power source priority to the generator/converter buses shall be: main generators, first priority; AC tie bus, second priority. (RAT generator/converter is for emergency power only).

CIRCLE ONE:..1..2..3..4..5

142. INSTALLATION, POWER CABLE RETENTION

A retention device shall be installed on the receptacle to protect against inadvertent disconnection of the main external power cable.

CIRCLE ONE:..1..2..3..4..5

143. INSTALLATION, POWER CENTERS-ELECTRICAL

Power distribution centers and panels shall be located so as to facilitate the control, protection and economical distribution of power to the loads.

CIRCLE ONE:..1..2..3..4..5

144. INSTALLATION, POWER CENTERS-PHYSICAL

Power centers and panels shall be located to benefit/accommodate weight and balance, structural requirements and clear-volume requirements of the airplane.

CIRCLE ONE:..1..2..3..4..5

145. PERFORMANCE, POWER QUALITY

Power quality shall be in accordance with MIL-STD-704 (400 Hz, 60/50 Hz AND 28 VDC) or AS4385 (20kHz) or other specified control document(s).

CIRCLE ONE:..1..2..3..4..5

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

146. PERFORMANCE, POWER TRANSMISSION BUSES

Power to all aircraft loads is distributed by the two 20 kHz main power transmission buses, which are normally operated in parallel.

CIRCLE ONE:..1..2..3..4..5

147. CREW INTERFACE, PREFLIGHT TESTING

Automatic and manual system tests shall be provided for the electrical power system by the centralized fault display system (CFDS).

CIRCLE ONE:..1..2..3..4..5

148. EMERG PROVISION, RAT BATTERY CHARGING

The RAT may be used to power the battery chargers to restore charge to the battery.

CIRCLE ONE:..1..2..3..4..5

149. EMERG PROVISION, RAT CONTROL

A RAT power switch shall be included on the electrical system control panel to provide control of the RAT generator and converter electrical power onto the 20 kHz main generator buses.

CIRCLE ONE:..1..2..3..4..5

150. EMERG PROVISION, RAT DEPLOYMENT

A RAT release (deploy) handle shall be installed at the pedestal in the cockpit.

CIRCLE ONE:..1..2..3..4..5

151. EMERG PROVISION, RAT GENERATOR

One TBD KVA, 3 phase, 120/208 volt or 240/416 volt, 400-1200 Hz generator shall be installed on the ram air turbine (RAT).

CIRCLE ONE:..1..2..3..4..5

152. EMERG PROVISION, RAT GENERATOR CONTROL UNIT

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

A RAT generator control unit shall be installed in a location (TBD).

CIRCLE ONE:..1..2..3..4..5

153. EMERG PROVISION, RAT POWER

When deployed, the RAT shall normally provide power through the RAT converter and 20 kHz transmission bus B to the emergency buses and to the flight control buses.

CIRCLE ONE:..1..2..3..4..5

154. CREW INTERFACE, RAT POWER ANNUNCIATION

RAT Power Available and RAT Power On annunciations shall be included on the electrical system control panel.

CIRCLE ONE:..1..2..3..4..5

155. EMERG PROVISION, RAT POWER CONVERSION

A bi-directional converter shall be installed in a TBD location to convert the RAT generator low-frequency power to 20 kHz power.

CIRCLE ONE:..1..2..3..4..5

156. EMERG PROVISION, RAT POWER RATING

The RAT channel(s) shall be sufficient to provide emergency power in case of all-engine failure or for long duration loss of the main electrical system.

CIRCLE ONE:..1..2..3..4..5

157. EMERG PROVISION, RAT POWER TRANSFER

A RAT switch shall be included on the electrical system control panel to transfer RAT power from 20 Khz transmission bus B to 20 kHz transmission bus A.

CIRCLE ONE:..1..2..3..4..5

158. INSTALLATION, RAT REGULATOR

A RAT regulator assembly shall be installed in a TBD location to provide voltage regulation of the RAT generator.

CIRCLE ONE:..1..2..3..4..5

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

159. EMERG PROVISION, RAT STOWAGE

After the RAT has been deployed, stowage of the RAT can be accomplished on the ground only.

CIRCLE ONE:..1..2..3..4..5

160. INSTALLATION, SCAVENGE OIL FILTER

The scavenge oil filter shall include a filter differential pressure indicator.

CIRCLE ONE:..1..2..3..4..5

161. EMERG PROVISION, SHORT-TERM POWER SOURCE

Short-term operational power may be provided by a RAT or a conbination of two or more of these dynamic power generators.

CIRCLE ONE:..1..2..3..4..5

162. CREW INTERFACE, SMOKE SWITCH

A smoke switch shall be included on the electrical panel, an automated electrical smoke isolation procedure shall be provided and inadvertant operation shall be precluded.

CIRCLE ONE:..1..2..3..4..5

163. INSTALLATION, SPLINE DRIVE LUBRICATION

The generator shall have a positively wet input spline drive using engine oil.

CIRCLE ONE:..1..2..3..4..5

164. PERFORMANCE, SPLIT SYSTEM FOR DUAL-LAND

The EPS achitecture must provide for a "split" system to accommodate Category III and Dual Land configurations.

CIRCLE ONE:..1..2..3..4..5

165. INSTALLATION, TERMINAL PROTECTION

An easily removable cover shall be provided to protect all terminal

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

strips.

CIRCLE ONE:..1..2..3..4..5

166. PERFORMANCE, TIE BUS POWER PRIORITY

Power source priority to the 20 kHz tie bus shall be in the following order, ground service (external power); main generator #4; main generator #3; main generator #2: main generator #1.

CIRCLE ONE:..1..2..3..4..5

167. INSTALLATION, TRANSFORMER RECTIFIER (T/R)

DC power should be processed from the 20kHz distribution bus as near to the utilization equipment as possible. The conversion will be regulated and filtered only as required by the load.

CIRCLE ONE:..1..2..3..4..5

168. INSTALLATION, UTILITY BUS LOCATION

The utility buses may be single buses or may be duplicated in several regions of the aircraft.

CIRCLE ONE:..1..2..3..4..5

169. PERFORMANCE, UTILITY BUS LOW FREQUENCY POWER

Each utility bus or segment thereof shall supply a transformer to support a 115 volt, 60 Hz or 50 Hz, single phase converter and low voltage bus.

CIRCLE ONE:..1..2..3..4..5

170. PERFORMANCE, UTILITY BUS POWER

Each utility bus shall supply power to either a 400 Hz conveter (synthesizer) for a 400 Hz load bus or a 20 kHz transformer for a low-voltage bus.

CIRCLE ONE:..1..2..3..4..5

171. PERFORMANCE, UTILITY BUSES

Left and right utility buses shall be powered by either the left or right 20 kHz, 440 volt, single phase transmission lines.

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

CIRCLE ONE:..1..2..3..4..5

172. INSTALLATION, UTILITY OUTLETS-400 Hz

115 volt, 400 Hz, single phase utility outlets, powered from the 20 kHz to 400 Hz converters, shall be provided in the flight compartment, avionics compartment and passenger compartment.

CIRCLE ONE:..1..2..3..4..5

173. INSTALLATION, UTILITY OUTLETS-60 Hz

115 volt, 60 Hz, single phase utility outlets, powered from the 20 kHz to 60 Hz converters, shall be provided in the lavoratories.

CIRCLE ONE:..1..2..3..4..5

174. PERFORMANCE, UTILITY & BUS POWER

Low frequency utility buses shall be provided by conversion from the 20 kHz power system to 115 volt 400 Hz single phase or to 60 Hz (domestic) or 50 Hz (foreign).

CIRCLE ONE:..1..2..3..4..5

175. PERFORMANCE, WAVEFORM

The output power characteristics must be acceptable in regard to: Voltage regulation and waveform (including T.H.C., Crest Factor, and Deviation Factor), as specified in WZZ7364.

CIRCLE ONE:..1..2..3..4..5

Relevance: 1-critical, 2-highly, 3-moderately, 4-marginally, 5-non

DESIGN EVALUATION PROCESS

ALL-ELECTRIC TRANSPORT AIRCRAFT EVALUATION

PROCESS

1. ENTER EVALUATORS ORGANIZATION, NAME AND DATE.
2. REVIEW CRITERIA/GUIDELINE "Recno" IN LISTING.
3. ENTER A "1" IN THE APPROPRIATE GRADING COLLUMN.
4. PROVIDE COMMENT IF NECESSARY.
5. SPREADSHEET EQUATIONS WILL SUM AND MULTIPLY TO GET TOTAL VOTES AND TOTAL SCORE.
6. INDIVIDUAL SPREADSHEETS WILL BE SUMMED TO GET A COMPOSITE SCORE.

ORG:
NAME:
DATE:

NUMERICAL GRADE

1	POOR	BARELY MEETS CRITERIA/GUIDELINE: BARELY ACCEPTABLE AND REDESIGN IS ADVISABLE.
2	FAIR	MARGINALLY MEETS CRITERIA/GUIDELINE; SHOULD HAVE OTHER SPECIFIC STRENGTHS
3	GOOD	CLEARLY MEETS CRITEREA/GUIDELINE; THIS IS THE MINIMUM DESIGN GOAL.
4	EXCELLENT	FULLY MEETS CRITERIA/GUIDEDLINE IN EVERY RESPECT.
5	SUPERIOR	EXCEEDS CRITERIA/GUIDELINE.

Recno	SUBJECT	N/A	POOR	FAIR	GOOD	EXCEL	SUPER	TOT	COMMENT
CERTIFICABILITY									
1	GENERAL REQUIREMENTS							0	
2	PARTICULAR REQUIREMENTS							0	
3	SPECIFICATIONS-INDUSTRIAL							0	
4	SPECIFICATIONS-MILITARY							0	
5	SPECIFICATIONS-REGULATORY							0	
6	SPECIFICATION-MDC							0	
COST									
7	MANUFACTURING COST							0	
CREW INTERFACE									
8	CIRCUIT AMBIGUITY							0	
9	CREW INFORMATION PROCESSING							0	
10	CREW INTERFACE							0	
11	CREW INTERVENTION							0	
12	CREW STATION ARRANGEMENT							0	
13	CREW WORKLOAD							0	
14	DISPLAY FAILURE							0	
15	DISPLAYED INFORMATION							0	
16	FAILURE ANNUNCIATION							0	
17	FLIGHT CRITICAL CIRCUIT CONTROLS							0	
18	FLIGHT DECK CREW							0	
19	GENERATOR CONTROL SWITCHES							0	
20	SOFTWARE ERRORS							0	
EMERG PROVISION									
21	AUTOMATIC RESTART							0	
22	BACKUP CONTROL							0	
23	BACKUP REVERSION							0	
24	CABIN TEMPERATURE CONTROL							0	
25	FIRE PROCEDURES							0	
26	GEN EQUIP SELECTION							0	
27	INDEPENDENT CABIN AIR SOURCES							0	
FAULT TOLERANCE									
28	ABNORMAL OPERATION							0	
29	FAULT TOLERANCE							0	
30	FAULT TOLERANCE							0	
31	PARTS STRESS LEVEL							0	
32	SINGLE FAULT VULNERABILITY							0	
33	TOLERANCE FOR DEGRADED PWR							0	

Recno	SUBJECT	N/A	POOR	FAIR	GOOD	EXCEL	SUPER	TOT	COMMENT
INSTALLATION									
34	AIRCRAFT MODEL							0	
35	COOLING							0	
36	DETAILED SYSTEM DESIGN							0	
37	DIGITAL FLY-BY-WIRE SYSTEM							0	
38	ELECTRICAL SYSTEM CONFIG							0	
39	EMC CONTROL							0	
40	EMC SPECIFICATIONS							0	
41	EMI REDUCTION							0	
42	ENGINE GENERATORS							0	
43	ENVIRONMENTAL CONSTRAINTS							0	
44	ENVIRONMENTAL CONSTRAINTS							0	
45	GND FOR LIGHTNING PROTECT'N							0	
46	HIGH TEMPERATURE WIRING							0	
47	INSTALLATION							0	
48	MAIN ELECT PWR CONVERTERS							0	
49	MATERIALS							0	
50	MINIMUM WIRE SIZE - 18 ga							0	
51	MINIMUM WIRE SIZE - 20 ga							0	
52	OIL SYSTEM							0	
53	OPEN WIRING							0	
54	PACKAGING							0	
55	PACKAGING TECHNOLOGY							0	
56	PHYSICAL INSTALLAT'N CONSTRAINTS							0	
57	PRIMARY CONTROL							0	
58	PROTECTION AGAINST FLUIDS							0	
59	SEGREGATE CRIT LOADS/EMERG BUS							0	
60	THERMAL MANAGEMENT							0	
61	WIRE AND BUS SIZE SELECTION							0	
62	WIRE BUNDLE INSTALLATION							0	
63	WIRE BUNDLE INSTALLATION							0	
64	WIRE HARNESSES							0	
65	WIRE INSULATION							0	
66	WIRE MOISTURE PREVENTION							0	
67	WIRE ROUTING							0	
68	WIRE SIZE SELECTION							0	
69	WIRING IN CONDUITS							0	
70	WIRING INSTALLATION							0	
LOADS									
71	AIR CONDITION							0	
72	ELECTRICAL LOAD ANALYSIS							0	
73	POWER CLASSIFICATION FOR EQUIP							0	
74	VOLTAGE & FREQUENCY REGULATION							0	
LOGISTICS									
75	COMPONENT AVAILABILITY							0	
76	EXOTIC MATERIALS							0	
77	MATERIALS							0	
78	TECHNOLOGY COMPLEXITY							0	
79	TOXIC MATERIAL							0	

Recno	SUBJECT	N/A	POOR	FAIR	GOOD	EXCEL	SUPER	TOT	COMMENT
MAINTENANCE									
80	BUILT-IN TEST							0	
81	COMPONENT INTERCHANGEABILITY							0	
82	DISPATCHABILITY							0	
83	EIDI							0	
84	EIDI FAILURE IDENTIFICATION							0	
85	FAULT REPORTING							0	
86	MAINTAINABILITY							0	
87	MOUNTING PAD							0	
88	VAPOR CYCLE REFRIGERATION							0	
89	VAPOR CYCLE SYSTEM PACKAGING							0	
OTHER IMPACTS									
90	BLEED AIR SYSTEM							0	
91	GROUND SERVICE							0	
92	GROUND SUPPORT EQUIPMENT							0	
93	ICE PROTECTION							0	
94	INTERACTION SENSITIVITY							0	
95	WATER EXTRACTION							0	
OWNERSHIP COST									
96	MAINTENANCE HOUR/FLIGHT HOUR							0	
97	MTBUR/MTBF							0	
98	OWNERSHIP COST							0	
PERFORMANCE									
99	7754150							0	
100	A111317							0	
101	CABIN AIR TEMP RESPONSE RATE							0	
102	CABIN PRESSURE CONTROL							0	
103	CARGO HEATING							0	
104	COLD AIR							0	
105	CONTROL ELECTRICAL POWER							0	
106	EFFICIENCY							0	
107	EMI SUPPRESSION							0	
108	EME/HIRF							0	
109	ENVIRONMENTAL SYSTEM CONFIG							0	
110	FIBER OPTIC COMPONENTS							0	
111	FIBER OPTIC UTILIZATION							0	
112	SMOKE REMOVAL							0	
113	SWITCHING TRANSIENTS							0	
114	SYSTEM AUTOMATION							0	
115	TRIM AIR							0	
PROTECTION									
116	AUTOMATIC PROTECTIVE DEVICE							0	
117	CIRCUIT BREAKER AUTOMATIC RESET							0	
118	CIRCUIT BREAKER RESET							0	
119	CONTROL ISOLATION							0	
120	ESSENTIAL LOAD PROTECTION							0	
121	FAULT PROTECTION							0	
122	FIBER OPTIC DATA RATES							0	
123	FIBER OPTIC EMI IMMUNITY							0	
124	FLT CRITICAL CIRCUIT PROTECTION							0	
125	LOCAL DC SYSTEMS							0	
126	PASSIVE CIRCUIT CHECKS							0	
127	PHASE SEQUENCE PROTECTION							0	
128	PROTECTIVE AND CONTROL DEVICES							0	
129	RESETTABLE CKT PORTECT DEVICES							0	

Recno	SUBJECT	N/A	POOR	FAIR	GOOD	EXCEL	SUPER	TOT	COMMENT
REDUNDANCY									
130	AIR SOURCE RELIABILITY							0	
131	AVIONICS COOLING							0	
132	BACKUP POWER							0	
133	BUS, FEEDER & BRANCH CKT ROUTE							0	
134	CABIN PRESSURIZATION							0	
135	CIRCUIT REDUNDANCY							0	
136	CONTROL POWER							0	
137	DISPATCH LIMITS							0	
138	FLY-BY-WIRE SYSTEM REDUNDANCY							0	
139	ICE PROTECTION FAILURE							0	
140	OPERATIONAL DEGRADATION							0	
141	POST FAILURE ICE PROTECTION							0	
142	PRIMARY ACTUATORS							0	
143	REDUNDANCY							0	
144	REDUNDANCY - COMPONENTS							0	
145	SECONDAY ACTUATORS							0	
146	SOURCE INDEPENDENCE							0	
RELIABILITY									
147	AUTOLAND							0	
148	CONTROL COMPUTERS							0	
149	DISPATCH RELIABILITY							0	
150	FAIL OPERATIONAL/SAFE							0	
151	FAILURE PROBABILITY							0	
152	RELIABILITY							0	
153	SYS & COMP'NT ADVERSE OPERATING							0	
154	SYS/ASSOCIATED COMP'NT RELIAB							0	
VALIDATION									
155	CONTROL SOFTWARE							0	
156	EMC TESTING							0	
	TOTAL VOTES	0	0	0	0	0	0	0	
	TOTAL SCORE	0	0	0	0	0	0	0	

Evaluation Process

Objective

- Evaluate Conceptual All-Electric Air Transport Design Against 156 Criteria and Guidelines (Crit/Guid)

Evaluation Team

- Use Design Specialists and Cost Analysts
- Use Five Evaluators (Min) and Preferential Ranking System
- Use Airline Advisory Committee

Numerical Grading

1=Poor	Barely Meets Crit/Guid; Barely Acceptable and Redesign is Advisable
2=Fair	Marginally Meets Crit/Guid; Should Have Other Specific Strengths
3=Good	Clearly Meets Crit/Guid; This is The Minimum Design Goal
4=Excellent	Fully Meets Crit/Guid in Every Respect
5=Superior	Exceeds The Crit/Guid

Results

- Prepare a Composite Score Sheet
- Identify Significant Items Not Meeting a Grade of 3 or Above
- Provide Analysis and Comment in Final Report

Evaluation Example

INSTALLATION	37	CERTIFICABILITY	6
PERFORMANCE	17	FAULT TOLERANCE	6
REDUNDANCY	17	OTHER SYS IMPACT	6
PROTECTION	14	LOGISTICS	5
CREW INTERFACE	13	LOADS	4
MAINTENANCE	10	OWNERSHIP COST	3
RELIABILITY	8	VALIDATION	2
EMERGENCY PROVISIONS	7	COST, MFGR	1

Recno	PROTECTION	N/A	Poor	Fair	Good	Excel	Super	Total	Comment
116	AUTOMATIC PROTECTIVE					1		1	
117	CIRCUIT BREAKER AUTO	1						1	
118	CIRCUIT BREAKER RESE				1			1	
119	CONTROL ISOLATION				1			1	
120	ESSENTIAL LOAD PROTE					1		1	
121	FAULT PROTECTION	1						1	Not Enough Detail
122	FIBER OPTIC DATA RAT				1			1	
123	FIBER OPTIC EMI IMMU				1			1	
124	FLIGHT CRITICAL CIRC					1		1	
125	LOCAL DC SYSTEMS	1						1	20 KHz item
126	PASSIVE CIRCUIT CHEC	1						1	
127	PHASE SEQUENCE PROTE	1						1	
128	PROTECTIVE AND CONTR					1		1	
129	RESETTABLE CIRCUIT P					1		1	
	Total Votes	**5**	**0**	**0**	**4**	**5**	**0**	**14**	
	Total Score	**0**	**0**	**0**	**12**	**16**	**0**	**28**	

Evaluation Criteria

Task 5.1 Technical Benefit Evaluation

• **CERTIFICABILITY**	COMPLIANCE WITH FAA REGULATION/CRITERIA/GUIDELINES
• **SATISFIES LOAD RQMNTS**	PMAD ARCHITECTURE & SIZING FOR PWR FLOW REQMNTS
• **DISPATCH RELIABILITY**	SATISFIES AIRLINE OPERATION NEEDS
• **ADEQUATE REDUNDANCY**	SATISFIES FO/FO/FS CRITERIA
• **EASE OF MAINTENANCE**	REDUCES AIRLINE OPERATIONAL COST
• **IMPACT OTHER ACFT SYS**	HAS NO UNFAVORABLE OPERATIONAL MODES
• **OPERATION IN AUTO MODES**	ACCEPTABLE FOR 2-PERSON FLIGHT DECK
• **PERFORMANCE**	EFFICIENCY, REGULATION
• **CONTROLLABILITY**	INTRODUCES NO UNUSUAL OR MARGINAL CONTROL MODES
• **ELECT/MECH CHARACTER**	WEIGHT, FAULT TOLERANCE, INTEGRITY

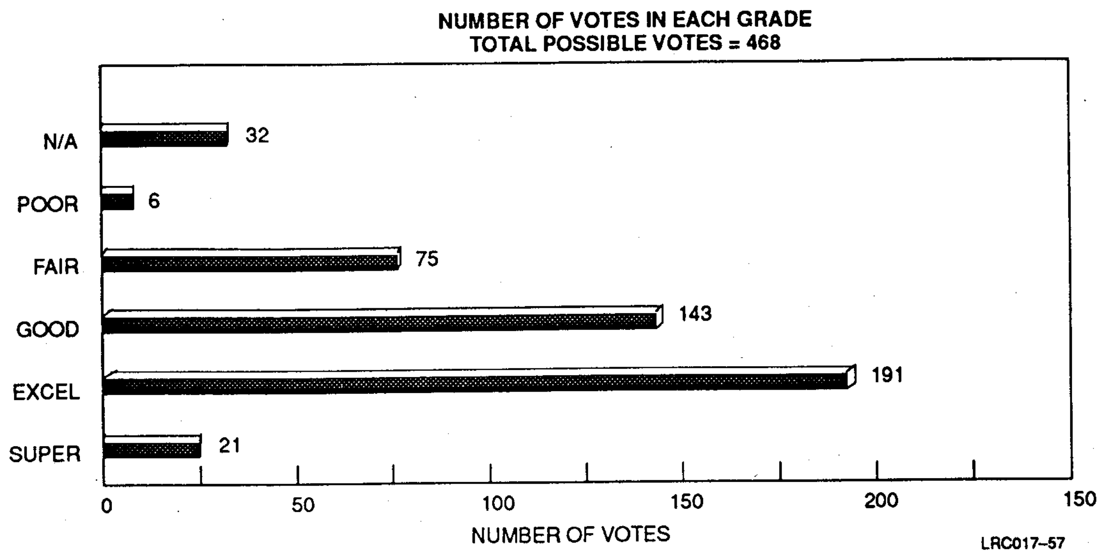
Task 5.2 Cost Impact Evaluation

• **EFFECT MFG COSTS**	MINIMIZES AIRCRAFT INITIAL COST
• **EASE OF INSTALLATION**	MINIMIZES INITIAL MFG & AIRLINE MAINTENANCE COST
• **SAFETY**	DOMINANT DESIGN CRITERION
• **COST**	ACQUISITION ,OWNERSHIP, OPERATION, MAINTENANCE

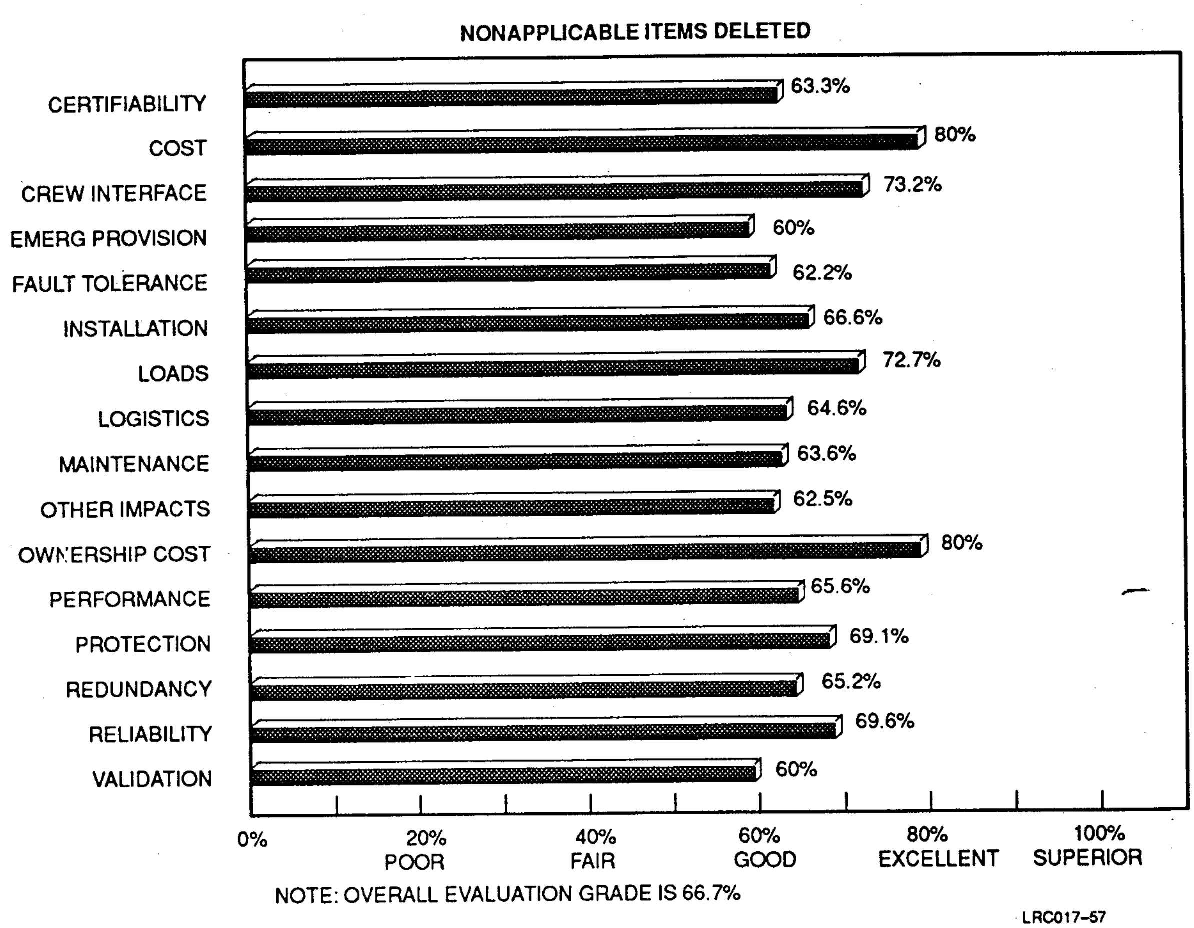
Criteria and Guidelines

- CRITERIA - MANDATORY STATEMENT ("SHALL BE" OR "MUST BE")
  GUIDELINES - ADVISORY STATEMENT ("SHOULD BE" OR "MAY BE")
- DERIVED FROM MD-11 AIRCRAFT DESIGN TECHNICAL SPEC (DAC DTS 1100C)
- INITIAL LIST OF 634 ITEMS REDUCED TO 156 BY SCREENING, PEER REVIEW, SPECIALISTS' REVIEW AND TRANSFER OF 175 DESIGN-SPECIFIC ITEMS TO A PRELIMINARY DESIGN REQUIREMENTS SPECIFICATION
- REVIEWS WERE BASED ON RELEVANCE TO THE 20 kHz ALL-ELECTRIC DESIGN
- DATABASE WAS ORGANIZED BY 16 SUBJECTS:

INSTALLATION	37	CERTIFICABILITY	6
PERFORMANCE	17	FAULT TOLERANCE	6
REDUNDANCY	17	OTHER SYS IMPACT	6
PROTECTION	14	LOGISTICS	5
CREW INTERFACE	13	LOADS	4
MAINTENANCE	10	OWNERSHIP COST	3
RELIABILITY	8	VALIDATION	2
EMERGENCY PROVISIONS	7	COST, MFGR	1



COMPOSITE SCORE SUMMARY



EVALUATION RESULTS

EVALUATION SUMMARY

TOTAL VOTES BY CRITERIA GROUP

GROUP	N/A	POOR	FAIR	GOOD	EXCEL	SUPER	TOTAL	MAX POSSIBLE	MAX POSSIBLE WITHOUT N/A
1 CERTIFICABILITY	0	0	5	5	8	0	18	90	90
2 COST	0	0	0	1	1	1	3	15	15
3 CREW INTERFACE	1	0	3	11	20	4	39	195	190
4 EMERG PROVISION	1	2	6	2	10	0	21	105	100
5 FAULT TOLERANCE	0	1	6	1	10	0	18	90	90
6 INSTALLATION	5	0	21	34	46	5	111	555	530
7 LOADS	1	0	1	3	6	1	12	60	55
8 LOGISTICS	2	0	5	1	6	1	15	75	65
9 MAINTENANCE	2	0	7	9	12	0	30	150	140
10 OTHER IMPACTS	2	2	4	3	4	3	18	90	80
11 OWNERSHIP COST	0	0	0	3	3	3	9	45	45
12 PERFORMANCE	8	0	3	25	15	0	51	255	215
13 PROTECTION	7	0	1	18	15	1	42	210	175
14 REDUNDANCY	1	1	9	18	20	2	51	255	250
15 RELIABILITY	1	0	3	6	14	0	24	120	115
16 VALIDATION	1	0	1	3	1	0	6	30	25
TOTAL	32	6	75	143	191	21	468	2340	2180

WEIGHTED SCORES BY CRITERIA GROUP

GROUP	N/A	POOR	FAIR	GOOD	EXCEL	SUPER	TOTAL	MAX POSSIBLE	MAX POSSIBLE WITHOUT N/A	% OF POSSIBLE
1 CERTIFICABILITY	0	0	10	15	32	0	57	90	90	63.3%
2 COST	0	0	0	3	4	5	12	15	15	80.0%
3 CREW INTERFACE	0	0	6	33	80	20	139	195	190	73.2%
4 EMERG PROVISION	0	2	12	6	40	0	60	105	100	60.0%
5 FAULT TOLERANCE	0	1	12	3	40	0	56	90	90	62.2%
6 INSTALLATION	0	0	42	102	184	25	353	555	530	66.6%
7 LOADS	0	0	2	9	24	5	40	60	55	72.7%
8 LOGISTICS	0	0	10	3	24	5	42	75	65	64.6%
9 MAINTENANCE	0	0	14	27	48	0	89	150	140	63.6%
10 OTHER IMPACTS	0	2	8	9	16	15	50	90	80	62.5%
11 OWNERSHIP COST	0	0	0	9	12	15	36	45	45	80.0%
12 PERFORMANCE	0	0	6	75	60	0	141	255	215	65.6%
13 PROTECTION	0	0	2	54	60	5	121	210	175	69.1%
14 REDUNDANCY	0	1	18	54	80	10	163	255	250	65.2%
15 RELIABILITY	0	0	6	18	56	0	80	120	115	69.6%
16 VALIDATION	0	0	2	9	4	0	15	30	25	60.0%
TOTAL	0	6	150	429	764	105	1454	2340	2180	66.7%

1. MAX POSSIBLE IS THE HIGHEST SCORE IF ALL VOTES ARE SUPERIOR.
2. MAX POSSIBLE WITHOUT N/A IS THE HIGHEST SCORE IF ALL VOTES ARE SUPERIOR AFTER NOT APPLICABLE ARE REMOVED.

ALL-ELECTRIC TRANSPORT AIRCRAFT EVALUATION

PROCESS

1. ENTER EVALUATORS ORGANIZATION, NAME AND DATE.
2. REVIEW CRITERIA/GUIDELINE "Recno" IN LISTING.
3. ENTER A "1" IN THE APPROPRIATE GRADING COLLUMN.
4. PROVIDE COMMENT IF NECESSARY.
5. SPREADSHEET EQUATIONS WILL SUM AND MULTIPLY TO GET TOTAL VOTES AND TOTAL SCORE.
6. INDIVIDUAL SPREADSHEETS WILL BE SUMMED TO GET A COMPOSITE SCORE.

ORG: COMPOSITE
NAME:
DATE: 11/14/91

NUMERICAL GRADE

1	POOR	BARELY MEETS CRITERIA/GUIDELINE: BARELY ACCEPTABLE AND REDESIGN IS ADVISABLE.
2	FAIR	MARGINALLY MEETS CRITERIA/GUIDELINE; SHOULD HAVE OTHER SPECIFIC STRENGTHS
3	GOOD	CLEARLY MEETS CRITEREA/GUIDELINE; THIS IS THE MINIMUM DESIGN GOAL.
4	EXCELLENT	FULLY MEETS CRITERIA/GUIDEDLINE IN EVERY RESPECT.
5	SUPERIOR	EXCEEDS CRITERIA/GUIDELINE.

Recn	SUBJECT	N/A	POOR	FAIR	GOOD	EXCEL	SUPER	TOT	COMMENT
CERTIFICABILITY									
1	GENERAL REQUIREMENTS			1	0	2		3	
2	PARTICULAR REQUIREMENTS			1	1	1		3	
3	SPECIFICATIONS-INDUSTRIAL				2	1		3	
4	SPECIFICATIONS-MILITARY			1	1	1		3	
5	SPECIFICATIONS-REGULATORY			1		2		3	
6	SPECIFICATION-MDC			1	1	1		3	
COST									
7	MANUFACTURING COST				1	1	1	3	
CREW INTERFACE									
8	CIRCUIT AMBIGUITY				1	2		3	
9	CREW INFORMATION PROCESSING				1	1	1	3	
10	CREW INTERFACE				1	2		3	
11	CREW INTERVENTION				1	2		3	
12	CREW STATION ARRANGEMENT				1	2		3	
13	CREW WORKLOAD				1	2		3	
14	DISPLAY FAILURE				1	2		3	
15	DISPLAYED INFORMATION				1	2		3	
16	FAILURE ANNUNCIATION				1	1	1	3	
17	FLIGHT CRITICAL CIRCUIT CONTROLS			1	1	1		3	
18	FLIGHT DECK CREW			1		1	1	3	
19	GENERATOR CONTROL SWITCHES				1	1	1	3	
20	SOFTWARE ERRORS	1		1		1		3	
EMERG PROVISION									
21	AUTOMATIC RESTART			2		1		3	
22	BACKUP CONTROL		1	1		1		3	
23	BACKUP REVERSION		1	1		1		3	
24	CABIN TEMPERATURE CONTROL			1		2		3	
25	FIRE PROCEDURES	1			1	1		3	
26	GEN EQUIP SELECTION				1	2		3	
27	INDEPENDENT CABIN AIR SOURCES			1		2		3	
FAULT TOLERANCE									
28	ABNORMAL OPERATION		1	1		1		3	
29	FAULT TOLERANCE			1		2		3	
30	FAULT TOLERANCE			1		2		3	
31	PARTS STRESS LEVEL			1	1	1		3	
32	SINGLE FAULT VULNERABILITY			1		2		3	
33	TOLERANCE FOR DEGRADED PWR			1		2		3	

Recn	SUBJECT	N/A	POOR	FAIR	GOOD	EXCEL	SUPER	TOT	
INSTALLATION									
34	AIRCRAFT MODEL				1	1	1	3	
35	COOLING			1	1	1		3	
36	DETAILED SYSTEM DESIGN				1	1	1	3	
37	DIGITAL FLY-BY-WIRE SYSTEM					2	1	3	
38	ELECTRICAL SYSTEM CONFIG					2	1	3	
39	EMC CONTROL				2	1		3	
40	EMC SPECIFICATIONS				2	1		3	
41	EMI REDUCTION			1	1		1	3	
42	ENGINE GENERATORS					3		3	
43	ENVIRONMENTAL CONSTRAINTS				1	2		3	
44	ENVIRONMENTAL CONSTRAINTS				2	1		3	
45	GND FOR LIGHTNING PROTECT'N			1		2		3	
46	HIGH TEMPERATURE WIRING			1		2		3	
47	INSTALLATION				1	2		3	
48	MAIN ELECT PWR CONVERTERS	1				2		3	
49	MATERIALS	1			1	1		3	
50	MINIMUM WIRE SIZE - 18 ga			1		2		3	
51	MINIMUM WIRE SIZE - 20 ga			1		2		3	
52	OIL SYSTEM	1				2		3	
53	OPEN WIRING			1	1	1		3	
54	PACKAGING	1			2			3	
55	PACKAGING TECHNOLOGY	1		1		1		3	
56	PHYSICAL INSTALLAT'N CONSTRAINTS			1		2		3	
57	PRIMARY CONTROL				1	2		3	
58	PROTECTION AGAINST FLUIDS			1	2			3	
59	SEGREGATE CRIT LOADS/EMERG BUS				1	2		3	
60	THERMAL MANAGEMENT			2	1			3	
61	WIRE AND BUS SIZE SELECTION				1	2		3	
62	WIRE BUNDLE INSTALLATION			1		2		3	
63	WIRE BUNDLE INSTALLATION			1		2		3	
64	WIRE HARNESSES			1	1	1		3	
65	WIRE INSULATION			1	2			3	
66	WIRE MOISTURE PREVENTION			1	2			3	
67	WIRE ROUTING			1	2			3	
68	WIRE SIZE SELECTION			1	1	1		3	
69	WIRING IN CONDUITS			1	2			3	
70	WIRING INSTALLATION			1	2			3	
LOADS									
71	AIR CONDITION			1		2		3	
72	ELECTRICAL LOAD ANALYSIS				2		1	3	
73	POWER CLASSIFICATION FOR EQUIP	1				2		3	
74	VOLTAGE & FREQUENCY REGULATION				1	2		3	
LOGISTICS									
75	COMPONENT AVAILABILITY			3				3	
76	EXOTIC MATERIALS	1				2		3	
77	MATERIALS			1		2		3	
78	TECHNOLOGY COMPLEXITY			1	1		1	3	
79	TOXIC MATERIAL	1				2		3	

Recn	SUBJECT	N/A	POOR	FAIR	GOOD	EXCEL	SUPER	TOT	
MAINTENANCE									
80	BUILT-IN TEST			2		1		3	
81	COMPONENT INTERCHANGEABILITY			1		2		3	
82	DISPATCHABILITY			1	1	1		3	
83	EIDI	1		1	1			3	
84	EIDI FAILURE IDENTIFICATION	1		1	1			3	
85	FAULT REPORTING				2	1		3	
86	MAINTAINABILITY				1	2		3	
87	MOUNTING PAD				2	1		3	
88	VAPOR CYCLE REFRIGERATION				1	2		3	
89	VAPOR CYCLE SYSTEM PACKAGING			1		2		3	
OTHER IMPACTS									
90	BLEED AIR SYSTEM			1		1	1	3	
91	GROUND SERVICE	2			1			3	
92	GROUND SUPPORT EQUIPMENT			1			2	3	
93	ICE PROTECTION		2		1			3	
94	INTERACTION SENSITIVITY			1		2		3	
95	WATER EXTRACTION			1	1	1		3	
OWNERSHIP COST									
96	MAINTENANCE HOUR/FLIGHT HOUR				1	1	1	3	
97	MTBUR/MTBF				1	1	1	3	
98	OWNERSHIP COST				1	1	1	3	
PERFORMANCE									
99	7754150	1			1	1		3	
100	A111317	1			1	1		3	
101	CABIN AIR TEMP RESPONSE RATE				3			3	
102	CABIN PRESSURE CONTROL				3			3	
103	CARGO HEATING			1	2			3	
104	COLD AIR				3			3	
105	CONTROL ELECTRICAL POWER				1	2		3	
106	EFFICIENCY	1			1	1		3	
107	EMI SUPPRESSION	1		1	1			3	
108	EME/HIRF			1	1	1		3	
109	ENVIRONMENTAL SYSTEM CONFIG	1			1	1		3	
110	FIBER OPTIC COMPONENTS	1			1	1		3	
111	FIBER OPTIC UTILIZATION	1			1	1		3	
112	SMOKE REMOVAL				2	1		3	
113	SWITCHING TRANSIENTS				1	2		3	
114	SYSTEM AUTOMATION				2	1		3	
115	TRIM AIR	1				2		3	
PROTECTION									
116	AUTOMATIC PROTECTIVE DEVICE				1	2		3	
117	CIRCUIT BREAKER AUTOMATIC RESET				3			3	
118	CIRCUIT BREAKER RESET	1			1	1		3	
119	CONTROL ISOLATION				1	2		3	
120	ESSENTIAL LOAD PROTECTION				2	1		3	
121	FAULT PROTECTION	1				2		3	
122	FIBER OPTIC DATA RATES	1			1	1		3	
123	FIBER OPTIC EMI IMMUNITY	1			1	1		3	
124	FLT CRITICAL CIRCUIT PROTECTION	1				1	1	3	
125	LOCAL DC SYSTEMS	2			1			3	
126	PASSIVE CIRCUIT CHECKS			1	2			3	
127	PHASE SEQUENCE PROTECTION				2	1		3	
128	PROTECTIVE AND CONTROL DEVICES				1	2		3	
129	RESETTABLE CKT PORTECT DEVICES				2	1		3	

Recn	SUBJECT	N/A	POOR	FAIR	GOOD	EXCEL	SUPER	TOT
REDUNDANCY								
130	AIR SOURCE RELIABILITY			1	1	1		3
131	AVIONICS COOLING			2	1			3
132	BACKUP POWER			1	1	1		3
133	BUS, FEEDER & BRANCH CKT ROUTE			1	1		1	3
134	CABIN PRESSURIZATION				2	1		3
135	CIRCUIT REDUNDANCY				1	1	1	3
136	CONTROL POWER				1	2		3
137	DISPATCH LIMITS			1	2			3
138	FLY-BY-WIRE SYSTEM REDUNDANCY				1	2		3
139	ICE PROTECTION FAILURE	1			1	1		3
140	OPERATIONAL DEGRADATION			1	1	1		3
141	POST FAILURE ICE PROTECTION		1		2			3
142	PRIMARY ACTUATORS				1	2		3
143	REDUNDANCY			1		2		3
144	REDUNDANCY – COMPONENTS			1		2		3
145	SECONDAY ACTUATORS				1	2		3
146	SOURCE INDEPENDENCE				1	2		3
RELIABILITY								
147	AUTOLAND				1	2		3
148	CONTROL COMPUTERS			2		1		3
149	DISPATCH RELIABILITY	1			1	1		3
150	FAIL OPERATIONAL/SAFE				1	2		3
151	FAILURE PROBABILITY			1		2		3
152	RELIABILITY				1	2		3
153	SYS & COMP'NT ADVERSE OPERATING				1	2		3
154	SYS/ASSOCIATED COMP'NT RELIAB				1	2		3
VALIDATION								
155	CONTROL SOFTWARE	1			1	1		3
156	EMC TESTING			1	2			3
	TOTAL VOTES	32	6	75	143	191	21	468
	TOTAL SCORE	0	6	150	429	764	105	1454

The lowest scores should be improved during future optimization studies. These are the "poor" votes. The interpretation of a "poor" vote is given on Page C-73 as follows: "Barely meets criteria/ guideline: barely acceptable and redesign is advisable." The criteria which received one or more "poor" votes and suggestions for future improvement are:

Group 4 — Emergency Provisions; Criterion 22 — Backup Control:

This criterion required an independent autopilot backup such as the mechanical cable system used on the baseline trijet. The mechanical cables were removed for the all-electric design. Redundant independent channels can be provided, selected flight control surfaces can be powered by the ADG through the emergency power buses, and the emergency PFCC can be used to generate command signals to these surfaces. Such a design would satisfy the criterion and can be implemented with the hardware shown for the all-electric aircraft.

Group 4 — Emergency Provisions; Criterion 23 — Backup Reversion:

This criterion required that the system prevent accidental reversion to the backup mode.

If the solution described above for meeting Criterion 22 is adopted, Criterion 23 would also be satisfied. The reversion to the backup mode could then occur only when the emergency system is activated and the ADG is deployed.

Group 5 — Fault Tolerance; Criterion 28 — Abnormal Operation:

This criterion requires that indication be provided of failures or abnormal operation of the air supply or air-conditioning system which would result in abnormal cabin pressures; specifically to allow corrective action or maintenance.

The existing BIT system would provide the data necessary for maintenance actions. The existing central aural and warning system (CAWS) would provide visual alerts on the multifunction display on the cockpit instrument panel and on the overhead panel in the event of abnormal cabin pressure. These provisions should satisfy this criterion.

Group 10 — Other Impacts; Criterion 93:

This criterion required that wing and engine inlet de-icing be provided by EIDI if *possible* according to NASA CR-4175 issued September 1988.

This study took a conservative approach and did not assess EIDI as a lower risk option, preferring to accept the weight and power penalties associated with electrical heater blankets for wing and tail de-icing, and keeping the small integral engine bleed supply for local hot-air supply to the engine cowls. Interpretation of the term "if possible" led to avoidance of the EIDI system concept entirely. A vote of "not applicable" (N/A) appears to be appropriate, although one "good" vote was made to indicate that a good alternative design was adopted in place of EIDI.

Group 14 — Redundancy, Criterion 141 — Postfailure Ice Protection:

This criterion required complete ice protection for the wing, engine cowl, air inlets, and air data sensors after any probable failures.

This requirement should be compared with the existing baseline design for pneumatic hot-air ice protection. Equivalency was used as a conservative design driver. Multiple electrical sources are available to power the electrical blanket heaters; this is equivalent to the multiple engine bleed-air sources which are used to provide hot air to the piccolo tubes in the baseline design. Other than an all-engine failure condition, which is *not* a probable failure, one or more electrical power sources or hot-air sources would be available. Load-sharing with cabin air-conditioning and galley electrical loads should allow electrical de-icing when it is essential, even with a one-engine shutdown or a generator failure. Therefore, operational procedures should be followed to better satisfy this criterion.

APPENDIX D

ELECTROMAGNETIC ENVIRONMENT (EME) — AIRWORTHINESS DOCUMENTS

ELECTROMAGNETIC ENVIRONMENT/AIRWORTHINESS REQUIREMENTS

1. Industry Regulations:

   RTCA/DO-160C, Sec. 18, Audio Frequency Conducted Susceptibility

   RTCA/DO-160C, Sec. 21, Emission of Radio Frequency Energy

   RTCA/DO-160C, Sec. 19, Induced Signal Susceptibility

   RTCA/DO-160C, Sec. 20, Radio Frequency Susceptibility (Radiated and Conducted)

   RTCA/DO-160C, Sec. 22, Lightning Induced Transient Susceptibility (Interim Procedure)

   RTCA/DO-160C, Sec. 17, Voltage Spike

2. FAA-Special Conditions for MD-11:

   Radio Frequency (RF) Energy Protection [FAR 21.16 — 25.1309, 25.1431]

   Lightning Protection Requirements [FAR 21.16 — 25.581, 25.954, 25.1309(a), (c), and (g)]

3. Military Specification:

   MIL-B-5087B, Bonding, Electrical, and Lightining Protection for Aerospace Systems

4. Military Standards:

   MIL-STD-454H, Corona Discharge

   MIL-STD-461C CE07, Switching Spike

5. DAC Specifications:

   WZZ 7000, Specification — Electromagnetic Interference Control

   WZZ 7001, Specification — Bonding, Electrical

   WZZ 7002, Specification — Aircraft Wiring Installation Classification

   WZZ 7364, Electrical Requirements for Aircraft Utilization Equipment

   BXU 7026, Requirements for Protection of Electrical and Electronics Equipment from Lightning Induced Electrical Transients

APPENDIX E

PRELIMINARY STUDIES OF 20-kHz POWER TRANSMISSION/DISTRIBUTION AND RESONANT CONVERTERS

BILINEAR TECHNOLOGIES, INC.

[redacted]

APPENDIX E

FINAL REPORT
AGREEMENT FOR SERVICES NO. AS-25529-C

PRELIMINARY MODELLING OF 20 KHZ SINGLE PHASE POWER DISTRIBUTION -- TRANSMISSION AND CONVERSION TECHNIQUES

AS PART OF NASA-LeRC CONTRACT NAS3-25965
EVALUATION OF ALL-ELECTRIC SECONDARY POWER FOR TRANSPORT AIRCRAFT

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Sept. 1, 1991

September 1, 1991

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I. INTRODUCTION AND SUMMARY

With the well-proven capabilities of modern power electronics and the already-in-place electrical sensor and computation networks, the replacement of hydraulic systems on commercial aircraft has become feasible. Preliminary estimates made by Douglas of the effect on aircraft fuel consumption for existing secondary power systems show that a high-frequency AC (20 kHz) generation and distribution system based on bidirectional resonant power converters would be significant enough to study detailed models.

The basic thrust of this report is to consider ***modelling this secondary power system so that fault and loading analysis can be performed.*** In order to carry out this task, two *preliminary* steps have been taken:

[1] "Provide analysis of the change from 400 Hz to 20 kHz power distribution"

[2] "Initialize modelling and synthesis of power converters, using a 20kHz conversion frequency."

The results of the first task are: 1) The previous analysis of power distribution systems operating at 400 Hz is not directly applicable at 20 kHz and 2) existing, closed form solutions for "shielded two-wire" transmission lines appear to be the most reasonable design and modelling approach for 20 kHz power transmission.

The second task, unlike the first, has not had ***any*** previous work performed on it. The initial study of resonant power converters shows that design modelling of a secondary power system formed from such devices is reasonable and challenging.

Conclusions drawn from the effort are that it is feasible to develop software for the converter, cable, pulse density modulated driver and inductive motor load in a single personal computer (PC) package. This allows design engineers interested in different aspects of the power distribution system to quickly evaluate overall performance under a variety of fault or loading conditions.

II. 20 KHZ DISTRIBUTION SYSTEM

The previous work performed on 400 Hz introduced the concept of modifying the impedance of a transmission system due to the presence of a ground plane of irregular shape. This analysis -- described below -- could have application to the shielding configuration of a more radiative, higher frequency power transmission proposal. However, for simplicity, an available, closed-form analysis for "shielded two-wire" line has been applied to the problem to initiate modelling of the distribution system. The higher frequency of the 20 kHz distribution requires a nominal pi model to account for the enhanced shunt admittance.

A. Use of 400 Hz Analysis For 20 KHz Power Distribution

The first task was to review previous techniques for analysis of aircraft power distribution at 400 Hz. Conventional systems utilize unshielded, multiwire, three-phase cable configurations, as shown in Figure 1E. These models prove inappropriate for frequencies in the 20 kHz range because the location of the ground plane can no longer be simply modeled by an infinite slab -- due to the enhanced radiation fields at those frequencies. The cable for 20 KHz distribution will have to be shielded in a *consistent* manner rather than to have random positioning with respect to the cableways in commercial aircraft.

Because the aircraft skin becomes far less effective as a return conductor at those frequencies, a separate return wire must be added to the configuration. Also, single-phase transmission of three-phase is impractical at high frequencies, so a shielded, two-wire transmission line is being considered.

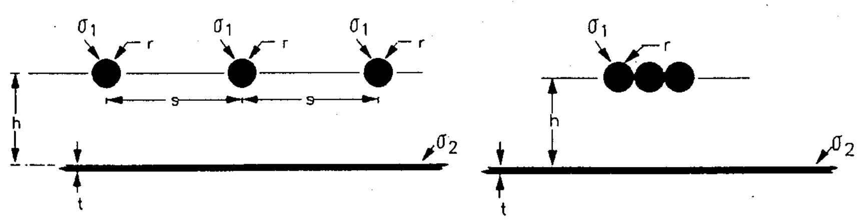


Figure 1E: Conventional Power Distribution Geometries

The problem of a current-carrying filament above a ground plane of finite thickness and finite conductivity can be resolved by solving Maxwell's wave equation in all three regions, then matching boundary conditions at the two interfaces. This approach generates the electric field above the ground plane, which in turn, must be integrated to produce the total electric field; which is then divided by the current to yield the impedance. Typically, the solution consists of two terms; the first term is the impedance of the filament as though no ground plane were present; the second term is a correction to allow for presence of the ground plane. The correction term is not in closed form, i.e., it is an infinite summation of terms which will converge, but very slowly. Often, the summation is of such a nature as to require a "mainframe" computer with "double precision" -- precluding any immediate "trial and error" engineering design. The "receding image method" devised by the author overcomes this difficulty and still yields valid, design results for the problem. At 20kHz the technique is still valid.

1. Elementary Static Image Model

By following the exact approach as delineated above, one can surmise the approximate location of a current-carrying filament image. This is accomplished by using the exactly determined electric field for the region above the ground plane, and determining the location of a current carrying filament (with the same magnitude but opposite sense) which -- when coupled with the original filament -- will produce the same field. This technique is common to all electromagnetic image problems. The results, however, are less than satisfactory due to both the time dependent nature of the problem and the non-infinite nature of the ground plane (this is similar to the problem of non-infinite conductivity).

2. Complex Image Model

By noting the physical inference of the receding image, modified from Maxwell's equations, one can visualize an infinite train of straight wire images moving perpendicularly away from the ground plane -- one image is formed for each incremental change in the current in the wire. This is shown in Figure 2E below.

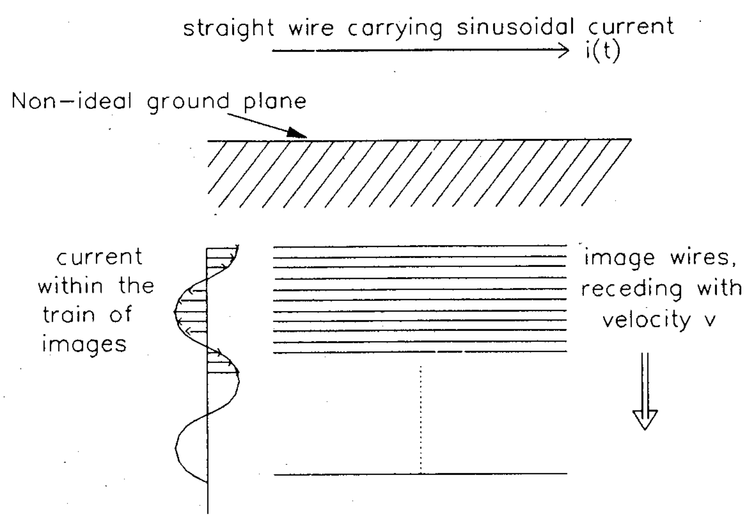


Figure 2E: Maxwell Receding Image Model

Because the current in the wire is sinusoidal in nature, the image currents are also varying sinusoidally; although the entire image structure can be considered a steady-state sum of phasors. The result is an overall effective image which is at a distance slightly greater than the static image distance and its current have an additional slight phase shift relative to the current in the wire.

As was done for analysis of electromagnetic deicing (EIDI) studies fir DAC, the finite thickness of the ground plane is accounted for by determining how much current is converted to eddy currents in the sheet. This factor can be straightforwardly determined from knowledge of the skin depth.

3. Complex Image Distance

After some manipulation of the steady-state set of the infinite number of receding images, one can arrive at an "effective image", i.e. one image which has the characteristic of the set. That effective image current is at a conventional image distance plus a distance on the order of a skin-depth and has been slightly phase shifted by the same skin-depth factor. In the form of an equation, the "imaginary distance" (real distance plus phase shift forming complex number) of the effective image from the wire, D_i, is given as:

$$D_i = 2h_i + (1 + j)\frac{\delta}{m} \tag{1E}$$

where h_i is the normal static image distance or twice the height of the wire above the ground plane, δ is the skin- depth, and m is the correction factor for the finite character of the ground plane. All dimensions are in centimeters.

4. Correction for Real Ground Plane

The finite character of the ground plane infers that the energy radiated by the wire and converted into eddy currents in the ground plane is the energy from the wire absorbed by the plane. This energy can be computed by integrating the attenuated wave over the thickness of the ground plane, t. The result is, of course, a function of the ground plane conductivity and operating frequency, as accounted for in the skin-depth. The result for the correction factor, m, as used in equation (1) is given as:

$$m = 1 - \exp\left\{-2\frac{t}{\delta}\right\} \tag{2E}$$

These two simple equations, (1) and (2), can be coupled to yield viable engineering design results as used in a discussion of three-phase transmission lines.

5. Current Crowding

For purposes of modeling, the wires of the three-phase transmission line were represented as current filaments at the wire center. Using geometric mean radii and distances allowed computation of effective inductance of the finite wires using only the filaments in the 1988 modelling. As the finite wire approaches the ground plane, however, the filament representing the wire no longer simply resides at the center of the wire but migrates toward the edge of the wire as do the actual currents in the wire. This phenomenon is called "current crowding".

Using a standard rational that the ground plane is at zero potential, Poisson's equation[1] shows that the location of the current filaments representing both the wire and its complex image are offset from the center by a distance, a, toward the ground plane, where:

$$a = \frac{2r^2}{h} \tag{3E}$$

and r is the radius of the wire and h is the height of the wire above the ground plane. This correction is easily added to the model. This correction is considered negligible if $10h \geq 2r^2$ or $r < (5h)^{1/2}$.

B. Two-Wire Transmission Lines

No specific cable design has yet been defined for secondary power applications, so a simple shielded pair has been considered. This geometry is straight-forward enough to yield a closed form solution without application of the complex image analysis. The shallow skin depth of a 20 kHz wave implies that a finite thickness of almost any conductive structure may be considered infinite. These closed-form solutions for impedance and other transmission line characteristics are direct enough in most cases; such as coaxial, twin lead and parallel plate transmission lines. When shielded two-wire is used, however, the forms become more complex and require some machine computation. The bulk of the analysis utilizes the closed-form impedance of the shielded two-wire configuration. Noting Figure 3E, the equations for chacteristic impedance[2] for shielded, two-wire line as a function of its geometry become:

$$Z_o = \frac{\eta}{\pi}\{\ln\left(2p\left(\frac{1-q^2}{1+q^2}\right)\right) - \frac{1+4p^2}{16p^2}(1-4q^2)\} \tag{4E}$$

where

$$p = \frac{s}{d} \text{ and } q = \frac{s}{D}$$

---

1 $\vec{\nabla}^2 V = \frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} + \frac{\partial^2 V}{\partial z^2} = -\frac{\rho}{\epsilon}$

2 The characteristic impedance is defined as the square root of the series impednace per unit length of the divided by the shunt admittance per unit length of the line. Mathematically:

$$\sqrt{\frac{(R+j\omega L)}{G+j\omega C}}$$

where R, L, G, and C are the resistance, inductance, conductance, and capacitance per unit length of the line.

Appendix I has MathCAD analyses which generates parametric plots of the cable impedance as functions of the wire diameter, wire separation and inside diameter of the shield. The MathCAD analysis also compares the characteristic impedance of a two-wire line with and without the shielding to determine the effect of the complex image in the shield.

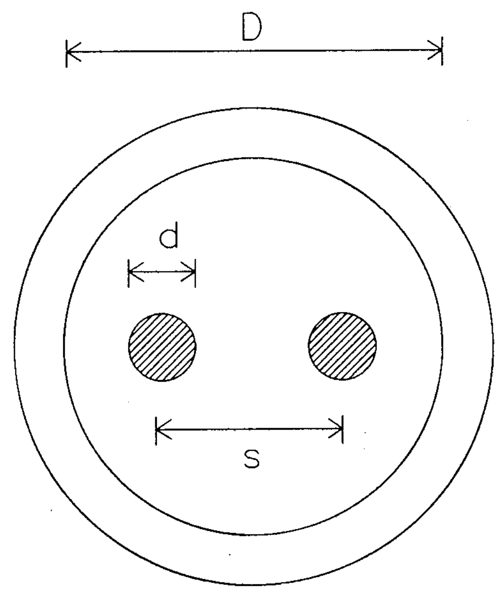
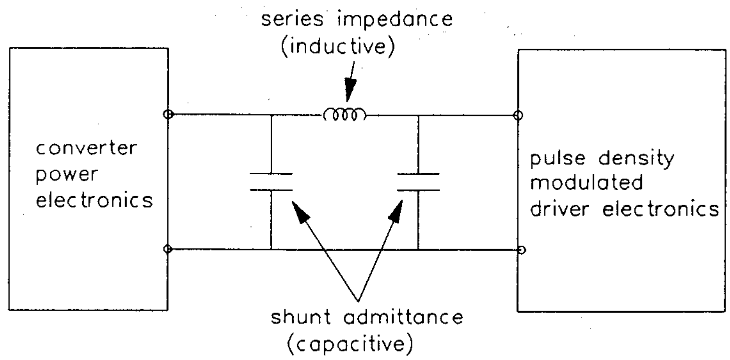


Figure 3E: Shielded Two-Wire Configuration

C. Transmission Line Modelling

Due to the unconventionally high frequencies of power transmission proposed for secondary power distribution, the transmission line should be modelled as something other than a short line. Normally, one uses a single series impedance equal to the series impedance of the line, and shunt admittance -- which is mostly capacitive -- is ignored. For more precision, one should use a nominal pi representation of the line.



The nominal pi model calls for knowledge of series impedance and shunt admittance. These parameters have closed form solutions similar to the characteristic impedance. The model is shown in Figure 4E.

Figure 4E: Nominal Pi Model of Transmission Line

For practical reasons, shielded two-wire is the selected form of distribution hardware for aircraft secondary power in that commercial cable and connectors already exist with FAA standards. Such cable needs to be further electrically modelled in the context of a 20 kHz power distribution model with bidirectional, full-wave resonant converters, as addressed in the second task, and with inductive loads.

III. RESONANT POWER CONVERTERS

The second task was to build onto the model of the power distribution system by adding converter electronics to the cable model. While a variety of circuit analysis software is available, software which lends itself to "desktop" analysis was selected. *MICROCAP* offers schematic capture, steady-state and transient analysis, and a variety of user-defined options. The converter, cable, pulse-density modulated driver and inductive motor load can all be modelled in a single circuit to allow quick evaluation of a particular configuration of the distribution system. The first component of the system model to be evaluated was the DC to AC inverter.

The primary technology used in the high frequency AC power distribution systems is resonant power conversion. Converters of this type have been built and tested for space applications. Although the space applications used DC sources and different loads than an aircraft, the basic technology has been tested.

In the basic concept of the resonant power converter, electronic switches are alternately switched in such a manner as to present the series inductor/capacitor (LC) circuit with square wave voltage. The LC circuitry, performing the function of a low-pass filter, allows essentially only the fundamental (sinusoidal) current to flow in the series circuit. In this configuration the load is placed across the capacitor and thus provides a low impedance sinusoidal voltage source. Because the current in the inductor is sinusoidal, the switch can be opened as the current passes through zero. Zero cross-over switching yields an advantage that cannot be overemphasized: *the absence of energy loss during power switch turnoff is a* *major advantage of resonant power conversion.* Not only will silicon-controlled rectifier (SCR) switches self-commutate, but also there is no frequency-proportional converter power loss at turnoff. As a result, power devices may be safely and efficiently operated at power and frequency levels unobtainable by other conversion techniques (e.g. pulse-width modulation or phase-control modulation).

Lower frequency waveforms can be synthesized from this high frequency carrier as required to satisfy load requirements. In a similar circuit to that described above, the electronic switches are operated in such a manner as to perform synchronous rectification of the 20 kHz source and thus to synthesize a lower frequency, i.e. 400 Hz, output. Proper sequencing of the switch pairs will also allow reverse power flow by chopping a lower frequency (including DC) into the 20 kHz source, thus allowing for induction motor braking, etc. to supply power to the distribution system.

A. Overall Inverter Characterizations

Before analyzing and modelling specific converters, some specification as to frequencies, voltage/current is required. One must speculate as to the nature of the initial generator on an aircraft system. Under typical conditions the sychronous generators driven by fanjet engines provide 440V, 1200Hz, three-phase power. The voltage and frequency vary as the engine speed varies, but the voltage is regulated by controlling the excitation. Since this type of regulation responds slowly, rapid regulation will be provided by controlling the relationship between the three converter phases. It is anticipated that this type of regulation can be made to respond within one cycle of the converter frequency, or approximately 50 millisecs. The frequency of the converter is controlled by its resonant circuit and is therefore independent of the input frequency. The result is a constant frequency (20 kHz), constant voltage (440 V), single phase output to the distribution bus. Because the power to the loads is synthesized by a load receiver, some latitude in the bus voltage and frequency can be allowed. So the first circuit considered is a 1600 Hz to 20kHz resonant converter.

In most instances 20kHz and 440V power cannot be used directly by the loads. Load receivers -- AC/AC or AC/DC converters -- are used to synthesize the output required by the load. Even though the bus is single phase, a three phase motor can be driven from the receiver by using a simple set of electrical switches to produce a quasi-square wave by switching in each of three phases with time phase shift between phases. The power flow from the main distribution bus is managed in half cycle increments by the load converter switches. The pulses generate a sinusoidal energy pattern when the proper switching sequence is used. General Pulse Width Modulated (PWM) converters are considered next.

B. Inverter Perfomance Parameters

The output of practical inverters contain certain harmonics and the quality of an inverter is normally evaluated in terms of the following performance parameters.

1. *n*th harmonic factor, HF_n

The harmonic factor (of "n^{th}" harmonic), which is a measure of individual harmonic contribution, is defined as

$$HF_n = \frac{V_n}{V_1} \tag{5E}$$

where V_1 is the rms value of the fundamental component and V_n is the rms value of the nth harmonic contribution.

2. Total harmonic distortion, *THD*

The total harmonic distortion, which is a measure of closeness in shape between a waveform and its fundamental component, is defined as

$$THD = \frac{1}{V_1}\left(\sum_{n=2,3,..}^{\infty} V_n^2\right)^{1/2} \tag{6E}$$

3. Distortion factor, *DF*

The THD gives the total harmonic content, but it does not indicate the level of each harmonic component. If a filter is used at the output of inverters, the higher order harmonics would be attenuated more effectively. Therefore, knowledge of both the frequency and magnitude of each harmonic is important. The distortion factor indicates the amount of harmonic distortion that remains in a particular waveform after the harmonics of that waveform have been subjected to a second order attenuation (i.e., divided by n^2) Thus DF is a measure of effectiveness in reducing unwanted harmonics without having to specify the values of a secondorder load filter and is defined as

$$DF = \frac{1}{V_1}\left(\sum_{n=2,3,..}^{\infty} \left(\frac{V_n}{n^2}\right)^2\right)^{1/2} \tag{7E}$$

The distortion factor of an individual (or n^{th}) harmonic component is defined as

$$DF_n = \frac{V_n}{V_1 n^2} \tag{8E}$$

4. Lowest-order harmonic, LOH.

The lowest order harmonic is that harmonic component whose frequency is closest to the fundamental one, and its amplitude is greater than or equal to 3% of the fundamental component.

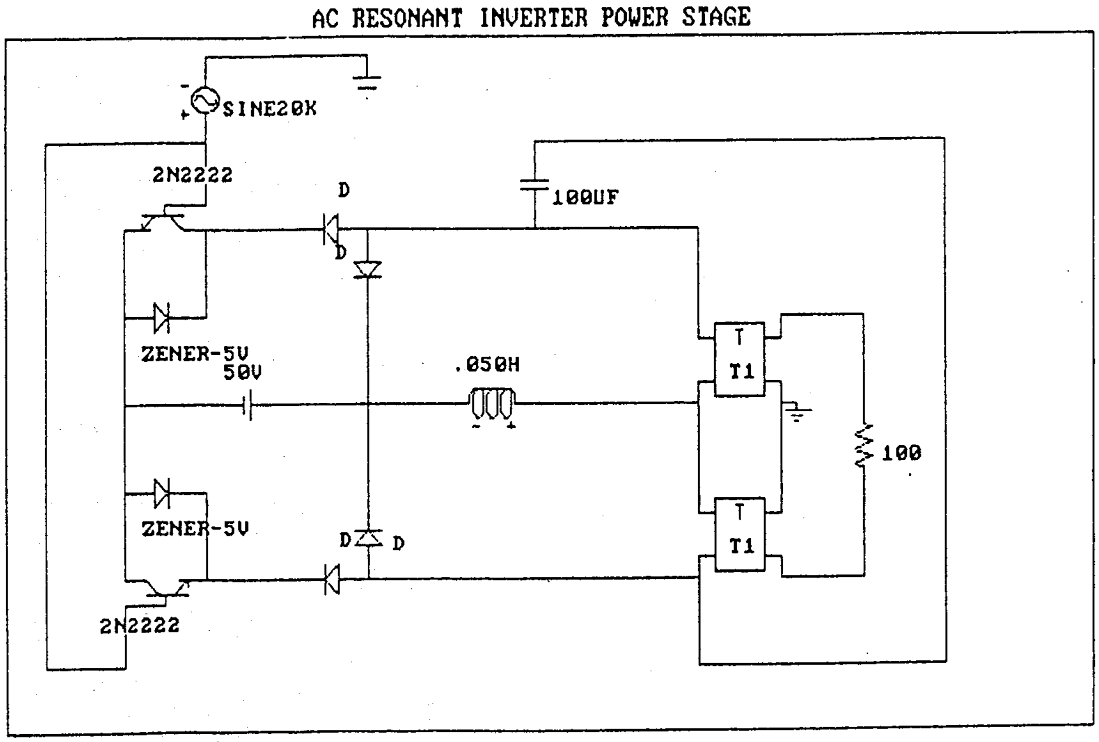
These characteristics must eventually be used in evaluating the performance of any resonant inverter model. With the preliminary investigation performed here, however, they are only guidelines in the utilization of the software package. All the sundry components of these evaluation parameters should be present in any software package selected for modelling.

C. Theoretical Operation of a Simple Series Resonant Inverter with Unidirectional Switches (SCRS)

The series resonant inverters are based on resonant current oscillation. The commutating components and switching device are placed in series with the load to form an underdamped circuit. The current through the switching devices falls to zero due to the natural characteristics of the circuit. If the switching element is a thyristor, it is said to be self-commutated. This type of inverter produces an approximately sinusoidal waveform which may be at a high output frequency, ranging from 200 Hz to 100 kHz, and is commonly used in relatively fixed output applications (e.g., induction heating, sonar transmitter, fluorescent lighting, or ultrasonic generators). Due to the high switching frequency, the sizes of commutating components are small.
There are various configurations of series inverters, depending on the connections of the switching devices and loads. The series inverters may be classified into two categories:

1. Series resonant inverters with unidirectional switches
2. Series resonant inverters with bidirectional switches

A simple inverter was modelled using the *MICROCAP* simulation program. The circuit, as shown in Figure 5E on the following page, has an effective gain of 12.37 and the output waveform is identical to that of the input.



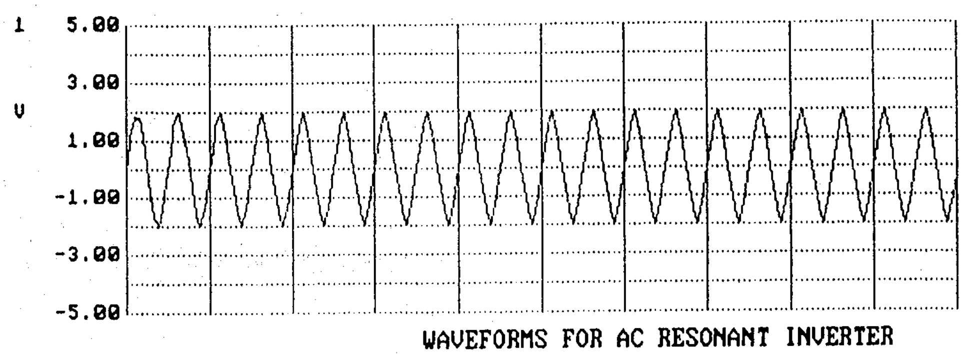


Figure 5E: DC to 20 kHz inverter model

D. PWM Converter Characteristics

1. Single Pulse Width Modulation

In single pulsewidth modulation control, there is only one pulse per half cycle and the width of the pulse is varied to control the inverter output voltage. The gating signals are generated by comparing a rectangular reference signal of amplitude, A_r, with a triangular carrier wave of amplitude, A_c. The frequency of the carrier wave determines the fundamental frequency of output voltage. By varying Ar from 0 to Ac, the pulse width can be varied from 0 to 180 degrees. The ratio of A_r to Ac is the control variable and is defined as the *modulation index.*

2. Multiple Pulse Width Modulation

The harmonic content can be reduced by using several pulses in each half-cycle of output voltage. The generation of gating signals for turning transistors on and off can be accomplished by comparing a reference signal with a triangular carrier wave. The frequency of the reference signal sets the output frequency, f_o. and the carrier frequency, f_c, determines the number of pulses per half-cycle, *p*. The modulation index controls the output voltage. This type of modulation is also known as *uniform pulsewidth modulation* (UPWM).

IV. CONCLUSIONS AND RECOMMENDATIONS

Initial results of the cable modelling and inverter circuit modelling show that it indeed is feasible to develop software for the converter, cable, pulse density modulated (PDM) driver and inductive motor load in a single personal computer (PC) package.

Based on the preliminary studies of this task, the following are recommendations for further development of the secondary power model:

[1] Continue model development for the nominal pi representation of shielded two-wire, transmission/distribution lines.

[2] Continue modelling of resonant inverters, complete with evaluation of the defined performance parameters.

[3] Model pulse density modulated (PDM) drivers (three-phase) loaded by induction motors.

[4] Combine models for converters, cable, drivers and motors into a single circuit model for "desktop" evaluation of fault loading analysis.

APPENDIX I-E: Characteristic impedance of shielded two-wire -- as shown in figure 3E in the text -- compared to unshielded. Varying wire diameter, d in centimeters, while holding wire separation, s also in centimeters, and shielding inside diameter, D in centimeters, constant. The dimensionless variables, p and q are defined in equation E5 and below. The subscripted variables are designated by a 'sub i'.

$\pi := 3.1416$

$i := 1 \,..\, 8$

$d_i := .1 \cdot i$

$$\eta_o := \frac{377}{2.2}$$ impedance of dielectric

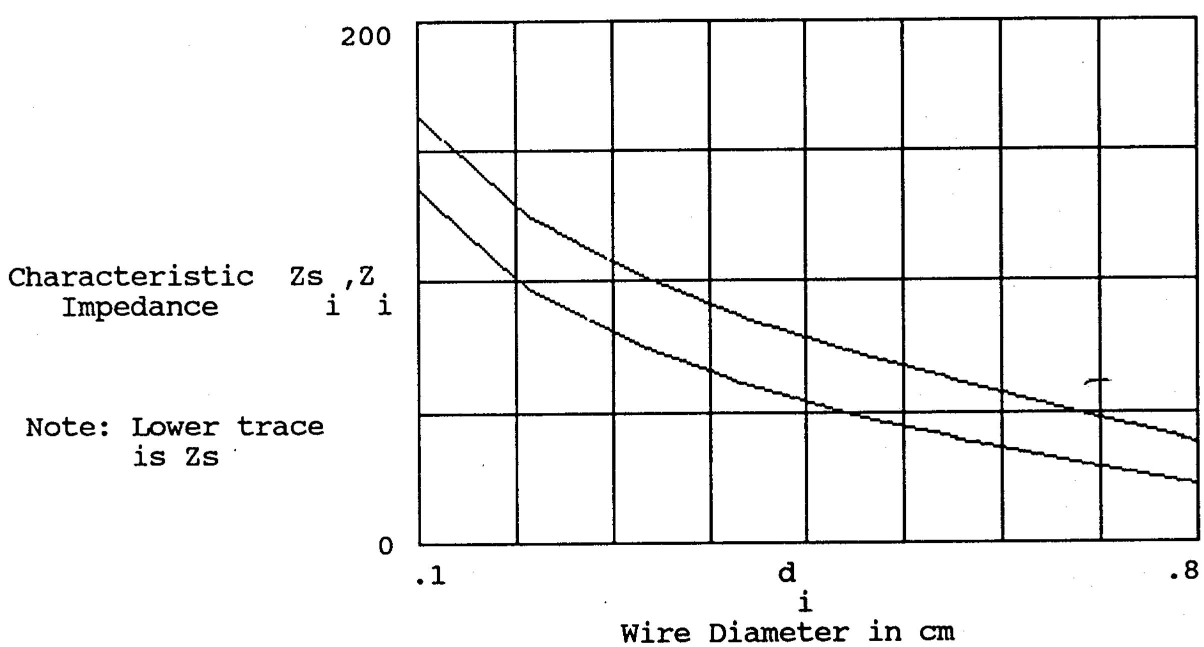
$D := 2$ $\qquad$ $s := 1$

$$p_i := \frac{s}{d_i} \qquad q := \frac{s}{D}$$

$$Z_i := \frac{\eta_o}{\pi} \cdot \underbrace{\text{acosh}}_{\text{"arc cosh"}}\left[p_i\right]$$

Note: These impedances, Z and Zs are characteristic impedances as defined in them footnote in the text.

$$Zs_i := \frac{\eta_o}{\pi} \cdot \left[\ln\left[\left[2 \cdot p_i\right] \cdot \frac{1 - q^2}{1 + q^2} \right] - \left[\frac{1 + 4 \cdot p_i^2}{16 \cdot p_i^4} \cdot \left[1 - 4 \cdot q^2\right] \right] \right]$$



APPENDIX I-E (cont): Characteristic impedance of shielded two-wire -- as shown in figure 3E in the text -- compared to unshielded. Varying shielding diameter, D in centimeters, while holding wire separation, s also in centimeters, and wire diameter, d in centimeters, constant. The dimensionless variables, p and q are defined in equation E5 and below. The subscripted variables are designated by a 'sub i'.

$\pi := 3.1416$

$i := 1 \,..15$

$d := .2$

$\eta_o := \dfrac{377}{2.2}$ impednace of dielectric

$D_i := 1 + .2 \cdot i \qquad s := 1$

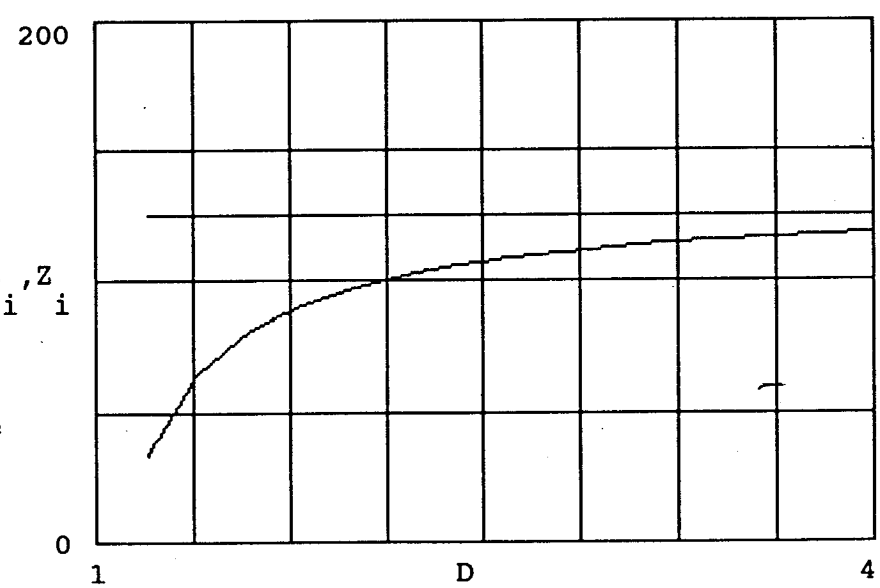
$p := \dfrac{s}{d} \qquad q_i := \dfrac{s}{D_i}$

$$Z_i := \frac{\eta_o}{\pi} \cdot \operatorname{acosh}(p)$$

"arc cosh"

Note: These impedances, Z and Zs are characteristic impedances, in ohms, as defined in the footnote in the text.

$$Zs_i := \frac{\eta_o}{\pi} \cdot \left[\ln\left[(2 \cdot p) \cdot \frac{1 - q_i^{\,2}}{1 + q_i^{\,2}} \right] - \left[\frac{1 + 4 \cdot p^2}{16 \cdot p^4} \cdot \left[1 - 4 \cdot q_i^{\,2} \right] \right] \right]$$



Note: Lower trace is Zs

APPENDIX I-E (cont): Characteristic impedance of shielded two-wire -- as shown in figure 3E in the text -- compared to unshielded. Varying wire separation, s in centimeters, while holding shielding diameter, D also in centimeters, and wire diameter, d in centimeters, constant. The dimensionless variables, p and q are defined in equation E5 and below. The subscripted variables are designated by a 'sub i'.

$\pi := 3.1416$

$i := 1 \,..10$

$D := 3$

$\eta_o := \frac{377}{2.2}$ impednace of dielectric

$d := .2$

$s_i := 1 + .1 \cdot i$

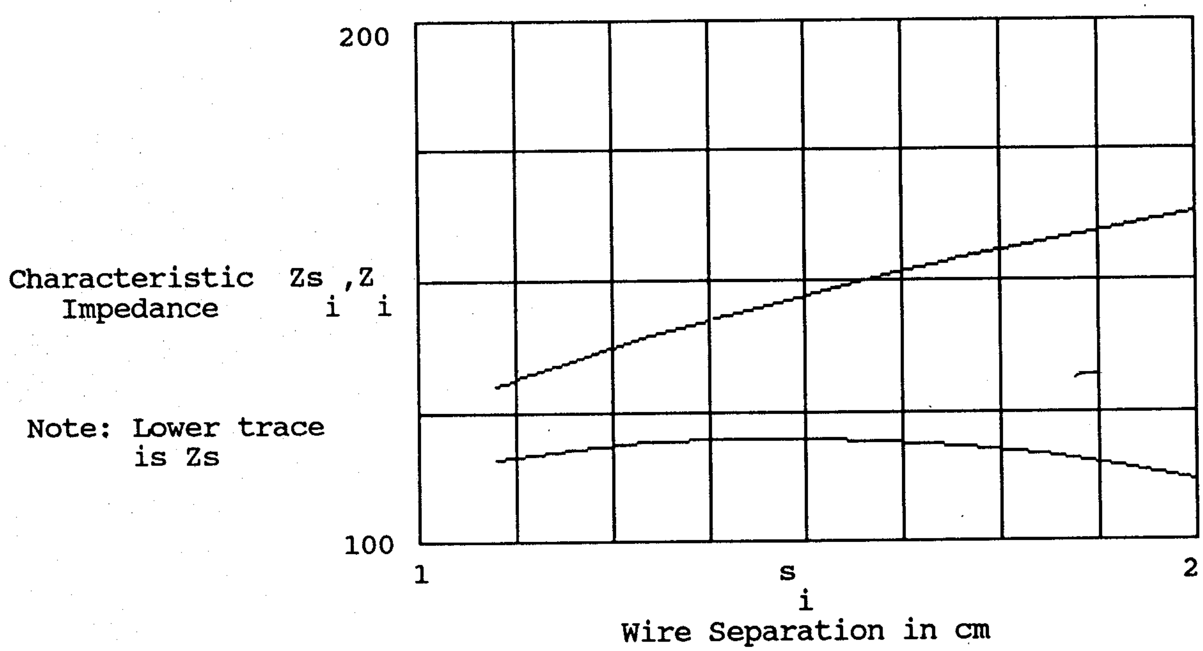
$p_i := \frac{s_i}{d}$

$q_i := \frac{s_i}{D}$

$Z_i := \frac{\eta_o}{\pi} \cdot \text{acosh}\left[p_i\right]$ "arc cosh"

Note: These impedances, Z and Zs are characteristic impedances, in ohms, as defined in the footnote in the text.

$$Zs_i := \frac{\eta_o}{\pi} \cdot \left[\ln\left[\left[2 \cdot p_i\right] \cdot \frac{1 - {q_i}^2}{1 + {q_i}^2}\right] - \left[\frac{1 + 4 \cdot {p_i}^2}{16 \cdot {p_i}^4} \cdot \left[1 - 4 \cdot {q_i}^2\right]\right]\right]$$



APPENDIX F

WEIGHT DATA BASE AND SPREADSHEET

EXPLANATION OF SYMBOLS AND HEADINGS

The abbreviated column headings starting on page F-6 are explained in the following text.

A name and an alpha code for each component are derived from the baseline weight data. The data under the column HP (horsepower) were used to determine the phase current (PH_I) requirements. The RPM (revolutions per minute) and LB_FT (pound-feet) data columns were used to determine the torque requirements for each electric motor. The LTH (length) column displays the approximate cable feeder length. The GAGE column is the wire gauge determined by phase current (PH_I) for each feeder and selected from Table F-1. The FACTOR column is the constant used to calculate cable feeder weights (lb/1,000 ft) from Table F-2. The FACTOR column also provides a LB/HP value for each electric motor actuator, controller or combination, and its associated hydraulic pump. The AS IS, TO BE, and DELTA columns provide the weights of each specific component on the existing aircraft, the new (all-electric) aircraft, and the difference in weights.

TABLE F-1
WIRE GAGES AND CIRCUIT PROTECTORS

WIRE					CONTINUOUS-DUTY CURRENT — AMPERES	
AI-GAGE ALUMINUM	AN-GAGE COPPER	CIRCUIT BREAKERS — MAX RATING(6)	FUSE MAX(3)	LIMITERS MAX(3)(4)(5)	SINGLE WIRE IN FREE AIR	WIRES IN CONDUIT OR BUNDLES
	26	—	—	—	—	—
	24	5	5	—	—	2
	22	7.5	5	—	—	5
	20	10	10	10	11	7.5
	18	15	15	10	16	10
	16	20	15	15	22	13
	14	25	20	15	32	17
	12	30	20	20	41	23
	10	40	30	30	55	33
6	8	50		40	73	46
4	6	75		50	101	60
2	4	80		80	135	80
0	2	100			181	100
00	0				245	150
000	00				283	175
0000	000				328	200
	0000				380	225

The above is based on circuit protectors at room ambient temperature; wire in bundles at 135°F ambient; 3 wires or 20 percent of the wires, whichever is greater, carrying bundle rating current.

NOTES: (1) Circuit breakers may give nuisance trips under excessive vibration and elevated temperature when carrying over 80 percent of their rated current

(2) AN-26 and AN-24 wires are copper alloy (cadmium-bronze) wire

(3) Use of circuit breakers is preferred

(4) Before selecting, verify the wire smoke curves with the current rating and the installed environment, i.e., temperature vibration, etc. The Burndy limiters, FQL series, are available 10 through 125 amperes. Use MS24000-1, -2, or F3H3MG3 limiter bases as required

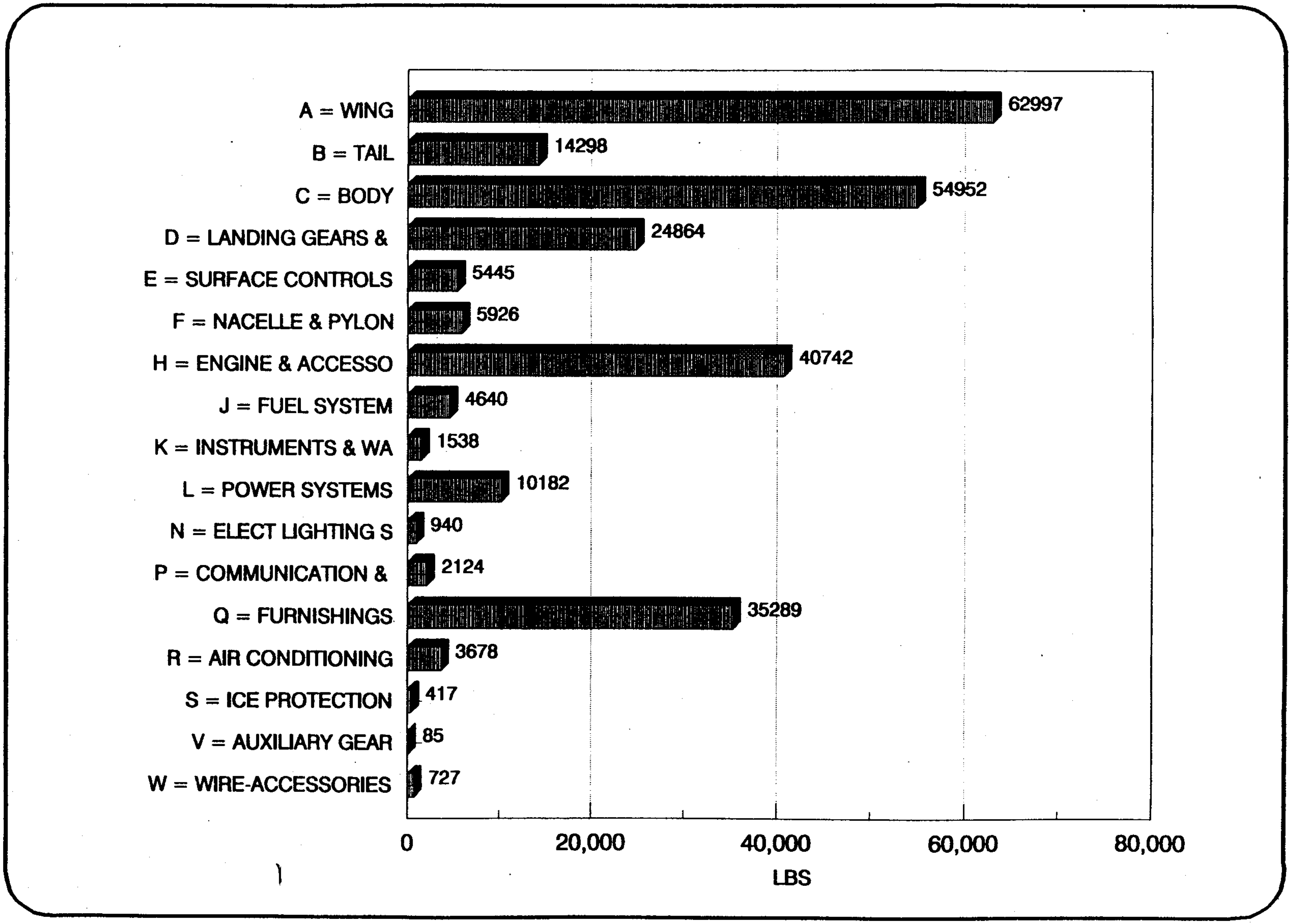
(5) Suitable for AC operation only

(6) If remote control circuit breakers are selected, smoke curve verification must be made

TABLE F-2
SINGLE-CONDUCTOR DATA
DAC TYPE 7891145

GAGE	DIAMETER (INCHES)			WEIGHT (LB/1,000 FT)	
	MIN	NOM	MAX	NOM	MAX
24	0.043	0.045	0.047	2.1	2.2
22	0.048	0.051	0.054	3.0	3.2
20	0.056	0.059	0.062	4.6	4.7
18	0.067	0.070	0.072	6.8	7.0
16	0.074	0.078	0.082	8.7	9.0
14	0.091	0.095	0.099	13.4	13.7
12	0.108	0.112	0.116	20.1	20.4
10	0.130	0.136	0.142	31.3	31.8
8	0.191	0.201	0.211	58.3	60.1
6	0.237	0.249	0.261	90.7	93.1
4	0.297	0.309	0.321	144	149
2	0.369	0.384	0.399	224	231
0	0.467	0.482	0.497	354	365
00	0.524	0.542	0.560	460	483

BASELINE TRI-JET WEIGHTS



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ALL-ELECTRIC TRI-JET WEIGHT SUMMARY

	CATEGORY	AS_IS	DELTA	TO_BE	% REDUCTION
1	A = WING	62997	0	62997	0.0%
2	B = TAIL	14298	0	14298	0.0%
3	C = BODY	54952	0	54952	0.0%
4	D = LANDING GEARS & TAIL BUMPR	24864	142	25006	0.6%
5	E = SURFACE CONTROLS	5445	-2037	3408	-37.4%
6	F = NACELLE & PYLON	5926	0	5926	0.0%
7	H = ENGINE & ACCESSORY STYSTEMS	40742	0	40742	0.0%
8	J = FUEL SYSTEM	4640	0	4640	0.0%
9	K = INSTRUMENTS & WARNING SYS	1538	0	1538	0.0%
10	L = POWER SYSTEMS	10182	-1348	8834	-13.2%
11	N = ELECT LIGHTING SYSTEMS	940	0	940	0.0%
12	P = COMMUNICATION & NAVIGATION SYS	2124	0	2124	0.0%
13	Q = FURNISHINGS	35289	0	35289	0.0%
14	R = AIR CONDITIONING	3678	847	4525	23.0%
15	S = ICE PROTECTION	417	91	508	21.9%
16	V = AUXILIARY GEAR	85	0	85	0.0%
17	W = WIRE-ACCESSORIES AND NO TITLE	727	0	727	0.0%
	TOTALS	268843	-2304	266539	-0.9%

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NOTE: THE WEIGHTS IN THIS SUMMARY REPRESENT ONLY NEW OR CHANGED WEIGHTS AND SHOULD NOT BE MISSTAKEN AS TOTAL WEIGHT FOR EACH CATEGORY.

	WEIGHT SUMMARY	AS_IS	TO_BE	DELTA
1	DA* = MAIN LANDING GEAR	0	130	130
2	DB* = NOSE LANDING GEAR	63	75	12
3	EE* = MISC NEW EQUIP	0	34	34
4	EF* = AILERON	584	382	-202
5	EH* = ELEVATOR	816	719	-96
6	EJ* = RUDDER	378	322	-56
7	EL* = FLAPS	575	274	-301
8	EN* = SPOILERS	639	433	-206
9	EP* = HORIZ STAB	692	597	-95
10	ET* = GENERAL PLUMBING-SURFACE CTRL	81	0	-81
11	EV* = SLATS	1700	667	-1033
12	LA* = AC POWER SYSTEM	5534	8276	2824
13	LH* = HYD POWER SYSTEM	2277	0	-2277
14	LP* = PNEUMATIC POWER SYSTEM	1932	37	-1896
15	RN* = COOLING AIR SYSTEM	1263	2110	847
16	SA* = WING ICE PROTECTION	183	243	60
17	SB* = TAIL ICE PROTECTION	111	141	31
	TOTAL	16826	14440	-2304

LN_N	TYPE	NAME	HP	RPM	LB_FT	PH_I	LTH	GAGE	FACTOR	AS_IS	TO_BE	DELTA	NOTES
1	DA-01	ELECT SERVO PUMP ACTUATOR-MAIN	20.0						3.25	0.0	65.0	65.0	
2	DA-02	ELECT SERVO PUMP ACTUATOR-MAIN	20.0						3.25	0.0	65.0	65.0	
3	DBJB	PLUMBING-RETRACT								18.8	2.7	-16.0	
4	DBJF	FLUID-RETARACT								17.8	5.7	-12.1	
5	DBKE	VALVES-STEERING								18.0	11.1	-6.8	
6	DBKF	FLUID-STEERING								8.7	8.3	-0.4	
7	DB-01	ELECT SERVO PUMP ACTUATOR-NOSE	7.3						3.25	0.0	23.8	23.8	
8	DB-02	ELECT SERVO PUMP ACTUATOR-NOSE	7.3						3.25	0.0	23.8	23.8	
9	EEGC1	PRIMARY FLT CTRL CMPTR-1								0.0	7.5	7.5	
10	EEGC2	PRIMARY FLT CTRL CMPTR-2								0.0	7.5	7.5	
11	EEGC3	PRIMARY FLT CTRL CMPTR-3								0.0	7.5	7.5	
12	EEGC4	PRIMARY FLT CTRL CMPTR-4								0.0	7.5	7.5	
13	EEGC4	COCKPIT DISPLAY PANEL ADDITIONS								0.0	4.0	4.0	
14	EFA	MECH CONTROLS-AILERON								137.0	0.8	-136.2	NOTE: ADD WT FOR AILERON/FLAT LOCKOUT MECHANISIM (.8 LB)
15	EFA01	ELECT CTRL-AILERON TRANS								0.0	4.0	4.0	NOTE: 4 REQD AT 1LB EACH
16	EFA02	ELECT CTRL-AILERON RCVR								0.0	4.0	4.0	NOTE: 4 REQD AT 1LB EACH
17	EFB	TRIM CONTROLS-AILERON								24.5	0.0	-24.5	
18	EFC01	ELECTRICAL CABLE 1-LEFT OUTBD	2.4			8.1	70	20	4.6	0.0	1.3	1.3	
19	EFC01A	ELECTRICAL CABLE 2-LEFT OUTBD	2.4			8.1	70	20	4.6	0.0	1.3	1.3	
20	EFC02	ELECTRICAL CABLE 1-LEFT INBD	16.2			54.8	40	8	58.3	0.0	9.3	9.3	
21	EFC02A	ELECTRICAL CABLE 2-LEFT INBD	16.2			54.8	40	8	58.3	0.0	9.3	9.3	
22	EFC03	ELECTRICAL CABLE 1-RIGHT OUTBD	2.4			8.1	70	20	4.6	0.0	1.3	1.3	
23	EFC03A	ELECTRICAL CABLE 2-RIGHT OUTBD	2.4			8.1	70	20	4.6	0.0	1.3	1.3	
24	EFC04	ELECTRICAL CABLE 1-RIGHT INBD	16.2			54.8	40	8	58.3	0.0	9.3	9.3	
25	EFC04A	ELECTRICAL CABLE 2-RIGHT INBD	16.2			54.8	40	8	58.3	0.0	9.3	9.3	
26	EFC05	ELECTRICAL 1-LEFT OUTBD RPC								0.0	2.0	2.0	
27	EFC06	ELECTRICAL 2-LEFT OUTBD RPC								0.0	2.0	2.0	
28	EFC07	ELECTRICAL 1-LEFT INBD RPC								0.0	2.0	2.0	
29	EFC08	ELECTRICAL 2-LEFT INBD RPC								0.0	2.0	2.0	
30	EFC09	ELECTRICAL 1-RIGHT OUTBD RPC								0.0	2.0	2.0	
31	EFC10	ELECTRICAL 2-RIGHT OUTBD RPC								0.0	2.0	2.0	
32	EFC11	ELECTRICAL 1-RIGHT INBD RPC								0.0	2.0	2.0	
33	EFC12	ELECTRICAL 2-RIGHT INBD RPC								0.0	2.0	2.0	
34	EFD	HYD PLUMBING-AIL CONT								12.7	0.0	-12.7	

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LN_N	TYPE	NAME	HP	RPM	LB_FT	PH_I	LTH	GAGE	FACTOR	AS_IS	TO_BE	DELTA	NOTES
35	EFF	HYD FLUID-AILERON								19.4	4.9	-14.5	
36	EFF01	ACTUATOR MOTOR 1-LEFT OUTBD	2.4	12000	1.4				1	0.0	2.4	2.4	
37	EFF02	ACTUATOR MOTOR 2-LEFT OUTBD	16.2	12000	9.6				1	0.0	16.2	16.2	
38	EFF03	ACTUATOR MOTOR 1-LEFT INBD	2.4	12000	1.4				1	0.0	2.4	2.4	
39	EFF04	ACTUATOR MOTOR 2-LEFT INBD	16.2	12000	9.6				1	0.0	16.2	16.2	
40	EFF05	ACTUATOR MOTOR 1-RIGHT OUTBD	2.4	12000	1.4				1	0.0	2.4	2.4	
41	EFF06	ACTUATOR MOTOR 2-RIGHT OUTBD	16.2	12000	9.6				1	0.0	16.2	16.2	
42	EFF07	ACTUATOR MOTOR 1-RIGHT INBD	2.4	12000	1.4				1	0.0	2.4	2.4	
43	EFF08	ACTUATOR MOTOR 2-RIGHT INBD	16.2	12000	9.6				1	0.0	16.2	16.2	
44	EFF09	ACTUATOR PUMP 1-LEFT OUTBD	2.4						2.25	0.0	5.4	5.4	
45	EFF10	ACTUATOR PUMP 2-LEFT OUTBD	16.2						2.25	0.0	36.5	36.5	
46	EFF11	ACTUATOR PUMP 1-LEFT INBD	2.4						2.25	0.0	5.4	5.4	
47	EFF12	ACTUATOR PUMP 2-LEFT INBD	16.2						2.25	0.0	36.5	36.5	
48	EFF13	ACTUATOR PUMP 1-RIGHT OUTBD	2.4						2.25	0.0	5.4	5.4	
49	EFF14	ACTUATOR PUMP 2-RIGHT OUTBD	16.2						2.25	0.0	36.5	36.5	
50	EFF15	ACTUATOR PUMP 1-RIGHT INBD	2.4						2.25	0.0	5.4	5.4	
51	EFF16	ACTUATOR PUMP 2-RIGHT INBD	16.2						2.25	0.0	36.5	36.5	
52	EFF17	ACTUATOR CTRL 1-LEFT OUTBD							1.5	0.0	0.0	0.0	
53	EFF18	ACTUATOR CTRL 2-LEFT OUTBD							1.5	0.0	0.0	0.0	
54	EFF19	ACTUATOR CTRL 1-LEFT INBD							1.5	0.0	0.0	0.0	
55	EFF20	ACTUATOR CTRL 2-LEFT INBD							1.5	0.0	0.0	0.0	
56	EFF21	ACTUATOR CTRL 1-RIGHT OUTBD							1.5	0.0	0.0	0.0	
57	EFF22	ACTUATOR CTRL 2-RIGHT OUTBD							1.5	0.0	0.0	0.0	
58	EFF23	ACTUATOR CTRL 1-RIGHT INBD							1.5	0.0	0.0	0.0	
59	EFF24	ACTUATOR CTRL 2-RIGHT INBD							1.5	0.0	0.0	0.0	
60	EFF-A	ACTUATOR-LEFT OUTBD	2.4							47.0	10.0	-37.0	NOTE: MAIN CONTROL VALVE REPLACED BY PUMP/SWASH PLATE
61	EFF-B	ACTUATOR-LEFT INBD	16.2							100.0	20.0	-80.0	NOTE: MAIN CONTROL VALVE REPLACED BY PUMP/SWASH PLATE
62	EFF-C	ACTUATOR-RIGHT OUTBD	2.4							47.0	10.0	-37.0	NOTE: MAIN CONTROL VALVE REPLACED BY PUMP/SWASH PLATE
63	EFF-D	ACTUATOR-RIGHT INBD	16.2							100.0	20.0	-80.0	NOTE: MAIN CONTROL VALVE REPLACED BY PUMP/SWASH PLATE
64	EFF-E	ACTUATOR-ELEVATOR MISC HDWR								8.0	8.0	0.0	
65	EFH	FEEL BUNGEE-AILERON								2.3	0.0	-2.3	
66	EFK	SUPPORTS-AILERON CONT								86.4	0.0	-86.4	
67	EHA	MECH CTRL-ELEVATOR								116.8	0.0	-116.8	
68	EHA01	ELECT CTRL-ELEVATOR TRANS								0.0	4.0	4.0	NOTE: 4 REQD AT 1LB EACH

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LN_N	TYPE	NAME	HP	RPM	LB_FT	PH_I	LTH	GAGE	FACTOR	AS_IS	TO_BE	DELTA	NOTES
69	EHA02	ELECT CTRL-ELEVATOR RCVR								0.0	4.0	4.0	NOTE: 4 REQD AT 1LB EACH
70	EHA03	ELECT CTRL-WIRE					150	20	4.6	0.0	13.8	13.8	
71	EHB	TRIM CTRL-ELEVATOR								0.1	0.0	-0.1	
72	EHC	ELECT DISTRIBUTION-ELEVATOR								14.3	14.3	-0.0	NOTE: LOAD FEEL ACTUATOR
73	EHC01	ELECTRICAL CABLE 1-LEFT OUTBD	5.4			18.2	30	16	8.7	0.0	1.0	1.0	
74	EHC01A	ELECTRICAL CABLE 2-LEFT OUTBD	5.4			18.2	30	16	8.7	0.0	1.0	1.0	
75	EHC02	ELECTRICAL CABLE 1-LEFT INBD	8.0			27.0	30	12	20.1	0.0	2.4	2.4	
76	EHC02A	ELECTRICAL CABLE 2-LEFT INBD	8.0			27.0	30	12	20.1	0.0	2.4	2.4	
77	EHC03	ELECTRICAL CABLE 1-RIGHT OUTBD	5.4			18.2	30	16	8.7	0.0	1.0	1.0	
78	EHC03A	ELECTRICAL CABLE 2-RIGHT OUTBD	5.4			18.2	30	16	8.7	0.0	1.0	1.0	
79	EHC04	ELECTRICAL CABLE 1-RIGHT INBD	8.0			27.0	30	12	20.1	0.0	2.4	2.4	
80	EHC04A	ELECTRICAL CABLE 2-RIGHT INBD	8.0			27.0	30	12	20.1	0.0	2.4	2.4	
81	EHC05	ELECTRICAL 1-LEFT OUTBD RPC								0.0	2.0	2.0	
82	EHC06	ELECTRICAL 2-LEFT OUTBD RPC								0.0	2.0	2.0	
83	EHC07	ELECTRICAL 1-LEFT INBD RPC								0.0	2.0	2.0	
84	EHC08	ELECTRICAL 2-LEFT INBD RPC								0.0	2.0	2.0	
85	EHC09	ELECTRICAL 1-RIGHT OUTBD RPC								0.0	2.0	2.0	
86	EHC10	ELECTRICAL 2-RIGHT OUTBD RPC								0.0	2.0	2.0	
87	EHC11	ELECTRICAL 1-RIGHT INBD RPC								0.0	2.0	2.0	
88	EHC12	ELECTRICAL 2-RIGHT INBD RPC								0.0	2.0	2.0	
89	EHE	HYDRAULIC PLUMBING-ELEVATOR								50.0	0.0	-50.0	
90	EHF01	ACTUATOR MOTOR 1-LEFT OUTBD	5.4	12000	3.2				1	0.0	5.4	5.4	
91	EHF02	ACTUATOR MOTOR 2-LEFT OUTBD	5.4	12000	3.2				1	0.0	5.4	5.4	
92	EHF03	ACTUATOR MOTOR 1-LEFT INBD	8.0	12000	4.7				1	0.0	8.0	8.0	
93	EHF04	ACTUATOR MOTOR 2-LEFT INBD	8.0	12000	4.7				1	0.0	8.0	8.0	
94	EHF05	ACTUATOR MOTOR 1-RIGHT OUTBD	5.4	12000	3.2				1	0.0	5.4	5.4	
95	EHF06	ACTUATOR MOTOR 2-RIGHT OUTBD	5.4	12000	3.2				1	0.0	5.4	5.4	
96	EHF07	ACTUATOR MOTOR 1-RIGHT INBD	8.0	12000	4.7				1	0.0	8.0	8.0	
97	EHF08	ACTUATOR MOTOR 2-RIGHT INBD	8.0	12000	4.7				1	0.0	8.0	8.0	
98	EHF09	ACTUATOR PUMP 1-LEFT OUTBD	5.4						2.25	0.0	12.2	12.2	
99	EHF10	ACTUATOR PUMP 2-LEFT OUTBD	5.4						2.25	0.0	12.2	12.2	
100	EHF11	ACTUATOR PUMP 1-LEFT INBD	8.0						2.25	0.0	18.0	18.0	
101	EHF12	ACTUATOR PUMP 2-LEFT INBD	8.0						2.25	0.0	18.0	18.0	
102	EHF13	ACTUATOR PUMP 1-RIGHT OUTBD	5.4						2.25	0.0	12.2	12.2	

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LN_N	TYPE	NAME	HP	RPM	LB_FT	PH_I	LTH	GAGE	FACTOR	AS_IS	TO_BE	DELTA	NOTES
103	EHF14	ACTUATOR PUMP 2-RIGHT OUTBD	5.4						2.25	0.0	12.2	12.2	
104	EHF15	ACTUATOR PUMP 1-RIGHT INBD	8.0						2.25	0.0	18.0	18.0	
105	EHF16	ACTUATOR PUMP 2-RIGHT INBD	8.0						2.25	0.0	18.0	18.0	
106	EHF17	ACTUATOR CTRL 1-LEFT OUTBD							1.5	0.0	0.0	0.0	
107	EHF18	ACTUATOR CTRL 2-LEFT OUTBD							1.5	0.0	0.0	0.0	
108	EHF19	ACTUATOR CTRL 1-LEFT INBD							1.5	0.0	0.0	0.0	
109	EHF20	ACTUATOR CTRL 2-LEFT INBD							1.5	0.0	0.0	0.0	
110	EHF21	ACTUATOR CTRL 1-RIGHT OUTBD							1.5	0.0	0.0	0.0	
111	EHF22	ACTUATOR CTRL 2-RIGHT OUTBD							1.5	0.0	0.0	0.0	
112	EHF23	ACTUATOR CTRL 1-RIGHT INBD							1.5	0.0	0.0	0.0	
113	EHF24	ACTUATOR CTRL 2-RIGHT INBD							1.5	0.0	0.0	0.0	
114	EHF-A	ACTUATOR-LEFT OUTBD	10.8							108.9	88.9	-20.0	NOTE: MAIN CONTROL VALVE REPLACED BY PUMP/SWASH PLATE
115	EHF-B	ACTUATOR-LEFT INBD	16.0							136.6	116.6	-20.0	NOTE: MAIN CONTROL VALVE REPLACED BY PUMP/SWASH PLATE
116	EHF-C	ACTUATOR-RIGHT OUTBD	10.8							108.9	88.9	-20.0	NOTE: MAIN CONTROL VALVE REPLACED BY PUMP/SWASH PLATE
117	EHF-D	ACTUATOR-RIGHT INBD	16.0							136.6	116.6	-20.0	NOTE: MAIN CONTROL VALVE REPLACED BY PUMP/SWASH PLATE
118	EHF-E	ACTUATOR-ELEVATOR MISC HDWR								10.2	10.2	0.0	
119	EHG	HYDRAULIC FLUID-ELEVATOR								44.2	19.6	-24.6	
120	EHH	BUNGEE-ELEVATOR								27.6	0.0	-27.6	
121	EHJ	DAMPERS-ELEVATOR								38.5	38.5	0.0	
122	EHK	SUPPORTS-ELEVATOR CONT								23.1	0.0	-23.1	
123	EJA	MECH CTRL-RUDDER								86.7	32.7	-54.0	NOTE: MC11 19.6LB RUD INSTAL-BH01 12.9LB CTRL INSTAL-FLT,NOSE
124	EJA01	ELECT CTRL-RUDDER TRANS								0.0	2.0	2.0	NOTE: 2 REQD AT 1LB EACH
125	EJA02	ELECT CTRL-RUDDER RCVR								0.0	2.0	2.0	NOTE: 2 REQD AT 1LB EACH
126	EJA03	ELECT CTRL-WIRE					1500		4.6	0.0	6.9	6.9	
127	EJB	TRIM CTRL-RUDDER								18.6	4.0	-14.6	NOTE: REPLACED BY SERVO ADJUSTMENT ON COLUMN
128	EJC01	ELECTRICAL CABLE-UPPER	9.5	12000	5.6	36.9	30	10	31.3	0.0	3.8	3.8	
129	EJC02	ELECTRICAL CABLE-UPPER STANDBY	9.5	12000	5.6	36.9	30	8	58.3	0.0	7.0	7.0	
130	EJC03	ELECTRICAL CABLE-LOWER	12.4	12000	7.3	48.2	30	10	31.3	0.0	3.8	3.8	
131	EJC04	ELECTRICAL CABLE-LOWER STANDBY	12.4	12000	7.3	48.2	30	8	58.3	0.0	7.0	7.0	
132	EJC05	ELECTRICAL -UPPER RUDDER RPC								0.0	2.0	2.0	
133	EJC06	ELECTRICAL -UPPER RUDDER RPC STANDBY								0.0	2.0	2.0	
134	EJC07	ELECTRICAL -LOWER RUDDER RPC								0.0	2.0	2.0	
135	EJC08	ELECTRICAL -LOWER RUDDER RPC STANDBY								0.0	2.0	2.0	
136	EJD	STANDBY PWR-RUDDER CTRL								0.4	0.0	-0.4	

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LN_N	TYPE	NAME	HP	RPM	LB_FT	PH_I	LTH	GAGE	FACTOR	AS_IS	TO_BE	DELTA	NOTES
137	EJDA	HYDRAULIC CTRL-STANDBY PWR								35.5	0.0	-35.5	
138	EJDB	HYDRAULIC FLUID-STANDBY PWR								8.3	0.0	-8.3	
139	EJDC	HYDRAULIC PLUMBING-STANDBY PWR								8.0	0.0	-8.0	
140	EJF	HYDRAULIC FLUID-RUDDER CTRL (UP+LWR)								15.0	4.5	-10.5	
141	EJH	HYDRAULIC PLUMBING-RUDDER CTRL								20.0	0.0	-20.0	
142	EJJ01	ACTUATOR MOTOR-LOWER RUDDER	12.4						1	0.0	12.4	12.4	
143	EJJ02	ACTUATOR MOTOR-UPPER RUDDER	9.5						1	0.0	9.5	9.5	
144	EJJ03	ACTUATOR PUMP-LOWER RUDDER	12.4						2.25	0.0	27.8	27.8	
145	EJJ04	ACTUATOR PUMP-UPPER RUDDER	9.5						2.25	0.0	21.3	21.3	
146	EJJ05	TRANSFER RELAY-LOWER RUDDER	12.4			41.8				0.0	2.0	2.0	
147	EJJ06	TRANSFER RELAY-UPPER RUDDER	9.5			31.9				0.0	2.0	2.0	
148	EJJ07	ACTUATOR CTRL-LOWER RUDDER	0.0						1.5	0.0	0.0	0.0	
149	EJJ08	ACTUATOR CTRL-UPPER RUDDER	0.0						1.5	0.0	0.0	0.0	
150	EJJ-A	ACTUATOR-LWR RUDDER	12.4							83.5	83.5	0.0	
151	EJJ-B	ACTUATOR-UPPER RUDDER	9.5							81.5	81.5	0.0	
152	EJN	SUPPORTS-RUDDER CTRL								20.2	0.0	-20.2	
153	ELA	MECH CTRLS-FLAP								214.8	0.0	-214.8	
154	ELA-01	ELECT MOTOR 1-LEFT O/B FLAP	2.0	12000	1.2				1	0.0	2.0	2.0	
155	ELA-02	ELECT MOTOR 2-LEFT O/B FLAP	2.0	12000	1.2				1	0.0	2.0	2.0	
156	ELA-03	ELECT MOTOR 1-LEFT I/B FLAP	1.3	12000	0.7				1	0.0	1.3	1.3	
157	ELA-04	ELECT MOTOR 2-LEFT I/B FLAP	1.3	12000	0.7				1	0.0	1.3	1.3	
158	ELA-05	ELECT MOTOR 1-RIGHT O/B FLAP	2.0	12000	1.2				1	0.0	2.0	2.0	
159	ELA-06	ELECT MOTOR 2-RIGHT O/B FLAP	2.0	12000	1.2				1	0.0	2.0	2.0	
160	ELA-07	ELECT MOTOR 1-RIGHT I/B FLAP	1.3	12000	0.7				1	0.0	1.3	1.3	
161	ELA-08	ELECT MOTOR 2-RIGHT I/B FLAP	1.3	12000	0.7				1	0.0	1.3	1.3	
162	ELA-09	ELECT CNTL MOTOR 1-LEFT O/B FLAP	2.0						1.5	0.0	3.0	3.0	
163	ELA-10	ELECT CNTL MOTOR 2-LEFT O/B FLAP	2.0						1.5	0.0	3.0	3.0	
164	ELA-11	ELECT CNTL MOTOR 1-LEFT I/B FLAP	1.3						1.5	0.0	1.9	1.9	
165	ELA-12	ELECT CNTL MOTOR 2-LEFT I/B FLAP	1.3						1.5	0.0	1.9	1.9	
166	ELA-13	ELECT CNTL MOTOR 1-RIGHT O/B FLAP	2.0						1.5	0.0	3.0	3.0	
167	ELA-14	ELECT CNTL MOTOR 2-RIGHT O/B FLAP	2.0						1.5	0.0	3.0	3.0	
168	ELA-15	ELECT CNTL MOTOR 1-RIGHT I/B FLAP	1.3						1.5	0.0	1.9	1.9	
169	ELA-16	ELECT CNTL MOTOR 2-RIGHT I/B FLAP	1.3						1.5	0.0	1.9	1.9	
170	ELA-17	ELECT CABLE MOTOR 1-LEFT O/B FLAP	2.0			6.8	40	20	4.6	0.0	0.7	0.7	

LN_N	TYPE	NAME	HP	RPM	LB_FT	PH_I	LTH	GAGE	FACTOR	AS_IS	TO_BE	DELTA	NOTES
171	ELA-18	ELECT CABLE MOTOR 2-LEFT O/B FLAP	2.0			6.8	40	20	4.6	0.0	0.7	0.7	
172	ELA-19	ELECT CABLE MOTOR 1-LEFT I/B FLAP	1.3			4.2	80	20	4.6	0.0	1.5	1.5	
173	ELA-20	ELECT CABLE MOTOR 2-LEFT I/B FLAP	1.3			4.2	80	20	4.6	0.0	1.5	1.5	
174	ELA-21	ELECT CABLE MOTOR 1-RIGHT O/B FLAP	2.0			6.8	40	20	4.6	0.0	0.7	0.7	
175	ELA-22	ELECT CABLE MOTOR 2-RIGHT O/B FLAP	2.0			6.8	40	20	4.6	0.0	0.7	0.7	
176	ELA-23	ELECT CABLE MOTOR 1-RIGHT I/B FLAP	1.3			4.2	80	20	4.6	0.0	1.5	1.5	
177	ELA-24	ELECT CABLE MOTOR 2-RIGHT I/B FLAP	1.3			4.2	80	20	4.6	0.0	1.5	1.5	
178	ELA-25	ELECT RPC MOTOR 1-LEFT O/B FLAP								0.0	2.0	2.0	
179	ELA-25	FLAP CTRL PANEL								0.0	2.0	2.0	NOTE:FLAP/SLAT/SPOILER CONTROLS COMBINE INTO NEW PANEL
180	ELA-26	ELECT CONTROL WIRE								0.0	2.0	2.0	NOTE:FLAP/SLAT/SPOILER CONTROLS CONBINE INTO NEW PANEL
181	ELA-26	ELECT RPC MOTOR 2-LEFT O/B FLAP								0.0	2.0	2.0	
182	ELA-27	ELECT RPC MOTOR 1-LEFT I/B FLAP								0.0	2.0	2.0	
183	ELA-27	POWER BUS XFR RELAY-LEFT WING SLATS	4.5			9.7				0.0	1.0	1.0	
184	ELA-28	POWER BUS XFR RELAY-RIGHT WING SLATS	4.5			9.7				0.0	1.0	1.0	
185	ELA-28	ELECT RPC MOTOR 2-LEFT I/B FLAP								0.0	2.0	2.0	
186	ELA-29	ELECT RPC MOTOR 1-RIGHT O/B FLAP								0.0	2.0	2.0	
187	ELA-30	ELECT RPC MOTOR 2-RIGHT O/B FLAP								0.0	2.0	2.0	
188	ELA-31	ELECT RPC MOTOR 1-RIGHT I/B FLAP								0.0	2.0	2.0	
189	ELA-32	ELECT RPC MOTOR 2-RIGHT I/B FLAP								0.0	2.0	2.0	
190	ELB	HYDRAULIC CTRLS-FLAP								31.6	0.0	-31.6	
191	ELC	HYDRAULIC PLUMGING-FLAP CTRL								39.9	0.0	-39.9	
192	ELD	ACTUATORS-FLAP CTRL								210.4	210.4	0.0	NOTE:PRESENT HYD ACT FLAP REDESIGNED-JACKSCW/OVRD CLUTCH-EQ WT
193	ELF	HYDRALUC FLUID-FLAP CTRL								24.7	0.0	-24.7	
194	ELH	SUPPORTS-FLAP CTRL								53.4	0.0	-53.4	
195	ENA	MECH CTRLS-SPOILER								149.3	0.0	-149.3	
196	ENA-01	SPOILER CONTROL PANEL									0.0	0.0	NOTE:SEE FLAPS-PART OF NEW PANEL
197	ENA-02	ELECT CONTROL WIRE									0.0	0.0	NOTE:SEE FLAPS-PART OF NEW PANEL
198	ENA-03	ELECT MOTOR-SPOILER L1	8.4	12000	5.0				1	0.0	8.4	8.4	
199	ENA-04	ELECT MOTOR-SPOILER L2	8.4	12000	5.0				1	0.0	8.4	8.4	
200	ENA-05	ELECT MOTOR-SPOILER L3	8.4	12000	5.0				1	0.0	8.4	8.4	
201	ENA-06	ELECT MOTOR-SPOILER L4	8.4	12000	5.0				1	0.0	8.4	8.4	
202	ENA-07	ELECT MOTOR-SPOILER L5	8.4	12000	5.0				1	0.0	8.4	8.4	
203	ENA-08	ELECT MOTOR-SPOILER R1	8.4	12000	5.0				1	0.0	8.4	8.4	
204	ENA-09	ELECT MOTOR-SPOILER R2	8.4	12000	5.0				1	0.0	8.4	8.4	

LN_N	TYPE	NAME	HP	RPM	LB_FT	PH_I	LTH	GAGE	FACTOR	AS_IS	TO_BE	DELTA	NOTES
205	ENA-10	ELECT MOTOR-SPOILER R3	8.4	12000	5.0				1	0.0	8.4	8.4	
206	ENA-11	ELECT MOTOR-SPOILER R4	8.4	12000	5.0				1	0.0	8.4	8.4	
207	ENA-12	ELECT MOTOR-SPOILER R5	8.4	12000	5.0				1	0.0	8.4	8.4	
208	ENA-13	ELECT CABLE-SPOILER L1	8.4			28.4	40	12	20.1	0.0	3.2	3.2	
209	ENA-14	ELECT CABLE-SPOILER L2	8.4			28.4	55	12	20.1	0.0	4.4	4.4	
210	ENA-15	ELECT CABLE-SPOILER L3	8.4			28.4	65	12	20.1	0.0	5.2	5.2	
211	ENA-16	ELECT CABLE-SPOILER L4	8.4			28.4	75	12	20.1	0.0	6.0	6.0	
212	ENA-17	ELECT CABLE-SPOILER L5	8.4			28.4	80	12	20.1	0.0	6.4	6.4	
213	ENA-18	ELECT CABLE-SPOILER R1	8.4			28.4	40	12	20.1	0.0	3.2	3.2	
214	ENA-19	ELECT CABLE-SPOILER R2	8.4			28.4	55	12	20.1	0.0	4.4	4.4	
215	ENA-20	ELECT CABLE-SPOILER R3	8.4			28.4	65	12	20.1	0.0	5.2	5.2	
216	ENA-21	ELECT CABLE-SPOILER R4	8.4			28.4	75	12	20.1	0.0	6.0	6.0	
217	ENA-22	ELECT CABLE-SPOILER R5	8.4			28.4	80	12	20.1	0.0	6.4	6.4	
218	ENA-23	MOTOR CTRL-SPOILER L1	8.4						1.5	0.0	12.6	12.6	
219	ENA-24	MOTOR CTRL-SPOILER L2	8.4						1.5	0.0	12.6	12.6	
220	ENA-25	MOTOR CTRL-SPOILER L3	8.4						1.5	0.0	12.6	12.6	
221	ENA-26	MOTOR CTRL-SPOILER L4	8.4						1.5	0.0	12.6	12.6	
222	ENA-27	MOTOR CTRL-SPOILER L5	8.4						1.5	0.0	12.6	12.6	
223	ENA-28	MOTOR CTRL-SPOILER R1	8.4						1.5	0.0	12.6	12.6	
224	ENA-29	MOTOR CTRL-SPOILER R2	8.4						1.5	0.0	12.6	12.6	
225	ENA-30	MOTOR CTRL-SPOILER R3	8.4						1.5	0.0	12.6	12.6	
226	ENA-31	MOTOR CTRL-SPOILER R4	8.4						1.5	0.0	12.6	12.6	
227	ENA-32	MOTOR CTRL-SPOILER R5	8.4						1.5	0.0	12.6	12.6	
228	ENA-33	ELECT RPC-SPOILER L1								0.0	2.0	2.0	
229	ENA-34	ELECT RPC-SPOILER L2								0.0	2.0	2.0	
230	ENA-35	ELECT RPC-SPOILER L3								0.0	2.0	2.0	
231	ENA-36	ELECT RPC-SPOILER L4								0.0	2.0	2.0	
232	ENA-37	ELECT RPC-SPOILER L5								0.0	2.0	2.0	
233	ENA-38	ELECT RPC-SPOILER R1								0.0	2.0	2.0	
234	ENA-39	ELECT RPC-SPOILER R2								0.0	2.0	2.0	
235	ENA-40	ELECT RPC-SPOILER R3								0.0	2.0	2.0	
236	ENA-41	ELECT RPC-SPOILER R4								0.0	2.0	2.0	
237	ENA-42	ELECT RPC-SPOILER R5								0.0	2.0	2.0	
238	ENA-43	ACTUATOR-SPOILER L1								15.3	15.3	0.0	NOTE:PRESENT HYD ACT-SPOILER REDESIGNED TO JACKSCREW-EQUIV WT.

LN_N	TYPE	NAME	HP	RPM	LB_FT	PH_I	LTH	GAGE	FACTOR	AS_IS	TO_BE	DELTA	NOTES
239	ENA-44	ACTUATOR-SPOILER L2								15.3	15.3	0.0	NOTE:PRESENT HYD ACT-SPOILER REDESIGNED TO JACKSCREW-EQUIV WT.
240	ENA-45	ACTUATOR-SPOILER L3								15.3	15.3	0.0	NOTE:PRESENT HYD ACT-SPOILER REDESIGNED TO JACKSCREW-EQUIV WT.
241	ENA-46	ACTUATOR-SPOILER L4								15.3	15.3	0.0	NOTE:PRESENT HYD ACT-SPOILER REDESIGNED TO JACKSCREW-EQUIV WT.
242	ENA-47	ACTUATOR-SPOILER L5								15.3	15.3	0.0	NOTE:PRESENT HYD ACT-SPOILER REDESIGNED TO JACKSCREW-EQUIV WT.
243	ENA-48	ACTUATOR-SPOILER R1								15.3	15.3	0.0	NOTE:PRESENT HYD ACT-SPOILER REDESIGNED TO JACKSCREW-EQUIV WT.
244	ENA-49	ACTUATOR-SPOILER R2								15.3	15.3	0.0	NOTE:PRESENT HYD ACT-SPOILER REDESIGNED TO JACKSCREW-EQUIV WT.
245	ENA-50	ACTUATOR-SPOILER R3								15.3	15.3	0.0	NOTE:PRESENT HYD ACT-SPOILER REDESIGNED TO JACKSCREW-EQUIV WT.
246	ENA-51	ACTUATOR-SPOILER R4								15.3	15.3	0.0	NOTE:PRESENT HYD ACT-SPOILER REDESIGNED TO JACKSCREW-EQUIV WT.
247	ENA-52	ACTUATOR-SPOILER R5								15.3	15.3	0.0	NOTE:PRESENT HYD ACT-SPOILER REDESIGNED TO JACKSCREW-EQUIV WT.
248	ENC	ELECT-SPOILER								0.8	0.0	-0.8	
249	END	HYDRAULIC PLUMBING-SPOILER								24.6	0.0	-24.6	
250	ENF	HYDRAULIC FLUIT-SPOILER CTRL								19.1	0.0	-19.1	
251	ENJ	RESERVIOR-SPOILER CTRL								0.0	0.0	-0.0	
252	ENL	ACTUATOR-SPOILER CONT								192.1	0.0	-192.1	
253	ENP	SUPPORTS-SPOILER CTRL								100.8	0.0	-100.8	
254	EPA	MECH CONTROLS- ADJ STAB								80.2	61.4	-18.8	NOTE: KEPT AFT BODY CONTROL(GEAR BOX)
255	EPA01	ACTUATOR MOTOR 1- ADJ STAB CONT	21.5						1	0.0	21.5	21.5	
256	EPA02	ACTUATOR MOTOR 2- ADJ STAB CONT	21.5						1	0.0	21.5	21.5	
257	EPA05	ELECTRICAL CABLE 1-ADJ STAB CONT	21.5			72.7	30	6	90.7	0.0	10.9	10.9	
258	EPA06	ELECTRICAL CABLE 2-ADJ STAB CONT	21.5			72.7	30	6	90.7	0.0	10.9	10.9	
259	EPA07	ELECTRICAL CABLE 3-ADJ STAB CONT	21.5			72.7	30	6	90.7	0.0	10.9	10.9	
260	EPA08	ELECTRICAL 1-ADJ STAB CONT RPC								0.0	2.0	2.0	
261	EPA09	ELECTRICAL 2-ADJ STAB CONT RPC								0.0	2.0	2.0	
262	EPA10	ELECTRICAL 3-ADJ STAB CONT RPC								0.0	2.0	2.0	
263	EPA11	TRANSFER RELAY-ADJ STAB CONT								0.0	2.0	2.0	
264	EPA12	ELECT CTRL RELAY 1-ADJ STAB CONT								0.0	4.0	4.0	
265	EPA13	ELECT CTRL RELAY 2-ADJ STAB CONT								0.0	4.0	4.0	
266	EPC	HYD CONTROLS-ADJ STAB								52.0	0.0	-52.0	
267	EPD	HYD PLUMBING ADJ STAB CONT								62.0	0.0	-62.0	
268	EPE	ACTUATOR-ADJ STAB CONT	21.5							301.4	266.6	-34.9	NOTE: REMOVED (2) HYD BRAKES-11.88, (2) HYD MOTORS-23.
269	EPEA01	ELECTRIC BRAKE 1-ADJ STAB CONT								5.9	6.9	1.0	NOTE: ELECTRIC BRAKE ADDED 1LB TO MECH EQUIV FOR MAGNETICS.
270	EPEA02	ELECTRIC BRAKE 2-ADJ STAB CONT								5.9	6.9	1.0	
271	EPF	HYD FLUID-ADJ STAB CONT								21.1	0.0	-21.1	NOTE: FLUID FOR MOTORS
272	EPH	MECHANISM-ADJ STAB CONT								42.9	42.9	0.0	

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LN_N	TYPE	NAME	HP	RPM	LB_FT	PH_I	LTH	GAGE	FACTOR	AS_IS	TO_BE	DELTA	NOTES
273	EPJ	SUPPORTS- ADJ STAB CONT								120.1	120.1	0.0	
274	ETA	PLUMB-SURF CONT								56.7	0.0	-56.7	
275	ETB	FLUID-SURF CONT								24.1	0.0	-24.1	
276	EVA	MECH CTRLS-LE SLATS								1017.9	0.0	-1017.9	
277	EVA01	SLAT CONTROL PANEL								0.0	0.0	0.0	NOTE:SEE FLAPS-PART OF NEW PANEL
278	EVA02	ELECT CONTROL WIRE								0.0	0.0	0.0	NOTE:SEE FLAPS-PART OF NEW PANEL
279	EVA03	ELECT POWER WIRE-SLATS L2,DLE,L8	33.5			72.5	100	2	79.1	0.0	31.6	31.6	NOTE: AL WIRE USED
280	EVA04	ELECT POWER WIRE-SLATS L1,L3,L7	40.2			87.0	90	1/0	122	0.0	43.9	43.9	NOTE: AL WIRE USED
281	EVA05	ELECT POWER WIRE-SLATS L4,L5,L6	40.2			87.0	80	1/0	122	0.0	39.0	39.0	NOTE: AL WIRE USED
282	EVA06	ELECT POWER WIRE-SLATS R2,DLE,R8	33.5			72.5	100	2	79.1	0.0	31.6	31.6	NOTE: AL WIRE USED
283	EVA07	ELECT POWER WIRE-SLATS R1,R3,R7	40.2			87.0	90	1/0	122	0.0	43.9	43.9	NOTE: AL WIRE USED
284	EVA08	ELECT POWER WIRE-SLATS R4,R5,R6	40.2			87.0	80	1/0	122	0.0	39.0	39.0	NOTE: AL WIRE USED
285	EVA09	ELECT MOTORS-SLAT L1	2.0	12000	1.2				1	0.0	2.0	2.0	NOTE: REDESIGN TO INCLUDE ONE SCREW JACK ACTUATOR PER SLAT
286	EVA10	ELECT MOTORS-SLAT L2	2.0	12000	1.2				1	0.0	2.0	2.0	NOTE: REDESIGN TO INCLUDE ONE SCREW JACK ACTUATOR PER SLAT
287	EVA11	ELECT MOTORS-LEFT DLE	2.0	12000	1.2				1	0.0	2.0	2.0	NOTE: REDESIGN TO INCLUDE ONE SCREW JACK ACTUATOR PER DLE
288	EVA12	ELECT MOTORS-SLAT L3	2.0	12000	1.2				1	0.0	2.0	2.0	NOTE: REDESIGN TO INCLUDE ONE SCREW JACK ACTUATOR PER SLAT
289	EVA13	ELECT MOTORS-SLAT L4	2.0	12000	1.2				1	0.0	2.0	2.0	NOTE: REDESIGN TO INCLUDE ONE SCREW JACK ACTUATOR PER SLAT
290	EVA14	ELECT MOTORS-SLAT L5	2.0	12000	1.2				1	0.0	2.0	2.0	NOTE: REDESIGN TO INCLUDE ONE SCREW JACK ACTUATOR PER SLAT
291	EVA15	ELECT MOTORS-SLAT L6	2.0	12000	1.2				1	0.0	2.0	2.0	NOTE: REDESIGN TO INCLUDE ONE SCREW JACK ACTUATOR PER SLAT
292	EVA16	ELECT MOTORS-SLAT L7	2.0	12000	1.2				1	0.0	2.0	2.0	NOTE: REDESIGN TO INCLUDE ONE SCREW JACK ACTUATOR PER SLAT
293	EVA17	ELECT MOTORS-SLAT L8	2.0	12000	1.2				1	0.0	2.0	2.0	NOTE: REDESIGN TO INCLUDE ONE SCREW JACK ACTUATOR PER SLAT
294	EVA18	ELECT MOTORS-SLAT R1	2.0	12000	1.2				1	0.0	2.0	2.0	NOTE: REDESIGN TO INCLUDE ONE SCREW JACK ACTUATOR PER SLAT
295	EVA19	ELECT MOTORS-SLAT R2	2.0	12000	1.2				1	0.0	2.0	2.0	NOTE: REDESIGN TO INCLUDE ONE SCREW JACK ACTUATOR PER SLAT
296	EVA20	ELECT MOTORS-RIGHT DLE	2.0	12000	1.2				1	0.0	2.0	2.0	NOTE: REDESIGN TO INCLUDE ONE SCREW JACK ACTUATOR PER DLE
297	EVA22	ELECT MOTORS-SLAT R3	2.0	12000	1.2				1	0.0	2.0	2.0	NOTE: REDESIGN TO INCLUDE ONE SCREW JACK ACTUATOR PER SLAT
298	EVA23	ELECT MOTORS-SLAT R4	2.0	12000	1.2				1	0.0	2.0	2.0	NOTE: REDESIGN TO INCLUDE ONE SCREW JACK ACTUATOR PER SLAT
299	EVA24	ELECT MOTORS-SLAT R5	2.0	12000	1.2				1	0.0	2.0	2.0	NOTE: REDESIGN TO INCLUDE ONE SCREW JACK ACTUATOR PER SLAT
300	EVA25	ELECT MOTORS-SLAT R6	2.0	12000	1.2				1	0.0	2.0	2.0	NOTE: REDESIGN TO INCLUDE ONE SCREW JACK ACTUATOR PER SLAT
301	EVA26	ELECT MOTORS-SLAT R7	2.0	12000	1.2				1	0.0	2.0	2.0	NOTE: REDESIGN TO INCLUDE ONE SCREW JACK ACTUATOR PER SLAT
302	EVA27	ELECT MOTORS-SLAT R8	2.0	12000	1.2				1	0.0	2.0	2.0	NOTE: REDESIGN TO INCLUDE ONE SCREW JACK ACTUATOR PER SLAT
303	EVA28	ELECTRICAL CABLE-SLAT L1	2.0			6.8	3	20	4.6	0.0	0.0	0.0	
304	EVA29	ELECTRICAL CABLE-SLAT L2	2.0			6.8	3	20	4.6	0.0	0.0	0.0	
305	EVA30	ELECTRICAL CABLE-LEFT DLE	2.0			6.8	3	20	4.6	0.0	0.0	0.0	
306	EVA31	ELECTRICAL CABLE-SLAT L3	2.0			6.8	3	20	4.6	0.0	0.0	0.0	

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LN_N	TYPE	NAME	HP	RPM	LB_FT	PH_I	LTH	GAGE	FACTOR	AS_IS	TO_BE	DELTA	NOTES
307	EVA32	ELECTRICAL CABLE-SLAT L4	2.0			6.8	3	20	4.6	0.0	0.0	0.0	
308	EVA33	ELECTRICAL CABLE-SLAT L5	2.0			6.8	3	20	4.6	0.0	0.0	0.0	
309	EVA34	ELECTRICAL CABLE-SLAT L6	2.0			6.8	3	20	4.6	0.0	0.0	0.0	
310	EVA35	ELECTRICAL CABLE-SLAT L7	2.0			6.8	3	20	4.6	0.0	0.0	0.0	
311	EVA36	ELECTRICAL CABLE-SLAT L8	2.0			6.8	3	20	4.6	0.0	0.0	0.0	
312	EVA37	ELECTRICAL CABLE-SLAT R1	2.0			6.8	3	20	4.6	0.0	0.0	0.0	
313	EVA38	ELECTRICAL CABLE-SLAT R2	2.0			6.8	3	20	4.6	0.0	0.0	0.0	
314	EVA39	ELECTRICAL CABLE-RIGHT DLE	2.0			6.8	3	20	4.6	0.0	0.0	0.0	
315	EVA40	ELECTRICAL CABLE-SLAT R3	2.0			6.8	3	20	4.6	0.0	0.0	0.0	
316	EVA41	ELECTRICAL CABLE-SLAT R4	2.0			6.8	3	20	4.6	0.0	0.0	0.0	
317	EVA42	ELECTRICAL CABLE-SLAT R5	2.0			6.8	3	20	4.6	0.0	0.0	0.0	
318	EVA43	ELECTRICAL CABLE-SLAT R6	2.0			6.8	3	20	4.6	0.0	0.0	0.0	
319	EVA44	ELECTRICAL CABLE-SLAT R7	2.0			6.8	3	20	4.6	0.0	0.0	0.0	
320	EVA45	ELECTRICAL CABLE-SLAT R8	2.0			6.8	3	20	4.6	0.0	0.0	0.0	
321	EVA46	MOTOR CONTROL-SLAT L1	2.0						1.5	0.0	3.0	3.0	
322	EVA47	MOTOR CONTROL-SLAT L2	2.0						1.5	0.0	3.0	3.0	
323	EVA48	MOTOR CONTROL-LEFT DLE	2.0						1.5	0.0	3.0	3.0	
324	EVA49	MOTOR CONTROL-SLAT L3	2.0						1.5	0.0	3.0	3.0	
325	EVA50	MOTOR CONTROL-SLAT L4	2.0						1.5	0.0	3.0	3.0	
326	EVA51	MOTOR CONTROL-SLAT L5	2.0						1.5	0.0	3.0	3.0	
327	EVA52	MOTOR CONTROL-SLAT L6	2.0						1.5	0.0	3.0	3.0	
328	EVA53	MOTOR CONTROL-SLAT L7	2.0						1.5	0.0	3.0	3.0	
329	EVA54	MOTOR CONTROL-SLAT L8	2.0						1.5	0.0	3.0	3.0	
330	EVA55	MOTOR CONTROL-SLAT R1	2.0						1.5	0.0	3.0	3.0	
331	EVA56	MOTOR CONTROL-SLAT R2	2.0						1.5	0.0	3.0	3.0	
332	EVA57	MOTOR CONTROL-RIGHT DLE	2.0						1.5	0.0	3.0	3.0	
333	EVA58	MOTOR CONTROL-SLAT R3	2.0						1.5	0.0	3.0	3.0	
334	EVA59	MOTOR CONTROL-SLAT R4	2.0						1.5	0.0	3.0	3.0	
335	EVA60	MOTOR CONTROL-SLAT R5	2.0						1.5	0.0	3.0	3.0	
336	EVA61	MOTOR CONTROL-SLAT R6	2.0						1.5	0.0	3.0	3.0	
337	EVA62	MOTOR CONTROL-SLAT R7	2.0						1.5	0.0	3.0	3.0	
338	EVA63	MOTOR CONTROL-SLAT R8	2.0						1.5	0.0	3.0	3.0	
339	EVA64	ELECT RPC-SLAT L1								0.0	2.0	2.0	
340	EVA65	ELECT RPC-SLAT L2								0.0	2.0	2.0	

LN_N	TYPE	NAME	HP	RPM	LB_FT	PH_I	LTH	GAGE	FACTOR	AS_IS	TO_BE	DELTA	NOTES
341	EVA67	ELECT RPC-SLAT L6								0.0	2.0	2.0	
342	EVA68	ELECT RPC-SLAT L7								0.0	2.0	2.0	
343	EVA69	ELECT RPC-SLAT L8								0.0	2.0	2.0	
344	EVA70	ELECT RPC-SLAT R1								0.0	2.0	2.0	
345	EVA71	ELECT RPC-SLAT R2								0.0	2.0	2.0	
346	EVA72	ELECT RPC-RIGHT DLE								0.0	2.0	2.0	
347	EVA73	ELECT RPC-SLAT R3								0.0	2.0	2.0	
348	EVA74	ELECT RPC-SLAT R4								0.0	2.0	2.0	
349	EVA75	ELECT RPC-SLAT R5								0.0	2.0	2.0	
350	EVA76	ELECT RPC-SLAT R6								0.0	2.0	2.0	
351	EVA77	ELECT RPC-SLAT R7								0.0	2.0	2.0	
352	EVA78	ELECT RPC-SLAT R8								0.0	2.0	2.0	
353	EVA79	POWER BUS XFR RELAY 1-LEFT WING SLATS	33.5			72.5				0.0	3.0	3.0	
354	EVA80	POWER BUS XFR RELAY 1-RIGHT WING SLATS	33.5			72.5				0.0	3.0	3.0	
355	EVA81	POWER BUS XFR RELAY 2-LEFT WING SLATS	40.2			87.0				0.0	3.0	3.0	
356	EVA82	POWER BUS XFR RELAY 2-RIGHT WING SLATS	40.2			87.0				0.0	3.0	3.0	
357	EVA83	POWER BUS XFR RELAY 3-LEFT WING SLATS	40.2			87.0				0.0	3.0	3.0	
358	EVA84	POWER BUS XFR RELAY 3-RIGHT WING SLATS	40.2			87.0				0.0	3.0	3.0	
359	EVA85	ANTI-ICE/SLAT POWER XFR RELAY-SLAT L1	13.4			29.0				0.0	3.0	3.0	
360	EVA85.1	ELECT RPC-LEFT DLE								0.0	2.0	2.0	
361	EVA86	ANTI-ICE/SLAT POWER XFR RELAY-SLAT L2	6.7			14.5				0.0	3.0	3.0	
362	EVA86.1	ELECT RPC-SLAT L3								0.0	2.0	2.0	
363	EVA87	ANTI-ICE/SLAT POWER XFR RELAY-LEFT DLE	13.4			29.0				0.0	3.0	3.0	
364	EVA87.1	ELECT RPC-SLAT L4								0.0	2.0	2.0	
365	EVA88	ANTI-ICE/SLAT POWER XFR RELAY-SLAT L3	13.4			29.0				0.0	3.0	3.0	
366	EVA88.1	ELECT RPC-SLAT L5								0.0	2.0	2.0	
367	EVA89	ANTI-ICE/SLAT POWER XFR RELAY-SLAT L4	13.4			29.0				0.0	3.0	3.0	
368	EVA90	ANTI-ICE/SLAT POWER XFR RELAY-SLAT L5	13.4			29.0				0.0	3.0	3.0	
369	EVA91	ANTI-ICE/SLAT POWER XFR RELAY-SLAT L6	13.4			29.0				0.0	3.0	3.0	
370	EVA92	ANTI-ICE/SLAT POWER XFR RELAY-SLAT L7	13.4			29.0				0.0	3.0	3.0	
371	EVA93	ANTI-ICE/SLAT POWER XFR RELAY-SLAT L8	13.4			29.0				0.0	3.0	3.0	
372	EVA94	ANTI-ICE/SLAT POWER XFR RELAY-SLAT R1	13.4			29.0				0.0	3.0	3.0	
373	EVA95	ANTI-ICE/SLAT POWER XFR RELAY-SLAT R2	13.4			29.0				0.0	3.0	3.0	
374	EVA96	ANTI-ICE/SLAT POWER XFR RELAY-RIGHT DLE	6.7			14.5				0.0	3.0	3.0	

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LN_N	TYPE	NAME	HP	RPM	LB_FT	PH_I	LTH GAGE FACTOR	AS_IS	TO_BE	DELTA	NOTES
375	EVA97	ANTI-ICE/SLAT POWER XFR RELAY-SLAT R3	13.4			29.0		0.0	3.0	3.0	
376	EVA98	ANTI-ICE/SLAT POWER XFR RELAY-SLAT R4	13.4			29.0		0.0	3.0	3.0	
377	EVA99	ANTI-ICE/SLAT POWER XFR RELAY-SLAT R5	13.4			29.0		0.0	3.0	3.0	
378	EVA99.1	ANTI-ICE/SLAT POWER XFR RELAY-SLAT R6	13.4			29.0		0.0	3.0	3.0	
379	EVA99.2	ANTI-ICE/SLAT POWER XFR RELAY-SLAT R7	13.4			29.0		0.0	3.0	3.0	
380	EVA99.3	ANTI-ICE/SLAT POWER XFR RELAY-SLAT R8	13.4			29.0		0.0	3.0	3.0	
381	EVB	HYDRAULIC CTRL-LE SLATS						15.4	0.0	-15.4	
382	EVC	HYDRAULIC PLUMBING-LE SLATS						37.9	0.0	-37.9	
383	EVD	ACTUATORS-LE SLAT CTRL						164.6	0.0	-164.6	
384	EVF	HYDRAULIC FLUID-LE SLATS						43.3	0.0	-43.3	
385	EVG	SUPPORTS-SLAT CTRL						182.1	0.0	-182.1	
386	EV-AWA1	TRACK 1						33.5	33.5	0.0	NOTE: SLAT TRACK REDESIGN TO INCLUDE JACK SCREW
387	EV-AWA1	TRACK 9						35.3	35.3	0.0	NOTE: SLAT TRACK REDESIGN TO INCLUDE JACK SCREW
388	EV-AWA1	TRACK 11						30.1	30.1	0.0	NOTE: SLAT TRACK REDESIGN TO INCLUDE JACK SCREW
389	EV-AWA1	TRACK 2						32.4	32.4	0.0	NOTE: SLAT TRACK REDESIGN TO INCLUDE JACK SCREW
390	EV-AWA1	TRACK 4						29.8	29.8	0.0	NOTE: SLAT TRACK REDESIGN TO INCLUDE JACK SCREW
391	EV-AWA1	TRACK 7						35.0	35.0	0.0	NOTE: SLAT TRACK REDESIGN TO INCLUDE JACK SCREW
392	EV-AWA1	TRACK 13						21.8	21.8	0.0	NOTE: SLAT TRACK REDESIGN TO INCLUDE JACK SCREW
393	EV-AWA1	TRACK 15						21.1	21.1	0.0	NOTE: SLAT TRACK REDESIGN TO INCLUDE JACK SCREW
394	LAAE	DRIVE LUBE-AC PWR SUPPLY						5.9	5.9	0.0	
395	LAAJ	ELECT HDW-AC PWR SUPPLY						5.1	5.1	0.0	
396	LAB	AC PWR CONVERSION SYS						35.7	35.7	0.0	
397	LABC	TR RECTIFIER-AC PWR CONV						110.2	110.2	0.0	
398	LABD	ELECT HWD-AC PWR CONVERSION						28.3	28.3	0.0	
399	LABH	FREQ CONVERTER-AC PWR CONV						9.9	9.9	0.0	
400	LAC	AC PWR DIST SYS						455.0	455.0	0.0	
401	LACA	CONT BOX-AC PWR DIST						93.2	141.2	47.9	NOTE:DEL APU CTRL UNIT, ADDED GEN RELAYS, 3 PSTR, 4 X-TIE
402	LACB	VOLTAGE REG-AC PWR DIST						7.9	7.9	0.0	
403	LACC	ELECT HDW-AC PWR DIST						190.5	190.5	0.0	
404	LACD	JUNCT BOX-AC PWR DIST						152.4	152.4	0.0	
405	LACG	WIRE -AC PWR SYS						90.8	90.8	0.0	
406	LAE	EXTERNAL AC PWR SUPPLY						10.6	10.6	0.0	
407	LAEB	ELECT HDW-EXTERNAL PWR						101.6	101.6	0.0	
408	LAHF	NO TITLE						0.5	0.5	0.0	

LN_N	TYPE	NAME	HP	RPM	LB_FT	PH_I	LTH	GAGE	FACTOR	AS_IS	TO_BE	DELTA	NOTES
409	LA+1	RESONANT CONVERTER								0.0	86.4	86.4	NOTE:.48LB/KVA (40% CONVENTIONAL)
410	LA+2	PDM SYNTHESIZER TO 400HZ								0.0	54.0	54.0	NOTE:.3LB/KVA (25% CONVENTIONAL)
411	LA+3	RESONANT CONVERTER								0.0	86.4	86.4	NOTE:.48LB/KVA (40% CONVENTIONAL)
412	LA+4	PDM SYNTHESIZER TO 400HZ								0.0	54.0	54.0	NOTE:.3LB/KVA (25% CONVENTIONAL)
413	LA+5	RESONANT CONVERTER								0.0	86.4	86.4	NOTE:.48LB/KVA (40% CONVENTIONAL)
414	LA+6	PDM SYNTHESIZER TO 400HZ								0.0	54.0	54.0	NOTE:.3LB/KVA (25% CONVENTIONAL)
415	LA+LACA	CONT BOX-AC PWR DIST								0.0	93.2	93.2	NOTE:3 GEN CTRL UNITS,ELECT PWR CTRL UNIT,PWR RELAYS
416	LA+LACB	VOLTAGE REG-AC PWR DIST								0.0	7.9	7.9	NOTE:CT'S,MISC HDWR,
417	LA+LACC	ELECT HDW-AC PWR DIST								0.0	11.1	93.2	NOTE:POWER ISOLATION & PROTECTION-CONTACTORS
418	LA+LACD	JUNCT BOX-AC PWR DIST								0.0	84.3	84.3	NOTE:NEW EPC STRUCTURE
419	LA+LACG	WIRE -AC PWR SYS								0.0	307.2	307.2	NOTE:EPC WIRE ASSY ADJUSTED FOR 180KVA + ADDED X-TIE BUS
420	LA+LAC-1	AC PWR DIST SYS					540	2/0	525	0.0	283.5	283.5	NOTE:USED AN WIRE
421	LA+LAC-2	AC PWR DIST SYS					1233	4/0	296	0.0	365.0	365.0	NOTE:USED AN WIRE
422	LA+LA-01	QUICK ATTACH DET								0.0	6.2	6.2	
423	LA+LA-02	STARTER/GENERATOR								0.0	120.0	120.0	
424	LA+LA-03	QUICK ATTACH DET								0.0	12.4	12.4	
425	LA+LA-04	STARTER/GENERATOR								0.0	120.0	120.0	
426	LA+LA-05	STARTER/GENERATOR								0.0	120.0	120.0	
427	LA+LA-A	A C POWER SYSTEM- R & C CTR FUS								0.0	7.2	7.2	NOTE:ALL NEW MISC WIRING/ATTACH IS ESTIMATED AT 5% OF THE BASE.
428	LA+LA-B	A C POWER SYSTEM- R & C AFT FUS								0.0	5.3	5.3	NOTE:ALL NEW MISC WIRING/ATTACH IS ESTIMATED AT 5% OF THE BASE.
429	LA+LA-C	A C POWER SYSTEM- DIST WIRING								0.0	178.0	178.0	NOTE:ALL NEW MISC WIRING/ATTACH IS ESTIMATED AT 5% OF THE BASE.
430	LA-A	A C POWER SYSTEM- R & C CTR FUS								145.0	145.0	0.0	
431	LA-B	A C POWER SYSTEM- R & C AFT FUS								105.2	105.2	0.0	
432	LA-C	A C POWER SYSTEM- DIST WIRING								3559.1	3559.1	0.0	
433	LA-HA	INT DRIVE GEN								136.1	136.1	0.0	
434	LA-HA	QUICK ATTACH DET								12.4	12.4	0.0	
435	LA-HA	INT DRIVE GEN								136.1	136.1	0.0	
436	LA-HA	INT DRIVE GEN								136.1	136.1	0.0	
437	LA-HA	QUICK ATTACH DET								6.2	6.2	0.0	
438	LA+LAC-3	AC PWR DIST SYS-NOSE					900	4/0	296		266.4	266.4	NOTE:USED AL WIRE
439	LA+LAC-4	AC PWR DIST SYS-TAIL					720	4/0	296		213.1	213.1	NOTE:USED AL WIRE & FAILURE CASE INCLUDED
440	LA-LAEB	ELECT HDW-EXTERNAL PWR								0.0	72.5	72.5	NOTE:SAME AS EXISTING LESS GALLEY CTRL & AUX HYD RELAY
441	LDAB	BATTERY CHARGER								17.6	17.6	0.0	
442	LDAC	BATTERY CONTAINER & SUPPORTS								9.2	9.2	0.0	

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LN_N	TYPE	NAME	HP	RPM	LB_FT	PH_I	LTH	GAGE	FACTOR	AS_IS	TO_BE	DELTA	NOTES
443	LDBA	DC TO AC-DC PWR CONV								32.0	32.0	0.0	
444	LDBB	XFMR-DC PWR CONV								1.4	1.4	0.0	
445	LDCC	ELECT HDW-DC PWR CONV								51.3	51.3	0.0	
446	LDDA	BATTERY								126.0	126.0	0.0	
447	LEAB	ELECT HDW-ADG								100.4	100.4	0.0	
448	LEBA	DOORS-ADG								8.7	8.7	0.0	
449	LEBB	SUPTS & ATTACH-ADG								3.1	3.1	0.0	
450	LEC	MECH CNTL SYS-ADG								14.6	14.6	0.0	
451	LEDF	FLUID-ADG								0.4	0.4	0.0	
452	LEDH	VALVES-ADG								2.2	2.2	0.0	
453	LEDK	PLUMBING-ADG								0.9	0.9	0.0	
454	LHA	HYDRAULIC UTILITY POWER SYSTEM								64.5	0.0	-64.5	
455	LHAA	PUMPS-HYDRAULIC UTILITY								11.6	0.0	-11.6	
456	LHAAH	VALVES-HYD UTILITY								37.0	0.0	-37.0	
457	LHAB	RESERVOIRS-HYD UTILITY								201.1	0.0	-201.1	
458	LHAC	ACCUMULATOR-HYD UTILITY								37.4	0.0	-37.4	
459	LHAD	FILTER-HYD UTILITY								7.7	0.0	-7.7	
460	LHAF	FLUIDS-HYD UTILITY								524.5	0.0	-524.5	
461	LHAJ	CONTROLS-HYD UTILITY								57.3	0.0	-57.3	
462	LHAK	PLUMBING-HYD UTILITY								316.7	0.0	-316.7	
463	LHAL	SUPPORT-HYD UTILITY								77.8	0.0	-77.8	
464	LHAM	ELECTRICAL HARDWARE-HYD UTILITY								2.1	0.0	-2.1	
465	LHBA	PUMPS-HYD AUX								179.2	0.0	-179.2	
466	LHBD	FILTERS-HYD AUX								6.5	0.0	-6.5	
467	LHBF	FLUID-HYD AUX								30.6	0.0	-30.6	
468	LHBH	VLAVES-HYD AUX								18.7	0.0	-18.7	
469	LHBJ	CONTROLS-HYD AUX								6.4	0.0	-6.4	
470	LHBK	PLUMBING-HYD AUX								61.4	0.0	-61.4	
471	LHBL	SUPPORTS-HYD AUX								11.3	0.0	-11.3	
472	LHBM	E/E HARDWARE-HYD AUX								0.1	0.0	-0.1	
473	LHFD	FILTERS-FAULT ISOLATION								0.8	0.0	-0.8	
474	LHFF	FLUID-FAULT ISOLATION								8.7	0.0	-8.7	
475	LHFH	VALVES-FAULT ISOLATION								1.4	0.0	-1.4	
476	LHFJ	CONTROLS-FAULT ISOLATION								0.4	0.0	-0.4	

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LN_N	TYPE	NAME	HP	RPM	LB_FT	PH_I	LTH	GAGE	FACTOR	AS_IS	TO_BE	DELTA	NOTES
477	LHFK	PLUMBING-FAULT ISOLATION								13.3	0.0	-13.3	
478	LHFM	SUPPORTS-FAULT ISOLATION								1.5	0.0	-1.5	
479	LHKF	FLUID-HEAT CONTROLS SYS								8.5	0.0	-8.5	
480	LHKK	PLUMBING-HEAT CONTROLS SYSTEM								16.7	0.0	-16.7	
481	LHKM	SUPPORTS-HEAT CONTROLS SYSTEM								0.7	0.0	-0.7	
482	LH-HA01	HYDRAULIC PUMP ASSY								28.5	0.0	-28.5	
483	LH-HA02	HYDRAULIC PUMP ASSY								28.5	0.0	-28.5	
484	LH-HA03	HYDRAULIC PUMP ASSY								28.5	0.0	-28.5	
485	LH-HA04	HYDRAULIC PUMP ASSY								28.5	0.0	-28.5	
486	LH-HA05	SPC-ADJ								19.0	0.0	-19.0	
487	LH-HA06	VALVE-CHECK								15.0	0.0	-15.0	
488	LH-HA07	VALVE CONTROL HI PRESSURE								32.8	0.0	-32.8	
489	LH-HA08	HYDRAULIC PUMP ASSY								28.5	0.0	-28.5	
490	LH-HA09	HYDRAULIC PUMP ASSY								28.5	0.0	-28.5	
491	LH-HA10	SPC-ADJ								9.0	0.0	-9.0	
492	LH-HA11	VALVE-CHECK								7.5	0.0	-7.5	
493	LH-HA12	VALVE CONTROL HI PRESSURE								16.4	0.0	-16.4	
494	LH-HA17	HYD SYS PER GE								277.0	0.0	-277.0	NOTE:90LB PER WING ENG + 97 LBS TAIL ENG OF PLUMB/FILTER PACKS
495	LH-KDCC	HYD SYSTEM CONTROLLER								25.4	0.0	-25.4	
496	LPA	PNEU UTILITY POWER SYS								548.2	0.0	-548.2	
497	LPAC	VALVES-PNEU UTILITY								65.2	0.0	-65.2	
498	LPAD	CTRL & RELAYS-PNEU UTILITY								6.5	0.0	-6.5	
499	LPAE	DUCTS & SHROUDS-PNEU UTILITY								882.6	0.0	-882.6	
500	LPAF	DUCT SUPPORT-PNEU UTILITES								137.3	0.0	-137.3	
501	LPAG	WIRING-PNEU UTILITIES								0.0	0.0	-0.0	
502	LP-	VALVE REG PNTU								24.5	0.0	-24.5	
503	LP-	VALVE REG PNTU								49.0	0.0	-49.0	
504	LP-HA13	VALVE-CHECK								22.5	0.0	-22.5	NOTE:NOT REQUIRED
505	LP-HA14	VALVE- CNTL HP								49.2	0.0	-49.2	NOTE:NOT REQUIRED
506	LP-HA15	VALVE-REG PNUE								73.5	36.8	-36.8	NOTE:REDUCED BY 50% SINCE ONLY THRUST REV/COWL ANTI-ICE SOURCE
507	LP-HA16	STARTER SYSTEM PER GE								74.0	0.0	-74.0	NOTE:74 LBS INCLUDES STARTER,VALVE AND ASSOCIATED DUCTING
508	RNC	COOLING AIR SYSTEM								172.0	172.0	0.0	
509	RNC1	CARGO COMP FAN/HEATERS (8)	32.2						1	32.2	0.0	-32.2	
510	RNC2	CARGO COMP FAN/HEATERS-WIRING (8)	4.0			8.7	400	20	31.3	0.0	37.6	37.6	

LN_N	TYPE	NAME	HP	RPM	LB_FT	PH_I	LTH	GAGE	FACTOR	AS_IS	TO_BE	DELTA	NOTES
511	RNH	CONTROLS								76.6	57.3	-19.2	NOTE:REMOVED TURBINE BY PASS VALVE
512	RNK	FAN CONTROL & CIRCUITRY								2.2	2.2	0.0	
513	RNN	TURBINE-COMPRESSOR-1								178.6	0.0	-178.6	
514	RNN	TURBINE-COMPRESSOR-2								178.6	0.0	-178.6	
515	RNN	TURBINE-COMPRESSOR-3								178.6	0.0	-178.6	
516	RNP	WATER SEPERATORS								54.7	0.0	-54.7	NOTE:WATER SEPERATION WILL BE DONE BY NEW PACK.
517	RNS	UNITS SUPPORTS								36.5	36.5	0.0	NOTE:ASSUMED SUPPORTS FOR VAPOR CYCLE INSTALLATIONS IS EQUIV
518	RNT	PIPING								91.4	0.0	-91.4	NOTE:TO BE PART OF VAPOR CYCLE PACK
519	RNV	RAM AIR								261.2	261.2	0.0	
520	SAB	DUCTING-WING ICE PROTECTION								173.0	0.0	-173.0	
521	SAB01	ELECT ANTI-ICE-SLAT L1								0.0	12.0	12.0	NOTE: ONE HEATER BLANKET PER SLAT
522	SAB02	ELECT ANTI-ICE-SLAT L2								0.0	12.0	12.0	NOTE: ONE HEATER BLANKET PER SLAT
523	SAB03	ELECT ANTI-ICE-LEFT DLE								0.0	6.0	6.0	NOTE: ONE HEATER BLANKET PER SLAT
524	SAB04	ELECT ANTI-ICE-SLAT L3								0.0	12.0	12.0	NOTE: ONE HEATER BLANKET PER SLAT
525	SAB05	ELECT ANTI-ICE-SLAT L4								0.0	12.0	12.0	NOTE: ONE HEATER BLANKET PER SLAT
526	SAB06	ELECT ANTI-ICE-SLAT L5								0.0	12.0	12.0	NOTE: ONE HEATER BLANKET PER SLAT
527	SAB07	ELECT ANTI-ICE-SLAT L6								0.0	12.0	12.0	NOTE: ONE HEATER BLANKET PER SLAT
528	SAB08	ELECT ANTI-ICE-SLAT L7								0.0	12.0	12.0	NOTE: ONE HEATER BLANKET PER SLAT
529	SAB09	ELECT ANTI-ICE-SLAT L8								0.0	12.0	12.0	NOTE: ONE HEATER BLANKET PER SLAT
530	SAB10	ELECT ANTI-ICE-SLAT R1								0.0	12.0	12.0	NOTE: ONE HEATER BLANKET PER SLAT
531	SAB11	ELECT ANTI-ICE-SLAT R2								0.0	12.0	12.0	NOTE: ONE HEATER BLANKET PER SLAT
532	SAB12	ELECT ANTI-ICE-RIGHT DLE								0.0	6.0	6.0	NOTE: ONE HEATER BLANKET PER SLAT
533	SAB13	ELECT ANTI-ICE-SLAT R3								0.0	12.0	12.0	NOTE: ONE HEATER BLANKET PER SLAT
534	SAB14	ELECT ANTI-ICE-SLAT R4								0.0	12.0	12.0	NOTE: ONE HEATER BLANKET PER SLAT
535	SAB15	ELECT ANTI-ICE-SLAT R5								0.0	12.0	12.0	NOTE: ONE HEATER BLANKET PER SLAT
536	SAB16	ELECT ANTI-ICE-SLAT R6								0.0	12.0	12.0	NOTE: ONE HEATER BLANKET PER SLAT
537	SAB17	ELECT ANTI-ICE-SLAT R7								0.0	12.0	12.0	NOTE: ONE HEATER BLANKET PER SLAT
538	SAB18	ELECT ANTI-ICE-SLAT R8								0.0	12.0	12.0	NOTE: ONE HEATER BLANKET PER SLAT
539	SAB19	ELECT CABLE ANTI-ICE-SLAT L1	13.4			29.0	3	12	20.1	0.0	0.2	0.2	
540	SAB20	ELECT CABLE ANTI-ICE-SLAT L2	13.4			29.0	3	12	20.1	0.0	0.2	0.2	
541	SAB21	ELECT CABLE ANTI-ICE-LEFT DLE	6.7			14.5	3	16	8.7	0.0	0.1	0.1	
542	SAB22	ELECT CABLE ANTI-ICE-SLAT L3	13.4			29.0	3	12	20.1	0.0	0.2	0.2	
543	SAB23	ELECT CABLE ANTI-ICE-SLAT L4	13.4			29.0	3	12	20.1	0.0	0.2	0.2	
544	SAB24	ELECT CABLE ANTI-ICE-SLAT L5	13.4			29.0	3	12	20.1	0.0	0.2	0.2	

LN_N	TYPE	NAME	HP	RPM	LB_FT	PH_I	LTH	GAGE	FACTOR	AS_IS	TO_BE	DELTA	NOTES
545	SAB25	ELECT CABLE ANTI-ICE-SLAT L6	13.4			29.0	3	12	20.1	0.0	0.2	0.2	
546	SAB26	ELECT CABLE ANTI-ICE-SLAT L7	13.4			29.0	3	12	20.1	0.0	0.2	0.2	
547	SAB27	ELECT CABLE ANTI-ICE-SLAT L8	13.4			29.0	3	12	20.1	0.0	0.2	0.2	
548	SAB28	ELECT CABLE ANTI-ICE-SLAT R1	13.4			29.0	3	12	20.1	0.0	0.2	0.2	
549	SAB29	ELECT CABLE ANTI-ICE-SLAT R2	13.4			29.0	3	12	20.1	0.0	0.2	0.2	
550	SAB30	ELECT CABLE ANTI-ICE-RIGHT DLE	6.7			14.5	3	16	8.7	0.0	0.1	0.1	
551	SAB31	ELECT CABLE ANTI-ICE-SLAT R3	13.4			29.0	3	12	20.1	0.0	0.2	0.2	
552	SAB32	ELECT CABLE ANTI-ICE-SLAT R4	13.4			29.0	3	12	20.1	0.0	0.2	0.2	
553	SAB33	ELECT CABLE ANTI-ICE-SLAT R5	13.4			29.0	3	12	20.1	0.0	0.2	0.2	
554	SAB34	ELECT CABLE ANTI-ICE-SLAT R6	13.4			29.0	3	12	20.1	0.0	0.2	0.2	
555	SAB35	ELECT CABLE ANTI-ICE-SLAT R7	13.4			29.0	3	12	20.1	0.0	0.2	0.2	
556	SAB36	ELECT CABLE ANTI-ICE-SLAT R8	13.4			29.0	3	12	20.1	0.0	0.2	0.2	
557	SAB37	ELECT RPC ANTI-ICE-SLAT L1								0.0	2.0	2.0	
558	SAB38	ELECT RPC ANTI-ICE-SLAT L2								0.0	2.0	2.0	
559	SAB39	ELECT RPC ANTI-ICE-LEFT DLE								0.0	2.0	2.0	
560	SAB40	ELECT RPC ANTI-ICE-SLAT L3								0.0	2.0	2.0	
561	SAB41	ELECT RPC ANTI-ICE-SLAT L4								0.0	2.0	2.0	
562	SAB42	ELECT RPC ANTI-ICE-SLAT L5								0.0	2.0	2.0	
563	SAB43	ELECT RPC ANTI-ICE-SLAT L6								0.0	2.0	2.0	
564	SAB44	ELECT RPC ANTI-ICE-SLAT L7								0.0	2.0	2.0	
565	SAB45	ELECT RPC ANTI-ICE-SLAT L8								0.0	2.0	2.0	
566	SAB46	ELECT RPC ANTI-ICE-SLAT R1								0.0	2.0	2.0	
567	SAB47	ELECT RPC ANTI-ICE-SLAT R2								0.0	2.0	2.0	
568	SAB48	ELECT RPC ANTI-ICE-RIGHT DLE								0.0	2.0	2.0	
569	SAB49	ELECT RPC ANTI-ICE-SLAT R3								0.0	2.0	2.0	
570	SAB50	ELECT RPC ANTI-ICE-SLAT R4								0.0	2.0	2.0	
571	SAB51	ELECT RPC ANTI-ICE-SLAT R5								0.0	2.0	2.0	
572	SAB52	ELECT RPC ANTI-ICE-SLAT R6								0.0	2.0	2.0	
573	SAB53	ELECT RPC ANTI-ICE-SLAT R7								0.0	2.0	2.0	
574	SAB54	ELECT RPC ANTI-ICE-SLAT R8								0.0	2.0	2.0	
575	SAF	SUPPORTS-WING ICE PROTECTION								9.6	0.0	-9.6	
576	SBA	DUCTING-TAIL ICE PROTECTION								78.7	0.0	-78.7	
577	SBA01	ELECT ANTI-ICE-L & R INBD, LOWER								0.0	36.0	36.0	
578	SBA02	ELECT POWER WIRE-L & R INBD, LOWER	40.2			87.0	45	1/0	122	0.0	22.0	22.0	NOTE: AL WIRE USED

LN_N	TYPE	NAME	HP	RPM	LB_FT	PH_I	LTH	GAGE	FACTOR	AS_IS	TO_BE	DELTA	NOTES
579	SBA03	ELECT ANTI-ICE-L & R OTBD, UPPER								0.0	36.0	36.0	
580	SBA04	ELECT POWER WIRE-L & R OTBD, UPPER	40.2			87.0	90	1/0	122	0.0	43.9	43.9	NOTE: AL WIRE USED
581	SBB	VALVES-TAIL ICE PROTECTION								9.4	0.0	-9.4	
582	SBC	ELECT HARDWARE & WIRE TAIL ICE PROT								3.5	3.5	0.0	
583	SBD	TAIL SUPPORTS-TAIL ICE PROTECTION								6.7	0.0	-6.7	
584	SBE	FUSE SUPPORTS-TAIL ICE PROTECTTION								2.7	0.0	-2.7	
585	SBH	HEAT SHIELD-TAIL ICE PROTECTION								9.6	0.0	-9.6	
586	SCA	DUCTING-AIR IND ICE PROTECTION								30.5	30.5	0.0	
587	SCF	NACELLE SUPPORT-AIR IND ICE PROT								3.4	3.4	0.0	
588	SEA	DUCTING-NAC ICE PROT								2.9	2.9	0.0	
589	SEC	ELECTRICAL HARDWARE-NAC ICE PROT								0.3	0.3	0.0	
590	RNN-04	HEATER-FWD CABIN	27			58.0				0	20.0	20.0	
591	RNN-05	HEATER-MID CABIN	27			58.0				0	20.0	20.0	
592	RNN-06	HEATER-AFT CABIN	27			58.0				0	20.0	20.0	
593	RNN-01	COMPRESSOR-PRESSURE & VAPOR CYCLE-1	220			475.4				0	494.3	494.3	
594	RNN-02	COMPRESSOR-PRESSURE & VAPOR CYCLE-2	220			475.4				0	494.3	494.3	
595	RNN-03	COMPRESSOR-PRESSURE & VAPOR CYCLE-3	220			475.4				0	494.3	494.3	
									TOTALS	32076	12541	-2304	

APPENDIX G

ELECTRICAL LOAD DATA BASE

G.1 BASELINE TRIJET AIR TRANSPORT MD-11 DATA BASE ELOAD, ELECTRICAL POWER LOAD ANALYSIS

NOTE: Included by reference only (ELOAD is Douglas proprietary data) see Reference 5.

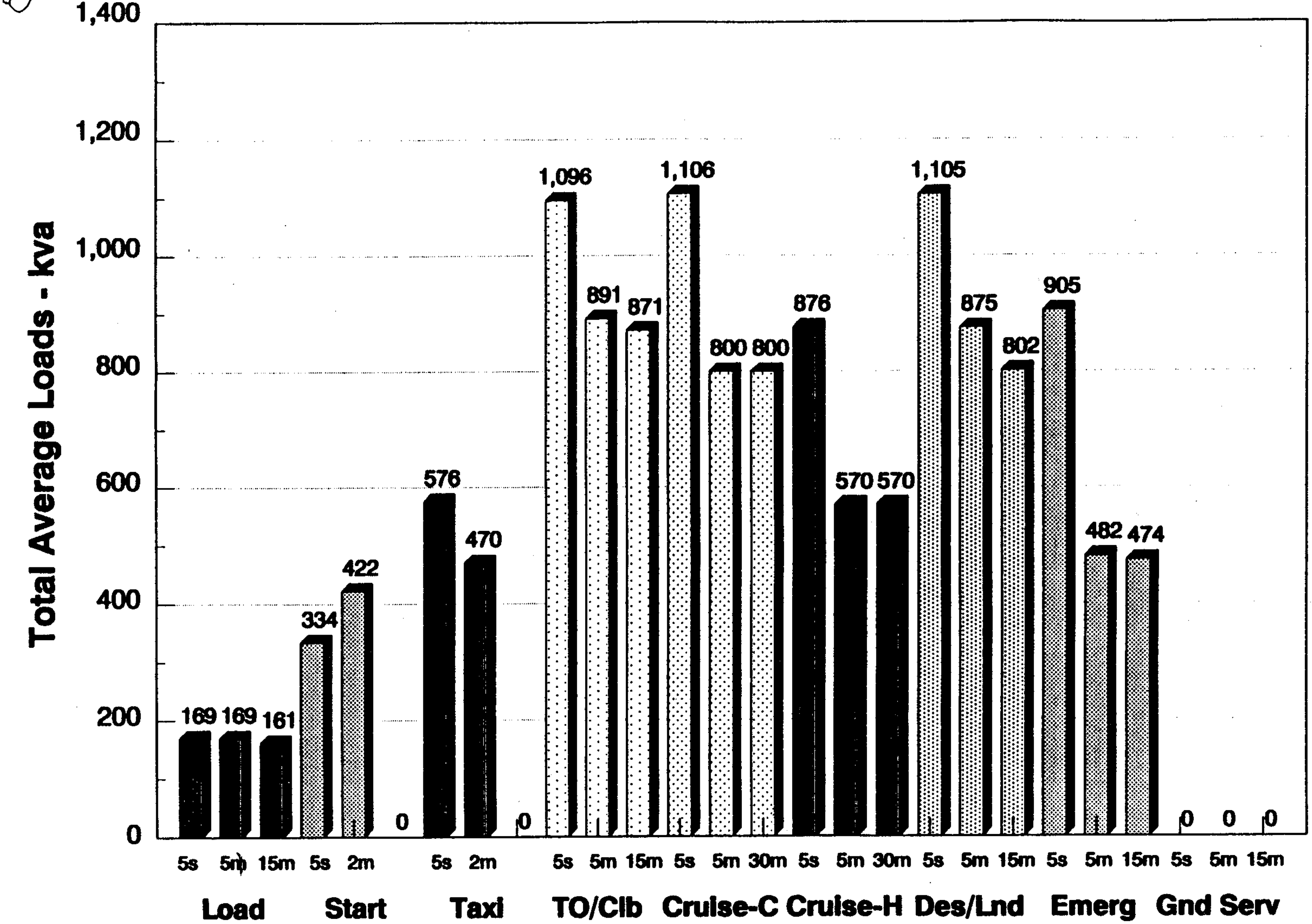
G.2 ALL-ELECTRIC TRIJET DATA

COMMONLY USED ELECTRICAL FORMULAS

To Find	Single-Phase	Three-Phase	D.C.
Amperes when KVA is known	$\frac{KVA \times 1000}{V}$	$\frac{KVA \times 1000}{V \times 1.73}$	not applicable
Amperes when horsepower is known	$\frac{HP \times 746}{V \times eff. \times p.f.}$	$\frac{HP \times 746}{V \times 1.73 \times eff. \times p.f.}$	$\frac{HP \times 746}{V \times eff.}$
Amperes when kilowatts are known	$\frac{KW \times 1000}{V \times p.f.}$	$\frac{KW \times 1000}{V \times 1.73 \times p.f.}$	$\frac{KW \times 1000}{V}$
Kilowatts	$\frac{I \times V \times p.f.}{1000}$	$\frac{I \times V \times 1.73 \times p.f.}{1000}$	$\frac{I \times V}{1000}$
Kilovolt Amperes	$\frac{I \times V}{1000}$	$\frac{I \times V \times 1.73}{1000}$	not applicable
Horsepower	$\frac{I \times V \times eff. \times p.f.}{746}$	$\frac{I \times V \times 1.73 \times eff. \times p.f.}{746}$	$\frac{I \times V \times eff.}{746}$
Watts	$V \times I \times p.f.$	$V \times I \times 1.73 \times p.f.$	$V \times I$

I = amperes
V = volts
KW = kilowatts
KVA = kilovolt-amperes
HP = horsepower
eff. = percent efficiency/100
p.f. = power factor

All-Electric AC New Loads Analysis



EXPLANATION OF SYMBOLS AND HEADINGS

The abbreviated column headings in the following tables are explained below.

The columns shown as REF (reference number) and REFD NO. are codes used for data manipulation. UTS (number of units), PER (percent of operation time), and ENM (essential/nonessential/monitored load) are requirements of baseline load analysis computer program ELOAD. These were included in anticipation of integrating the new all-electric loads with the existing baseline loads. The columns BUS and PH, which describe power bus and phase identifications, are also ELOAD requirements and are used in this analysis for determining load and phase balancing throughout the distribution system. Horsepower ratings are included in the load analysis primarily for hydraulic, mechanical, and pneumatic requirements. These horsepower ratings allow for conversion to electrical requirements using the mathematical formulas shown earlier.

To remain consistent throughout the anlaysis, horsepower ratings are included for nonhydraulic, nonmechanical, and nonpneumatic devices (e.g., flight computers or relays).

VAC (the voltage column) denotes the voltage requirement at the terminals of the load. For single-phase power, it represents the voltage from any one of the line phases, A, B, or C, to neutral. For three-phase power, it is the voltage between any two of the three line phases, A, B, or C. In the analysis, this is described as line-to-line voltage. The kilowatt (KW), kilovolt-amperes (KVA), and phase current (I_PH) columns are calculated using the formulas shown earlier. The power factor (PF) and efficiency (EFF) values were derived from similar state-of-the-art equipment.

Other column headings were coded to indicate the phase of fight (e.g., LD1 or ST1) and the time-interval headings – 5S (5 seconds), 5M (5 minutes), and 15M (15 minutes). These are identified sequentially (i.e., LD1_5S, LD2_5M, and LD3_15M) in order to accommodate computer data manipulation.

																	LOADING			START		TAXI	
	REF	REFD NO	EQUIP_NAME	UTS	PER	BUS	PH	HP	KW	KVA	VAC	I_PH	EFF	PF	ENM	LD1_5S	LD2_5M	LD3_15M	ST1_5S	ST2_2M	TX1_5S	TX2_5M	TC1_5S
1	DA-01	M1A- 1	ELECT SERVO PUMP ACTUATOR-MAIN	1	100	47	D	20.000	17.546	23.395	199	67.810	0.85	0.75	E	0.000	0.000	0.000	0.000	0.000	23.3945	0.7018	23.3945
2	DA-02	M1A- 2	ELECT SERVO PUMP ACTUATOR-MAIN	1	100	67	D	20.000	17.546	23.395	199	67.810	0.85	0.75	E	0.000	0.000	0.000	0.000	0.000	23.3945	0.7018	23.3945
3	DA-03	B1A- 83	ELECT SERVO PUMP ACTUATOR-MAIN	1	100	47	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0013	0.0000	0.0013
4	DA-04	B1A- 84	ELECT SERVO PUMP ACTUATOR-MAIN	1	100	67	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0013	0.0000	0.0013
5	DB-01	M1A- 3	ELECT SERVO PUMP ACTUATOR-NOSE	1	100	48	D	7.310	6.413	8.551	199	24.785	0.85	0.75	E	0.000	0.000	0.000	0.000	0.000	8.5507	0.2565	8.5507
6	DB-02	M1A- 4	ELECT SERVO PUMP ACTUATOR-NOSE	1	100	68	D	7.310	6.413	8.551	199	24.785	0.85	0.75	E	0.000	0.000	0.000	0.000	0.000	8.5507	0.2565	8.5507
7	DB-03	B1A- 85	ELECT SERVO PUMP ACTUATOR-NOSE	1	100	48	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0013	0.0000	0.0013
8	DB-04	B1A- 86	ELECT SERVO PUMP ACTUATOR-NOSE	1	100	68	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0013	0.0000	0.0013
9	EEGC1	U1A- 1	PRIMARY FLT CTRL CMPTR-1	1	100	46	A	0.173	0.129	0.143	115	1.245	1	0.90	E	0.143	0.143	0.143	0.143	0.143	0.1432	0.1432	0.1432
10	EEGC11	I2A- 2	COCKPIT DISPLAY PANEL ADDITIONS	1	100	56	A	0.007	0.005	0.006	115	0.048	1	0.90	E	0.006	0.006	0.006	0.006	0.006	0.0056	0.0056	0.0056
11	EEGC12	B1A-103	COCKPIT DISPLAY PANEL ADDITIONS	1	100	46	A	0.001	0.001	0.001	115	0.011	0.85	0.90	E	0.001	0.001	0.001	0.001	0.001	0.0013	0.0013	0.0013
12	EEGC13	B1A-104	COCKPIT DISPLAY PANEL ADDITIONS	1	100	56	A	0.001	0.001	0.001	115	0.011	0.85	0.90	E	0.001	0.001	0.001	0.001	0.001	0.0013	0.0013	0.0013
13	EEGC2	U1A- 2	PRIMARY FLT CTRL CMPTR-2	1	100	56	A	0.173	0.129	0.143	115	1.245	1	0.90	E	0.143	0.143	0.143	0.143	0.143	0.1432	0.1432	0.1432
14	EEGC3	U1A- 3	PRIMARY FLT CTRL CMPTR-3	1	100	66	A	0.173	0.129	0.143	115	1.245	1	0.90	E	0.143	0.143	0.143	0.143	0.143	0.1432	0.1432	0.1432
15	EEGC4	U1A- 4	PRIMARY FLT CTRL CMPTR-4	1	100	X	A	0.173	0.129	0.143	115	1.245	1	0.90	E	0.143	0.143	0.143	0.143	0.143	0.1432	0.1432	0.1432
16	EEGC5	I2A- 1	COCKPIT DISPLAY PANEL ADDITIONS	1	100	46	A	0.007	0.005	0.006	115	0.048	1	0.90	E	0.006	0.006	0.006	0.006	0.006	0.0056	0.0056	0.0056
17	EEGC6	B1A-111	PRIMARY FLT CTRL CMPTR-1	1	100	46	A	0.001	0.001	0.001	115	0.011	0.85	0.90	E	0.001	0.001	0.001	0.001	0.001	0.0013	0.0013	0.0013
18	EEGC7	B1A-112	PRIMARY FLT CTRL CMPTR-2	1	100	56	A	0.001	0.001	0.001	115	0.011	0.85	0.90	E	0.001	0.001	0.001	0.001	0.001	0.0013	0.0013	0.0013
19	EEGC8	B1A-113	PRIMARY FLT CTRL CMPTR-3	1	100	66	A	0.001	0.001	0.001	115	0.011	0.85	0.90	E	0.001	0.001	0.001	0.001	0.001	0.0013	0.0013	0.0013
20	EEGC9	B1A-114	PRIMARY FLT CTRL CMPTR-4	1	100	X	A	0.001	0.001	0.001	115	0.011	0.85	0.90	E	0.001	0.001	0.001	0.001	0.001	0.0013	0.0013	0.0013
21	EF-1	B1A-105	ELECT CTRL-AILERON TRANS	1	100	X	A	0.001	0.001	0.001	115	0.011	0.85	0.90	E	0.001	0.001	0.001	0.001	0.001	0.0013	0.0013	0.0013
22	EF-1	B1A-106	ELECT CTRL-AILERON RCVR	1	100	X	A	0.001	0.001	0.001	115	0.011	0.85	0.90	E	0.001	0.001	0.001	0.001	0.001	0.0013	0.0013	0.0013
23	EFA01	T1A- 1	ELECT CTRL-AILERON TRANS	1	100	X	A	0.005	0.005	0.005	115	0.045	0.85	0.90	E	0.005	0.005	0.005	0.005	0.005	0.0052	0.0052	0.0052
24	EFA02	T1A- 2	ELECT CTRL-AILERON RCVR	1	100	X	A	0.005	0.005	0.005	115	0.045	0.85	0.90	E	0.005	0.005	0.005	0.005	0.005	0.0052	0.0052	0.0052
25	EFC05	B1A- 1	ELECT 1-LEFT OUTBD AIL RPC	1	100	44	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0001	0.0001	0.0013
26	EFC06	B1A- 2	ELECT 2-LEFT OUTBD AIL RPC	1	100	54	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0001	0.0001	0.0013
27	EFC07	B1A- 3	ELECT 1-LEFT INBD AIL RPC	1	100	54	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0001	0.0001	0.0013
28	EFC08	B1A- 4	ELECT 2-LEFT INBD AIL RPC	1	100	64	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0001	0.0001	0.0013
29	EFC09	B1A- 5	ELECT 1-RIGHT OUTBD AIL RPC	1	100	54	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0001	0.0001	0.0013
30	EFC10	B1A- 6	ELECT 2-RIGHT OUTBD AIL RPC	1	100	64	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0001	0.0001	0.0013
31	EFC11	B1A- 7	ELECT 1-RIGHT INBD AIL RPC	1	100	44	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0001	0.0001	0.0013
32	EFC12	B1A- 8	ELECT 2-RIGHT INBD AIL RPC	1	100	64	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0001	0.0001	0.0013
33	EFF01	M1A- 5	ACTUATOR MOTOR 1-LEFT OUTBD	1	100	44	D	2.410	2.114	2.819	199	8.171	0.85	0.75	E	0.000	0.000	0.000	0.282	0.282	0.2819	0.2819	2.8190
34	EFF02	M1A- 6	ACTUATOR MOTOR 2-LEFT OUTBD	1	100	54	D	2.410	2.114	2.819	199	8.171	0.85	0.75	E	0.000	0.000	0.000	0.282	0.282	0.2819	0.2819	2.8190
35	EFF03	M1A- 7	ACTUATOR MOTOR 1-LEFT INBD	1	100	54	D	16.225	14.234	18.979	199	55.011	0.85	0.75	E	0.000	0.000	0.000	1.898	1.898	1.8979	1.8979	18.9788
36	EFF04	M1A- 8	ACTUATOR MOTOR 2-LEFT INBD	1	100	64	D	16.225	14.234	18.979	199	55.011	0.85	0.75	E	0.000	0.000	0.000	1.898	1.898	1.8979	1.8979	18.9788
37	EFF05	M1A- 9	ACTUATOR MOTOR 1-RIGHT OUTBD	1	100	54	D	2.410	2.114	2.819	199	8.171	0.85	0.75	E	0.000	0.000	0.000	0.282	0.282	0.2819	0.2819	2.8190
38	EFF06	M1A- 10	ACTUATOR MOTOR 2-RIGHT OUTBD	1	100	64	D	2.410	2.114	2.819	199	8.171	0.85	0.75	E	0.000	0.000	0.000	0.282	0.282	0.2819	0.2819	2.8190
39	EFF07	M1A- 11	ACTUATOR MOTOR 1-RIGHT INBD	1	100	44	D	16.225	14.234	18.979	199	55.011	0.85	0.75	E	0.000	0.000	0.000	1.898	1.898	1.8979	1.8979	18.9788
40	EFF08	M1A- 12	ACTUATOR MOTOR 2-RIGHT INBD	1	100	64	D	16.225	14.234	18.979	199	55.011	0.85	0.75	E	0.000	0.000	0.000	1.898	1.898	1.8979	1.8979	18.9788
41	EH-1	B1A-107	ELECT CTRL-ELEVATOR TRANS	1	100	X	A	0.001	0.001	0.001	115	0.011	0.85	0.90	E	0.001	0.001	0.001	0.001	0.001	0.0013	0.0013	0.0013
42	EH-1	B1A-108	ELECT CTRL-ELEVATOR RCVR	1	100	X	A	0.001	0.001	0.001	115	0.011	0.85	0.90	E	0.001	0.001	0.001	0.001	0.001	0.0013	0.0013	0.0013
43	EHA01	T1A- 3	ELECT CTRL-ELEVATOR TRANS	1	100	X	A	0.005	0.005	0.005	115	0.045	0.85	0.90	E	0.005	0.005	0.005	0.005	0.005	0.0052	0.0052	0.0052
44	EHA02	T1A- 4	ELECT CTRL-ELEVATOR RCVR	1	100	X	A	0.005	0.005	0.005	115	0.045	0.85	0.90	E	0.005	0.005	0.005	0.005	0.005	0.0052	0.0052	0.0052
45	EHC05	B1A- 9	ELECT 1-LEFT OUTBD ELEV RPC	1	100	45	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0001	0.0001	0.0013
46	EHC06	B1A- 10	ELECT 2-LEFT OUTBD ELEV RPC	1	100	55	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0001	0.0001	0.0013
47	EHC07	B1A- 11	ELECT 1-LEFT INBD ELEV RPC	1	100	55	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0001	0.0001	0.0013

48	EHC08	B1A- 12	ELECT 2-LEFT INBD ELEV RPC	1	100	65	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0001	0.0001	0.0013
49	EHC09	B1A- 13	ELECT 1-RIGHT OUTBD ELEV RPC	1	100	45	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0001	0.0001	0.0013
50	EHC10	B1A- 14	ELECT 2-RIGHT OUTBD ELEV RPC	1	100	55	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0001	0.0001	0.0013
51	EHC11	B1A- 15	ELECT 1-RIGHT INBD ELEV RPC	1	100	45	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0001	0.0001	0.0013
52	EHC12	B1A- 16	ELECT 2-RIGHT INBD ELEV RPC	1	100	65	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0001	0.0001	0.0013
53	EHF01	M1A- 13	ACTUATOR MOTOR 1-LEFT OUTBD	1	100	45	D	5.400	4.737	6.317	199	18.309	0.85	0.75	E	0.000	0.000	0.000	0.632	0.632	0.6317	0.6317	6.3165
54	EHF02	M1A- 14	ACTUATOR MOTOR 2-LEFT OUTBD	1	100	55	D	5.400	4.737	6.317	199	18.309	0.85	0.75	E	0.000	0.000	0.000	0.632	0.632	0.6317	0.6317	6.3165
55	EHF03	M1A- 15	ACTUATOR MOTOR 1-LEFT INBD	1	100	55	D	8.000	7.018	9.358	199	27.124	0.85	0.75	E	0.000	0.000	0.000	0.936	0.936	0.9358	0.9358	9.3578
56	EHF04	M1A- 16	ACTUATOR MOTOR 2-LEFT INBD	1	100	65	D	8.000	7.018	9.358	199	27.124	0.85	0.75	E	0.000	0.000	0.000	0.936	0.936	0.9358	0.9358	9.3578
57	EHF05	M1A- 17	ACTUATOR MOTOR 1-RIGHT OUTBD	1	100	45	D	5.400	4.737	6.317	199	18.309	0.85	0.75	E	0.000	0.000	0.000	0.632	0.632	0.6317	0.6317	6.3165
58	EHF06	M1A- 18	ACTUATOR MOTOR 2-RIGHT OUTBD	1	100	55	D	5.400	4.737	6.317	199	18.309	0.85	0.75	E	0.000	0.000	0.000	0.632	0.632	0.6317	0.6317	6.3165
59	EHF07	M1A- 19	ACTUATOR MOTOR 1-RIGHT INBD	1	100	45	D	8.000	7.018	9.358	199	27.124	0.85	0.75	E	0.000	0.000	0.000	0.936	0.936	0.9358	0.9358	9.3578
60	EHF08	M1A- 20	ACTUATOR MOTOR 2-RIGHT INBD	1	100	65	D	8.000	7.018	9.358	199	27.124	0.85	0.75	E	0.000	0.000	0.000	0.936	0.936	0.9358	0.9358	9.3578
61	EJ-1	B1A-109	ELECT CTRL-RUDDER TRANS	1	100	X	A	0.001	0.001	0.001	115	0.011	0.85	0.90	E	0.001	0.001	0.001	0.001	0.001	0.0013	0.0013	0.0013
62	EJ-1	B1A-110	ELECT CTRL-RUDDER RCVR	1	100	X	A	0.001	0.001	0.001	115	0.011	0.85	0.90	E	0.001	0.001	0.001	0.001	0.001	0.0013	0.0013	0.0013
63	EJA01	T1A- 5	ELECT CTRL-RUDDER TRANS	1	100	X	A	0.005	0.005	0.005	115	0.045	0.85	0.90	E	0.005	0.005	0.005	0.005	0.005	0.0052	0.0052	0.0052
64	EJA02	T1A- 6	ELECT CTRL-RUDDER RCVR	1	100	X	A	0.005	0.005	0.005	115	0.045	0.85	0.90	E	0.005	0.005	0.005	0.005	0.005	0.0052	0.0052	0.0052
65	EJC05	B1A- 17	ELECT-UPPER RUDDER RPC	1	100	45	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0001	0.0001	0.0013
66	EJC06	B1A- 18	ELECT-UPPER RUDDER RPC STANDBY	1	100	55	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
67	EJC07	B1A- 19	ELECT-LOWER RUDDER RPC	1	100	55	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0001	0.0001	0.0013
68	EJC08	B1A- 20	ELECT-LOWER RUDDER RPC STANDBY	1	100	65	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
69	EJJ01	M1A- 21	ACTUATOR MOTOR-LOWER RUDDER	1	100	55	D	12.370	10.852	14.470	199	41.941	0.85	0.75	E	0.000	0.000	0.000	1.447	1.447	1.4470	1.4470	14.4695
70	EJJ02	M1A- 22	ACTUATOR MOTOR-UPPER RUDDER	1	100	45	D	9.460	8.299	11.066	199	32.074	0.85	0.75	E	0.000	0.000	0.000	1.107	1.107	1.1066	1.1066	11.0656
71	EJJ05	R2A- 1	TRANSFER RELAY-LOWER RUDDER	1	100	65	A	0.012	0.010	0.012	115	0.100	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
72	EJJ06	R2A- 2	TRANSFER RELAY-UPPER RUDDER	1	100	45	A	0.012	0.010	0.012	115	0.100	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
73	ELA-01	M1A- 23	ELECT MOTOR 1-LEFT O/B FLAP	1	100	44	D	2.000	1.755	2.339	199	6.781	0.85	0.75	E	0.000	0.000	0.000	2.339	0.398	2.3395	0.1638	2.3395
74	ELA-02	M1A- 24	ELECT MOTOR 2-LEFT O/B FLAP	1	100	44	D	2.000	1.755	2.339	199	6.781	0.85	0.75	E	0.000	0.000	0.000	2.339	0.398	2.3395	0.1638	2.3395
75	ELA-03	M1A- 25	ELECT MOTOR 1-LEFT I/B FLAP	1	100	54	D	1.250	1.097	1.462	199	4.238	0.85	0.75	E	0.000	0.000	0.000	1.462	0.249	1.4622	0.1024	1.4622
76	ELA-04	M1A- 26	ELECT MOTOR 2-LEFT I/B FLAP	1	100	54	D	1.250	1.097	1.462	199	4.238	0.85	0.75	E	0.000	0.000	0.000	1.462	0.249	1.4622	0.1024	1.4622
77	ELA-05	M1A- 27	ELECT MOTOR 1-RIGHT O/B FLAP	1	100	44	D	2.000	1.755	2.339	199	6.781	0.85	0.75	E	0.000	0.000	0.000	2.339	0.398	2.3395	0.1638	2.3395
78	ELA-06	M1A- 28	ELECT MOTOR 2-RIGHT O/B FLAP	1	100	44	D	2.000	1.755	2.339	199	6.781	0.85	0.75	E	0.000	0.000	0.000	2.339	0.398	2.3395	0.1638	2.3395
79	ELA-07	M1A- 29	ELECT MOTOR 1-RIGHT I/B FLAP	1	100	54	D	1.250	1.097	1.462	199	4.238	0.85	0.75	E	0.000	0.000	0.000	1.462	0.249	1.4622	0.1024	1.4622
80	ELA-08	M1A- 30	ELECT MOTOR 2-RIGHT I/B FLAP	1	100	54	D	1.250	1.097	1.462	199	4.238	0.85	0.75	E	0.000	0.000	0.000	1.462	0.249	1.4622	0.1024	1.4622
81	ELA-25	B1A- 21	ELECT RPC MOTOR 1-LEFT O/B FLAP	1	100	44	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.001	0.000	0.0013	0.0001	0.0013
82	ELA-26	B1A- 22	ELECT RPC MOTOR 2-LEFT O/B FLAP	1	100	44	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.001	0.000	0.0013	0.0001	0.0013
83	ELA-27	B1A- 23	ELECT RPC MOTOR 1-LEFT I/B FLAP	1	100	54	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.001	0.000	0.0013	0.0001	0.0013
84	ELA-27	R2A- 3	PWR XFR RELAY-LEFT WING FLAPS	1	100	44	A	0.012	0.010	0.012	115	0.100	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
85	ELA-28	B1A- 24	ELECT RPC MOTOR 2-LEFT I/B FLAP	1	100	54	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.001	0.000	0.0013	0.0001	0.0013
86	ELA-28	R2A- 4	PWR XFR RELAY-RIGHT WING FLAPS	1	100	54	A	0.012	0.010	0.012	115	0.100	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
87	ELA-29	B1A- 25	ELECT RPC MOTOR 1-RIGHT O/B FLAP	1	100	44	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.001	0.000	0.0013	0.0001	0.0013
88	ELA-30	B1A- 26	ELECT RPC MOTOR 2-RIGHT O/B FLAP	1	100	44	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.001	0.000	0.0013	0.0001	0.0013
89	ELA-31	B1A- 27	ELECT RPC MOTOR 1-RIGHT I/B FLAP	1	100	54	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.001	0.000	0.0013	0.0001	0.0013
90	ELA-32	B1A- 28	ELECT RPC MOTOR 2-RIGHT I/B FLAP	1	100	54	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.001	0.000	0.0013	0.0001	0.0013
91	ENA-03	M1A- 31	ELECT MOTOR-SPOILER L1	1	100	54	D	8.400	7.369	9.826	199	28.480	0.85	0.75	E	0.000	0.000	0.000	1.965	0.000	1.9651	0.0000	1.9651
92	ENA-04	M1A- 32	ELECT MOTOR-SPOILER L2	1	100	44	D	8.400	7.369	9.826	199	28.480	0.85	0.75	E	0.000	0.000	0.000	1.965	0.000	1.9651	0.0000	1.9651
93	ENA-05	M1A- 33	ELECT MOTOR-SPOILER L3	1	100	64	D	8.400	7.369	9.826	199	28.480	0.85	0.75	E	0.000	0.000	0.000	1.965	0.000	1.9651	0.0000	1.9651
94	ENA-06	M1A- 34	ELECT MOTOR-SPOILER L4	1	100	44	D	8.400	7.369	9.826	199	28.480	0.85	0.75	E	0.000	0.000	0.000	1.965	0.000	1.9651	0.0000	1.9651
95	ENA-07	M1A- 35	ELECT MOTOR-SPOILER L5	1	100	54	D	8.400	7.369	9.826	199	28.480	0.85	0.75	E	0.000	0.000	0.000	1.965	0.000	1.9651	0.0000	1.9651
96	ENA-08	M1A- 36	ELECT MOTOR-SPOILER R1	1	100	54	D	8.400	7.369	9.826	199	28.480	0.85	0.75	E	0.000	0.000	0.000	1.965	0.000	1.9651	0.0000	1.9651

97	ENA-09	M1A- 37	ELECT MOTOR-SPOILER R2	1	100	44 D	8.400	7.369	9.826	199	28.480	0.85	0.75	E	0.000	0.000	0.000	1.965	0.000	1.9651	0.0000	1.9651
98	ENA-10	M1A- 38	ELECT MOTOR-SPOILER R3	1	100	64 D	8.400	7.369	9.826	199	28.480	0.85	0.75	E	0.000	0.000	0.000	1.965	0.000	1.9651	0.0000	1.9651
99	ENA-11	M1A- 39	ELECT MOTOR-SPOILER R4	1	100	44 D	8.400	7.369	9.826	199	28.480	0.85	0.75	E	0.000	0.000	0.000	1.965	0.000	1.9651	0.0000	1.9651
100	ENA-12	M1A- 40	ELECT MOTOR-SPOILER R5	1	100	54 D	8.400	7.369	9.826	199	28.480	0.85	0.75	E	0.000	0.000	0.000	1.965	0.000	1.9651	0.0000	1.9651
101	ENA-33	B1A- 29	ELECT RPC-SPOILER L1	1	100	54 D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0003	0.0000	0.0003
102	ENA-34	B1A- 30	ELECT RPC-SPOILER L2	1	100	44 D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0003	0.0000	0.0003
103	ENA-35	B1A- 31	ELECT RPC-SPOILER L3	1	100	64 D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0003	0.0000	0.0003
104	ENA-36	B1A- 32	ELECT RPC-SPOILER L4	1	100	44 D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0003	0.0000	0.0003
105	ENA-37	B1A- 33	ELECT RPC-SPOILER L5	1	100	54 D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0003	0.0000	0.0003
106	ENA-38	B1A- 34	ELECT RPC-SPOILER R1	1	100	54 D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0003	0.0000	0.0003
107	ENA-39	B1A- 35	ELECT RPC-SPOILER R2	1	100	44 D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0003	0.0000	0.0003
108	ENA-40	B1A- 36	ELECT RPC-SPOILER R3	1	100	64 D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0003	0.0000	0.0003
109	ENA-41	B1A- 37	ELECT RPC-SPOILER R4	1	100	44 D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0003	0.0000	0.0003
110	ENA-42	B1A- 38	ELECT RPC-SPOILER R5	1	100	54 D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0003	0.0000	0.0003
111	EPA01	M1A- 41	ACTUATOR MOTOR 1- ADJ STAB CONT	1	100	45 D	21.529	18.887	25.183	199	72.993	0.85	0.75	E	0.000	0.000	0.000	5.037	0.000	5.0365	0.0000	25.1825
112	EPA02	M1A- 42	ACTUATOR MOTOR 2- ADJ STAB CONT	1	100	65 D	21.529	18.887	25.183	199	72.993	0.85	0.75	E	0.000	0.000	0.000	5.037	0.000	5.0365	0.0000	25.1825
113	EPA08	B1A- 39	ELECT 1-ADJ STAB CONT RPC	1	100	45 D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0003	0.0000	0.0013
114	EPA09	B1A- 40	ELECT 2-ADJ STAB CONT RPC	1	100	65 D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0003	0.0000	0.0013
115	EPA10	B1A- 41	ELECT 3-ADJ STBY STAB RPC	1	100	55 D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
116	EPA11	R2A- 5	TRANSFER RELAY-ADJ STAB CONT	1	100	45 A	0.012	0.010	0.012	115	0.100	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
117	EPA12	R2A- 6	ELECT CTRL RELAY 1-ADJ STAB CONT	1	100	45 A	0.012	0.010	0.012	115	0.100	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
118	EPA13	R2A- 7	ELECT CTRL RELAY 2-ADJ STAB CONT	1	100	65 A	0.012	0.010	0.012	115	0.100	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
119	EPA14	B1A- 87	ELECTRIC BRAKE 1-ADJ STAB CONT	1	100	45 D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0003	0.0000	0.0013
120	EPA15	B1A- 88	ELECTRIC BRAKE 2-ADJ STAB CONT	1	100	65 D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0003	0.0000	0.0013
121	EPEA01	M1A- 43	ELECTRIC BRAKE 1-ADJ STAB CONT	1	100	45 D	0.013	0.012	0.016	199	0.045	0.85	0.75	E	0.000	0.000	0.000	0.003	0.000	0.0031	0.0000	0.0157
122	EPEA02	M1A- 44	ELECTRIC BRAKE 2-ADJ STAB CONT	1	100	65 D	0.013	0.012	0.016	199	0.045	0.85	0.75	E	0.000	0.000	0.000	0.003	0.000	0.0031	0.0000	0.0157
123	EVA09	M1A- 45	ELECT MOTORS-SLAT L1	1	100	54 D	2.000	1.755	2.339	199	6.781	0.85	0.75	E	0.000	0.000	0.000	2.339	0.187	0.0000	0.0000	2.3395
124	EVA10	M1A- 46	ELECT MOTORS-SLAT L2	1	100	44 D	2.000	1.755	2.339	199	6.781	0.85	0.75	E	0.000	0.000	0.000	2.339	0.187	0.0000	0.0000	2.3395
125	EVA11	M1A- 47	ELECT MOTORS-LEFT DLE	1	100	44 D	2.000	1.755	2.339	199	6.781	0.85	0.75	E	0.000	0.000	0.000	2.339	0.187	0.0000	0.0000	2.3395
126	EVA12	M1A- 48	ELECT MOTORS-SLAT L3	1	100	54 D	2.000	1.755	2.339	199	6.781	0.85	0.75	E	0.000	0.000	0.000	2.339	0.187	0.0000	0.0000	2.3395
127	EVA13	M1A- 49	ELECT MOTORS-SLAT L4	1	100	64 D	2.000	1.755	2.339	199	6.781	0.85	0.75	E	0.000	0.000	0.000	2.339	0.187	0.0000	0.0000	2.3395
128	EVA14	M1A- 50	ELECT MOTORS-SLAT L5	1	100	64 D	2.000	1.755	2.339	199	6.781	0.85	0.75	E	0.000	0.000	0.000	2.339	0.187	0.0000	0.0000	2.3395
129	EVA15	M1A- 51	ELECT MOTORS-SLAT L6	1	100	64 D	2.000	1.755	2.339	199	6.781	0.85	0.75	E	0.000	0.000	0.000	2.339	0.187	0.0000	0.0000	2.3395
130	EVA16	M1A- 52	ELECT MOTORS-SLAT L7	1	100	54 D	2.000	1.755	2.339	199	6.781	0.85	0.75	E	0.000	0.000	0.000	2.339	0.187	0.0000	0.0000	2.3395
131	EVA17	M1A- 53	ELECT MOTORS-SLAT L8	1	100	44 D	2.000	1.755	2.339	199	6.781	0.85	0.75	E	0.000	0.000	0.000	2.339	0.187	0.0000	0.0000	2.3395
132	EVA18	M1A- 54	ELECT MOTORS-SLAT R1	1	100	54 D	2.000	1.755	2.339	199	6.781	0.85	0.75	E	0.000	0.000	0.000	2.339	0.187	0.0000	0.0000	2.3395
133	EVA19	M1A- 55	ELECT MOTORS-SLAT R2	1	100	44 D	2.000	1.755	2.339	199	6.781	0.85	0.75	E	0.000	0.000	0.000	2.339	0.187	0.0000	0.0000	2.3395
134	EVA20	M1A- 56	ELECT MOTORS-RIGHT DLE	1	100	44 D	2.000	1.755	2.339	199	6.781	0.85	0.75	E	0.000	0.000	0.000	2.339	0.187	0.0000	0.0000	2.3395
135	EVA22	M1A- 57	ELECT MOTORS-SLAT R3	1	100	54 D	2.000	1.755	2.339	199	6.781	0.85	0.75	E	0.000	0.000	0.000	2.339	0.187	0.0000	0.0000	2.3395
136	EVA23	M1A- 58	ELECT MOTORS-SLAT R4	1	100	64 D	2.000	1.755	2.339	199	6.781	0.85	0.75	E	0.000	0.000	0.000	2.339	0.187	0.0000	0.0000	2.3395
137	EVA24	M1A- 59	ELECT MOTORS-SLAT R5	1	100	64 D	2.000	1.755	2.339	199	6.781	0.85	0.75	E	0.000	0.000	0.000	2.339	0.187	0.0000	0.0000	2.3395
138	EVA25	M1A- 60	ELECT MOTORS-SLAT R6	1	100	64 D	2.000	1.755	2.339	199	6.781	0.85	0.75	E	0.000	0.000	0.000	2.339	0.187	0.0000	0.0000	2.3395
139	EVA26	M1A- 61	ELECT MOTORS-SLAT R7	1	100	54 D	2.000	1.755	2.339	199	6.781	0.85	0.75	E	0.000	0.000	0.000	2.339	0.187	0.0000	0.0000	2.3395
140	EVA27	M1A- 62	ELECT MOTORS-SLAT R8	1	100	44 D	2.000	1.755	2.339	199	6.781	0.85	0.75	E	0.000	0.000	0.000	2.339	0.187	0.0000	0.0000	2.3395
141	EVA64	B1A- 42	ELECT RPC-SLAT L1	1	100	54 D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.001	0.000	0.0000	0.0000	0.0013
142	EVA65	B1A- 43	ELECT RPC-SLAT L2	1	100	44 D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.001	0.000	0.0000	0.0000	0.0013
143	EVA67	B1A- 44	ELECT RPC-SLAT L6	1	100	44 D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.001	0.000	0.0000	0.0000	0.0013
144	EVA68	B1A- 45	ELECT RPC-SLAT L7	1	100	54 D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.001	0.000	0.0000	0.0000	0.0013
145	EVA69	B1A- 46	ELECT RPC-SLAT L8	1	100	64 D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.001	0.000	0.0000	0.0000	0.0013

146	EVA70	B1A- 47	ELECT RPC-SLAT R1	1	100	64	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.001	0.000	0.0000	0.0000	0.0013
147	EVA71	B1A- 48	ELECT RPC-SLAT R2	1	100	64	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.001	0.000	0.0000	0.0000	0.0013
148	EVA72	B1A- 49	ELECT RPC-RIGHT DLE	1	100	54	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.001	0.000	0.0000	0.0000	0.0013
149	EVA73	B1A- 50	ELECT RPC-SLAT R3	1	100	44	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.001	0.000	0.0000	0.0000	0.0013
150	EVA74	B1A- 51	ELECT RPC-SLAT R4	1	100	54	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.001	0.000	0.0000	0.0000	0.0013
151	EVA75	B1A- 52	ELECT RPC-SLAT R5		100	44	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.001	0.000	0.0000	0.0000	0.0013
152	EVA76	B1A- 53	ELECT RPC-SLAT R6		100	44	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.001	0.000	0.0000	0.0000	0.0013
153	EVA77	B1A- 54	ELECT RPC-SLAT R7		100	54	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.001	0.000	0.0000	0.0000	0.0013
154	EVA78	B1A- 55	ELECT RPC-SLAT R8	1	100	64	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.001	0.000	0.0000	0.0000	0.0013
155	EVA79	R2A- 8	PWR XFR RELAY 1-LEFT WING SLATS	1	100	44	A	0.012	0.010	0.012	115	0.100	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
156	EVA80	R2A- 9	PWR XFR RELAY 1-RIGHT WING SLATS	1	100	44	A	0.012	0.010	0.012	115	0.100	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
157	EVA81	R2A- 10	PWR XFR RELAY 2-LEFT WING SLATS	1	100	54	A	0.012	0.010	0.012	115	0.100	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
158	EVA82	R2A- 11	PWR XFR RELAY 2-RIGHT WING SLATS	1	100	54	A	0.012	0.010	0.012	115	0.100	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
159	EVA83	R2A- 12	PWR XFR RELAY 3-LEFT WING SLATS	1	100	64	A	0.012	0.010	0.012	115	0.100	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
160	EVA84	R2A- 13	PWR XFR RELAY 3-RIGHT WING SLATS	1	100	64	A	0.012	0.010	0.012	115	0.100	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
161	EVA85	R2A- 14	A-I/SLAT PWR XFR RELAY-SLAT L1	1	100	54	A	0.012	0.010	0.012	115	0.100	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0001
162	EVA85.1	B1A- 56	ELECT RPC-LEFT DLE	1	100	64	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.001	0.000	0.0000	0.0000	0.0013
163	EVA86	R2A- 15	A-I/SLAT PWR XFR RELAY-SLAT L2	1	100	44	A	0.012	0.010	0.012	115	0.100	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0001
164	EVA86.1	B1A- 57	ELECT RPC-SLAT L3	1	100	64	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.001	0.000	0.0000	0.0000	0.0013
165	EVA87	R2A- 16	A-I/SLAT PWR XFR RELAY-LT DLE	1	100	44	A	0.012	0.010	0.012	115	0.100	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0001
166	EVA87.1	B1A- 58	ELECT RPC-SLAT L4	1	100	54	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.001	0.000	0.0000	0.0000	0.0013
167	EVA88	R2A- 17	A-I/SLAT PWR XFR RELAY-SLAT L3	1	100	54	A	0.012	0.010	0.012	115	0.100	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0001
168	EVA88.1	B1A- 59	ELECT RPC-SLAT L5	1	100	44	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.001	0.000	0.0000	0.0000	0.0013
169	EVA89	R2A- 18	A-I/SLAT PWR XFR RELAY-SLAT L4	1	100	64	A	0.012	0.010	0.012	115	0.100	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0001
170	EVA90	R2A- 19	A-I/SLAT PWR XFR RELAY-SLAT L5	1	100	64	A	0.012	0.010	0.012	115	0.100	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0001
171	EVA91	R2A- 20	A-I/SLAT PWR XFR RELAY-SLAT L6	1	100	64	A	0.012	0.010	0.012	115	0.100	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0001
172	EVA92	R2A- 21	A-I/SLAT PWR XFR RELAY-SLAT L7	1	100	54	A	0.012	0.010	0.012	115	0.100	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0001
173	EVA93	R2A- 22	A-I/SLAT PWR XFR RELAY-SLAT L8	1	100	44	A	0.012	0.010	0.012	115	0.100	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0001
174	EVA94	R2A- 23	A-I/SLAT PWR XFR RELAY-SLAT R1	1	100	54	A	0.012	0.010	0.012	115	0.100	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0001
175	EVA95	R2A- 24	A-I/SLAT PWR XFR RELAY-SLAT R2	1	100	44	A	0.012	0.010	0.012	115	0.100	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0001
176	EVA96	R2A- 25	A-I/SLAT PWR XFR RELAY-RT DLE	1	100	44	A	0.012	0.010	0.012	115	0.100	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0001
177	EVA97	R2A- 26	A-I/SLAT PWR XFR RELAY-SLAT R3	1	100	54	A	0.012	0.010	0.012	115	0.100	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0001
178	EVA98	R2A- 27	A-I/SLAT PWR XFR RELAY-SLAT R4	1	100	64	A	0.012	0.010	0.012	115	0.100	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0001
179	EVA99	R2A- 28	A-I/SLAT PWR XFR RELAY-SLAT R5	1	100	64	A	0.012	0.010	0.012	115	0.100	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0001
180	EVA99.1	R2A- 29	A-I/SLAT PWR XFR RELAY-SLAT R6	1	100	64	A	0.012	0.010	0.012	115	0.100	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0001
181	EVA99.2	R2A- 30	A-I/SLAT PWR XFR RELAY-SLAT R7	1	100	54	A	0.012	0.010	0.012	115	0.100	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0001
182	EVA99.3	R2A- 31	A-I/SLAT PWR XFR RELAY-SLAT R8	1	100	44	A	0.012	0.010	0.012	115	0.100	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0001
183	RNC01	M1A- 63	CARGO COMP FAN 1	1	100	43	D	1.341	1.176	1.569	199	4.547	0.85	0.75	M	1.569	1.569	0.523	1.569	1.569	1.5686	1.5686	1.5686
184	RNC03	B1A- 89	CARGO COMP FAN 1	1	100	43	D	0.001	0.001	0.001	199	0.004	0.85	0.90	M	0.001	0.001	0.000	0.001	0.001	0.0013	0.0013	0.0013
185	RNC04	B1A- 90	CARGO COMP FAN 2	1	100	53	D	0.001	0.001	0.001	199	0.004	0.85	0.90	M	0.001	0.001	0.000	0.001	0.001	0.0013	0.0013	0.0013
186	RNC05	B1A- 91	CARGO COMP FAN 3	1	100	63	D	0.001	0.001	0.001	199	0.004	0.85	0.90	M	0.001	0.001	0.000	0.001	0.001	0.0013	0.0013	0.0013
187	RNC06	B1A- 92	CARGO COMP FAN 4	1	100	63	D	0.001	0.001	0.001	199	0.004	0.85	0.90	M	0.001	0.001	0.000	0.001	0.001	0.0013	0.0013	0.0013
188	RNC07	B1A- 93	CARGO COMP FAN 5	1	100	41	D	0.001	0.001	0.001	199	0.004	0.85	0.90	M	0.001	0.001	0.000	0.001	0.001	0.0013	0.0013	0.0013
189	RNC08	B1A- 94	CARGO COMP FAN 6	1	100	61	D	0.001	0.001	0.001	199	0.004	0.85	0.90	M	0.001	0.001	0.000	0.001	0.001	0.0013	0.0013	0.0013
190	RNC09	B1A- 95	CARGO COMP FAN 7	1	100	42	D	0.001	0.001	0.001	199	0.004	0.85	0.90	M	0.001	0.001	0.000	0.001	0.001	0.0013	0.0013	0.0013
191	RNC10	B1A- 96	CARGO COMP FAN 8	1	100	62	D	0.001	0.001	0.001	199	0.004	0.85	0.90	M	0.001	0.001	0.000	0.001	0.001	0.0013	0.0013	0.0013
192	RNC11	B1A-115	HEATER-CKPT	1	100	43	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
193	RNC12	B1A-116	CARGO COMP HEATER 1	1	100	43	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
194	RNC13	B1A-117	CARGO COMP HEATER 2	1	100	53	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000

195	RNC14	B1A-118	CARGO COMP HEATER 3	1	100	63	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
196	RNC15	B1A-119	CARGO COMP HEATER 4	1	100	63	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
197	RNC16	B1A-120	CARGO COMP HEATER 5	1	100	41	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
198	RNC17	B1A-121	CARGO COMP HEATER 6	1	100	61	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
199	RNC18	B1A-122	CARGO COMP HEATER 7	1	100	42	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
200	RNC19	B1A-123	CARGO COMP HEATER 8	1	100	62	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
201	RNC20	M1A- 68	CARGO COMP FAN 6	1	100	61	D	1.341	1.176	1.569	199	4.547	0.85	0.75	M	1.569	1.569	0.523	1.569	3.922	1.5686	1.5686	1.5686
202	RNC21	M1A- 65	CARGO COMP FAN 3	1	100	63	D	1.341	1.176	1.569	199	4.547	0.85	0.75	M	1.569	1.569	0.523	1.569	3.922	1.5686	1.5686	1.5686
203	RNC22	M1A- 64	CARGO COMP FAN 2	1	100	53	D	1.341	1.176	1.569	199	4.547	0.85	0.75	M	1.569	1.569	0.523	1.569	3.922	1.5686	1.5686	1.5686
204	RNC23	M1A- 67	CARGO COMP FAN 5	1	100	41	D	1.341	1.176	1.569	199	4.547	0.85	0.75	M	1.569	1.569	0.523	1.569	3.922	1.5686	1.5686	1.5686
205	RNC24	M1A- 69	CARGO COMP FAN 7	1	100	42	D	1.341	1.176	1.569	199	4.547	0.85	0.75	M	1.569	1.569	0.523	1.569	3.922	1.5686	1.5686	1.5686
206	RNC25	M1A- 66	CARGO COMP FAN 4	1	100	63	D	1.341	1.176	1.569	199	4.547	0.85	0.75	M	1.569	1.569	0.523	1.569	3.922	1.5686	1.5686	1.5686
207	RNC26	M1A- 70	CARGO COMP FAN 8	1	100	62	D	1.341	1.176	1.569	199	4.547	0.85	0.75	M	1.569	1.569	0.523	1.569	3.922	1.5686	1.5686	1.5686
208	RNC27	H1A- 25	CARGO COMP HEATER 1	1	100	43	D	2.682	2.000	2.000	199	5.797	1	1	M	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
209	RNC28	H1A- 26	CARGO COMP HEATER 2	1	100	53	D	2.682	2.000	2.000	199	5.797	1	1	M	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
210	RNC29	H1A- 27	CARGO COMP HEATER 3	1	100	63	D	2.682	2.000	2.000	199	5.797	1	1	M	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
211	RNC30	H1A- 28	CARGO COMP HEATER 4	1	100	63	D	2.682	2.000	2.000	199	5.797	1	1	M	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
212	RNC31	H1A- 29	CARGO COMP HEATER 5	1	100	41	D	2.682	2.000	2.000	199	5.797	1	1	M	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
213	RNC32	H1A- 30	CARGO COMP HEATER 6	1	100	61	D	2.682	2.000	2.000	199	5.797	1	1	M	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
214	RNC33	H1A- 31	CARGO COMP HEATER 7	1	100	42	D	2.682	2.000	2.000	199	5.797	1	1	M	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
215	RNC34	H1A- 32	CARGO COMP HEATER 8	1	100	62	D	2.682	2.000	2.000	199	5.797	1	1	M	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
216	RNC35	H1A- 4	HEATER-AFT CABIN	1	100	51	D	26.820	20.000	20.000	199	57.971	1	1.00	M	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
217	RNC36	B1A- 80	HEATER-AFT CABIN	1	100	51	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
218	RNC37	H1A- 1	HEATER-CKPT	1	100	43	D	26.820	20.000	20.000	199	57.971	1	1.00	M	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
219	RNC38	H1A- 2	HEATER-FWD CABIN	1	100	53	D	26.820	20.000	20.000	199	57.971	1	1.00	M	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
220	RNC39	B1A- 78	HEATER-FWD CABIN	1	100	53	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
221	RNC40	B1A- 79	HEATER-MID CABIN	1	100	41	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
222	RNC41	H1A- 3	HEATER-MID CABIN	1	100	41	D	26.820	20.000	20.000	199	57.971	1	1.00	M	0.000	0.000	0.000	0.000	0.000	0.0000	0.0000	0.0000
223	RNN-01	M1A- 71	TURBINE-COMPRESSOR-1	1	100	43	D	167.628	125.000	166.667	199	483.09	1	0.75	E	0.000	0.000	0.000	0.000	0.000	16.6667	16.667	166.667
224	RNN-02	M1A- 72	TURBINE-COMPRESSOR-2	1	100	53	D	167.628	125.000	166.667	199	483.09	1	0.75	E	0.000	0.000	0.000	0.000	0.000	16.6667	16.667	166.667
225	RNN-03	M1A- 73	TURBINE-COMPRESSOR-3	1	100	63	D	167.628	125.000	166.667	199	483.09	1	0.75	E	0.000	0.000	0.000	0.000	0.000	16.6667	16.667	166.667
226	RNN-04	B1A- 97	TURBINE-COMPRESSOR-1	1	100	43	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0001	0.0001	0.0013
227	RNN-05	B1A- 98	TURBINE-COMPRESSOR-2	1	100	53	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0001	0.0001	0.0013
228	RNN-06	B1A- 99	TURBINE-COMPRESSOR-3	1	100	63	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.000	0.0001	0.0001	0.0013
229	RNN-07	B1A-100	TURBINE-VAPOR CYCLE-1	1	100	43	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.001	0.001	0.001	0.001	0.001	0.0013	0.0013	0.0013
230	RNN-08	B1A-101	TURBINE-VAPOR CYCLE-2	1	100	53	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.001	0.001	0.001	0.001	0.001	0.0013	0.0013	0.0013
231	RNN-09	B1A-102	TURBINE-VAPOR CYCLE-3	1	100	63	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.001	0.001	0.001	0.001	0.001	0.0013	0.0013	0.0013
232	RNN-10	M1A- 74	TURBINE-VAPOR CYCLE-1	1	100	43	D	52.300	39.000	52.000	199	150.72	1	0.75	E	52.000	52.000	52.000	52.000	52.000	52.0000	52.000	52.0000
233	RNN-11	M1A- 75	TURBINE-VAPOR CYCLE-2	1	100	53	D	52.300	39.000	52.000	199	150.72	1	0.75	E	52.000	52.000	52.000	52.000	52.000	52.0000	52.000	52.0000
234	RNN-12	M1A- 76	TURBINE-VAPOR CYCLE-3	1	100	63	D	52.300	39.000	52.000	199	150.72	1	0.75	E	52.000	52.000	52.000	52.000	52.000	52.0000	52.000	52.0000
235	SAB01	H1A- 5	ELECT ANTI-ICE-SLAT L1	1	100	54	D	13.410	10.000	10.000	199	28.986	1	1.00	E	0.000	0.000	0.000	0.000	9.000	10.0000	10.000	0.0000
236	SAB02	H1A- 6	ELECT ANTI-ICE-SLAT L2	1	100	44	D	13.410	10.000	10.000	199	28.986	1	1.00	E	0.000	0.000	0.000	0.000	9.000	10.0000	10.000	0.0000
237	SAB03	H1A- 7	ELECT ANTI-ICE-LEFT DLE	1	100	44	D	6.705	5.000	5.000	199	14.493	1	1.00	E	0.000	0.000	0.000	0.000	4.500	5.0000	5.000	0.0000
238	SAB04	H1A- 8	ELECT ANTI-ICE-SLAT L3	1	100	54	D	13.410	10.000	10.000	199	28.986	1	1.00	E	0.000	0.000	0.000	0.000	9.000	10.0000	10.000	0.0000
239	SAB05	H1A- 9	ELECT ANTI-ICE-SLAT L4	1	100	64	D	13.410	10.000	10.000	199	28.986	1	1.00	E	0.000	0.000	0.000	0.000	9.000	10.0000	10.000	0.0000
240	SAB06	H1A- 10	ELECT ANTI-ICE-SLAT L5	1	100	64	D	13.410	10.000	10.000	199	28.986	1	1.00	E	0.000	0.000	0.000	0.000	9.000	10.0000	10.000	0.0000
241	SAB07	H1A- 11	ELECT ANTI-ICE-SLAT L6	1	100	64	D	13.410	10.000	10.000	199	28.986	1	1.00	E	0.000	0.000	0.000	0.000	9.000	10.0000	10.000	0.0000
242	SAB08	H1A- 12	ELECT ANTI-ICE-SLAT L7	1	100	54	D	13.410	10.000	10.000	199	28.986	1	1.00	E	0.000	0.000	0.000	0.000	9.000	10.0000	10.000	0.0000
243	SAB09	H1A- 13	ELECT ANTI-ICE-SLAT L8	1	100	44	D	13.410	10.000	10.000	199	28.986	1	1.00	E	0.000	0.000	0.000	0.000	9.000	10.0000	10.000	0.0000

244	SAB10	H1A- 14	ELECT ANTI-ICE-SLAT R1	1	100	54	D	13.410	10.000	10.000	199	28.986	1	1.00	E	0.000	0.000	0.000	0.000	9.000	10.0000	10.000	0.0000
245	SAB11	H1A- 15	ELECT ANTI-ICE-SLAT R2	1	100	44	D	13.410	10.000	10.000	199	28.986	1	1.00	E	0.000	0.000	0.000	0.000	9.000	10.0000	10.000	0.0000
246	SAB12	H1A- 16	ELECT ANTI-ICE-RIGHT DLE	1	100	44	D	6.705	5.000	5.000	199	14.493	1	1.00	E	0.000	0.000	0.000	0.000	4.500	5.0000	5.000	0.0000
247	SAB13	H1A- 17	ELECT ANTI-ICE-SLAT R3	1	100	54	D	13.410	10.000	10.000	199	28.986	1	1.00	E	0.000	0.000	0.000	0.000	9.000	10.0000	10.000	0.0000
248	SAB14	H1A- 18	ELECT ANTI-ICE-SLAT R4	1	100	64	D	13.410	10.000	10.000	199	28.986	1	1.00	E	0.000	0.000	0.000	0.000	9.000	10.0000	10.000	0.0000
249	SAB15	H1A- 19	ELECT ANTI-ICE-SLAT R5	1	100	64	D	13.410	10.000	10.000	199	28.986	1	1.00	E	0.000	0.000	0.000	0.000	9.000	10.0000	10.000	0.0000
250	SAB16	H1A- 20	ELECT ANTI-ICE-SLAT R6	1	100	64	D	13.410	10.000	10.000	199	28.986	1	1.00	E	0.000	0.000	0.000	0.000	9.000	10.0000	10.000	0.0000
251	SAB17	H1A- 21	ELECT ANTI-ICE-SLAT R7	1	100	54	D	13.410	10.000	10.000	199	28.986	1	1.00	E	0.000	0.000	0.000	0.000	9.000	10.0000	10.000	0.0000
252	SAB18	H1A- 22	ELECT ANTI-ICE-SLAT R8	1	100	44	D	13.410	10.000	10.000	199	28.986	1	1.00	E	0.000	0.000	0.000	0.000	9.000	10.0000	10.000	0.0000
253	SAB37	B1A- 60	ELECT RPC ANTI-ICE-SLAT L1	1	100	54	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.001	0.0013	0.001	0.0000
254	SAB38	B1A- 61	ELECT RPC ANTI-ICE-SLAT L2	1	100	44	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.001	0.0013	0.001	0.0000
255	SAB39	B1A- 62	ELECT RPC ANTI-ICE-LEFT DLE	1	100	44	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.001	0.0013	0.0013	0.0000
256	SAB40	B1A- 63	ELECT RPC ANTI-ICE-SLAT L3	1	100	54	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.001	0.0013	0.0013	0.0000
257	SAB41	B1A- 64	ELECT RPC ANTI-ICE-SLAT L4	1	100	64	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.001	0.0013	0.0013	0.0000
258	SAB42	B1A- 65	ELECT RPC ANTI-ICE-SLAT L5	1	100	64	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.001	0.0013	0.0013	0.0000
259	SAB43	B1A- 66	ELECT RPC ANTI-ICE-SLAT L6	1	100	64	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.001	0.0013	0.0013	0.0000
260	SAB44	B1A- 67	ELECT RPC ANTI-ICE-SLAT L7	1	100	54	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.001	0.0013	0.0013	0.0000
261	SAB45	B1A- 68	ELECT RPC ANTI-ICE-SLAT L8	1	100	44	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.001	0.0013	0.0013	0.0000
262	SAB46	B1A- 69	ELECT RPC ANTI-ICE-SLAT R1	1	100	54	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.001	0.0013	0.0013	0.0000
263	SAB47	B1A- 70	ELECT RPC ANTI-ICE-SLAT R2	1	100	44	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.001	0.0013	0.0013	0.0000
264	SAB48	B1A- 71	ELECT RPC ANTI-ICE-RIGHT DLE	1	100	44	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.001	0.0013	0.0013	0.0000
265	SAB49	B1A- 72	ELECT RPC ANTI-ICE-SLAT R3	1	100	54	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.001	0.0013	0.0013	0.0000
266	SAB50	B1A- 73	ELECT RPC ANTI-ICE-SLAT R4	1	100	64	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.001	0.0013	0.0013	0.0000
267	SAB51	B1A- 74	ELECT RPC ANTI-ICE-SLAT R5	1	100	64	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.001	0.0013	0.0013	0.0000
268	SAB52	B1A- 75	ELECT RPC ANTI-ICE-SLAT R6	1	100	64	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.001	0.0013	0.0013	0.0000
269	SAB53	B1A- 76	ELECT RPC ANTI-ICE-SLAT R7	1	100	54	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.001	0.0013	0.0013	0.0000
270	SAB54	B1A- 77	ELECT RPC ANTI-ICE-SLAT R8	1	100	44	D	0.001	0.001	0.001	199	0.004	0.85	0.90	E	0.000	0.000	0.000	0.000	0.001	0.0013	0.0013	0.0000
271	SBA01	H1A- 23	ELECT ANTI-ICE-L & R INBD,LOWER	1	100	62	D	40.231	30.000	30.000	199	86.957	1	1.00	E	0.000	0.000	0.000	30.000	30.000	30.0000	30.000	30.0000
272	SBA03	H1A- 24	ELECT ANTI-ICE-L & R OTBD,UPPER	1	100	62	D	40.231	30.000	30.000	199	86.957	1	1.00	E	0.000	0.000	0.000	30.000	30.000	30.0000	30.000	30.0000
273	SBA05	B1A- 81	ELECT ANTI-ICE-L & R INBD,LOWER	1	100	42	D	0.001	0.001	0.001	199	0.003	0.85	1.00	E	0.000	0.000	0.000	0.001	0.001	0.0012	0.0012	0.0012
274	SBA06	B1A- 82	ELECT ANTI-ICE-L & R OTBD,UPPER	1	100	62	D	0.001	0.001	0.001	199	0.003	0.85	1.00	E	0.000	0.000	0.000	0.001	0.001	0.0012	0.0012	0.0012
								1489.63	1162.39	1440.97						169.19	169.19	160.82	333.83	422.19	575.61	469.75	1095.95

	TO/CLIMB			CRUISE COLD			CRUISE HOT			DESCENT/LAND			EMERGENCY			GND SERVICE	
	TC2_5M	TC3_15M	CC1_5S	CC2_5M	CC3_30M	CH1_5S	CH2_5M	CH3_30M	DL1_5S	DL2_5M	DL3_15M	E1_5S	E2_5M	E3_15M	GS1_5S	GS2_5M	GS3_15M	NOTES
1	0.7018	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	23.3945	0.7018	0.0000	23.3945	0.7018	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=10SEC
2	0.7018	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	23.3945	0.7018	0.0000	23.3945	0.7018	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=10SEC
3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	
4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	
5	0.2565	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	8.5507	0.2565	0.0000	8.5507	0.2565	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=10SEC
6	0.2565	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	8.5507	0.2565	0.0000	8.5507	0.2565	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=10SEC
7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	
8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	
9	0.1432	0.1432	0.1432	0.1432	0.1432	0.1432	0.1432	0.1432	0.1432	0.1432	0.1432	0.1432	0.1432	0.1432	0.0000	0.0000	0.0000	
10	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0000	0.0000	0.0000	
11	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0000	0.0000	0.0000	
12	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0000	0.0000	0.0000	
13	0.1432	0.1432	0.1432	0.1432	0.1432	0.1432	0.1432	0.1432	0.1432	0.1432	0.1432	0.1432	0.1432	0.1432	0.0000	0.0000	0.0000	
14	0.1432	0.1432	0.1432	0.1432	0.1432	0.1432	0.1432	0.1432	0.1432	0.1432	0.1432	0.1432	0.1432	0.1432	0.0000	0.0000	0.0000	
15	0.1432	0.1432	0.1432	0.1432	0.1432	0.1432	0.1432	0.1432	0.1432	0.1432	0.1432	0.1432	0.1432	0.1432	0.0000	0.0000	0.0000	
16	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0000	0.0000	0.0000	
17	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0000	0.0000	0.0000	
18	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0000	0.0000	0.0000	
19	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0000	0.0000	0.0000	
20	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0000	0.0000	0.0000	
21	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0000	0.0000	0.0000	
22	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0000	0.0000	0.0000	
23	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0000	0.0000	0.0000	
24	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0000	0.0000	0.0000	
25	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0000	0.0000	0.0000	
26	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0000	0.0000	0.0000	
27	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0000	0.0000	0.0000	
28	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0000	0.0000	0.0000	
29	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0000	0.0000	0.0000	
30	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0000	0.0000	0.0000	
31	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0000	0.0000	0.0000	
32	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0000	0.0000	0.0000	
33	0.2819	0.2819	2.8190	0.2819	0.2819	2.8190	0.2819	0.2819	2.8190	0.2819	0.2819	2.8190	0.2819	0.2819	0.0000	0.0000	0.0000	NL COND=10%,FULL TRAVEL=.5SEC
34	0.2819	0.2819	2.8190	0.2819	0.2819	2.8190	0.2819	0.2819	2.8190	0.2819	0.2819	2.8190	0.2819	0.2819	0.0000	0.0000	0.0000	NL COND=10%,FULL TRAVEL=.5SEC
35	1.8979	1.8979	18.9788	1.8979	1.8979	18.9788	1.8979	1.8979	18.9788	1.8979	1.8979	18.9788	1.8979	1.8979	0.0000	0.0000	0.0000	NL COND=10%,FULL TRAVEL=.5SEC
36	1.8979	1.8979	18.9788	1.8979	1.8979	18.9788	1.8979	1.8979	18.9788	1.8979	1.8979	18.9788	1.8979	1.8979	0.0000	0.0000	0.0000	NL COND=10%,FULL TRAVEL=.5SEC
37	0.2819	0.2819	2.8190	0.2819	0.2819	2.8190	0.2819	0.2819	2.8190	0.2819	0.2819	2.8190	0.2819	0.2819	0.0000	0.0000	0.0000	NL COND=10%,FULL TRAVEL=.5SEC
38	0.2819	0.2819	2.8190	0.2819	0.2819	2.8190	0.2819	0.2819	2.8190	0.2819	0.2819	2.8190	0.2819	0.2819	0.0000	0.0000	0.0000	NL COND=10%,FULL TRAVEL=.5SEC
39	1.8979	1.8979	18.9788	1.8979	1.8979	18.9788	1.8979	1.8979	18.9788	1.8979	1.8979	18.9788	1.8979	1.8979	0.0000	0.0000	0.0000	NL COND=10%,FULL TRAVEL=.5SEC
40	1.8979	1.8979	18.9788	1.8979	1.8979	18.9788	1.8979	1.8979	18.9788	1.8979	1.8979	18.9788	1.8979	1.8979	0.0000	0.0000	0.0000	NL COND=10%,FULL TRAVEL=.5SEC
41	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0000	0.0000	0.0000	
42	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0000	0.0000	0.0000	
43	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0000	0.0000	0.0000	
44	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0000	0.0000	0.0000	
45	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0000	0.0000	0.0000	
46	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0000	0.0000	0.0000	
47	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0000	0.0000	0.0000	

48	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0000	0.0000	0.0000	
49	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0000	0.0000	0.0000	
50	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0000	0.0000	0.0000	
51	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0000	0.0000	0.0000	
52	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0000	0.0000	0.0000	
53	0.6317	0.6317	6.3165	0.6317	0.6317	6.3165	0.6317	0.6317	6.3165	0.6317	0.6317	6.3165	0.6317	0.4211	0.0000	0.0000	0.0000	NL COND=10%,FULL TRAVEL=.7SEC
54	0.6317	0.6317	6.3165	0.6317	0.6317	6.3165	0.6317	0.6317	6.3165	0.6317	0.6317	6.3165	0.6317	0.4211	0.0000	0.0000	0.0000	NL COND=10%,FULL TRAVEL=.7SEC
55	0.9358	0.9358	9.3578	0.9358	0.9358	9.3578	0.9358	0.9358	9.3578	0.9358	0.9358	9.3578	0.9358	0.6239	0.0000	0.0000	0.0000	NL COND=10%,FULL TRAVEL=.7SEC
56	0.9358	0.9358	9.3578	0.9358	0.9358	9.3578	0.9358	0.9358	9.3578	0.9358	0.9358	9.3578	0.9358	0.6239	0.0000	0.0000	0.0000	NL COND=10%,FULL TRAVEL=.7SEC
57	0.6317	0.6317	6.3165	0.6317	0.6317	6.3165	0.6317	0.6317	6.3165	0.6317	0.6317	6.3165	0.6317	0.4211	0.0000	0.0000	0.0000	NL COND=10%,FULL TRAVEL=.7SEC
58	0.6317	0.6317	6.3165	0.6317	0.6317	6.3165	0.6317	0.6317	6.3165	0.6317	0.6317	6.3165	0.6317	0.4211	0.0000	0.0000	0.0000	NL COND=10%,FULL TRAVEL=.7SEC
59	0.9358	0.9358	9.3578	0.9358	0.9358	9.3578	0.9358	0.9358	9.3578	0.9358	0.9358	9.3578	0.9358	0.6239	0.0000	0.0000	0.0000	NL COND=10%,FULL TRAVEL=.7SEC
60	0.9358	0.9358	9.3578	0.9358	0.9358	9.3578	0.9358	0.9358	9.3578	0.9358	0.9358	9.3578	0.9358	0.6239	0.0000	0.0000	0.0000	NL COND=10%,FULL TRAVEL=.7SEC
61	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0000	0.0000	0.0000	
62	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0000	0.0000	0.0000	
63	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0000	0.0000	0.0000	
64	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0052	0.0000	0.0000	0.0000	
65	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0000	0.0000	0.0000	
66	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	STDBY MODE ONLY,SAME PWR
67	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0013	0.0001	0.0001	0.0000	0.0000	0.0000	
68	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	STDBY MODE ONLY,SAME PWR
69	1.4470	1.4470	14.4695	1.4470	1.4470	14.4695	1.4470	1.4470	14.4695	1.4470	1.4470	14.4695	1.4470	0.9646	0.0000	0.0000	0.0000	NL COND=10%,FULL TRAVEL=.8SEC
70	1.1066	1.1066	11.0656	1.1066	1.1066	11.0656	1.1066	1.1066	11.0656	1.1066	1.1066	11.0656	1.1066	0.7377	0.0000	0.0000	0.0000	NL COND=10%,FULL TRAVEL=.8SEC
71	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	
72	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	
73	0.1638	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.3395	0.1638	0.0000	2.3395	0.1638	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=20SEC
74	0.1638	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.3395	0.1638	0.0000	2.3395	0.1638	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=20SEC
75	0.1024	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.4622	0.1024	0.0000	1.4622	0.1024	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=20SEC
76	0.1024	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.4622	0.1024	0.0000	1.4622	0.1024	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=20SEC
77	0.1638	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.3395	0.1638	0.0000	2.3395	0.1638	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=20SEC
78	0.1638	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.3395	0.1638	0.0000	2.3395	0.1638	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=20SEC
79	0.1024	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.4622	0.1024	0.0000	1.4622	0.1024	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=20SEC
80	0.1024	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.4622	0.1024	0.0000	1.4622	0.1024	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=20SEC
81	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.0001	0.0000	0.0013	0.0001	0.0000	0.0000	0.0000	0.0000	
82	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.0001	0.0000	0.0013	0.0001	0.0000	0.0000	0.0000	0.0000	
83	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.0001	0.0000	0.0013	0.0001	0.0000	0.0000	0.0000	0.0000	
84	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	
85	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.0001	0.0000	0.0013	0.0001	0.0000	0.0000	0.0000	0.0000	
86	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	
87	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.0001	0.0000	0.0013	0.0001	0.0000	0.0000	0.0000	0.0000	
88	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.0001	0.0000	0.0013	0.0001	0.0000	0.0000	0.0000	0.0000	
89	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.0001	0.0000	0.0013	0.0001	0.0000	0.0000	0.0000	0.0000	
90	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.0001	0.0000	0.0013	0.0001	0.0000	0.0000	0.0000	0.0000	
91	0.0000	0.0000	9.8257	0.0000	0.0000	9.8257	0.0000	0.0000	9.8257	0.0000	0.0000	9.8257	0.0000	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=1SEC
92	0.0000	0.0000	9.8257	0.0000	0.0000	9.8257	0.0000	0.0000	9.8257	0.0000	0.0000	9.8257	0.0000	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=1SEC
93	0.0000	0.0000	9.8257	0.0000	0.0000	9.8257	0.0000	0.0000	9.8257	0.0000	0.0000	9.8257	0.0000	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=1SEC
94	0.0000	0.0000	9.8257	0.0000	0.0000	9.8257	0.0000	0.0000	9.8257	0.0000	0.0000	9.8257	0.0000	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=1SEC
95	0.0000	0.0000	9.8257	0.0000	0.0000	9.8257	0.0000	0.0000	9.8257	0.0000	0.0000	9.8257	0.0000	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=1SEC
96	0.0000	0.0000	9.8257	0.0000	0.0000	9.8257	0.0000	0.0000	9.8257	0.0000	0.0000	9.8257	0.0000	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=1SEC

97	0.0000	0.0000	9.8257	0.0000	0.0000	9.8257	0.0000	0.0000	9.8257	0.0000	0.0000	9.8257	0.0000	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=1SEC
98	0.0000	0.0000	9.8257	0.0000	0.0000	9.8257	0.0000	0.0000	9.8257	0.0000	0.0000	9.8257	0.0000	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=1SEC
99	0.0000	0.0000	9.8257	0.0000	0.0000	9.8257	0.0000	0.0000	9.8257	0.0000	0.0000	9.8257	0.0000	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=1SEC
100	0.0000	0.0000	9.8257	0.0000	0.0000	9.8257	0.0000	0.0000	9.8257	0.0000	0.0000	9.8257	0.0000	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=1SEC
101	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	
102	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	
103	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	
104	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	
105	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	
106	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	
107	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	
108	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	
109	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	
110	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	
111	0.0000	0.0000	25.1825	0.0000	0.0000	25.1825	0.0000	0.0000	10.0730	0.0000	0.0000	25.1825	0.0000	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=? SEC
112	0.0000	0.0000	25.1825	0.0000	0.0000	25.1825	0.0000	0.0000	10.0730	0.0000	0.0000	25.1825	0.0000	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=? SEC
113	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0005	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	
114	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0005	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	
115	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	STDBY MODE ONLY,SAME PWR
116	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	
117	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	
118	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	
119	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0005	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	
120	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0005	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	
121	0.0000	0.0000	0.0157	0.0000	0.0000	0.0157	0.0000	0.0000	0.0063	0.0000	0.0000	0.0157	0.0000	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=? SEC
122	0.0000	0.0000	0.0157	0.0000	0.0000	0.0157	0.0000	0.0000	0.0063	0.0000	0.0000	0.0157	0.0000	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=? SEC
123	0.0702	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.3395	0.0702	0.0000	2.3395	0.0702	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=10 SEC
124	0.0702	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.3395	0.0702	0.0000	2.3395	0.0702	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=10 SEC
125	0.0702	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.3395	0.0702	0.0000	2.3395	0.0702	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=10 SEC
126	0.0702	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.3395	0.0702	0.0000	2.3395	0.0702	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=10 SEC
127	0.0702	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.3395	0.0702	0.0000	2.3395	0.0702	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=10 SEC
128	0.0702	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.3395	0.0702	0.0000	2.3395	0.0702	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=10 SEC
129	0.0702	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.3395	0.0702	0.0000	2.3395	0.0702	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=10 SEC
130	0.0702	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.3395	0.0702	0.0000	2.3395	0.0702	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=10 SEC
131	0.0702	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.3395	0.0702	0.0000	2.3395	0.0702	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=10 SEC
132	0.0702	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.3395	0.0702	0.0000	2.3395	0.0702	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=10 SEC
133	0.0702	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.3395	0.0702	0.0000	2.3395	0.0702	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=10 SEC
134	0.0702	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.3395	0.0702	0.0000	2.3395	0.0702	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=10 SEC
135	0.0702	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.3395	0.0702	0.0000	2.3395	0.0702	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=10 SEC
136	0.0702	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.3395	0.0702	0.0000	2.3395	0.0702	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=10 SEC
137	0.0702	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.3395	0.0702	0.0000	2.3395	0.0702	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=10 SEC
138	0.0702	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.3395	0.0702	0.0000	2.3395	0.0702	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=10 SEC
139	0.0702	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.3395	0.0702	0.0000	2.3395	0.0702	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=10 SEC
140	0.0702	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2.3395	0.0702	0.0000	2.3395	0.0702	0.0000	0.0000	0.0000	0.0000	FULL TRAVEL=10 SEC
141	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	
142	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	
143	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	
144	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	
145	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	

146	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	
147	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	
148	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	
149	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	
150	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	
151	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	
152	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	
153	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	
154	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	
155	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	
156	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	
157	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	
158	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	
159	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	
160	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	
161	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	
162	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	
163	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	
164	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	
165	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	
166	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	
167	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	
168	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	
169	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	
170	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	
171	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	
172	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	
173	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	
174	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	
175	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	
176	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	
177	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	
178	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	
179	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	
180	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	
181	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	
182	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	
183	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
184	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
185	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
186	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
187	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
188	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
189	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
190	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
191	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
192	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	HEATING OFF WHEN A/C ON
193	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	HEATING OFF WHEN A/C ON
194	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	HEATING OFF WHEN A/C ON

195	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	HEATING OFF WHEN A/C ON
196	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	HEATING OFF WHEN A/C ON
197	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	HEATING OFF WHEN A/C ON
198	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	HEATING OFF WHEN A/C ON
199	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	HEATING OFF WHEN A/C ON
200	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	HEATING OFF WHEN A/C ON
201	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
202	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
203	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
204	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
205	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
206	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
207	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	1.5686	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
208	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	HEATING OFF WHEN A/C ON
209	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	HEATING OFF WHEN A/C ON
210	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	HEATING OFF WHEN A/C ON
211	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	HEATING OFF WHEN A/C ON
212	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	HEATING OFF WHEN A/C ON
213	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	HEATING OFF WHEN A/C ON
214	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	HEATING OFF WHEN A/C ON
215	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	HEATING OFF WHEN A/C ON
216	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	HEATING OFF WHEN A/C ON
217	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	HEATING OFF WHEN A/C ON
218	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	HEATING OFF WHEN A/C ON
219	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	HEATING OFF WHEN A/C ON
220	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	HEATING OFF WHEN A/C ON
221	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	HEATING OFF WHEN A/C ON
222	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	HEATING OFF WHEN A/C ON
223	166.667	166.667	166.667	166.667	166.667	166.667	166.667	166.667	166.667	166.67	166.667	116.667	116.67	116.67	0.00	0.00	0.0000	MOTOR EFF FACTORED INTO LOAD BY VENDOR
224	166.667	166.667	166.667	166.667	166.667	166.667	166.667	166.667	166.667	166.67	166.667	116.667	116.67	116.67	0.00	0.00	0.0000	MOTOR EFF FACTORED INTO LOAD BY VENDOR
225	166.667	166.667	166.667	166.667	166.667	166.667	166.667	166.667	166.667	166.67	166.667	116.667	116.67	116.67	0.00	0.00	0.0000	MOTOR EFF FACTORED INTO LOAD BY VENDOR
226	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0009	0.0009	0.0009	0.0000	0.0000	0.0000	
227	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0009	0.0009	0.0009	0.0000	0.0000	0.0000	
228	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0009	0.0009	0.0009	0.0000	0.0000	0.0000	
229	0.0013	0.0013	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0010	0.0010	0.0010	0.0009	0.0009	0.0009	0.0000	0.0000	0.0000	
230	0.0013	0.0013	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0010	0.0010	0.0010	0.0009	0.0009	0.0009	0.0000	0.0000	0.0000	
231	0.0013	0.0013	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0010	0.0010	0.0010	0.0009	0.0009	0.0009	0.0000	0.0000	0.0000	
232	52.0000	52.0000	13.0000	13.0000	13.0000	13.0000	13.0000	13.0000	39.0000	39.000	39.000	36.400	36.400	36.400	0.000	0.0000	0.0000	MOTOR EFF FACTORED INTO LOAD BY VENDOR
233	52.0000	52.0000	13.0000	13.0000	13.0000	13.0000	13.0000	13.0000	39.0000	39.000	39.000	36.400	36.400	36.400	0.000	0.0000	0.0000	MOTOR EFF FACTORED INTO LOAD BY VENDOR
234	52.0000	52.0000	13.0000	13.0000	13.0000	13.0000	13.0000	13.0000	39.0000	39.000	39.000	36.400	36.400	36.400	0.000	0.0000	0.0000	MOTOR EFF FACTORED INTO LOAD BY VENDOR
235	8.6000	9.7000	10.0000	10.0000	10.0000	0.0000	0.0000	0.0000	0.0000	9.6000	6.7000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	OFF DURING SLAT DEPLOYMENT
236	8.6000	9.7000	10.0000	10.0000	10.0000	0.0000	0.0000	0.0000	0.0000	9.6000	6.7000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	OFF DURING SLAT DEPLOYMENT
237	4.3000	4.8500	5.0000	5.0000	5.0000	0.0000	0.0000	0.0000	0.0000	4.8000	3.3500	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	OFF DURING SLAT DEPLOYMENT
238	8.6000	9.7000	10.0000	10.0000	10.0000	0.0000	0.0000	0.0000	0.0000	9.6000	6.7000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	OFF DURING SLAT DEPLOYMENT
239	8.6000	9.7000	10.0000	10.0000	10.0000	0.0000	0.0000	0.0000	0.0000	9.6000	6.7000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	OFF DURING SLAT DEPLOYMENT
240	8.6000	9.7000	10.0000	10.0000	10.0000	0.0000	0.0000	0.0000	0.0000	9.6000	6.7000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	OFF DURING SLAT DEPLOYMENT
241	8.6000	9.7000	10.0000	10.0000	10.0000	0.0000	0.0000	0.0000	0.0000	9.6000	6.7000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	OFF DURING SLAT DEPLOYMENT
242	8.6000	9.7000	10.0000	10.0000	10.0000	0.0000	0.0000	0.0000	0.0000	9.6000	6.7000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	OFF DURING SLAT DEPLOYMENT
243	8.6000	9.7000	10.0000	10.0000	10.0000	0.0000	0.0000	0.0000	0.0000	9.6000	6.7000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	OFF DURING SLAT DEPLOYMENT

244	8.6000	9.7000	10.0000	10.0000	10.0000	0.0000	0.0000	0.0000	0.0000	9.6000	6.7000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	OFF DURING SLAT DEPLOYMENT
245	8.6000	9.7000	10.0000	10.0000	10.0000	0.0000	0.0000	0.0000	0.0000	9.6000	6.7000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	OFF DURING SLAT DEPLOYMENT
246	4.3000	4.8500	5.0000	5.0000	5.0000	0.0000	0.0000	0.0000	0.0000	4.8000	3.3500	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	OFF DURING SLAT DEPLOYMENT
247	8.6000	9.7000	10.0000	10.0000	10.0000	0.0000	0.0000	0.0000	0.0000	9.6000	6.7000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	OFF DURING SLAT DEPLOYMENT
248	8.6000	9.7000	10.0000	10.0000	10.0000	0.0000	0.0000	0.0000	0.0000	9.6000	6.7000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	OFF DURING SLAT DEPLOYMENT
249	8.6000	9.7000	10.0000	10.0000	10.0000	0.0000	0.0000	0.0000	0.0000	9.6000	6.7000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	OFF DURING SLAT DEPLOYMENT
250	8.6000	9.7000	10.0000	10.0000	10.0000	0.0000	0.0000	0.0000	0.0000	9.6000	6.7000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	OFF DURING SLAT DEPLOYMENT
251	8.6000	9.7000	10.0000	10.0000	10.0000	0.0000	0.0000	0.0000	0.0000	9.6000	6.7000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	OFF DURING SLAT DEPLOYMENT
252	8.6000	9.7000	10.0000	10.0000	10.0000	0.0000	0.0000	0.0000	0.0000	9.6000	6.7000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	OFF DURING SLAT DEPLOYMENT
253	0.0011	0.0013	0.0013	0.0013	0.0013	0.0000	0.0000	0.0000	0.0000	0.0013	0.0009	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	OFF DURING SLAT DEPLOYMENT
254	0.0011	0.0013	0.0013	0.0013	0.0013	0.0000	0.0000	0.0000	0.0000	0.0013	0.0009	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	OFF DURING SLAT DEPLOYMENT
255	0.0011	0.0013	0.0013	0.0013	0.0013	0.0000	0.0000	0.0000	0.0000	0.0013	0.0009	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	OFF DURING SLAT DEPLOYMENT
256	0.0011	0.0013	0.0013	0.0013	0.0013	0.0000	0.0000	0.0000	0.0000	0.0013	0.0009	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	OFF DURING SLAT DEPLOYMENT
257	0.0011	0.0013	0.0013	0.0013	0.0013	0.0000	0.0000	0.0000	0.0000	0.0013	0.0009	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	OFF DURING SLAT DEPLOYMENT
258	0.0011	0.0013	0.0013	0.0013	0.0013	0.0000	0.0000	0.0000	0.0000	0.0013	0.0009	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	OFF DURING SLAT DEPLOYMENT
259	0.0011	0.0013	0.0013	0.0013	0.0013	0.0000	0.0000	0.0000	0.0000	0.0013	0.0009	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	OFF DURING SLAT DEPLOYMENT
260	0.0011	0.0013	0.0013	0.0013	0.0013	0.0000	0.0000	0.0000	0.0000	0.0013	0.0009	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	OFF DURING SLAT DEPLOYMENT
261	0.0011	0.0013	0.0013	0.0013	0.0013	0.0000	0.0000	0.0000	0.0000	0.0013	0.0009	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	OFF DURING SLAT DEPLOYMENT
262	0.0011	0.0013	0.0013	0.0013	0.0013	0.0000	0.0000	0.0000	0.0000	0.0013	0.0009	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	OFF DURING SLAT DEPLOYMENT
263	0.0011	0.0013	0.0013	0.0013	0.0013	0.0000	0.0000	0.0000	0.0000	0.0013	0.0009	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	OFF DURING SLAT DEPLOYMENT
264	0.0011	0.0013	0.0013	0.0013	0.0013	0.0000	0.0000	0.0000	0.0000	0.0013	0.0009	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	OFF DURING SLAT DEPLOYMENT
265	0.0011	0.0013	0.0013	0.0013	0.0013	0.0000	0.0000	0.0000	0.0000	0.0013	0.0009	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	OFF DURING SLAT DEPLOYMENT
266	0.0011	0.0013	0.0013	0.0013	0.0013	0.0000	0.0000	0.0000	0.0000	0.0013	0.0009	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	OFF DURING SLAT DEPLOYMENT
267	0.0011	0.0013	0.0013	0.0013	0.0013	0.0000	0.0000	0.0000	0.0000	0.0013	0.0009	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	OFF DURING SLAT DEPLOYMENT
268	0.0011	0.0013	0.0013	0.0013	0.0013	0.0000	0.0000	0.0000	0.0000	0.0013	0.0009	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	OFF DURING SLAT DEPLOYMENT
269	0.0011	0.0013	0.0013	0.0013	0.0013	0.0000	0.0000	0.0000	0.0000	0.0013	0.0009	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	OFF DURING SLAT DEPLOYMENT
270	0.0011	0.0013	0.0013	0.0013	0.0013	0.0000	0.0000	0.0000	0.0000	0.0013	0.0009	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	OFF DURING SLAT DEPLOYMENT
271	27.0000	9.7000	30.0000	30.0000	30.0000	0.0000	0.0000	0.0000	30.0000	30.000	20.1000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
272	27.0000	9.7000	30.0000	30.0000	30.0000	0.0000	0.0000	0.0000	30.0000	30.000	20.1000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
273	0.0011	0.0004	0.0012	0.0012	0.0012	0.0000	0.0000	0.0000	0.0012	0.0012	0.0008	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
274	0.0011	0.0004	0.0012	0.0012	0.0012	0.0000	0.0000	0.0000	0.0012	0.0012	0.0008	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
	891.21	871.07	1106.34	799.77	799.77	876.31	569.74	569.74	1105.32	875.21	801.86	905.20	481.63	474.44	0.00	0.00	0.00	

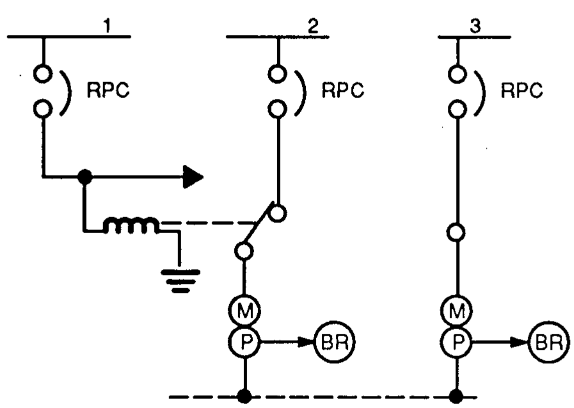
APPENDIX H
RELIABILITY ANALYSES

TABLE H-1
RELIABILITY PARAMETERS

COMPONENT	MTBF (HR)	RELIABILITY	
		1 HR	1,000 HR
BUS	1,000,000	0.999999	0.999
RPC	10,000	0.99990	0.90
TFR RELAY	10,000	0.99990	0.90
FEEDER	20,000	0.99995	0.95
MOTOR	50,000	0.99998	0.98
PUMP	100,000	0.99999	0.99

RELIABILITY ANALYSIS
EXAMPLE SHOWING ASSUMPTIONS AND METHODS

TRIPLE ELECTRICAL; DUAL FEED AND DUAL (BACKUP) ELECT/HYDRAULIC



NOTE: LATER CHANGED TO TRIPLE ELECTRICAL SOURCES; USES A DUAL-FEED EMA/BRAKE ASSEMBLY. THE BRAKE IS A SIMPLE ELECTRICAL SOLENOID ASSEMBLY WITH 100,000 HR MTBF AND GIVES THE SAME RELIABILITY VALUES AS A HYDRAULIC PUMP UNIT.

RELIABILITY OF POWER FROM PUMPS

$R_{1,000}$ = 0.98939 FOR 1,000-HR BASE
OR R_1 = 0.9999894 FOR 1-HR BASE
OR $MTBF_{SYSTEM}$ = 94,339 HR

FIGURE H-1. EXAMPLE FOR HORIZONTAL STABILIZER

RELIABILITY COMPUTATION

Left channels from BUS 1 and BUS 2:

$0.90 \times 0.95 \times 0.90 = 0.7695$

$0.90 \times 0.95 = 0.855$

$1 - [(1 - 0.7695)(1 - 0.855)] =$

$1 - (0.2305 \times 0.145) = 1 - 0.03342 = 0.96658$

$0.96658 \times 0.98 \times 0.99 = 0.93778$

Right channel from BUS 3:

$0.90 \times 0.95 \times 0.98 \times 0.99 = 0.82952$

Combined reliability:

$1 - [(1 - 0.93778)(1 - 0.82952)] =$

$1 - (0.0622 \times 0.17048) =$

$1 - 0.0100607$ $= 0.98939$ on 1,000-hr basis

$= 0.9999894$ on 1-hr basis

These give 94,339 hours MTBF

APPENDIX I

FLY-BY-WIRE AND FLY-BY-LIGHT STUDY

(PRELIMINARY DATA)

FBW and FBL Systems Configurations for POWER-BY-WIRE Study

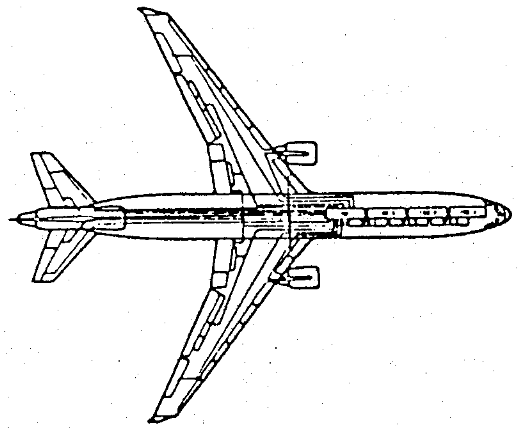
FBW and FBL Config 1 (1W = FBW Config 1; 1L = FBL Config 1)

- Direct and Dedicated Data Links for Control Command Signalling and Feedback / Loop Closure
- No additional use of data buses beyond those already used on the MD-11
- All control surfaces are converted to FBW / FBL
- MD-11 FBW engine controls are not changed
- Replacement of MD-11 hydraulic actuation is not included in this part of the study

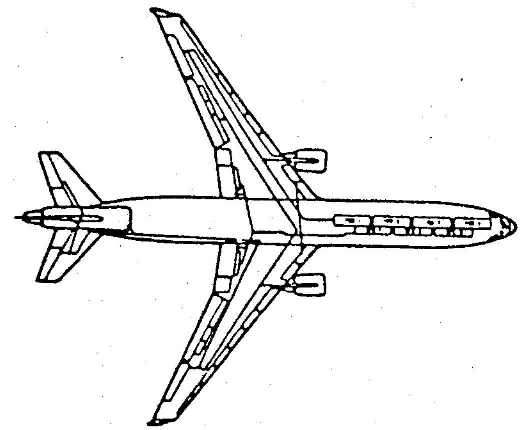
FBW and FBL Config 2 (2W = FBW Config 2; 2L = FBL Config 2)

- Bidirectional Data Buses for Control Command Signalling and Feedback / Loop Closure
- All new data busses are bidirectional Arinc 629. The existing ARINC 429 data buses were left as is (not replaced by ARINC 629 or converted to fiber optics)
- All control surfaces are converted to FBW / FBL
- MD-11 FBW engine controls are not changed
- Replacement of MD-11 hydraulic actuation is not included in this part of the study

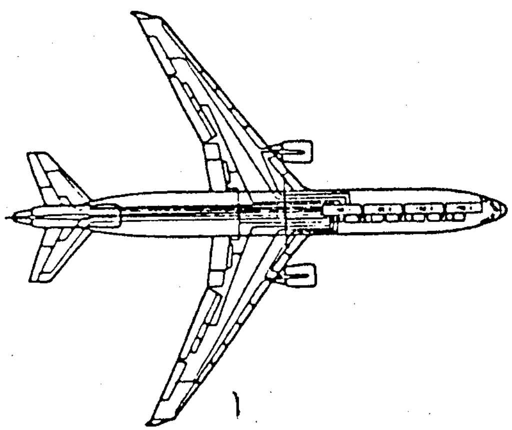
FBW and FBL Systems Configurations
for POWER-BY-WIRE Study



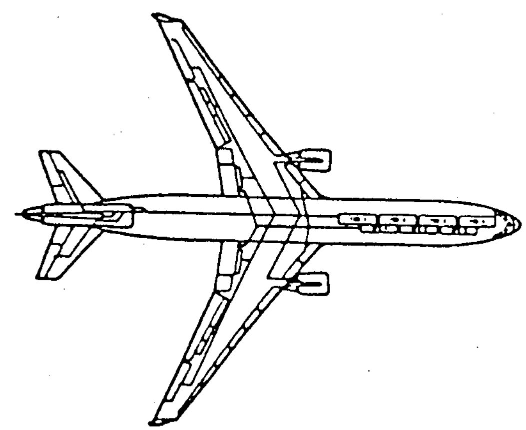
CONFIG 1W



CONFIG 2W



CONFIG 1L



CONFIG 2L

FLIGHT CONTROLS MD-11 CONVERISION TO FBW and FBL
WEIGHT ANALYSIS (all weights in lbs)

ITEM CODE	EXISTING	CONFIG 1W	CONFIG 1L	CONFIG 2W	CONFIG 2L
EA = COCKPIT CONTROLS	44.54	37	34	37	33
EB = RUDDER PEDALS	42.63	38	35	38	34
EC = GUST LOCK	22.74	22.74	19	22.74	19
EE = AUTOMATIC FLT CONTROLS SYSTEM & FBW	227.76	300	275	300	260
EF = AILERON CONTROLS	602.07	500	450	450	410
EH = ELEVATOR CONTROLS	810.62	700	620	625	590
EJ = RUDDER CONTROLS	362.58	300	260	240	210
EL = FLAP CONTROLS	561.40	500	470	470	460
EN = SPOILER CONTROLS	476.95	400	320	350	285
EP = ADJUST HORIZ STAB	658.03	600	560	560	530
ER = UTIL MECH CONTROLS	4.17	4.17	4	4.17	4
ET = GENERL PLUMB	130.30	130.30	130	130.30	130
EV = SLAT CONTROLS	1453.57	1350	1300	1325	1290
EZ = UNDISTRIBUTED ITEMS	60.06	20	20	17	17
E = SURFACE CONTROLS (TOTALS)	5457.49	4902.21	4497	4569.21	4272

COST BENEFITS OF FLY-BY-LIGHT TECHNOLOGY

NATIONAL

- 0 PREVENT FURTHER EROSION OF U.S. WORLD MARKET SHARE OF TRANSPORT AIRCRAFT

OPERATOR'S

- 0 DECREASED OPERATOR'S COST
- 0 DECREASED MAINTENANCE
- 0 INCREASED RELIABILITY

MANUFACTURER'S

- 0 WEIGHT SAVINGS
- 0 LIGHTWEIGHT EME IMMUNITY
- 0 DECREASED DESIGN AND MANUFACTURING COSTS
- 0 FACILITATES GREATER SYSTEMS INTEGRATION
- 0 HIGHER DATA RATE TRANSMISSION CAPABILITY

RISK ASSESSMENT / TRADEOFFS - ASPECTS

- o CERTIFICATION
  - DEFINED CRITERIA vs SPECIAL CONDITIONS
- o SAFETY
  - RELIABILITY
  - EME
- o WEIGHT
  - NARROWBODY
  - WIDEBODY
- o COST
  - DESIGN / PRODUCTION
  - LIFE CYCLE

OPTICS - BARRIERS TO COMMERCIAL INTRODUCTION

CERTIFICATION ISSUES FOR OPTICAL SYSTEMS ARE LARGELY UNADDRESSED AT THIS TIME

INSTALLATION AND LONG - TERM MAINTENANCE ISSUES HAVE NOT BEEN FULLY EXAMINED

MANY PROMISING OPTICAL TECHNOLOGIES REQUIRE SUBSTANTIAL DEVELOPMENT FOR PRODUCTION AIRCRAFT SYSTEMS

AREAS REQUIRING FURTHER DEVELOPMENT FOR FIBER OPTICS ON AIRCRAFT

AREA	DIFFICULTIES
FIBERS	MICROCRACKING, MICROBEND LOSSES, STABILITY OVER LARGE TEMPERATURE RANGE
CONNECTORS	VIBRATION-SENSITIVE, TEMPERATURE-INDUCED PISTONING, REPEATABILITY, BACK REFLECTIONS (INCLUDING DIFFERENTIAL WAVELENGTH), HIGH LOSS, CONTAMINATION, POT AND POLISH TERMINATIONS, INDEX MATCHING GELS, COHERENCE LENGTH INTERFERENCE
PASSIVE COUPLERS	HIGH LOSS, BACK REFLECTIONS, EXPENSIVE
LEDs	LOW POWER OUTPUT, BANDWIDTH DRIFT WITH TEMPERATURE
LASER DIODES	SHORT LIFE, REQUIRES TEMPERATURE STABILIZATION, SAFETY CONCERNS, EXPENSIVE
WDM	HIGH LOSS, INSUFFICIENT CHANNELS, BANDPASS DRIFT WITH TEMPERATURE, EXPENSIVE
TDM	HIGH LOSS, INTENSITY BASED (VARIATION WITH TEMPERATURE), SYSTEM SPECIFIC (ASSOCIATED ELECTRONICS), DIFFICULT TO REPAIR, EXPENSIVE
DIGITAL SENSORS	ELECTRONICALLY AND MECHANICALLY COMPLEX, SINGLE-BIT LOSS CAN CAUSE MAJOR LOSS OF ACCURACY, REQUIRES LARGE POWER BUDGET
ANALOG SENSORS	REQUIRES REFERENCE SIGNAL TO COMPENSATE FOR TEMPERATURE VARIATIONS, SENSITIVE TO CONNECTOR LOSS, ETC.
ASSEMBLY, INSTALLATION, AND REPAIR	COMPLICATED, SPECIALIZED, INCOMPATIBLE WITH CURRENT AIRCRAFT TECHNIQUES

FLY - BY - LIGHT CONTROL SUITE ASPECTS

- CONTROL INTEGRATION
- FLIGHT CONTROLS
- BACKUP FLIGHT CONTROLS
- COMPUTERS
- ENGINE CONTROLS
- SURFACE ACTUATION
- ACTUATION POWER
- SELF REPAIRING
- FIELD MAINTAINABILITY

Typical Wire and Fiber Optic Cable Weights

GAUGE	NO. CONDUCTORS	WEIGHT UNSHIELDED (LB/1000 FT)	WEIGHT SHIELDED (LB/1000 FT)
24	3	7.3	14.4
22	3	10.4	18.7
20	3	15.2	24.9
24	2	4.8	11.2
22	2	6.9	14.1
20	2	10.0	18.4
24	1	2.4	6.4
22	1	3.4	8.0
20	1	5.0	10.2
FIBER OPTIC	1	1.6 STANDARD JACKET	—
100/140 MICRON	1	4.0 REINFORCED JACKET	—
FIBER OPTIC	1	2.0 STANDARD JACKET	—
200/240 MICRON	1	4.4 REINFORCED JACKET	—
FIBER OPTIC 100/140 MICRON (RIBBON CABLE)	18	1.0	—

Widebody Weight Comparison

Direct (signal to signal) Conversion of Flight Control Signal Wires to Fiber Optics for a MD-11 Type Aircraft

	Flight Control	Aircraft
Total Signal Path Length	130,500 ft	303,200 ft
Signal Wire Weight	1,330 lbs	3,100 lbs
Signal Fiber Optic Weight	210 lbs	485 lbs
Approx. Weight Savings	1,120 lbs	2,615 lbs

* wire 20 gauge shielded/jacketed
* fiber 100/140 micron jacketed
* wire ground return loops eliminated for fiber optics
* new electro-optics (Tx & Rx) added

Widebody Flight Controls Development and Production Cost Comparison

	Mechanical Baseline	Fly-By-Wire	Projected Fly-By-Light (ROM)
Non-Recurring			
Engineering and Development	$14,000,000	$38,000,000	$60,000,000
Recurring Per Aircraft			
Material Cost	$90,000	$55,000	$63,000
Avionics Assembly Co	$70,000	$43,000	$35,000
Equipement Cost	$950,000	$1,000,000	$1,030,000
Handling/Installation	$250,000	$210,000	$220,000
TOTAL	$1,370,000	$1,308,000	$1,348,000

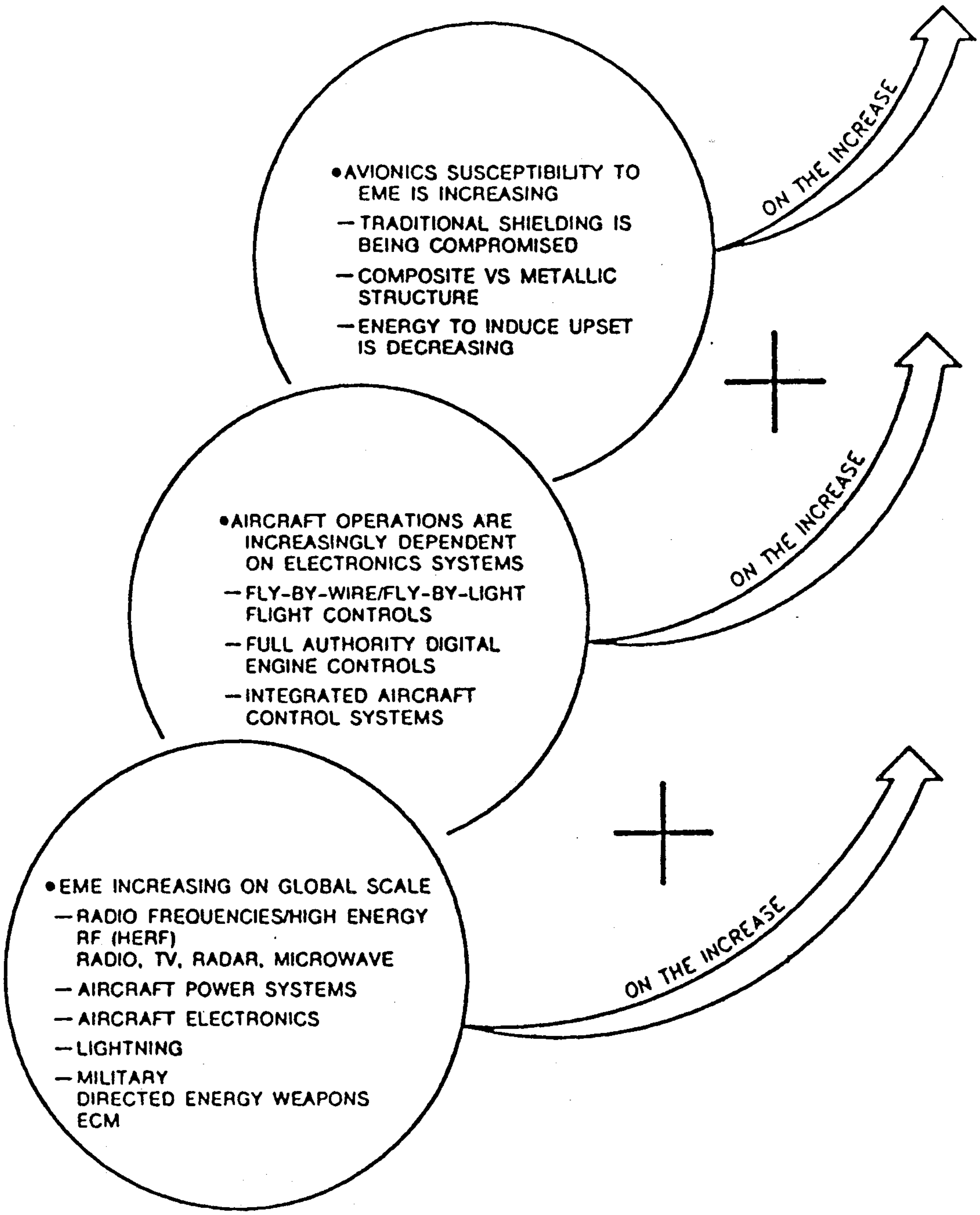
Widebody Maintenance Life Cycle Cost Comparison

	Mechanical Baseline		Fly-By-Wire		Fly-By-Light	
	$/HR	$/Life	$/HR	$/Life	$/HR	$/Life
Autoflight	3.7	$222,000	3.2	$192,000	2.6	$156,000
Communications	1.8	$108,000	1.5	$90,000	1.1	$66,000
Flight Controls	1.7	$102,000	1.0	$60,000	0.7	$42,000
Instrumentation	1.6	$96,000	1.2	$72,000	0.8	$48,000
Navigation	10.4	$624,000	8.3	$498,000	6.9	$414,000
TOTAL	19.2	$1,152,000	15.2	$912,000	12.1	$726,000

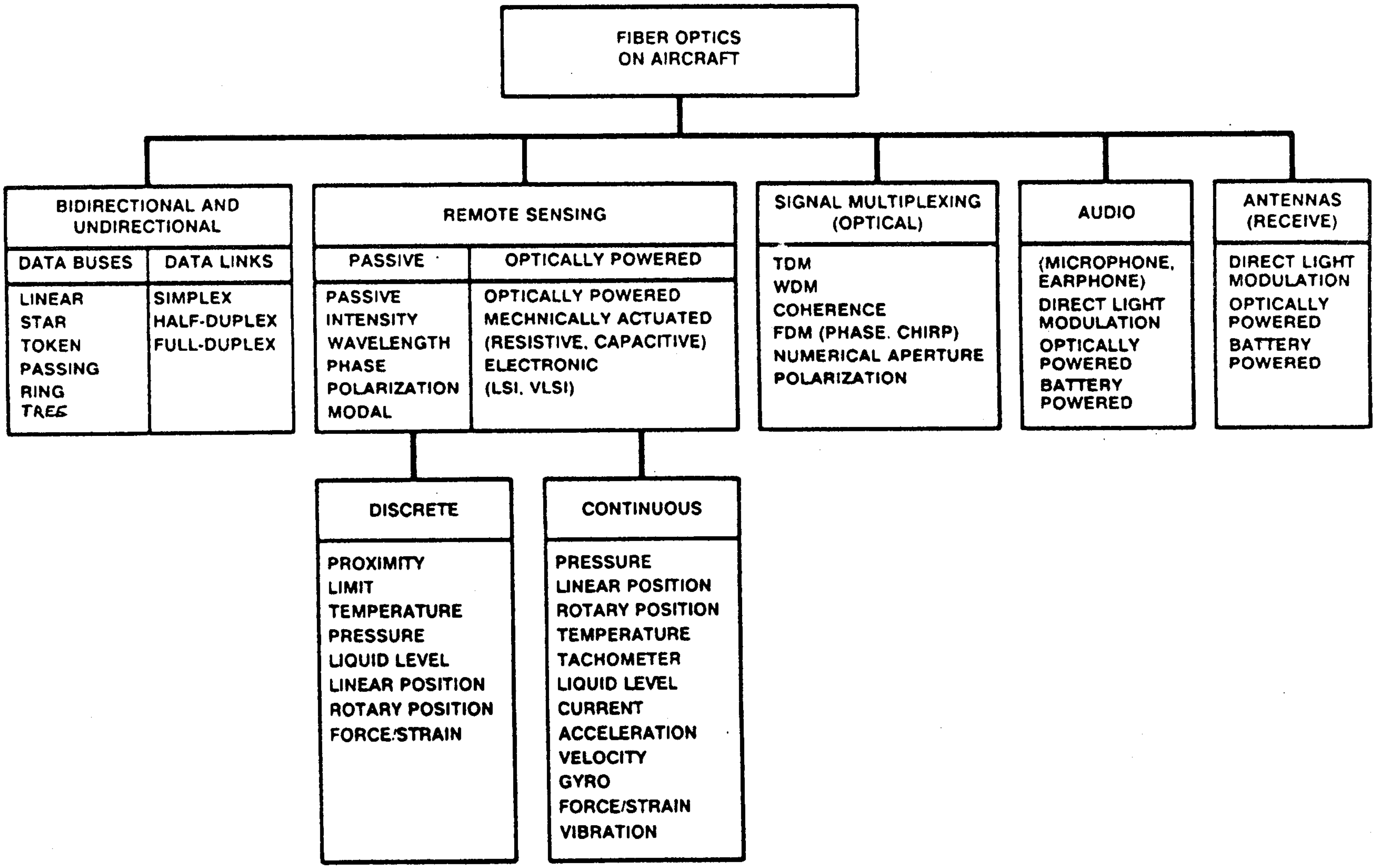
Widebody Flight Controls Life Cycle Cost Comparison per Aircraft

	Mechanical Baseline	Fly-By-Wire	Fly-By-Light
Non-Recurring		$30,000	$57,500
Recurring		($62,000)	($22,000)
Maintenance (Labor)		($240,000)	($426,000)
Equivalent Revenue (relative to baseline)		($3,409,000) nt	($7,146,000) nt
TOTAL		($3,681,000)	($7,536,500)
DIRECT OPERATING COST		4.5% reduction	7.4% reduction
RETURN ON INVESTMENT		5.1% improvement	10.2% improvement

* utilization 8 hrs/day
* 800 aircraft production run
* ave. life = 20 yrs.
* 60,000 flight hrs
* "()" additional profits above the mechanical baseline aircraft
* all types include flight guidance systems
* ave speed = 320 mi/hr
* ave yield = $0.10/passenger mi.
* load factor = 0.7
* "nt" = near term weight savings
* costs estimated in 1989 dollars
* ave for FBW and FBL configurations
* mechanical baseline includes flight engineer



EME Threat Trends



Aircraft Applications for Fiber Optics

Fiber Optic Developments for Aircraft

COMPONENT	DEVELOPMENT
FIBER	HIGH-TEMPERATURE GLASS AND PLASTIC IMPROVED BEND RADIUS RADIATION-HARDENED POLARIZATION PRESERVING PARAMETER-SENSITIVE RIBBON
CONNECTORS	VIBRATION- AND SHOCK-RESISTANT REPEATABLE TERMINATIONS CRIMP AND CLEAVE ENVIRONMENTALLY SEALED TEMPERATURE-INSENSITIVE RIBBON MULTIPIN MILITARY STANDARD AUTOMATED TERMINATION REDUCED LOSS
COUPLERS	TEMPERATURE- AND SHOCK-RESISTANT ETCHED GLASS TEMPERATURE-INSENSITIVE MULTICHANNEL WAVELENGTH DIVISION MULTIPLEXERS IMPROVED PACKAGING REDUCED LOSS
EMITTERS/DETECTORS	IMPROVED LAUNCH POWER/SENSITIVITY REDUCED ELECTRICAL POWER CONSUMPTION REDUCED TEMPERATURE DRIFT
SENSORS AND SWITCHES	VIABLE OPTICAL POWERING DIGITAL AND ANALOG TECHNIQUES IMPROVED PERFORMANCE AND RELIABILITY
OTHER	INTEGRATED OPTICS SMART SKINS OPTICAL COMPUTING

Potential Savings of 100-Percent Signal Path Conversion to Fiber

WEIGHT	1,000-1,500 LB/ACFT	
CONDUCTOR	$20,000/ACFT	
CABLE INSTALLATION DESIGN	35 PERCENT	50 PERCENT FEWER RUNS
WIRE DESIGN	45,000 HR	5 HR/SEGMENT
EMC DESIGN/TEST	35 PERCENT	
MFG LABOR	$45,000/ACFT $25,000/ACFT	$5/SEGMENT 500 HR/ACFT • $50

Impact of Signal Path Conversion to Fiber

	1985 ALL COPPER	1995 20-PERCENT FIBER	2000 50-PERCENT FIBER	2010 100-PERCENT FIBER
SIGNAL PATHS	3,900	3,510	2,925	1,950
CONDUCTOR LENGTH (MILES)	52	47	39	26
CONDUCTOR SEGMENTS (WIRES)	18,000	16,200	13,500	9,000
ROUTING PATHS	13	13	?	4

NOTES:
1. DATA BASED ON MD-80, DC-10, AND C-17 AVERAGED
2. ANALYSIS BASED ON 60 PERCENT OF PATHS BEING FOR SIGNALS

Potential Savings of 100-Percent Signal Path Conversion to Fiber

Benefits of Fiber Optics on Aircraft

SIMPLIFICATION BENEFITS

WEIGHT
- LESS CABLE
- LIGHTER CABLE
- NO CABLE SHIELDING
- FEWER CONNECTORS

RELIABILITY
- FEWER TERMINATIONS
- CORROSION-RESISTANT CABLES

INSTALLATION COSTS
- FEWER RUNS
- FEWER CLAMPS

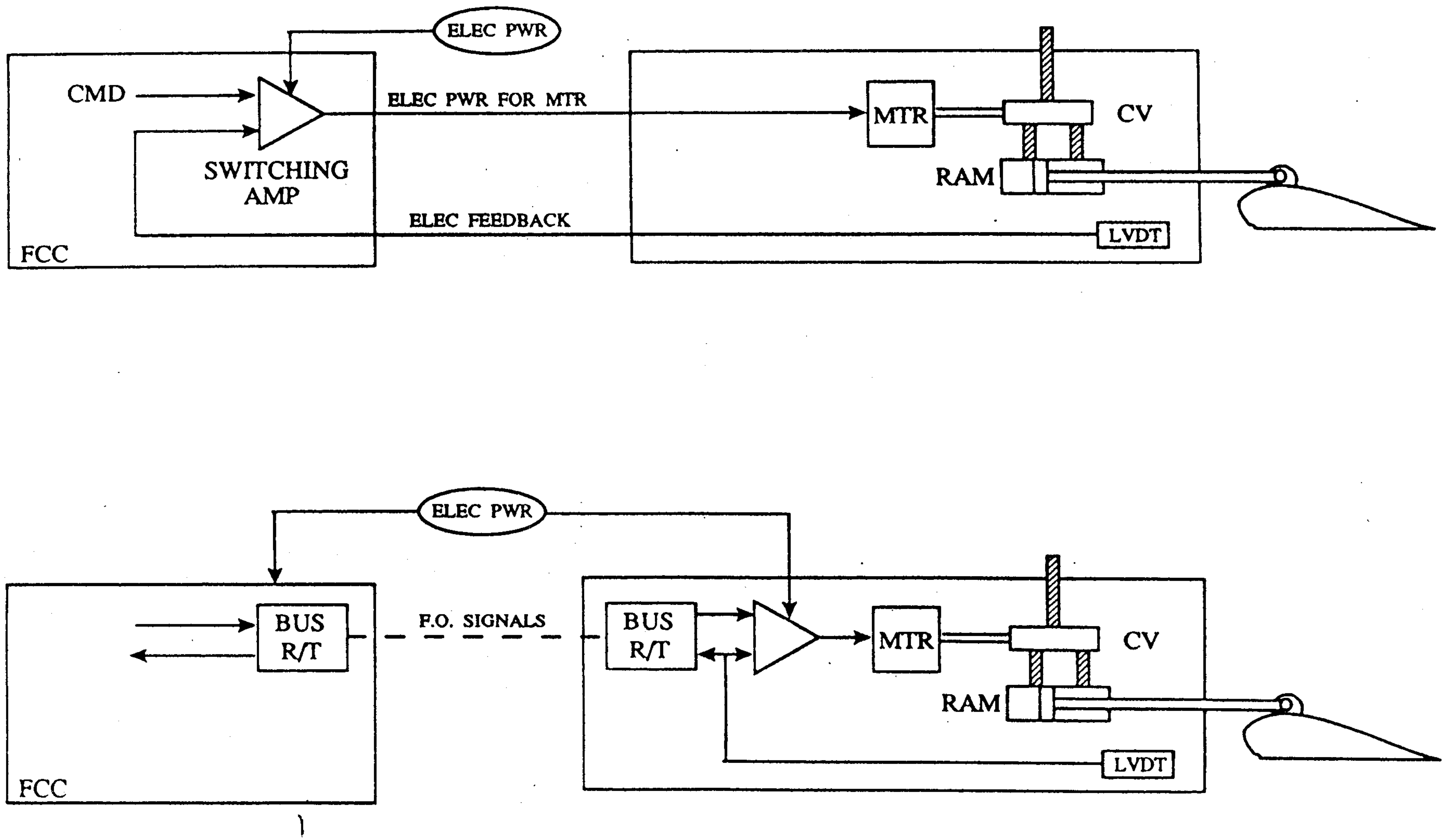
MATERIAL COSTS
- LESS CABLE
- FEWER CONTACTS

DESIGN SIMPLIFICATION
- FEWER SIGNAL PATHS
- SIMPLER WIRING DIAGRAMS

PERFORMANCE BENEFITS

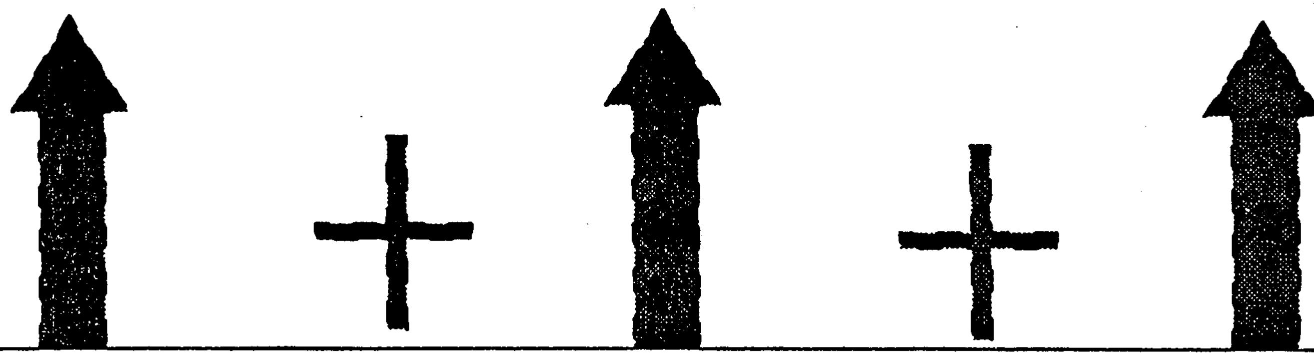
- ELECTRICAL ISOLATION
- NO SPARK OR FIRE HAZARDS
- NO SHORT CIRCUITS
- NO GROUND LOOPS
- NO CROSS TALK BETWEEN CABLES
- IMMUNITY TO EMI
- IMMUNITY TO LIGHTNING SURGE CURRENT
- WIDE BANDWIDTH
- GREATER TRANSMISSION SECURITY

BASELINE FBW VS FBL ACTUATOR INTERFACE



BACKGROUND

EME THREAT TRENDS



- EME INCREASING ON GLOBAL SCALE
  - RADIO FREQUENCIES/HIGH ENERGY
    RF (HERF)
    RADIO, TV, RADAR, MICROWAVE
  - AIRCRAFT POWER SYSTEMS
  - AIRCRAFT ELECTRONICS
  - LIGHTNING
  - MILITARY
    DIRECTED ENERGY WEAPONS
    ECM

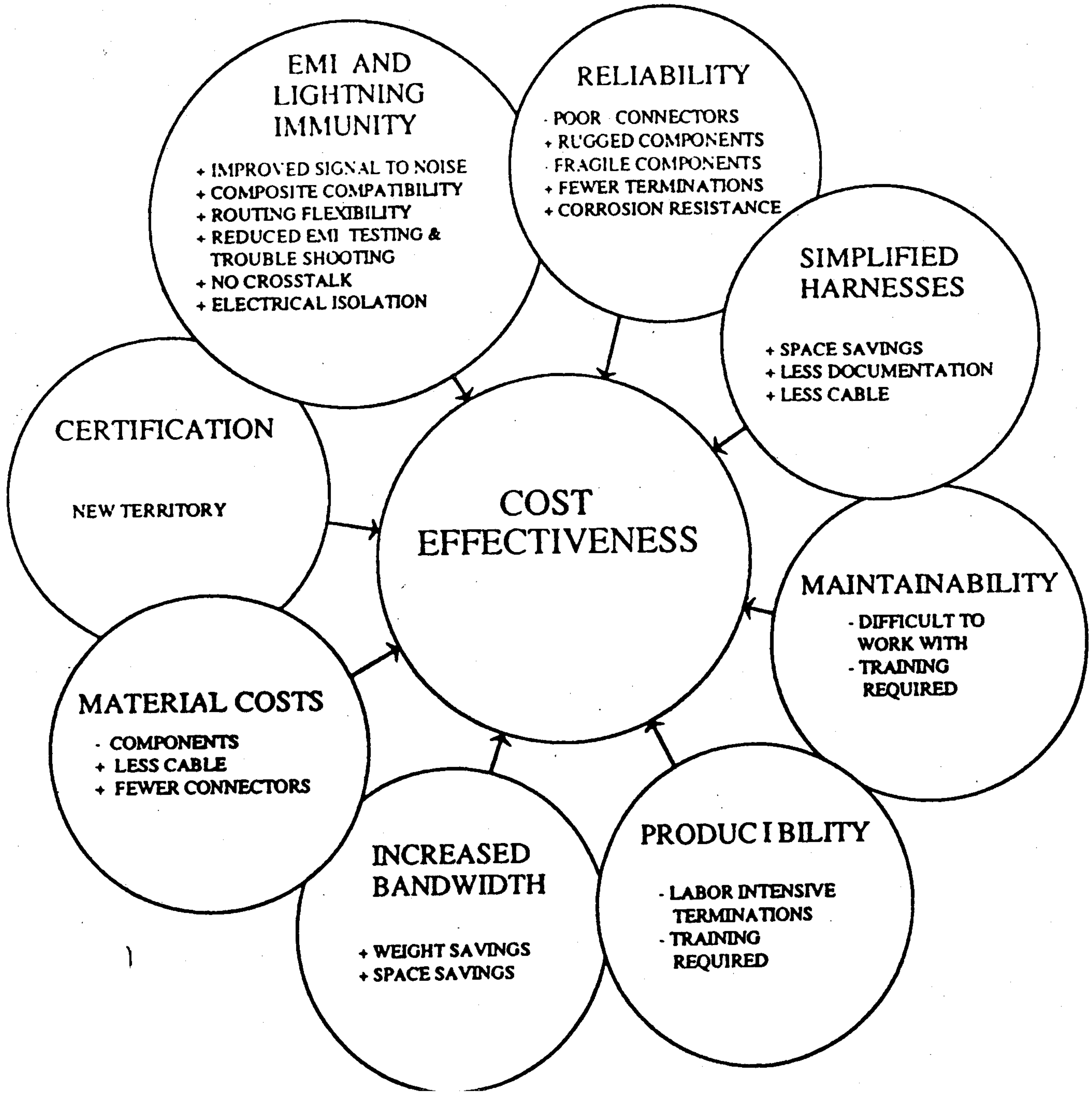
- AIRCRAFT OPERATIONS ARE INCREASINGLY DEPENDENT ON ELECTRONIC SYSTEMS
  - FLY-BY-WIRE/FLY-BY-LIGHT FLIGHT CONTROLS
  - FULL AUTHORITY DIGITAL ENGINE CONTROLS
  - INTEGRATED AIRCRAFT CONTROL SYSTEMS

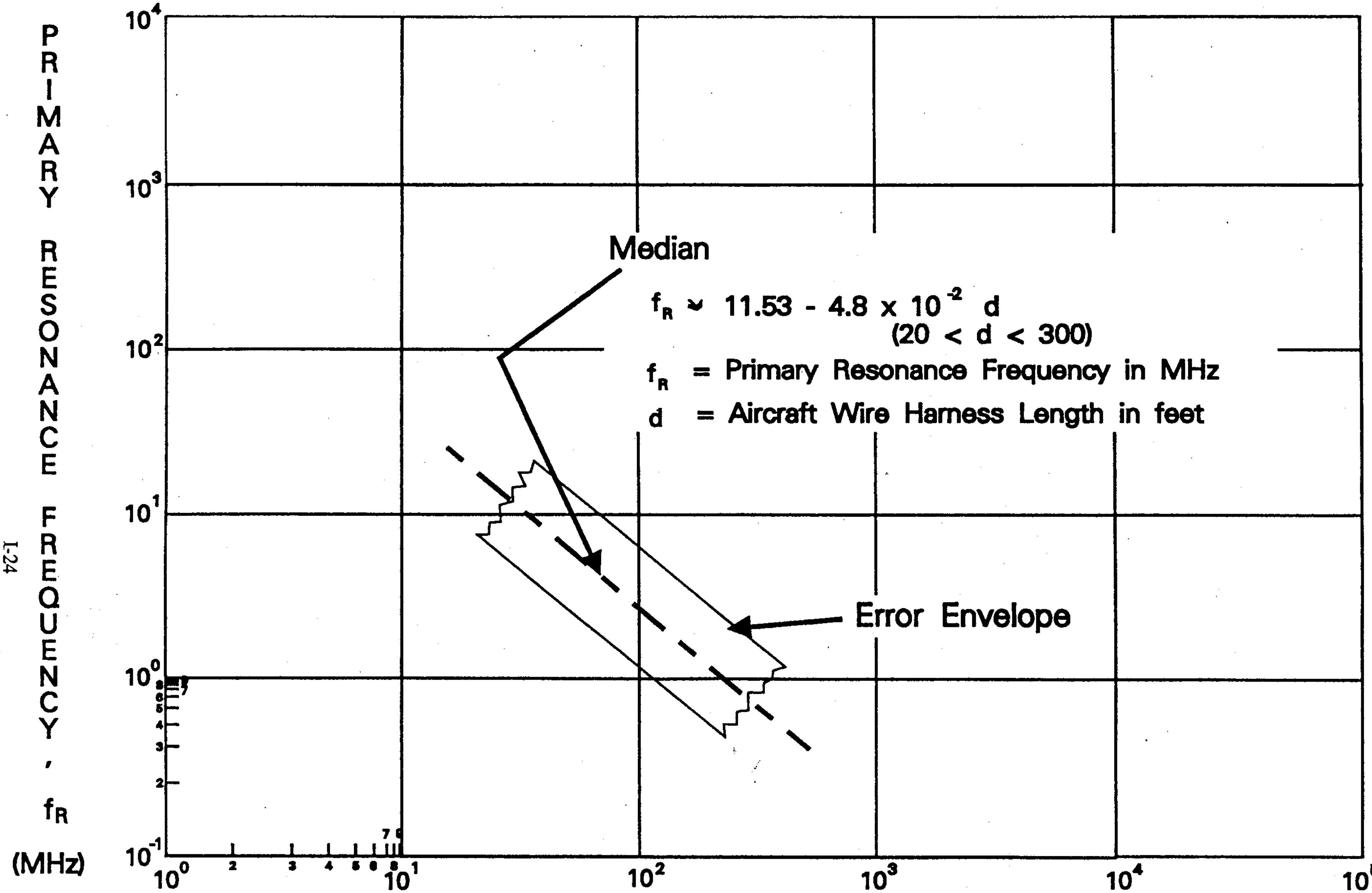
- AVIONICS SUSCEPTIBILITY TO EME IS INCREASING
  - TRADITIONAL SHIELDING IS BEING COMPROMISED
    - COMPOSITE VS. METALLIC STRUCTURE
  - ENERGY TO INDUCE UPSET IS DECREASING

Driving Forces for Fiber Optics on Aircraft

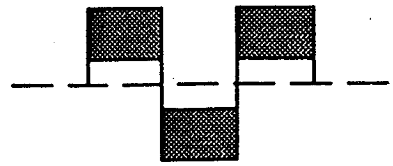
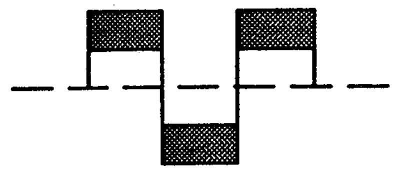
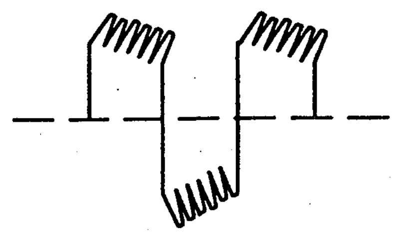
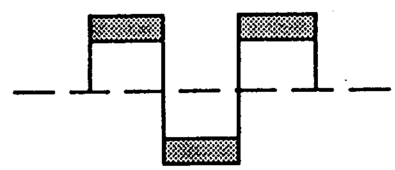
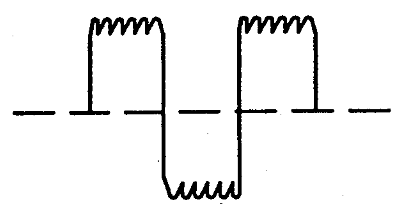
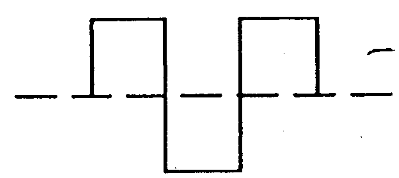
SOURCE	NEED	FIBER OPTICS SOLUTION
MILITARY	HIGH DATA TRANSMISSION RATES	HIGH BANDWIDTH, LIGHTWEIGHT
MILITARY	EMI/RFI IMMUNITY • INCREASED USE OF COMPOSITES • NUCLEAR BLAST PROXIMITY EMP • ELECTRONIC WARFARE • FLY-BY-WIRE SYSTEMS (SAFETY)	INHERENT EMI/RFI IMMUNITY
GOVERNMENT	TECHNOLOGY COMPETITIVENESS	ADVANCED TECHNOLOGY
COMMERCIAL	EMI/RFI IMMUNITY • INCREASED USE OF COMPOSITES • FLY-BY-WIRE SYSTEMS (SAFETY) • HIGHER FEDERAL REQUIREMENTS	INHERENT EMI/RFI IMMUNITY
SUPPLIERS	FUTURE PROFITS	EXPANDING MARKET

FIBER OPTIC TRADEOFFS





GENERAL RELATIONSHIP BETWEEN ELECTROMAGNETIC PRIMARY RESONANCE FREQUENCY AND AIRCRAFT WIRE HARNESS LENGTH (LOG-LOG scale)

MEDIUM	OUTPUT SIGNAL QUALITY	OUTPUT WAVEFORM
Single Conductor (above conductive plane)	VERY POOR	
Twisted Shielded Pair (shielding not properly terminated)	POOR	
Twisted Unshielded Pair	FAIR	
Co-Axial Cable	FAIR	
Twisted Shielded Pair (shielding properly terminated)	GOOD	
Fiber Optic Cable	EXCELLENT	

GENERALIZED RESULTS OF CONDUCTED SUSCEPTIBILITY FOR 80Kbps TO 2Mbps 100 v/m RTCA D0 160C DEFINED 100 v/m INTERFERENCE LEVELS FROM 10 HZ TO 400 MHz

APPENDIX J

ENGINE-STARTING DATA FOR GENERAL ELECTRIC CF6-80C2 ENGINES

STARTER TORQUE CHARACTERISTICS
CF6-80C2 ENGINE

ENGINE DRAG TORQUE (LB/FT G)	LDGS DRAG TORQUE (LB-IN. G' x 12)	SPEED (RPM)	POWER P (LB-FPS)	KVA AT HP ROTOR	KVA AT STARTER PAD	HORSEPOWER AT STARTER PAD
630	130	10	671	0.910	0.952	1.276
620	450	100	6,882	9.334	9.763	13.087
610	625	200	13,860	18.799	19.662	26.356
575	1,000	500	34,453	46.730	48.876	65.518
540	925	800	51,670	70.084	73.302	98.260
518	875	1,000	61,849	83.890	87.742	117.617
410	625	2,000	96,729	131.200	137.224	183.947
310	600	3,000	113,040	153.323	160.363	214.964
220	515	4,000	110,074	149.301	156.156	209.325
170	515	4,500	100,284	136.021	142.267	190.706

P = (G + G')w = (G + G') x RPM x 2 pi/60

KVA at HP rotor = P x 0.746/550,000

Starter (KVA) = KVA at high-pressure rotor/0.956

NOTES:

1. CF6-80C2 FADEC Instl Manual, 35-sec start requirement at 59°F
2. IDGS drag torque from Sundstrand curve for a 120-KVA unit at –40°F
3. 0 ft-lb used as margin

Recommended starter size:

Starter size = max torque required + no margin.

Starter size = ((370 x 600/12) x 3,000 x 2 pi)/6

= F38 x 0.746/550,000/0.956 = 160.363 KVA

4. 70 ft-lb used as margin

Recommended starter size

Starter size = max torque required + 70 lb-ft margin

Starter size = ((310 + 600/12) x 3,000 x 2 pi)/6

= F38 x 0.746/550,000/0.956 = 191.545 KVA

5. 45 ft-lb used as margin

Recommended starter size:

Starter size = max torque required + 45 lb-ft margin

Starter size = ((310 + 600/12) x 3,000 x 2 pi)/6

= F38 x 0.746/550,000/0.956 = 180.409 KVA

6. Assumes that starter and generator efficiency are equal at 88 percent

APPENDIX K
COST ANALYSES DATA

ALL ELECTRIC TRIJET AIRCRAFT
COST COMPARISONS
($ MILLION, 1990)

	TRIJET BASELINE	ALL ELECTRIC TRIJET NONRESIZED	ALL ELECTRIC TRIJET RESIZED
RDT&E	$	$	$
ENGINEERING	1,198.702	1,124.352	1,116.189
TEST AND DEVELOPMENT	671.480	654.305	650.521
INITIAL TOOLING	817.983	822.931	816.316
SUPPLIER NONRECURRING	906.657	956.240	942.064
FSD ILS	57.550	54.969	54.594
PROJECT MANAGEMENT	118.352	115.165	114.338
TOTAL RDT&E	3770.725	3,727.963	3,694.023
PRODUCTION			
TOTAL (800 AIRCRAFT)	68,662.278	67,030.819	66,474.957
UNIT AVERAGE	85.828	83.789	83.094
PRODUCT SUPPORT			
NONRECURRING	308.980	301.639	299.137
RECURRING	2,972.219	2,901.596	2,877.535
TOTAL PRODUCT SUPPORT	3,281.199	3,203.235	3,176.672

EACH AIRCRAFT ASSUMED TO BE ALL NEW, NONDERIVATIVE IN DESIGN AND CONFIGURATION.

OPERATING COST COMPARISON - DOLLARS PER TRIP
1990 ESTIMATES
3000 N MILES

		BASE	ALL-ELEC	ALL-ELEC RESIZED
Seats		323	323	323
Passengers		323	323	323
Revenue Cargo	**(Lb)**	0	0	0
Study Payload	**(Lb)**	67,830	67,830	67,830
Study Price	**($M)**	0.00	0.00	0.00
MTOW	**(Lb)**	602,500	596,500	591,500
Fuel Capacity	**(Lb)**	258,966	258,966	258,966
OEW	**(Lb)**	278,400	276,100	273,000
Block Time	**(Hr)**	6.775	6.776	6.779
Utilization:	**(B.Hr/Yr)**	4,234	4,235	4,237
Trip Costs	**($/Trip)**			
Flight Crew		5,056	5,036	5,020
Cabin Crew		6,674	6,675	6,678
Maintenance		8,608	8,386	8,391
Navigation		1,227	1,221	1,216
Landing Fee		2,350	2,326	2,307
Fuel @ 0.60 $/gal		8,211	8,112	8,037
Total Cash Cost	**($/Trip)**	**32,126**	**31,756**	**31,649**
	($/Seat)	99.46	98.32	97.98
	(%)	0.00	-1.15	-1.48
Yearly Savings	**($)**	**Base**	**231,250**	**298,125**

COST ASSUMPTIONS IN 1990 DOLLARS

Cost Assumptions

Flight Crew		
Two Crew	$/BH	430. + 0.525 MTOW/1000
Three Crew	$/BH	538. + 0.656 MTOW/1000
Cabin Crew	$/BH/Seat	3.05
Maintenance		
Labor Rate	$/MMH	30.00
Labor Burden	%	350.
Fuel	$/U.S.Gal.	0.60
Fuel Density	Lb/U.S.Gal.	6.70
Navigation	$/N Mi	0.100 * SQRT OF MTOW/1000 * 500. N Mi
Landing Fees	$/Trip	3.90 * MTOW/1000

Performance Assumptions

Range	N Mi	3000
Ground Maneuver Time	Minutes	14
Fuel Burn Markup	%	0.0
OEW Markup	%	0.0

Study Payload Assumptions

Weight per Passenger	Lbs	165.0
Weight per Passenger Bags	Lbs	45.0
Baggage and Freight Density	Lb/Cu Ft	10.0
Passenger Load Factor	%	100.
Freight Load Factor	%	0.
Equiv. Rev. Seats per Ton Freight		4.0

AVOID VERBAL INSTRUCTIONS

AVI-C1-RWS-91-197

31 July 1991

TO: L. Feiner

FROM: R. Schmid

SUBJECT: All - Electric Tri-jet Study

COPIES: R. S. Bird, D. Kosmal, G. S. Page, C. J. Turner, File.

This AVI summarizes the performance data requested for three versions of the tri-jet aircraft studied. The results are tabulated below for the baseline aircraft, an unresized aircraft (with an operating empty weight reduction of 2304 pounds and a SFC improvement of 0.67%), and a resized aircraft including the improvements mentioned.

	BASELINE	ALL-ELECTRIC UNRESIZED	ALL-ELECTRIC RESIZED
ENGINE	GE	GE	GE
MTOGW (lbs)	602,500	596,500	591,500
OEW (lbs)	278,400	276,100	273,000
Passengers	323	323	323
Payload (lbs)	67,830	67,830	67,830
Thrust /Engine (lbs)	61,500	61,500	60,225
Wing Area (sq. ft)	3647.5	3647.5	3588.7
Range (n. mi.)	6,600	6,600	6,600
Approach Speed (KEAS)	138.8	137.8	138.8
TOFL (ft)	10,550	10,200	10,550
3000 N MI Mission			
Block Fuel (lbs)	91,692	90,588	89,750
Block Time (hrs)	6.8	6.8	6.8

The methodology for resizing the aircraft was to keep the landing approach speed, takeoff field length, and range all constant.

Roland Schmid
Aerodynamics
Advanced Design Engineering

PARAMETRIC COST SUMMARY S1
(CY90 M$) TRIJET BASELINE 02-Aug-91

WORK ELEMENT	NOMENCLATURE	CONTRACTOR COST	FEE @	COST (CY90 M$)	UNIT COST	REF
100	AIRCRAFT RDT&E					
110	ENGINEERING	1198.702		1198.702		S2
120	MOCKUP, TEST & DEVELOPMENT	671.480		671.480		S2
130	INITIAL TOOLING	817.983		817.983		S2
140	SUPPLIER NON-RECURRING	906.657		906.657		S2
150	FSD ILS	57.550		57.550		S2
160	PROJECT MANAGEMENT	118.352		118.352		S2
	AIRCRAFT RDT&E TOTAL	3770.725		3770.725		
200	PRODUCTION					
210	PRODUCTION LOT 1 - 200 A/C	20892.376		20892.376	104.462	S3A
220	PRODUCTION LOT 2 - 200 A/C	16711.332		16711.332	83.557	S3B
230	PRODUCTION LOT 3 - 200 A/C	15773.158		15773.158	78.866	S3C
240	PRODUCTION LOT 4 - 200 A/C	15285.412		15285.412	76.427	S3D
	PRODUCTION TOTAL	68662.278		68662.278	85.828	
300	PRODUCT SUPPORT (AIRFRAMER FURNISHED)					
300 R&D	PRODUCT SUPPORT N. R.			308.980		S4
310	PECULIAR GROUND SUPPORT EQUIPMENT			146.766		S4
320	TRAINING SERVICES & EQUIPMENT			326.146		S4
330	ENGINEERING & SUPPORT DATA			514.967		S4
340	INITIAL SPARES			1922.544		S4
350	SITE ACTIVATION/FIELD SERVICES			61.796		S4
	AIRFRAMER FURNISHED PRODUCT SUPPORT TOTAL			3281.199		
	COMMERCIAL PROGRAM COST TOTAL			75714.201		
	UNIT PRODUCTION FLYAWAY COST		800 UNITS	85.828		
	AMORTISED N.R. COST PER UNIT		100 UNITS	37.707		

TRIJET BASELINE PRODUCTION SUMMARY	LOT 1	LOT 2	LOT 3	LOT 4	AVERAGE
AIRCRAFT UNIT FLYAWAY COST	104.462	83.557	78.866	76.427	85.828
ENGINES WITH PODS/TR	21.556	21.556	21.556	21.556	21.556
BFE SEATS & GALLEYS	1.711	1.492	1.418	1.372	1.498
BFE AVIONICS	2.273	2.190	2.139	2.101	2.176
AIRFRAME & FIXED EQUIPMENT	78.921	58.319	53.753	51.398	60.598

RDT&E COST SUMMARY S2

(CY90 M$) TRIJET BASELINE 02-Aug-91

WE		COST ELEMENT	INPUT	MARKUP	COST	REF
110		ENGINEERING	12853056	89.68	1152.598	L1
ENGR	0.04	ODC $	42.297	1.09	46.104	
		110 TOTAL ENGINEERING			1198.702	
120		MATERIAL (HIGH VALUE) $	5.315	1.05	5.581	L5B
MOCKUP		MATERIAL (MFG) $	71.752	1.05	75.315	L5B
TEST &		ENGINEERING TEST	1807125	86.51	156.334	L2
DEVEL		DEVELOPMENT	3634917	50.64	184.072	L2
		ENGINEERING LIAISON		89.68		L7A
		MANUFACTURING	3307148	50.64	167.474	L4A
		MANUFACTURING SUPPORT	69421	54.86	3.808	L7A
		QUALITY ASSURANCE	784453	56.97	44.690	L7A
		TOOLING M & R	152725	54.86	8.379	L7A
	0.04	ODC $	23.694	1.09	25.826	
		120 TOTAL MCKUP TEST & DEV			671.480	
130		MATERIAL (MFG) $	60.906	1.05	63.931	L5B
INITIAL		TOOLING	11937672	54.86	654.901	L3
TOOLING		MANUFACTURING SUPPORT	596884	54.86	32.745	L7A
		QUALITY ASSURANCE	656572	56.97	37.405	L7A
	0.04	ODC $	26.607	1.09	29.002	
		130 TOTAL INITIAL TOOLING			817.983	
140		MATERIAL (HIGH VALUE) $	25.347	1.05	26.615	A5B
SUPPLIER		MATERIAL (MFG) $	805.191	1.05	845.171	A5B
NR		ENGINEERING		89.68		A7A
		ILS		82.29		A7A
		MANUFACTURING		50.64		A4A
		MANUFACTURING SUPPORT		54.86		A7A
		QUALITY ASSURANCE		56.97		A7A
		TOOLING M&R		54.86		A7A
	0.04	ODC $	31.992	1.09	34.871	
		140 TOTAL SUPPLIER N.R.			906.657	
150		MATERIAL (HIGH VALUE) $	10.015	1.05	10.516	L6
ILS		MATERIAL (MFG) $	2.003	1.05	2.102	L6
		ILS	519116	82.29	42.718	L6
	0.04	ODC $	2.031	1.09	2.213	
		150 TOTAL ILS			57.550	
160		PROJECT MANAGEMENT	1198530	94.95	113.800	L8
PROJECT	0.04	ODC $	4.176	1.09	4.552	
MGT						
		160 TOTAL PROJECT MGMT			118.352	
		TOTAL RDT&E COST	(CY90 M$)		3770.725	

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PRODUCTION COST SUMMARY LOT 1 S3A
(CY90 M$) TRIJET BASELINE 02-Aug-91

WE		COST ELEMENT	INPUT	MARKUP	PRODUCTION COST	REF
210		MATERIAL (MFG) $	8.177	1.05	8.583	M5B
RATE		TOOLING	1635461	54.86	89.721	L3
TOOLING		MANUFACTURING SUPPORT	81773	54.86	4.486	L7A
		QUALITY ASSURANCE	89950	56.97	5.124	L7A
	0.04	ODC $	3.960	1.09	4.317	
		210 TOTAL RATE TOOLING			112.232	
		MATERIAL (HIGH VALUE) $	5374.323	1.05	5643.039	M5C
		MATERIAL (MFG) $	4640.600	1.05	4871.019	M5C
		ENGINEERING	8810464	89.68	790.078	L7A
PRO-		TEST ENGINEERING	83858	86.51	7.255	L2
DUCTION		ILS	2202616	82.29	181.253	L7A
220		MANUFACTURING	110130796	50.64	5577.024	L4B
		MANUFACTURING SUPPORT	13215696	54.86	725.013	L7A
		QUALITY ASSURANCE	16519619	56.97	941.123	L7A
		TOOLING M&R	13215696	54.86	725.013	L7A
	0.04	ODC $	714.158	1.09	778.433	
		220A TOTAL PRODUCTION			20239.248	
230		PROJECT MANAGEMENT	5477536	94.95	520.092	L8
PROJECT	0.04	ODC $	19.086	1.09	20.804	
MGMT						
		230 TOTAL PROJECT MGMT			540.896	
		TOTAL LOT 1 PRODUCTION COST	200	EACH	$20892.376	
		UNIT PRODUCTION COST			$ 104.462	

PRODUCTION COST SUMMARY LOT 2 S3B
(CY90 M$) TRIJET BASELINE 02-Aug-91

WE		COST ELEMENT	INPUT	MARKUP	PRODUCTION COST	REF
210		MATERIAL (MFG) $		1.05		M5D
RATE		TOOLING		54.86		L3
TOOLING		MANUFACTURING SUPPORT		54.86		L7B
		QUALITY ASSURANCE		56.97		L7B
	0.04	ODC $		1.09		
		210 TOTAL RATE TOOLING				
		MATERIAL (HIGH VALUE) $	5312.569	1.05	5578.197	M5D
		MATERIAL (MFG) $	4045.591	1.05	4246.465	M5D
		ENGINEERING	5812097	89.68	521.200	L7B
PRO-		TEST ENGINEERING	83858	86.51	7.255	L2
DUCTION		ILS	1453024	82.29	119.569	L7B
220		MANUFACTURING	72651208	50.64	3679.057	L4C
		MANUFACTURING SUPPORT	8718145	54.86	478.277	L7B
		QUALITY ASSURANCE	10897681	56.97	620.841	L7B
		TOOLING M&R	8718145	54.86	478.277	L7B
	0.04	ODC $	577.216	1.09	629.166	
		220A TOTAL PRODUCTION			16358.305	
230		PROJECT MANAGEMENT	3575027	94.95	339.449	L8
PROJECT	0.04	ODC $	12.457	1.09	13.578	
MGMT						
		230 TOTAL PROJECT MGMT			353.027	
		TOTAL LOT 2 PRODUCTION COST	200	EACH	$16711.332	
		UNIT PRODUCTION COST			$ 83.557	

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PRODUCTION COST SUMMARY LOT 3 S3C

(CY90 M$) TRIJET BASELINE 02-Aug-91

WE		COST ELEMENT	INPUT	MARKUP	PRODUCTION COST	REF
210		MATERIAL (MFG) $		1.05		M5D
RATE		TOOLING		54.86		L3
TOOLING		MANUFACTURING SUPPORT		54.86		L7B
		QUALITY ASSURANCE		56.97		L7B
	0.04	ODC $		1.09		
		210 TOTAL RATE TOOLING				
		MATERIAL (HIGH VALUE) $	5286.014	1.05	5550.315	M5D
		MATERIAL (MFG) $	3845.265	1.05	4036.193	M5D
		ENGINEERING	5193334	89.68	465.712	L7B
PRO-		TEST ENGINEERING	83858	86.51	7.255	L2
DUCTION		ILS	1298334	82.29	106.840	L7B
220		MANUFACTURING	64916680	50.64	3287.381	L4C
		MANUFACTURING SUPPORT	7790002	54.86	427.359	L7B
		QUALITY ASSURANCE	9737502	56.97	554.745	L7B
		TOOLING M&R	7790002	54.86	427.359	L7B
	0.04	ODC $	545.437	1.09	594.526	
		220A TOTAL PRODUCTION			15457.686	
230		PROJECT MANAGEMENT	3194720	94.95	303.339	L8
PROJECT	0.04	ODC $	11.132	1.09	12.134	
MGMT						
		230 TOTAL PROJECT MGMT			315.472	
		TOTAL LOT 3 PRODUCTION COST	200	EACH	$15773.158	
		UNIT PRODUCTION COST			$ 78.866	

PRODUCTION COST SUMMARY LOT 4 S3D
(CY90 M$) TRIJET BASELINE 02-Aug-91

WE		COST ELEMENT	INPUT	MARKUP	PRODUCTION COST	REF
210		MATERIAL (MFG) $		1.05		M5D
RATE		TOOLING		54.86		L3
TOOLING		MANUFACTURING SUPPORT		54.86		L7B
		QUALITY ASSURANCE		56.97		L7B
	0.04	ODC $		1.09		
		210 TOTAL RATE TOOLING				
		MATERIAL (HIGH VALUE) $	5267.049	1.05	5530.401	M5D
		MATERIAL (MFG) $	3720.627	1.05	3905.366	M5D
		ENGINEERING	4896741	89.68	439.115	L7B
PRO-		TEST ENGINEERING	83858	86.51	7.255	L2
DUCTION		ILS	1224185	82.29	100.738	L7B
220		MANUFACTURING	61209264	50.64	3099.637	L4C
		MANUFACTURING SUPPORT	7345112	54.86	402.953	L7B
		QUALITY ASSURANCE	9181390	56.97	523.064	L7B
		TOOLING M&R	7345112	54.86	402.953	L7B
	0.04	ODC $	528.862	1.09	576.459	
		220A TOTAL PRODUCTION			14987.941	
230		PROJECT MANAGEMENT	3012427	94.95	286.030	L8
PROJECT	0.04	ODC $	10.497	1.09	11.441	
MGMT						
		230 TOTAL PROJECT MGMT			297.471	
		TOTAL LOT 4 PRODUCTION COST	200	EACH	$15285.412	
		UNIT PRODUCTION COST			$ 76.427	

SUPPORT INVESTMENT S4
(CY90 M$) TRIJET BASELINE 02-Aug-91

	PRODUCTION AUTHORIZATION	800 EACH	
	A/C PRODUCTION COST (FLYAWAY)	68662.278	
	UNIT FLYAWAY COST	85.828	

WORK ELEMENT	ILS INVESTMENT ELEMENT	f(FLYAWAY COST)	ILS INVEST
310	PECULIAR GROUND SUPPORT EQUIP	0.015	1029.934
320	TRAINING EQUIP/SERVICES	0.025	1716.557
330	SUPPORT DATA	0.010	686.623
340	INITIAL SPARES	0.040	2746.491
	SUBTOTAL ILS INVESTMENT LESS SITE ACTIVATION		6179.605
		F(ILS SUBTOT)	
350	SITE ACTIVATION/FIELD SERVICE	0.050	308.980
	TOTAL ILS INVESTMENT		6488.585

PRODUCT SUPPORT INVESTMENT ALLOCATION (CY90 M$) TRIJET BASELINE	AIRFRAMER PRODUCT SUPPORT RDT&E	AIRLINE RECURRING PRODUCT SUPPORT	AIRFRAMER FURNISHED PRODUCT SUPPORT
PECULIAR GROUND SUPPORT EQUIP	51.497	978.437	146.766
TRAINING EQUIP/SERVICES	85.828	1630.729	326.146
SUPPORT DATA	171.656	514.967	514.967
INITIAL SPARES		2746.491	1922.544
SITE ACTIVATION/FIELD SERVICE		308.980	61.796
TOTAL AIRFRAMER NONRECURRING	308.980		
TOTAL AIRLINE SUPPORT INVESTMENT		6179.605	
TOTAL AIRFRAMER SUPPORT INVESTMENT			2972.218

PARAMETRIC COST SUMMARY S1
(CY90 M$) TRIJET ALL ELECT. A/C (not resized) 02-Aug-91

WORK ELEMENT	NOMENCLATURE	CONTRACTOR COST	FEE @	COST (CY90 M$)	UNIT COST	REF
100	AIRCRAFT RDT&E					
110	ENGINEERING	1124.352		1124.352		S2
120	MOCKUP, TEST & DEVELOPMENT	654.305		654.305		S2
130	INITIAL TOOLING	822.931		822.931		S2
140	SUPPLIER NON-RECURRING	956.240		956.240		S2
150	FSD ILS	54.969		54.969		S2
160	PROJECT MANAGEMENT	115.165		115.165		S2
	AIRCRAFT RDT&E TOTAL	3727.963		3727.963		
200	PRODUCTION					
210	PRODUCTION LOT 1 - 200 A/C	20378.233		20378.233	101.891	S3A
220	PRODUCTION LOT 2 - 200 A/C	16315.796		16315.796	81.579	S3B
230	PRODUCTION LOT 3 - 200 A/C	15404.982		15404.982	77.025	S3C
240	PRODUCTION LOT 4 - 200 A/C	14931.808		14931.808	74.659	S3D
	PRODUCTION TOTAL	67030.819		67030.819	83.789	
300	PRODUCT SUPPORT (AIRFRAMER FURNISHED)					
300 R&D	PRODUCT SUPPORT N. R.			301.639		S4
310	PECULIAR GROUND SUPPORT EQUIPMENT			143.278		S4
320	TRAINING SERVICES & EQUIPMENT			318.396		S4
330	ENGINEERING & SUPPORT DATA			502.731		S4
340	INITIAL SPARES			1876.863		S4
350	SITE ACTIVATION/FIELD SERVICES			60.328		S4
	AIRFRAMER FURNISHED PRODUCT SUPPORT TOTAL			3203.235		
	COMMERCIAL PROGRAM COST TOTAL			73962.017		
	UNIT PRODUCTION FLYAWAY COST	800 UNITS		83.789		
	AMORTISED N.R. COST PER UNIT	100 UNITS		37.280		

TRIJET ALL ELECT. A/C (not resized) PRODUCTION SUMMARY	LOT 1	LOT 2	LOT 3	LOT 4	AVERAGE
AIRCRAFT UNIT FLYAWAY COST	101.891	81.579	77.025	74.659	83.789
ENGINES WITH PODS/TR	21.556	21.556	21.556	21.556	21.556
BFE SEATS & GALLEYS	1.711	1.492	1.418	1.372	1.498
BFE AVIONICS	2.273	2.190	2.139	2.101	2.176
AIRFRAME & FIXED EQUIPMENT	76.351	56.341	51.912	49.630	58.558

RDT&E COST SUMMARY S2

(CY90 M$) TRIJET ALL ELECT. A/C (not resized) 02-Aug-91

WE		COST ELEMENT	INPUT	MARKUP	COST	REF
110		ENGINEERING	12055842	89.68	1081.108	L1
ENGR	0.04	ODC $	39.674	1.09	43.244	
		110 TOTAL ENGINEERING			1124.352	
120		MATERIAL (HIGH VALUE) $	5.315	1.05	5.581	L5B
MOCKUP		MATERIAL (MFG) $	69.113	1.05	72.545	L5B
TEST &		ENGINEERING TEST	1757635	86.51	152.053	L2
DEVEL		DEVELOPMENT	3532628	50.64	178.892	L2
		ENGINEERING LIAISON		89.68		L7A
		MANUFACTURING	3248595	50.64	164.509	L4A
		MANUFACTURING SUPPORT	67812	54.86	3.720	L7A
		QUALITY ASSURANCE	766278	56.97	43.655	L7A
		TOOLING M & R	149187	54.86	8.184	L7A
	0.04	ODC $	23.088	1.09	25.166	
		120 TOTAL MCKUP TEST & DEV			654.305	
130		MATERIAL (MFG) $	61.275	1.05	64.317	L5B
INITIAL		TOOLING	12009880	54.86	658.862	L3
TOOLING		MANUFACTURING SUPPORT	600494	54.86	32.943	L7A
		QUALITY ASSURANCE	660543	56.97	37.631	L7A
	0.04	ODC $	26.768	1.09	29.177	
		130 TOTAL INITIAL TOOLING			822.931	
140		MATERIAL (HIGH VALUE) $	25.347	1.05	26.615	A5B
SUPPLIER		MATERIAL (MFG) $	850.611	1.05	892.846	A5B
NR		ENGINEERING		89.68		A7A
		ILS		82.29		A7A
		MANUFACTURING		50.64		A4A
		MANUFACTURING SUPPORT		54.86		A7A
		QUALITY ASSURANCE		56.97		A7A
		TOOLING M&R		54.86		A7A
	0.04	ODC $	33.742	1.09	36.778	
		140 TOTAL SUPPLIER N.R.			956.240	
150		MATERIAL (HIGH VALUE) $	9.812	1.05	10.303	L6
ILS		MATERIAL (MFG) $	1.963	1.05	2.060	L6
		ILS	492066	82.29	40.492	L6
	0.04	ODC $	1.940	1.09	2.114	
		150 TOTAL ILS			54.969	
160		PROJECT MANAGEMENT	1166252	94.95	110.736	L8
PROJECT	0.04	ODC $	4.064	1.09	4.429	
MGT						
		160 TOTAL PROJECT MGMT			115.165	
		TOTAL RDT&E COST	(CY90 M$)		3727.963	

PRODUCTION COST SUMMARY LOT 1 S3A

(CY90 M$) TRIJET ALL ELECT. A/C (not resized) 02-Aug-91

WE		COST ELEMENT	INPUT	MARKUP	PRODUCTION COST	REF
210		MATERIAL (MFG) $	8.047	1.05	8.446	M5B
RATE		TOOLING	1609324	54.86	88.288	L3
TOOLING		MANUFACTURING SUPPORT	80466	54.86	4.414	L7A
		QUALITY ASSURANCE	88513	56.97	5.043	L7A
	0.04	ODC $	3.897	1.09	4.248	
		210 TOTAL RATE TOOLING			110.438	
		MATERIAL (HIGH VALUE) $	5374.323	1.05	5643.039	M5C
		MATERIAL (MFG) $	4437.015	1.05	4657.324	M5C
		ENGINEERING	8550578	89.68	766.773	L7A
PRO-		TEST ENGINEERING	83858	86.51	7.255	L2
DUCTION		ILS	2137645	82.29	175.907	L7A
220		MANUFACTURING	106882227	50.64	5412.516	L4B
		MANUFACTURING SUPPORT	12825867	54.86	703.627	L7A
		QUALITY ASSURANCE	16032334	56.97	913.362	L7A
		TOOLING M&R	12825867	54.86	703.627	L7A
	0.04	ODC $	696.640	1.09	759.337	
		220A TOTAL PRODUCTION			19742.767	
230		PROJECT MANAGEMENT	5316850	94.95	504.835	L8
PROJECT	0.04	ODC $	18.526	1.09	20.193	
MGMT						
		230 TOTAL PROJECT MGMT			525.028	
		TOTAL LOT 1 PRODUCTION COST	200	EACH	$20378.233	
		UNIT PRODUCTION COST			$ 101.891	

PRODUCTION COST SUMMARY LOT 2 S3B
(CY90 M$) TRIJET ALL ELECT. A/C (not resized) 02-Aug-91

WE		COST ELEMENT	INPUT	MARKUP	PRODUCTION COST	REF
210		MATERIAL (MFG) $		1.05		M5D
RATE		TOOLING		54.86		L3
TOOLING		MANUFACTURING SUPPORT		54.86		L7B
		QUALITY ASSURANCE		56.97		L7B
	0.04	ODC $		1.09		
		210 TOTAL RATE TOOLING				
		MATERIAL (HIGH VALUE) $	5312.569	1.05	5578.197	M5D
		MATERIAL (MFG) $	3868.108	1.05	4060.170	M5D
		ENGINEERING	5631270	89.68	504.984	L7B
PRO-		TEST ENGINEERING	83858	86.51	7.255	L2
DUCTION		ILS	1407818	82.29	115.849	L7B
220		MANUFACTURING	70390879	50.64	3564.594	L4C
		MANUFACTURING SUPPORT	8446906	54.86	463.397	L7B
		QUALITY ASSURANCE	10558632	56.97	601.525	L7B
		TOOLING M&R	8446906	54.86	463.397	L7B
	0.04	ODC $	563.647	1.09	614.375	
		220A TOTAL PRODUCTION			15973.744	
230		PROJECT MANAGEMENT	3463887	94.95	328.896	L8
PROJECT	0.04	ODC $	12.070	1.09	13.156	
MGMT						
		230 TOTAL PROJECT MGMT			342.052	
		TOTAL LOT 2 PRODUCTION COST	200	EACH	$16315.796	
		UNIT PRODUCTION COST			$ 81.579	

PRODUCTION COST SUMMARY LOT 3 S3C
(CY90 M$) TRIJET ALL ELECT. A/C (not resized) 02-Aug-91

WE		COST ELEMENT	INPUT	MARKUP	PRODUCTION COST	REF
210		MATERIAL (MFG) $		1.05		M5D
RATE		TOOLING		54.86		L3
TOOLING		MANUFACTURING SUPPORT		54.86		L7B
		QUALITY ASSURANCE		56.97		L7B
	0.04	ODC $		1.09		
		210 TOTAL RATE TOOLING				
		MATERIAL (HIGH VALUE) $	5286.014	1.05	5550.315	M5D
		MATERIAL (MFG) $	3676.571	1.05	3859.123	M5D
		ENGINEERING	5028428	89.68	450.924	L7B
PRO-		TEST ENGINEERING	83858	86.51	7.255	L2
DUCTION		ILS	1257107	82.29	103.447	L7B
220		MANUFACTURING	62855344	50.64	3182.995	L4C
		MANUFACTURING SUPPORT	7542641	54.86	413.789	L7B
		QUALITY ASSURANCE	9428302	56.97	537.130	L7B
		TOOLING M&R	7542641	54.86	413.789	L7B
	0.04	ODC $	532.799	1.09	580.751	
		220A TOTAL PRODUCTION			15099.518	
230		PROJECT MANAGEMENT	3093365	94.95	293.715	L8
PROJECT	0.04	ODC $	10.779	1.09	11.749	
MGMT						
		230 TOTAL PROJECT MGMT			305.464	
		TOTAL LOT 3 PRODUCTION COST	200	EACH	$15404.982	
		UNIT PRODUCTION COST			$ 77.025	

PRODUCTION COST SUMMARY LOT 4 S3D

(CY90 M$) TRIJET ALL ELECT. A/C (not resized) 02-Aug-91

WE		COST ELEMENT	INPUT	MARKUP	PRODUCTION COST	REF
210		MATERIAL (MFG) $		1.05		M5D
RATE		TOOLING		54.86		L3
TOOLING		MANUFACTURING SUPPORT		54.86		L7B
		QUALITY ASSURANCE		56.97		L7B
	0.04	ODC $		1.09		
		210 TOTAL RATE TOOLING				
		MATERIAL (HIGH VALUE) $	5267.049	1.05	5530.401	M5D
		MATERIAL (MFG) $	3557.401	1.05	3734.035	M5D
		ENGINEERING	4739544	89.68	425.019	L7B
PRO-		TEST ENGINEERING	83858	86.51	7.255	L2
DUCTION		ILS	1184886	82.29	97.504	L7B
220		MANUFACTURING	59244306	50.64	3000.132	L4C
		MANUFACTURING SUPPORT	7109317	54.86	390.017	L7B
		QUALITY ASSURANCE	8886646	56.97	506.272	L7B
		TOOLING M&R	7109317	54.86	390.017	L7B
	0.04	ODC $	516.721	1.09	563.226	
		220A TOTAL PRODUCTION			14643.878	
230		PROJECT MANAGEMENT	2915810	94.95	276.856	L8
PROJECT	0.04	ODC $	10.160	1.09	11.074	
MGMT						
		230 TOTAL PROJECT MGMT			287.930	
		TOTAL LOT 4 PRODUCTION COST	200	EACH	$14931.808	
		UNIT PRODUCTION COST			$ 74.659	

SUPPORT INVESTMENT S4

(CY90 M$) TRIJET ALL ELECT. A/C (not resized) 02-Aug-91

PRODUCTION AUTHORIZATION	800 EACH
A/C PRODUCTION COST (FLYAWAY)	67030.819
UNIT FLYAWAY COST	83.789

WORK ELEMENT	ILS INVESTMENT ELEMENT	f(FLYAWAY COST)	ILS INVEST
310	PECULIAR GROUND SUPPORT EQUIP	0.015	1005.462
320	TRAINING EQUIP/SERVICES	0.025	1675.770
330	SUPPORT DATA	0.010	670.308
340	INITIAL SPARES	0.040	2681.233
	SUBTOTAL ILS INVESTMENT LESS SITE ACTIVATION		6032.774
		F(ILS SUBTOT)	
350	SITE ACTIVATION/FIELD SERVICE	0.050	301.639
	TOTAL ILS INVESTMENT		6334.412

PRODUCT SUPPORT INVESTMENT ALLOCATION (CY90 M$) TRIJET ALL ELECT. A/C (not resi	AIRFRAMER PRODUCT SUPPORT RDT&E	AIRLINE RECURRING PRODUCT SUPPORT	AIRFRAMER FURNISHED PRODUCT SUPPORT
PECULIAR GROUND SUPPORT EQUIP	50.273	955.189	143.278
TRAINING EQUIP/SERVICES	83.789	1591.982	318.396
SUPPORT DATA	167.577	502.731	502.731
INITIAL SPARES		2681.233	1876.863
SITE ACTIVATION/FIELD SERVICE		301.639	60.328
TOTAL AIRFRAMER NONRECURRING	301.639		
TOTAL AIRLINE SUPPORT INVESTMENT		6032.774	
TOTAL AIRFRAMER SUPPORT INVESTMENT			2901.597

PARAMETRIC COST SUMMARY S1

(CY90 M$) TRIJET ALL ELECT. A/C (resized) 02-Aug-91

WORK ELEMENT	NOMENCLATURE	CONTRACTOR COST	FEE @	COST (CY90 M$)	UNIT COST	REF
100	AIRCRAFT RDT&E					
110	ENGINEERING	1116.189		1116.189		S2
120	MOCKUP, TEST & DEVELOPMENT	650.521		650.521		S2
130	INITIAL TOOLING	816.316		816.316		S2
140	SUPPLIER NON-RECURRING	942.064		942.064		S2
150	FSD ILS	54.594		54.594		S2
160	PROJECT MANAGEMENT	114.338		114.338		S2
	AIRCRAFT RDT&E TOTAL	3694.023		3694.023		
200	PRODUCTION					
210	PRODUCTION LOT 1 - 200 A/C	20214.604		20214.604	101.073	S3A
220	PRODUCTION LOT 2 - 200 A/C	16179.915		16179.915	80.900	S3B
230	PRODUCTION LOT 3 - 200 A/C	15275.230		15275.230	76.376	S3C
240	PRODUCTION LOT 4 - 200 A/C	14805.208		14805.208	74.026	S3D
	PRODUCTION TOTAL	66474.957		66474.957	83.094	
300	PRODUCT SUPPORT (AIRFRAMER FURNISHED)					
300 R&D	PRODUCT SUPPORT N. R.			299.137		S4
310	PECULIAR GROUND SUPPORT EQUIPMENT			142.090		S4
320	TRAINING SERVICES & EQUIPMENT			315.756		S4
330	ENGINEERING & SUPPORT DATA			498.562		S4
340	INITIAL SPARES			1861.299		S4
350	SITE ACTIVATION/FIELD SERVICES			59.827		S4
	AIRFRAMER FURNISHED PRODUCT SUPPORT TOTAL			3176.672		
	COMMERCIAL PROGRAM COST TOTAL			73345.652		
	UNIT PRODUCTION FLYAWAY COST		800 UNITS	83.094		
	AMORTISED N.R. COST PER UNIT		100 UNITS	36.940		

TRIJET ALL ELECT. A/C (resized) PRODUCTION SUMMARY	LOT 1	LOT 2	LOT 3	LOT 4	AVERAGE
AIRCRAFT UNIT FLYAWAY COST	101.073	80.900	76.376	74.026	83.094
ENGINES WITH PODS/TR	21.269	21.269	21.269	21.269	21.269
BFE SEATS & GALLEYS	1.711	1.492	1.418	1.372	1.498
BFE AVIONICS	2.273	2.190	2.139	2.101	2.176
AIRFRAME & FIXED EQUIPMENT	75.820	55.949	51.550	49.284	58.151

RDT&E COST SUMMARY S2

(CY90 M$) TRIJET ALL ELECT. A/C (resized) 02-Aug-91

WE		COST ELEMENT	INPUT	MARKUP	COST	REF
110		ENGINEERING	11968319	89.68	1073.259	L1
ENGR	0.04	ODC $	39.386	1.09	42.930	
		110 TOTAL ENGINEERING			1116.189	
120		MATERIAL (HIGH VALUE) $	5.315	1.05	5.581	L5B
MOCKUP		MATERIAL (MFG) $	68.651	1.05	72.060	L5B
TEST &		ENGINEERING TEST	1750550	86.51	151.440	L2
DEVEL		DEVELOPMENT	3512995	50.64	177.898	L2
		ENGINEERING LIAISON		89.68		L7A
		MANUFACTURING	3225033	50.64	163.316	L4A
		MANUFACTURING SUPPORT	67380	54.86	3.696	L7A
		QUALITY ASSURANCE	761397	56.97	43.377	L7A
		TOOLING M & R	148237	54.86	8.132	L7A
	0.04	ODC $	22.954	1.09	25.020	
		120 TOTAL MCKUP TEST & DEV			650.521	
130		MATERIAL (MFG) $	60.782	1.05	63.800	L5B
INITIAL		TOOLING	11913346	54.86	653.566	L3
TOOLING		MANUFACTURING SUPPORT	595667	54.86	32.678	L7A
		QUALITY ASSURANCE	655234	56.97	37.329	L7A
	0.04	ODC $	26.553	1.09	28.943	
		130 TOTAL INITIAL TOOLING			816.316	
140		MATERIAL (HIGH VALUE) $	25.347	1.05	26.615	A5B
SUPPLIER		MATERIAL (MFG) $	837.626	1.05	879.216	A5B
NR		ENGINEERING		89.68		A7A
		ILS		82.29		A7A
		MANUFACTURING		50.64		A4A
		MANUFACTURING SUPPORT		54.86		A7A
		QUALITY ASSURANCE		56.97		A7A
		TOOLING M&R		54.86		A7A
	0.04	ODC $	33.242	1.09	36.233	
		140 TOTAL SUPPLIER N.R.			942.064	
150		MATERIAL (HIGH VALUE) $	9.721	1.05	10.207	L6
ILS		MATERIAL (MFG) $	1.944	1.05	2.041	L6
		ILS	489088	82.29	40.247	L6
	0.04	ODC $	1.926	1.09	2.100	
		150 TOTAL ILS			54.594	
160		PROJECT MANAGEMENT	1157879	94.95	109.941	L8
PROJECT	0.04	ODC $	4.035	1.09	4.398	
MGT						
		160 TOTAL PROJECT MGMT			114.338	
		TOTAL RDT&E COST	(CY90 M$)		3694.023	

PRODUCTION COST SUMMARY LOT 1 S3A

(CY90 M$) TRIJET ALL ELECT. A/C (resized) 02-Aug-91

WE		COST ELEMENT	INPUT	MARKUP	PRODUCTION COST	REF
210		MATERIAL (MFG) $	7.982	1.05	8.378	M5B
RATE		TOOLING	1596388	54.86	87.578	L3
TOOLING		MANUFACTURING SUPPORT	79819	54.86	4.379	L7A
		QUALITY ASSURANCE	87801	56.97	5.002	L7A
	0.04	ODC $	3.866	1.09	4.213	
		210 TOTAL RATE TOOLING			109.551	
		MATERIAL (HIGH VALUE) $	5316.904	1.05	5582.749	M5C
		MATERIAL (MFG) $	4404.936	1.05	4623.652	M5C
		ENGINEERING	8492353	89.68	761.552	L7A
PRO-		TEST ENGINEERING	83858	86.51	7.255	L2
DUCTION		ILS	2123088	82.29	174.709	L7A
220		MANUFACTURING	106154410	50.64	5375.659	L4B
		MANUFACTURING SUPPORT	12738529	54.86	698.836	L7A
		QUALITY ASSURANCE	15923162	56.97	907.143	L7A
		TOOLING M&R	12738529	54.86	698.836	L7A
	0.04	ODC $	691.023	1.09	753.216	
		220A TOTAL PRODUCTION			19583.606	
230		PROJECT MANAGEMENT	5280592	94.95	501.392	L8
PROJECT	0.04	ODC $	18.400	1.09	20.056	
MGMT						
		230 TOTAL PROJECT MGMT			521.448	
		TOTAL LOT 1 PRODUCTION COST	200	EACH	$20214.604	
		UNIT PRODUCTION COST			$ 101.073	

PRODUCTION COST SUMMARY LOT 2 S3B
(CY90 M$) TRIJET ALL ELECT. A/C (resized) 02-Aug-91

WE		COST ELEMENT	INPUT	MARKUP	PRODUCTION COST	REF
210		MATERIAL (MFG) $		1.05		M5D
RATE		TOOLING		54.86		L3
TOOLING		MANUFACTURING SUPPORT		54.86		L7B
		QUALITY ASSURANCE		56.97		L7B
	0.04	ODC $		1.09		
		210 TOTAL RATE TOOLING				
		MATERIAL (HIGH VALUE) $	5255.151	1.05	5517.908	M5D
		MATERIAL (MFG) $	3840.143	1.05	4030.816	M5D
		ENGINEERING	5593049	89.68	501.557	L7B
PRO-		TEST ENGINEERING	83858	86.51	7.255	L2
DUCTION		ILS	1398262	82.29	115.063	L7B
220		MANUFACTURING	69913118	50.64	3540.400	L4C
		MANUFACTURING SUPPORT	8389574	54.86	460.252	L7B
		QUALITY ASSURANCE	10486968	56.97	597.443	L7B
		TOOLING M&R	8389574	54.86	460.252	L7B
	0.04	ODC $	558.934	1.09	609.238	
		220A TOTAL PRODUCTION			15840.183	
230		PROJECT MANAGEMENT	3440395	94.95	326.666	L8
PROJECT	0.04	ODC $	11.988	1.09	13.067	
MGMT						
		230 TOTAL PROJECT MGMT			339.732	
		TOTAL LOT 2 PRODUCTION COST	200	EACH	$16179.915	
		UNIT PRODUCTION COST			$ 80.900	

PRODUCTION COST SUMMARY LOT 3 S3C

(CY90 M$) TRIJET ALL ELECT. A/C (resized) 02-Aug-91

WE		COST ELEMENT	INPUT	MARKUP	PRODUCTION COST	REF
210		MATERIAL (MFG) $		1.05		M5D
RATE		TOOLING		54.86		L3
TOOLING		MANUFACTURING SUPPORT		54.86		L7B
		QUALITY ASSURANCE		56.97		L7B
	0.04	ODC $		1.09		
		210 TOTAL RATE TOOLING				
		MATERIAL (HIGH VALUE) $	5228.596	1.05	5490.026	M5D
		MATERIAL (MFG) $	3649.990	1.05	3831.222	M5D
		ENGINEERING	4994344	89.68	447.868	L7B
PRO-		TEST ENGINEERING	83858	86.51	7.255	L2
DUCTION		ILS	1248586	82.29	102.746	L7B
220		MANUFACTURING	62429303	50.64	3161.420	L4C
		MANUFACTURING SUPPORT	7491516	54.86	410.985	L7B
		QUALITY ASSURANCE	9364396	56.97	533.490	L7B
		TOOLING M&R	7491516	54.86	410.985	L7B
	0.04	ODC $	528.293	1.09	575.840	
		220A TOTAL PRODUCTION			14971.835	
230		PROJECT MANAGEMENT	3072416	94.95	291.726	L8
PROJECT	0.04	ODC $	10.706	1.09	11.669	
MGMT						
		230 TOTAL PROJECT MGMT			303.395	
		TOTAL LOT 3 PRODUCTION COST	200	EACH	$15275.230	
		UNIT PRODUCTION COST			$ 76.376	

PRODUCTION COST SUMMARY LOT 4 S3D
(CY90 M$) TRIJET ALL ELECT. A/C (resized) 02-Aug-91

WE		COST ELEMENT	INPUT	MARKUP	PRODUCTION COST	REF
210		MATERIAL (MFG) $		1.05		M5D
RATE		TOOLING		54.86		L3
TOOLING		MANUFACTURING SUPPORT		54.86		L7B
		QUALITY ASSURANCE		56.97		L7B
	0.04	ODC $		1.09		
		210 TOTAL RATE TOOLING				
		MATERIAL (HIGH VALUE) $	5209.630	1.05	5470.112	M5D
		MATERIAL (MFG) $	3531.681	1.05	3707.039	M5D
		ENGINEERING	4707443	89.68	422.140	L7B
PRO-		TEST ENGINEERING	83858	86.51	7.255	L2
DUCTION		ILS	1176861	82.29	96.844	L7B
220		MANUFACTURING	58843034	50.64	2979.811	L4C
		MANUFACTURING SUPPORT	7061164	54.86	387.375	L7B
		QUALITY ASSURANCE	8826455	56.97	502.843	L7B
		TOOLING M&R	7061164	54.86	387.375	L7B
	0.04	ODC $	512.323	1.09	558.432	
		220A TOTAL PRODUCTION			14519.226	
230		PROJECT MANAGEMENT	2896079	94.95	274.983	L8
PROJECT	0.04	ODC $	10.091	1.09	10.999	
MGMT						
		230 TOTAL PROJECT MGMT			285.982	
		TOTAL LOT 4 PRODUCTION COST	200	EACH	$14805.208	
		UNIT PRODUCTION COST			$ 74.026	

SUPPORT INVESTMENT S4
(CY90 M$) TRIJET ALL ELECT. A/C (resized) 02-Aug-91

	PRODUCTION AUTHORIZATION	800 EACH	
	A/C PRODUCTION COST (FLYAWAY)	66474.957	
	UNIT FLYAWAY COST	83.094	

WORK ELEMENT	ILS INVESTMENT ELEMENT	f(FLYAWAY COST)	ILS INVEST
310	PECULIAR GROUND SUPPORT EQUIP	0.015	997.124
320	TRAINING EQUIP/SERVICES	0.025	1661.874
330	SUPPORT DATA	0.010	664.750
340	INITIAL SPARES	0.040	2658.998
	SUBTOTAL ILS INVESTMENT LESS SITE ACTIVATION		5982.746
		F(ILS SUBTOT)	
350	SITE ACTIVATION/FIELD SERVICE	0.050	299.137
	TOTAL ILS INVESTMENT		6281.883

PRODUCT SUPPORT INVESTMENT ALLOCATION (CY90 M$) TRIJET ALL ELECT. A/C (resized)	AIRFRAMER PRODUCT SUPPORT RDT&E	AIRLINE RECURRING PRODUCT SUPPORT	AIRFRAMER FURNISHED PRODUCT SUPPORT
PECULIAR GROUND SUPPORT EQUIP	49.856	947.268	142.090
TRAINING EQUIP/SERVICES	83.094	1578.780	315.756
SUPPORT DATA	166.187	498.562	498.562
INITIAL SPARES		2658.998	1861.299
SITE ACTIVATION/FIELD SERVICE		299.137	59.827
TOTAL AIRFRAMER NONRECURRING	299.137		
TOTAL AIRLINE SUPPORT INVESTMENT		5982.746	
TOTAL AIRFRAMER SUPPORT INVESTMENT			2877.535

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
24 January 1992

3. REPORT TYPE AND DATES COVERED
Contractor Final Report

4. TITLE AND SUBTITLE
Evaluation of All-Electric Secondary Power for Transport Aircraft
(was: Evaluation of 20-kHz All-Electric Aircraft)

5. FUNDING NUMBERS
NAS 3-25965
Task No. 1

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
McDonnell Douglas Corporation
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3855 Lakewood Boulevard
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8. PERFORMING ORGANIZATION REPORT NUMBER
MDC 91K0418

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio 44135-3191

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
NASA CR-189077

11. SUPPLEMENTARY NOTES
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12a. DISTRIBUTION/AVAILABILITY STATEMENT
[redacted]

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
This report covers a study by Douglas Aircraft Company of electrical power systems for advanced transport aircraft based upon an all-electric design concept. The concept would eliminate distributed hydraulic and pneumatic secondary power systems, and feature an expanded secondary electrical power system redesigned to supply power to the loads customarily supplied by hydraulic or pneumatic power. The initial study was based on an advanced 20-kHz electrical power transmission and distribution system, using a system architecture supplied by NASA-Lewis Research Center for twin-engine aircraft with many advanced power conversion concepts. NASA-LeRC later requested Douglas to refocus the study on 400-Hz secondary power distribution. Subsequent work was based on a three-engine MD-11 aircraft, selected by Douglas as a baseline system design that would provide data for the comparative cost/benefit analysis.

The study concluded that the 20-kHz concept produced many expected benefits, and that the all-electric trijet weight savings on hardware redesign would be 2,304 pounds plus a 2.1-percent fuel reduction and resized for a total weight reduction of 11,000 pounds. Cost reductions for a fleet of 800 aircraft in a 15-year production program were estimated at $76.71 million for RDT&E, $2.74 million per aircraft for production; $9.84 million for nonrecurring expenses; $120,000 per aircraft for product support; and $300,000 per aircraft per year for operating and maintenance costs, giving a present value of $1.914 billion saved or a future value of $10.496 billion saved.

14. SUBJECT TERMS
Advanced Aircraft, Secondary Power, Electrical Systems, Hydraulic Systems, Pneumatic Systems, Flight Control, Environmental Control, Landing Gear and Braking

15. NUMBER OF PAGES
329

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	SAR

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

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