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# NIMBUS D LONG LIFE PNEUMATIC SUBSYSTEM

## FINAL REPORT

REPORT 06158-R0-00

2 JULY 1970

Prepared for

GODDARD SPACE FLIGHT CENTER  
GREENBELT, MARYLAND 20771

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**TRW**  
SYSTEMS GROUP

ONE SPACE PARK • REDONDO BEACH, CALIFORNIA 92773

**NIMBUS D**  
**LONG LIFE PNEUMATIC SUBSYSTEM**

**FINAL REPORT**

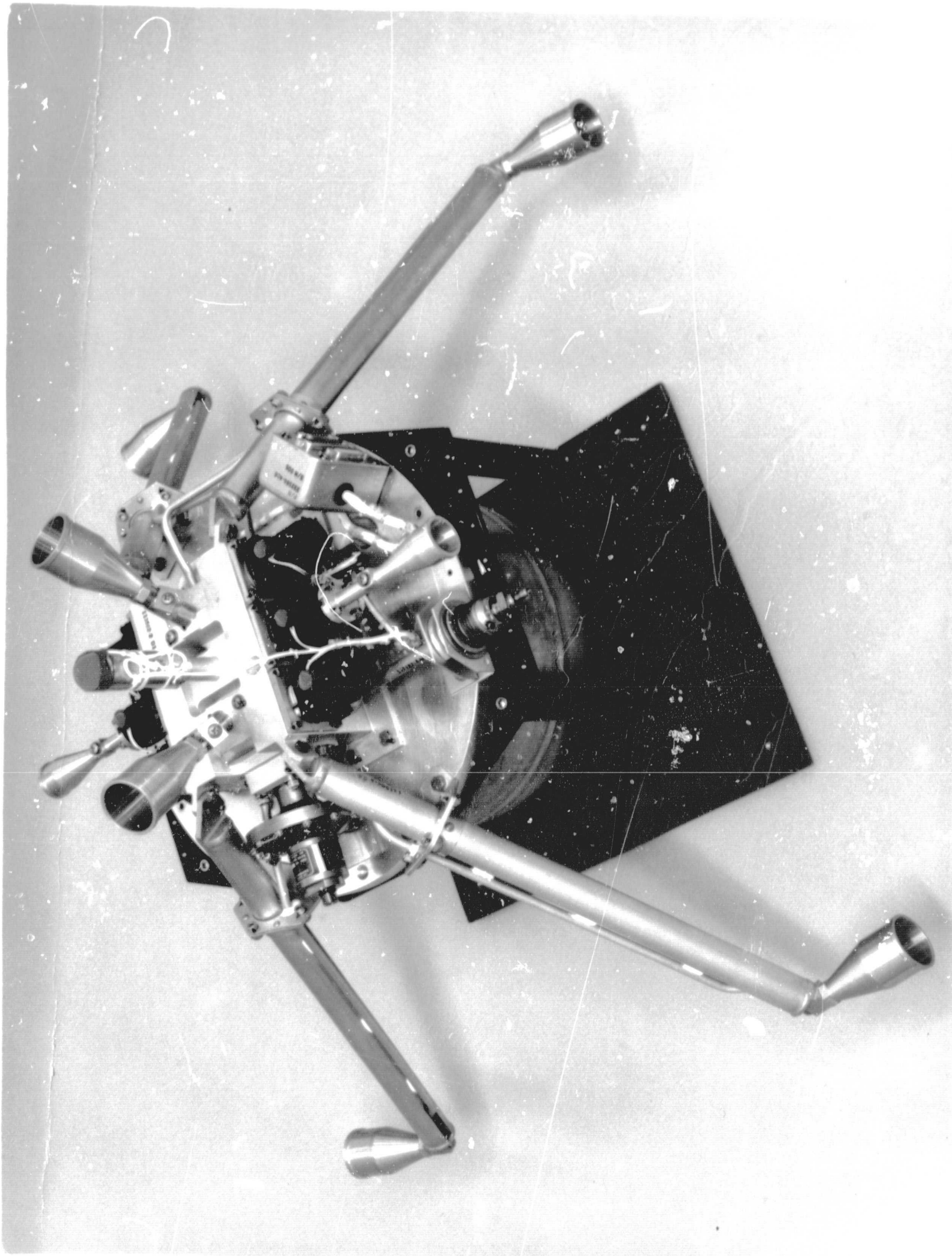
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LONG LIFE PNEUMATIC SUBSYSTEM

06158-6002-R0-00

FINAL REPORT  
NIMBUS D  
LONG LIFE PNEUMATIC SUBSYSTEM  
2 July 1970

Prepared by: J. S. Tillotson  
J. S. Tillotson  
Program Manager, Nimbus D  
Pneumatic Subsystems

Approved by: W. J. Wellens  
W. J. Wellens, Manager  
Control Systems Laboratory

TRW SYSTEMS GROUP  
One Space Park  
Redondo Beach, California 90278

CONTRACT No. NAS5-10182

PREPARED FOR  
GODDARD SPACE FLIGHT CENTER  
GREENBELT, MARYLAND 20771

	<u>PAGE</u>
1.0 SUMMARY . . . . .	1
2.0 SUBSYSTEM REQUIREMENTS . . . . .	2
3.0 HARDWARE DESIGN . . . . .	3
3.1 Pressure Regulator . . . . .	3
3.2 Manifold . . . . .	3
3.3 Solenoid Valve . . . . .	4
3.4 Tank . . . . .	4
3.5 Nozzles . . . . .	4
3.6 Nozzle Alignment . . . . .	4
4.0 SUBSYSTEM BUILT AND TEST HISTORY. . . . .	4
4.1 Simulated Mass Mock-up . . . . .	4
4.2 Engineering Model (LLPS S/N 001) . . . . .	4
4.3 Prototype Model . . . . .	5
4.4 Flight Model (LLPS S/N 003). . . . .	8
4.5 Flight Model Back-up (LLPS S/N 004). . . . .	10
5.0 COMPONENT HISTORY	
5.1 Regulator Stability . . . . .	11
5.2 Crack in the Yaw Arm Brackets. . . . .	12
5.3 Low Pressure Transducer. . . . .	12
5.4 Roll Nozzle Adapters . . . . .	13
5.5 Fill Valve . . . . .	13
5.6 Filter . . . . .	13
5.7 Regulator Primary Seat Leakage . . . . .	14

## 1.0 SUMMARY

This report summarizes the design and development history of the Long Life Pneumatic Subsystem (LLPS) for the Nimbus "D" Spacecraft. The contract was awarded to TRW System in April 1966 and work officially started on 2 May 1966. The contract called for design, development, manufacture, test and delivery to NASA/GSFC of one Engineering Model and one Prototype Model Long Life Pneumatic Subsystem. The contract was later modified to include two flight subsystems and two sets of portable test equipment.

The contract was originally scheduled for completion in May of 1968. However, due to technical problems, the delivery of the final backup system was in January of 1970. The delivery of the first flight system in February 1969 did support the Spacecraft schedule and did not cause any delay in the launch. The most serious development problem was with the regulator and the survival of the primary seat. Although this was not a new development in regulators, its use with Freon-14 gas was unique. The problem was believed to be alleviated by the better control of the gas, especially moisture control.

The flight subsystem was integrated into the Attitude Control Subsystem (ACS) at General Electric Co. and subsequently the ACS into the Spacecraft. The LLPS met all the requirements of Subsystem and Spacecraft prelaunch testing. The Spacecraft was launched on 8 April 1970 and to date the subsystem has performed perfectly.

Item	Date of Authorization	Original Schedule
1 Engineering Model and 1 Prototype Model	May 1966	May 1967
2 Sets Portable Test Equipment	Dec. 1966	22 Dec. 1967
2 Flight Subsystems	Mar. 1967	2 May 1968

## 2.0 SUBSYSTEM REQUIREMENTS

The LLPS design was conceived in response to GSFC requirement to have a completely modular pneumatic system for the Nimbus spacecraft. The idea was to have a completely interchangeable unit, such that if a failure was encountered anytime prior to spacecraft integration to the launch vehicle, that a complete subsystem could be quickly substituted in its place without the necessity of breaking into the system to replace a component, as would be required by a conventional system that is plumbed on the spacecraft.

It was also a design requirement that the subsystem provide sufficient torque so that the acquisition could be made from a separation tip-off rate of  $5^\circ/\text{sec}$  and the earth reference  $180^\circ$  out-of-phase. This was reported to be a  $3\sigma$  condition for acquisition. Freon-14 was selected as the expulsion gas because of its high mass and compression characteristics.

After acquisition the pneumatic subsystem would be used only for unloading the roll and pitch momentum wheels. This was anticipated to be several pulses per orbit.

Later control system studies indicated a requirement that the "plus" and "minus" impulse of each of the axes had to be extremely well matched in order to insure a successful acquisition.

Finally, it is a design objective for an orbital life of 5 years for the spacecraft.

## 3.0 HARDWARE DESIGN

The hardware was designed to 1) use proven design concepts to the maximum degree 2) provide dual static seals to minimize total system leakage and 3) provide redundancy to the maximum extent. The following paragraphs of this section contain a brief description only of those components that received special design or testing to insure meeting these requirements of the attitude control system.

- 3.1 PRESSURE REGULATOR. The pressure regulator is the heart of the pneumatic system. To provide the highest degree of confidence a Vela type regulator was selected. This regulator has a dual seat configuration to provide redundancy; if the primary seat develops a higher than specified leakage it does not build up pressure on the low pressure side of the system until it eventually loses gas out of the relief valve. With the dual seat configuration, if the primary seat leaks at a greater rate than the gas is utilized in the low pressure side, the pressure will build up so that the secondary seat will seal, thus preventing the continual build-up of pressure in the low pressure area and eventual loss of gas.

Both primary and secondary seals utilize a tungsten carbide ball. The primary seat is formed out of the regulator housing, thus eliminating the requirement of a seal between what would normally be two separate pieces. The secondary seat is made of Delrin, a semi-resilient material which provides a more durable seat and one that has a certain tolerance for contamination that the metal primary seat does not have. However, the secondary seat, not being of the parent housing material, and as such a separate piece, must have a seat between it and the housing.

- 3.2 MANIFOLD. The concept of an integral subsystem providing extremely low external leakage dictates the elimination of long plumbing lines and many joints. To replace all of this tubing is a single manifold to which the high pressure storage tank is directly coupled and all other components are cartridge type inserts. A 10 micron system filter is inserted in the manifold flow stream ahead of the regulator on the high pressure side of the manifold. The gas, regulated to approximately 55 psia, is ported to the six solenoid valves that are installed into the manifold.

To minimize the leakage all components that are installed into the manifold, that are subject continuously to either the high or low pressure gas, utilize a two "O" ring gland design.

- 3.3 SOLENOID VALVE. To insure minimum leakage through the normal thrust path of the solenoid valve and nozzle, a dual seat valve configuration similar to that of the regulator has been incorporated. The dual seat configuration uses a tungsten carbide ball in the integral primary seat that is part of the housing and a larger tungsten carbide ball on a semi-soft Delrin seat.
- 3.4 TANK. The tank is a weldment of two hemisphere of titanium forgings. A burst test is performed on each lot of tanks. For Nimbus D tank the burst pressure was 9850 psi.
- 3.5 NOZZLES. Each nozzle receives thrust and flow calibration. The thrust is measured on a TRW magnetic damped thrust measuring device that is accurate to 2%. Experience to date indicates that the nozzle coefficient of thrust has been so repeatable that match selection is not necessary.
- 3.6 NOZZLE ALIGNMENT. The actual alignment measurement is made by tool inspectors, using tool inspection methods. The results to date have proven that the "built-in" alignment, a function of the geometry of the hardware, is excellent and no changes due to environmental testing and/or handling have been noted.

#### 4.0 SUBSYSTEM BUILT AND TEST HISTORY

- 4.1 SIMULATED MASS MOCK-UP. The simulated mass mock-up fabrication was initiated in February 1967. The mock-up was delivered 30 June 1967, after completing qualification level vibration testing. Later it was determined that the welded collar on yaw tube support brackets had developed cracks. This area was redesigned to eliminate welds.
- 4.2 ENGINEERING MODEL (LLPS S/N 001). Fabrication of Engineering Model hardware began in August 1966. Technical problems were experienced by the solenoid valve and regulator manufacturer. These valves and regulators were not received by TRW until April of 1967. In-house testing until mid-May prevented complete assembly of the Engineering Model until June 1967. The Engineering Model was delivered on 7 July 1967.

4.3 PROTOTYPE MODEL. The prototype unit completed assembly on 25 November 1967. Nozzle alignment was accomplished utilizing tool gaging techniques and results were excellent. Performance tests were completed satisfactorily. Vibration at qualification levels was run for both the sine and random conditions in the x axis. Y axis survey at 5 g's, as well as the "x" axis data, indicated extremely high amplification (in excess of 20X) across the platform. "Z" axis survey at 5 g's indicated no problems in that axis. Further reduction of "x" axis vibration data indicated that regulator had experienced a 30 psi p to p oscillation, with a duration of about 60 ms during the vibration. The low pressure transducer also failed during vibration, indicated by a shift in levels. It was replaced with transducer of same design. Redesign of platform was accomplished in effort to reduce transverse amplification factors. The platform was originally made of honeycomb, redesign was a solid aluminum plate.

The prototype subsystem was reassembled with a new platform and S/N 003 regulator. Alignment, electrical, proof and external leak checks were performed. One time qualification level humidity test was accomplished. "Y" axis vibration was initiated with a 1 g survey. Upon completion, a new set of test levels were agreed to with GSFC. During the sine vibration to these levels the low pressure transducer again failed. Failure analysis indicated that the transducer needle bearing pivot points failed. A strain gage test transducer was substituted for the remainder of the testing. The fill valve was replaced. Disassembly of the fill valve indicated wear out of the seat, due to repeated closing. GSFC requested redesign of fill valve for longer life.

The vibration test was resumed to the new set of levels. X-axis sine sweep was completed successfully. At the conclusion of the x-axis random vibration test it was observed that the roll nozzle adapter had failed. The failure occurred at undercut for the thread that screws into the manifold.

In two weeks the unit was reassembled incorporating a new fill valve made by TAVCO, and new roll nozzle adapters made of titanium. Electrical, proof and performance tests were performed in preparation for the vibration test. Vibration testing was completed with only a minor problem in that the fill valve had not been lock-wired and it backed-off causing a minor leak. Post vibration alignment, electrical, leak and performance tests were completed successfully.

The unit was taken to Durkee Labs in Torrance, California to perform the Qualification Acceleration Tests. The qualification requirement was 30 g's. The centrifuge was not quite capable of meeting the 30 g's with the pneumatic system in place. The subsystem had been exposed to acceleration in excess of 25 g's for 70 seconds when the centrifuge failed. Since the requirement was so nearly fulfilled GSFC elected to accept the test data as completing this requirement. Post acceleration alignment, electrical and performance tests were acceptable.

Thermal vacuum testing was started on 16 March 1968 and completed 25 March 1968. The testing was accomplished at the qualification levels of  $-5^{\circ}\text{C}$  and  $+50^{\circ}\text{C}$ . Post thermal vacuum electrical, leak and performance tests were completed successfully, thus completing the qualification testing.

S/N 002 Long Life Pneumatic Subsystem was shipped to GE on 28 March 1968.

During the testing of the prototype at GE it was discovered that one of its operating characteristics was an oscillation of the secondary seat when a certain condition occurred. The condition occurs when the subsystem has remained inoperative long enough for the regulator to reach secondary lock-up and subsequent primary seat leakage will build up the pressure between the primary and secondary seat. Upon a flow demand the secondary seat will regulate the flow until this interseat pressure reaches the normal primary regulation pressure. Stable regulation across the secondary seat was not a design requirement. Previous regulator testing had not considered this condition, however, it was verified that

this oscillation had no detrimental effect on the regulator or the subsystem performance when installed in the spacecraft. The condition was accentuated on this subsystem, as the primary seat leakage had increased to between 5 and 10 scc/hr. It was decided by the customer (GSFC) to return the subsystem to TRW to replace the regulator, because of this higher than acceptance level leakage.

On 6 August 1968 TRW ran verification lock-up tests and leak tests and obtained similar data to that run at GE. S/N 003 regulator was removed from the subsystem and S/N 005 was installed.

Subsystem was reorificed to the S/N 005 regulator band. Later when pressure was being reduced at the conclusion of the 3000 psi proof test, the test medium, 100% helium gas was being exhausted through the nozzles, the primary seat regulation became unstable and caused the primary seat seal to be destroyed. It was later determined by both analysis and test that the regulator is unstable when used with 100% helium.

S/N 002 regulator was installed in the subsystem. It was agreed with GSFC that the regulation band of this regulator was similar enough to that of S/N 005 regulator and that reorificing was not necessary. The new flight type Low Pressure transducer was also installed at this time. Preliminary testing of the subsystem was complete. A workmanship vibration, 20 g random for 4 minutes, was directed by the customer. The subsystem completed performance tests in the clean room and in the vacuum chamber. During six minute blow-down test in the vacuum chamber the low pressure oscillograph trace indicated a 60 cycle oscillation. Numerous tests were run, but the oscillation could not be induced again. GSFC accepted the data and the subsystem was shipped to GE.

Regulator S/N 003, the regulator that was in the subsystem when returned to GE, was sent to GSFC for special tests. The testing of this regulator was to verify that this secondary seat oscillation was as TRW stated - not damaging to the regulator. The performance of this regulator during all the testing at GSFC was gratifying. The leakage across the primary seat actually decreased, and no detrimental effects to the regulator were observed

after approximately a million cycles of the secondary ball oscillation.

The prototype subsystem was integrated into the Nimbus Control System module at GE and subjected to the system qualification tests. After a low temp plateau of the thermal vacuum test it was noted that primary seat leakage was grossly out of specification. Suspecting that the problem could be caused by a contaminate that might be cleared by flow, the subsystem was subjected to a number of commands that pulsed the valve, causing the regulator to flow gas. The leakage increased. S/N 002 regulator was removed from the subsystem and replaced with S/N 003 regulator that had recently completed the life testing at GSFC.

Subsequent performance of this subsystem has met all the design requirements.

S/N 002 regulator was cut up by GSFC in an effort to better understand the primary seat problem.

- 4.4 FLIGHT MODEL (LLPS S/N 003). Flight Model S/N 003 Long Life Pneumatic Subsystem was partially assembled in June, 1968. The unit was short a regulator and a low pressure transducer. It remained in this partially assembled status during the time that the prototype was back at TRW for the regulator replacement. During this period of June, 1968 through December, 1968 was a period where the problems with the regulator were the most severe.

After the reacceptance testing of the prototype GSFC proposed to TRW that we reevaluate the subsystem acceptance testing and incorporate what we had learned to date from our experience. In early November TRW presented their recommendation to GSFC. TRW recommended that non-vacuum chamber performance testing and one nozzle alignment test be deleted. TRW also stated that the thermal black paint presented a source of contamination to the subsystem that was extremely difficult to cope with. GSFC was not willing to give up the pre-vibration performance nor the alignment, and it was agreed that all performance testing would be accomplished in the T/V chamber. GSFC also directed that over and above the deletion of the black paint that, hereafter,

all surfaces exposed to the gas shall be cleaned to the PR2-2 level "0" rather than level "1", which has been TRW's practice.

During December 1968 and the first two weeks of January 1969, the subsystem was disassembled, stripped of paint, and most parts cleaned to level "0". The solenoid valves and the regulator were not cleaned to level "0" because it would be necessary to disassemble to meet this requirement. In an attempt to clean the system filter it was discovered that the filter itself was "sluffing" off. Examining the filter under a microscope, it was determined that the sintered metal was breaking off of the metal woven duck. It was decided that a new filter type was required. A review of the possible alternate was made and it was decided that Wintec had the best reputation at TRW for providing clean filters. The filter was to be just a plain duck without the sintered metal covering. This filter did not meet the design requirements of 5 microns; however, the other considerations with the unit were so favorable that their requirement was waived by GSFC. The filter was designed, built and delivered to TRW within one week.

The subsystem was reassembled on the 22nd of January, 1969, with S/N 005 regulator. Testing proceeded normally up to the leak test in the Thermal Vacuum Chamber. With the subsystem in the chamber it was not possible to evacuate the chamber to the required  $1 \times 10^{-6}$  mm vacuum. When it was verified that the problem was not with the Chamber, the vacuum was then broken and the unit was checked with the Gas Detector and it was found that gas was leaking out the -yaw nozzle. The solenoid valve was removed and returned to the vendor for failure analysis. The valve was disassembled and both seats were found to be contaminated. Long gas flows were made through each of the remaining solenoid valves with the outlet flowing through millipore patches. No evidence of contamination could be found in any of these patches, and it was concluded that the remaining valves were clean.

Acceptance testing was again initiated. All testing proceeded without incident and was successfully completed on 21 February 1969. The unit was shipped to GE on 25 February 1969. The subsystem was integrated to the attitude control system and passed all testing without problems. The

only problem encountered was at the lock-off of the fill valve at the final pressurization of the system just prior to the spacecraft being integrated to the launch vehicle. A gas purge and retorquing of the fill valve nut cured the problem.

- 4.5 FLIGHT MODEL BACK-UP (LLPS S/N 004). The subsystem was assembled, all cleaned to level "0" requirements, S/N 004 regulator was installed, ready for testing at the end of March, 1969. Testing proceeded through "y" axis Random Vibration when a high leakage from the relief port was noted. The regulator was removed and sent to vendor for failure analysis. Disassembly revealed a tiny tear in the regulator diaphragm. Tear was apparently caused by a piece of contaminant between the diaphragm and the piston. Failure was assessed to be random in nature and corrective action lay in the area of more stringent Quality Control. S/N 004 Regulator was rebuilt, retested, returned and installed in LLPS Subsystem. Acceptance testing was again started. A delay was encountered due to an instrumentation problem. Considerable performance data has to be rerun. At conclusion of performance, when the unit was in a long lock-up, the low pressure rose to 66 psia. 66 psia is well above secondary seat lock-up and close to relief valve reseal pressure. This condition could only be reached by leakage across both seats at a rate not having been observed previously. This condition was left without explanation. The first pulse with this condition exhibited typical secondary seat regulation oscillation. Subsequent performance did not indicate a seat problem. Vibration was accomplished and the post vibration performance indicated possible primary seat out of specification leakage. A series of leak tests were performed and the final test indicated acceptable leak data.

At this time the Ramp Test was initiated. The test uses an actual autopilot model (furnished by GSFC). This model pulses the solenoid valves as a function of a pseudo error signal. As many as 400 pulses can be commanded in 90 seconds.

Thermal Vacuum Testing was initiated with special attention on leakage data, proceeded through to final low temp plateau when leak rate again went out of limit. On 29 October 1969 Thermal Vacuum Test called off. Regulator was returned to vendor where it was determined that primary seat was severely damaged.

At this time S/N 006 Regulator also had a damaged primary seat that occurred during regulation acceptance testing at the vendor. S/N 006 regulator was repaired on expedited basis and was installed in subsystem on 20 December 1969. System was subjected to full T/V test, a workmanship vibration, final leakage and alignment. Testing was completed on 9 January 1970. Unit was shipped to GE on 13 January 1970.

## 5.0 COMPONENT HISTORY

5.1 REGULATOR STABILITY. The regulator configuration dual poppet, redundant seats is quite similar to that TRW has used in other applications, but using  $\text{GN}_2$  as the stored gas. Initial development testing of the Nimbus Regulator was performed using  $\text{GN}_2$ , and the regulator performance was excellent. However, when Freon-14 was used, several stability problems were encountered. The first problem was that the regulator was only marginally stable under any condition. This condition was corrected by increasing the low pressure sensing feedback port area. The second problem was the low temperature instability. The requirement was originally for the regulator to regulate gas with conditions at the inlet port of 2000 psia and 20°F. The instability was caused by the gas crossing into the liquid domain during its expansion process. The gas would partially become liquid as it passed through the expansion orifice, (i.e. the area between the primary seat and the primary ball) then as soon as it got into the low pressure cavity flash back into a gas, thus causing an unstable flow. This problem was not solved, but it was determined that the condition of 20°F at 2000 psia was not a representative requirement. If the subsystem is charged to 2000 psia at an ambient temperature of 77°F and the temperature dropped to 20°F, the pressure would drop to approximately 1400 psia. Under these conditions the regulator performed in a stable condition.

- 5.2 CRACKS IN THE YAW ARM BRACKETS. Both the mass mock-up and the engineering model had completed vibration testing when it was discovered that there were hairline cracks in the weld joints of the yaw arm brackets. The results of failure analysis showed that the weld material failed due to fatigue induced by higher than anticipated loads. The design was revised to incorporate rivets.
- 5.3 LOW PRESSURE TRANSDUCER. A low pressure transducer failed during the initial vibration testing of the Prototype LLPS. The failure was due to excessive wear on the resistance coil of the potentiometer. The wear was apparently caused by excessively high "g" levels experienced during vibration. The problem was expected to be alleviated with the substitution of the solid aluminum base plate and its lower amplification factors.

A second transducer failed component level testing. The failure was a broken drive band that links the pressure sensing diaphragm to the potentiometer wiper. The vendor attributed the failure to manufacture operation and assured TRW that the possibility of a recurrence of such a failure was remote.

A third transducer failed during the qualification vibration testing of the prototype subsystem with the solid platform. The failure occurred when the needle-bearing pivot points failed, due to vibration environment. The conclusion was that the high transmissibility factors at the low-pressure transducer location precluded the use of an instrument using a mechanical movement. A technical survey of the strain gage type units was made and it was decided to use a Statham strain gage type transducer.

Four transducers passed acceptance tests at the vendors and were witnessed by TRW engineering personnel. When the units were tested at TRW all four units showed signs of failure. One failed open, one failed short, and two exhibited calibration shifts. The vendor failure analysis attributes the failure to electrostatic discharge generated by standard handling techniques in TRW's clean room. A Zener Diode was incorporated in the units which would ground

any static charge. The vendor's analysis was viewed with some question, but the fix was effective in that no further problems were encountered with this transducer.

- 5.4 ROLL NOZZLE ADAPTERS. At the completion of "x" axis Qualification Level Random Vibration one of the roll nozzles and the associated adapter were found lying on the shaker head. Just a touch on the other nozzle and it too came off. The failure of the roll nozzle adapter occurred at the undercut at the end of the threaded portion.

Examination by microscopy indicated failure by both over-torquing and by fatigue. Original adapters were made of aluminum.

A new titanium adapter was made, maintaining a minimum of .020 thickness in the undercut area. The titanium adapter has successfully passed the tests that failed the previous units.

- 5.5 FILL VALVE. The fill valve failed during prototype testing. It was decided that the failure was in fact just a wear out from the number of times it had been opened and closed. GSFC was after a better ground handling capability and requested TRW to seek a better unit. A fill valve made by TAVCO, supposedly good for 1,000 cycles, was selected. The valve performed satisfactorily until just prior to launch when it leaked after final fill. A gas purge and retorquing solved the problem.

- 5.6 FILTER. In an effort to clean the filter to level "0" requirement, it was determined that the filter itself was actually a source of contamination. The filter was made of a metal woven duck covered with a sintered stainless steel powder. Under a microscope areas could be seen where the sintered metal had come completely off the duck. It was decided that this filter design was not acceptable.

A TRW filter selection committee was formed to investigate available filters and made a recommendation for a replacement. The requirement was for 5 micron absolute filters. Investigation revealed that there is no true 5 micron absolute filter for this application. Some manufacturers will

advertise such, but it cannot be verified by a bubble point test. Investigation also disclosed that filters must be controlled through their manufacturing processes to prevent them from being a source of contamination. To obtain a filter that does not generate contamination it must be cleaned at every step of manufacture. The filter meeting the cleanliness requirement was made by Wintec.

The Wintec filter was only guaranteed to meet 10 micron absolute; however, the confidence that it would not be a source of contamination justified the relaxation of the 5 micron requirement.

- 5.7 REGULATOR PRIMARY SEAT LEAKAGE. By far the most serious problem encountered in the development of the Long Life Pneumatic Subsystem was that of the leakage across the regulator primary seat. Because of the long life design objective, a design requirement of 1 scc/hr was established as the allowable primary seat leakage. Leakage rates of 5 scc/hr and 2 scc/hr had previously been met on similar regulators. These regulators operated using nitrogen as the working gas. The problem encountered was not one of experiencing leakage rates of 2, 3, 4 or even 5 scc/hr. Ordinarily it was possible to lap the seat in with a leak rate in the range of 1 scc/hr. However, when the leak rate started to climb it would go to 50 scc/hr or greater.

Reviewing the history of the testing that preceded the leak rate going out of specification disclosed that the problem occurred usually after cold temperature testing or long blow down test where the regulator and test manifold would get very cold. In tests at Sterer with a temperature probe in the test port just downstream of the primary seat, temperatures below  $-150^{\circ}\text{F}$  were observed. Another symptom observed on regulators that later failed was large quantities (500 scc or greater) of gas escaping out of the relief port after a 6 minute blow down test. At disassembly of these failed regulators water spots were observed on the upstream side of the T.C. Ball. The failed seat, when observed with a microscope, showed marks that resembled claw marks across the seat area.

In low temperature tests it had been noted that high primary seat leakage at low temperature would become allowable leakage when the regulator was

stabilized at room temperature. From all of the foregoing it was theorized that a probable cause of the problem was that the moisture in the gas was becoming ice as it is throttled across the primary seat. In the case of the high leakage out of the relief port, after a long blow down, it is surmised that a slight glaze of ice crystals formed on both the primary and secondary balls, permitting a high leak rate past both seats and hence, leakage out of the relief valve. Tracing the pressure downstream after the long blow down it is difficult to identify the pressure rises in the low pressure volume, as to what is leakage and what is the increasing temperature effect. This theory is also applicable for the observation of the high primary leak associated with cold testing, this leakage going away when the regulator is stabilized back to the ambient temperature. This also could explain the presence of the water spots on the upstream side of the primary seat T.C. Ball.

The ice-theory runs into trouble as a mechanism for the outright destruction of the primary seat. It can be proven that ice is just not hard enough to damage a titanium seat if caught in between the ball and seat when it is closing. Tests were run to explore the possibility of the ice eroding the tungsten binder away from the carbide particles in the T.C. Ball, thus leaving a rough surface with associated high localized loading, and subsequent deterioration of the seat, without success.

There is also a data point in that S/N 003 Regulator in the Prototype Subsystem and S/N 005 Regulator in the flight unit have performed beautifully; both have experienced severe testing. These units prove that it is possible to build a good unit.

One of the tests performed at GSFC demonstrated that taking a T.C. Ball, loading it, then scraping it across titanium, rather than just digging a furrow through the titanium, resulted in the titanium building up in front of the contact area much like snow will build up in front of a plow. This will tend to explain the claw-like appearance of the deteriorated primary seat. One possible explanation is the following: as long as the ball seats in the seat in a straight non-scraping fashion, (i.e. the ball contacts the entire seat area simultaneously), the seat will perform well. If, due to

some contamination between the ball and the seat, the ball is prevented from setting evenly, the contamination acts as a pivot for the ball to rock into the seat, causing a scraping action and hence initiating the deterioration of the seat. This non-even seating would be caused by any type of contamination between the ball and the seat; however, prior to the time of performing additional drying of the Freon-14 an additional contaminate was being introduced into the system that could not be filtered out. The contaminate was the moisture vapor that would pass through the filter as a gas, than during the expansion process as the gas temperature goes below the dew point temperature the moisture will solidify out on a T.C. Ball and seat. It is this super cooling that is experienced with Freon-14 that does not exist when using similar designed regulator, using  $\text{GN}_2$ .

As a result of not being able to positively identify this problem, Sterer Engineering & Manufacturing Co. was requested to explore the possibility of altering the design to use a soft or semi-soft poppet or ball in conjunction with the primary seat. As a result of this request work is being expended in a development of a regulator with a vespel poppet with a conical shape. The titanium primary seat is lapped to a conical form. Testing to date has indicated that the semi-hard vespel poppet and conical seat design has equal response, regulation, and life characteristics while providing vastly superior leak results.

LLPS CONTRACT HISTORY

06158-6002-R0-00

Date	Action	Value	Cum Neg. Con Value	Contract Mod No.	Fee Amount
05-66	Engineering Model LLPS	159K	159K	Original	12K
05-66	Qual Test & Spec Changes	55K	213K	1	5K
09-66	Definitizes C.O. #2	33K	246K	3	3K
12-66	Additional Test Equip.	13K	259K	6	1K
03-67	Two (2) Flight Models & Spares	303K	561K	7	22K
01-68	Variance Adjustment	63K	624K	19	
01-69	Definitizes C.O. Nos. 12 and 20	98K	722K	37	7K
11-68	Definitizes C.O. No. 21	111K	833K	38	8K
12-68	Definitizes C.O. No. 15	86K	919K	39	6K
01-69	Refurbish Subsystem and additional regulator	69K	988K	41	5K
05-69	Definitizes C.O. No. 42	86K	1074K	49	6K
08-69	Variance Adjustment	415K	1489K	51	
12-69	Variance Adjustment	50K	1539K	55	
02-70	Variance Adjustment	111K	1650K	56	
08-70	Variance Adjustment	87K	1737K	58	



ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

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TITLE

EQUIPMENT SPECIFICATION,  
LONG LIFE PNEUMATIC SUBSYSTEM  
FOR  
NIMBUS SPACECRAFT

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PREPARED BY: C. N. LACKIDES

APPROVAL SIGNATURES:

G. F. Haack

G. F. Haack

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**TRW SYSTEMS**  
ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

**REVISION RECORD**

REV	DATE	AUTHORIZATION	CHANGE	PAGES AFFECTED
	6/20/69	Original Issue		
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EQUIPMENT SPECIFICATION  
LONG LIFE PNEUMATIC SUBSYSTEMS

	<u>PAGE</u>
1.0 SCOPE . . . . .	2
2.0 APPLICABLE DOCUMENTS . . . . .	2
2.1 Documents . . . . .	2
3.0 REQUIREMENTS . . . . .	5
3.1 Qualification . . . . .	5
3.2 Components. . . . .	5
3.3 Materials . . . . .	6
3.4 Finishes . . . . .	8
3.5 Design and Construction . . . . .	8
3.6 Reliability . . . . .	9
3.7 Mechanical Requirements . . . . .	10
3.8 Thermal Requirements . . . . .	13
3.9 System Performance . . . . .	14
3.10 Overall Electrical Requirements . . . . .	15
3.11 Component Requirements . . . . .	16
3.12 Environmental Conditions . . . . .	19
3.13 Identification of Product . . . . .	19
3.14 Assembly Area and Techniques . . . . .	20
3.15 Workmanship . . . . .	20
3.16 Test Equipment and Fixtures . . . . .	21
4.0 QUALITY ASSURANCE AND RELIABILITY PROVISIONS . . . . .	21
4.1 Quality Assurance Program . . . . .	21
4.2 Reliability Program Plan . . . . .	21
4.3 Responsibility for Inspection and Test. . . . .	22
4.4 Inspection Requirements . . . . .	22
4.5 Classification of Inspection and Tests. . . . .	22
4.6 Acceptance Inspection and Test. . . . .	22

	<u>PAGE</u>
4.7 Test Procedure . . . . .	22
4.8 Test Conditions . . . . .	23
4.9 Test Methods . . . . .	23
4.10 Rejection and Retest . . . . .	23
4.11 Failure Reporting . . . . .	23
4.12 Substitution of Components . . . . .	23
5.0 PREPARATION FOR DELIVERY . . . . .	23
6.0 NOTES . . . . .	23
Figure 1 Block Diagram Nimbus.D.Long Life.Pneumatic Subsystem	24
Attachment I . . . . .	25

EQUIPMENT SPECIFICATION  
LONG LIFE PNEUMATIC SUBSYSTEM

1. SCOPE

This Specification establishes the requirements for performance, design, fabrication, test, and quality assurance provisions for the NIMBUS Long Life Pneumatic Subsystem (LLPS) PN 113580, hereafter referred to as the "unit". The unit shall provide torques about all three axes to stabilize the spacecraft after orbital injection and provide torques to acquire a designated celestial target. Each unit delivered under this specification shall be a product which fulfills the requirements of Section 3 and passes the inspection and tests of Section 4.

2. APPLICATION DOCUMENTS

2.1 Documents. The following documents of the latest issue in effect or of the specified revision form a part of this specification to the extent specified herein. Where differences occur between the requirements of this specification and the following documents, the requirements of this specification shall apply.

SPECIFICATIONS

NASA

S-450-P-1A	Quality and Reliability Provisions for Nimbus D Procurements (per Attachment I herein)
S-450-P-3	Screening of Semiconductors for the Nimbus Meteorological Satellite Program
S-450-P-4	Screening of High Usage Electronic Parts for the Nimbus Satellite Program
S-323-P-2	Workmanship, Marking, Traceability, Age Control and Packaging Requirements for All Semi-conductors Procured to EIA Specification for GSFC Use
S-320-N1-3-A	Environmental Specification for the Nimbus D Subsystems
NHB 5300.4(3A)	Requirements for Soldered Electrical Connections

Military

FED-STD-209	Clean Room and Work Station Requirements, Controlled Environment
MIL-C-5541	Chemical Film for Aluminum Alloys
MS 33656	Fitting End for Flare Tubes
MS 33540	Safety Wiring, General Practice
MS 20995	Wire, Locking

TRW

PT2-3030	Specification, Low Pressure Solenoid Valve, Leakage Redundant
PT2-3032	Specification, Pneumatic Pressure Regulator, Leakage Redundant
PT2-3035	Temperature Transducer
PT2-3068	Low Pressure Transducer
PT2-3033	High Pressure Transducer

NASA

NPC 200-2	Quality Program Provisions for Space System Contractors
NPC 250-1	Reliability Program Provisions for Space System Contractors

Drawings

TRW

233586	Box, Junction
113580	Assembly, LLPS Subsystem
M117313	Outline and Mounting, LLPS Subsystem
H306160	Container, Shipping, LLPS Subsystem
233589	Schematic, Electronic LLPS Subsystem

WL241935	Wire List, Assembly, LLPS Subsystem
WL233592	Wire List, Pneumatic Gas Dump
SK071166	Test Equipment, Portable, LLPS Subsystem

NASA FORMS

GSFC	Malfunctions Report 4-2
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Other Documents

TRW SYSTEMS

7423.3-830	Reliability Program Plan, Nimbus Long Life Pneumatic Subsystem
69-7234.2-537	Quality Assurance Program Plan, Nimbus D Long Life Pneumatic Subsystem
69.7234.2-538	Manufacturing Plan, Long Life Pneumatic Subsystem, Nimbus D
BP-08Q-01 and Appendix	Test Procedure, Pneumatic Pressure Regulator, Leakage Redundant
BP-08A-01	Acceptance Test Procedure, Long Life Pneumatic Subsystem Flight, Nimbus D
BP-08Q-09	Test Procedure, Junction Box, Pneumatic Gas Dump
BP-08Q-12	Test Procedure, Fill Valve
BP-08Q-08	Test Procedure, Pressure Vessel
BP-08Q-04	Test Procedure, Filter
BP-08Q-03	Test Procedure, Temperature Transducer -1 and -2
BP-08Q-10	Test Procedure, High Pressure Transducer, 0-2000 psia

BP-08Q-16	Test Procedure, Low Pressure Transducer, 0-100 psia
BP-08Q-2	Test Procedure, Low Pressure Solenoid Valve, Basic and -1
BP-08Q-15	Test Procedure, Orifice Sizing
BP-08Q-14	Test Procedure, Nozzle Thrust Test
BP-08Q-06	Test Procedure, Tube Assembly Support Nozzle, Plus and Minus Y Axis
BP-08Q-05	Test Procedure, Manifold
BP-08M-01	Packaging and Handling

### 3. REQUIREMENTS

- 3.1 Qualification. Each unit delivered under the specification shall be a product which fulfills the requirements of Section 3 and has passed the inspections and tests of Section 4.
- 3.2 Components. The unit shall consist of the following major components:
- a) One High Pressure Gas Storage Vessel, PN-C113441.
  - b) One combination Gas Pressure Regulator and Relief Valve, PN PT2-3032.
  - c) One central Distribution Manifold and Mounting Platform; one each required, PN 113582 and 113581.
  - d) Eight control Thruster Nozzles; two pitch required PN 113591 and six roll-yaw, PN 113593.

- e) Six Solenoid Control Valves; two -1's and four basics required, PN PT2-3030.
- f) Two Temperature Transducers; one each of -1 and -2, PN PT2-3035.
- g) Two Pressure Transducers; one high and one low pressure required, PN PT2-3033 and PT2-3068, respectively.
- h) One System Filter; PN C 120631.
- i) Four Nozzle Support Assemblies, 2 each required, PN 113586 and 116599.
- j) One central Junction Box (J.Box); PN 233586.
- k) One Fill Valve Assembly; C118459.

### 3.3 Materials.

- 3.3.1 Fungus Resistance. Materials that are nutrients for fungi shall not be used when their use can be avoided. Where used, they shall be treated with a suitable fungicidal agent.
- 3.3.2 Corrosion of Materials. Materials used shall be corrosion resistance or shall be suitably treated to resist corrosive effects resulting from environmental conditions specified herein. Protective coatings shall not be damaged in any way when subjected to the environmental conditions specified herein.
- 3.3.3 Dissimilar Metals. Unless suitably protected against electrolytic corrosion, dissimilar metals, as defined in MS 33586A, shall not be used in contact with each other.
- 3.3.4 "O" Ring Material. Only Buna-N "O" ring material, Parker compound N219-7, shall be used in the assembly of this unit.
- 3.3.5 "O" Ring Lubricant. Only Dow Corning Silicon Lubricant DC 55M, per MIL-G-4343, shall be used in the assembly of this unit.

3.3.6 Gases. The unit shall be operated with the following gases and gas mixture only.

- 1) Freon-14 gas
- 2) 90  $\pm$  1% Nitrogen, 10  $\pm$  1% Helium.

The gases used shall conform to the following:

- |   |                        |
|---|------------------------|
| a) Minimum purity, exclusive of air plus carbon monoxide        | 99.8%<br>by volume     |
| b) Maximum Dew Point Temperature                                | -100°F at<br>14.7 psia |
| c) Maximum carbon monoxide content in a room temperature sample | 1.0%                   |
| d) Maximum organic impurities content (other halocarbons)       | 0.3%                   |
| e) Acidity  | 6.5 to 7.0 pH          |
| f) Maximum hydrocarbon compound content                         | 5 ppm by volume        |

3.3.7 Gas Particulate Contaminants. All gases used in the unit must conform to the following particulate contamination limits.

<u>Size Range (Microns)*</u>	<u>Maximum Number of Particles per 10 cu ft gas**</u>
Less than 5	No requirement
5 - 24	150
25 - 50	3
Over 50	None

\* Maximum linear dimension for fibers, maximum diameter for particles.

\*\* Samples at 2  $\pm$  SCFM for 5  $\pm$  1 minute.

3.3.8 Gas Tests. Prior to use in the unit, the gas shall be tested for moisture (Chandler Dewpoint Indicator, Model A-2) and particle count and hydrocarbon (by blacklight method).

3.4 Finishes

3.4.1 Thermal Paint. There shall be no provision to control the thermal properties of the subsystem through application of thermally emissive coatings. Its surface area and condition is adequate to dissipate all internally generated heat during the worst thermal vacuum conditions.

3.4.2 Surface Treatment. All surfaces shall be chemically filmed per MIL-C-5541, Class 1 (irridite) except if noted otherwise on drawings or specification.

3.5 Design and Construction. The design and construction of the unit shall be in accordance with the requirements of this specification.

3.5.1 Configuration. The unit specified here shall consist of the components noted in Paragraph 3.2 and shall be assembled per TRW Drawing 113580. The electrical wiring and terminations shall be as indicated in TRW Drawing 233586.

3.5.2 Outline/Envelope. The unit shall meet the outline and envelope requirements of TRW Drawing M117313.

3.5.3 Safety Locking. All threaded parts shall be postively locked by safety wiring, self-locking nuts, loctite nyloc or other approved methods. Safety wire shall be applied in accordance with the practice outlined in Standard MS 33540 and shall be applied in accordance with the practice outlined in Standard MS 33540 and shall conform to Standard MS 20995. A torque stripe shall be applied after torquing up nuts and fittings to indicate the torqued position.

3.5.4 Soldering of Electrical Connections. Soldering of electrical connections shall be in accordance with NASA Document NHB 5300.4 (3A) as modified by the Appendix included in the TRW Quality Assurance Program Plan.

3.5.5 Operating Attitude. The unit shall be capable of meeting the requirements of this specification when mounted in any attitude in a zero or 1-g field.

3.5.6 Alignment. The alignment of the unit with respect to the spacecraft interface shall be maintained by a master alignment tool furnished by the customer.

3.5.7 Mounting Interface. The subsystem is mechanically mounted to the spacecraft by its base plate and attached by ten (10) bolts dimensionally specified by TRW Drawing M117313. The base plate is accurately aligned to the spacecraft by inserting a close tolerance pin through two keyed alignment holes on the spacecraft mounting ring and subsystem base plate. The electrical subsystem spacecraft interface is established with three connections inserted into the subsystem J Box. The mounting surfaces between base plate and spacecraft shall have a finish of 63 micro-inches RMS or better.

3.5.8 Interchangeability. The unit shall be interchangeable without requiring selection for fit to the spacecraft.

### 3.6 Reliability

3.6.1 Life Sequence. The unit will be exposed to the following sequence of events.

- a) Acceptance Test, per BP-08A-01.
- b) Shipping - During shipping the unit will be exposed to normal shipping environments while contained in its shipping container. (Drawing No. H306160).
- c) Storage and Ground Tests. These tests are performed when the unit is installed within the spacecraft. During this time the unit may be subjected to environmental exposure of a level not exceeding that which the unit experiences during acceptance testing.
- d) Launch Exposure.
- e) Orbit. Continuous operation for five years (600 mile earth orbit).

3.6.2 Reliability Provisions. The quality and reliability assurance provisions of NASA/GSFC Specifications S-450-P-1A shall apply as modified by Appendix 2 of this specification.

### 3.7 Mechanical Requirements

- 3.7.1 Function. The unit shall contain compressed Freon-14 gas which is expelled through thrust nozzles to create appropriate torques to provide coarse attitude control of the spacecraft throughout its orbital life. The unit shall contain a central J-Box which shall provide for transmission of electrical power and signals to and from the unit.
- 3.7.2 Nozzle Location and Orientation. The pitch, roll, and yaw nozzle locations and orientations shall be specified in TRW Drawing M117313 and 113580. No subsystem component shall be permitted within a boundary formed by a hypothetical cone with a 90° included angle from each nozzle exit.
- 3.7.3 Dimensional Tolerance and Adjustments. The LLPS shall be fabricated so that the nozzles are within  $\pm .050$  in. and  $\pm 30$  min. of arc from their designated location and orientation (Sec. 3.7.2). These nozzle locations shall be attained without any mechanical adjustments provisions in the subsystem design. These dimensions shall be referenced to bolt hole and alignment pins on the base plate which are accurately drilled with a customer-supplied drill template.
- 3.7.4 Static Loading.
- 3.7.4.1 Operating Pressure. The high pressure side of the subsystem is nominally loaded to 2000 psia at a temperature of 68°F. The pressure will fluctuate from 1450 psia to 2600 psia with a temperature swing from 20°F to 125° F.
- The low pressure side of the subsystem (downstream of the regulator) will normally regulate gas pressure between 51 psia to 62 psia with a vacuum reference on the regulator. A secondary seat will lock up normally at 2 psi minimum above the primary seat with the same initial conditions.
- A relief valve that will flow a maximum of 0.85 SCFM at a low pressure cavity pressure of 75 psig is contained in the regulator.
- 3.7.4.2 Proof Pressure. The high pressure section of the subsystem shall be capable of withstanding a pressure of 300 psia without damage or subsequent degradation of performance. The low pressure section shall be capable of withstanding 180 psia without damage to components.

3.7.4.3 Burst Pressure. The high and low pressure sections of the subsystem shall withstand a minimum of 4 times the operating pressure before they rupture.

3.7.4.4 Component Safety. The following is a list of subsystem components and their operating, proof and burst pressures:

PN	ITEM	PRESSURE PSIA		
		Operating	Proof	Burst
C113441	Pressure Vessel	2000	3000	8000
PT2-3032	Pressure Regulator	61.5	100	260
113582	Manifold (High Pres. Sec.)	2000	3000	8000
113582	Manifold (Low Pres. Sec.)	61.5	100	260
113591	Pitch Nozzle	35	100	150
113593	Roll/Yaw Nozzle	35	100	150
PT2-3030	Solenoid Valves	61.5	100	260
PT2-3035	Temperature Transducer	2000	3000	8000
PT2-3033	High Pressure Transducer	2000	3000	8000
PT2-3068	Low Pressure Transducer	100	150	400
113586	+ Yaw Arm Assembly	35	100	150
116599	- Yaw Arm Assembly	35	100	150
C118459	Fill Valve Assembly	2000	3000	8000
113580	LLPS Unit (High Pres. Sec.)	2000	3000	8000
113580	LLPS Unit (Low Pres. Sec.)	61.5	100	260

- 3.7.4.5 Pressure Cycles. The subsystem shall withstand 200 cycles of 0 to 2000 psia and 10 cycles from 0 to 3000 psia without any detrimental effects to system performance or safety while subjected to ambient temperatures and pressures.
- 3.7.4.6 Lifting Attach Points. The subsystem shall be moved from one area to another by temporarily attaching it to its shipping container (#H306160). If it is to be moved a short distance (fixture to bench), it shall be lifted by the yaw arm tube sections between the manifold and base plate. The subsystems shall not be lifted by any other point - such as yaw arm extending from base plate, solenoid valves, charging tube, etc.
- 3.7.5 Sealing. Each component of the unit that is pressurized shall be sealed with a set of redundant "O" rings. Each component mounting interface shall have a leakage of less than 0.1 scc/hr of helium gas while satisfying all the requirements of this specification. The solenoid valves and regulator shall have redundant seats, one "hard" and one "soft". These seats shall have a leakage rate of less than 1.0 scc/hr. each.
- 3.7.6 Dynamic Loading. The unit shall meet all the requirements of this specification after being exposed to the environments of Paragraph 3.12.
- 3.7.7 Mass Properties. The mass properties of the unit shall be as listed below. The axes centerlines are defined in TRW Drawing M117313.

The weight of the unit empty shall be  $27.20 \pm 20$  lbs. and  $39.00 \pm 40$  lbs. when pressurized to 2000 psi at 25°C with Freon-14.

Axis	Tank Empty	Tank Full
	C.G. Offset from Centerline	
X-X	$+0.175 \pm .005$ in.	$+0.122 \pm .005$ in.
Y-Y	$+0.145 \pm .005$ in.	$+0.140 \pm .005$ in.
Z-Z	$+0.149 \pm .010$ in.	$+1.488 \pm .010$ in.

Axis	Tank Empty	Tank Full
	Moment of Inertia ( $Wr^2$ ) about C.G. Axes	
$I_{XX}$	$666 \pm 7 \text{ lb-in}^2$	$1025 \pm 10 \text{ lb-in}^2$
$I_{YY}$	$595 \pm 6 \text{ lb-in}^2$	$954 \pm 10 \text{ lb-in}^2$
$I_{ZZ}$	$598 \pm 6 \text{ lb-in}^2$	$709 \pm 7 \text{ lb-in}^2$

### 3.8 Thermal Requirements

- 3.8.1 Heat Transfer Mode. The primary methods of transferring heat from the unit shall be: conduction from the mounting surfaces and radiation. The unit shall be designed so that all internal sources of heat shall have adequate heat flow paths to the mounting surfaces of the unit.

The external surfaces of the housing shall not be coated with a thermally emissive paint (see Paragraph 3.4.1 of this specification). All environmental requirements of this specification shall be considered in the thermal design and the unit shall withstand the specified temperature extremes of  $-5$  to  $+50^\circ\text{C}$  with no performance degradation beyond the limits of the detail functional test procedures.

- 3.8.2 Temperature Transducers. One transducer shall be designed to measure the static gas temperature in the high pressure section of the unit. The other transducer shall measure the manifold temperature.
- 3.8.3 Transducer Calibration. All transducers shall be calibrated over the temperature range of  $-20^\circ\text{C}$  to  $+80^\circ\text{C}$ . The calibration shall be performed by recording the output voltage when the unit is excited by  $24.5 \pm 0.1 \text{ VDC}$ .

3.9 System Performance

- 3.9.1 Response. The elapsed time for nozzle inlet pressure to rise to 63% of the steady state value from the point of application of -24.5 VDC to its respective solenoid valve shall not exceed 60 milliseconds for any nozzle.
- 3.9.2 Leakage. The LLPS leakage shall not exceed 10 scc/hr of a gas mixture of 90% N<sub>2</sub>, 10% He during the thermal vacuum environmental test specified in Paragraph 4.6. The leakage of a subsystem loaded with 2000 psia Freon-14 and subjected to the vibration environment of Paragraph 4.6 shall not exceed 100 scc.
- 3.9.3 Thrust. The nozzles when designed and fabricated per drawings 113591 and 113593 shall have the following thrust ratings when tested per procedure BP-08Q-14 with Freon-14 gas:

Nozzle P/N	Vacuum Thrust (lbs.) Required	Nozzle Thrust Pres. (PSIA)
Pitch/113591	.1925 $\pm$ .011	34 to 34.5
Roll/ 113591	.4150 $\pm$ .024	33 to 34
Yaw/ 113593	.4280 $\pm$ .025	34 to 35

Nozzle calibration curves and unit's orifice adjustments shall be used to achieve the required vacuum thrust as specified above.

- 3.9.4 Ramp Mode Operation. The subsystem shall be capable of operation with 50-millisecond voltage pulses to any Pitch or Roll Solenoid valve increasing from 20% "on" to 100% "on" over one (1) minute intervals (approximately 250 pulses) at any operating temperature and from initial tank pressures equivalent to 2000 psia at 25°C.

3.9.5 Acquisition Mode Operation. The subsystem shall be capable of intermittent-flow operation for intervals up to 100 seconds and flow rates up to 7.3 SCFM of Freon-14 gas from varying nozzle combinations at any operating temperatures and from initial tank pressures equivalent to 2000 psia at 25°C.

3.10 Overall Electrical Requirements

3.10.1 Schematic Diagram. The unit shall conform to the electrical schematic shown by TRW Drawing 233589.

3.10.2 Wire List. The unit shall be electrically wired using TRW Drawings WL 241935 and WL 233592.

3.10.3 Connectors. There shall be three special gold-plated connectors per unit supplied by the customer and installed per TRW Drawing 113580. The connector part numbers and unit function are listed in TRW Drawing 233586.

3.10.4 J-Box and Harness. The J-Box shall contain the three connectors, all subsystem interconnections, a gas dump circuit isolation relay and isolation diodes. It shall not be sealed against humidity or R.F. environments. However, the harness, terminal board, connectors, and component connections shall be potted to protect them from corrosion or shorting resulting from humid environments. The J-Box and harness shall be fabricated per TRW Drawing 233586 and acceptance tested per BP-08Q-09.

3.10.5 General Transducer Requirements. All transducers shall be individually protected against misapplication of -24.5 VDC to the output terminals. Each unit shall have its own calibration curves. In addition, all the transducers shall have the following characteristics:

- |   |   |
|---|---|
| a) Static error band (excluding thermal errors) | +1% max of full scale (except +2% for high pressure transducer) |
| b) Time constant                                | 50 millisecond max (from input stimulus to output voltage)      |
| c) Power consumption                            | 1/10 watt max (except low pressure transducers, 6/10 watt max)  |

- d) Output impedance 3000 ohms max.
- e) Input voltage -24.5 0.5 VDC
- f) Output voltage range 0 to -6.35  $\pm$  5% VDC (except temp. transducers which are -0.5 to -6.35 VDC)

3.10.6 Electrical Power. The LLPS shall be designed to operate on -24.5 VDC, but the solenoid valves shall be capable of continuous duty operating at -35.0 VDC for one hour at 25°C ambient temperature. The average power consumption during standby shall be less than one watt (transducers only) and at peak operation (three solenoids operating) in less than 51 watts.

### 3.11 Component Requirements

- 3.11.1 Fill Fitting. The unit shall be charged through a fill fitting similar to an MS 33656. It shall be produced per TRW PN C118459, and shall be acceptance tested per BP-08Q-12. It shall be capable of 1000 on-off cycles without exceeding a leak rate of 0.5 scc/hr of Freon-14.
- 3.11.2 Pressure Vessel. The pressure vessel shall have a minimum volume of 475 in<sup>3</sup> and a minimum burst pressure limit of 8000 psig. It shall not exceed 10.50 inches in diameter and weigh no more than 7.35 pounds. This results in a gas storage capability of 12.6 pounds of Freon-14 gas at 2000 psig and 25°C. The unit shall be secured to the units subsystem manifold (113582) with four high strength titanium bolts and shall have a double "O" ring seal - one flange and one "crushed AN" type. The pressure vessel shall be manufactured per TRW Part No. C113441, and it shall be acceptance tested per BP-08Q-08.
- 3.11.3 Subsystem Filter. A ten-micron absolute filter shall be placed in the pneumatic circuit between the pressure vessel and the regulator. This unit shall be fabricated per TRW Drawing 120631 and shall be acceptance tested per BP-08Q-08.
- 3.11.4 Gas Temperature Transducer. This transducer shall sense the static temperature of the stored gas by having its sensing element partially protruding into the gas stream between the tank and the regulator. It shall have a range of -20 to +80C and shall be fabricated per TRW specification PT2-3035-1, and acceptance tested per TRW Procedure BP-08Q-03.

- 3.11.5 Manifold Temperature Transducer. This transducer shall sense the manifold metal temperature by contacting the manifold surface rather than the gas flow. It shall also have a range of  $-20^{\circ}$  to  $+80^{\circ}\text{C}$ , be manufactured per TRW Specification PT2-3035-2 and tested per TRW Procedure BP-08Q-03.
- 3.11.6 High Pressure Transducer. This transducer shall measure the gas pressure in the high pressure section (in absolute pressure) of the pneumatic circuit. It shall have a range of 0 to 2000 psia and shall not be damaged if overpressured to 3000 psia. This transducer shall be manufactured per TRW Specification PT2-3033 and acceptance tested per TRW Test Procedure BP-08Q-10.
- 3.11.7 Low Pressure Transducer. This transducer shall measure the gas pressure in the low pressure section (in absolute pressure) of the pneumatic circuit downstream of the regulator and shall have a range of 0 to 100 psia. It shall have a strain gage bridge which will measure the regulator's output characteristics. The transducer shall be manufactured per TRW Specification PT2-3068 and acceptance tested per TRW Procedure BP-08Q-16.
- 3.11.8 Regulator and Relief Valve. The pressure regulator shall be capable of supplying gas flow from 0 to 8 SCFM of Freon-14 at a nominal regulated discharge pressure of 55 psia with tank pressures of 300 to 2000 psia. The regulator shall permit unregulated gas flow after the tank pressure is depleted below 300 psia. The regulator has as an integral part a relief valve providing a maximum flow of 0.85 SCFM at 75 psig. The relief valve will reseal at a minimum of 3 psi above secondary lock-up. The regulators shall be produced per TRW Specification PT2-3032 and acceptance tested per Sterer Procedure ATP33120 and Addendum 1.
- 3.11.9 Solenoid Valves. There shall be six (6) solenoid actuated valves which control the flow of gas to each of the + pitch, roll, and yaw axes nozzles. One solenoid valve shall be used to supply gas to the two +yaw nozzles and another valve to the -yaw nozzles. The pitch solenoid valve shall be capable of passing 1-1/4 SCFM, the roll solenoid 2-1/2 SCFM, and the yaw solenoid valve 4-1/2 SCFM of Freon-14 gas. The maximum solenoid coil current with an applied voltage of 24.5 VDC, and at a coil temperature of  $0^{\circ}\text{C}$  shall not exceed 0.75 amperes. The solenoids shall be produced per TRW Specification PT2-3030 and acceptance tested per TRW Procedure BP-08Q-02.

3.11.10 Nozzles and Orifice. All nozzles shall have a nominal area ratio of 220:1 and a contour specified in TRW Drawing 113593 and 113591 (generated by Prandtl-Meyer flow theory). The throat diameter of the pitch and roll/yaw nozzles shall be  $.062 \pm .0005$  in. and  $.092 \pm .0005$  in. respectively. The exit surface of each nozzle shall be perpendicular to the geometric centerline to within .005 inches and shall be designed to accept an optical alignment fixture PN F248143.

The pitch, roll, and yaw orifices (117197, 117303 and 117196 respectively) shall be used to trim the chamber pressure of each nozzle, such that it will produce the required vacuum thrust specified in Paragraph 3.9.3 of this specification as outlined in TRW Procedure BP-08Q-15. The nozzles shall be produced to the above-mentioned drawings and acceptance tested per TRW Procedure BP-08Q-14.

3.11.11 Yaw Arm Assembly. This item shall be of a welded and machined tube assembly which shall be accurately fixed to the manifold and base plate (by means of a dowel pin). It shall route the low pressure gas to the yaw nozzles and have provision for retaining the trimming orifices. It shall be so machined that there is no need for adjusting the yaw nozzle position and shall be sturdy enough to retain that position after it is subjected to all flight, handling, and shipping environments. It shall be fabricated by TRW to drawing numbers 113586 and 116599 using the special weld fixture specified therein and acceptance tested per TRW Procedure BP-08Q-06.

3.11.12 Manifold. The subsystem manifold shall be fabricated accurately enough so that there is no need to adjust the position of the pitch and roll nozzle and that it aligns with the base plate without adjustment. It shall contain all the interconnecting gas passages to and from the unit's components. This part shall be designed to adequately transfer all dynamic loads from the pressure vessel and other cantilevered components to the base plate. It shall be fabricated per TRW Drawing 113587 and acceptance tested per TRW Procedure BP-08Q-05.

3.11.13 Base Plate. This component shall be accurately machined to align with the manifold and the spacecraft without provision for subsequent adjustment. A special drill template supplied by the customer shall be used to drill ten (10) mounting and two (2) alignment pin holes into the outer rim and twelve (12) mounting and two (2) alignment holes on the inner cut-out of the plate for mounting and customer furnished template for manifold interface. It shall be the only mechanical interface and thus, load carrying member between the unit and the spacecraft. It shall be fabricated and inspected per TRW Drawing number 113581.

3.11.14 Subsystem-Block Diagram. The aforementioned components shall be interconnected as shown on the block diagram in Figure 1.

3.12 Environmental Conditions. This unit shall be capable of withstanding the following environments and meet the requirements of S-320-N1-3-A.

3.12.1 Operating.

- a) Temperature extremes      20°F to 130°F
- b) Vacuum                      10<sup>-5</sup> Torr

3.12.2 Standby. The unit shall meet all performance requirements of this specification after being subjected to the following environments while powered in launch mode. Random and sinusoidal vibration need not be imposed on the unit simultaneously.

- a) Sinusoidal                      See Paragraph 4.6
- b) Random                         See Paragraph 4.6

3.13 Identification of Product. Marking and identification shall be done in accordance with TRW Process Specification PR12-1. Each unit shall be permanently labeled with an identification plate, or other permanent means, in accordance with TRW Process Specification PR12-1, which will include the following information.

- a) Manufacturer's Name (TRW)
- b) Part Number (113580)
- c) Serial Number (Start with S/N 001)

3.13 (Continued)

- d) Equipment Name (Long Life Pneumatic Subsystem)
- e) Weight (to nearest 0.1 lb.)
- f) Contract Number (Supplied by Customer)

3.14 Assembly Area and Techniques

3.14.1 Cleanliness Level. All pneumatic components shall be cleaned per PR2-2. Those surfaces exposed to gas flow shall meet Level "0". All other surfaces shall meet Level "1" except those areas with special surface coatings that would prevent meeting this condition. All assembly on the subsystem shall be accomplished in a Class 10,000 Clean Room or better, as defined by Federal Standard 209.

3.14.2 Port and Line Capping. All pneumatic ports shall be sealed with appropriate caps, plugs, or plastic covers when a component or an assembly is removed from the "clean environment". All lines of the external system shall be capped when not in use. Nozzles and fill valve shall be covered when not in use. All pneumatic lines, fittings, and test fixtures shall be flushed and purged per TRW Specification PR2-2, level "0". prior to usage to insure cleanliness is maintained in the unit's internal passages.

3.15 Workmanship

The workmanship and assembly of the unit shall be representative of the highest standard of manufacturing and fabrication techniques. Inferior workmanship which might jeopardize the serviceability of the unit shall be cause for rejection.

3.16 Test Equipment and Fixtures. Test equipment and fixtures necessary to test and fabricate the unit shall be defined by engineering drawings and sketches. The requirements of NPC-200-2 do not apply to these items.

3.16.1 Portable Test Equipment. The portable test equipment SK 071166, shall be designed to perform mass flow and functional tests, with the use of the test manual, No. SK 071166 on the unit by demonstrating that:

- a) The specified nozzle flow conditions are satisfied.
- b) The solenoid valves operate within the specified limits.
- c) The regulator output pressure is within the specified limits.
- d) All components are correctly wired and no impedance paths or ground loops exist.
- e) The transducers operate satisfactorily and are capable of furnishing the specified signal levels to the telemetry subsystem.

The test equipment shall weigh  $4 \pm 2$  pounds and shall be contained in a metal suitcase which is 9 inches by 12 inches by 26 inches.

3.16.2 Fixtures. Fixtures for testing, handling, mounting, fabricating, assembly, and aligning the unit and/or its component parts are listed on the respective drawings and test procedures.

#### 4. QUALITY ASSURANCE AND RELIABILITY PROVISIONS

4.1 Quality Assurance Program. All units shall be produced in accordance with the TRW Quality Assurance Program Plan No. 69-7234.2-537.

4.2 Reliability Program Plan. A Reliability Program shall be established and maintained in accordance with the TRW Program Plan 7423.3-830 and applicable portions of NASA Specification S-450-P-1A.

- 4.3 Responsibility for Inspection and Test. TRW Systems is responsible for performing all specified inspections and tests shown on Manufacturing Flow Diagram 69-7234.2-538. The customer will have the right to perform inspections and tests of this specification as shown on this Program Manufacturing Flow Diagram.
- 4.4 Inspection Requirements. The provisions of the TRW Quality Assurance Program Plan shall be used for verifying that the hardware and documentation comply with the design, test, and workmanship requirements.
- 4.5 Classification of Inspection and Tests. Inspection and testing of the unit shall be classified Acceptance Inspection and Test, (See Paragraph 4.6).
- 4.6 Acceptance Inspection and Test. Acceptance inspection and test shall consist of the inspections and tests described in 4.9, Test Methods, to extent specified in Section 4.10.
- 4.6.1 Inspection Sample. Acceptance inspection and test shall be conducted on each unit produced in accordance with this specification.
- 4.6.2 Inspection Sequence. The inspection sequence shall be as indicated in the Manufacturing Flow Diagram, per Paragraph 4.3.
- 4.6.3 Failure Criteria. The unit shall exhibit no failure, malfunction, out-of-tolerance performance degradation or trends as a result of the examinations and tests specified herein. Any such failure, malfunction, or out-of-tolerance performance degradation shall be cause for rejection, unless waived by customer.
- 4.6.4 Test Data. Following completion of acceptance inspection and test, a copy of all test data shall accompany the unit to the purchasing agency of unit.
- 4.7 Test Procedure. All acceptance inspections and tests shall be performed in accordance with the unit's detailed test procedure BP-08A-01. The test procedure shall specify at least the following:

All test equipment, including recording, measuring, monitoring, and alignment equipment; equipment settings and parameters; parameters to be measured; tolerances on measurable parameters; environmental test conditions; and acceptance criteria for all inspections and tests.

- 4.8 Test Conditions. Unless otherwise specified for specific tests listed under Test Methods, acceptance inspection and test shall be conducted in accordance with the conditions and tolerances specified herein.
- 4.8.1 Atmospheric and Environmental. All examinations and tests shall be conducted under the local prevailing pressure at the time of test at a temperature between 60°F and 90°F and at a relative humidity of 90% or less.
- 4.9 Test Methods. The unit's acceptance test shall be conducted per the test procedure indicated in Paragraph 4.7.
- 4.10 Rejection and Retest. Performance degradation of the unit which exceeds the limits established by the performance requirements defined in the applicable test procedures shall be considered as a failure; testing shall be discontinued until a failure analysis is made and the malfunction (including design defects) is corrected, or until subassembly or component has been substituted in accordance with the procedures of Section 4.12. For further requiring redesign, the complete test procedure under which the failure occurred shall be repeated in its entirety without further failure before the test may be considered completed. If the validity of previously completed tests is affected, all prior tests so affected shall be repeated. For other failures (such as workmanship defects), the extent of retest shall be determined from an analysis of the cause and effect of the failure.
- 4.11 Failure Reporting. Every failure shall be noted and reported in accordance with Nimbus Pneumatic "Reliability Program Plan" 7423.3-830.
- 4.12 Substitution of Components. If a component or subassembly is operated or tested in excess of design life and wears out or becomes unsuitable for further testing during a test sequence due to cause other than design deficiencies, a different component may be substituted. If the substitution affects the significance of results of the test during which the component was substituted, that test and any previously completed procedures which are affected shall also be repeated.

## 5.0 PREPARATION FOR DELIVERY

A shipping container, in accordance with TRW Drawing H 306160, shall be provided for each deliverable unit. The container shall provide for packaging and preservation of the unit to protect it from damage when subjected to all shipping and handling environments defined in this specification. The unit shall be sealed prior to shipment per the instructions of BP-08M-C1.

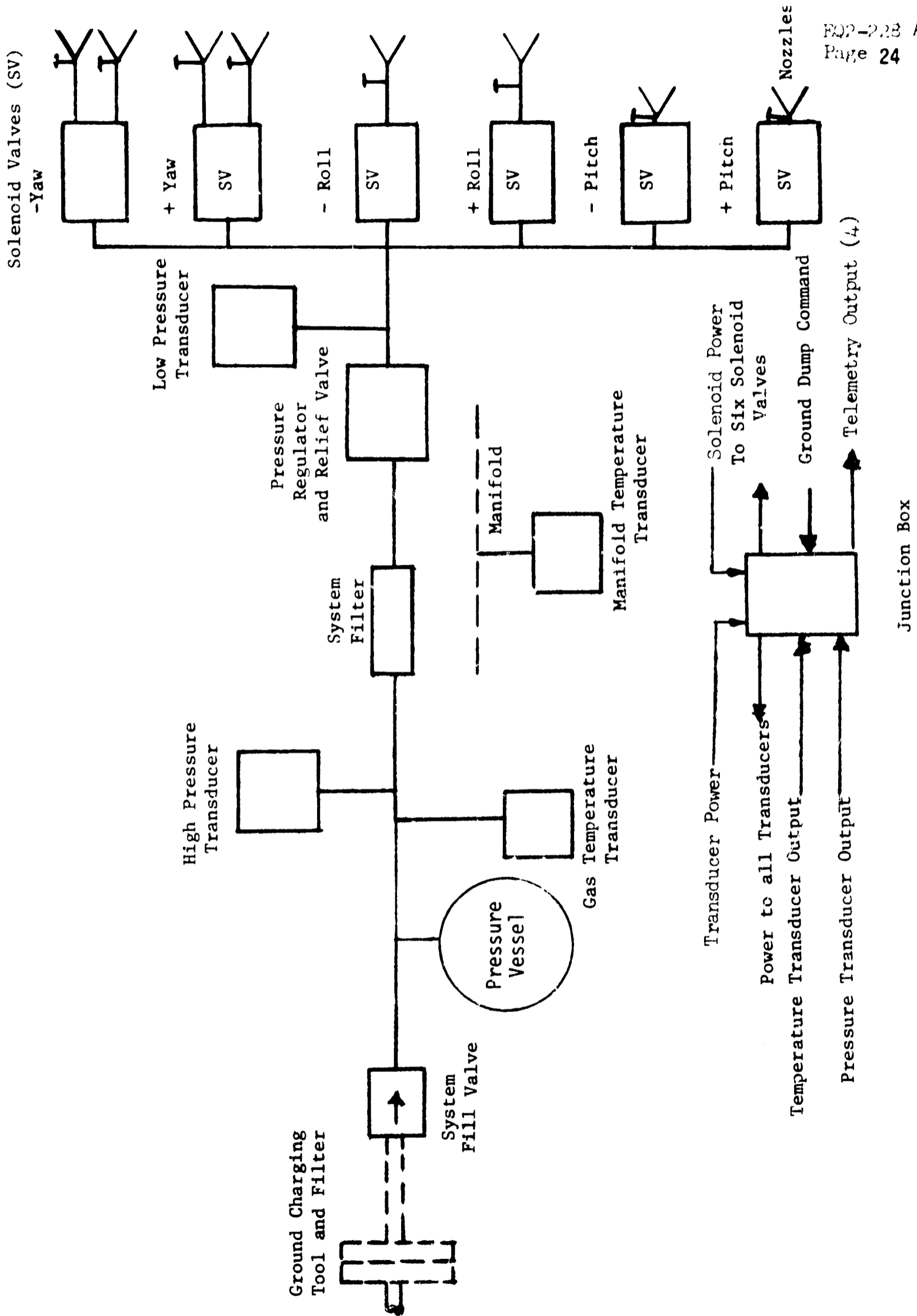
## 6.0 NOTES

See Section 6 of BP-08A-01.

Figure 1

BLOCK DIAGRAM

NIMBUS "D" LONG LIFE PNEUMATIC SUBSYSTEM



ATTACHMENT I

ERRATA SHEET TO GSFC SPECIFICATION S-450-P-1A

GSFC Specification S-450-P-1A is applicable to the Long Life Pneumatic Subsystem subject to the Quality/Reliability Program Plan referred to in Paragraph 2.1 herein. (These paragraphs refer to Specification S-450-P-1A)

- 2.4 Substitute Appendix A, Revision 1, for that Appendix A, now appearing in that specification.
- 3.2 Drawing and Specification Review - Delete the second sentence in its entirety.
- 3.3 Qualification Tests - Wherever the word qualification appears in this paragraph, the words "and/or acceptance" shall be added.
- 3.7 Government Source Inspection - Add the following sentence to the end of the paragraph: "DCASR inspection shall be limited to those points designated on the approved inspection flow chart for TRW fabricated hardware".
- 3.8 Inspection and Test Procedures - In the last sentence, substitute the word "information" for the word "review".
- 3.12 Fabrication Control - In the first sentence, delete the words "under control and". In the last sentence, delete the phrase "and made available as requested by the Technical Officer".
- 3.13 Material Review - Add the following sentence at the end of the paragraph: "Disapproval by the Technical Officer of MRB dispositions must be made within five (5) working days after receipt by the Technical Officer, otherwise approval is assumed".
- 3.14 Calibration and Evaluation of Test Equipment - Delete the third and fourth sentences in their entirety; delete subparagraphs (a) and (b) in their entirety.
  - 3.14.1 Written Procedures - Add the following phrase to the end of the sentence: "at the contractor's facility".
  - 3.14.2 Records - Delete the second sentence in its entirety.

- 3.16 Preservation, Handling, Packaging, Storage and Shipping - Delete the first sentence in its entirety and substitute the following therefore: "The contractor shall prepare drawings from which storage and shipping containers will be fabricated". In the second and third sentences, substitute the word "drawings" for the word "procedures". In the fourth sentence, delete the words "handling instructions" and "installation manual".
- 3.18 Malfunction Reporting - At the end of the first sentence, insert the following: "(TRW forms will be used to report such malfunctions and appropriate data appearing on these forms will subsequently be transcribed to NASA/GSFC malfunctions report Form 4-2)". Delete the phrase "engineering models (except for malfunctions attributed to workmanship); and to". In the fifth sentence, insert the word "working" after the phrase "to NASA within 24-48".
- 3.19 Quality Status Report - Delete the words "and/or quarterly" from the paragraph.
- 3.20 Drawing and Change Control - In the last sentence, delete the words "A drawing tree" and replace with the words "an indentured assembly list".
- 3.21 Hand Soldering - Add the phrase "as modified by Appendix 1 to TRW Proposal 6380.001 entitled "TRW Interpretation of NPC 200-4".
- 4.2 Subcontractor and Supplier Control - Delete this paragraph in its entirety.
- 4.6 Design Review - Delete the first sentence in its entirety.
- 4.7 Parts and Materials Selection Program - Delete this paragraph in its entirety and substitute the following therefore: "Component parts shall be selected from the TRW Preferred Parts List. Parts and materials lists shall be submitted to the Technical Officer for review by the NRO and shall be accompanied by contractor-generated parts and material specifications when these exist or have been prepared for the Program. Applicable military specifications or Established Reliability military specifications need not be submitted, but should be referenced as the governing documents in the procurement of parts".
- 4.9 Parts Application Review - Delete the word "report" in the fourth sentence and substitute the words "work sheets".
- 4.12 Reliability Progress Reports - Delete the words "and quarterly" from this paragraph.

DOCUMENTATION MATRIX

for

QUALITY CONTROL & RELIABILITY

SPEC. PARA.	ITEM	NIMBUS RELIABILITY OFFICER ACTIONS		
		<u>INFORMATION</u>	<u>REVIEW</u>	<u>APPROVAL</u>
3.1	Quality Program Plan			
	Preliminary	X	X	
	Final			X
	Q.C. Manual & Workmanship Manual	X		
3.13	MRB Actions Summary in Monthly	X		
3.18	Contractor Malfunction Report Form			X
	Malfunction Reports (Data from TRW Forms)	X		
	Failure Analyses	X		
	Status Report of Malfunctioning	X		
3.20	Indentured Assembly List	X		
	Parts Lists & Parts Specs		X	
	Parts Specifications	X		
4.1	Reliability Program Plan			
	Preliminary	X		
	Final			X
	Reliability Manual (on file)	X		
4.3	Parts Derating Information	X		
4.4	Reliability Predictions		X	
4.5	Failure Modes Analysis		X	
4.8	Deviations from Screening Specs			X
4.8.1	Summaries of Screening Results	X		
4.9	Stress Analysis (Electronic only)	X		
4.11	Reliability Assessments	X		