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AEROSPACE INFORMATION REPORT

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Revised

ACTUATION SYSTEM DATA SUMMARY FOR MISSILES AND LAUNCH VEHICLES

1. PURPOSE: A survey of existing designs (past and present) is a valuable aid during the concept formulation stage of a new design. This summary report on missile and launch vehicle actuation systems has been formulated to provide a data base that should be useful in the initial design stages of a new system.
2. SCOPE: The scope of this document includes all missile and launch vehicle actuation systems, including electrohydraulic, electropneumatic, and electromechanical types. The data for many systems are not complete. As more information becomes available, periodic updates will be issued to complete existing data sheets and to add new ones.

An index by type of vehicle and by type of actuation system is included. The actual data sheets in the body of the report are organized in alphabetical order.

3. VEHICLE INDEX:

3.1 Type of Vehicle:

3.1.1 Missile:

- AMRAAM (Advanced Development)
- ASALM
- Condor
- Copperhead
- Dragon
- Falcon (Aim 4D, F and G)
- GBU-15
- Hawk

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3.1.1 Missile (Continued):

- Hellfire
- HOBOS (GBU-8)
- Hornet
- Maverick
- Nike Hercules
- Patriot
- Pershing (P-1a)
- Phoenix
- SIAM
- Sidewinder
- Sparrow
- Stinger Alternate
- Talos
- Tomahawk (Rocket Motor, Rocket Motor Improved, and Cruise)
- TOW

3.1.2 Booster/Space Vehicle:

- Atlas (Booster, Sustainer, Vernier)
- Centaur
- Delta (1st Stage)
- IUS
- Titan (1st Stage, 2nd Stage Main and Roll Engines)

3.1.3 ICBM/ABM:

- Minuteman I, II, III (Stages 1, 2, 3)
- Peacekeeper (Stages 1 and 3)
- Spartan
- Sprint (Stages 1 and 2)

3.2 Type of Actuation System:

3.2.1 Electrohydraulic:

- ASALM
- Atlas (Booster, Sustainer, Vernier)
- Centaur

3.2.1 Electrohydraulic (Continued):

- Delta (1st Stage)
- Falcon (Aim 4D, F, and G)
- Hawk
- Maverick
- Minuteman I, II, III (Stages 1, 2, and 3)
- Nike Hercules
- Patriot
- Peacekeeper (Stages 1 and 3)
- Pershing (P-1a)
- Phoenix
- Sparrow
- Spartan
- Sprint (Stages 1 and 2)
- Talos
- Titan III (1st Stage, 2nd Stage Main and Roll Engines)
- Tomahawk (Rocket Motor and Rocket Motor Improved)

3.2.2 Electropneumatic:

- Copperhead
- Dragon
- GBU-15
- Hellfire
- HOBOS (GBU-8)
- Hornet
- SIAM
- Sidewinder
- Stinger Alternate
- TOW

3.2.3 Electromechanical:

- AMRAAM (Advanced Development)
- ASALM
- Condor
- IUS
- Tomahawk (Cruise)

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PREPARED BY
THE MISSILE AND SPACE SYSTEMS PANEL
OF SAE SUBCOMMITTEE A-6A,
FLUID POWER SYSTEMS OF SAE COMMITTEE A-6,
AEROSPACE FLUID POWER AND CONTROL TECHNOLOGIES

MISSILE/SPACE VEHICLE ACTUATION SYSTEM DATA SHEET

1 GENERAL DESCRIPTION <u>VEHICLE</u> Applicable to Advanced - NAME: <u>Medium Range Air-Air Missile (ANRAAM)</u> - TYPE: _____ - CONTROL: <u>Propulsion Control Valve (1 actuator)</u> - COMPANY: _____ - PROGRAM: _____ <u>ACTUATION SYSTEM</u> - COMPANY: <u>United Technologies</u> - TYPE PROGRAM: <u>Development, 1978</u> - TYPE DESIGN: <u>Electromechanical</u> - AXES: _____ - COMPENSATION: <u>Electronic</u> - REDUNDANCY: <u>No</u> - TEMP. RANGE: <u>-65° to +250°F</u> <u>LOAD</u> - TRAVEL: <u>45 deg</u> - TYPE: <u>Coulomb friction, aero</u> - INERTIA: _____ - f_n: _____ - Other: <u>Aero: 50 lb-in</u> <u>Friction: 50 lb-in</u>	4 HYDRAULIC <u>SYSTEM</u> - TYPE: _____ - PRESSURE: _____ - FLOW: _____ - FLUID: _____ - SEALS: _____ - FILTER: _____ <u>SERVO VALVE</u> - OPERATION: _____ - CONFIGURATION: _____ <u>ACTUATOR</u> - LINEAR: _____ - ROTARY: _____ <u>POWER SUPPLY</u> - PUMP • TYPE: _____ • POWER SOURCE: _____ - ENERGY SOURCE • BATTERY: _____ • OTHER: _____ - STORED GAS: _____ - GAS GEN/ACCUM: _____
2 ACTUATION SYSTEM DESIGN <u>RATED CONDITIONS</u> - DESIGN LOAD: <u>150 lb-in</u> - STALL LOAD: <u>300 lb-in</u> - DESIGN RATE: <u>30 deg/sec</u> - NO LOAD RATE: <u>400 deg/sec</u> <u>DUTY CYCLE</u> - DURATION: <u>180 sec</u> - DESCRIPTION: <u>Hold-ramp open-hold-ramp closed-hold</u> <u>DYNAMIC PERFORMANCE</u> - BANDWIDTH: <u>15 Hz based on -3 dB</u> - STEP RESPONSE: <u>5 deg step in 20 msec; 10% overshoot</u> <u>STATIC PERFORMANCE</u> - RESOLUTION: <u>0.2 deg</u> - THRESHOLD: <u>0.05 deg</u> - HYSTERESIS: <u><0.05 deg</u> - CLOSED LOOP STIFFNESS: <u>>50,000 lb-in/deg</u> STROKE: _____ <u>45 deg</u> WEIGHT: <u>3 lbs</u> <u>FEEDBACK</u> - TYPE: <u>Position</u> - METHOD: <u>Film potentiometer</u> <u>ELECTRONIC CONTROLLER</u> - TYPE: <u>PWM at 3 KHz</u> - SIGNAL LEVEL: <u>28V; 10A</u> <u>LOOP ELECTRONICS: Analog</u>	5 PNEUMATIC/WARM GAS <u>SYSTEM</u> - STORED GAS • TYPE GAS: _____ • SUPPLY PRESS: _____ • PROOF PRESS: _____ • BURST PRESS: _____ • VESSEL TYPE: _____ • VESSEL VOL: _____ • SEALS: _____ - GAS GENERATOR • PROPELLANT: _____ • FLOWRATE: _____ • REG. VALVE: _____ • TEMP @ ACT: _____ • PRESS @ ACT: _____ <u>CONTROL VALVE</u> - OPERATION: _____ - CONFIGURATION: _____ <u>ACTUATOR</u> - LINEAR: _____ - ROTARY: _____ - ROTARY/LINEAR: _____
3 ELECTROMECHANICAL - MOTOR • DC: <u>Brush motor rated at 27V & 20A</u> • AC: _____ • STEPPER: _____ - ACTUATOR • LINEAR: _____ • ROTARY: <u>Servomotor</u>	6 STORED GAS VESSEL SHIPMENT - TYPE GAS: _____ - GAS PRESSURE: _____ - BURST FACTOR: _____ - DDT APPROVAL: _____ 7 SELECTION CRITERIA AND/OR SPECIAL FEATURES Planetary or harmonic gearing drives high speed servomotor and hot gas butterfly valve

MISSILE/SPACE VEHICLE ACTUATION SYSTEM DATA SHEET

1 GENERAL DESCRIPTION <u>VEHICLE</u> - NAME: <u>ASALM (Advanced Strategic Air Launched Missile)</u> - TYPE: <u>Air-to-surface</u> - CONTROL: <u>Aerodynamic fin (4 actuators)</u> - COMPANY: <u>Martin/Orlando</u> - PROGRAM: <u>Development, 1978-1980</u> <u>ACTUATION SYSTEM</u> - COMPANY: <u>Martin/Orlando</u> - TYPE PROGRAM: <u>Development, 1978-1980</u> - TYPE DESIGN: <u>Electromechanical</u> - AXES: <u>Pitch, yaw, roll</u> - COMPENSATION: <u>Electronic</u> - REDUNDANCY: <u>No</u> - TEMP. RANGE: <u>-60 to +600°F</u> <u>LOAD</u> - TRAVEL: <u>±26.5 deg</u> - TYPE: <u>Aero and inertia</u> - INERTIA: <u>0.46 lb-in-sec²</u> - f_n: _____ - Other: <u>Aero: 3700 lb-in</u> <u>Coulomb friction: 90 lb-in</u>	4 HYDRAULIC <u>SYSTEM</u> - TYPE: _____ - PRESSURE: _____ - FLOW: _____ - FLUID: _____ - SEALS: _____ - FILTER: _____ <u>SERVO VALVE</u> - OPERATION: _____ - CONFIGURATION: _____ <u>ACTUATOR</u> - LINEAR: _____ - ROTARY: _____ <u>POWER SUPPLY</u> - PUMP • TYPE: _____ • POWER SOURCE: _____ - ENERGY SOURCE • BATTERY: _____ • OTHER: _____ - STORED GAS: _____ - GAS GEN/ACCUM: _____
2 ACTUATION SYSTEM DESIGN <u>RATED CONDITIONS</u> - DESIGN LOAD: <u>1200 lb-in</u> - STALL LOAD: <u>3000 lb-in</u> - DESIGN RATE: <u>180 deg/sec</u> - NO LOAD RATE: <u>250 deg/sec</u> <u>DUTY CYCLE</u> - DURATION: <u>1000 sec</u> - DESCRIPTION: <u>120 in-lbs/deg, 5 Hz, ±0.40 deg</u> <u>DYNAMIC PERFORMANCE</u> - BANDWIDTH: <u>30 Hz based on $\phi = 90^\circ$</u> - STEP RESPONSE: <u>±5°, ±20% overshoot</u> <u>STATIC PERFORMANCE</u> - RESOLUTION: <u>0.10 deg</u> - THRESHOLD: <u>0.02 deg</u> - HYSTERESIS: <u>0.38 deg</u> - CLOSED LOOP STIFFNESS: <u>9950 lb-in/deg</u> STROKE: <u>27 deg</u> WEIGHT: <u>≈55 lbs</u> <u>FEEDBACK</u> - TYPE: <u>Position</u> - METHOD: <u>Film potentiometer</u> <u>ELECTRONIC CONTROLLER</u> - TYPE: <u>AC</u> - SIGNAL LEVEL: <u>2.5 deg/volt ±10%</u> <u>LOOP ELECTRONICS</u>: <u>Digital and analog with D/A converter</u>	5 PNEUMATIC/WARM GAS <u>SYSTEM</u> - STORED GAS • TYPE GAS: _____ • SUPPLY PRESS: _____ • PROOF PRESS: _____ • BURST PRESS: _____ • VESSEL TYPE: _____ • VESSEL VOL: _____ • SEALS: _____ - GAS GENERATOR • PROPELLANT: _____ • FLOWRATE: _____ • REG. VALVE: _____ • TEMP @ ACT: _____ • PRESS @ ACT: _____ <u>CONTROL VALVE</u> - OPERATION: _____ - CONFIGURATION: _____ <u>ACTUATOR</u> - LINEAR: _____ - ROTARY: _____ - ROTARY/LINEAR: _____
3 ELECTROMECHANICAL - MOTOR • DC: <u>Brushless with 8 VDC @ 3200 Hz and 0.02 amps</u> • AC: _____ • STEPPER: _____ - ACTUATOR • LINEAR: <u>Ballscrew with linear to rotary link</u> • ROTARY: _____	6 STORED GAS VESSEL SHIPMENT - TYPE GAS: _____ - GAS PRESSURE: _____ - BURST FACTOR: _____ - DOT APPROVAL: _____ 7 SELECTION CRITERIA AND/OR SPECIAL FEATURES Samarium cobalt magnets resulted in competitive EM performance.

MISSILE/SPACE VEHICLE ACTUATION SYSTEM DATA SHEET

1 GENERAL DESCRIPTION <u>VEHICLE</u> - NAME: <u>ASALM (Advanced Strategic Air Launched Missile)</u> - TYPE: <u>Air-to-surface</u> - CDNTRDL: <u>Aerodynamic fin (4 actuators)</u> - COMPANY: <u>Martin/Orlando</u> - PROGRAM: <u>Development, 1978-1980</u> <u>ACTUATION SYSTEM</u> - COMPANY: <u>Martin/Orlando</u> - TYPE PROGRAM: <u>Development, 1978-1980</u> - TYPE DESIGN: <u>Hydraulic</u> - AXES: <u>Pitch, yaw, roll</u> - COMPENSATION: <u>Electronic</u> - REDUNDANCY: <u>No</u> - TEMP. RANGE: <u>-12 to +600°F</u> <u>LOAD</u> - TRAVEL: <u>+22 deg</u> - TYPE: <u>Inertia and areo</u> - INERTIA: <u>0.46 lb-in-sec²</u> - f_n: <u></u> - Other: <u>Aero: 3700 lb-in</u> <u>Coulomb Fric: <400 lb-in</u>	4 HYDRAULIC <u>SYSTEM</u> - TYPE: <u>Recirculating</u> - PRESSURE: <u>3500 psi</u> - FLOW: <u>2 gpm</u> - FLUID: <u>Chevron M2-V</u> - SEALS: <u>Fluorocarbon</u> - FILTER: <u>40 micron</u> <u>SERVO VALVE</u> - OPERATION: <u>4-way flow control</u> - CONFIGURATION: <u>2-stage single nozzle flapper</u> <u>ACTUATOR</u> - LINEAR: <u></u> - ROTARY: <u>Rack and pinion with 0.67 in² effective area</u> <u>POWER SUPPLY</u> - PUMP • TYPE: <u>Fixed piston</u> • POWER SOURCE: <u>Gas turbine</u> - ENERGY SOURCE • BATTERY: <u></u> • OTHER: <u></u> - STORED GAS: <u>Stored gas accumulator</u> - GAS GEN/ACCUM: <u>Gas generator bleed air</u>
2 ACTUATION SYSTEM DESIGN <u>RATED CONDITIONS</u> - DESIGN LOAD: <u>1200 lb-in</u> - STALL LOAD: <u>3000 lb-in</u> - DESIGN RATE: <u>180 deg/sec</u> - NO LOAD RATE: <u>25 deg/sec</u> <u>DUTY CYCLE</u> - DURATION: <u>1000 sec</u> - DESCRIPTION: <u>Max activity of 600 deg in 1.0 sec (sum of 4 fins)</u> <u>DYNAMIC PERFORMANCE</u> - BANDWIDTH: <u>30 Hz based on $\phi = 90^\circ$</u> - STEP RESPONSE: <u>+5°, ≤ 20% overshoot</u> <u>STATIC PERFORMANCE</u> - RESOLUTION: <u>0.05 deg</u> - THRESHOLD: <u>0.05 deg</u> - HYSTERESIS: <u>1.00 deg</u> - CLOSED LOOP STIFFNESS: <u>97 Hz at 100°F fluid temp.</u> - STROKE: <u>+24 deg</u> - WEIGHT: <u>100 lbs</u> <u>FEEDBACK</u> - TYPE: <u>Position</u> - METHOD: <u>RVDT</u> <u>ELECTRONIC CONTROLLER</u> - TYPE: <u>DC</u> - SIGNAL LEVEL: <u>< 13.5 ma</u> <u>LOOP ELECTRONICS: Digital and analog with D/A converter</u>	5 PNEUMATIC/WARM GAS <u>SYSTEM</u> - STORED GAS • TYPE GAS: <u>N₂</u> • SUPPLY PRESS: <u>3500 psi</u> • PROOF PRESS: <u>5300 psi</u> • BURST PRESS: <u>15000 psi</u> • VESSEL TYPE: <u>Cylinder</u> • VESSEL VOL: <u></u> • SEALS: <u>Fluorocarbon</u> - GAS GENERATOR • PROPELLANT: <u>Ammonia Nitrate</u> • FLOWRATE: <u>0.2 lbs/sec</u> • REG. VALVE: <u>No</u> • TEMP @ ACT: <u>1500°F at turbine</u> • PRESS @ ACT: <u></u> <u>CONTROL VALVE</u> - OPERATION: <u></u> - CONFIGURATION: <u></u> <u>ACTUATOR</u> - LINEAR: <u></u> - ROTARY: <u></u> - ROTARY/LINEAR: <u></u>
3 ELECTROMECHANICAL - MOTOR • DC: <u></u> • AC: <u></u> • STEPPER: <u></u> - ACTUATOR • LINEAR: <u></u> • ROTARY: <u></u>	6 STORED GAS VESSEL SHIPMENT - TYPE GAS: <u></u> - GAS PRESSURE: <u></u> - BURST FACTOR: <u></u> - DOT APPROVAL: <u></u> 7 SELECTION CRITERIA AND/OR SPECIAL FEATURES Selection based primarily upon high temperature performance and stiffness.

MISSILE/SPACE VEHICLE ACTUATION SYSTEM DATA SHEET

1 GENERAL DESCRIPTION <u>VEHICLE</u> - NAME: <u>Atlas Booster (2 engines)</u> - TYPE: <u>Space Launch Vehicle</u> - CONTROL: <u>Gimbaled nozzles(4 actuators)</u> - COMPANY: <u>Convair</u> - PROGRAM: <u>Production 1957 -</u> <u>ACTUATION SYSTEM</u> - COMPANY: <u>Convair & Hydraulic Research</u> - TYPE PROGRAM: <u>Production, 1957 -</u> - TYPE DESIGN: <u>Hydraulic</u> - AXES: <u>Pitch, yaw, roll</u> - COMPENSATION: _____ - REDUNDANCY: <u>None</u> - TEMP. RANGE: _____ <u>LOAD</u> - TRAVEL: <u>+5 deg</u> - TYPE: _____ - INERTIA: _____ - f_n: _____ - Other: _____	4 HYDRAULIC <u>SYSTEM</u> - TYPE: <u>Recirculating</u> - PRESSURE: <u>3000 psi</u> - FLOW: <u>22.5 gpm</u> - FLUID: <u>MIL-H-5606</u> - SEALS: _____ - FILTER: _____ <u>SERVO VALVE</u> - OPERATION: <u>4-way flow control</u> - CONFIGURATION: <u>2-stage dual nozzle flapper</u> <u>ACTUATOR</u> - LINEAR: <u>3.5 in² balanced area</u> - ROTARY: _____ <u>POWER SUPPLY</u> - PUMP • TYPE: <u>Variable volume</u> • POWER SOURCE: <u>Turbine driven gearbox</u> - ENERGY SOURCE • BATTERY: _____ • OTHER: <u>Engine fuel</u> - STORED GAS: _____ - GAS GEN/ACCUM: _____
2 ACTUATION SYSTEM DESIGN <u>RATED CONDITIONS</u> - DESIGN LOAD: <u>75,470 lb-in</u> - STALL LOAD: <u>226,410 lb-in</u> - DESIGN RATE: <u>24.0 deg/sec</u> - NO LOAD RATE: <u>27.5 deg/sec</u> <u>DUTY CYCLE</u> - DURATION: _____ - DESCRIPTION: _____ <u>DYNAMIC PERFORMANCE</u> - BANDWIDTH: _____ - STEP RESPONSE: _____ <u>STATIC PERFORMANCE</u> - RESOLUTION: _____ - THRESHOLD: <u>0.1 ma</u> - HYSTERESIS: <u>0.2 ma</u> - CLOSED LOOP STIFFNESS: _____ STROKE: <u>+1.85 in.</u> WEIGHT: _____ <u>FEEDBACK</u> - TYPE: <u>Position</u> - METHOD: <u>Variable reluctance</u> <u>ELECTRONIC CONTROLLER</u> - TYPE: <u>DC</u> - SIGNAL LEVEL: <u>4.0 ma</u> <u>LOOP ELECTRONICS: Analog</u>	5 PNEUMATIC/WARM GAS <u>SYSTEM</u> - STORED GAS • TYPE GAS: _____ • SUPPLY PRESS: _____ • PROOF PRESS: _____ • BURST PRESS: _____ • VESSEL TYPE: _____ • VESSEL VOL: _____ • SEALS: _____ - GAS GENERATOR • PROPELLANT: _____ • FLOWRATE: _____ • REG. VALVE: _____ • TEMP @ ACT: _____ • PRESS @ ACT: _____ <u>CONTROL VALVE</u> - OPERATION: _____ - CONFIGURATION: _____ <u>ACTUATOR</u> - LINEAR: _____ - ROTARY: _____ - ROTARY/LINEAR: _____
3 ELECTROMECHANICAL - MOTOR • DC: _____ • AC: _____ • STEPPER: _____ - ACTUATOR • LINEAR: _____ • ROTARY: _____	6 STORED GAS VESSEL SHIPMENT - TYPE GAS: _____ - GAS PRESSURE: _____ - BURST FACTOR: _____ - DDT APPROVAL: _____ 7 SELECTION CRITERIA AND/OR SPECIAL FEATURES Fuel/hydraulic interface valve to provide fuel to back up limited hydraulic fluid supply in the event of system leakage.

MISSILE/SPACE VEHICLE ACTUATION SYSTEM DATA SHEET

1 GENERAL DESCRIPTION <u>VEHICLE</u> - NAME: <u>Atlas Sustainer (1 engine)</u> - TYPE: <u>Space Launch Vehicle</u> - CONTROL: <u>Gimbaled nozzle (2 actuators)</u> - COMPANY: <u>Convair</u> - PROGRAM: <u>Production 1957 -</u> <u>ACTUATION SYSTEM</u> - COMPANY: <u>Convair</u> - TYPE PROGRAM: <u>Production 1957 -</u> - TYPE DESIGN: <u>Hydraulic</u> - AXES: <u>Pitch, yaw</u> - COMPENSATION: _____ - REDUNDANCY: <u>No</u> - TEMP. RANGE: _____ <u>LOAD</u> - TRAVEL: <u>+3 deg</u> - TYPE: _____ - INERTIA: _____ - f_n: _____ - Other: _____	4 HYDRAULIC <u>SYSTEM</u> - TYPE: <u>Recirculating</u> - PRESSURE: <u>3000 psi</u> - FLOW: <u>MTI-H-5606</u> - FLUID: _____ - SEALS: _____ - FILTER: _____ <u>SERVO VALVE</u> - OPERATION: <u>4-way flow control</u> - CONFIGURATION: <u>2-stage dual nozzle flapper</u> <u>ACTUATOR</u> - LINEAR: <u>5.9 in² balanced area</u> - ROTARY: _____ <u>POWER SUPPLY</u> - PUMP • TYPE: <u>Variable volume</u> • POWER SOURCE: <u>Turbine driven gearbox</u> - ENERGY SOURCE • BATTERY: _____ • OTHER: <u>Engine fuel</u> - STORED GAS: _____ - GAS GEN/ACCUM: _____
2 ACTUATION SYSTEM DESIGN <u>RATED CONDITIONS</u> - DESIGN LOAD: <u>49,300 lb-in</u> - STALL LOAD: <u>177,120 lb-in</u> - DESIGN RATE: <u>7.9 deg/sec</u> - NO LOAD RATE: <u>14.2 deg/sec</u> <u>DUTY CYCLE</u> - DURATION: _____ - DESCRIPTION: _____ <u>DYNAMIC PERFORMANCE</u> - BANDWIDTH: _____ - STEP RESPONSE: _____ <u>STATIC PERFORMANCE</u> - RESOLUTION: _____ - THRESHOLD: <u>0.1 ma</u> - HYSTERESIS: <u>0.2 ma</u> - CLOSED LOOP STIFFNESS: _____ <u>STROKE</u>: <u>+0.51 in.</u> <u>WEIGHT</u>: _____ <u>FEEDBACK</u> - TYPE: <u>Position</u> - METHOD: <u>Variable reluctance</u> <u>ELECTRONIC CONTROLLER</u> - TYPE: <u>DC</u> - SIGNAL LEVEL: <u>4.0 ma</u> <u>LOOP ELECTRONICS</u>: <u>Analog</u>	5 PNEUMATIC/WARM GAS <u>SYSTEM</u> - STORED GAS • TYPE GAS: _____ • SUPPLY PRESS: _____ • PROOF PRESS: _____ • BURST PRESS: _____ • VESSEL TYPE: _____ • VESSEL VOL: _____ • SEALS: _____ - GAS GENERATOR • PROPELLANT: _____ • FLOWRATE: _____ • REG. VALVE: _____ • TEMP @ ACT: _____ • PRESS @ ACT: _____ <u>CONTROL VALVE</u> - OPERATION: _____ - CONFIGURATION: _____ <u>ACTUATOR</u> - LINEAR: _____ - ROTARY: _____ - ROTARY/LINEAR: _____
3 ELECTROMECHANICAL - MOTOR • DC: _____ • AC: _____ • STEPPER: _____ - ACTUATOR • LINEAR: _____ • ROTARY: _____	6 STORED GAS VESSEL SHIPMENT - TYPE GAS: _____ - GAS PRESSURE: _____ - BURST FACTOR: _____ - DOT APPROVAL: _____ 7 SELECTION CRITERIA AND/OR SPECIAL FEATURES Fuel/hydraulic interface valve to provide fuel to back up limited hydraulic fluid supply in the event of system leakage

MISSILE/SPACE VEHICLE ACTUATION SYSTEM DATA SHEET

1 GENERAL DESCRIPTION <u>VEHICLE</u> - NAME: <u>Atlas Vernier (2 engines)</u> - TYPE: <u>Space Launch Vehicle</u> - CONTROL: <u>Gimbaled nozzles(4 actuators)</u> - COMPANY: <u>Convair</u> - PROGRAM: <u>Production, 1957 -</u> <u>ACTUATION SYSTEM</u> - COMPANY: <u>Convair</u> - TYPE PROGRAM: <u>Production 1957 -</u> - TYPE DESIGN: <u>Hydraulic</u> - AXES: <u>Pitch, yaw, roll</u> - COMPENSATION: _____ - REDUNDANCY: <u>No</u> - TEMP. RANGE: _____ <u>LOAD</u> - TRAVEL: <u>Inboard: +70 deg</u> <u>Outboard: +25 deg</u> - TYPE: _____ - INERTIA: _____ - f_n: _____ - Other: _____	4 HYDRAULIC <u>SYSTEM</u> - TYPE: <u>Blowdown</u> - PRESSURE: <u>3000 to 1000 psi</u> - FLOW: <u>4.85 gpm</u> - FLUID: <u>MIL-H-5606</u> - SEALS: _____ - FILTER: _____ <u>SERVO VALVE</u> - OPERATION: <u>4-way flow control</u> - CONFIGURATION: <u>2-stage dual nozzle flapper</u> <u>ACTUATOR</u> - LINEAR: <u>0.5 in² balanced</u> - ROTARY: _____ <u>POWER SUPPLY</u> - PUMP • TYPE: <u>Variable volume (sustainer engine operation)</u> • POWER SOURCE: _____ - ENERGY SOURCE • BATTERY: _____ • OTHER: _____ - STORED GAS: <u>Accumulator (after engine shuts down)</u> - GAS GEN/ACCUM: _____
2 ACTUATION SYSTEM DESIGN <u>RATED CONDITIONS</u> - DESIGN LOAD: <u>3430 lb-in</u> - STALL LOAD: <u>4120 lb-in</u> - DESIGN RATE: <u>393 deg/sec</u> - NO LOAD RATE: <u>436 deg/sec</u> <u>DUTY CYCLE</u> - DURATION: _____ - DESCRIPTION: _____ <u>DYNAMIC PERFORMANCE</u> - BANDWIDTH: _____ - STEP RESPONSE: _____ <u>STATIC PERFORMANCE</u> - RESOLUTION: _____ - THRESHOLD: <u>0.1 ma</u> - HYSTERESIS: <u>0.2 ma</u> - CLOSED LOOP STIFFNESS: _____ <u>STROKE</u>: <u>Inboard, ± 1.5 in; Outboard, ± 0.5 in.</u> <u>WEIGHT</u>: _____ <u>FEEDBACK</u> - TYPE: <u>Position</u> - METHOD: <u>Variable reluctance</u> <u>ELECTRONIC CONTROLLER</u> - TYPE: <u>DC</u> - SIGNAL LEVEL: <u>4 ma</u> <u>LOOP ELECTRONICS</u>: <u>Analog</u>	5 PNEUMATIC/WARM GAS <u>SYSTEM</u> <u>STORED GAS</u> • TYPE GAS: _____ • SUPPLY PRESS: _____ • PROOF PRESS: _____ • BURST PRESS: _____ • VESSEL TYPE: _____ • VESSEL VOL: _____ • SEALS: _____ - GAS GENERATOR • PROPELLANT: _____ • FLOWRATE: _____ • REG. VALVE: _____ • TEMP @ ACT: _____ • PRESS @ ACT: _____ <u>CONTROL VALVE</u> - OPERATION: _____ - CONFIGURATION: _____ <u>ACTUATOR</u> - LINEAR: _____ - ROTARY: _____ - ROTARY/LINEAR: _____
3 ELECTROMECHANICAL - MOTOR • DC: _____ • AC: _____ • STEPPER: _____ - ACTUATOR • LINEAR: _____ • ROTARY: _____	6 STORED GAS VESSEL SHIPMENT - TYPE GAS: _____ - GAS PRESSURE: _____ - BURST FACTOR: _____ - DOT APPROVAL: _____ 7 SELECTION CRITERIA AND/OR SPECIAL FEATURES Fuel/hydraulic interface valve provides fuel to backup limited hydraulic fluid supply in the event of system leakage during engine powered flight.

MISSILE/SPACE VEHICLE ACTUATION SYSTEM DATA SHEET

1 GENERAL DESCRIPTION <u>VEHICLE</u> - NAME: <u>Centaur</u> - TYPE: <u>Space Launch Vehicle</u> - CONTROL: <u>Gimballed nozzle (2 nozzles, 2 act/nozzle)</u> - COMPANY: <u>Convair</u> - PROGRAM: <u>Production, 1958 -</u> <u>ACTUATION SYSTEM</u> - COMPANY: <u>Convair</u> - TYPE PROGRAM: <u>Production, 1958 -</u> - TYPE DESIGN: <u>Hydraulic</u> - AXES: <u>Pitch, yaw, roll</u> - COMPENSATION: <u>Electronic</u> - REDUNDANCY: <u>No</u> - TEMP. RANGE: <u>-30 to +275°F</u> <u>LOAD</u> - TRAVEL: <u>+3 deg</u> - TYPE: _____ - INERTIA: _____ - f_n: _____ - Other: _____	4 HYDRAULIC <u>SYSTEM</u> - TYPE: <u>Recirculating</u> - PRESSURE: <u>1000 psi</u> - FLOW: <u>1.64 gpm</u> - FLUID: <u>MIL-H-5606</u> - SEALS: <u>Nitrile</u> - FILTER: <u>10 micron</u> <u>SERVO VALVE</u> - OPERATION: <u>4-way flow control</u> - CONFIGURATION: <u>2-stage let pipe</u> <u>ACTUATOR</u> - LINEAR: <u>1.5 in² balanced area</u> - ROTARY: _____ <u>POWER SUPPLY</u> - PUMP • TYPE: <u>Fixed vane</u> • POWER SOURCE: <u>Turbine driven gearbox</u> - ENERGY SOURCE • BATTERY: _____ • OTHER: <u>Engine fuel</u> - STORED GAS: _____ - GAS GEN/ACCUM: _____
2 ACTUATION SYSTEM DESIGN <u>RATED CONDITIONS</u> - DESIGN LOAD: <u>5144 lb-in</u> - STALL LOAD: <u>15,447 lb-in</u> - DESIGN RATE: <u>8.1 deg/sec</u> - NO LOAD RATE: <u>14.1 deg/sec</u> <u>DUTY CYCLE</u> - DURATION: <u>10 min</u> - DESCRIPTION: _____ <u>DYNAMIC PERFORMANCE</u> - BANDWIDTH: _____ - STEP RESPONSE: _____ <u>STATIC PERFORMANCE</u> - RESOLUTION: _____ - THRESHOLD: <u>0.10 ma</u> - HYSTERESIS: <u>0.20 ma</u> - CLOSED LOOP STIFFNESS: _____ STROKE: <u>+0.75 in</u> WEIGHT: _____ <u>FEEDBACK</u> - TYPE: <u>Position</u> - METHDD: <u>Variable reluctance</u> <u>ELECTRONIC CONTROLLER</u> - TYPE: <u>DC</u> - SIGNAL LEVEL: <u>4 ma</u> LOOP ELECTRONICS: <u>Analog</u>	5 PNEUMATIC/WARM GAS <u>SYSTEM</u> - STORED GAS • TYPE GAS: _____ • SUPPLY PRESS: _____ • PROOF PRESS: _____ • BURST PRESS: _____ • VESSEL TYPE: _____ • VESSEL VOL: _____ • SEALS: _____ - GAS GENERATOR • PROPELLANT: _____ • FLOWRATE: _____ • REG. VALVE: _____ • TEMP @ ACT: _____ • PRESS @ ACT: _____ <u>CONTROL VALVE</u> - OPERATION: _____ - CONFIGURATION: _____ <u>ACTUATOR</u> - LINEAR: _____ - ROTARY: _____ - ROTARY/LINEAR: _____
3 ELECTROMECHANICAL - MOTOR • DC: _____ • AC: _____ • STEPPER: _____ - ACTUATOR • LINEAR: _____ • ROTARY: _____	6 STORED GAS VESSEL SHIPMENT - TYPE GAS: _____ - GAS PRESSURE: _____ - BURST FACTOR: _____ - DDT APPROVAL: _____ 7 SELECTION CRITERIA AND/OR SPECIAL FEATURES Performance; hydraulic fluid used to maintain actuator temperature during orbit coast phase via a second electrically driven pump.

MISSILE/SPACE VEHICLE ACTUATION SYSTEM DATA SHEET

1 GENERAL DESCRIPTION <u>VEHICLE</u> - NAME: <u>Condor</u> - TYPE: <u>Air-to-surface</u> - CONTROL: <u>Aerodynamic fin (4 actuators)</u> - COMPANY: <u>Rockwell</u> - PROGRAM: <u>Development, 1964-1977</u> <u>ACTUATION SYSTEM</u> - COMPANY: <u>Conductron</u> - TYPE PROGRAM: <u>Development, 1964-1977</u> - TYPE DESIGN: <u>Electromechanical</u> - AXES: <u>Pitch, yaw, roll</u> - COMPENSATION: <u>Electronic</u> - REDUNDANCY: <u>No</u> - TEMP. RANGE: <u>-65 to +195°F</u> <u>LOAD</u> - TRAVEL: <u>+3D deg</u> - TYPE: <u>Inertia</u> - INERTIA: <u>1.56 lb-in-sec²</u> - f_n: _____ - Other: _____	4 HYDRAULIC <u>SYSTEM</u> - TYPE: _____ - PRESSURE: _____ - FLOW: _____ - FLUID: _____ - SEALS: _____ - FILTER: _____ <u>SERVO VALVE</u> - OPERATION: _____ - CONFIGURATION: _____ <u>ACTUATOR</u> - LINEAR: _____ - ROTARY: _____ <u>POWER SUPPLY</u> - PUMP • TYPE: _____ • POWER SOURCE: _____ - ENERGY SOURCE • BATTERY: _____ • OTHER: _____ - STORED GAS: _____ - GAS GEN/ACCUM: _____
2 ACTUATION SYSTEM DESIGN <u>RATED CONDITIONS</u> - DESIGN LOAD: _____ - STALL LOAD: <u>1000 lb-in</u> - DESIGN RATE: _____ - NO LOAD RATE: <u>85 deg/sec</u> <u>DUTY CYCLE</u> - DURATION: <u>12 min</u> - DESCRIPTION: _____ <u>DYNAMIC PERFORMANCE</u> - BANDWIDTH: _____ - STEP RESPONSE: _____ <u>STATIC PERFORMANCE</u> - RESOLUTION: _____ - THRESHOLD: _____ - HYSTERESIS: _____ - CLOSED LOOP STIFFNESS: _____ <u>STROKE: +30 deg</u> <u>WEIGHT: _____</u> <u>FEEDBACK</u> - TYPE: <u>Position</u> - METHOD: <u>Film potentiometer</u> <u>ELECTRONIC CONTROLLER</u> - TYPE: <u>DC</u> - SIGNAL LEVEL: _____ <u>LOOP ELECTRONICS: Analog</u>	5 PNEUMATIC/WARM GAS <u>SYSTEM</u> <u>STORED GAS</u> • TYPE GAS: _____ • SUPPLY PRESS: _____ • PRODF PRESS: _____ • BURST PRESS: _____ • VESSEL TYPE: _____ • VESSEL VOL: _____ • SEALS: _____ <u>GAS GENERATOR</u> • PROPELLANT: _____ • FLOWRATE: _____ • REG. VALVE: _____ • TEMP @ ACT: _____ • PRESS @ ACT: _____ <u>CONTROL VALVE</u> - OPERATION: _____ - CONFIGURATION: _____ <u>ACTUATOR</u> - LINEAR: _____ - ROTARY: _____ - ROTARY/LINEAR: _____
3 ELECTROMECHANICAL - MOTOR • DC: <u>28 V compound brush</u> • AC: _____ • STEPPER: _____ - ACTUATOR • LINEAR: _____ • ROTARY: <u>Mag particle clutch</u>	6 STORED GAS VESSEL SHIPMENT - TYPE GAS: _____ - GAS PRESSURE: _____ - BURST FACTOR: _____ - DOT APPROVAL: _____ 7 SELECTION CRITERIA AND/OR SPECIAL FEATURES

MISSILE/SPACE VEHICLE ACTUATION SYSTEM DATA SHEET

1 GENERAL DESCRIPTION <u>VEHICLE</u> - NAME: <u>Copperhead (M-712)</u> - TYPE: <u>Battlefield Support (Gun Launched)</u> - CONTROL: <u>Aerodynamic fin (4 fins/3 actuators)</u> - COMPANY: <u>Martin/Orlando</u> - PROGRAM: <u>Production, 1981 -</u> <u>ACTUATION SYSTEM</u> - COMPANY: <u>Chandler Evans</u> - TYPE PROGRAM: <u>Production, 1981 -</u> - TYPE DESIGN: <u>Pneumatic</u> - AXES: <u>Pitch, yaw, roll</u> - COMPENSATION: <u>None</u> - REDUNDANCY: <u>No</u> - TEMP. RANGE: <u>-25 to +145°F</u> <u>LOAD</u> - TRAVEL: <u>Pitch: ±16 deg; yaw & roll: ±20 deg</u> - TYPE: <u>Inertia and aero</u> - INERTIA: <u>Pitch: .0052 lb-in-sec²</u> <u>Yaw & roll: .0026 lb-in-sec²</u> - Other: <u>Aero: 1.25 lb-in/deg</u>	4 HYDRAULIC <u>SYSTEM</u> - TYPE: _____ - PRESSURE: _____ - FLOW: _____ - FLUID: _____ - SEALS: _____ - FILTER: _____ <u>SERVO VALVE</u> - OPERATION: _____ - CONFIGURATION: _____ <u>ACTUATOR</u> - LINEAR: _____ - ROTARY: _____ <u>POWER SUPPLY</u> - PUMP • TYPE: _____ • POWER SOURCE: _____ - ENERGY SOURCE • BATTERY: _____ • OTHER: _____ - STORED GAS: _____ - GAS GEN/ACCUM: _____
2 ACTUATION SYSTEM DESIGN <u>RATED CONDITIONS</u> - DESIGN LOAD: <u>Pitch: 190 lb-in; Yaw & roll: 95 lb-in</u> - STALL LOAD: <u>Pitch: 150 lb-in; Yaw & roll: 75 lb-in</u> - DESIGN RATE: <u>120 deg/sec</u> - NO LOAD RATE: <u>Pitch: 500 deg/sec;</u> <u>Yaw & roll: 450 deg/sec</u> <u>DUTY CYCLE</u> - DURATION: <u>65 sec @ -25°F</u> - DESCRIPTION: <u>+5° deflection at 1 Hz</u> <u>DYNAMIC PERFORMANCE</u> - BANDWIDTH: <u>12 Hz based on -3 db</u> - STEP RESPONSE: <u>.80% max overshoot at +5 and +10° steps</u> <u>STATIC PERFORMANCE</u> - RESOLUTION: <u>Pitch: ±16 deg; Yaw & roll: ±20 deg</u> - THRESHOLD: <u>17.5 lbs (with fins)</u> - HYSTERESIS: _____ - CLOSED LOOP STIFFNESS: _____ STROKE: <u>Pitch: ±16 deg.; Yaw & roll: ±20 deg</u> WEIGHT: <u>17.5 lbs (with fins)</u> <u>FEEDBACK</u> - TYPE: <u>Position</u> - METHOD: <u>Film potentiometer</u> <u>ELECTRONIC CONTROLLER</u> - TYPE: <u>DC</u> - SIGNAL LEVEL: <u>30V & 4 amps</u> LOOP ELECTRONICS: <u>Analog</u>	5 PNEUMATIC/WARM GAS <u>SYSTEM</u> - STORED GAS • TYPE GAS: <u>Helium regulated to 550 psi</u> • SUPPLY PRESS: <u>10,000 psi</u> • PROOF PRESS: <u>15,000 psi</u> • BURST PRESS: <u>23,600 psi min.</u> • VESSEL TYPE: <u>Cylinder</u> • VESSEL VOL: <u>25 in³</u> • SEALS: <u>Nitrile</u> - GAS GENERATOR • PROPELLANT: _____ • FLOWRATE: _____ • REG. VALVE: _____ • TEMP @ ACT: _____ • PRESS @ ACT: _____ <u>CONTROL VALVE</u> - OPERATION: <u>3-way Solenoid</u> - CONFIGURATION: <u>Open center</u> <u>ACTUATOR</u> - LINEAR: <u>2/1 unbalanced area</u> - ROTARY: _____ - ROTARY/LINEAR: _____
3 ELECTROMECHANICAL - MOTOR • DC: _____ • AC: _____ • STEPPER: _____ - ACTUATOR • LINEAR: _____ • ROTARY: _____	6 STORED GAS VESSEL SHIPMENT - TYPE GAS: <u>Helium</u> - GAS PRESSURE: <u>10,000 psi</u> - BURST FACTOR: <u>2.36</u> - DOT APPROVAL: <u>DOT-E 6672</u> 7 SELECTION CRITERIA AND/OR SPECIAL FEATURES - 10 year storage - 10,000 G's launch shock

MISSILE/SPACE VEHICLE ACTUATION SYSTEM DATA SHEET

1 GENERAL DESCRIPTION <u>VEHICLE</u> - NAME: <u>Delta, 1st stage</u> - TYPE: <u>Stage Launch Vehicle</u> - CONTROL: <u>Gimballed nozzle (2 actuators)</u> - COMPANY: <u>McDonnell Douglas/Huntington Beach</u> - PROGRAM: <u>Production, 1958 -</u> <u>ACTUATION SYSTEM</u> - COMPANY: <u>McDonnell Douglas/Huntington Beach</u> - TYPE PROGRAM: <u>Production, 1958 -</u> - TYPE DESIGN: <u>Hydraulic</u> - AXES: <u>Pitch, yaw</u> - COMPENSATION: <u></u> - REDUNDANCY: <u>No</u> - TEMP. RANGE: <u>-65 to +275°F</u> <u>LOAD</u> - TRAVEL: <u>+7 deg</u> - TYPE: <u>Combination</u> - INERTIA: <u>5,880 lb-in-sec²</u> - f_n: <u></u> - Other: <u>Aero: 27,400 lb-in</u> <u>Spring: 8,000 lb-in</u> <u>Coulomb fric: 10,600 lb-in</u>	4 HYDRAULIC <u>SYSTEM</u> - TYPE: <u>Recirculating</u> - PRESSURE: <u>3200 psi</u> - FLOW: <u>4 gpm</u> - FLUID: <u>MTI-H-5606</u> - SEALS: <u>Nitrile</u> - FILTER: <u>15 micron</u> <u>SERVO VALVE</u> - OPERATION: <u>4-way flow control</u> - CONFIGURATION: <u>2-stage jet pipe</u> <u>ACTUATOR</u> - LINEAR: <u>2 in² balanced</u> - ROTARY: <u></u> <u>POWER SUPPLY</u> - PUMP • TYPE: <u>Variable piston</u> • POWER SOURCE: <u>Turbine driven gearbox</u> - ENERGY SOURCE • BATTERY: <u></u> • OTHER: <u>Engine fuel</u> - STORED GAS: <u></u> - GAS GEN/ACCUM: <u></u>
2 ACTUATION SYSTEM DESIGN <u>RATED CONDITIONS</u> - DESIGN LOAD: <u>96,000 lb-in</u> - STALL LOAD: <u>153,500 lb-in</u> - DESIGN RATE: <u>17 deg/sec</u> - NO LOAD RATE: <u>30 deg/sec</u> <u>DUTY CYCLE</u> - DURATION: <u>225 sec</u> - DESCRIPTION: <u>+0.5 deg. at 0.5 Hz for full</u> <u>duration</u> <u>DYNAMIC PERFORMANCE</u> - BANDWIDTH: <u>10 Hz based on -3 dB</u> - STEP RESPONSE: <u></u> <u>STATIC PERFORMANCE</u> - RESOLUTION: <u>0.04 ma</u> - THRESHOLD: <u>0.04 ma</u> - HYSTERESIS: <u>0.40 ma</u> - CLOSED LOOP STIFFNESS: <u>>200,000 lb-in/deg</u> <u>STROKE:</u> <u>3.3 in.</u> <u>WEIGHT:</u> <u>136 lbs</u> <u>FEEDBACK</u> - TYPE: <u>Position</u> - METHOD: <u>Wire wound potentiometer</u> <u>ELECTRONIC CONTROLLER</u> - TYPE: <u>DC</u> - SIGNAL LEVEL: <u>20 v</u> <u>LOOP ELECTRONICS:</u> <u>Analog</u>	5 PNEUMATIC/WARM GAS <u>SYSTEM</u> - STORED GAS • TYPE GAS: <u></u> • SUPPLY PRESS: <u></u> • PROOF PRESS: <u></u> • BURST PRESS: <u></u> • VESSEL TYPE: <u></u> • VESSEL VOL: <u></u> • SEALS: <u></u> - GAS GENERATOR • PROPELLANT: <u></u> • FLOWRATE: <u></u> • REG. VALVE: <u></u> • TEMP @ ACT: <u></u> • PRESS @ ACT: <u></u> <u>CONTROL VALVE</u> - OPERATION: <u></u> - CONFIGURATION: <u></u> <u>ACTUATOR</u> - LINEAR: <u></u> - ROTARY: <u></u> - ROTARY/LINEAR: <u></u>
3 ELECTROMECHANICAL - MOTOR • DC: <u></u> • AC: <u></u> • STEPPER: <u></u> - ACTUATOR • LINEAR: <u></u> • ROTARY: <u></u>	6 STORED GAS VESSEL SHIPMENT - TYPE GAS: <u></u> - GAS PRESSURE: <u></u> - BURST FACTOR: <u></u> - DOT APPROVAL: <u></u> 7 SELECTION CRITERIA AND/OR SPECIAL FEATURES

MISSILE/SPACE VEHICLE ACTUATION SYSTEM DATA SHEET

1 GENERAL DESCRIPTION <u>VEHICLE</u> - NAME: <u>Dragon</u> - TYPE: <u>Battlefield Support</u> - CONTROL: <u>Solid Rocket Thrusters</u> - COMPANY: <u>Raytheon</u> - PROGRAM: <u>Production, 1978 -</u> <u>ACTUATION SYSTEM</u> - COMPANY: <u>Raytheon</u> - TYPE PROGRAM: <u>Production, 1978 -</u> - TYPE DESIGN: _____ - AXES: <u>Pitch, yaw</u> - COMPENSATION: _____ - REDUNDANCY: _____ - TEMP. RANGE: _____ <u>LOAD</u> - TRAVEL: _____ - TYPE: _____ - INERTIA: _____ - f_n: _____ - Other: _____	4 HYDRAULIC <u>SYSTEM</u> - TYPE: _____ - PRESSURE: _____ - FLOW: _____ - FLUID: _____ - SEALS: _____ - FILTER: _____ <u>SERVO VALVE</u> - OPERATION: _____ - CONFIGURATION: _____ <u>ACTUATOR</u> - LINEAR: _____ - ROTARY: _____ <u>POWER SUPPLY</u> - PUMP • TYPE: _____ • POWER SOURCE: _____ - ENERGY SOURCE • BATTERY: _____ • OTHER: _____ - STORED GAS: _____ - GAS GEN/ACCUM: _____
2 ACTUATION SYSTEM DESIGN <u>RATED CONDITIONS</u> - DESIGN LOAD: _____ - STALL LOAD: _____ - DESIGN RATE: _____ - NO LOAD RATE: _____ <u>DUTY CYCLE</u> - DURATION: _____ - DESCRIPTION: _____ <u>DYNAMIC PERFORMANCE</u> - BANDWIDTH: _____ - STEP RESPONSE: _____ <u>STATIC PERFORMANCE</u> - RESOLUTION: _____ - THRESHOLD: _____ - HYSTERESIS: _____ - CLOSED LOOP STIFFNESS: _____ <u>STROKE</u>: _____ <u>WEIGHT</u>: _____ <u>FEEDBACK</u> - TYPE: <u>None</u> - METHOD: _____ <u>ELECTRONIC CONTROLLER</u> - TYPE: <u>DC with 50 μsec pulse</u> - SIGNAL LEVEL: <u>22-41V</u> <u>LOOP ELECTRONICS</u>: _____	5 PNEUMATIC/WARM GAS <u>SYSTEM</u> <u>STORED GAS</u> • TYPE GAS: _____ • SUPPLY PRESS: _____ • PROOF PRESS: _____ • BURST PRESS: _____ • VESSEL TYPE: _____ • VESSEL VOL: _____ • SEALS: _____ - GAS GENERATOR • PROPELLANT: _____ • FLOWRATE: _____ • REG. VALVE: _____ • TEMP @ ACT: _____ • PRESS @ ACT: _____ <u>CONTROL VALVE</u> - OPERATION: _____ - CONFIGURATION: _____ <u>ACTUATOR</u> - LINEAR: _____ - ROTARY: _____ - ROTARY/LINEAR: _____
3 ELECTROMECHANICAL <u>MOTOR</u> • DC: _____ • AC: _____ • STEPPER: _____ - ACTUATOR • LINEAR: _____ • ROTARY: _____	6 STORED GAS VESSEL SHIPMENT - TYPE GAS: _____ - GAS PRESSURE: _____ - BURST FACTOR: _____ - DOT APPROVAL: _____ 7 SELECTION CRITERIA AND/OR SPECIAL FEATURES - Spinning vehicle with small thrusters that provide steering and sustaining thrust - Thrusters are fired in pairs - Near equilibrium maintained between sustaining thrusters and aerodynamic drag.

MISSILE/SPACE VEHICLE ACTUATION SYSTEM DATA SHEET

1 GENERAL DESCRIPTION <u>VEHICLE</u> - NAME: <u>Falcon (AIM - 4D)</u> - TYPE: <u>Air to air</u> - CONTROL: <u>Aerodynamic fin (2 actuators)</u> - COMPANY: <u>Hughes/Tucson</u> - PROGRAM: <u>Production, 1952 - 1961</u> <u>ACTUATION SYSTEM</u> - COMPANY: <u>Hughes/Tucson</u> - TYPE PROGRAM: <u>Production, 1952-1961</u> - TYPE DESIGN: <u>Hydraulic</u> - AXES: <u>Pitch, yaw, roll</u> - COMPENSATION: _____ - REDUNDANCY: <u>No</u> - TEMP. RANGE: _____ <u>LOAD</u> - TRAVEL: _____ - TYPE: _____ - INERTIA: _____ - f_n: _____ - Other: _____	4 HYDRAULIC <u>SYSTEM</u> - TYPE: <u>Blowdown</u> - PRESSURE: <u>2000 psi</u> - FLOW: <u>0.093 gpm</u> - FLUID: <u>Brayco 762</u> - SEALS: <u>Nitrile</u> - FILTER: <u>No</u> <u>SERVD VALVE</u> - OPERATION: <u>3-way</u> - CONFIGURATION: <u>1-stage</u> <u>ACTUATOR</u> - LINEAR: _____ - ROTARY: <u>Push-push</u> <u>POWER SUPPLY</u> - PUMP • TYPE: _____ • POWER SOURCE: _____ - ENERGY SOURCE • BATTERY: _____ • OTHER: _____ - STORED GAS: <u>He at 7400 psi accumulator</u> - GAS GEN/ACCUM: _____
2 ACTUATION SYSTEM DESIGN <u>RATED CONDITIONS</u> - DESIGN LOAD: _____ - STALL LOAD: <u>150 lb-in</u> - DESIGN RATE: _____ - NO LOAD RATE: <u>600-750 deg/sec</u> <u>DUTY CYCLE</u> - DURATION: _____ - DESCRIPTION: _____ <u>DYNAMIC PERFORMANCE</u> - BANDWIDTH: _____ - STEP RESPONSE: _____ <u>STATIC PERFORMANCE</u> - RESOLUTION: _____ - THRESHOLD: <u>0.3 ma</u> - HYSTERESIS: _____ - CLOSED LOOP STIFFNESS: _____ <u>STROKE</u>: _____ <u>WEIGHT</u>: _____ <u>FEEDBACK</u> - TYPE: <u>Position</u> - METHOD: <u>Wire wound potentiometer</u> <u>ELECTRONIC CONTROLLER</u> - TYPE: <u>DC</u> - SIGNAL LEVEL: _____ <u>LOOP ELECTRONICS</u>: <u>Analog</u>	5 PNEUMATIC WARM GAS <u>SYSTEM</u> - STORED GAS • TYPE GAS: _____ • SUPPLY PRESS: _____ • PROOF PRESS: _____ • BURST PRESS: _____ • VESSEL TYPE: _____ • VESSEL VOL: _____ • SEALS: _____ - GAS GENERATOR • PROPELLANT: _____ • FLOWRATE: _____ • REG. VALVE: _____ • TEMP @ ACT: _____ • PRESS @ ACT: _____ <u>CONTROL VALVE</u> - OPERATION: _____ - CONFIGURATION: _____ <u>ACTUATOR</u> - LINEAR: _____ - ROTARY: _____ - ROTARY/LINEAR: _____
3 ELECTROMECHANICAL - MOTOR • DC: _____ • AC: _____ • STEPPER: _____ - ACTUATOR • LINEAR: _____ • ROTARY: _____	6 STORED GAS VESSEL SHIPMENT - TYPE GAS: _____ - GAS PRESSURE: _____ - BURST FACTOR: _____ - DOT APPROVAL: _____ 7 SELECTION CRITERIA AND/OR SPECIAL FEATURES

1 GENERAL DESCRIPTION <u>VEHICLE</u> - NAME: <u>Falcon (AIM - F&G)</u> - TYPE: <u>Air-to-air</u> - CONTROL: <u>Aerodynamic fin (2 actuators)</u> - COMPANY: <u>Hughes/Tucson</u> - PROGRAM: <u>Production, 1955 - 1961</u> <u>ACTUATION SYSTEM</u> - COMPANY: <u>Hughes/Tucson</u> - TYPE PROGRAM: <u>Production, 1955-1961</u> - TYPE DESIGN: <u>Hydraulic</u> - AXES: <u>Pitch, yaw, roll</u> - COMPENSATION: _____ - REDUNDANCY: <u>No</u> - TEMP. RANGE: _____ <u>LOAD</u> - TRAVEL: _____ - TYPE: _____ - INERTIA: _____ - f_n: _____ - Other: _____	4 HYDRAULIC <u>SYSTEM</u> - TYPE: <u>Recirculating</u> - PRESSURE: <u>2090 psi</u> - FLOW: _____ - FLUID: <u>Brayco 762</u> - SEALS: <u>Nitrile</u> - FILTER: <u>5-15 Micron</u> <u>SERVO VALVE</u> - OPERATION: <u>3-way</u> - CONFIGURATION: <u>1-stage</u> <u>ACTUATOR</u> - LINEAR: _____ - ROTARY: <u>Push-push</u> <u>POWER SUPPLY</u> - PUMP • TYPE: <u>Fixed piston</u> • POWER SOURCE: <u>Turbine</u> - ENERGY SOURCE • BATTERY: _____ • OTHER: _____ - STORED GAS: _____ - GAS GEN/ACCUM: _____
2 ACTUATION SYSTEM DESIGN <u>RATED CONDITIONS</u> - DESIGN LOAD: _____ - STALL LOAD: <u>150 lb-in</u> - DESIGN RATE: _____ - NO LOAD RATE: <u>275-375 deg/sec</u> <u>DUTY CYCLE</u> - DURATION: _____ - DESCRIPTION: _____ <u>DYNAMIC PERFORMANCE</u> - BANDWIDTH: _____ - STEP RESPONSE: _____ <u>STATIC PERFORMANCE</u> - RESOLUTION: _____ - THRESHOLD: <u>0.3 ma</u> - HYSTERESIS: _____ - CLOSED LOOP STIFFNESS: _____ <u>STROKE</u>: _____ <u>WEIGHT</u>: _____ <u>FEEDBACK</u> - TYPE: <u>Position</u> - METHOD: <u>Wire wound potentiometer</u> <u>ELECTRONIC CONTROLLER</u> - TYPE: <u>DC</u> - SIGNAL LEVEL: _____ <u>LOOP ELECTRONICS</u>: <u>Analog</u>	5 PNEUMATIC/WARM GAS <u>SYSTEM</u> - STORED GAS • TYPE GAS: _____ • SUPPLY PRESS: _____ • PROOF PRESS: _____ • BURST PRESS: _____ • VESSEL TYPE: _____ • VESSEL VOL: _____ • SEALS: _____ - GAS GENERATOR • PROPELLANT: _____ • FLOWRATE: _____ • REG. VALVE: _____ • TEMP @ ACT: _____ • PRESS @ ACT: _____ <u>CONTROL VALVE</u> - OPERATION: _____ - CONFIGURATION: _____ <u>ACTUATOR</u> - LINEAR: _____ - ROTARY: _____ - ROTARY/LINEAR: _____
3 ELECTROMECHANICAL - MOTOR • DC: _____ • AC: _____ • STEPPER: _____ - ACTUATOR • LINEAR: _____ • ROTARY: _____	6 STORED GAS VESSEL SHIPMENT - TYPE GAS: _____ - GAS PRESSURE: _____ - BURST FACTOR: _____ - DOT APPROVAL: _____ 7 SELECTION CRITERIA AND/OR SPECIAL FEATURES

MISSILE/SPACE VEHICLE ACTUATION SYSTEM DATA SHEET

1 GENERAL DESCRIPTION <u>VEHICLE</u> - NAME: <u>GBU-15</u> - TYPE: <u>Air-to-surface</u> - CONTROL: <u>Aerodynamic fin (4 actuators)</u> - COMPANY: <u>Rockwell</u> - PROGRAM: <u>Production, 1974 -</u> <u>ACTUATION SYSTEM</u> - COMPANY: <u>Garrett/Phoenix</u> - TYPE PROGRAM: <u>Production, 1974 -</u> - TYPE DESIGN: <u>Pneumatic</u> - AXES: <u>Pitch, yaw, roll</u> - COMPENSATION: <u>Electronic</u> - REDUNDANCY: <u>No</u> - TEMP. RANGE: <u>-65 to +130°F</u> <u>LOAD</u> - TRAVEL: <u>+10 deg</u> - TYPE: <u>Inertia</u> - INERTIA: <u>0.05 lb-in-sec²</u> - f_n: _____ - Other: _____	4 HYDRAULIC <u>SYSTEM</u> - TYPE: _____ - PRESSURE: _____ - FLOW: _____ - FLUID: _____ - SEALS: _____ - FILTER: _____ <u>SERVO VALVE</u> - OPERATION: _____ - CONFIGURATION: _____ <u>ACTUATOR</u> - LINEAR: _____ - ROTARY: _____ <u>POWER SUPPLY</u> - PUMP • TYPE: _____ • POWER SOURCE: _____ - ENERGY SOURCE • BATTERY: _____ • OTHER: _____ - STORED GAS: _____ - GAS GEN/ACCUM: _____
2 ACTUATION SYSTEM DESIGN <u>RATED CONDITIONS</u> <u>40 lb-in opposing and</u> <u>20 lb-in aiding</u> - DESIGN LOAD: <u>20 lb-in aiding</u> - STALL LOAD: <u>625 lb-in</u> - DESIGN RATE: _____ - NO LOAD RATE: <u>100 deg/sec</u> <u>DUTY CYCLE</u> - DURATION: <u>16 min</u> - DESCRIPTION: _____ <u>DYNAMIC PERFORMANCE</u> - BANDWIDTH: <u>9 Hz based on -3 dB</u> - STEP RESPONSE: _____ <u>STATIC PERFORMANCE</u> - RESOLUTION: <u>0.5 deg max</u> - THRESHOLD: <u>0.5 deg max</u> - HYSTERESIS: <u>0.5 deg max</u> - CLOSED LOOP STIFFNESS: _____ <u>STROKE</u>: <u>±20 deg</u> <u>WEIGHT</u>: <u>63 lbs</u> <u>FEEDBACK</u> - TYPE: <u>Position</u> - METHOD: <u>Film potentiometer</u> <u>ELECTRONIC CONTROLLER</u> - TYPE: <u>DC</u> - SIGNAL LEVEL: <u>28 V and 4 amps</u> <u>LOOP ELECTRONICS</u>: <u>Analog</u>	5 PNEUMATIC/WARM GAS <u>SYSTEM</u> - STORED GAS • TYPE GAS: <u>He regulated to 775 psf</u> • SUPPLY PRESS: <u>7800 psi</u> • PROOF PRESS: _____ • BURST PRESS: _____ • VESSEL TYPE: <u>Sphere</u> • VESSEL VOL: <u>230 in³</u> • SEALS: _____ - GAS GENERATOR • PROPELLANT: _____ • FLOWRATE: _____ • REG. VALVE: _____ • TEMP @ ACT: _____ • PRESS @ ACT: _____ <u>CONTROL VALVE</u> - OPERATION: <u>Proportional solenoid</u> - CONFIGURATION: <u>Closed center</u> <u>ACTUATOR</u> - LINEAR: <u>2/1 unbalanced area</u> - ROTARY: _____ - ROTARY/LINEAR: _____
3 ELECTROMECHANICAL - MOTOR • DC: _____ • AC: _____ • STEPPER: _____ - ACTUATOR • LINEAR: _____ • ROTARY: _____	6 STORED GAS VESSEL SHIPMENT - TYPE GAS: _____ - GAS PRESSURE: _____ - BURST FACTOR: _____ - DOT APPROVAL: _____ 7 SELECTION CRITERIA AND/OR SPECIAL FEATURES 10 year storage and wide temperature range

MISSILE/SPACE VEHICLE ACTUATION SYSTEM DATA SHEET

1 GENERAL DESCRIPTION <u>VEHICLE</u> - NAME: <u>HAWK</u> - TYPE: <u>Surface-to-air</u> - CONTROL: <u>Aerodynamic fin (4 actuators)</u> - COMPANY: <u>Raytheon</u> - PROGRAM: <u>Production, 1959 -</u> <u>ACTUATION SYSTEM</u> - COMPANY: <u>Raytheon</u> - TYPE PROGRAM: <u>Production, 1959 -</u> - TYPE DESIGN: <u>Hydraulic</u> - AXES: <u>Pitch, yaw, roll</u> - COMPENSATION: <u>No</u> - REDUNDANCY: <u>No</u> - TEMP. RANGE: <u>-25 to +165°F</u> <u>LOAD</u> - TRAVEL: <u>+30 deg</u> - TYPE: <u>Inertia & coulomb friction</u> - INERTIA: <u>0.1 lb-in-sec</u> - f_n: <u></u> - Other: <u>Coulomb friction: 230 lb-in</u>	4 HYDRAULIC <u>SYSTEM</u> - TYPE: <u>Blowdown</u> - PRESSURE: <u>2000 psi</u> - FLOW: <u>8 gpm</u> - FLUID: <u>MIL-H-5606</u> - SEALS: <u>Polyurethane</u> - FILTER: <u>None</u> <u>SERVO VALVE</u> - OPERATION: <u>3-way flow control</u> - CONFIGURATION: <u>2-stage</u> <u>ACTUATOR</u> - LINEAR: <u>2:1 unbalanced push-push</u> - ROTARY: <u></u> <u>POWER SUPPLY</u> - PUMP • TYPE: <u></u> • POWER SOURCE: <u></u> - ENERGY SOURCE • BATTERY: <u></u> • OTHER: <u></u> - STORED GAS: <u>N₂ Accumulator</u> - GAS GEN/ACCUM: <u></u>
2 ACTUATION SYSTEM DESIGN <u>RATED CONDITIONS</u> - DESIGN LOAD: <u>1670 lb-in</u> - STALL LOAD: <u>2300 lb-in</u> - DESIGN RATE: <u>300 deg/sec</u> - NO LOAD RATE: <u>450 deg/sec</u> <u>DUTY CYCLE</u> - DURATION: <u>>80 sec</u> - DESCRIPTION: <u>6000 deg total travel</u> <u>DYNAMIC PERFORMANCE</u> - BANDWIDTH: <u>20 Hz based on $\phi = 90^\circ$</u> - STEP RESPONSE: <u></u> <u>STATIC PERFORMANCE</u> - RESOLUTION: <u>0.01 deg</u> - THRESHOLD: <u>0.02 deg</u> - HYSTERESIS: <u><0.50 deg</u> - CLOSED LOOP STIFFNESS: <u>>12,000 psi/ma</u> STROKE: <u>+30 deg</u> WEIGHT: <u>18 lbs</u> <u>FEEDBACK</u> - TYPE: <u>Position</u> - METHOD: <u>Film type potentiometer</u> <u>ELECTRONIC CONTROLLER</u> - TYPE: <u>DC</u> - SIGNAL LEVEL: <u>+15 ma</u> <u>LOOP ELECTRONICS</u>: <u>Analog</u>	5 PNEUMATIC/WARM GAS <u>SYSTEM</u> - STORED GAS • TYPE GAS: <u></u> • SUPPLY PRESS: <u></u> • PROOF PRESS: <u></u> • BURST PRESS: <u></u> • VESSEL TYPE: <u></u> • VESSEL VOL: <u></u> • SEALS: <u></u> - GAS GENERATOR • PROPELLANT: <u></u> • FLOWRATE: <u></u> • REG. VALVE: <u></u> • TEMP @ ACT: <u></u> • PRESS @ ACT: <u></u> <u>CONTROL VALVE</u> - OPERATION: <u></u> - CONFIGURATION: <u></u> <u>ACTUATOR</u> - LINEAR: <u></u> - ROTARY: <u></u> - ROTARY/LINEAR: <u></u>
3 ELECTROMECHANICAL - MOTOR • DC: <u></u> • AC: <u></u> • STEPPER: <u></u> - ACTUATOR • LINEAR: <u></u> • ROTARY: <u></u>	6 STORED GAS VESSEL SHIPMENT - TYPE GAS: <u></u> - GAS PRESSURE: <u></u> - BURST FACTOR: <u></u> - DOT APPROVAL: <u></u> 7 SELECTION CRITERIA AND/OR SPECIAL FEATURES - Low leakage servo valves - Bladder type accumulator

MISSILE/SPACE VEHICLE ACTUATION SYSTEM DATA SHEET

1 GENERAL DESCRIPTION <u>VEHICLE</u> - NAME: <u>Hellfire</u> - TYPE: <u>Air-to-surface</u> - CONTROL: <u>Aerodynamic fin (4 actuators)</u> - COMPANY: <u>Rockwell</u> - PROGRAM: <u>Production, 1977 -</u> <u>ACTUATION SYSTEM</u> - COMPANY: <u>Rockwell</u> - TYPE PROGRAM: <u>Production, 1977 -</u> - TYPE DESIGN: <u>Pneumatic</u> - AXES: <u>Pitch, yaw, roll</u> - COMPENSATION: <u>Electronic</u> - REDUNDANCY: <u>No</u> - TEMP. RANGE: <u>-45 to +145°F</u> <u>LOAD</u> - TRAVEL: <u>+20 deg</u> - TYPE: <u>Inertia</u> - INERTIA: <u>0.01 lb-in-sec²</u> - f_n: <u></u> - Other: <u></u>	4 HYDRAULIC <u>SYSTEM</u> - TYPE: <u></u> - PRESSURE: <u></u> - FLOW: <u></u> - FLUID: <u></u> - SEALS: <u></u> - FILTER: <u></u> <u>SERVO VALVE</u> - OPERATION: <u></u> - CONFIGURATION: <u></u> <u>ACTUATOR</u> - LINEAR: <u></u> - ROTARY: <u></u> <u>POWER SUPPLY</u> - PUMP • TYPE: <u></u> • POWER SOURCE: <u></u> - ENERGY SOURCE • BATTERY: <u></u> • OTHER: <u></u> - STORED GAS: <u></u> - GAS GEN/ACCUM: <u></u>
2 ACTUATION SYSTEM DESIGN <u>RATED CONDITIONS</u> - DESIGN LOAD: <u></u> - STALL LOAD: <u>120 lb-in</u> - DESIGN RATE: <u></u> - NO LOAD RATE: <u>400 deg/sec</u> <u>DUTY CYCLE</u> - DURATION: <u>46 sec</u> - DESCRIPTION: <u></u> <u>DYNAMIC PERFORMANCE</u> - BANDWIDTH: <u>16 Hz based on $\phi = 90^\circ$</u> - STEP RESPONSE: <u></u> <u>STATIC PERFORMANCE</u> - RESOLUTION: <u>0.2 deg max</u> - THRESHOLD: <u>0.2 deg max</u> - HYSTERESIS: <u>0.2 deg max</u> - CLOSED LOOP STIFFNESS: <u>2500 lb-in/rad</u> - STROKE: <u>+0.38 in</u> - WEIGHT: <u>9.1 lbs</u> <u>FEEDBACK</u> - TYPE: <u>Position</u> - METHOD: <u>Film potentiometer</u> <u>ELECTRONIC CONTROLLER</u> - TYPE: <u>PWM at 125 Hz</u> - SIGNAL LEVEL: <u>28 VDC & 1.5 amps</u> <u>LOOP ELECTRONICS: Analog</u>	5 PNEUMATIC/WARM GAS <u>SYSTEM</u> - STORED GAS • TYPE GAS: <u>N₂ regulated to 600 psi</u> • SUPPLY PRESS: <u>8000 psi</u> • PROOF PRESS: <u></u> • BURST PRESS: <u></u> • VESSEL TYPE: <u>Sphere</u> • VESSEL VOL: <u>50 in³</u> • SEALS: <u>Teflon, Nitrile, Silicone</u> - GAS GENERATOR • PROPELLANT: <u></u> • FLOWRATE: <u></u> • REG. VALVE: <u></u> • TEMP @ ACT: <u></u> • PRESS @ ACT: <u></u> <u>CONTROL VALVE</u> - OPERATION: <u>3-way solenoid</u> - CONFIGURATION: <u>Open center</u> <u>ACTUATOR</u> - LINEAR: <u>2/1 unbalanced area</u> - ROTARY: <u></u> - ROTARY/LINEAR: <u></u>
3 ELECTROMECHANICAL - MOTOR • DC: <u></u> • AC: <u></u> • STEPPER: <u></u> - ACTUATOR • LINEAR: <u></u> • ROTARY: <u></u>	6 STORED GAS VESSEL SHIPMENT - TYPE GAS: <u></u> - GAS PRESSURE: <u></u> - BURST FACTOR: <u></u> - DOT APPROVAL: <u></u> 7 SELECTION CRITERIA AND/OR SPECIAL FEATURES 10 year storage, cost and packaging - thermo setting plastic pistons and actuator housings

MISSILE/SPACE VEHICLE ACTUATION SYSTEM DATA SHEET

1 GENERAL DESCRIPTION VEHICLE - NAME: HOBOS (GBU-B) - TYPE: Air-to-surface - CONTROL: Aerodynamic fin (4 actuators) - COMPANY: Rockwell - PROGRAM: Production, 1967-1975 ACTUATION SYSTEM - COMPANY: Chandler Evans - TYPE PROGRAM: Production, 1967-1975 - TYPE DESIGN: Pneumatic - AXES: Pitch, yaw, roll - COMPENSATION: Electronic - REDUNDANCY: No - TEMP. RANGE: -13 to +131°F LOAD - TRAVEL: ±20 deg - TYPE: Inertia and aero - INERTIA: - f_n: - Other: Aero: 7.0 lb-in/deg	4 HYDRAULIC SYSTEM - TYPE: - PRESSURE: - FLOW: - FLUID: - SEALS: - FILTER: SERVO VALVE - OPERATION: - CONFIGURATION: ACTUATOR - LINEAR: - ROTARY: POWER SUPPLY - PUMP • TYPE: • POWER SOURCE: - ENERGY SOURCE • BATTERY: • OTHER: - STORED GAS: - GAS GEN/ACCUM:
2 ACTUATION SYSTEM DESIGN RATED CONDITIONS - DESIGN LOAD: 350 lb-in - STALL LOAD: 540 lb-in - DESIGN RATE: 80 deg/sec - NO LOAD RATE: 100 lb-in DUTY CYCLE - DURATION: 120 sec - DESCRIPTION: DYNAMIC PERFORMANCE - BANDWIDTH: 9 Hz based on $\phi = 90^\circ$ - STEP RESPONSE: STATIC PERFORMANCE - RESOLUTION: 0.5 deg max - THRESHOLD: 0.5 deg max - HYSTERESIS: 0.5 deg max - CLOSED LOOP STIFFNESS: STROKE: ±21 deg WEIGHT: 46 lbs FEEDBACK - TYPE: Position - METHOD: Film potentiometer ELECTRONIC CONTROLLER - TYPE: PWM at 100 Hz - SIGNAL LEVEL: 28 VDC LOOP ELECTRONICS: Analog	5 PNEUMATIC/WARM GAS SYSTEM - STORED GAS • TYPE GAS: N₂ regulated to 550 psi • SUPPLY PRESS: 7000 psi • PROOF PRESS: 11,900 psi • BURST PRESS: 15,400 psi • VESSEL TYPE: Sphere • VESSEL VOL: 225 in³ • SEALS: Nitrile - GAS GENERATOR • PROPELLANT: • FLOWRATE: • REG. VALVE: • TEMP @ ACT: • PRESS @ ACT: CONTROL VALVE - OPERATION: 3-way solenoid - CONFIGURATION: Open center ACTUATOR - LINEAR: 2/1 unbalanced area - ROTARY: - ROTARY/LINEAR:
3 ELECTROMECHANICAL - MOTOR • DC: • AC: • STEPPER: - ACTUATOR • LINEAR: • ROTARY:	6 STORED GAS VESSEL SHIPMENT - TYPE GAS: - GAS PRESSURE: - BURST FACTOR: - DOT APPROVAL: 7 SELECTION CRITERIA AND/OR SPECIAL FEATURES Cost primary factor

MISSILE/SPACE VEHICLE ACTUATION SYSTEM DATA SHEET

1 GENERAL DESCRIPTION VEHICLE - NAME: <u>Hornet</u> - TYPE: <u>Air-to-surface</u> - CONTROL: <u>Aerodynamic fin (4 actuators)</u> - COMPANY: <u>Rockwell</u> - PROGRAM: <u>Development, 1961-1969</u> ACTUATION SYSTEM - COMPANY: <u>Chandler Evans</u> - TYPE PROGRAM: <u>Development, 1961-1969</u> - TYPE DESIGN: <u>Pneumatic</u> - AXES: <u>Pitch, yaw, roll</u> - COMPENSATION: <u>Electronic</u> - REDUNDANCY: <u>No</u> - TEMP. RANGE: _____ LOAD - TRAVEL: <u>±20 deg</u> - TYPE: _____ - INERTIA: _____ - f_n: _____ - Other: _____	4 HYDRAULIC SYSTEM - TYPE: _____ - PRESSURE: _____ - FLOW: _____ - FLUID: _____ - SEALS: _____ - FILTER: _____ SERVO VALVE - OPERATION: _____ - CONFIGURATION: _____ ACTUATOR - LINEAR: _____ - ROTARY: _____ POWER SUPPLY - PUMP • TYPE: _____ • POWER SOURCE: _____ - ENERGY SOURCE • BATTERY: _____ • OTHER: _____ - STORED GAS: _____ - GAS GEN/ACCUM: _____
2 ACTUATION SYSTEM DESIGN RATED CONDITIONS - DESIGN LOAD: _____ - STALL LOAD: <u>100 lb-in</u> - DESIGN RATE: _____ - NO LOAD RATE: <u>400 deg/sec</u> DUTY CYCLE - DURATION: _____ - DESCRIPTION: _____ DYNAMIC PERFORMANCE - BANDWIDTH: <u>8 Hz based on</u> <u>1</u> = 90° - STEP RESPONSE: _____ STATIC PERFORMANCE - RESOLUTION: _____ - THRESHOLD: _____ - HYSTERESIS: _____ - CLOSED LOOP STIFFNESS: _____ STROKE: <u>±20 deg</u> WEIGHT: <u>10 lbs</u> FEEDBACK - TYPE: <u>None</u> - METHOD: _____ ELECTRONIC CONTROLLER - TYPE: <u>OC</u> - SIGNAL LEVEL: _____ LOOP ELECTRONICS: <u>Analog</u>	5 PNEUMATIC/WARM GAS SYSTEM STORED GAS • TYPE GAS: <u>N₂ regulated to 500 psi</u> • SUPPLY PRESS: <u>8000 psi</u> • PROOF PRESS: _____ • BURST PRESS: _____ • VESSEL TYPE: <u>Sphere</u> • VESSEL VOL: _____ • SEALS: _____ - GAS GENERATOR • PROPELLANT: _____ • FLOWRATE: _____ • REG. VALVE: _____ • TEMP @ ACT: _____ • PRESS @ ACT: _____ CONTROL VALVE - OPERATION: <u>2-way</u> - CONFIGURATION: <u>Solenoid</u> ACTUATOR - LINEAR: <u>Balanced</u> - ROTARY: _____ - ROTARY/LINEAR: _____
3 ELECTROMECHANICAL - MOTOR • DC: _____ • AC: _____ • STEPPER: _____ - ACTUATOR • LINEAR: _____ • ROTARY: _____	6 STORED GAS VESSEL SHIPMENT - TYPE GAS: _____ - GAS PRESSURE: _____ - BURST FACTOR: _____ - OOT APPROVAL: _____ 7 SELECTION CRITERIA AND/OR SPECIAL FEATURES

MISSILE/SPACE VEHICLE ACTUATION SYSTEM DATA SHEET

1 GENERAL DESCRIPTION <u>VEHICLE</u> - NAME: <u>IUS (Inertial Upper Stage)</u> - TYPE: <u>Space Launch Vehicle</u> - CONTROL: <u>Gimballed Nozzle (2 actuators)</u> - COMPANY: <u>United Technology</u> - PROGRAM: <u>Production, 1979-</u> <u>ACTUATION SYSTEM</u> - COMPANY: <u>United Technology</u> - TYPE PROGRAM: <u>Production, 1979-</u> - TYPE DESIGN: <u>Electromechanical</u> - AXES: <u>Pitch, Yaw</u> - COMPENSATION: <u>Electronic</u> - REDUNDANCY: <u>Yes</u> - TEMP. RANGE: <u>-34 to +72°C</u> <u>LOAD</u> - TRAVEL: <u>+ 7 deg</u> - TYPE: <u>Combination</u> - INERTIA: <u>840 lb-in-sec²</u> - f_n: _____ - Other: <u>Spring: 600 lb-in/deg</u> <u>Coulomb fric: 2000 lb-in</u> <u>Offset: 1800 lb-in</u>	4 HYDRAULIC <u>SYSTEM</u> - TYPE: _____ - PRESSURE: _____ - FLOW: _____ - FLUID: _____ - SEALS: _____ - FILTER: _____ <u>SERVO VALVE</u> - OPERATION: _____ - CONFIGURATION: _____ <u>ACTUATOR</u> - LINEAR: _____ - ROTARY: _____ <u>POWER SUPPLY</u> - PUMP • TYPE: _____ • POWER SOURCE: _____ - ENERGY SOURCE • BATTERY: _____ • OTHER: _____ - STORED GAS: _____ - GAS GEN/ACCUM: _____
2 ACTUATION SYSTEM DESIGN <u>RATED CONDITIONS</u> - DESIGN LOAD: <u>1000 lb-in</u> - STALL LOAD: <u>1000 lb-in</u> - DESIGN RATE: <u>20 deg/sec</u> - NO LOAD RATE: <u>20 deg/sec</u> <u>DUTY CYCLE</u> - DURATION: <u>200 sec</u> - DESCRIPTION: <u>20% for 50 sec</u> <u>DYNAMIC PERFORMANCE</u> - BANDWIDTH: <u>5 Hz based on -3 dB</u> - STEP RESPONSE: <u>0.016 in. step; 0.4 sec to 90%</u> <u>STATIC PERFORMANCE</u> - RESOLUTION: <u>0.001 in.</u> - THRESHOLD: <u>0.001 in.</u> - HYSTERESIS: <u>0.001 in.</u> - CLOSED LOOP STIFFNESS: _____ <u>STROKE: 2 in.</u> <u>WEIGHT: 30 lbs</u> <u>FEEDBACK</u> - TYPE: <u>Position and estimated rate</u> - METHOD: <u>Film potentiometer</u> <u>ELECTRONIC CONTROLLER</u> - TYPE: <u>DC and variable freq. PWM</u> - SIGNAL LEVEL: <u>26-32 V @ 30 amp max</u> <u>LOOP ELECTRONICS: Analog</u>	5 PNEUMATIC/WARM GAS <u>SYSTEM</u> - STORED GAS • TYPE GAS: _____ • SUPPLY PRESS: _____ • PROOF PRESS: _____ • BURST PRESS: _____ • VESSEL TYPE: _____ • VESSEL VOL: _____ • SEALS: _____ - GAS GENERATOR • PROPELLANT: _____ • FLOWRATE: _____ • REG. VALVE: _____ • TEMP @ ACT: _____ • PRESS @ ACT: _____ <u>CONTROL VALVE</u> - OPERATION: _____ - CONFIGURATION: _____ <u>ACTUATOR</u> - LINEAR: _____ - ROTARY: _____ - ROTARY/LINEAR: _____
3 ELECTROMECHANICAL - MOTOR • DC: <u>Brush motor @ 10 V and 35 A</u> • AC: _____ • STEPPER: _____ - ACTUATOR • LINEAR: <u>Ball screw with brake</u> • ROTARY: _____	6 STORED GAS VESSEL SHIPMENT - TYPE GAS: _____ - GAS PRESSURE: _____ - BURST FACTOR: _____ - DOT APPROVAL: _____ 7 SELECTION CRITERIA AND/OR SPECIAL FEATURES - Performance and cleanliness - Dual motors for redundancy

MISSILE/SPACE VEHICLE ACTUATION SYSTEM DATA SHEET

1 GENERAL DESCRIPTION <u>VEHICLE</u> - NAME: <u>Maverick</u> - TYPE: <u>Air-to-surface</u> - CONTROL: <u>Aerodynamic fin (4 actuators)</u> - COMPANY: <u>Hughes/Tucson</u> - PROGRAM: <u>Production, 1969 -</u> <u>ACTUATION SYSTEM</u> - COMPANY: <u>National Water Lift</u> - TYPE PROGRAM: <u>Production, 1969 -</u> - TYPE DESIGN: <u>Hydraulic</u> - AXES: <u>Pitch, yaw, roll</u> - COMPENSATION: <u>Electronic</u> - REDUNDANCY: <u>No</u> - TEMP. RANGE: <u>-65 to +160°F</u> <u>LOAD</u> - TRAVEL: <u>+30 deg</u> - TYPE: <u>Aero and inertia</u> - INERTIA: <u>.009 lb-in-sec²</u> - f_n: _____ - Other: <u>Aero: 125 lb-in</u>	4 HYDRAULIC <u>SYSTEM</u> - TYPE: <u>Recirculating</u> - PRESSURE: <u>3200 psi</u> - FLOW: <u>0.2 gpm</u> - FLUID: <u>Brayco #762</u> - SEALS: <u>Nitrile, fluorosilicone, teflon</u> - FILTER: <u>3 micron</u> <u>SERVO VALVE</u> - OPERATION: <u>3-way</u> - CONFIGURATION: <u>1-stage (direct drive)</u> <u>ACTUATOR</u> - LINEAR: <u>2:1 unbalanced area</u> - ROTARY: _____ <u>POWER SUPPLY</u> - PUMP • TYPE: <u>Free piston intensifier</u> • POWER SOURCE: <u>He regulated to 500 psi</u> - ENERGY SOURCE • BATTERY: _____ • OTHER: _____ - STORED GAS: <u>7500 psi He</u> - GAS GEN/ACCUM: <u>Accum. pressurized with 500 psi He</u>
2 ACTUATION SYSTEM DESIGN <u>RATED CONDITIONS</u> - DESIGN LOAD: <u>125 lb-in</u> - STALL LOAD: <u>350 lb-in</u> - DESIGN RATE: <u>300 deg/sec</u> - NO LOAD RATE: <u>350 deg/sec</u> <u>DUTY CYCLE</u> - DURATION: <u>105 sec</u> - DESCRIPTION: <u>300°/sec @ 125 lb-in for 0.5 sec</u> <u>50°/sec @ 200 lb-in for 0.5 sec</u> <u>25°/sec @ 130 lb-in for duration</u> <u>DYNAMIC PERFORMANCE</u> - BANDWIDTH: <u>13 Hz based on $\phi = 90^\circ$</u> - STEP RESPONSE: <u>3° step with <15% overshoot</u> <u>STATIC PERFORMANCE</u> - RESOLUTION: <u>1.5 deg</u> - THRESHOLD: <u><0.05 deg</u> - HYSTERESIS: <u><0.42 deg</u> - CLOSED LOOP STIFFNESS: <u>>1500 lb-in/deg</u> <u>STROKE</u>: <u>+30 deg</u> <u>WEIGHT</u>: <u>47 lbs</u> <u>FEEDBACK</u> - TYPE: <u>Position</u> - METHOD: <u>Film potentiometer (rotary)</u> <u>ELECTRONIC CONTROLLER</u> - TYPE: <u>DC</u> - SIGNAL LEVEL: <u>28 VDC, 600 ma</u> <u>LOOP ELECTRONICS</u>: <u>Analog</u>	5 PNEUMATIC/WARM GAS <u>SYSTEM</u> <u>STORED GAS</u> • TYPE GAS: <u>Helium</u> • SUPPLY PRESS: <u>7500 psi</u> • PROOF PRESS: <u>13,460 psi</u> • BURST PRESS: <u>16,440 psi</u> • VESSEL TYPE: <u>Steel reservoir</u> • VESSEL VOL: <u>68 in³</u> • SEALS: <u>Crush type metal</u> - GAS GENERATOR • PROPELLANT: _____ • FLOWRATE: _____ • REG. VALVE: _____ • TEMP @ ACT: _____ • PRESS @ ACT: _____ <u>CONTROL VALVE</u> - OPERATION: _____ - CONFIGURATION: _____ <u>ACTUATOR</u> - LINEAR: _____ - ROTARY: _____ - ROTARY/LINEAR: _____
3 ELECTROMECHANICAL - MOTOR • DC: _____ • AC: _____ • STEPPER: _____ - ACTUATOR • LINEAR: _____ • ROTARY: _____	6 STORED GAS VESSEL SHIPMENT - TYPE GAS: <u>Helium</u> - GAS PRESSURE: <u>7500 psi</u> - BURST FACTOR: <u>2.2</u> - DOT APPROVAL: <u>Yes</u> 7 SELECTION CRITERIA AND/OR SPECIAL FEATURES - Free piston pump strokes upon demand - Flexible actuator connecting rod - Self filling accumulator prior to system activation

MISSILE/SPACE VEHICLE ACTUATION SYSTEM DATA SHEET

1 GENERAL DESCRIPTION <u>VEHICLE</u> - NAME: Minuteman I, 1st Stage - TYPE: Surface-to-Surface (ICBM) - CONTROL: 4 hinged nozzles (1 actuator per nozzle) - COMPANY: Autonetics - PROGRAM: Production, 1959-1966 <u>ACTUATION SYSTEM</u> - COMPANY: Autonetics - TYPE PROGRAM: Production, 1959-1966 - TYPE DESIGN: Hydraulic - AXES: Pitch, yaw, roll - COMPENSATION: No - REDUNDANCY: No - TEMP. RANGE: +40°F to +275°F <u>LOAD</u> - TRAVEL: ±8 deg - TYPE: Primarily inertia & coulomb friction - INERTIA: _____ - f_n: _____ - Other: _____	4 HYDRAULIC <u>SYSTEM</u> - TYPE: Recirculating - PRESSURE: 3000 psig - FLOW: 3.72 GPM - FLUID: MIL-H-5606 - SEALS: Nitrile - FILTER: 15 μ absolute <u>SERVO VALVE</u> - OPERATION: 3-way flow control - CONFIGURATION: 2-stage dual nozzle flapper or jet pipe <u>ACTUATOR</u> - LINEAR: 2:1 unbalanced area - ROTARY: _____ <u>POWER SUPPLY</u> - PUMP • TYPE: Variable piston • POWER SOURCE: 28 VDC motor, 320 amps - ENERGY SOURCE • BATTERY: silver-zinc • OTHER: _____ - STORED GAS: _____ - GAS GEN/ACCUM: _____
2 ACTUATION SYSTEM DESIGN <u>RATED CONDITIONS</u> - DESIGN LOAD: 14,600 lb-in - STALL LOAD: 26,000 lb-in - DESIGN RATE: 20 deg/sec - NO LOAD RATE: 28.8 deg/sec <u>DUTY CYCLE</u> - DURATION: 60 sec - DESCRIPTION: Considerable activity at staging, very little at other times. <u>DYNAMIC PERFORMANCE</u> - BANDWIDTH: B Hz based on -3 db - STEP RESPONSE: _____ <u>STATIC PERFORMANCE</u> - RESOLUTION: _____ - THRESHOLD: _____ - HYSTERESIS: _____ - CLOSED LOOP STIFFNESS: _____ STROKE: 3 IN WEIGHT: Actuators-5.4 lb ea; motor/pump - 29.0 lbs <u>FEEDBACK</u> - TYPE: Position - METHOD: LVDT <u>ELECTRONIC CONTROLLER</u> - TYPE: PWM @ 5000 Hz - SIGNAL LEVEL: 8 ma LOOP ELECTRONICS: Analog	5 PNEUMATIC/WARM GAS <u>SYSTEM</u> - STORED GAS • TYPE GAS: _____ • SUPPLY PRESS: _____ • PROOF PRESS: _____ • BURST PRESS: _____ • VESSEL TYPE: _____ • VESSEL VOL: _____ • SEALS: _____ - GAS GENERATOR • PROPELLANT: _____ • FLOWRATE: _____ • REG. VALVE: _____ • TEMP @ ACT: _____ • PRESS @ ACT: _____ <u>CONTROL VALVE</u> - OPERATION: _____ - CONFIGURATION: _____ <u>ACTUATOR</u> - LINEAR: _____ - ROTARY: _____ - ROTARY/LINEAR: _____
3 ELECTROMECHANICAL - MOTOR • DC: _____ • AC: _____ • STEPPER: _____ - ACTUATOR • LINEAR: _____ • ROTARY: _____	6 STORED GAS VESSEL SHIPMENT - TYPE GAS: _____ - GAS PRESSURE: _____ - BURST FACTOR: _____ - DOT APPROVAL: _____ 7 SELECTION CRITERIA AND/OR SPECIAL FEATURES Ability to perform full system checkout with vehicle installed in silo was primary criteria.

MISSILE/SPACE VEHICLE ACTUATION SYSTEM DATA SHEET

1 GENERAL DESCRIPTION VEHICLE - NAME: <u>Minuteman I, 2nd Stage</u> - TYPE: <u>Surface-to-surface (ICBM)</u> - CONTROL: <u>4 hinged nozzles (1 actuator per nozzle)</u> - COMPANY: <u>Autonetics</u> - PROGRAM: <u>Production, 1959-1966</u> ACTUATION SYSTEM - COMPANY: <u>Autonetics</u> - TYPE PROGRAM: <u>Production, 1959-1966</u> - TYPE DESIGN: <u>Hydraulic</u> - AXES: <u>Pitch, yaw, roll</u> - COMPENSATION: <u>No</u> - REDUNDANCY: <u>No</u> - TEMP. RANGE: <u>+40°F to +275°F</u> LOAD - TRAVEL: <u>+6 deg</u> - TYPE: <u>Primarily inertia & coulomb friction</u> - INERTIA: _____ - f_n: _____ - Other: _____	4 HYDRAULIC SYSTEM - TYPE: <u>Recirculating</u> - PRESSURE: <u>3000 psi</u> - FLOW: <u>2.49 GPM</u> - FLUID: <u>MIL-H-5606</u> - SEALS: <u>Nitrile</u> - FILTER: <u>15μ absolute</u> SERVO VALVE - OPERATION: <u>3-way flow control</u> - CONFIGURATION: <u>2-stage dual nozzle flapper or jet pipe</u> ACTUATOR - LINEAR: <u>2:1 unbalanced area</u> - ROTARY: _____ POWER SUPPLY - PUMP • TYPE: <u>Variable piston</u> • POWER SOURCE: <u>28 VDC motor; 195 amps</u> - ENERGY SOURCE • BATTERY: <u>Silver-zinc</u> • OTHER: _____ - STORED GAS: _____ - GAS GEN/ACCUM: _____
2 ACTUATION SYSTEM DESIGN RATED CONDITIONS - DESIGN LOAD: <u>9,500 lb-in</u> - STALL LOAD: <u>13,500 lb-in</u> - DESIGN RATE: <u>20 deg/sec</u> - NO LOAD RATE: <u>37 deg/sec</u> DUTY CYCLE - DURATION: <u>60 sec</u> - DESCRIPTION: <u>Considerable activity at staging, very little at other times</u> DYNAMIC PERFORMANCE - BANDWIDTH: <u>8 Hz based on -3 db</u> - STEP RESPONSE: _____ STATIC PERFORMANCE - RESOLUTION: _____ - THRESHOLD: _____ - HYSTERESIS: _____ - CLOSED LOOP STIFFNESS: _____ STROKE: <u>2 in.</u> WEIGHT: <u>Actuator-3.4 lbs. ea.; motor/pump-18.1 lbs.</u> FEEDBACK - TYPE: <u>Position</u> - METHOD: <u>LVDI</u> ELECTRONIC CONTROLLER - TYPE: <u>PWM @ 5000 Hz</u> - SIGNAL LEVEL: <u>8 ma</u> LOOP ELECTRONICS: <u>Analog</u>	5 PNEUMATIC/WARM GAS SYSTEM - STORED GAS • TYPE GAS: _____ • SUPPLY PRESS: _____ • PROOF PRESS: _____ • BURST PRESS: _____ • VESSEL TYPE: _____ • VESSEL VOL: _____ • SEALS: _____ - GAS GENERATOR • PROPELLANT: _____ • FLOW RATE: _____ • REG. VALVE: _____ • TEMP @ ACT: _____ • PRESS @ ACT: _____ CONTROL VALVE - OPERATION: _____ - CONFIGURATION: _____ ACTUATOR - LINEAR: _____ - ROTARY: _____ - ROTARY/LINEAR: _____
3 ELECTROMECHANICAL - MOTOR • DC: _____ • AC: _____ • STEPPER: _____ - ACTUATOR • LINEAR: _____ • ROTARY: _____	6 STORED GAS VESSEL SHIPMENT - TYPE GAS: _____ - GAS PRESSURE: _____ - BURST FACTOR: _____ - DOT APPROVAL: _____ 7 SELECTION CRITERIA AND/OR SPECIAL FEATURES Ability to perform full system checkout with vehicle installed in silo was primary criteria.

MISSILE/SPACE VEHICLE ACTUATION SYSTEM DATA SHEET

1 GENERAL DESCRIPTION <u>VEHICLE</u> - NAME: <u>Minuteman I, 3rd Stage</u> - TYPE: <u>Surface-to-surface (ICBM)</u> - CONTROL: <u>4 hinged nozzles; (1 actuator per nozzle)</u> - COMPANY: <u>Autonetics</u> - PROGRAM: <u>Production, 1959-1966</u> <u>ACTUATION SYSTEM</u> - COMPANY: <u>Autonetics</u> - TYPE PROGRAM: <u>Production, 1959-1966</u> - TYPE DESIGN: <u>Hydraulic</u> - AXES: <u>Pitch, yaw, roll</u> - COMPENSATION: <u>No</u> - REDUNDANCY: <u>No</u> - TEMP. RANGE: <u>+40°F to +275°F</u> <u>LOAD</u> - TRAVEL: <u>+4 deg</u> - TYPE: <u>Primarily inertia & coulomb friction</u> - INERTIA: _____ - f_n: _____ - Other: _____	4 HYDRAULIC <u>SYSTEM</u> - TYPE: <u>Recirculating</u> - PRESSURE: <u>1500 psi</u> - FLOW: <u>1.0 GPM</u> - FLUID: <u>MIL-H-5606</u> - SEALS: <u>Nitrile</u> - FILTER: <u>15 μ absolute</u> <u>SERVO VALVE</u> - OPERATION: <u>3-way flow control</u> - CONFIGURATION: <u>2-stage dual nozzle flapper or jet</u> pipe <u>ACTUATOR</u> - LINEAR: <u>2:1 unbalanced area</u> - ROTARY: _____ <u>POWER SUPPLY</u> - PUMP • TYPE: <u>Variable piston</u> • POWER SOURCE: <u>28 VDC motor; 80 amps</u> - ENERGY SOURCE • BATTERY: <u>Silver - zinc</u> • OTHER: _____ - STORED GAS: _____ - GAS GEN/ACCUM: _____
2 ACTUATION SYSTEM DESIGN <u>RATED CONDITIONS</u> - DESIGN LOAD: <u>3,700 lb-in</u> - STALL LOAD: <u>6,375 lb-in</u> - DESIGN RATE: <u>10 deg/sec</u> - NO LOAD RATE: <u>18 deg/sec</u> <u>DUTY CYCLE</u> - DURATION: <u>60 sec</u> - DESCRIPTION: <u>Considerable activity at staging, very little at other times.</u> <u>DYNAMIC PERFORMANCE</u> - BANDWIDTH: <u>8 Hz based on -3 db</u> - STEP RESPONSE: _____ <u>STATIC PERFORMANCE</u> - RESOLUTION: _____ - THRESHOLD: _____ - HYSTERESIS: _____ - CLOSED LOOP STIFFNESS: _____ <u>STROKE</u>: _____ <u>WEIGHT</u>: <u>Actuator - 2.8 lbs. ea.; motor/pump - 11.5 lbs</u> <u>FEEDBACK</u> - TYPE: <u>Position</u> - METHOD: <u>LVDT</u> <u>ELECTRONIC CONTROLLER</u> - TYPE: <u>PWM @ 5000 Hz</u> - SIGNAL LEVEL: <u>8 ma</u> <u>LOOP ELECTRONICS</u>: <u>Analog</u>	5 PNEUMATIC/WARM GAS <u>SYSTEM</u> - STORED GAS • TYPE GAS: _____ • SUPPLY PRESS: _____ • PROOF PRESS: _____ • BURST PRESS: _____ • VESSEL TYPE: _____ • VESSEL VOL: _____ • SEALS: _____ - GAS GENERATOR • PROPELLANT: _____ • FLDWRATE: _____ • REG. VALVE: _____ • TEMP @ ACT: _____ • PRESS @ ACT: _____ <u>CONTROL VALVE</u> - OPERATION: _____ - CONFIGURATION: _____ <u>ACTUATOR</u> - LINEAR: _____ - ROTARY: _____ - ROTARY/LINEAR: _____
3 ELECTROMECHANICAL - MOTOR • DC: _____ • AC: _____ • STEPPER: _____ - ACTUATOR • LINEAR: _____ • ROTARY: _____	6 STORED GAS VESSEL SHIPMENT - TYPE GAS: _____ - GAS PRESSURE: _____ - BURST FACTOR: _____ - DOT APPROVAL: _____ 7 SELECTION CRITERIA AND/OR SPECIAL FEATURES Ability to perform full system checkout with vehicle installed in silo was primary criteria.

MISSILE/SPACE VEHICLE ACTUATION SYSTEM DATA SHEET

1 GENERAL DESCRIPTION <u>VEHICLE</u> - NAME: <u>Minuteman II, 2nd Stage</u> - TYPE: <u>Surface-to-surface (ICBM)</u> - CONTROL: <u>Secondary injection (4 actuators)</u> - COMPANY: <u>Autonectics</u> - PROGRAM: <u>Production, 1964 -</u> <u>ACTUATION SYSTEM</u> - COMPANY: <u>Autonectics</u> - TYPE PROGRAM: <u>Production</u> - TYPE DESIGN: <u>Hydraulic</u> - AXES: <u>Pitch, yaw</u> - COMPENSATION: <u>None</u> - REDUNDANCY: <u>None</u> - TEMP. RANGE: <u>+40 to +275°F</u> <u>LOAD</u> - TRAVEL: _____ - TYPE: <u>Spring</u> - INERTIA: _____ - f_n: _____ - Other: <u>Fluid flow forces</u>	4 HYDRAULIC <u>SYSTEM</u> - TYPE: <u>Recirculating</u> - PRESSURE: <u>425 psi</u> - FLOW: <u>1.1 gpm</u> - FLUID: <u>MIL-H-5606</u> - SEALS: <u>Nitrile</u> - FILTER: <u>15μ absolute</u> <u>SERVO VALVE</u> - OPERATION: <u>3-way flow control</u> - CONFIGURATION: <u>2-stage dual nozzle flapper or jet</u> pipe <u>ACTUATOR</u> - LINEAR: <u>2:1 unbalanced area</u> - ROTARY: _____ <u>POWER SUPPLY</u> - PUMP • TYPE: <u>Variable piston</u> • POWER SOURCE: <u>28 VDC motor</u> - ENERGY SOURCE • BATTERY: <u>Silver - zinc</u> • OTHER: _____ - STORED GAS: _____ - GAS GEN/ACCUM: _____
2 ACTUATION SYSTEM DESIGN <u>RATED CONDITIONS</u> - DESIGN LOAD: <u>220 lbs.</u> - STALL LOAD: <u>300 lbs.</u> - DESIGN RATE: <u>1.5 in/sec</u> - NO LOAD RATE: <u>2.8 in/sec</u> <u>DUTY CYCLE</u> - DURATION: <u>60 sec</u> - DESCRIPTION: <u>Considerable activity at staging,</u> <u>very little at other times</u> <u>DYNAMIC PERFORMANCE</u> - BANDWIDTH: <u>8 Hz based on - 3 db</u> - STEP RESPONSE: _____ <u>STATIC PERFORMANCE</u> - RESOLUTION: _____ - THRESHOLD: _____ - HYSTERESIS: _____ - CLOSED LOOP STIFFNESS: _____ STROKE: <u>0.27 in</u> WEIGHT: <u>servo injector - 7.0 lbs each; Motor/Pump</u> <u>6.5 lbs</u> <u>FEEDBACK</u> - TYPE: <u>Position</u> - METHOD: <u>LVDT</u> <u>ELECTRONIC CONTROLLER</u> - TYPE: <u>PWM @ 5000 Hz</u> - SIGNAL LEVEL: <u>8 ma</u> LOOP ELECTRONICS: <u>Analog</u>	5 PNEUMATIC/WARM GAS <u>SYSTEM</u> - STORED GAS • TYPE GAS: _____ • SUPPLY PRESS: _____ • PROOF PRESS: _____ • BURST PRESS: _____ • VESSEL TYPE: _____ • VESSEL VOL: _____ • SEALS: _____ - GAS GENERATOR • PROPELLANT: _____ • FLOWRATE: _____ • REG. VALVE: _____ • TEMP @ ACT: _____ • PRESS @ ACT: _____ <u>CONTROL VALVE</u> - OPERATION: _____ - CONFIGURATION: _____ <u>ACTUATOR</u> - LINEAR: _____ - ROTARY: _____ - ROTARY/LINEAR: _____
3 ELECTROMECHANICAL - MOTOR • DC: _____ • AC: _____ • STEPPER: _____ - ACTUATOR • LINEAR: _____ • ROTARY: _____	6 STORED GAS VESSEL SHIPMENT - TYPE GAS: _____ - GAS PRESSURE: _____ - BURST FACTOR: _____ - DOT APPROVAL: _____ 7 SELECTION CRITERIA AND/OR SPECIAL FEATURES - 1st & 3rd stages same as Minuteman I - Freon 114-B2 injection fluid

MISSILE/SPACE VEHICLE ACTUATION SYSTEM DATA SHEET

1 GENERAL DESCRIPTION <u>VEHICLE</u> - NAME: <u>Minuteman III, 3rd stage</u> - TYPE: <u>Surface- to surface</u> - CONTROL: <u>Secondary injection (4 actuators)</u> - COMPANY: <u>Autonetics</u> - PROGRAM: <u>Production, 1969 -</u> <u>ACTUATION SYSTEM</u> - COMPANY: <u>Autonetics</u> - TYPE PROGRAM: <u>Production, 1969 -</u> - TYPE DESIGN: <u>Electromechanical</u> - AXES: <u>Pitch, yaw</u> - COMPENSATION: <u>None</u> - REDUNDANCY: <u>None</u> - TEMP. RANGE: <u>+40 to +275°F</u> <u>LOAD</u> - TRAVEL: _____ - TYPE: <u>Spring</u> - INERTIA: _____ - f_n: _____ - Other: <u>Fluid flow forces</u>	4 HYDRAULIC <u>SYSTEM</u> - TYPE: _____ - PRESSURE: _____ - FLOW: _____ - FLUID: _____ - SEALS: _____ - FILTER: _____ <u>SERVO VALVE</u> - OPERATION: _____ - CONFIGURATION: _____ <u>ACTUATOR</u> - LINEAR: _____ - ROTARY: _____ <u>POWER SUPPLY</u> - PUMP • TYPE: _____ • POWER SOURCE: _____ - ENERGY SOURCE • BATTERY: _____ • OTHER: _____ - STORED GAS: _____ - GAS GEN/ACCUM: _____
2 ACTUATION SYSTEM DESIGN <u>RATED CONDITIONS</u> - DESIGN LOAD: <u>60 lbs</u> - STALL LOAD: _____ - DESIGN RATE: <u>1.85 in/sec</u> - NO LOAD RATE: _____ <u>DUTY CYCLE</u> - DURATION: <u>60 sec</u> - DESCRIPTION: <u>Considerable activity at staging, very little at other times</u> <u>DYNAMIC PERFORMANCE</u> - BANDWIDTH: <u>8 Hz based on -3 db</u> - STEP RESPONSE: _____ <u>STATIC PERFORMANCE</u> - RESOLUTION: _____ - THRESHOLD: _____ - HYSTERESIS: _____ - CLOSED LOOP STIFFNESS: _____ <u>STROKE</u>: <u>0.25 in</u> <u>WEIGHT</u>: <u>Servo injector - 3.5 lbs</u> <u>FEEDBACK</u> - TYPE: <u>Position</u> - METHOD: <u>LVDT</u> <u>ELECTRONIC CONTROLLER</u> - TYPE: <u>PWM @ 5000 Hz</u> - SIGNAL LEVEL: <u>26 VDC</u> <u>LODP ELECTRONICS</u>: <u>Analog</u>	5 PNEUMATIC/WARM GAS <u>SYSTEM</u> - STORED GAS • TYPE GAS: _____ • SUPPLY PRESS: _____ • PROOF PRESS: _____ • BURST PRESS: _____ • VESSEL TYPE: _____ • VESSEL VOL: _____ • SEALS: _____ - GAS GENERATOR • PROPELLANT: _____ • FLOWRATE: _____ • REG. VALVE: _____ • TEMP @ ACT: _____ • PRESS @ ACT: _____ <u>CONTRDL VALVE</u> - OPERATION: _____ - CONFIGURATION: _____ <u>ACTUATOR</u> - LINEAR: _____ - ROTARY: _____ - ROTARY/LINEAR: _____
3 ELECTROMECHANICAL - MOTOR • DC: <u>26 VDC Torque motor</u> • AC: _____ • STEPPER: _____ - ACTUATOR • LINEAR: <u>Ball screw</u> • ROTARY: _____	6 STORED GAS VESSEL SHIPMENT - TYPE GAS: _____ - GAS PRESSURE: _____ - BURST FACTOR: _____ - DOT APPROVAL: _____
7 SELECTION CRITERIA AND/OR SPECIAL FEATURES -1st stage same as Minuteman I -2nd stage same as Minuteman II -Strontium-perchlorate injection fluid	

MISSILE/SPACE VEHICLE ACTUATION SYSTEM DATA SHEET

1 GENERAL DESCRIPTION <u>VEHICLE</u> - NAME: <u>Nike Hercules</u> - TYPE: <u>Surface-to-air</u> - CONTROL: <u>Aerodynamic fin (3 actuator)</u> - COMPANY: <u>McDonnell Douglas/Huntington Beach</u> - PROGRAM: <u>Production, 1954-1962</u> <u>ACTUATION SYSTEM</u> - COMPANY: <u>McDonnell Douglas/Huntington Beach</u> - TYPE PROGRAM: <u>Production, 1954-1962</u> - TYPE DESIGN: <u>Hydraulic</u> - AXES: <u>Pitch, yaw, roll</u> - COMPENSATION: <u>Electronic</u> - REDUNDANCY: <u>No</u> - TEMP. RANGE: <u>-65 to +165°F</u> <u>LOAD</u> - TRAVEL: <u>+25° for pitch & yaw; +15° for roll</u> - TYPE: <u>Aero and inertia</u> - INERTIA: <u>0.19 lb-in-sec²</u> - f_n: _____ - Other: _____	4 HYDRAULIC <u>SYSTEM</u> - TYPE: <u>Recirculating</u> - PRESSURE: <u>3000 psi</u> - FLOW: <u>2.5 gpm</u> - FLUID: <u>MIL-H-5606</u> - SEALS: <u>Nitrile</u> - FILTER: <u>25 micron</u> <u>SERVO VALVE</u> - OPERATION: <u>4-way flow control</u> - CONFIGURATION: <u>2-stage jet pipe</u> <u>ACTUATOR</u> - LINEAR: <u>0.64 in² balanced area</u> - ROTARY: _____ <u>POWER SUPPLY</u> - PUMP • TYPE: <u>Variable piston</u> • POWER SOURCE: <u>DC motor</u> - ENERGY SOURCE: _____ • BATTERY: _____ • OTHER: _____ - STORED GAS: _____ - GAS GEN/ACCUM: _____
2 ACTUATION SYSTEM DESIGN <u>RATED CONDITIONS</u> - DESIGN LOAD: <u>3820 lb-in</u> - STALL LOAD: <u>5500 lb-in</u> - DESIGN RATE: <u>226 deg/sec</u> - NO LOAD RATE: <u>358 deg/sec</u> <u>DUTY CYCLE</u> - DURATION: <u>6 min</u> - DESCRIPTION: <u>1.9 gpm for 400 sec, 2.5 gpm for 15 sec, 1.0 gpm for 5 sec</u> <u>DYNAMIC PERFORMANCE</u> - BANDWIDTH: <u>15-20 Hz based on -3 dB</u> - STEP RESPONSE: _____ <u>STATIC PERFORMANCE</u> - RESOLUTION: _____ - THRESHOLD: <u>0.45 ma max.</u> - HYSTERESIS: <u>0.70 ma max.</u> - CLOSED LOOP STIFFNESS: _____ STROKE: <u>+2.5 in. for pitch & yaw; +1.5 in. for roll</u> <u>WEIGHT</u> <u>FEEDBACK</u> - TYPE: <u>Position</u> - METHOD: <u>Film Potentiometer</u> <u>ELECTRONIC CONTROLLER</u> - TYPE: <u>DC</u> - SIGNAL LEVEL: <u>18 ma</u> LOOP ELECTRONICS: <u>Analog</u>	5 PNEUMATIC/WARM GAS <u>SYSTEM</u> - STORED GAS • TYPE GAS: _____ • SUPPLY PRESS: _____ • PROOF PRESS: _____ • BURST PRESS: _____ • VESSEL TYPE: _____ • VESSEL VOL: _____ • SEALS: _____ - GAS GENERATOR • PROPELLANT: _____ • FLOWRATE: _____ • REG. VALVE: _____ • TEMP @ ACT: _____ • PRESS @ ACT: _____ <u>CONTROL VALVE</u> - OPERATION: _____ - CONFIGURATION: _____ <u>ACTUATOR</u> - LINEAR: _____ - ROTARY: _____ - ROTARY/LINEAR: _____
3 ELECTROMECHANICAL - MOTOR • DC: _____ • AC: _____ • STEPPER: _____ - ACTUATOR • LINEAR: _____ • ROTARY: _____	6 STORED GAS VESSEL SHIPMENT - TYPE GAS: _____ - GAS PRESSURE: _____ - BURST FACTOR: _____ - DOT APPROVAL: _____
7 SELECTION CRITERIA AND/OR SPECIAL FEATURES	

MISSILE/SPACE VEHICLE ACTUATION SYSTEM DATA SHEET

1 GENERAL DESCRIPTION <u>VEHICLE</u> - NAME: <u>Patriot</u> - TYPE: <u>Surface-to-air</u> - CONTROL: <u>Aerodynamic fin (4 actuators)</u> - COMPANY: <u>Martin/Orlando & Raytheon</u> - PROGRAM: <u>Production, 1983 -</u> <u>ACTUATION SYSTEM</u> - COMPANY: <u>Martin/Orlando & Raytheon</u> - TYPE PROGRAM: <u>Production, 1983 -</u> - TYPE DESIGN: <u>Hydraulic</u> - AXES: <u>Pitch, yaw, roll</u> - COMPENSATION: <u>Electronic</u> - REDUNDANCY: <u>No</u> - TEMP. RANGE: <u>-30 to +130°F</u> <u>LOAD</u> - TRAVEL: <u>+31 deg</u> - TYPE: <u>Combination</u> - INERTIA: <u>1.2 lb-in-sec²</u> - f_n: <u>90 Hz</u> - Other: <u>Aero: 6400 lb-in</u> <u>Spring: 600 lb-in/deg</u> <u>Viscous fric: 640 lb-in-sec/rad</u> <u>Coulomb fric: 185 lb-in</u>	4 HYDRAULIC <u>SYSTEM</u> - TYPE: <u>Recirculating</u> - PRESSURE: <u>3000 psi</u> - FLOW: <u>4 gpm</u> - FLUID: <u>MIL-H-5606</u> - SEALS: <u>Nitrile</u> - FILTER: <u>10 micron</u> <u>SERVO VALVE</u> - OPERATION: <u>4-way flow control</u> - CONFIGURATION: <u>2-stage dual nozzle flapper</u> <u>ACTUATOR</u> - LINEAR: <u>1.22 in² balanced area with rocker arm</u> - ROTARY: <u></u> <u>POWER SUPPLY</u> - PUMP • TYPE: <u>Variable piston</u> • POWER SOURCE: <u>48-62 VDC motor</u> - ENERGY SOURCE • BATTERY: <u>Silver/zinc (6 Amp-Hr)</u> • OTHER: <u></u> - STORED GAS: <u>He accumulator</u> - GAS GEN/ACCUM: <u></u>
2 ACTUATION SYSTEM DESIGN <u>RATED CONDITIONS</u> - DESIGN LOAD: <u>4000 lb-in</u> - STALL LOAD: <u>4500 lb-in</u> - DESIGN RATE: <u>100 deg/sec</u> - NO LOAD RATE: <u>350 deg/sec</u> <u>DUTY CYCLE</u> - DURATION: <u>180 sec</u> - DESCRIPTION: <u>56 deg/sec max for 9.3 sec per fin</u> <u>DYNAMIC PERFORMANCE</u> - BANDWIDTH: <u>32.5 Hz based on $\phi = 90^\circ$</u> - STEP RESPONSE: <u>+5 deg < 30% overshoot</u> <u>STATIC PERFORMANCE</u> - RESOLUTION: <u>0.038 deg</u> - THRESHOLD: <u>0.035 deg</u> - HYSTERESIS: <u>0.077 deg</u> - CLOSED LOOP STIFFNESS: <u>>10,000 lb-in/deg</u> STROKE: <u>+32 deg</u> WEIGHT: <u>171 lbs control section (includes struct. & fins)</u> <u>FEEDBACK</u> - TYPE: <u>Position</u> - METHOD: <u>Film potentiometer</u> <u>ELECTRONIC CONTROLLER</u> - TYPE: <u>AC</u> - SIGNAL LEVEL: <u>30 ma</u> LOOP ELECTRONICS: <u>Digital and analog with D/A converter</u>	5 PNEUMATIC/WARM GAS <u>SYSTEM</u> - STORED GAS • TYPE GAS: <u></u> • SUPPLY PRESS: <u></u> • PROOF PRESS: <u></u> • BURST PRESS: <u></u> • VESSEL TYPE: <u></u> • VESSEL VOL: <u></u> • SEALS: <u></u> - GAS GENERATOR • PROPELLANT: <u></u> • FLOWRATE: <u></u> • REG. VALVE: <u></u> • TEMP @ ACT: <u></u> • PRESS @ ACT: <u></u> <u>CONTRDL VALVE</u> - OPERATION: <u></u> - CONFIGURATION: <u></u> <u>ACTUATOR</u> - LINEAR: <u></u> - ROTARY: <u></u> - ROTARY/LINEAR: <u></u>
3 ELECTROMECHANICAL - MOTOR • DC: <u></u> • AC: <u></u> • STEPPER: <u></u> - ACTUATOR • LINEAR: <u></u> • ROTARY: <u></u>	6 STORED GAS VESSEL SHIPMENT - TYPE GAS: <u>He</u> - GAS PRESSURE: <u>4700 psi @ 70°F</u> - BURST FACTOR: <u>2.5</u> - DOT APPROVAL: <u>Yes</u> 7 SELECTION CRITERIA AND/OR SPECIAL FEATURES Performance and stiffness with minimum risk

MISSILE/SPACE VEHICLE ACTUATION SYSTEM DATA SHEET

1 GENERAL DESCRIPTION <u>VEHICLE</u> - NAME: <u>Peacekeeper, 1st stage</u> - TYPE: <u>Surface-to-surface</u> - CONTROL: <u>Gimbaled nozzle (2 actuators)</u> - COMPANY: <u>Moog</u> - PROGRAM: <u>Production, 1984 -</u> <u>ACTUATION SYSTEM</u> - COMPANY: <u>Moog</u> - TYPE PROGRAM: <u>Production, 1984 -</u> - TYPE DESIGN: <u>Hydraulic</u> - AXES: <u>Pitch, yaw</u> - COMPENSATION: <u>Electronic</u> - REDUNDANCY: <u>No</u> - TEMP. RANGE: <u>+40 to +450°F</u> <u>LOAD</u> - TRAVEL: <u>+6 deg</u> - TYPE: <u>Combination; moment arm-16.2 in</u> - INERTIA: <u>1972 lb-in-sec²</u> - f_n: _____ - Other: <u>Spring: 100,000 lb-in/deg</u> <u>Viscous fric: 89,700 lb-in @ 40 deg/sec</u> <u>Offset torque: 11,000 lb-in</u>	4 HYDRAULIC <u>SYSTEM</u> - TYPE: <u>Recirculating</u> - PRESSURE: <u>3300psi</u> <u>2000 psi</u> - FLOW: <u>42 gpm</u> <u>70 gpm</u> - FLUID: <u>MIL-H-83282</u> - SEALS: <u>Fluorocarbon</u> - FILTER: <u>No</u> <u>SERVO VALVE</u> - OPERATION: <u>Flow control</u> - CONFIGURATION: <u>2-stage diverter jet</u> <u>ACTUATOR</u> - LINEAR: <u>13.78 in² balanced area</u> - ROTARY: _____ <u>POWER SUPPLY</u> - PUMP • TYPE: <u>Centrifugal</u> • POWER SOURCE: <u>Turbine</u> - ENERGY SOURCE • BATTERY: _____ • OTHER: <u>Solid propellant gas generator</u> - STORED GAS: _____ - GAS GEN/ACCUM: _____
2 ACTUATION SYSTEM DESIGN <u>RATED CONDITIONS</u> - DESIGN LOAD: <u>667,000 lb-in</u> - STALL LOAD: <u>800,000 lb-in</u> - DESIGN RATE: <u>40 deg/sec</u> - NO LOAD RATE: <u>100 deg/sec</u> <u>DUTY CYCLE</u> - DURATION: <u>60 sec</u> - DESCRIPTION: _____ <u>DYNAMIC PERFORMANCE</u> - BANDWIDTH: <u>5.5 Hz based on $\phi = 45^\circ$</u> - STEP RESPONSE: <u>6° in 40 msec; <10% overshoot</u> <u>STATIC PERFORMANCE</u> - RESOLUTION: <u><0.10 deg</u> - THRESHOLD: <u><0.10 deg</u> - HYSTERESIS: <u><0.15 deg</u> - CLOSED LOOP STIFFNESS: _____ STROKE: <u>+1.75 in.</u> WEIGHT: _____ <u>FEEDBACK</u> - TYPE: <u>Position</u> - METHOD: <u>LVDI</u> <u>ELECTRONIC CONTROLLER</u> - TYPE: <u>PWM at 5000 Hz</u> - SIGNAL LEVEL: _____ <u>LOOP ELECTRONICS: Digital</u>	5 PNEUMATIC/WARM GAS <u>SYSTEM</u> - STORED GAS • TYPE GAS: _____ • SUPPLY PRESS: _____ • PRODF PRESS: _____ • BURST PRESS: _____ • VESSEL TYPE: _____ • VESSEL VOL: _____ • SEALS: _____ - GAS GENERATOR • PROPELLANT: _____ • FLOWRATE: _____ • REG. VALVE: _____ • TEMP @ ACT: _____ • PRESS @ ACT: _____ <u>CONTROL VALVE</u> - OPERATION: _____ - CONFIGURATION: _____ <u>ACTUATOR</u> - LINEAR: _____ - ROTARY: _____ - ROTARY/LINEAR: _____
3 ELECTROMECHANICAL - MOTOR • DC: _____ • AC: _____ • STEPPER: _____ - ACTUATOR • LINEAR: _____ • ROTARY: _____	6 STORED GAS VESSEL SHIPMENT - TYPE GAS: _____ - GAS PRESSURE: _____ - BURST FACTOR: _____ - DOT APPROVAL: _____ 7 SELECTION CRITERIA AND/OR SPECIAL FEATURES - Enable time of 1.35 sec. - System uses pump-turbine inertia to supply high rates at low loads

MISSILE/SPACE VEHICLE ACTUATION SYSTEM DATA SHEET

1 GENERAL DESCRIPTION <u>VEHICLE</u> - NAME: <u>Peacekeeper, 3rd Stage</u> - TYPE: <u>Surface-to-surface</u> - CONTROL: <u>Gimbaled nozzle (2 actuators)</u> - COMPANY: <u>HR - Textron</u> - PROGRAM: <u>Production, 1984 -</u> <u>ACTUATION SYSTEM</u> - COMPANY: <u>HR - Textron</u> - TYPE PROGRAM: <u>Production, 1984 -</u> - TYPE DESIGN: <u>Hydraulic</u> - AXES: <u>Pitch, yaw</u> - COMPENSATION: <u>Electronic</u> - REDUNDANCY: <u>No</u> - TEMP. RANGE: <u>45 - 99°F</u> <u>LOAD</u> - TRAVEL: <u>+3 deg</u> - TYPE: <u>Combination: moment arm = 13.5 in.</u> - INERTIA: <u>664 lb-in-sec²</u> - f_n: <u>Spring: 1.89 x 10⁶ lb-in/rad max</u> <u>Coulomb friction: 975 lb-in</u> <u>Viscous friction coeff: 17,170 lb-in-sec/rad</u> <u>Structural stiffness: 200,000 lb/in</u>	4 HYDRAULIC <u>SYSTEM</u> - TYPE: <u>Recirculating</u> - PRESSURE: <u>1850 psi</u> - FLOW: <u>10.5 gpm</u> - FLUID: <u>MIL-H-83282</u> - SEALS: <u>Fluorocarbon</u> - FILTER: <u>No</u> <u>SERVO VALVE</u> - OPERATION: <u>4-way flow control</u> - CONFIGURATION: <u>2-stage jet pipe</u> <u>ACTUATOR</u> - LINEAR: <u>5.48 in² balanced area</u> - ROTARY: <u></u> <u>POWER SUPPLY</u> - PUMP • TYPE: <u>Centrifugal</u> • POWER SOURCE: <u>Turbine</u> - ENERGY SOURCE • BATTERY: <u></u> • OTHER: <u>Solid propellant gas generator</u> - STORED GAS: <u></u> - GAS GEN/ACCUM: <u></u>
2 ACTUATION SYSTEM DESIGN <u>RATED CONDITIONS</u> - DESIGN LOAD: <u></u> - STALL LOAD: <u>136,000 lb-in</u> - DESIGN RATE: <u></u> - NO LOAD RATE: <u></u> <u>DUTY CYCLE</u> - DURATION: <u>60-90 sec</u> - DESCRIPTION: <u>Max. activity at staging; full capability for mission duration</u> <u>DYNAMIC PERFORMANCE</u> - BANDWIDTH: <u>1 Hz based on $\delta = 47.5^\circ$</u> - STEP RESPONSE: <u>3°, 15°/sec min. ave between 10 & 90%</u> <u>STATIC PERFORMANCE</u> - RESOLUTION: <u>0.14 deg</u> - THRESHOLD: <u></u> - HYSTERESIS: <u></u> - CLOSED LOOP STIFFNESS: <u></u> <u>STROKE</u>: <u>0.92 in</u> <u>WEIGHT</u>: <u>65 lbs</u> <u>FEEDBACK</u> - TYPE: <u>Position</u> - METHOD: <u>LVDT</u> <u>ELECTRONIC CONTROLLER</u> - TYPE: <u>PWM at 5000 Hz</u> - SIGNAL LEVEL: <u>28 VDC; 8 ma; 1400 ohm driver output impedance</u> <u>LOOP ELECTRONICS</u>: <u>Digital</u>	5 PNEUMATIC/WARM GAS <u>SYSTEM</u> <u>STORED GAS</u> • TYPE GAS: <u></u> • SUPPLY PRESS: <u></u> • PROOF PRESS: <u></u> • BURST PRESS: <u></u> • VESSEL TYPE: <u></u> • VESSEL VOL: <u></u> • SEALS: <u></u> - GAS GENERATOR • PROPELLANT: <u></u> • FLOWRATE: <u></u> • REG. VALVE: <u></u> • TEMP @ ACT: <u></u> • PRESS @ ACT: <u></u> <u>CONTROL VALVE</u> - OPERATION: <u></u> - CONFIGURATION: <u></u> <u>ACTUATOR</u> - LINEAR: <u></u> - ROTARY: <u></u> - ROTARY/LINEAR: <u></u>
3 ELECTROMECHANICAL - MOTOR • DC: <u></u> • AC: <u></u> • STEPPER: <u></u> - ACTUATOR • LINEAR: <u></u> • ROTARY: <u></u>	6 STORED GAS VESSEL SHIPMENT - TYPE GAS: <u></u> - GAS PRESSURE: <u></u> - BURST FACTOR: <u></u> - DOT APPROVAL: <u></u> 7 SELECTION CRITERIA AND/OR SPECIAL FEATURES Min. risk and cost using existing state-of-art.

MISSILE/SPACE VEHICLE ACTUATION SYSTEM DATA SHEET

1 GENERAL DESCRIPTION <u>VEHICLE</u> - NAME: <u>Pershing (P-1a)</u> - TYPE: <u>Surface-to-surface</u> - CONTROL: <u>Aero and jet vanes (3 actuators)</u> - COMPANY: <u>Martin-Orlando</u> - PROGRAM: <u>Production, 1976-</u> <u>ACTUATION SYSTEM</u> - COMPANY: <u>Singer/Kearfott</u> - TYPE PROGRAM: <u>Production, 1976 -</u> - TYPE DESIGN: <u>Hydraulic</u> - AXES: <u>Pitch, yaw, roll</u> - COMPENSATION: <u>Electronic</u> - REDUNDANCY: <u>No</u> - TEMP. RANGE: <u>-65 to +160°F</u> <u>LOAD</u> - TRAVEL: <u>+26.5 deg</u> - TYPE: <u>Combination</u> - INERTIA: <u>0.093 lb-in-sec²</u> - f_n : - Other: <u>Aero: 4800 lb-in</u> <u>Coulomb fric: 75 lb-in</u>	4 HYDRAULIC <u>SYSTEM</u> - TYPE: <u>Recirculating</u> - PRESSURE: <u>3150 psi</u> - FLOW: <u>0.34 gpm</u> - FLUID: <u>MIL-H-5606</u> - SEALS: <u>Fluorosilicon</u> - FILTER: <u>10 micron</u> <u>SERVO VALVE</u> - OPERATION: <u>4-way flow control</u> - CONFIGURATION: <u>2-stage single nozzle flapper</u> <u>ACTUATOR</u> - LINEAR: <u>0.7 in² balanced area with rocker arm</u> - ROTARY: <u>POWER SUPPLY</u> - PUMP • TYPE: <u>Fixed piston or gear</u> • POWER SOURCE: <u>28 VDC motor</u> - ENERGY SOURCE • BATTERY: • OTHER: - STORED GAS: - GAS GEN/ACCUM: <u>2000 psi N₂ accumulator</u>
2 ACTUATION SYSTEM DESIGN <u>RATED CONDITIONS</u> - DESIGN LOAD: <u>2750 lb-in</u> - STALL LOAD: <u>3790 lb-in</u> - DESIGN RATE: <u>150 deg/sec</u> - NO LOAD RATE: <u>288 deg/sec</u> <u>DUTY CYCLE</u> - DURATION: <u>120 sec</u> - DESCRIPTION: <u>DYNAMIC PERFORMANCE</u> - BANDWIDTH: <u>30 Hz based on $\phi = 90^\circ$</u> - STEP RESPONSE: <u>+5 deg, 20% overshoot</u> <u>STATIC PERFORMANCE</u> - RESOLUTION: - THRESHOLD: <u>0.1 ma (includes deadband)</u> - HYSTERESIS: <u>0.3 ma</u> - CLOSED LOOP STIFFNESS: <u>STROKE:</u> <u>28.5 deg</u> <u>WEIGHT:</u> <u>86 lbs</u> <u>FEEDBACK</u> - TYPE: <u>Position</u> - METHOD: <u>Film potentiometer</u> <u>ELECTRONIC CONTROLLER</u> - TYPE: <u>AC at 60 Hz</u> - SIGNAL LEVEL: <u>5 ma (11 ma max)</u> <u>LOOP ELECTRONICS:</u> <u>Digital and analog with D/A converter</u>	5 PNEUMATIC/WARM GAS <u>SYSTEM</u> - STORED GAS • TYPE GAS: • SUPPLY PRESS: • PROOF PRESS: • BURST PRESS: • VESSEL TYPE: • VESSEL VOL: • SEALS: - GAS GENERATOR • PROPELLANT: • FLOWRATE: • REG. VALVE: • TEMP @ ACT: • PRESS @ ACT: <u>CONTROL VALVE</u> - OPERATION: - CONFIGURATION: <u>ACTUATOR</u> - LINEAR: - ROTARY: - ROTARY/LINEAR:
3 ELECTROMECHANICAL - MOTOR • DC: • AC: • STEPPER: - ACTUATOR • LINEAR: • ROTARY:	6 STORED GAS VESSEL SHIPMENT - TYPE GAS: - GAS PRESSURE: - BURST FACTOR: - DOT APPROVAL: 7 SELECTION CRITERIA AND/OR SPECIAL FEATURES Combination of aero and jet vanes driven from same actuation system which can be replaced with missile in launch ready position.

MISSILE/SPACE VEHICLE ACTUATION SYSTEM DATA SHEET

1 GENERAL DESCRIPTION <u>VEHICLE</u> - NAME: <u>Phoenix</u> - TYPE: <u>Air-to-air</u> - CONTROL: <u>Aerodynamic fin (2 actuators)</u> - COMPANY: <u>Hughes/Tucson</u> - PROGRAM: <u>Production, 1975 -</u> <u>ACTUATION SYSTEM</u> - COMPANY: <u>Hughes/Tucson</u> - TYPE PROGRAM: <u>Production, 1975 -</u> - TYPE DESIGN: <u>Hydraulic</u> - AXES: <u>Pitch, yaw, roll</u> - COMPENSATION: _____ - REDUNDANCY: <u>No</u> - TEMP. RANGE: _____ <u>LOAD</u> - TRAVEL: _____ - TYPE: _____ - INERTIA: _____ - f_n: _____ - Other: _____	4 HYDRAULIC <u>SYSTEM</u> - TYPE: <u>Recirculating</u> - PRESSURE: <u>3200 psi</u> - FLOW: <u>1.5 gpm</u> - FLUID: <u>Bravco 762</u> - SEALS: <u>Nitrile</u> - FILTER: <u>3 micron</u> <u>SERVO VALVE</u> - OPERATION: <u>4-way flow control</u> - CONFIGURATION: <u>2-stage</u> <u>ACTUATOR</u> - LINEAR: _____ - ROTARY: <u>Push-push</u> <u>POWER SUPPLY</u> - PUMP • TYPE: <u>Variable piston</u> • POWER SOURCE: <u>DC motor</u> - ENERGY SOURCE • BATTERY: _____ • OTHER: _____ - STORED GAS: _____ - GAS GEN/ACCUM: _____
2 ACTUATION SYSTEM DESIGN <u>RATED CONDITIONS</u> - DESIGN LOAD: <u>1060 lb-in</u> - STALL LOAD: <u>1575 lb-in</u> - DESIGN RATE: <u>60 deg/sec</u> - NO LOAD RATE: <u>120-148 deg/sec</u> <u>DUTY CYCLE</u> - DURATION: <u>150 sec</u> - DESCRIPTION: _____ <u>DYNAMIC PERFORMANCE</u> - BANDWIDTH: <u>8 Hz based on -3 dB</u> - STEP RESPONSE: <u>50% rated current in 3 msec</u> <u>STATIC PERFORMANCE</u> - RESOLUTION: _____ - THRESHOLD: <u>0.06ma</u> - HYSTERESIS: _____ - CLOSED LOOP STIFFNESS: _____ STROKE: <u>32 deg</u> WEIGHT: <u>27 lbs</u> <u>FEEDBACK</u> - TYPE: <u>Position</u> - METHOD: <u>Film potentiometer</u> <u>ELECTRONIC CONTROLLER</u> - TYPE: <u>DC</u> - SIGNAL LEVEL: <u>12 ma</u> LOOP ELECTRONICS: <u>Analog</u>	5 PNEUMATIC/WARM GAS <u>SYSTEM</u> - STORED GAS • TYPE GAS: _____ • SUPPLY PRESS: _____ • PROOF PRESS: _____ • BURST PRESS: _____ • VESSEL TYPE: _____ • VESSEL VOL: _____ • SEALS: _____ - GAS GENERATOR • PROPELLANT: _____ • FLOWRATE: _____ • REG. VALVE: _____ • TEMP @ ACT: _____ • PRESS @ ACT: _____ <u>CONTROL VALVE</u> - OPERATION: _____ - CONFIGURATION: _____ <u>ACTUATOR</u> - LINEAR: _____ - ROTARY: _____ - ROTARY/LINEAR: _____
3 ELECTROMECHANICAL - MOTOR • OC: _____ • AC: _____ • STEPPER: _____ - ACTUATOR • LINEAR: _____ • ROTARY: _____	6 STORED GAS VESSEL SHIPMENT - TYPE GAS: _____ - GAS PRESSURE: _____ - BURST FACTOR: _____ - DOT APPROVAL: _____ 7 SELECTION CRITERIA AND/OR SPECIAL FEATURES

MISSILE/SPACE VEHICLE ACTUATION SYSTEM DATA SHEET

1 GENERAL DESCRIPTION <u>VEHICLE</u> - NAME: <u>SIAM</u> - TYPE: <u>Surface-to-air</u> - CONTROL: <u>Aerodynamic fir (4 actuators)</u> - COMPANY: <u>Ford Aerospace</u> - PROGRAM: <u>Development, 1979-1980</u> <u>ACTUATION SYSTEM</u> - COMPANY: <u>Ford Aerospace</u> - TYPE PROGRAM: <u>Development, 1979-1980</u> - TYPE DESIGN: <u>Pneumatic</u> - AXES: <u>Pitch, yaw, roll</u> - COMPENSATION: <u>Electronic</u> - REDUNDANCY: <u>No</u> - TEMP. RANGE: <u>Ambient</u> <u>LOAD</u> - TRAVEL: <u>+20 deg.</u> - TYPE: <u>Aero, inertia, friction</u> - INERTIA: _____ - f_n: <u>281 Hz</u> - Other: <u>Coulomb friction: 15 lb-in</u>	4 HYDRAULIC <u>SYSTEM</u> - TYPE: _____ - PRESSURE: _____ - FLOW: _____ - FLUID: _____ - SEALS: _____ - FILTER: _____ <u>SERVO VALVE</u> - OPERATION: _____ - CONFIGURATION: _____ <u>ACTUATOR</u> - LINEAR: _____ - ROTARY: _____ <u>POWER SUPPLY</u> - PUMP • TYPE: _____ • POWER SOURCE: _____ - ENERGY SOURCE • BATTERY: _____ • OTHER: _____ - STORED GAS: _____ - GAS GEN/ACCUM: _____
2 ACTUATION SYSTEM DESIGN <u>RATED CONDITIONS</u> - DESIGN LOAD: _____ - STALL LOAD: <u>150 lb-in</u> - DESIGN RATE: _____ - NO LOAD RATE: <u>2000 deg/sec</u> <u>DUTY CYCLE</u> - DURATION: <u>25 sec</u> - DESCRIPTION: <u>100% perf. for full duration</u> <u>DYNAMIC PERFORMANCE</u> - BANDWIDTH: <u>30 Hz based on $\phi = 90^\circ$</u> - STEP RESPONSE: _____ <u>STATIC PERFORMANCE</u> - RESOLUTION: <u>0.25 deg</u> - THRESHOLD: _____ - HYSTERESIS: <u><0.5 deg</u> - CLOSED LOOP STIFFNESS: _____ STROKE: <u>+20 deg</u> <u>WEIGHT:</u> _____ <u>FEEDBACK</u> - TYPE: _____ - METHOD: _____ <u>ELECTRONIC CONTROLLER</u> - TYPE: <u>PWM @ 100 Hz</u> - SIGNAL LEVEL: <u>28V</u> <u>LOOP ELECTRONICS:</u> <u>Digital</u>	5 PNEUMATIC/WARM GAS <u>SYSTEM</u> - STORED GAS • TYPE GAS: _____ • SUPPLY PRESS: _____ • PROOF PRESS: _____ • BURST PRESS: _____ • VESSEL TYPE: _____ • VESSEL VOL: _____ • SEALS: _____ - GAS GENERATOR • PROPELLANT: <u>Ammonium Nitrate</u> • FLDWRATE: <u>0.02 lbs/sec</u> • REG. VALVE: <u>No</u> • TEMP @ ACT: <u>1500°F</u> • PRESS @ ACT: <u>2000 psi</u> <u>CONTROL VALVE</u> - OPERATION: <u>3-way solenoid</u> - CONFIGURATION: <u>Open center</u> <u>ACTUATOR</u> - LINEAR: _____ - ROTARY: _____ - ROTARY/LINEAR: <u>2:1 unbalanced piston; push-push rotary output</u>
3 ELECTROMECHANICAL - MOTOR • DC: _____ • AC: _____ • STEPPER: _____ - ACTUATOR • LINEAR: _____ • ROTARY: _____	6 STORED GAS VESSEL SHIPMENT - TYPE GAS: _____ - GAS PRESSURE: _____ - BURST FACTOR: _____ - DOT APPROVAL: _____ 7 SELECTION CRITERIA AND/OR SPECIAL FEATURES Size and weight advantages

MISSILE/SPACE VEHICLE ACTUATION SYSTEM DATA SHEET

1 GENERAL DESCRIPTION <u>VEHICLE</u> - NAME: Sidewinder - TYPE: Air-to-air - CONTROL: Aerodynamic canard (2 actuators) - COMPANY: Ford Aerospace - PROGRAM: Production, 1965 - <u>ACTUATION SYSTEM</u> - COMPANY: NWC - China Lake & Ford Aerospace - TYPE PROGRAM: Production, 1965 - - TYPE DESIGN: Pneumatic - AXES: Pitch, yaw - COMPENSATION: Electronic - REDUNDANCY: No - TEMP. RANGE: -65° to +160°F <u>LOAD</u> - TRAVEL: +20 deg - TYPE: Aero and inertia - INERTIA: - f_n: 78 Hz - Other: Aero: 1000 lb-in	4 HYDRAULIC <u>SYSTEM</u> - TYPE: - PRESSURE: - FLOW: - FLUID: - SEALS: - FILTER: <u>SERVO VALVE</u> - OPERATION: - CONFIGURATION: <u>ACTUATOR</u> - LINEAR: - ROTARY: <u>POWER SUPPLY</u> - PUMP • TYPE: • POWER SOURCE: - ENERGY SOURCE • BATTERY: • OTHER: - STORED GAS: - GAS GEN/ACCUM:
2 ACTUATION SYSTEM DESIGN <u>RATED CONDITIONS</u> - DESIGN LOAD: - STALL LOAD: 1400 lb-in - DESIGN RATE: - NO LOAD RATE: 88 deg/sec <u>DUTY CYCLE</u> - DURATION: 60 sec - DESCRIPTION: 100% perf. over full duty cycle <u>DYNAMIC PERFORMANCE</u> - BANDWIDTH: 4 Hz based on -3 db - STEP RESPONSE: Typically 7 deg in 165 msec. <u>STATIC PERFORMANCE</u> - RESOLUTION: - THRESHOLD: - HYSTERESIS: - CLOSED LOOP STIFFNESS: <u>STROKE:</u> <u>WEIGHT:</u> 13.7 lbs <u>FEEDBACK</u> - TYPE: None - METHOD: <u>ELECTRONIC CONTROLLER</u> - TYPE: DC - SIGNAL LEVEL: 400 ma. max <u>LOOP ELECTRONICS:</u> Analog	5 PNEUMATIC/WARM GAS <u>SYSTEM</u> <u>STORED GAS</u> • TYPE GAS: • SUPPLY PRESS: • PROOF PRESS: • BURST PRESS: • VESSEL TYPE: • VESSEL VOL: • SEALS: - GAS GENERATOR • PROPELLANT: Ammonium Nitrate • FLOWRATE: 0.02 lb/sec • REG. VALVE: No • TEMP @ ACT: 1000°F • PRESS @ ACT: 1000 psi ave. <u>CONTROL VALVE</u> - OPERATION: 2-way solenoid - CONFIGURATION: Open center <u>ACTUATOR</u> - LINEAR: - ROTARY: Push-push balanced piston - ROTARY/LINEAR:
3 ELECTROMECHANICAL - MOTOR • DC: • AC: • STEPPER: - ACTUATOR • LINEAR: • ROTARY:	6 STORED GAS VESSEL SHIPMENT - TYPE GAS: - GAS PRESSURE: - BURST FACTOR: - DOT APPROVAL:
7 SELECTION CRITERIA AND/OR SPECIAL FEATURES	

MISSILE/SPACE VEHICLE ACTUATION SYSTEM DATA SHEET

1 GENERAL DESCRIPTION <u>VEHICLE</u> - NAME: <u>Sparrow</u> - TYPE: <u>Air-to-air & surface-to-air</u> - CONTROL: <u>Aerodynamic canard (2 actuators)</u> - COMPANY: <u>Raytheon</u> - PROGRAM: <u>Production, 1955 -</u> <u>ACTUATION SYSTEM</u> - COMPANY: <u>Raytheon</u> - TYPE PROGRAM: <u>Production, 1955 -</u> - TYPE DESIGN: <u>Hydraulic</u> - AXES: <u>Pitch, yaw, roll</u> - COMPENSATION: <u>No</u> - REDUNDANCY: <u>No</u> - TEMP. RANGE: <u>-35 to +165°F</u> <u>LOAD</u> - TRAVEL: <u>+22.5 deg</u> - TYPE: <u>Inertia & coulomb friction</u> - INERTIA: <u>0.2 lb-in-sec²</u> - f_n: <u></u> - Other: <u>Coulomb friction: 140 lb-in</u>	4 HYDRAULIC <u>SYSTEM</u> - TYPE: <u>Blowdown</u> - PRESSURE: <u>3250 psi</u> - FLOW: <u>1.6 gpm</u> - FLUID: <u>MIL-H-5606E</u> - SEALS: <u>Polyurethane</u> - FILTER: <u>None</u> <u>SERVO VALVE</u> - OPERATION: <u>4-way flow control</u> - CONFIGURATION: <u>7-stage</u> <u>ACTUATOR</u> - LINEAR: <u>0.52 in² balanced</u> - ROTARY: <u></u> <u>POWER SUPPLY</u> - PUMP • TYPE: <u></u> • POWER SOURCE: <u></u> - ENERGY SOURCE • BATTERY: <u></u> • OTHER: <u></u> - STORED GAS: <u>He accumulator</u> - GAS GEN/ACCUM: <u></u>
2 ACTUATION SYSTEM DESIGN <u>RATED CONDITIONS</u> - DESIGN LOAD: <u>1800 lb-in</u> - STALL LOAD: <u>2400 lb-in</u> - DESIGN RATE: <u>350 deg/sec</u> - NO LOAD RATE: <u>500 deg/sec</u> <u>DUTY CYCLE</u> - DURATION: <u>60 sec</u> - DESCRIPTION: <u>4000 deg total travel</u> <u>DYNAMIC PERFORMANCE</u> - BANDWIDTH: <u>40 Hz based on $\phi = 90^\circ$</u> - STEP RESPONSE: <u></u> <u>STATIC PERFORMANCE</u> - RESOLUTION: <u>0.01 deg</u> - THRESHOLD: <u>$\geq 0.02^\circ$ deg</u> - HYSTERESIS: <u>≤ 0.50 deg</u> - CLOSED LOOP STIFFNESS: <u>$> 40,000$ psi/deg</u> <u>STROKE</u>: <u>+22.5 deg</u> <u>WEIGHT</u>: <u>52 lbs</u> <u>FEEDBACK</u> - TYPE: <u>Position</u> - METHOD: <u>Film type potentiometer</u> <u>ELECTRONIC CONTROLLER</u> - TYPE: <u>DC</u> - SIGNAL LEVEL: <u>+30 ma</u> <u>LOOP ELECTRONICS</u>: <u>Analog</u>	5 PNEUMATIC/WARM GAS <u>SYSTEM</u> - STORED GAS • TYPE GAS: <u></u> • SUPPLY PRESS: <u></u> • PROOF PRESS: <u></u> • BURST PRESS: <u></u> • VESSEL TYPE: <u></u> • VESSEL VOL: <u></u> • SEALS: <u></u> - GAS GENERATOR • PROPELLANT: <u></u> • FLOWRATE: <u></u> • REG. VALVE: <u></u> • TEMP @ ACT: <u></u> • PRESS @ ACT: <u></u> <u>CONTROL VALVE</u> - OPERATION: <u></u> - CONFIGURATION: <u></u> <u>ACTUATOR</u> - LINEAR: <u></u> - ROTARY: <u></u> - ROTARY/LINEAR: <u></u>
3 ELECTROMECHANICAL - MOTOR • DC: <u></u> • AC: <u></u> • STEPPER: <u></u> - ACTUATOR • LINEAR: <u></u> • ROTARY: <u></u>	6 STORED GAS VESSEL SHIPMENT - TYPE GAS: <u></u> - GAS PRESSURE: <u></u> - BURST FACTOR: <u></u> - OOT APPROVAL: <u></u> 7 SELECTION CRITERIA AND/OR SPECIAL FEATURES - High torque with good dynamic performance - Bladder type accumulator

MISSILE/SPACE VEHICLE ACTUATION SYSTEM DATA SHEET

1 GENERAL DESCRIPTION <u>VEHICLE</u> - NAME: <u>Spartan</u> - TYPE: <u>Surface-to-air</u> - CONTROL: <u>Aero canard & gimbaled nozzle (4 actuators)</u> - COMPANY: <u>McDonnell Douglas/Huntington Beach</u> - PROGRAM: <u>Production, 1971-1975</u> <u>ACTUATION SYSTEM</u> - COMPANY: <u>McDonnell Douglas/Huntington Beach</u> - TYPE PROGRAM: <u>Production, 1971-1975</u> - TYPE DESIGN: <u>Hydraulic</u> - AXES: <u>Pitch, yaw, roll</u> - COMPENSATION: <u>Electronic</u> - REDUNDANCY: <u>No</u> - TEMP. RANGE: <u>+ 60 to + 450°F</u> <u>LOAD</u> (Hydraulic Fluid) - TRAVEL: <u>+40 deg</u> - TYPE: <u>Aero and inertia</u> - INERTIA: <u>12.7 lb-in-sec²</u> - f_n: <u>60 Hz</u> - Other: <u>Aero - 42,000 lb-in</u>	4 HYDRAULIC <u>SYSTEM</u> - TYPE: <u>Recirculation</u> - PRESSURE: <u>3600 psi</u> - FLOW: <u>23.5 gpm</u> - FLUID: <u>OS-45-IV</u> - SEALS: <u>Nitrile</u> - FILTER: <u>80 microns absolute</u> <u>SERVO VALVE</u> - OPERATION: <u>4-way flow control</u> - CONFIGURATION: <u>2-stage spool</u> <u>ACTUATOR</u> - LINEAR: <u>4.6 in² balanced area</u> - ROTARY: _____ <u>POWER SUPPLY</u> - PUMP • TYPE: <u>Fixed piston</u> • POWER SOURCE: <u>Turbine</u> - ENERGY SOURCE • BATTERY: _____ • OTHER: <u>Gas generator</u> - STORED GAS: _____ - GAS GEN/ACCUM: _____
2 ACTUATION SYSTEM DESIGN <u>RATED CONDITIONS</u> - DESIGN LOAD: <u>35,000 lb-in</u> - STALL LOAD: <u>55,000 lb-in</u> - DESIGN RATE: <u>200 deg/sec</u> - NO LOAD RATE: <u>450 deg/sec</u> <u>DUTY CYCLE</u> - DURATION: <u>120 sec</u> - DESCRIPTION: _____ <u>DYNAMIC PERFORMANCE</u> - BANDWIDTH: <u>29 Hz based on $\phi = 90^\circ$</u> - STEP RESPONSE: _____ <u>STATIC PERFORMANCE</u> - RESOLUTION: <u>0.095 deg/ma</u> - THRESHOLD: <u>5.8 μa</u> - HYSTERESIS: _____ - CLOSED LOOP STIFFNESS: <u>0.16 x 10⁶ lb-in/deg</u> STROKE: <u>+2 in</u> WEIGHT: <u>460 lbs</u> <u>FEEDBACK</u> - TYPE: <u>Position</u> - METHOD: <u>LVDT</u> <u>ELECTRONIC CONTROLLER</u> - TYPE: <u>DC</u> - SIGNAL LEVEL: <u>200 ma</u> <u>LODP ELECTRONICS</u>: <u>Analog</u>	5 PNEUMATIC/WARM GAS <u>SYSTEM</u> - STORED GAS • TYPE GAS: _____ • SUPPLY PRESS: _____ • PROOF PRESS: _____ • BURST PRESS: _____ • VESSEL TYPE: _____ • VESSEL VOL: _____ • SEALS: _____ - GAS GENERATOR • PROPELLANT: _____ • FLOWRATE: _____ • REG. VALVE: _____ • TEMP @ ACT: _____ • PRESS @ ACT: _____ <u>CONTROL VALVE</u> - OPERATION: _____ - CONFIGURATION: _____ <u>ACTUATOR</u> - LINEAR: _____ - ROTARY: _____ - ROTARY/LINEAR: _____
3 ELECTROMECHANICAL - MOTOR • DC: _____ • AC: _____ • STEPPER: _____ - ACTUATOR • LINEAR: _____ • ROTARY: _____	6 STORED GAS VESSEL SHIPMENT - TYPE GAS: <u>N₂</u> - GAS PRESSURE: <u>6000 psi</u> - BURST FACTOR: <u>4</u> - DOT APPROVAL: <u>DOT SP7033</u> 7 SELECTION CRITERIA AND/OR SPECIAL FEATURES - Nozzles are integral with canards - Insensitive to servo valve contamination

MISSILE/SPACE VEHICLE ACTUATION SYSTEM DATA SHEET

1 GENERAL DESCRIPTION <u>VEHICLE</u> - NAME: <u>Sprint, 1 st stage</u> - TYPE: <u>Surface-to-air ABM</u> - CONTROL: <u>TVC - Freon Secondary Injection</u> - COMPANY: <u>Martin/Orlando</u> - PROGRAM: <u>Production, 1972 -</u> <u>ACTUATION SYSTEM</u> - COMPANY: <u>Martin/Orlando</u> - TYPE PROGRAM: <u>Production, 1972 -</u> - TYPE DESIGN: <u>Hydraulic</u> - AXES: <u>Pitch, yaw</u> - COMPENSATION: <u>Electronic</u> - REDUNDANCY: <u>None</u> - TEMP. RANGE: <u>+40 to +275°F</u> <u>LOAD</u> - TRAVEL: <u>0.46 in.</u> - TYPE: <u>Freon injection valves</u> - INERTIA: _____ - f_n: _____ - Dther: _____	4 HYDRAULIC <u>SYSTEM</u> - TYPE: <u>Blowdown</u> - PRESSURE: <u>1000 psi</u> - FLOW: <u>20 gpm</u> - FLUID: <u>MIL-H-5606</u> - SEALS: <u>Elastomeric</u> - FILTER: <u>40 micron</u> <u>SERVD VALVE</u> - OPERATION: <u>4-way flow control</u> - CDFIGURATION: <u>2-stage dual nozzle flapper</u> <u>ACTUATOR</u> - LINEAR: <u>1.27 in² balanced area</u> - ROTARY: _____ <u>POWER SUPPLY</u> - PUMP • TYPE: _____ • POWER SOURCE: _____ - ENERGY SOURCE • BATTERY: _____ • Dther: _____ - STORED GAS: _____ - GAS GEN/ACCUM: <u>Ammonium nitrate regulated to 1000 psi</u>
2 ACTUATION SYSTEM DESIGN <u>RATED CONDITIONS</u> - DESIGN LOAD: _____ - STALL LOAD: _____ - DESIGN RATE: _____ - NO LOAD RATE: _____ <u>DUTY CYCLE</u> - DURATION: <u>2 sec</u> - DESCRIPTION: <u>100% for 0.4 sec; 10% for 1.6 sec</u> <u>DYNAMIC PERFORMANCE</u> - BANDWIDTH: <u>30 Hz</u> - STEP RESPONSE: <u>.02 sec</u> <u>STATIC PERFORMANCE</u> - RESOLUTION: _____ - THRESHOLD: _____ - HYSTERESIS: _____ - CLOSED LOOP STIFFNESS: _____ <u>STROKE</u>: <u>0.46 in.</u> <u>WEIGHT</u>: <u>≈137 lbs (integrated hyd. & freon systems)</u> <u>FEEDBACK</u> - TYPE: <u>Position</u> - METHOD: <u>LVDT</u> <u>ELECTRONIC CONTROLLER</u> - TYPE: <u>DC</u> - SIGNAL LEVEL: <u>80 ma</u> <u>LOOP ELECTRONICS</u>: <u>Analog</u>	5 PNEUMATIC/WARM GAS <u>SYSTEM</u> <u>STORED GAS</u> • TYPE GAS: _____ • SUPPLY PRESS: _____ • PROOF PRESS: _____ • BURST PRESS: _____ • VESSEL TYPE: _____ • VESSEL VOL: _____ • SEALS: _____ - GAS GENERATOR • PROPELLANT: <u>Ammonium nitrate/epoxy</u> • FLOWRATE: <u>6.56 lb/sec @ 1050 psi</u> • REG. VALVE: <u>Yes</u> • TEMP @ ACT: <u>2160°F at turbine</u> • PRESS @ ACT: _____ <u>CONTROL VALVE</u> - OPERATION: _____ - CONFIGURATION: _____ <u>ACTUATOR</u> - LINEAR: _____ - ROTARY: _____ - ROTARY/LINEAR: _____
3 ELECTROMECHANICAL - MOTOR • DC: _____ • AC: _____ • STEPPER: _____ - ACTUATOR • LINEAR: _____ • ROTARY: _____	6 STORED GAS VESSEL SHIPMENT - TYPE GAS: _____ - GAS PRESSURE: _____ - BURST FACTOR: _____ - DOT APPROVAL: _____ 7 SELECTION CRITERIA AND/OR SPECIAL FEATURES Control is provided by metering Freon through injection valves which are positioned hydraulically.