NASA Lewis
Research Center
Contract NAS3-25977

October 6, 1992

Vented Tank Resupply Experiment (VTRE) for In-Space Technology Experiments Program (IN-STEP)

Program Overview Presentation

Presented at:

NASA/DOD
Flight Experiments Technical
Interchange Meeting

Presented by:

William J. Bailey
Program Manager

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VTRE CONTRACT SUMMARY

PROGRAM DESCRIPTION	DEVELOP, DESIGN, BUILD & PROVIDE FLIGHT AND POST FLIGHT SUPPORT FOR A SHUTTLE HITCHHIKER EXPERIMENT TO INVESTIGATE AND DEMONSTRATE VENTED TANK RESUPPLY AND DIRECT TANK VENTING IN SPACE
CONTRACT	NAS3-25977
CUSTOMER	NASA LEWIS RESEARCH CENTER AL SEIGNEUR - PROJECT MANAGER
DESCRIPTION OF WORK ØB	DEVELOP THE CONCEPTUAL DESIGN FOR A SPACE SHUTTLE FLIGHT EXPERIMENT TO INVESTIGATE VENTED TANK RESUPPLY IN LOW-G. DEVELOP THE RATIONALE, OBJECTIVES & JUSTIFICATION, DEFINE THE DESIGN, ANALYSIS AND TESTING REQUIRED, AND DEVELOP A COMPLETE AND DETAILED MANAGEMENT PLAN FOR THE PHASE C/D OPTION. PRESENT AND ADVOCATE THIS PLAN BEFORE NASA MANAGEMENT.
DESCRIPTION OF WORK ØC/D	CONTINUE THE PHASE B EFFORT TO DESIGN, BUILD, TEST, AND DELIVER THE THE VTRE FLIGHT EXPERIMENT. SUPPORT THE PREPARATIONS FOR FLIGHT AND OPERATION OF THE EXPERIMENT AND REDUCE, ANALYZE, INTERPRET AND DISSEMINATE THE RESULTS OF THE EXPERIMENT.
PERIOD OF PERFORMANCE	JUNE 1991 - JULY 1992 (PHASE B) AUGUST 1992 - MAY 1996 (PHASE C/D)
PROGRAM MANAGER	WILLIAM J. BAILEY
CONTRACT VALUE	\$ 508 K (PHASE B) \$3,773 K (PHASE C/D) \$4,281 K (TOTAL PROGRAM)

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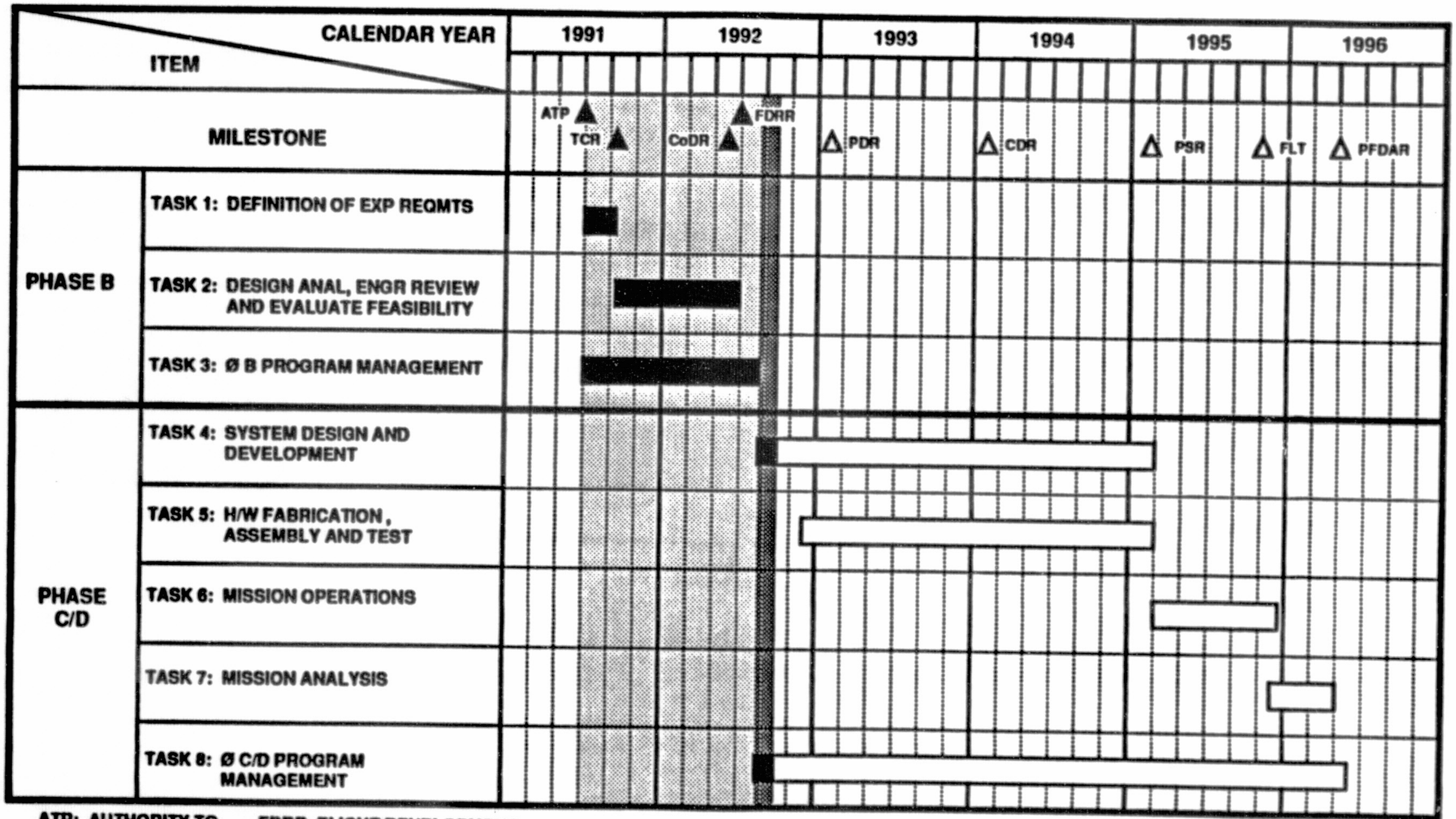
VTRE TOP-LEVEL PROGRAM SCHEDULE

Vented Tank Resupply Experiment



ATP: AUTHORITY TO PROCEED
TCR: TECHNICAL CONCEPT REVIEW
C oDR: CONCEPTUAL DESIGN REVIEW
PDR : PRELIMINARY DESIGN REVIEW
FDRR: FLIGHT DEVELOPMENT READINESS REVIEW
CDR: CRITICAL DESIGN REVIEW
PSR: PRESHIP REVIEW
PFDAR: POST FLIGHT DATA ANALYSIS REVIEW
FLT: FLIGHT

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VTRE TOP LEVEL SET OF TECHNICAL OBJECTIVES

Vented Tank Resupply Experiment

VTRE Top-Level Technical Objectives

1.0* Vented Tank Fill

Evaluate the filling of a vented tank without the loss of liquid at:

- various inflow rates
- different drag vectors
- empty and different initial fill conditions
- different initial tank pressures

2.0* Direct Tank Venting

Investigate direct tank venting without loss of liquid with:

- different vent rates
- different drag vectors
- different fluid states
- for two tanks with different tank sizes/shapes

3.0* Capillary Liquid Retention Capability

Demonstrate that the ullage can be maintained near the vent during a low level disturbance

4.0* Capillary Positioning Device Liquid Recovery

Demonstrate the recovery capability of the capillary positioning system to position the ullage near the vent after a major disturbance

* Test categories refer to Technology Requirements Document (TRD) test set definition which also establishes the priority of testing

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VTRE TECHNICAL OBJECTIVE No 1
TRANSFER WHILE VENTING

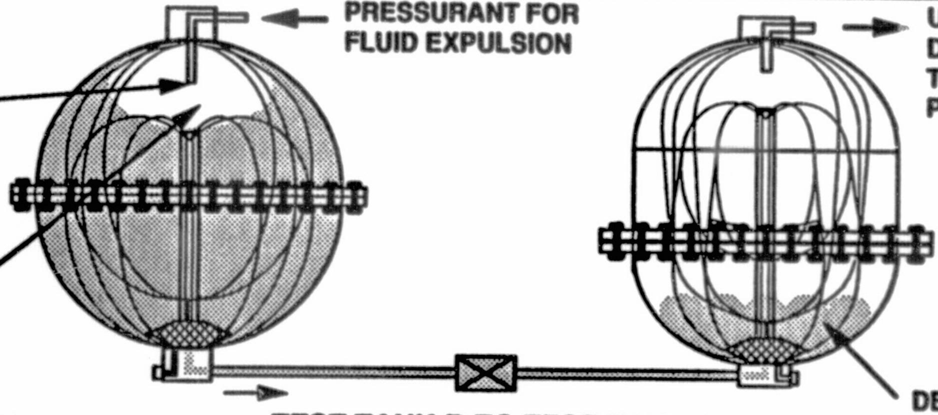
Vented Tank Resupply Experiment

DEMONSTRATE STABLE INFLOW DURING TRANSFER TO 95% FILL LEVEL

PRESSURANT FOR FLUID EXPULSION

ULLAGE VENTING DURING TANK FILL TO MAINTAIN DESIRED PRESSURE

VENT OUTLET LOCATED IN CENTER OF NON-WICKING REGION FOR BOTH TANKS



EARLY IN THE FILL PROCESS SHOWN

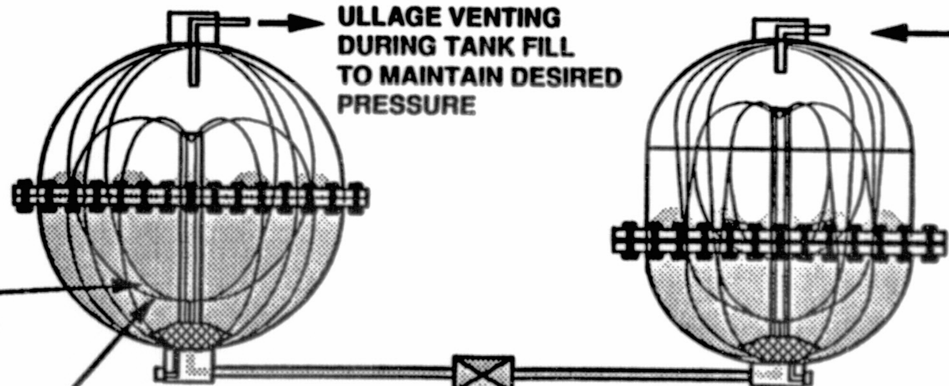
VANE CONFIGURATION MUST PROVIDE PREFERRED LOCATION FOR ALL LIQUID EXCEPT THE 5% ULLAGE REGION FOR BOTH TANKS

TEST TANK B TO TEST TANK A

DETERMINE THE ABILITY OF CAPILLARY VANE POSITIONING DEVICES TO HOLD THE INFLOW LIQUID INPLACE

ULLAGE VENTING DURING TANK FILL TO MAINTAIN DESIRED PRESSURE

PRESSURANT FOR FLUID EXPULSION



MIDWAY THROUGH THE FILL PROCESS SHOWN

CIRCUMFERENTIAL FLOW PATH WITHIN VANES PROVIDED TO ALLOW REDISTRIBUTION OF NON-UNIFORM INLET FLOW

TEST TANK A TO TEST TANK B

DETERMINE THE ABILITY OF CAPILLARY VANE POSITIONING DEVICES TO HOLD THE INFLOW LIQUID INPLACE

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CAPILLARY WICKING PRESSURE MUST EXCEED DYNAMIC PRESSURE OF INFLOWING LIQUID

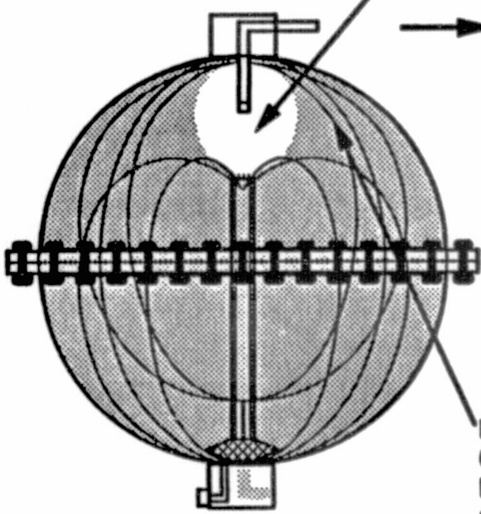
VTRE TECHNICAL OBJECTIVE No 2
DIRECT TANK VENTING

Vented Tank Resupply Experiment

VENT THE TANK WITHOUT ANY LIQUID LOSS WHILE AT THE 95% FILL LEVEL

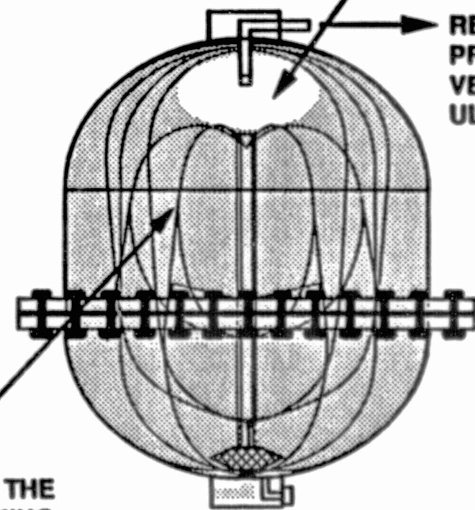
PROVIDE A WICKING VOLUME THAT WILL CONTROL THE LOCATION OF ALL LIQUID, LEAVING THE ULLAGE VOLUME (AT IT'S MINIMUM) AT THE A PREFERRED POSITION FROM WHICH TANK VENTING CAN BE ACCOMPLISHED

LARGER/SMALLER ULLAGE REGIONS THAN THE 95% FULL CONFIGURATION WILL ALSO OCCUPY THE REGION OF THE VENT PORT



REDUCE TANK PRESSURE BY VENTING TANK ULLAGE

RANGE OF FLOW THAT WILL BE PROVIDED WILL ALLOW FOR ASSESSMENT OF RATE EFFECT ON BUBBLE PHENOMENA



REDUCE TANK PRESSURE BY VENTING TANK ULLAGE

DETERMINE CAPABILITY OF THE CAPILLARY VANE DEVICE TO LIMIT LIQUID DISPLACEMENT OUT THE OPEN VENT BY PROVIDING A WICKING GRADIENT WITHIN THE VANE STRUCTURE THAT WILL PROPELL GAS BUBBLES TOWARD THE PREFERRED ULLAGE LOCATION

TEST TANK B **TEST TANK A**

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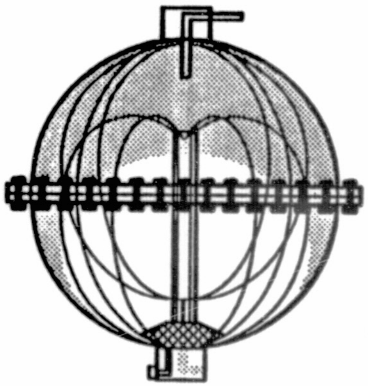
- GATHER BUBBLE GROWTH AND TRANSPORT DATA
- CHARACTERIZE EFFECTS DUE TO DRAG, VARYING FILL LEVELS AND TANK GEOMETRY

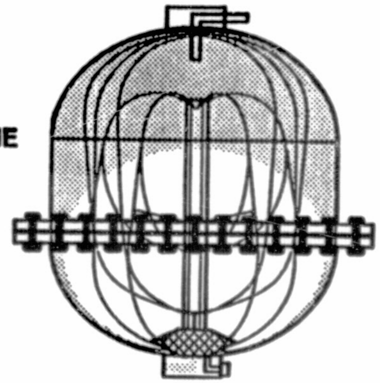
VTRE TECHNICAL OBJECTIVE No 3 & 4
CAPILLARY VANE DEVICE CAPABILITY

Vented Tank Resupply Experiment

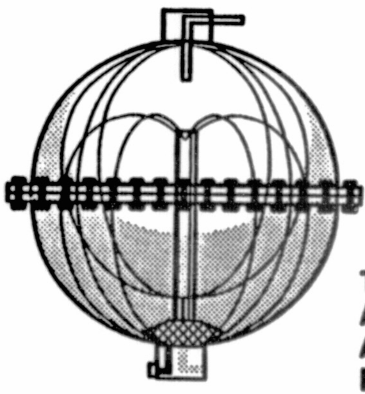
LIQUID RECOVERY CAPABILITY



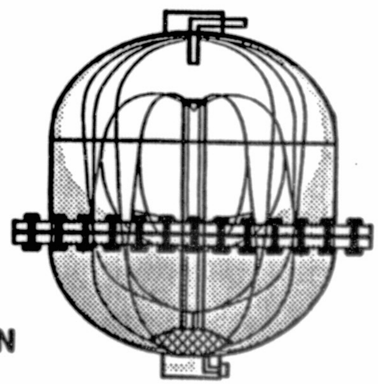
CAPILLARY VANE DEVICE WILL RELOCATE LIQUID AFTER AN INDUCED UPSET ACCELERATION



TEST START

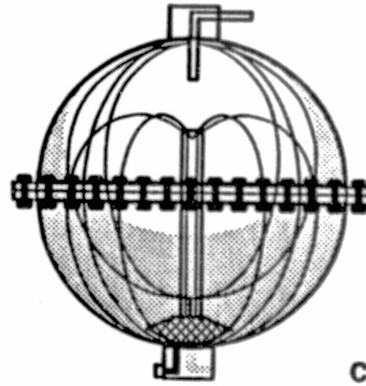


TEST END AFTER ACCELERATION REMOVED

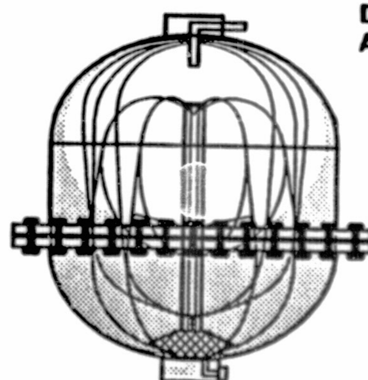


DETERMINE REFILL TIME OF VANE DEVICE

LIQUID RETENTION CAPABILITY



CAPILLARY VANE DEVICE WILL HOLD LIQUID AGAINST A DISTURBING ACCELERATION



DETERMINE LIQUID RETENTION CAPABILITY IN ADVERSE, LOW-LEVEL G FIELD

THESE SECONDARY TESTS DO NOT IMPOSE ANY ADDITIONAL HARDWARE DESIGN REQUIREMENTS ON THE VANES OR THE TANKS

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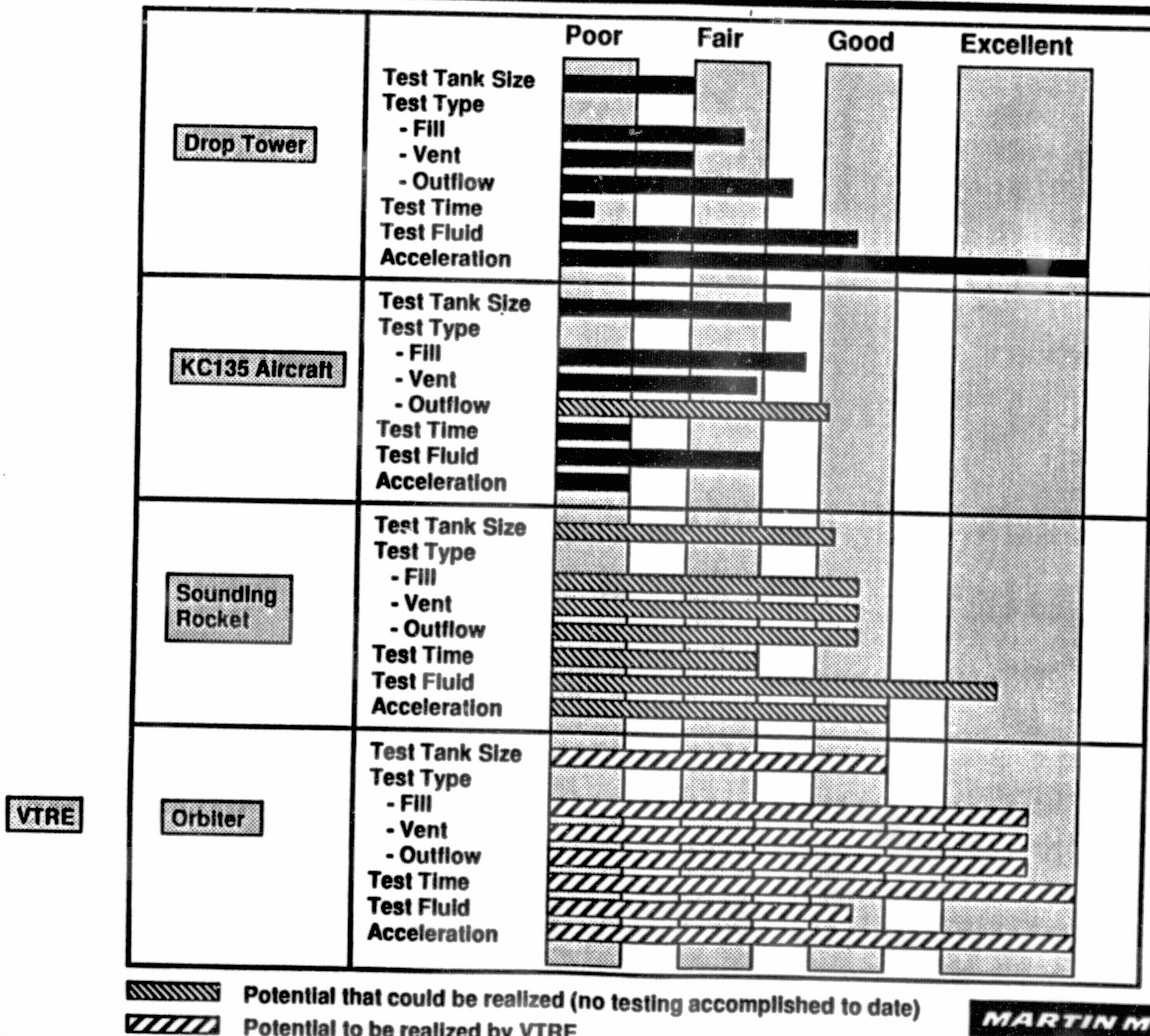
VALUE ADDED OF VTRE TO VANE TECHNOLOGY DATA BASE

Vented Tank Resupply Experiment



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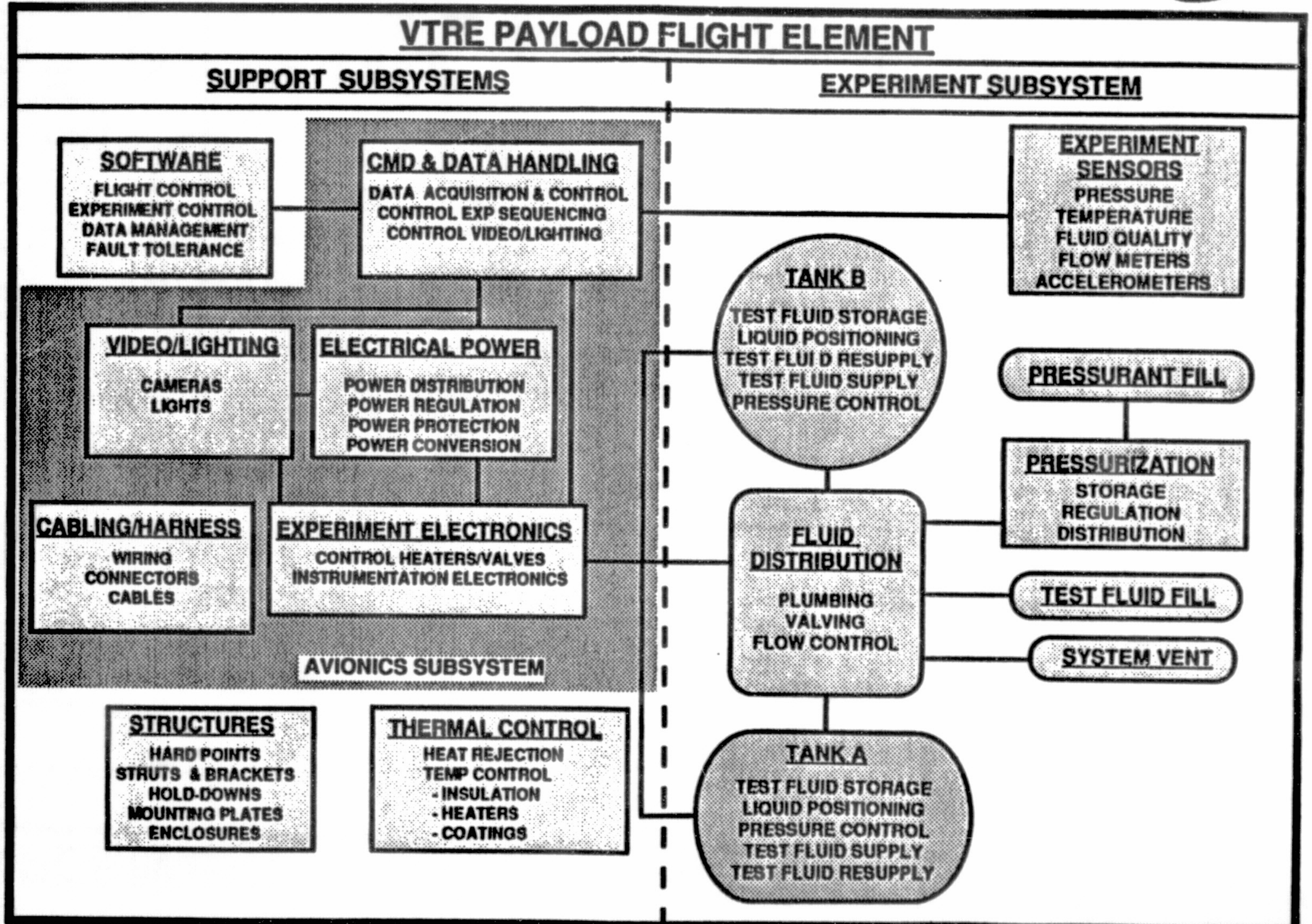
VTRE FUNCTIONAL BLOCK DIAGRAM



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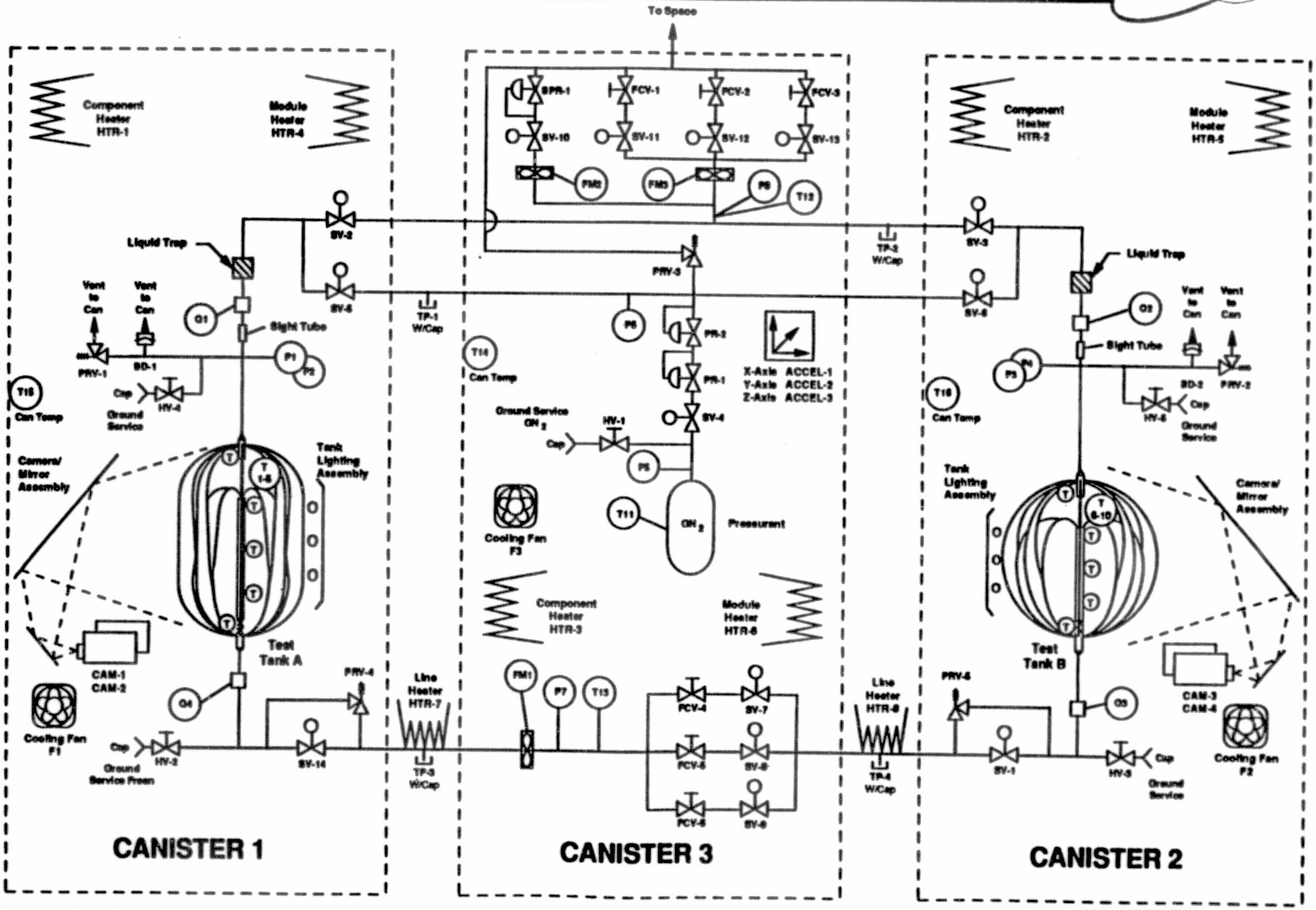
EXPERIMENT SUBSYSTEM SCHEMATIC

Vented Tank Resupply Experiment



VTRE Schematic Rev. 3/17/92

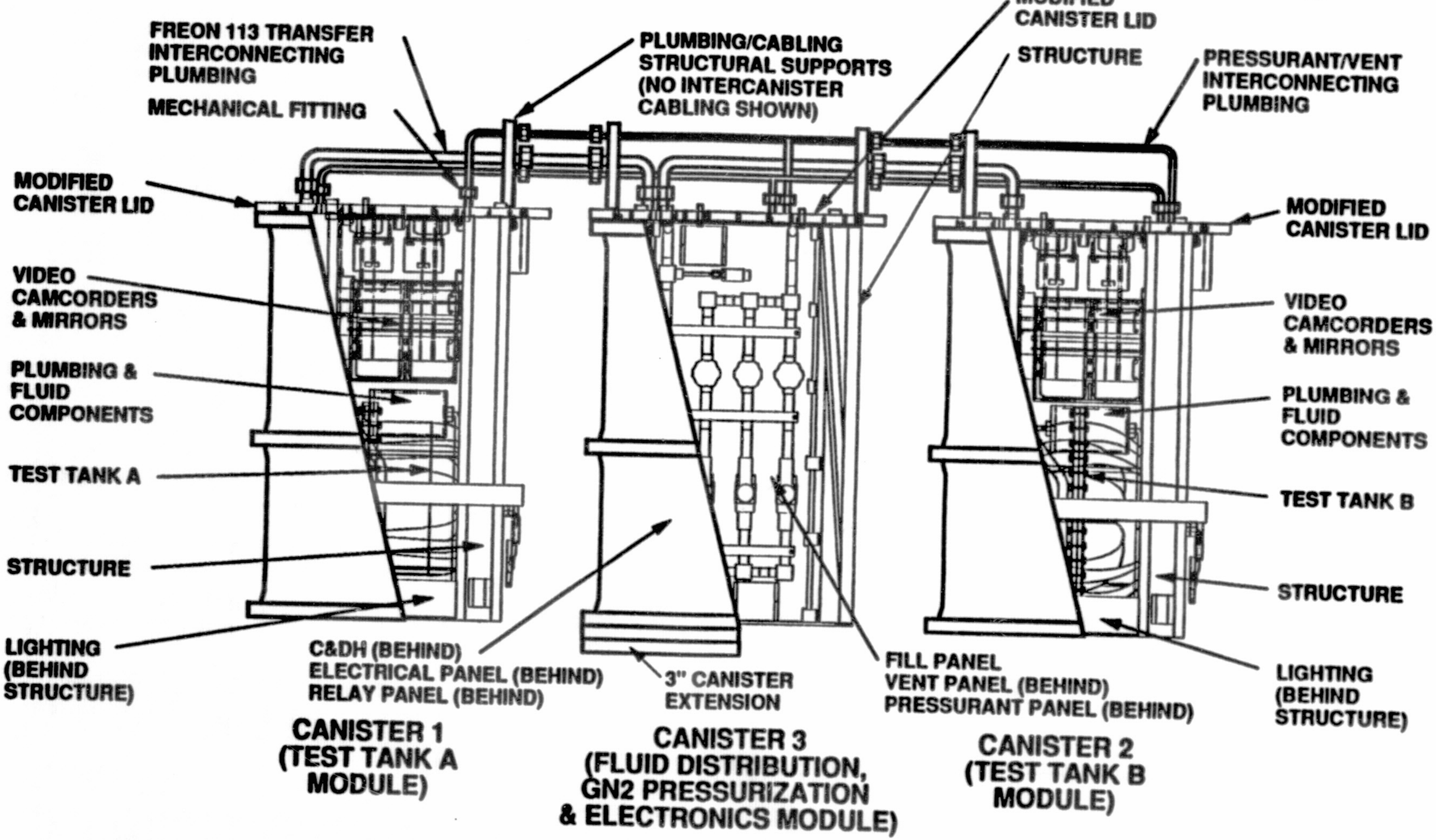
Vented Tank Resupply Experiment

VTRE TEST DATA REQUIREMENTS

INSTRUMENT ID	RANGE	SAMPLE PERIOD (SEC)	NUMBER SENSORS	LOCATION	ACCURACY (+-)
EXPERIMENT SUBSYSTEM					
TEMPERATURE (R)					
TANK FLUID, T1-5	400-600	10 or 60	5	TANK A	1
TANK FLUID, T6-10	400-600	10 or 60	5	TANK B	1
PRESSURANT GAS, T11	400-600	10	1	PRESSURANT	1
VENT GAS, T12	400-600	1 or 10	1	CAN C	1
TRANSFER LINE FLUID, T13	400-600	10	1	CAN C	1
PRESSURE (PSIA)					
TANK A, P1,P2	0-35	1 or 60	2	TANK A	0.2
TANK B, P3,P4	0-35	1 or 60	2	TANK B	0.2
PRESSURANT, P5	0-3000	10	1	PRESSURANT	20
REGULATED PRESSURANT, P6	0-35	10	1	CAN C	0.2
TRANSFER LINE, P7	0-35	1	1	CAN C	0.2
VENT LINE, P8	0-35	1	1	CAN C	0.2
FLOWRATE					
TRANSFER LINE, F1 (GPM)	0.1-10	1	1	CAN C	0.1
HIGH FLOW VENT GAS, F2 (FT^3/MIN)	0.08-1.25	1	1	CAN C	0.1
LOW FLOW VENT GAS, F3 (FT^3/MIN)	0.008-0.2	1	1	CAN C	0.0002
QUALITY GAUGING					
TANK A VENT GAS, Q1	0.0-1.0	1	1	TANK A	0.05
TANK B VENT GAS, Q2	0.0-1.0	1	1	TANK B	0.05
TRANSFER LINE FLOW, Q3	0.0-1.0	1	1	TANK B	0.05
TRANSFER LINE FLOW, Q4	0.0-1.0	1	1	TANK A	0.05
MISCELLANEOUS					
TANK A INTEGRATED LIQUID (FT^3)	0-.84	1	1	CAN A	0.1
TANK B INTEGRATED LIQUID (FT^3)	0-.84	1	1	CAN B	0.1
ACCELERATION (G'S)	+1 to -1	1	3	CAN C	1.00E-05
TIME (SEC)	0-7 DAYS	1	1	N/A	N/A

VTRE FLIGHT CONFIGURATION IN 3 MODIFIED HITCHHIKER CANISTERS

Vented Tank Resupply Experiment



- CANISTERS LIDS REQUIRE MODIFICATION TO ACCOMMODATE ELECTRICAL/MECHANICAL PENETRATIONS
- INTERCONNECT PLUMBING REQUIRES THERMAL PROTECTION
- INTERCONNECT PLUMBING AND CABLING REQUIRES STRUCTURAL SUPPORT TO THE CANISTER LIDS

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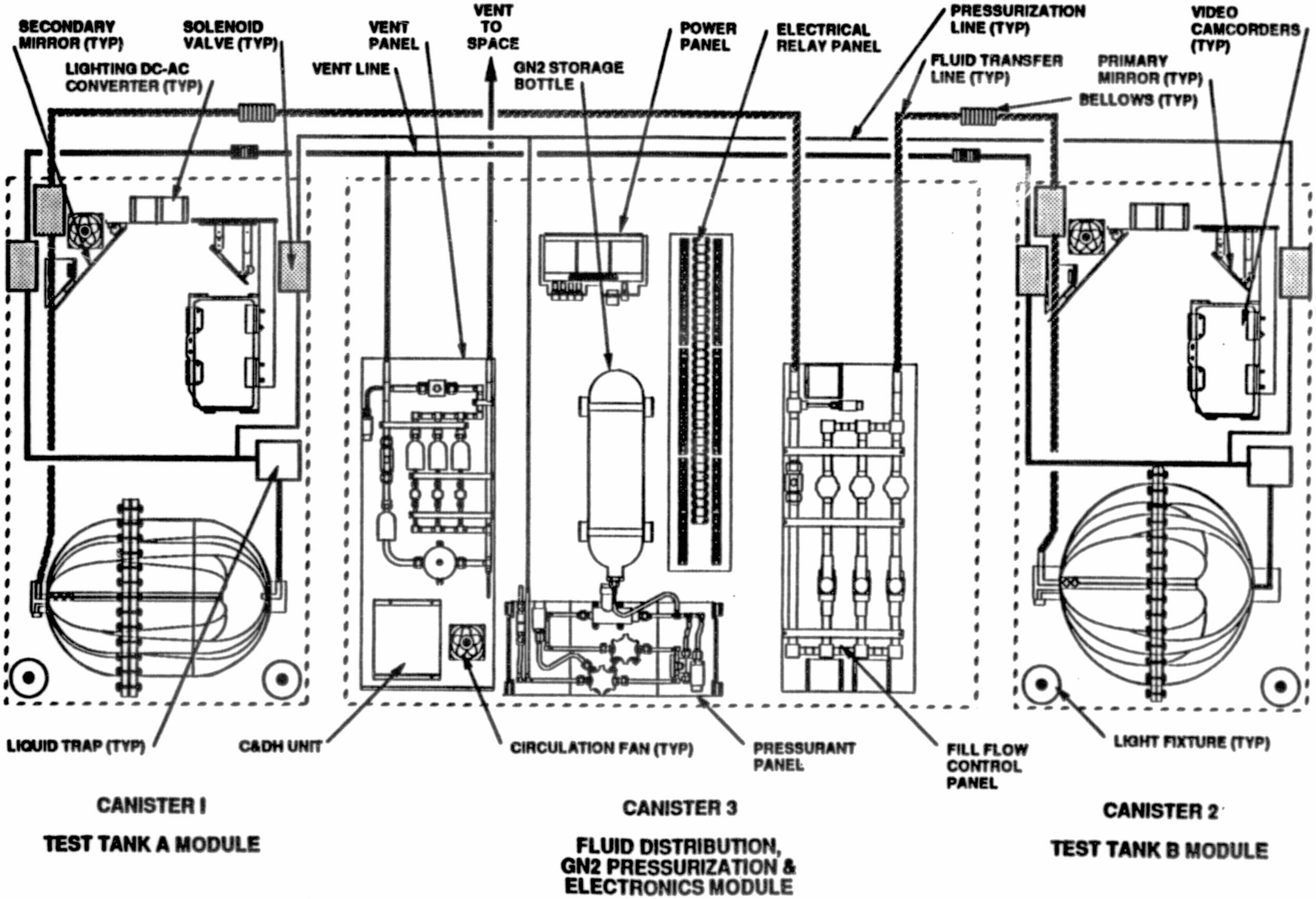
VTRE ELEMENTS INTERRELATIONSHIP

Vented Tank Resupply Experiment



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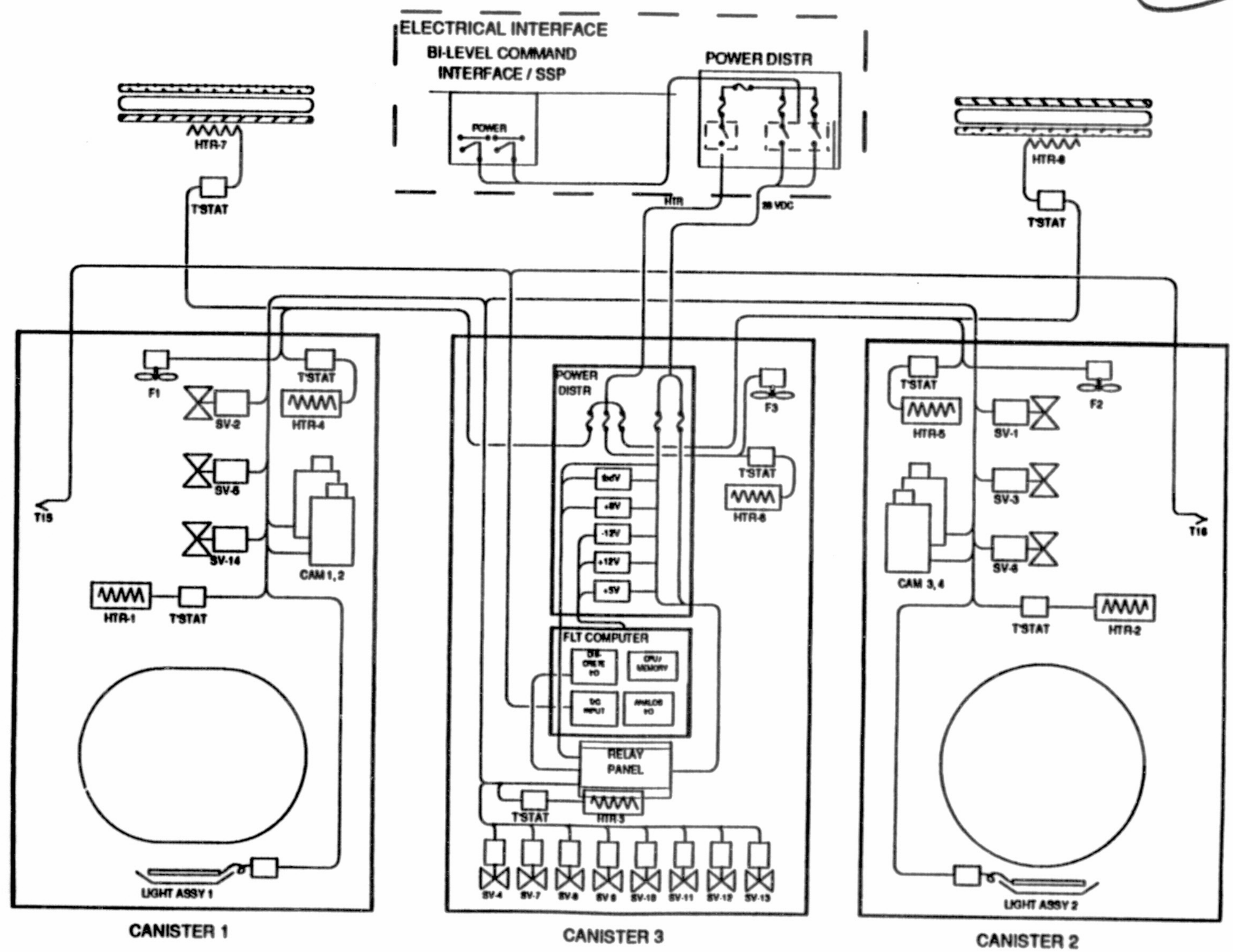
VTRE ELECTRICAL POWER SUBSYSTEM (EPS) SCHEMATIC

Vented Tank Resupply Experiment



Vented Tank Resupply Experiment

VTRE POWER REQUIREMENTS

SUBSYSTEM	# OF UNITS	POWER PER UNIT (W)	AVERAGE LOAD (W) OPERATING 8 HRS MAX	AVERAGE LOAD (W) IDLE	PEAK LOAD (W)	NOTES	HERITAGE
ELECTRICAL POWER SUBSYSTEM			16	16	16		
POWER DISTRIBUTION UNIT	1	3	3	3	3		
DC/DC CONVERTER	1	13	13	13	13	WITH 80% EFFICIENCY	ADTECH
EXPERIMENT SUBSYSTEM			90.2	3	90.2		
PRESSURE TRANSDUCERS	7	0.6	4.2	3	4.2	CONTINUOUSLY ON	DRUCK
FLOWMETER (INCLUDING ELECTRONICS)	3	1	3	0	3		FLOW TECH
LIQUID/GAS SENSORS	4	1	4	0	4		
SOLENOID VALVES - LATCHING	5	0	0	0	0		
SOLENOID VALVES - LOW POWER	4	1	4	0	4	* 18 W INRUSH, 1 W HOLD	
SOLENOID VALVES - HIGH POWER	5	25	75	0	75		
COMMAND & DATA SUBSYSTEM			21.8	21.8	21.8		
COMPUTER & I/O UNITS	1	21.8	21.8	21.8	21.8		PRO-LOG
THERMAL			0	67	180		
CANISTER 1 MAKEUP HEAT	1	60	0	31	60	AVERAGE OF 35 WATTS	
CANISTER 2 MAKEUP HEAT	1	60	0	31	60	DISSIPATION IN EACH	
CANISTER 3 MAKEUP HEAT	1	60	0	5	60	CANISTER, MINIMUM	
VIDEO SUBSYSTEM			51.5	0	103	MAX 2 CAMERAS ON	
VIDEO CAMCORDER	4	5.5	5.5	0	11	NORMALLY ONLY 1	SONY
LIGHTING SYSTEM (INCL POWER CONVERSION, 2 LAMPS EACH)	2	46	46	0	92	50% EFFICIENT POWER SUPPLY	SFMD
EXPERIMENT TOTALS			179.5	107.8	411		
HITCHHIKER AVIONICS			112	112	225		
HH- INTERNAL ELECTRONICS	1	100	100	100	125		HH
SUPPLEMENTAL HEATERS	2	50	12	12	100	12 W FOR FANS	HH
VTRE TOTALS			291.5	219.8	636		

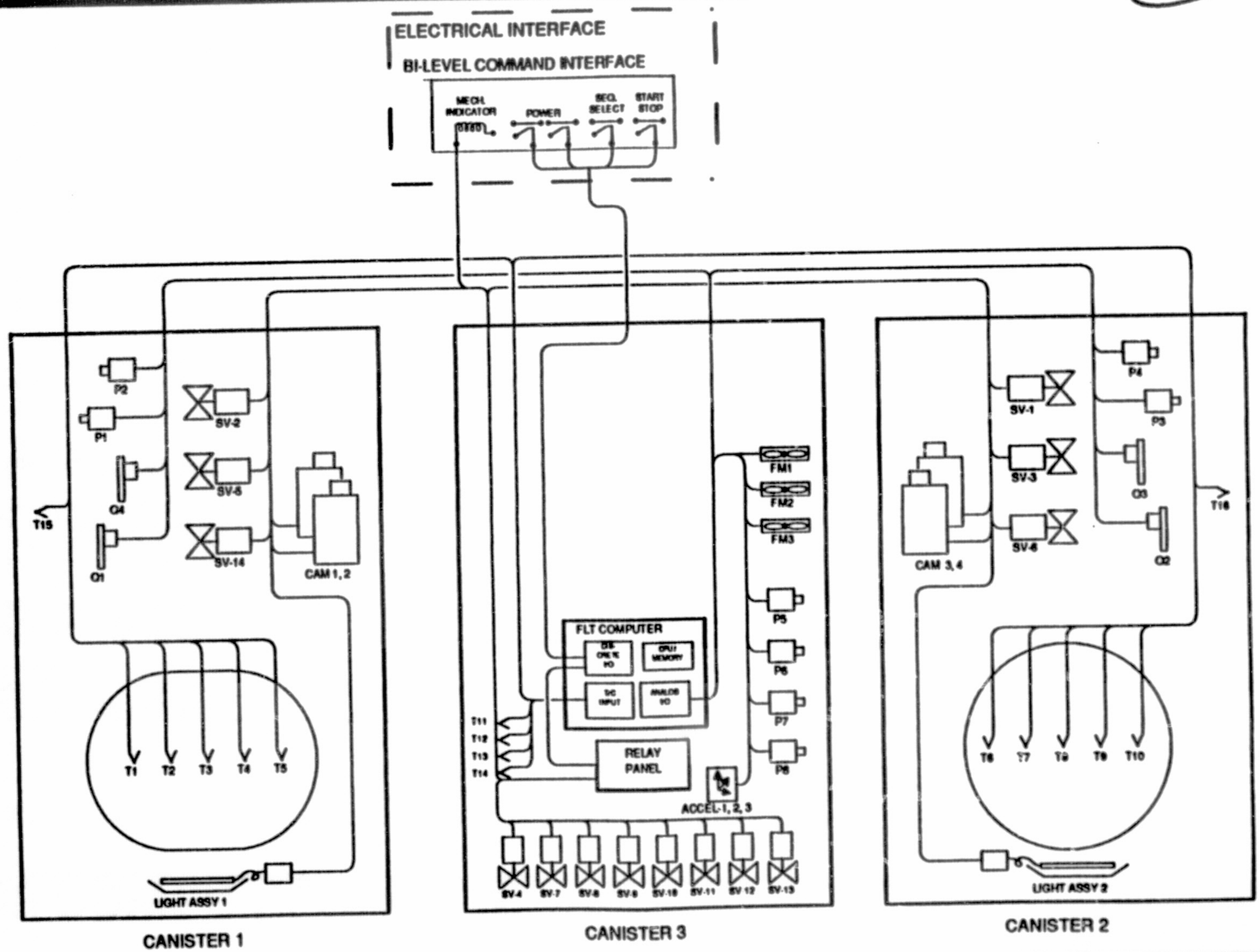
OPERATING POWER = 1.53 KWH OVER 8 HOURS
PLUS 4.31 KWH IDLE POWER OVER 36 HOURS FOR MINIMUM MISSSION
PLUS 16.29 KWH IDLE POWER OVER 136 HOURS FOR MAXIMUM MISSSION

TOTAL = 5.84 KWH FOR EXPERIMENT OVER MISSION
TOTAL = 17.82 KWH FOR EXPERIMENT OVER MISSION
TOTAL = 10.24 TO 32.22 KWH IF INCLUDE HH AVIONICS

NOTE : EXPERIMENT CAN BE POWERED DOWN BEFORE AND AFTER TEST SEQUENCES

VTRE COMMAND & DATA HANDLING SUBSYSTEM (C&DHS) SCHEMATIC

Vented Tank Resupply Experiment



VTRE PAYLOAD ASSEMBLIES

Vented Tank Resupply Experiment

Assembly	Weight	Size X (in)	Size Y (in)	Size Z (in)	Mount	Power	FOV	Temp (C) STG OP
Test Tank A Module	191.6 lbs	19.75	19.75	31.25	Modified Canister 1	84.7 w (36.2 w)	None	-15 to +42
Test Tank B Module	109.4 lbs	19.75	19.75	31.25	Modified Canister 2	84.7 w (36.2 w)	None	-15 to +42
Fluid Distribution, GN2 Pressurization & Electronics Module	139.6 lbs	19.75	19.75	31.25	Modified Canister 3*	73.6 w (47.4 w)	None	-4 to +42

All weights include 20% dry weight margin

Operating - no heaters on (Idle - heaters may be on, fans will be on)

* May require 3' canister extension

Vented Tank Resupply Experiment

VTRE WEIGHT SUMMARY

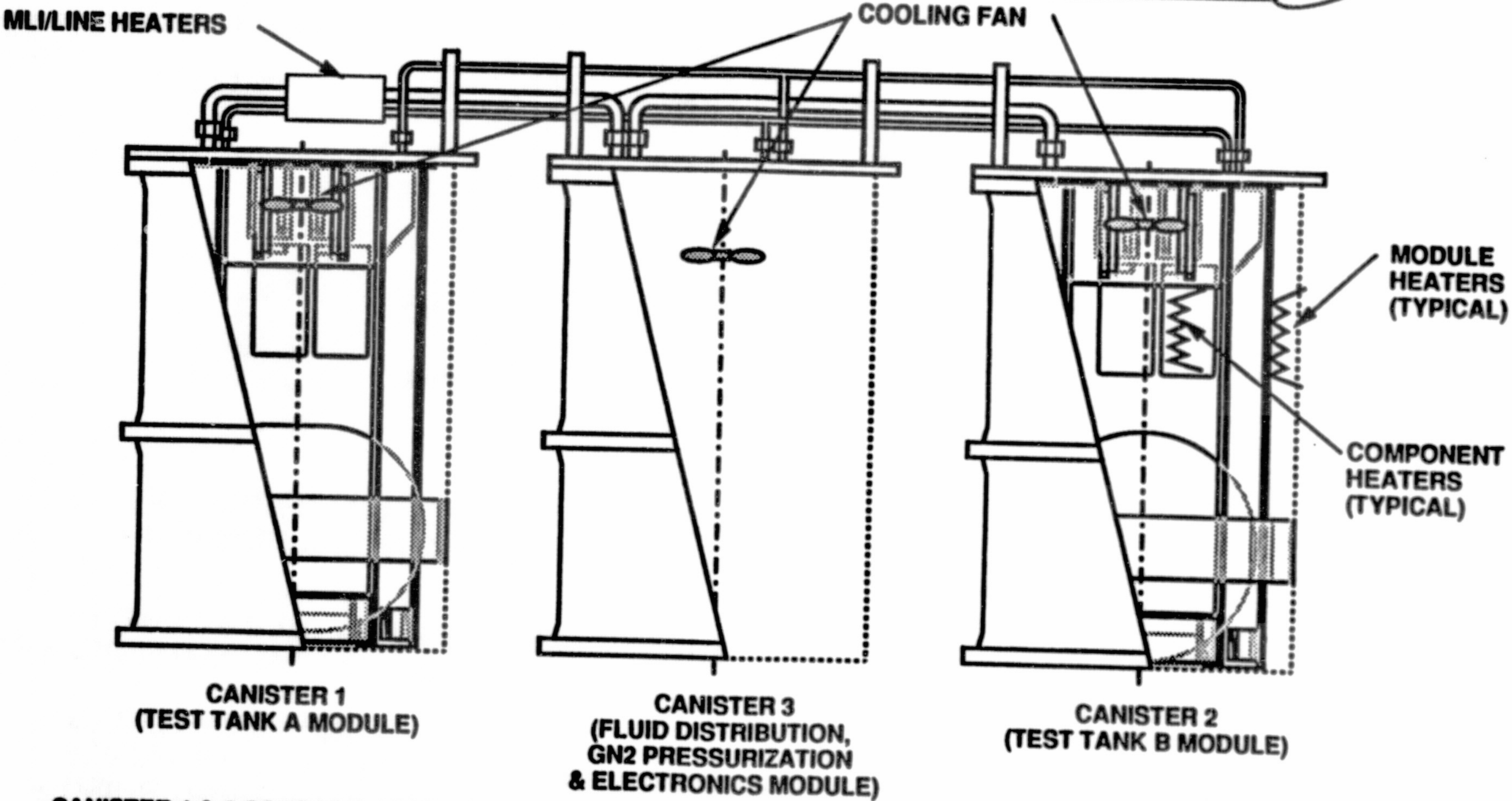
PAYLOAD DRY WEIGHT	295.9
CONSUMABLES	85.5
PAYLOAD (W/O HH AVIONICS OR PLATES)	381.4
MARGIN OF 20% ON ALL BUT FLUID ITEMS	59.2
LAUNCH WEIGHT WITH MARGIN	440.6
HITCHHIKER GAS CAN (3 REQUIRED)*	420.0
HITCHHIKER AVIONICS + PLATE	210.0
TOTAL IF CHARGED W/ HH AVIONICS	1070.6

COMPARISON WITH CARRIER CAPACITIES

	TANK/VIDEO SYSTEMS		AVIONICS/PLUMBING	HH AVIONICS
MASSES (LBM) W/ MARGIN	TANK A 191.6	TANK B 109.4	139.6	210.0
GAS CAN LIMITS	200.0*	200.0*	200.0*	210.0

* GAS CAN LISTED WITH 200 LBM MAX CARRYING CAPABILITY, BUT STRUCTURE CAN HOLD 400 LBM WITH 140 REQUIRED FOR GAS CAN ALLOWING A 260 LBM PAYLOAD IN GAS CAN

VTRE THERMAL CONTROL APPROACH USING HITCHHIKER CANISTERS



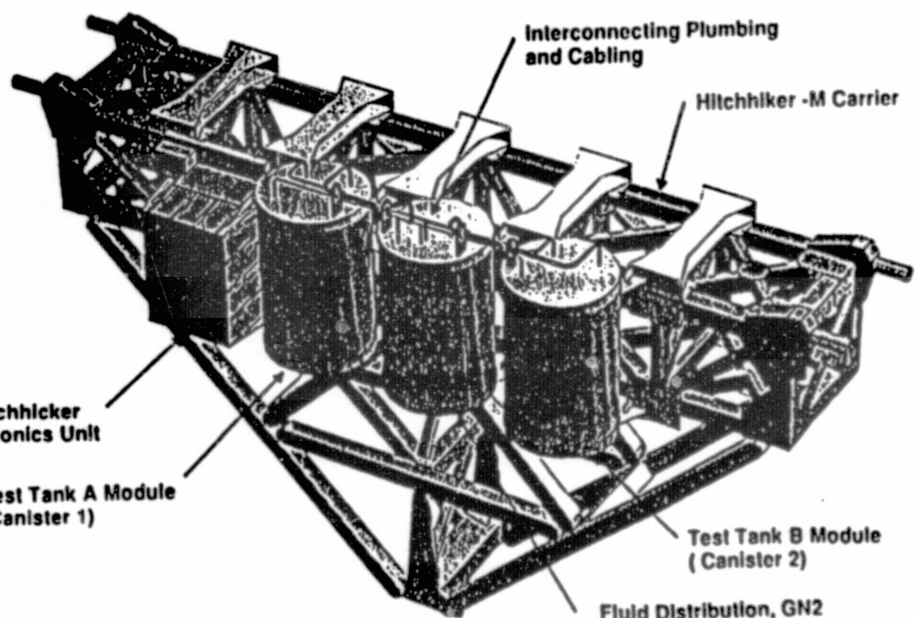
- CANISTER 1 & 2 CONTAINS CAMERAS, LIGHTS, VALVES AND ELECTRONICS THAT WILL BE THERMALLY MANAGED BY CONDUCTION/CONVECTION
- CANISTER 3 CONTAINS VALVES, MICROPROCESSOR, POWER AND ELECTRONICS THAT WILL BE THERMALLY MANAGED BY CONDUCTION/CONVECTION
- INTERCONNECT PLUMBING REQUIRES THERMAL PROTECTION (MLI AND HEATERS)
- CANISTER COOLING FAN APPROACH REQUIRES THAT CANISTERS BE PRESSURIZED (15 PSIG GN2)
- ALL CANISTERS CONTAIN COMPONENT & MODULE HEATERS FOR COLD CASE MANAGEMENT

CARRIER APPROACH

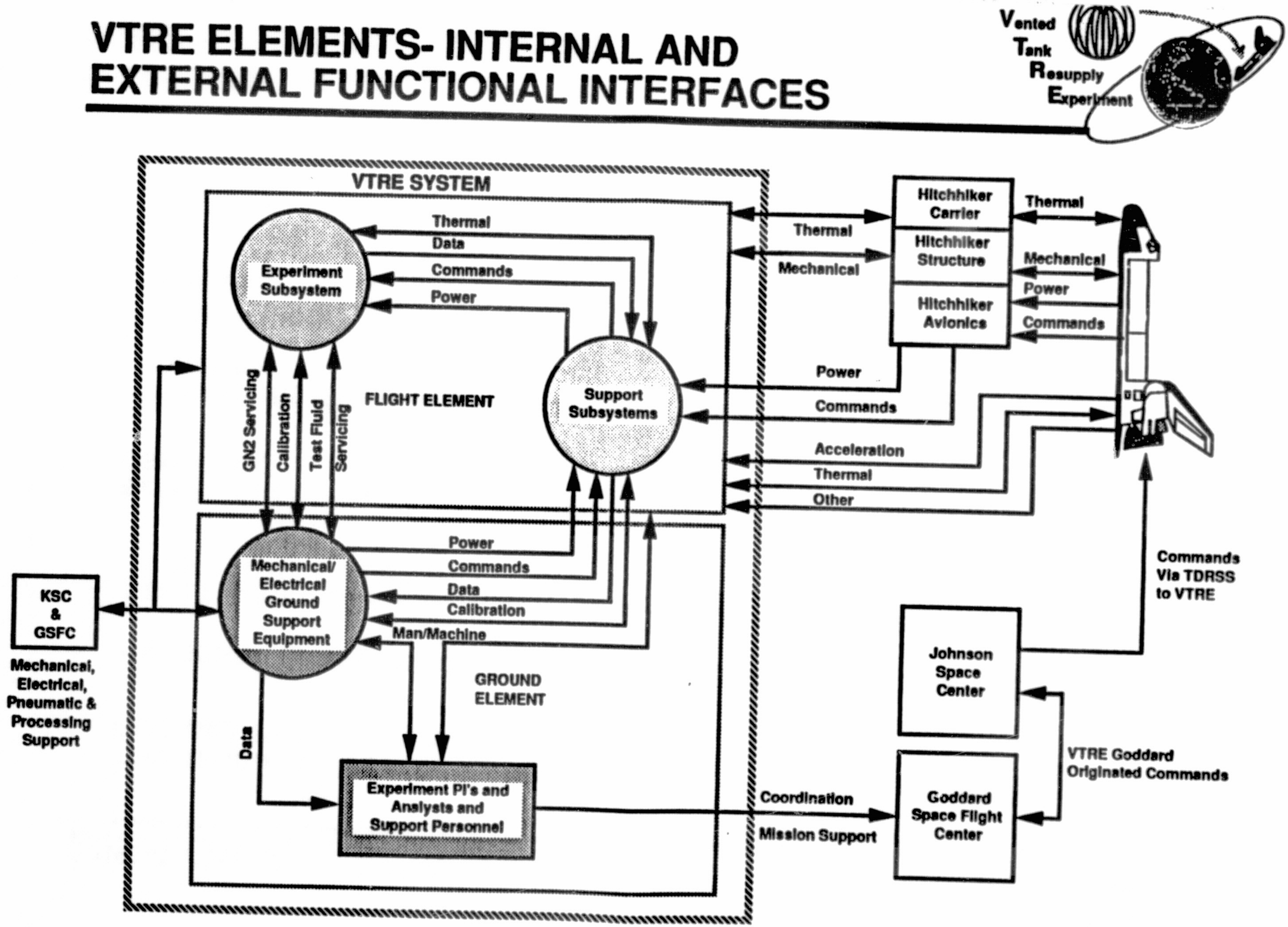
- USING THREE HITCHHIKER CANISTERS THAT WILL HAVE THE TOP MOUNTING PLATES MODIFIED TO ALLOW FOR FLUID AND ELECTRICAL CONNECTIONS BETWEEN THE UNITS

- CANISTERS WILL BE MOUNTED SIDE BY SIDE ON A HH-M MPESS BEAM TO BE FLOWN AS PART OF A MIXED EXPERIMENT

  - CONFIGURATION COULD ALSO BE FLOWN AS A HH-G PAYLOAD ATTACHED TO THE ORBITER SIDEWALL



VTRE ELEMENTS- INTERNAL AND EXTERNAL FUNCTIONAL INTERFACES



MISSION APPROACH

- VTRE TESTING TO BE INTEGRATED INTO MISSION TIMELINE IN A MANNER THAT WILL MINIMIZE THE ORBITER IMPACTS
  - MAJORITY OF TESTING CAN BE PERFORMED DURING SLEEP PERIODS
  - ONLY ASTRONAUT INVOLVEMENT WILL BE TWO THRUSTINGS AND ONE ATTITUDE MANEUVER
- EXPERIMENT CONSISTS OF 7 SEQUENCES THAT CAN BE CONTROLLED VIA THE GSFC POCC
  - COMMANDS ISSUED IN SIMILAR MANNER TO THOSE SET FROM SSP IN ORBITER
  - POWER ON/OFF, SEQUENCE START/STOP, AND SEQUENCE SELECT ARE ONLY REQUIRED COMMANDS

EXPERIMENT REQUIREMENTS IMPACT ON ORBITER MISSION

Vented Tank Resupply Experiment

• ACCELERATION	SHUTTLE PRCS TO PROVIDE THRUST IN X AXIS USING THRUSTERS TO PROVIDE A PURE TRANSLATION IN X.
• ALTITUDE	STS ALTITUDE DEPENDENT ON PRIMARY PAYLOADS; NO VTRE REQUIREMENT.
• ATTITUDE	FOR VENTING TEST WITH UPSETTING ACCELERATION, SHUTTLE MUST BE PLACED IN HIGH DRAG CONFIGURATION WITH SHUTTLE Z AXIS ALIGNED WITH VELOCITY VECTOR
• MISSION DURATION	44 HOURS MINIMUM TO AS LONG AS 144 HOURS
• CREW INTERACTION	THRUSTER OPERATIONS; SHUTTLE ORIENTATION TO HIGH DRAG ORIENTATION; STANDARD SWITCH PANEL
• PAYLOAD WEIGHT	1070.6 LBS INCLUDING 3 GAS CANISTERS AND HH AVIONICS
• PAYLOAD POWER	191.5 W - AVE POWER DURING TEST; MINIMUM OF 5.84 KWH/FLIGHT TO MAXIMUM OF 17.82 KWH/FLIGHT (DEPENDENT ON LENGTH OF POWERED-UP HOLD PERIODS)
• EXPULSION RATE OF FREON IN P/L BAY	2.5 LBM/HR MAXIMUM VENT RATE
• TEST START	START ASAP AFTER P/L BAY DOORS OPEN & CREW AVAILABLE

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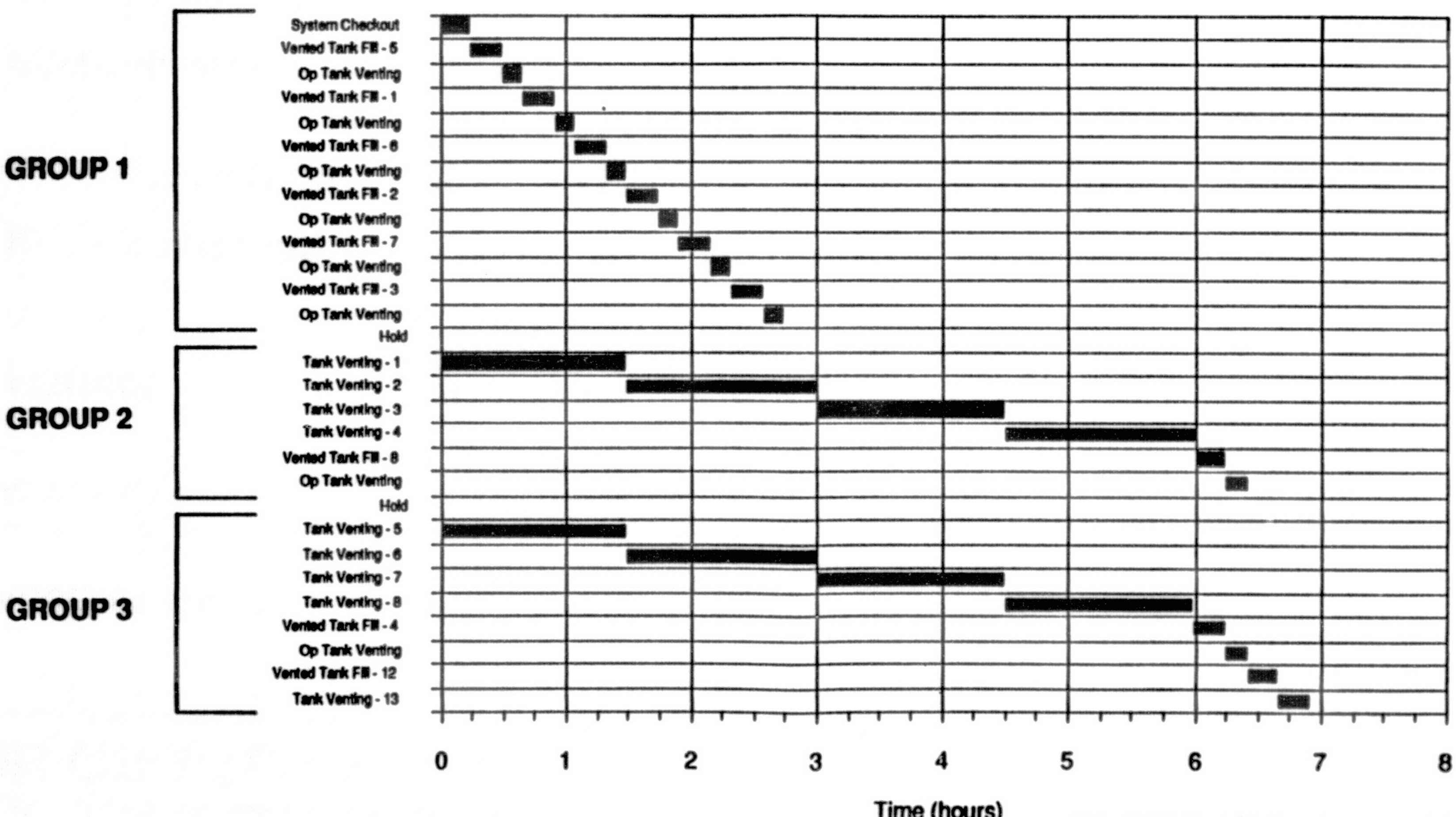
EXPERIMENT GROUPING TIMELINE

Vented Tank Resupply Experiment

- EXPERIMENT BROKEN INTO 7 GROUPINGS OF TESTS WITH HOLD PERIODS INBETWEEN (OTHER GROUPINGS OF TESTS ARE POSSIBLE AND WILL BE EVAUATED)



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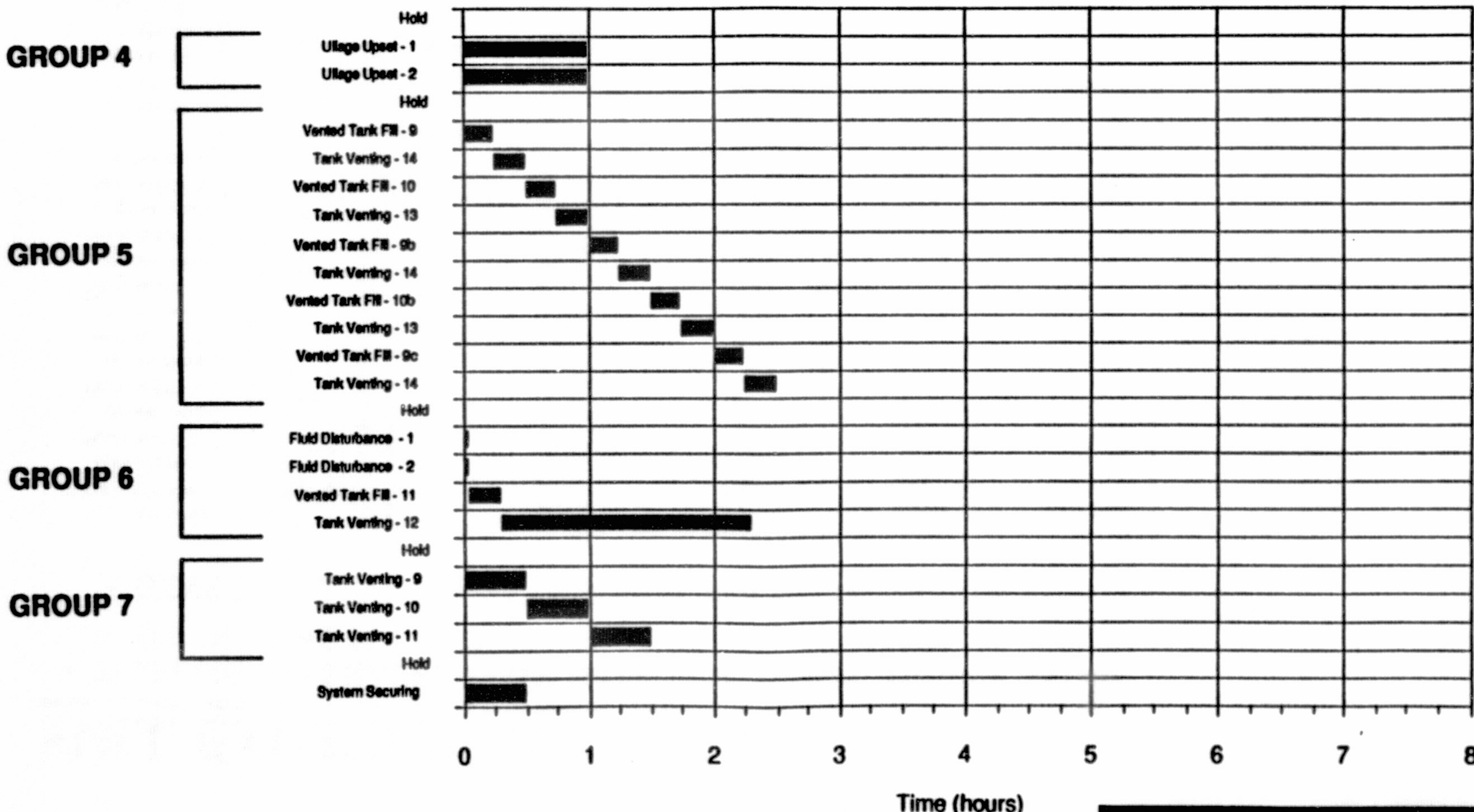
Vented
Tank
Resupply
Experiment

EXPERIMENT GROUPING TIMELINE (CONCLUDED)

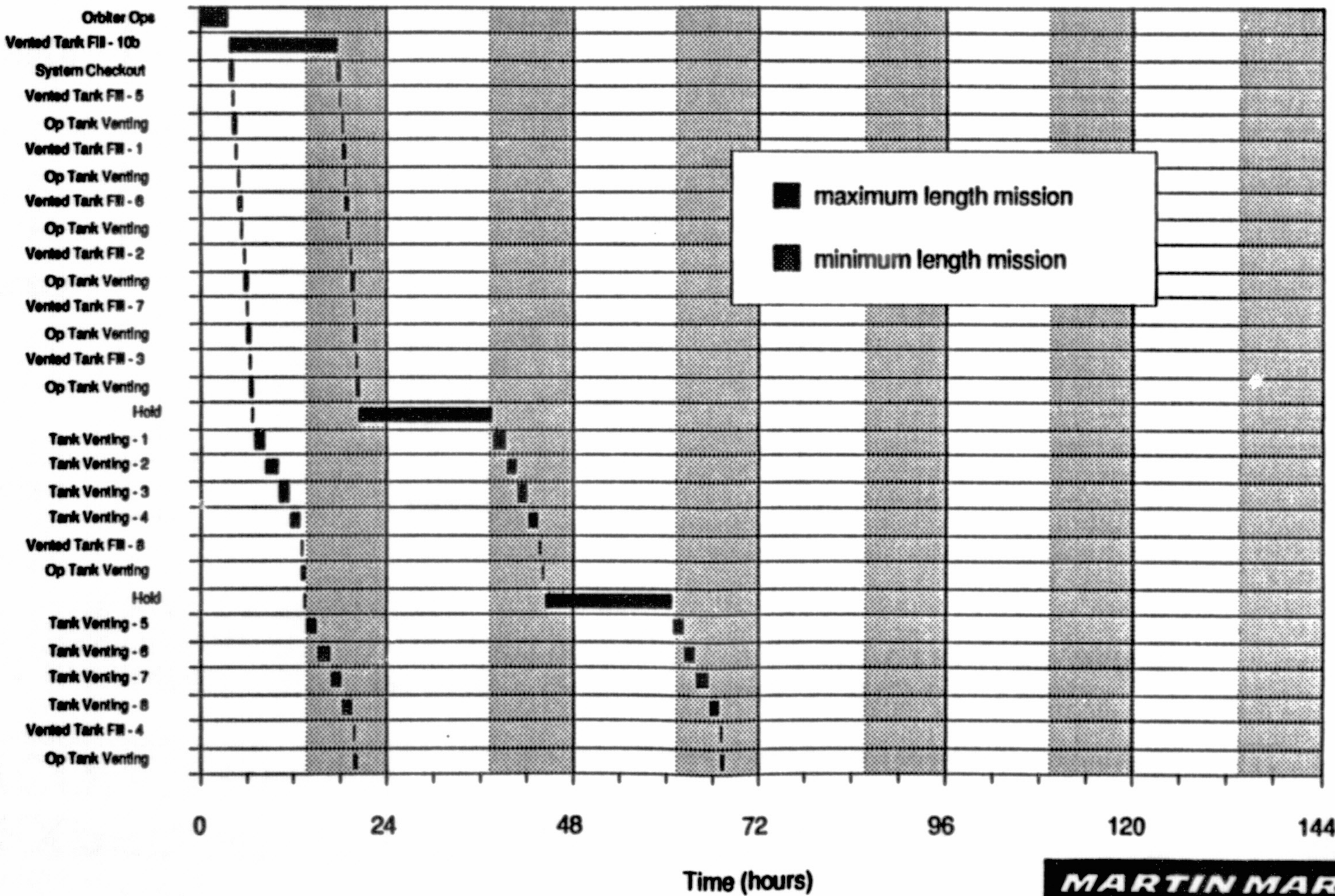
- EXPERIMENT BROKEN INTO 7 GROUPINGS OF TESTS WITH HOLD PERIODS INBETWEEN (OTHER GROUPINGS OF TESTS ARE POSSIBLE AND WILL BE EVAUATED)



FULL EXPERIMENT TIMELINE

Vented Tank Resupply Experiment

- TIMELINE GENERATED FROM DATABASE WHICH TRACKS ENTIRE FLOW OF VTRE TESTING
  - GENERATED TWO TIMELINES THAT BOUND MISSION REQUIREMENTS



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Vented Tank Resupply Experiment

FULL EXPERIMENT TIMELINE (CONCLUDED)

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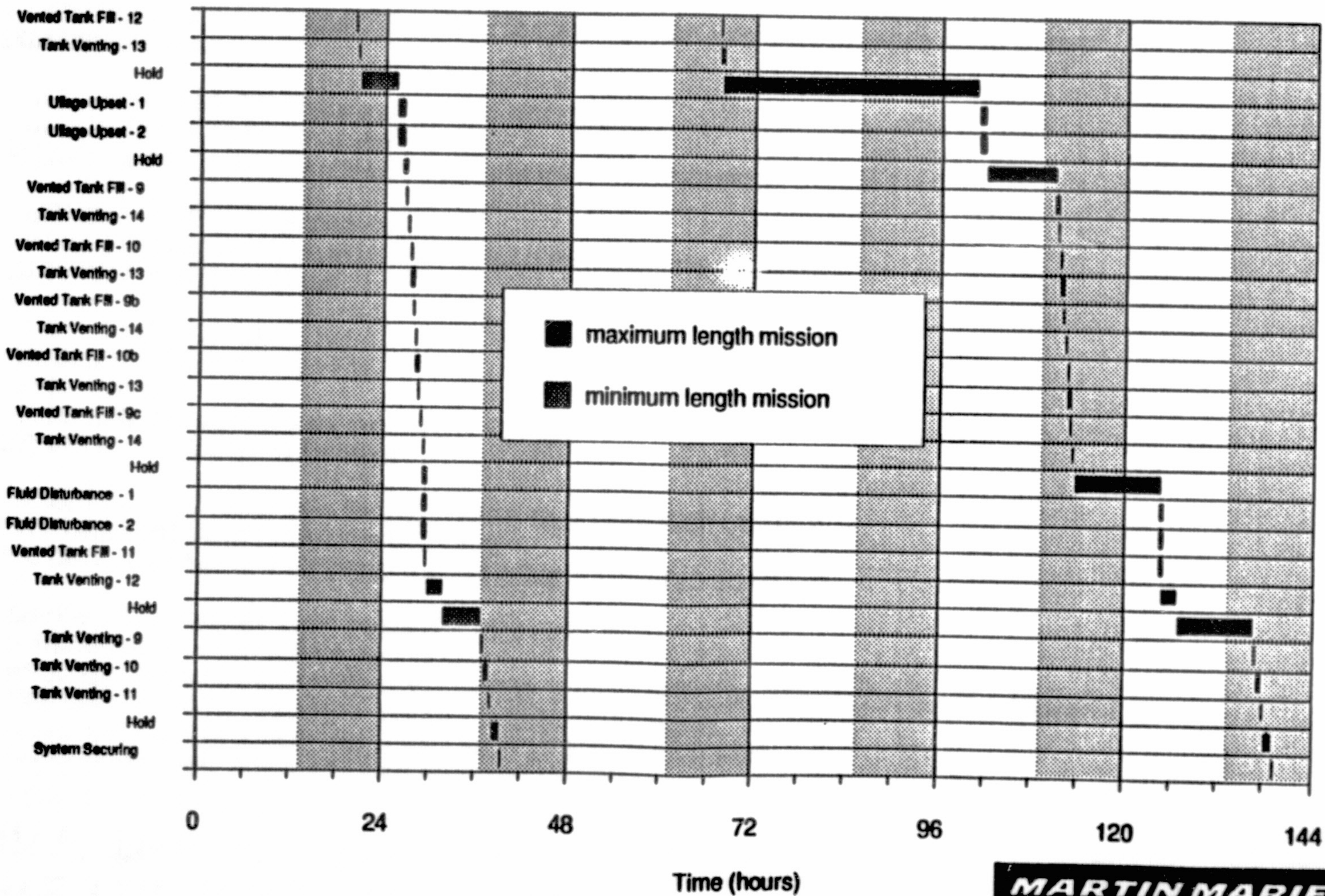
  - GENERATED TWO TIMELINES THAT BOUND MISSION REQUIREMENTS



VTRE TOP ISSUES & MAJOR AREAS WHICH DRIVE THE DESIGN, COST & SCIENCE FIDELITY OF THE PROGRAM

Vented Tank Resupply Experiment

- CARRIER SELECTION (GSFC HAS BASELINED THE HH-M CARRIER)
  - MEETING 35 - 50 HZ NATURAL FREQUENCY REQUIREMENT
  - NEGOTIATING MASS/CG CONSTRAINTS AND RESULTING CONFIGURATION ON THE CARRIER
  - MANIFESTING / CARRIER AVAILABILITY
  - THREE INTERCONNECTING CANISTER ARRANGEMENT

- FREE DRIFT OF ORBITER & DESIRED THRUSTING FOR FLUID SETTLING
  - ALL DRIFTING ACCELERATION REGIMES
  - INTERFACE POSITION AND MAINTENANCE OF STABILIZED INTERFACE

- SCALING OF EXPERIMENT DESIGN
  - TANK SIZES / EXPERIMENT WEIGHT
  - TANK SHAPES
  - ORBITER ORIENTATION
  - VANE CONFIGURATION

- STS SAFETY REQUIREMENTS
  - MORE EXTENSIVE SCRUTINY THAN SIMPLE GAS CAN EXPERIMENTS
  - VENTING FREON 113 IN THE BAY

- AMOUNT OF CONSUMABLE VIDEO TAPE FOR DATA COLLECTION
  - IMPACT ON DESIRED EXPERIMENT SET
  - ALLOCATION OF EXPERIMENTS TO THE RESOURCE

- EXPERIMENT RISK
  - DESIGN APPROACH IS SINGLE STRING, EXCEPT WHERE SAFETY DICTATES OTHERWISE
  - AUTONOMOUS TEST WITH NO GROUND MONITORING
  - USE OF "INEXPENSIVE" NOT PREVIOUSLY FLIGHT QUALIFIED HARDWARE

- USE OF HH CANISTERS
  - CONTAINMENT
  - USE OF HIGH STRUCTURAL SAFETY FACTORS / MARGIN
  - LID MODIFICATION IMPACT
  - IMPACT OF FREON SERVICING

- PROTECTING TEST FLUID FROM THERMAL HEATING

- THERMAL MANAGEMENT USING PRESSURIZED CANISTER AND CIRCULATION FANS