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REPUBLIC DIVISION

FRD 4087

TASK 3 -- MODEL SPECIFICATIONS REPORT

Pulsed Plasma Solid Propellant Microthruster
for the
Synchronous Meteorological Satellite

FAIRCHILD

Fairchild Republic Division Farmingdale, New York 11735

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Pulsed Plasma Solid Propellant Microthruster for the Synchronous Meteorological Satellite

June 1972

Prepared for

GODDARD SPACE FLIGHT CENTER
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16. Abstract

This report presents model specifications of the pulsed plasma solid propellant microthruster for the Synchronous Meteorological Satellite. The specifications include applicable documents, requirements and quality assurance provisions. The specifications include results of earlier tasks of analysis and preliminary design.

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PREFACE

This report presents the Model Specifications of the pulsed plasma solid propellant microthruster for the Synchronous Meteorological Satellite. The specifications presented herein include results of earlier tasks of the program which were concerned with the analysis and preliminary design of the system.

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This model specification defines requirements for the design, product configuration, manufacture, operating parameters, performance and tests of a flight prototype model pulsed plasma microthruster system for the Synchronous Meteorological Satellite (SMS).

2.0 APPLICABLE DOCUMENTS

2.1 NASA

a. Requirements for Soldered Electrical Connections, NHB 5300.4(3A), May 1968

b. Inspection System Provisions for Suppliers of Space Materials, Parts, Components, and Services; NPC 200-3, April 1962

c. Printed Wiring Boards, S-300-P-1A October 1966

d. General Environmental Test Specification for Spacecraft and Components, GSFC S-320-G-1, October 1969

e. Connectors, Subminiature, Electrical and Coaxial Contact, For Space Flight Use; GSFC S-323-P-10, March 1967

f. GSFC Preferred Parts List, GSFC PPL-11, July 1970

g. Contractor Malfunction Reporting, GSFC S-312-P-1, March 1970

2.2 Fairchild Industries, Fairchild Republic Division

PC145S-8000	Product Specification for SMS Power Conditioner
PC145S-8000	Amendment 1
PC145S-8001	Product Specification for Energy Storage Capacitor ESXP 405J20003
PC145S-8002 Rev. A	Screening Specification for Aerovox B161Y203-302K Capacitor
PC145S-8003 Rev. A	Screening Specification for Sprague 118P105910S2 Capacitor
PC145S8004 Rev. A	Screening Specification for High Reliability Silicon Controlled Rectifier GE C137PB1200
PC145S8005	Product Specification for Negator Spring SH8G28
PC145S8006	Screening Specification for UT2080 Diode
PC145S8007	Product Specification for Pulse Transformer
PC145S8008	Product Specification for High Reliability Igniter Plug 10-380729-1 Change A-4
PC145S8009 Rev. A	Material and Process Specification Inorganic Dry Film Lubricant Electrofilm 2306 for Negator Spring

PC145S8010	Screening Specification for RTH06BS472J Thermistor
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2.3 Drawings, Fairchild Industries, Fairchild Republic Division

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PC145D1090	Capacitor SCD
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3.0 REQUIREMENTS

3.1 General Requirements

The pulsed plasma microthruster system shall consist of a solid Teflon propellant impulse-type thruster module with integral propellant storage and feed components and a control logic and power conditioning subsystem. All of these subsystems shall be integrated into one common assembly known as the microthruster system.

3.2 Design Function

The pulsed plasma microthruster system shall provide discrete impulse bits under conditions prescribed herein.

3.3 Design Performance Requirements

3.3.1 Propulsive Performance

3.3.1.1 Impulse Bit Amplitude -- The average impulse bit amplitude over the life of the thruster shall be 25 ± 5 micro lb-sec (25 ± 5 x 10^{-6} lb-sec).

3.3.1.2 Total Impulse Capability -- Sufficient propellant shall be incorporated to provide a minimum total impulse capability of 400 ± 20 lb-sec.

3.3.1.3 Pulse Frequency Capability -- The system shall be capable of continuous operation when commanded to fire at rates between fifty (50) and one hundred ten (110) pulses per minute.

3.3.2 System Weight

The propulsion system shall be capable of operating within specifications from a power source having an output voltage of 29.4 ± 0.2 volts DC. The output impedance of this source shall be 0.5 ohms maximum 0.2 ohm typical from DC to 50 Khz.

3.3.3.1 Power Requirements -- System power shall be less than 23 watts time average and less than 29.4 watts instantaneous peak during operation at the maximum pulse rate of 110 ppm. Time average system power for pulse rates less than 110 ppm shall be less than that required at the maximum pulse rate of 110 ppm in accordance with the following schedule:

Pulse Frequency	Time Average Power
110 ppm	23 watts
90 ppm	19.5 watts
70 ppm	16.0 watts
50 ppm	12.5 watts

3.3.3.2 Solar Buss Current Requirements -- Solar buss current shall be less than 0.78 amps time average and less than 1.0 amps instantaneous peak during operation at the maximum pulse rate of 110 ppm. Average buss current for pulse rates less than 110 ppm shall be less than that required at the maximum pulse rate of 110 ppm in accordance with the following schedule:

Pulse Frequency	Time Average Current
110 ppm	0.78 amps
90 ppm	0.66 amps
70 ppm	0.54 amps
50 ppm	0.42 amps

3.3.4 Environmental Operational Capability

3.3.4.1 Pressure Environment -- The microthruster system shall be capable of operating as specified when the pressure is less than 2 x 10^{-4} Torr.

3.3.4.2 Acceleration Environment -- The microthruster system shall be capable of operating as specified under a sustained acceleration of up to 13 g's applied in the direction of the plasma exhaust for a period of five years. Proper operation shall be possible at loads equivalent to 20 g's.

3.3.4.3 Thermal Vacuum Environment

3.3.4.3.1 Spacecraft Sink Temperature -- The thruster shall be required to operate as specified when exposed to vacuum conditions with the temperature of the mounting platform and all of the surfaces surrounding the microthruster system (except those portions of the system which are exposed to space) in the range from -17.8°C to 48.9°C (i.e., 0°F to 120°F) as a steady-state temperature or cycling between these two temperature extremes over a period equal to or greater than 6.2 hours.

3.3.4.3.2 Hot-Cold Start Capability -- The thruster shall be capable of cold starting from -17.8°C or hot starting from 48.9°C or any temperature between these limits.

3.3.4.4 Vibration

3.3.4.4.1 General -- The microthruster shall be capable of performing as specified after having been subjected to sinusoidal and random vibration schedules. The microthruster system shall be attached to the vibration generator by means of a rigid fixture. Vibration shall be applied in each of three orthogonal directions (X-X, Y-Y, Z-Z) one direction (Z-Z) being parallel to the spacecraft thrust axis. The microthruster shall not be operational during the vibration schedules.

3.3.4.4.2 Sinusoidal Swept Frequency Schedule -- This portion of the test shall be conducted by sweeping the applied frequency once through each range specified in the schedule presented as Table 1. The rate of change of frequency shall be two octaves per minute.

The launch vehicle (L/V) thrust direction axis (Z-Z) is perpendicular to the mounting plane with one lateral axis in the direction of the microthruster thrust axis and the other lateral axis perpendicular to it.

3.3.4.4.3 Random Vibration Schedule -- Gaussian random motion vibration shall be applied with the g-peaks clipped at three times the rms acceleration specified in the schedule presented in Table 2. The three axis in Table 2 are defined in Para. 3.3.4.4.1.

TABLE 1. SINUSOIDAL VIBRATION SCHEDULE

	Frequency (Hz)	Level (g, 0 to peak)
Lateral	5 - 10	0.5" DA (double amplitude)
(L/V)	10 - 20	14.0
(X-X, Y-Y)	20 - 100	4.0
Axis	100 - 200	2.0
	200 - 2000	5.0
Thrust	5 - 11	0.5" DA (double amplitude)
(L/V)	11 - 17	3.0
(Z-Z)	17 - 23	7.0
Axis	23 - 30	12.5
	30 - 60	25.0
	60 - 100	8.0
	100 - 200	3.0
	200 - 2000	5.0

NOTE: Sweep rate is 2 octaves/minute for all spectra.

TABLE 2. RANDOM MOTION VIBRATION

Frequency (Hz)	Acceleration (g-rms)	Test Duration (minutes per axis)	PSD Level (g^2/Hz)
20 - 150	9.2	4	0.0225
150 - 300	9.2	4	Increasing from 150 Hz at constant rate of +3 db per octave
300 - 2000	9.2	4	0.045

3.3.5 Input Transients

The system shall perform within specifications when as much as one volt peak noise bursts of 15 to 100 microseconds in duration are fed into the 29.4 volt input power supply bus.

3.3.6 Commands

3.3.6.1 General -- The pulsed plasma microthruster systems shall require only one command to generate an impulse bit. This is the "fire" command. Application of power and enabling the thruster are spacecraft functions and not considered commands. A 29.4 ± 0.2 VDC solar array bus voltage will be continuously applied to the microthruster propulsion system. A separate 28 ± 2 volt enable signal from a 200 Ω source will be applied to energize the system. The system shall be "on" when the enable signal is 28 ± 2 volts DC and shall be "off" when the signal is 0 ± 1.2 volts DC from a 5000 ohm source impedance. Current drain from this source shall be 0.5 ma maximum. The system shall be capable of continuous operation when commanded to fire at rates between fifty (50) pulses per minute and one hundred ten (110) pulses per minute.

3.3.6.2 Fire Command -- The system shall be capable of accepting a firing command pulse as specified in Para. 3.6.8.2 to discharge the thruster at rated impulse bit amplitude within one second after application of the 28 ± 2 volt system enable signal whenever the 29.4 ± 0.2 VDC solar array buss voltage is applied. The thruster impulse bit shall be generated using the leading edge of the fire command signal as the time reference. The impulse bit follows the leading edge of the fire command signal by about 6 millisec.

3.4 Configuration

3.4.1 Envelope

The microthruster system envelope, mounting pad locations and electrical connector locations shall conform to Figure 1.

3.4.2 Operating Position

The system shall be designed to perform within specifications when mounted, such that the continuous thirteen "g" load is in a direction which is parallel with the plasma exhaust.

3.4.3 Mechanical Interface

The microthruster propulsion system shall be designed to allow it to be rigidly mounted in its operational position on a mounting platform which shall be one continous flat surface having three (3) mounting holes as per Figure 1.

3.5 Electrical Interface

3.5.1 Electrical Connectors

Only one electrical connector denoted as J-1 on the microthruster shall be required to completely electrically interface the pulsed plasma microthruster system to the SMS spacecraft. This connector is located on the propulsion system as per Figure 1. This connector shall mate with a DAM-15S-NMC connector provided by the spacecraft. Another electrical connector denoted as J-2 shall be provided on the propulsion system to serve as a hardwire monitor to supply information during ground tests. The location of this hardwire recorder on the thruster is also defined in Figure 1. This connector shall mate with a DEM-9P-NMC-2 connector provided by the spacecraft. No high voltages shall appear at any of the pins of either of the J-1 or the J-2 connectors.

3.5.2 Electrical Inputs

Only four electrical inputs shall be required to operate the pulsed plasma microthruster system on the SMS spacecraft. The inputs are:

a) +29.4 volt spacecraft power
b) +28 volt enable signal
c) Fire command signal as specified by Para. 3.6.8.2
d) 29.4 volt ground return (common ground return)

The four telemetry leads are considered outputs.

3.5.3 Telemetry Outputs

Four (4) telemetry output signals shall be provided as part of the J-1 electrical connector defined in Para. 3.5.1. The four telemetry signals shall be:

a) Enable voltage. The telemetry channel shall be capable of monitoring zero to positive thirty-two volts.

b) Main thruster capacitor voltage. The telemetry channel shall be capable of monitoring from zero to approximately 1.2 nominal rating of the main thruster capacitor voltage.

c) Discharge initiating capacitor voltage. The telemetry channel shall be capable of monitoring zero to approximately 1.2 nominal rating of the discharge initiating capacitor voltage.

d) Capacitor case temperature. The telemetry channel shall be capable of monitoring the temperature range from -5°F to +150°F.

Each telemetry signal level shall be between zero and plus five volts. The minimum allowable voltage shall be minus 0.7 volts and the maximum allowable voltage shall be plus 5.5 volts. The maximum output impedance of any telemetry channel shall be 1.0K ohms.

3.5.4 Ground

3.5.4.1 General -- The thruster electric circuit ground (power, enable and fire command signal) and the external housing ground shall be maintained separately by isolating the thruster electric circuit from the thruster housing.

3.5.4.2 Housing Ground -- The external housing of the propulsion system shall be at spacecraft ground potential which shall be the same as the 29.4 volt ground return.

3.5.4.3 Electric Circuit Ground -- The thruster electric circuit (power, enable and fire command signal) ground which floats relative to the housing shall be maintained as a single common ground and provided as one of the electric input terminal connections to the J-1 spacecraft interface connector in accordance with Para. 3.5.2d. This single ground shall be a negative ground.

3.6 Design and Construction

3.6.1 General

a. The design shall use materials and components consistent with a five year life in a geosynchronous orbit.

b. Standard electronic parts shall be specified in the GSFC Preferred Parts List PPL-11 July 1970, or shall be procured and screened in accordance with Fairchild Industries, Fairchild

Republic Division documents as specified in Para. 2.2 herein.

c. The thruster shall be designed to minimize the hazard of electrical shock, fire and explosion in the spacecraft and during ground tests. The only accessible source of potential high voltage shall be confined within the exhaust nozzle and then only when the 29.4 volt and 28 volt enable signal are applied simultaneously in accordance with Para. 3.3.6.1.

d. The system shall be designed to conserve power with maximum efficiency. The parts and material selected shall be used within their electrical ratings and environmental capability. Derating shall be accomplished as necessary to assure required equipment reliability within specified operating conditions.

3.6.2 Prelaunch Environmental Conditions

The microthruster system shall be designed such that it will not suffer detrimental effects to exposure to the following prelaunch environmental conditions:

a. Temperature 75°F ± 5°F

b. Relative humidity 50% maximum

c. Duration 3 weeks

Design verification by actual test over the duration indicated is not required.

3.6.3 Storage Temperature Conditions

The microthruster system shall be designed such that it will not suffer any detrimental effects from exposure to temperatures in the range of 0°F to 130°F for a storage duration of up to 3 years. Design verification by actual test over the duration indicated is not required.

3.6.4 Attitude

The microthruster system shall be designed to be capable of operating in any attitude at 1g or 0g and shall be capable of operating after storage in any attitude at 1g for three years. Design verification by actual test is not required.

3.6.5 Electrical Wiring

Electrical wiring shall conform to NASA GSFC Preferred Parts List PPL-11 July 1970.

3.6.6 Venting

The design shall be such that venting of the interior of the pulsed plasma microthruster shall be through the exhaust nozzle of the microthruster.

3.6.7 Telemetry

3.6.7.1 Limiting Circuitry -- Each telemetry channel shall contain limiting circuitry so that the output signal can go no more than 0.7 volts negative and 5.5 volts positive. The output impedance shall be one thousand ohms or less. The cutoff (3 db down) frequency for the voltage measurement shall be about 150 Hz.

3.6.7.2 Isolation -- Sufficient isolation shall be provided in the telemetry circuit such that shorting an output to ground or to any other telemetry output shall not damage the telemetry circuitry or affect in any manner the microthruster operation.

3.6.8 Commands

3.6.8.1 General -- The input impedance on the FIRE command line shall be 10K ohms minimum. The input command signal shall be as specified in Para. 1.2.7.2. The thruster shall be capable of continuously receiving fire commands while the power source is turned off. Upon application of power the thruster shall begin normal operation. Turning the power source on and off in this manner shall be considered a normal operating mode.

3.6.8.2 Fire Command Pulse Specification -- The specifications of the fire command pulse supplied to the input of the pulsed plasma microthruster system are:

a. Logic zero (ground level): 0.0 ± 0.5V
b. Logic one (command level): +5.0 ± 0.5V
c. Duration: 50 ± 5 milliseconds
d. Rise and fall times: greater than 2 microseconds and less than 10 microseconds

This fire command pulse shall be provided at a frequency whose rate can vary between fifty (50) pulses per minute and one hundred ten (110) pulses per minute. Thruster firing shall be with respect to the leading edge of the fire command pulse. The thruster shall reject apparent commands of substantially shorter duration than 50 ± 5 milliseconds (see Para. 3.3.6.2).

3.6.9 Connector Pin Assignment

The pins of connectors J-1 and J-2 shall be assigned as shown in Table 3 with redundancy as noted.

TABLE 3. CONNECTOR PIN ASSIGNMENT

Connector	Pin Number	Function	Signal Classification
J-1	1 and 2	+29.4 volts	Input
J-1	3 and 4	29.4 volt return (common ground	Input
J-1	5 and 6	Enable signal	Input
J-1	7 and 8	Fire command	Input
J-1	9	Thruster temperature telemetry	Output
J-1	10	1450V telemetry	Output
J-1	11	620V telemetry	Output
J-1	12	Enable signal telemetry	Output
J-2	1	Power return (common ground)	Input or Output
J-2	2 through 4	Not used	--
J-2	5	29.4 V monitor	Output
J-2	6	(Hold time monitor)	Output
J-2	7	1450 V monitor (low voltage output)	Output
J-2	8	Fire command monitor	Output
J-2	9	Enable monitor	Output

Redundancy shall be provided on input pins J-1-1, -2; J-1-3, -4; J-1-5, -6; and J-1-7, -8, as shown in Table 3.

3.6.10 Alignment Mirror

A 0.5 x 0.5 inch front surface mirror shall be located below the exhaust nozzle on the nozzle side of the thruster to allow alignment of the thruster on the spacecraft. This mirror shall have a set of cross hairs on it. The vertical line of the cross hairs shall be positioned to pass through the geometric center of the exhaust nozzle. The horizontal line of the cross hair shall be parallel to the thruster mounting plane. The mirror shall be in accordance with Drawing PC145D1092.

3.6.11 Noise Susceptibility

The design of the microthruster system shall be such that operation of the system shall not be disturbed nor performance degraded when the system is subjected to RF fields in the VHF-UHF band of as much as one volt per meter adjacent to the thruster system.

3.6.12 Electromagnetic Interference

The unit shall be designed to minimize conduction or radiation of EMI.

3.6.13 Identification

Black and white 73X ink (Independent Ink Co.) or equivalent shall be used for part identification.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 Electrical Parts

Standard electronic parts shall be specified in the GSFC Preferred Parts List PPL-11 July 1970, or shall be procured and screened in accordance with Fairchild Republic Division documents as specified in Para. 2.2 herein.

4.2 Inspection Records

An inspection system comprised of check lists shall be maintained during final assembly of the microthruster system.

4.3 Functional Tests

Functional tests shall be performed of subassemblies and of components in accordance with specifications PC145S8012 Rev. A through PC145S8019 and PC145S8021 through PC145S8024 Rev. A. These tests shall be performed to establish functional suitability for the intended application. Satisfactory demonstration of capability in accordance with the specifications cited is required prior to carrying out the acceptance tests.

4.4 Performance Acceptance Tests

Acceptance tests are to be performed on each pulsed plasma microthruster system to determine if production techniques have adversely affected the design from meeting acceptance performance requirements. The performance acceptance test shall be in accordance with specification PC145S8026 Rev. B.

5.0 PREPARATION FOR DELIVERY

5.1 Storage Protection

The microthruster system shall be sealed in a plastic bag prior to packaging.

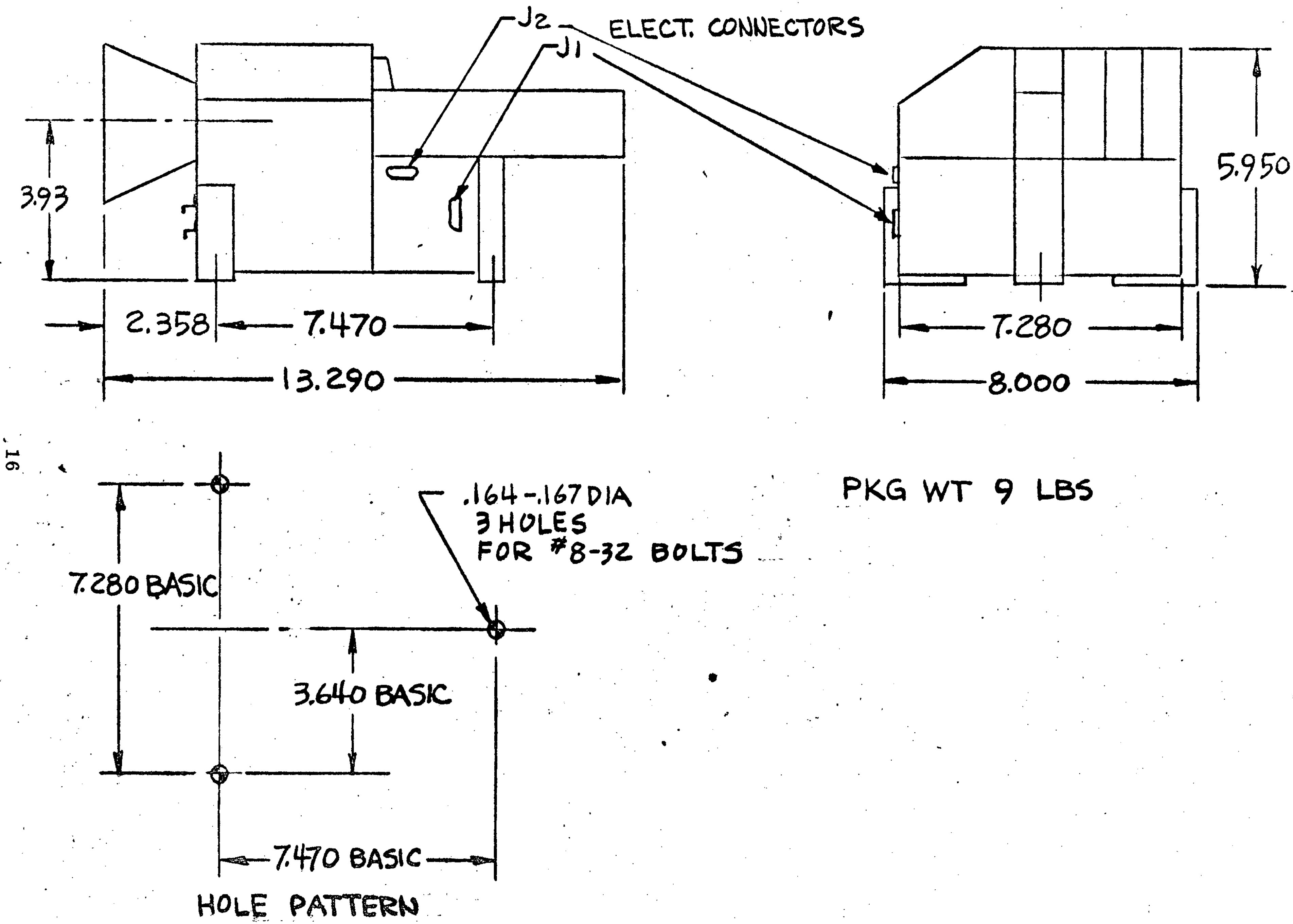

Figure 1. Outline Drawing -- SMS Microthruster