POBAL-S, THE ANALYSIS AND DESIGN OF A HIGH ALTITUDE AIRSHIP Jack D. Beemer, et al Raven Industries, Incorporated

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**POBAL-S, THE ANALYSIS AND DESIGN OF A HIGH** ALTITUDE AIRSHIP

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Raven Industries, Incorporated 205 Sast Sixth Street Sioux Falls, South Dakota 57101

15 February 1975

Final Report for Period October 1972 - March 1975

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Balloon						
Balloon film material						
Powered balloon						
Power sources						
Remotely piloted vehicle						
Superpressure balloon						
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#### 1. INTRODUCTION

Considerable effort has been expended during the last several years in the development of unmanned high altitude station keeping vehicles. Such vehicles are airborne platforms capable of loitering above a specific location or geographic area on the earth while maintaining a high altitude. These vehicles have applications encompassing military, civil, and scientific uses. Examples of vehicle concepts include drones, RPV's (Remotely Piloted Vehicles), flying wings, microwave beamed power vehicles, synchronous stationary satellites (not airborne), free floating balloons, tethered balloons, and powered balloons. This report is intended to concentrate on powered balloons. A brief discussion of balloon concepts follows.

Many studies of tethering balloons at altitudes in excess of 18,000 meters (60,000 feet) have been performed. The primary problem associated with this concept is the procurement of a lightweight, high strength tether cable which would make such a system design feasible. Present developments are centered on the use of Kevlar fibers for a dielectric cable. The high cable tensions and system performance characteristics are extremely difficult to predict because of the great changes in the relative wind conditions imposed on such a system. Thus, the primary disadvantage of the tethered balloon concept is the required direct link between the balloon and the ground.

Three types of free floating balloon systems have been studied. One study addressed the problem of setting up and maintaining a network of superpressure balloons such that from a statistical standpoint one of the balloons would be within a specified area for a certain percentage of the time.<sup>1</sup> The actual study looked more closely at the problem of a communications network instead of a down-looking reconnaissance type balloon, but the problems are similar. The disadvantage of this type of system is the obviously high number of balloons required and initial costs which would be incurred. Once the network is developed, then an on-going balloon replenishment program could be set up to maintain the network. One of the main advantages of this type of system is the simplicity of the individual vehicles. Winker, J. A., High Altitude Relay Platform System, Report No. 0669011, Raven Industries, Inc. Final Report, Contract 4691, Task Order 18. 15 May 1969.

The second type of free floating balloon concept utilizes a balloon floating in the stratosphere between 15 kilometer (50,000 feet) and 21 kilometer (70,000 feet) where easterly winds would prevail during much of the year.<sup>2</sup> To attain a loitering capability a reefable parachute would be lowered to a level where westerly winds would exist. In this way the parachute would act as a variable drag device such that a force balance between the balloon and the parachute would be attained so that no horizontal motion would exist. This type of system is entirely dependent upon proper wind conditions existing. This drastically reduces the operational capabilities of the system because of the dependence of the system upon the specific wind conditions. Thus such a system can only be used for a few months of each year.

The third type of station keeping free floating balloon is a concept which has actually been demonstrated and used.<sup>3,4,5</sup> This involves ballasting and valving to attain a reasonable degree of altitude changing and altitude control so that wind directions and speeds could be altered. This type of station keeping concept has been rather limited in duration because the mission generally needs to be terminated shortly after all the ballast is used up. Other limitations of this concept include its dependence upon proper wind conditions existing and of being able to find these advantageous wind fields.

Bourke, Edgan R. II, "Addenum To Presentation On a Unique Approach to Balloon Station Keeping", Raytheon Company. Presented at Earth Observations From Balloons Symposium, American Society of Photogrammetry. Published by Raytheon Company. 7 February 1969.

<sup>3</sup>Nolan, George F., <u>High Altitude Minimum Wind Fields and</u> and Balloon Applications, AFCRL 64-843, Air Force Cambridge Research Laboratories, 1964.

"NoIan, George F., <u>A Study of Mesoscale Features of Sum-</u> mertime Minimum Wind Fields in the Lower Stratosphere, AFCRL 67-0601, Air Force Cambridge Research Laboratories, 1967.

<sup>5</sup>Nolan, George F., "Meteorological Considerations for Tethered and Hovering Free Balloons", Air Force Cambridge Research Laboratories. <u>Symposium Proceedings, Earth Observa-</u> tions From Balloons, American Society of Photogrammetry. February 1969. The work performed under this contract was to result in a design of a superpressure airship capable of an airspeed of 8.18 meter/second (15.9 knot) at an altitude of approximately 21 kilometer (70,000 feet) for a 7 day duration with a payload weighing 890 newton (200 pounds) requiring 500 watts of power continuously.\* A major task under this POBAL-S program focused on the specific system design. The completeness of the design was limited by the availability of funds.

Prior to entering into a specific design of a selected system type, a parametric investigation of various system concepts was performed.<sup>6</sup> The various power sources which were investigated included internal combustion engines, fuel cells, batteries, and solar cells.

The system concept which was chosen utilized a fuel cell as the power source. The parametric analysis revealed that the fuel cell powered system would be cost effective and reliable as a demonstration vehicle capable of meeting the performance specifications.

\*Originally the speed requirement was 10.3 m/s (20 kn) and no power was to be allocated to the payload. During the course of the contract the speed requirement was reduced to 8.18 m/s (15.9 kn) and the payload power requirement was defined as 500 W continuous power. The effort reported on in Section 4.0 uses the original speed and payload power requirements. The design discussed in Section 5.0 uses the newer requirements.

<sup>6</sup>Beemer, Jack D., et al., <u>POBAL-S, R & D Design Evalua-</u> <u>tion Report, Part I, System Concept Choice</u>, Report No. 0273001, Raven Industries, Inc. Air Force Cambridge Research Laboratories Contract No. F19628-73-C-0076. 23 February 1973.

#### DEVELOPMENT OF HIGH ALTITUDE POWER BALLOONS

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The first serious study of the high altitude station keeping powered balloon concept was performed by General Mills, Inc. during the late 1950's.<sup>7</sup> This study described a powered airship which was to carry a payload of 440 to 1320 N (100 to 300 lb) to an altitude of 18 to 24.5 km (60,000 to 80,000 ft) for a duration of 1 to 8 hours. The Mechanical Division of General Mills, subsequently absorbed by Litton Industries, carried out a considerable amount of additional analysis after its Lighter-Than-Air Concepts Study was published. In 1967 Litton discontinued ballooning activities.

Since the first efforts performed by General Mills there was little actual work done until after 1965. At this time Goodyear Aerospace Corporation began work in this subject area which resulted in a report entitled An Investigation of <u>Powered, Lighter-Than-Air Vehicles.<sup>8</sup> This work was performed</u> under the sponsorship of the Air Force Cambridge Research Laboratories. Two basic concepts were studied in this report. The first was an aerodynamically shaped airship which could be flown to and from the 21 km (70,000 ft) design altitude, and the second was a natural shape balloon which only operated at the design altitude. For the second concept at termination of the mission the payload and power plant were to be parachuted back to earth.

The first hardware constructed and used in the manner of a high altitude station keeping vehicle was fabricated by Goodyear Aerospace Corporation.<sup>9</sup> The propulsion system consisted basically of a propeller at one end of a gondola and a rudder at the other. The gondola orientation, or heading, and the rudder position were telemetered to the ground along with other monitored flight information. The rudder position was changed by radio command to make the gondola point in the proper direction. This system was not demonstrated to be

'Anderson, A. A., et al., Lighter-Than-Air Concepts Study, Report No. 1765, General Mills, Inc. Final Report, Contract 1589 (07). 1 September 1957. Revised, March 1960.

<sup>8</sup>Vorachek, Jerome J., <u>Investigation of Powered Lighter-</u> <u>Than-Air Vehicles</u>, GER 14076, Goodyear Aerospace Corporation. <u>AFCRL-68-0626</u>, Final Report, Air Force Cambridge Research Laboratories, Contract No. F19628-67-C-0047. 27 November 1968.

<sup>9</sup>High Altitude Powered Balloon Test Program, Report No. BB-2304, Goodyear Aerospace Corporation. November 1968. controllable. It was likely that it was not controllable because of aerodynamic considerations and because an autopilot was not incorporated into the system.

The next effort pertinent to high altitude station keeping vehicles was performed by Raven Industries during 1969 and 1970.<sup>10</sup> This was the High Platform II program under which the first high altitude, solar powered, ( opiloted airship was successfully demonstrated. The main pupose of this program was to actually demonstrate, at a moderate cost, that a practical high altitude (21 km or 70,000 ft altitude), long duration, station keeping vehicle could be built.

The High Platform II vehicle itself was only a sun seeking vehicle and had a cadmium sulfide solar cell array placed on the balloon envelope such that when the vehicle was oriented toward the sun enough power would be supplied to propel the balloon at a design speed of 10.3m/s (20 kn). Also, the vehicle could only be used for daytime operation since batteries, which would have been necessary for nighttime operation, were not a part of this system. This superpressure balloon was configured with a propeller suspended underneath it on a gondola and was controlled with both moving and stationary horizontal and vertical statilizing surfaces. High Platform II was flown in May of 1970.

The next activity which was initiated was the <u>High Plat-fcrm III Design Study</u> performed by Raven Industries.<sup>11</sup> This was a paper study contract which resulted in a final report describing a preliminary design for a system having a four month operating duration at an altitude of 25.5 km (85,000 ft) with a capability of maintaining a continuous 7.7 m/s (15 kn) air speed. This paper study also generated a limited amount of parametric trade-off analysis information. Of particular importance, this analysis revealed that there was no advantage to utilizing altitude control to minimize the stress levels in the envelope by driving the vehicle up or down with a positive or negative angle of attack respectively.

R-0870025, Raven Industries, Inc., Final report, Contract 4691, Task Order 22. 14 August 1970.

<sup>11</sup>Beemer, J.D., et al., <u>High Platform III Design Study</u>, Report No. 0871005, Raven Industries, Inc., Final Report, Contract 5831. 31 August 1971. The airship designed under the <u>High Platform III Design</u> Study had a volume of 17,000 m<sup>3</sup> (600,000 ft<sup>3</sup>). The envelope length was 94 m (309 ft) and had a fineness ratio of 5.0. It was to be powered with cadmium sulfide solar panels which furnished the necessary electrical power to an electric motor driving a gimbaled propeller which was mounted on the tail of the airship. The horizontal and vertical stabilizing surfaces were to be pressurized with air and the envelope itself was fabricated from a biaxially oriented nylon film. One of the unproven assumptions used in the design of High Platform III was that a pulse charging technique could be used to increase the number of charging cycles available from the battery. Another assumption was that the nylon film would in fact be developed into a successful superpressure The High Platform III Design Study was balloon material. completed in August 1971.

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Shortly after the High Platform III Design Study was completed, the Air Force Cambridge Research Laboratories issued an RFP for a free balloon propulsion system. The basic goal of the system was to keep an 880 N (200 lb) payload on station at a nominal altitude of 18 km (60,000 ft) for a 24 The method of accomplishing this was to utilhour duration. ize altitude control on the balloon such that it could be propelled through a minimum wind field. Goodyear Aerospace Corporation was awarded the contract under this effort.<sup>12</sup> In September, 1972, the Goodyear free balloon propulsion system was flown from Holloman Air Force Base. The system consisted of a natural shape balloon from which a battery powered, electric motor driven propeller was suspended. This system was to have a 24 hour duration, 12 hours of which was to be under powered flight. The nominal thrust required by the propeller was 445 N (100 lb). Due to mechanical failure, the flight of this system was terminated with less than 6 hours of powered flight. During this time it was demonstrated that although the concept was feasible, problems of instability were present.

Because of the sensitivity of station keeping vehicle size, mass, and power requirements for various mission parameters, it was felt necessary to have a general overview of the concept of superpressure high altitude station keeping

<sup>1</sup><sup>2</sup>Vorachek, Jerome J., Edward W. McGraw, John W. Bezbatchenko, Development of a Free Balloon Propulsion System, Goodyear Aerospace Corporation. AFCRL TR-73-0128, Final Report, Air Force Cambridge Research Laboratories, Contract No. F19628-72-C-0072. April 1973.

airships. Thus, the Study of High Altitude Station Keeping Vehicles was performed by Raven Industries.<sup>1,3</sup> This resulted in a final report in March, 1973. It was under this study contract that the HASKV computer program was written to parametrically analyze various system concepts. Also, a vehicle capable of operating at 21 km (70,000 ft) for a few months duration with an average speed of 10.3 m/s (20 kn) carrying a 880 N (200 lb) payload was designed, and the results were presented in the final report.

Under the Study of High Altitude Station Keeping Vehicles Raven Industries utilized its own in-house expertise in electonic systems, superpressure balloon technology, and mechanical hardware design. However, an extensive literature search and subsequent vendor contact effort was spent to gain knowledge of the primary power sources and electric motor. More than seventy companies and organizations active in thermal electric generators, solar cells, fuel cells, batteries, turbine engines, reciprocating engines, and rotary piston engines were solicited for information pertinent to the study. With the information thus gained, it was possible to enter into a parametric analysis in which all vehicle components could be parametrically defined. The parametric work performed showed very clearly the great advantages of using a superpressure balloon material stronger than polyester film and the necessity of using solar power for such extended mission durations.

It was during this latter study contract that the POBAL-S project was begun. The remainder of this report summarizes the work performed under the POBAL-S program and presents the design of the POBAL-S airship.

Beemer, Jack D., et al., Study of High Altitude Station Keeping Vehicles, Report No. 0373003, Raven Industries, Inc., Advanced Research Projects Agency Order No. 1983 Final Report. 15 March 1973.

This section of the report discusses the various aspects of the balloon system design. The intent is to provide a simplified description of the system components. This will be beneficial in understanding the vehicle design and will aid in understanding the computer program. The readers attention is called to Section 5. of this report for a more detailed description of the fuel cell powered airship. The types of vehicle concepts which were studied are shown in Figure 3.1.

#### 3.1 Balloon Vehicle

For the aerodynamic shaped balloon systems, only balloon designs utilizing conventional high altitude superpressure spherical balloon technology were considered in the parametric analysis. This type of balloon has normally been constructed from polyester film laminates. The purpose of lamination is to prevent helium leakage due to pin holing, while the polyester film itself has very low permeability to helium and very high strength characteristics. The use of such materials allows the balloon envelope to be pressurized to a level such that at nighttime, when the radiation conditions may result in the balloon temperature being less than ambient temperature, the balloon will still be superpressured. If the pressure in the balloon goes below ambient pressure, the balloon will go slack and descend in altitude. Typically the duration of superpressure balloons is measured in terms of months, and several balloons have flown well in excess of 400 days. These long durations can be accomplished because it is not required that ballast be used to retain altitude throughout the nighttime.

Variations in material types, density, and acceptable stress levels have been considered in the parametric analysis. Ideas which have been considered include the use of high strength fibers laminated between layers of the balloon film to increase the film strength-to-weight ratio and applying to the film a thermochromic coating which exhibits transitional optical absorption and reflectance characteristics which could possibly help control the supertemperature. These approaches are not believed to be feasible for use with this type of balloon. Technological improvements in superpressure balloon materials will likely be accomplished in the near future, but the higher stressing limits which have been studied parametrically should encompass such improvements,



BATTERY POWERED AIRSHIP

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ENGINE POWERED AIRSHIP



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SOLAR ARRAY POWERED AIRSHIP



EUEL CELL POWERED AIRSHIP



The balloon vehicle itself is defined to include the envelope, the fins or stabilizing surfaces and any attachment hardware. The basic shape is assumed to be that of a Navy Class C airship with a fineness ratio of 5.0. Other fineness ratios have been investigated and it has been determined that near-optimum system design will occur within the range of fineness ratios of 5.0 to  $7.0.^{11}/14$ 

The stabilizing surfaces are assumed to be constructed from air pressurized conical shaped beams (two for each surface) with an impermeable membrane stretched between. (Refer to Figure 5.1 for a detailed sketch of the system.) The beams would be pressurized by use of a very small, low power consumption air compressor. In this way the integrity of the primary envelope is retained and minimal departure from conventional superpressure balloon technology is accomplished.

#### 3.2 Airship Propulsion and Control

The propulsion and gimbal assembly includes the motor or engine for propulsion and the mechanical hardware required to pitch and yaw the propeller. (Refer to Figures 5.3, 5.4, 5.17.) The actual thrust is derived by use of a propeller. The gimbaling mechanism itself is designed using roll nuts and screws powered by small electric motors to provide two-degree freedom of movement for the propeller. The control of the airship is thus accomplished by changing the propeller position by electronic signals provided by an autopilot so that the vehicle will remain within acceptable limits in pitch and yaw. A very important component of the system is the speed reducer which allows the propeller to operate at much slower angular velocity than does the motor or engine powering it. Experience has shown that belt drive systems are highly efficient and acceptable for the use as contemplated here.

#### 3.3 Power Source

The primary variation between system concepts was in the power source used to drive the propeller. In the parametric study the solar cell array, fuel cell, gas turbine, internal combustion engine, batteries, and advantageous wind fields were analyzed. Two of these sources, the solar cell array

"Rueter, Loren L., "Drag Analysis for POBAL-S & HASKV High Altitude Airships", informal paper, Raven Industries, Inc., 10 October 1972. and the advantageous wind fields, utilize ambient energy sources. All other types analyzed either burned fuel or generated their own emf (electromotive force). The solar cell array, fuel cell, and gas turbine powered concepts received the most attention in the analysis. Wankel and Diesel engines were the only two internal combustion engines studied, and parametrically they are quite similar to the gas turbine in concept.

The concept of using only primary batteries for power has been analyzed; and, as anticipated, because of system size it does not appear feasible except for very short duration missions. The advantages of such a concept lie in the simplicity of the design since all that is required is the batteries, mounted somewhere in front of the system center of gravity, with power cables running back to an electric motor.

The gas turbine and internal combustion engine concepts are very similar. These power sources would actually be mounted on the gimbal arrangement and gimbaled as with the electric motor for the electrical type systems. The fuel would be located near the front of the airship so that horizontal stability could be attained. Under this scheme it would not be possible to save the consumed fuel, and consequently a ballonet or pumping and valving scheme must be integrated into the system. The advantage of this type of system as compared to the fuel cell system is that the fuel can be stored in conventional type tanks. Considerations in final system design would have to be given to pumping the fuel from the storage area to the combustion chambers.

The fuel cell powered concept is similar to the solar powered concept in that it provides electrical power to a gimbaled motor/propeller arrangement. The water generated by the fuel cell would be stored and not disposed of. The advantages of storing the water is that the system mass remains constant during operation. Thus, the floating altitude and static trim angle of the airship will not change during the flight. Also, this allows the fuel to be located at that position along the balloon which is required to attain horizontal equilibrium when the system is shut down. The fuel cell concept also requires that the additional heat generated by the fuel cell be radiated. It may be possible to make use of this waste heat in controlling negative supertemperatures, but if one were to shut the system down at night then this heat would not be present. Thus, the system

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would have to be designed as if this capability were non-existent.

For the solar powered concept, the panels of cells, which are integrated to make the array, are placed on the surface of the balloon envelope and are located so that adequate power is delivered to the system for any conceivable sun angle. All individual panels would have to be diode-isolated so that those which are greater than 1.57 radians (90 degrees) from the sun would not act as loads on the rest of the panels. Major attention needs to be paid to the current/ voltage characteristics of the cells at various angles to the sun. These characteristics are temperature dependent, and under the configuration used here each panel would be operating at a different temperature because of radiation effects. The panels are connected either in series or parallel and are electrically integrated. Thus, they form an electrical energy source which will provide the required system power to operate the motor during the daylight hours and, at the same time, charge the batteries which are used for nighttime operation.

The use of advantageous wind fields was analyzed only in the sense that trade-offs between utilizing altitude control and not using altitude control were compared. Without the capability of changing altitude, the use of advantageous wind fields would not be feasible for this system. The most significant problem with this concept is determining where the winds are most favorable. To date, no acceptable wind sensing mechanisms are known to exist which could be applied to this type of system.

#### 3.4 Electrical & Electronic Systems

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Early in this study four different electrical systems were analyzed. The electronic requirements were virtually the same for all concepts. The term "electronics" as used herein includes navigation, command and control, stability control (autopilot), and telemetry.

The navigation unit provides the autopilot with the required error signals based on deviations from the desired station. The command and control assembly provides various switching and housekeeping functions when given commands from either on-board or radio command systems. The autopilot controls the direction of the airship to maintain stable flight. The telemetry system provides the down-link to the command station and provides system and flight evaluation and control data. Each of these systems will be discussed in further detail in Section 5.4.

A stand-by power source is provided and intended for use only if the main power source should experience a failure. The back-up battery powers vital control functions for 24 hours in case of a primary system failure. This would permit attempted restarts and trouble shooting with the option of terminating the flight at a time which best facilitates recovery.

All electrical systems use electric gimbal motors for directing the thrust vector of a propeller. The autopilot must have sufficient power, proper voltage, and correct dynamic characteristics to operate these motors.

The electrical systems were fit into four categories; pure battery, fuel cell, solar cell array, and combustion engine. All systems concepts except the combustion engine systems use an electric propulsion motor having conductors running from a control package, near the center of the balloon, to the motor at the stern. These wires carry the heaviest current in the system over the longest distance and must have very low impedance.

The simplest system, electrically, is a primary (nonrechargeable) battery for the basic power source. The computer inputs for this system were based on using lithiumorganic batteries for the main power source and regulating only the electronics supply voltage. Figure 3.2 is a simplified block diagram for a primary battery system. A CONTRACTOR OF

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Figure 3.2 Battery system block diagram.

The power distribution for the combustion engine system is actually two systems, both supplied by the same alternator. An electrical system similar to that in an aircraft is used for ignition and starting. A second power system is used for electrical and electronic control systems. The mass of the secondary battery for this system is based on silverzinc battery characteristics. Figure 3.3 is a simplified block diagram showing the increased complexity.



Figure 3.3 Combustion engine systems block diagram.

As explained in Section 4.3, the fuel cell system concept was chosen for this study effort. A simplified block diagram of the fuel cell electrical system is shown in Figure 3.4. The power losses in the control package of a fuel cell system are low since the propulsion power is adequately regulated by the fuel cell. The optimum voltage for this system was determined to be 30 volts.



Figure 3.4 Fuel cell system block diagram

The solar cell array system is the most complicated system considered; however, it also has a greater endurance than the other systems. The primary mass contribution comes from the rechargeable battery which was assumed to be made up of silver-zinc cells. One fact learned during this study was that when short days are encountered sizing of the storage battery is determined from limits of charging current rates based upon energy storage efficiency. Silicon solar cell data were used to compute solar array mass. Due to the amount of power conditioning required in a solar cell array system, efficiency of the power distribution system is lower than the other concepts. A considerable number of electrical connections and wires are required in a solar powered system, making it more difficult to fabricate and launch. Figure 3.5 is a simplified block diagram of a solar cell system. The increased complexity over previous systems appears within the control system.



Figure 3.5 Solar array system block diagram.

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#### 4. SYSTEM CONCEPT CHOICE ANALYSIS

A significant portion of the effort under this contract was expended in studying system types and choosing one type for a complete design. This analysis was performed prior to the finalization of system performance requirements and is intended to be a tool for comparison purposes only. This section describes the methods of analysis and presents the results.

## 4.1 Computer Program

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A detailed computer program, HASKV, was used to generate parametric information describing the system designs. A copy of the program and program output examples are included in Appendix A. The HASKV program was developed as an analytical aid in evaluating high altitude station keeping vehicles.<sup>13</sup> It is a versatile yet detailed program. The program can perform calculations involving the vollowing items: 1001

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- 1. Fifty-seven input parameters (constants for parametric equations).
- 2. Class C aerodynamic shape and natural shape balloons
- 3. Six different power sources:
  - a. Gas turbine
  - b. Wankel engine
  - c. Diesel engine
  - d. Fuel cell
  - e. Solar cell array
  - f. Battery
- 4. Altitudes from 16.5 km (54,000 ft) to 30.0 km (98,200 ft) in 1.5 km (5,000 ft) increments
- 5. Altitude control 1.5 km (5,000 ft) or 3.0 km (10,000 ft) excusion
- 6. Wind speeds from 2.574 m/s (5 kn) to 15.44 m/s (30 kn) in 2.574 m/s (5 kn) increments
- 7. Mission time variation
- 8. Balloon diameters up to 200 m (660 ft)

Basically the program determines a system size which is

capable of lifting the required mass. Required mass is a function of input conditions such as altitude, type of power source, wind speed, etc. It includes hull mass, payload mass, and all component masses required to power the system. For a given set of conditions, a plot of lifting capability versus system size, and a plot of required mass versus system size could be generated. These plots for a hypothetical set of conditions are shown below as a function of balloon radius:



# Figure 4.1 Hypothetical system weight and buoyancy versus balloon size.

A unique solution (R') is obtained if the two curves intersect. HASKV performs an iteration on balloon radius until the lifting mass equals the required mass. Output data generated by the program is then printed.

## 4.1.1. Flow Chart

A simplified flow chart of the HASKV computer program is shown in Figure 4.2. Literal phrases are substituted for mathematical expressions as an aid in discussing the program logic. Actual parametric equations are discussed separately.

4.1.1.1 Initialized Data. Variables that are a function of altitude are stored in the main program as arrays. Each element of the array corresponds to a fixed altitude and can be referenced by the main program. This decreases the amount of input required. Air density, helium lift, and pressure ratio are stored for all altitudes. In addition, standard



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sea level pressure and air density are stored.

4.1.1.2 Input Data. Necessary inputs include a heading, 57 input parameters and control cards. The heading may consist of a short phrase indicating the purpose of a run. If no more data are to be read, the program terminates.

The input parameters are used in the parametric equations as constants and are supplied as input variables so that effects of different choices can be analyzed. An example would be skin density per unit thickness. Since the skin density is an input variable, a system using a polyester envelope can be compared directly with one using a nylon envelope. All other parameters remain the same and the parametric equations are still valid. The large number of parameters which can be varied makes the program a powerful analytical tool.

Control cards supply information to the program regarding type of power source, altitude, wind speed, length of mission, and whether altitude control is or is not to be used. In the case of altitude, wind speed, and mission time, the card supplies initial value, maximum value, and the increment between each printing of output data. These control values are applied to the loop counters of the altitude loop, wind loop, and the time loop. Computer time is saved by analyzing specific ranges of interest without generating needless amounts of data.

Control cards may be stacked. After all loop counters have reached their maximum value specified by the present control card, a new control card is read. This enables different power sources, or altitude control versus no altitude control, to be run with the same input parameters. Each time a control card is read the heading, all input parameters with values, and the type of power source used are printed. If no more control cards are to be read, a new heading is read, new input parameters are read, and new control cards are read. When the input is exhausted, i.e., no new heading card, the program is terminated.

4.1.1.3 Altitude, Wind Speed, and Mission Time. These three variables are computed as a function of their respective loop counters. The general form is:

Variable = constant + second constant x counter.

All counters are whole numbers. Thus, altitude is computed as:

15,000 m + 1,500 m x altitude counter.

Initial value, maximum value, and the increment for each loop counter is specified by the control card. Each time the loop is executed, the loop counter is increased by the increment specified. The time loop is executed first, then the wind loop, and last, the altitude loop. Thus, each altitude increment lists data for each increment of wind and each wind increment list data for all time increments. Whenever these three values are calculated, they are printed.

4.1.1.4 Balloon Parameters. The program determines which balloon type is to be used by checking the fineness ratio. This ratio is included in the input parameter list. If the fineness ratio is greater than one, parameters for a Class C shape are calculated. Natural shape parameters can be calculated if the fineness ratio is less than or equal to one. No natural shape calculations were made for POBAL-S.

Such physical parameters as volume, surface area, skin thickness, and hull mass are computed by parametric equations. Data from the input parameter list and the current values of loop variables are utilized. This marks the beginning of the size loop or iteration loop. Consequently, the majority of the equations in this group are a function of balloon radius. At this point, net lift and power required for the balloon size being considered are computed.

4.1.1.5 Power Source Parameters. A decision must be made by the program as to which parametric equations are to be used. This is done by checking the value of K. It is the first parameter specified by the control card. K values and the corresponding power sources are:

Internal Combustion Systems:

- 1 Gas turbine
- 2 Wankel
- 3 Diesel

Electric Systems:

- 4 Fuel Cell
- 5 Solar cell array
- 6 Battery

All internal combustion engines use the same parametric equations. The variations are accounted for in the input parameter list. If K is less than or equal to 3, the internal combustion equations are used. For K greater than 3, the component masses common to the electrical systems are computed. These include the speed reducer and motor. A second check is then made on K. If K is less than 5, fuel cell parametric equations are used. If K is equal to 5, solar array parametric equations are used. For K greater than 5, parametric equations for a pure battery system are used.

The parametric equations of this group compute component masses for the power system. Included are equations for motor mass, fuel mass, battery mass, etc. These equations are functions of the power required computed earlier in the program.

4.1.1.6 Test for Solution. Required mass can now be computed by summing all the component masses for the power source, and payload. A difference is obtained by subtracting required mass from net lifting mass. If the absolute value of the difference is less than one kilogram, the present values are taken as solution values and printed. If this difference is greater than one kilogram, a check is made on the radius. If the radius is less than 100 m, a new radius is computed. The program loops back and computes new balloon and power parameters. Iteration continues within the size loop until a solution is found. If the solution has a radius equal to or greater than 100 m, "maximum size considered" is printed.

Time, Wind, and Altitude Loops. After output is 4.1.1.7 printed, whether maximum size or solution data, the time loop counter is checked. If it is less than the maximum value specified by the control card, the counter is incremented as specified. The program loops back, calculates a new mission time, and begins a new iteration. After the time loop counter reaches the maximum value specified, a similar check is made on the wind loop counter. It is incremented and loops until it reaches the specified maximum value. The process is then repeated for the altitude loop counter. After all loops have been completed, the program loops back and reads new input. With each new input, the loops are executed in turn until they have been completed. Program termination occurs when all input data are exhausted.

#### 4.1.2 Program Nomenclature

The following is a list of variable names used in the computer program. They are listed according to function in alphabetical order. Brief descriptions are included and appropriate units are indicated.

Initialized Data:

HLIFT Helium Lifting Mass Versus Altitude Array; kg/m<sup>3</sup>

PRESR Pressure Ratio Versus Altitude Array

RHO Air Density Versus Altitude Array; kg/m<sup>3</sup>

SPRES Standard Pressure at Sea Level; N/m<sup>2</sup>

SRHO Standard Air Density at Sea Level; kg/m<sup>3</sup>

Loop Counters:

IA Altitude Iteration

IAC Increment of Altitude Control

IT Time Iteration

K Integer for Power Source

KWD Wind Speed Iteration

Input Loop Variables: (Integers)

Altitude Iteration - Alt = 16,500 to 30,000 by 1,500, IA = 1 to 10; meters

IIA Initial Altitude

MIA Max Altitude

NIA Number of Altitude Increments Each Loop

Wind Iteration - VWind = 5 KN to 30 KN, KWD = 1 to 6 IWD Initial Wind Speed MWD Max Wind Speed

NWD Number of Wind Increments Each Loop

Day or Hour Loop - Days = 1 to 10, IT = 1 to 10, HRN = 1 to 24, IT = 1 to 24

IIT Initial Time

MIT Max Time

NIT Number of Time Increments Each Loop

Input Parameters:

ADDM1 Additional Mass - Control Package, Diffuser, etc. Gas Turbine; kg

ADDM2 Additional Mass - Control Package, Regulator, etc., Fuel Cell; kg

ADDM3 Additional Mass - Control Package, Regulator, etc., Solar Array; kg

ADHE Bilaminate Adhesive Mass/Unit area; kg/m<sup>2</sup>

AUTOM Autopilot Mass; kg

BASTM Ballast Mass for Natural Shape Balloon

- BAT1 Battery Mass/Unit Energy (Out), Primary Battery; kg/kW-hr
- BAT2 Secondary Battery Cell Mass/Cell Voltage Corrected for Packaging; kg/V
- BATCC Secondary Battery Capacity Corrected for Cycle Life; kA
- BATCY Secondary Battery Capacity Corrected for Cycle Life; kA-hr
- BCHEF Battery Charging Efficiency

BENGY Back Up Energy (kW-hr)

CD Drag Coefficient

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CELL1 First Order Constant for Fuel Cell Mass; kg/V CELL2 Second Order Constant for Fuel Cell Mass;  $kg/V^2$ CFCM Constant Fuel Cell Mass; kg CMM1 Constant Engine Mass - Gas Turbine; kg CMM2 Constant Motor Mass - Electric Motor; kg CSTRM Constant Structure Mass; kg DUTY Ratio of Fuel Cell Operation Time to Mission Time ECPB Efficiency of Control Package - Battery ECPPS Efficiency of Control Package - Power Source ECPSS Efficiency of Control Package - Subsystem ESPR Speed Reducer Efficiency EM Motor Efficiency EPROP Propeller Efficiency F Free Lift/System Weight FIN Fineness Ratio FINMR Fin Mass Ratio of Envelope Mass GEOF Geometry Factor for Solar Array GLC Gore Length Constant PAYM Payload Mass; kg PNBYPD Ratio of Power Required at Night to That of Day PROP Propeller Mass/Unit Radius Length; kg/m Radiator Mass/Unit Power (Out) - Fuel Cell; kg/kW RAD SA Solar Array Mass/Unit Power (Out); kg/kW

- SFC1 Specific Fuel Consumption Gas Turbine; kg/kW-hr
- SFC2 Specific Fuel Consumption Fuel Cell; kg/kW-hr
- SKIND Mass Density of Envelope Material; kg/m<sup>2</sup>/mm of Thickness
- SKINR Ratio of Average Skin Thickness to Maximum Skin Thickness for an Envelope Constructed of Multiple Thicknesses
- SMAT Stress Allowable for Envelope Material; N/m<sup>2</sup>
- SPR Speed Reducer Mass/Unit Power (Out); kg/kW
- STRMR Structure Mass Ratio; kg
- SUBPOW Independent Subsystem Power Required; kW
- SUPERT Supertemperature/Absolute Temperature
- TERMM Mass of Termination, Telemetry, and Navigation Packages
- TMR1 Tank Mass Ratio Gas Turbine; kg
- TMR2 Tank Mass Ratio Fuel Cell; kg
- TURBOR Turbocharger Compression Ratio
- UFLM Fuel Line Mass/Unit Length Gas Turbine; kg/m
- UMM1 Engine Mass/Unit Power Out Gas Turbine; kg/kW
- UMM2 Motor Mass/Unit Power Out Electric Motor; kg/kW
- VOLTFC System Voltage Fuel Cell

- VOLTSA System Voltage Solar Array
- WIREL Wire Mass/Unit Length Turbine to Battery; kg/m
- WIRE2 Wire Mass/Unit Length Turbine, Autopilot to Gimbals; kg/m
- WIRE3 Wire Mass/Unit Length Kiloamp, Control Package to Motor; kg/kW/kA

- WIRE4 Wire Mass/Unit Power Interconnecting Wire Solar Array; kg/kW
- WIRE5 Wire Mass/Unit Length Solar Array to Control Package; kg/m

Computed Variables:

- ALENG Length of Balloon; m
- ALIFT Available Lifting Mass; kg
- ALPHA Helium Volume/Balloon Volume
- ALT Altitude; m
- BALNM Mass of Ballonet; kg
- BALNR Ballonet Surface Area/Balloon Surface Area
- BBATM Back Up Battery Mass; kg

BATM Secondary Battery Mass; kg

- CELLM Cell Mass Fuel Cell; kg
- DAYS Number of Operating Days
- DELTAP Differential Pressure; N/m<sup>2</sup>
- DIFF Difference Between Available Lifting Mass and Required Mass; kg
- DRAG Aerodynamic Drag; N
- ENVM Envelope Mass; kg
- FINM Fin Mass; kg
- FUELM Fuel Mass Gas Turbine and Fuel Cell; kg
- GL Gore Length; m
- HRHO Air Density at Altitude; kg/m<sup>3</sup>
- HRN Hours of Night; Hours

HRS	Hours	of	Sunlight;	Hours
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NG Number of Gores

PIM Power into Motor; kW

POP Power Out of Propeller; kW

PREQ Power Required; kW

PRESS Pressure at Altitude; N/m<sup>2</sup>

PROPM Propeller Mass; kg

Q Dynamic Pressure; N/m<sup>2</sup>

RADM Radiator Mass - Fuel Cell; kg

RENV Radius of Envelope; m

REOM Required Mass = Sum of Component Masses; kg

RP Radius of Prop; m

S Surface Area of Envelope; m<sup>2</sup>

SPRM Speed Reducer Mass; kg

STRM Structure Mass; kg

SYSM System Mass; kg

TANKM Tank Mass - Gas Turbine and Fuel Cell; kg

TAPEM Tape Mass for Sealing Gores; kg

TBATM Total Battery Mass; kg

TFCM Total Fuel Cell Mass = Tank + Radiator + Cell; kg

THRUST Propeller Thrust = Drag; N

TMM Total Motor Mass; kg

TS Time on Station; - Hours

TSAM Total Solar Array Mass - Array Mass + Interconnecting Wire Mass; kg

TSKIN Thickness of Envelope; mm

TWIRM Total Wire Mass; kg

VOL Balloon Volume; m<sup>3</sup>

VWIND Wind Velocity; m/s

## 4.1.3 Parametric Equations

The computer variables are also referenced and defined in the discussion of equations. To the left of each equation or discussion, a statement number is listed. This number corresponds to the left most number on the compiler listing in Appendix A. The equations are presented in their order of computation.

4.1.3.1 Altitude Control. (23-35)\* A check is made for altitude control and the amount of control specified. When altitude control is specified, skin thickness and power required are computed at the lowest altitude (maximum differential pressure and maximum air density). The solution for floating equilibrium is determined at the maximum altitude (Minimum helium lift).

Variables for pressure, air density, and expansion ratio are determined for the altitude range being considered. For a natural shape balloon, no mass is computed for a ballonet.

(36) Ratio of ballonet surface area to balloon surface area, r<sub>B</sub> (BALNR):

 $r_{\rm p} = 1 - .27 e^{1 \cdot 1.9 \alpha}$ 

 $\alpha$  = ALPHA = Helium volume/balloon volume

If altitude control is not specified, statements 24 and 25 set BALNR equal to zero, and ALPHA equal to one. Statement number 36 is skipped.

(37) Differential pressure,  $\Delta P(DELTAP)$ :

$$\Delta P = P \left( \frac{.862F\alpha + (1+F)\gamma}{(1-.862\alpha) (F+1)} \right)$$

\*See explanation of number, paragraph 4.1.3.
F = F = Free lift/(system weight)

 $\alpha$  = ALPHA + Helium volume/balloon volume

P + PRESS + Ambient pressure at altitude

4.1.3.2 Balloon Equations. All balloon parameters are computed in the SHAPE subroutine. Statement numbers listed here correspond to the compiler printout of the SHAPE subroutine included in Appendix A.

4.1.3.2.1 Natural Shape. Natural shape parameters are based on the following assumptions:

1. Ballast requirement of 10% of gross mass/day

- 2.  $\Sigma^* = .1$
- 3.  $W_{\rm b}/W_{\rm p}^{\star} = .32$
- 4.  $C_D = .33$  Based on (volume)<sup>2/3</sup>

It should be noted that the HASKV program is not completely accurate for a natural shape balloon. Equations for structure mass, propeller radius, and wire lengths are based on a Class C shape. Since the natural shape balloon uses a gondola, structure mass would be larger and wire mass smaller. Also, the propeller radius was sized to operate in the wake of an aerodynamic shape balloon.

(5) Volume,  $\forall$  (VOL):

 $\Psi = 3.45 R^3$ 

R = RENV = Radius of Envelope

(6) Gross lift, G(GROSS):

- G = ¥(b)
- b = HLIFT = Helium lift at altitude

\*SBSC Nomenclature

- (7) Ballast mass, M<sub>b</sub> (BASTM):  $M_{b} = G(1, -.9^{N})$ N = DAYS + Mission time in days
- (8) Envelope mass, M<sub>e</sub>(ENVM):  $M_{e} = .243G$

## 4.1.3.2.2 Class C Shape.

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(13) Surface Area, S(S):  
The basic equation is: S=KL<sup>2</sup>  
L = ALENG = Inflated length  
K = Constant = Function of f  
L = 2Rf and S = 
$$4KR^2f^2$$
  
K as function of f was determined graphically to be:  
K = 2.641f<sup>-1 · 0 + 32</sup>  
Substituting, the computer equation becomes:  
S = (4) 2.641R<sup>2</sup>f<sup>(2-1.0+32)</sup>  
= 10.564R<sup>2</sup>f<sup>.3568</sup>  
(14) Skin thickness, t(TSKIN):

 $t = 1000 (\Delta P) R / \sigma$ 

 $\sigma = SMAT = Material stress allowable$   $\Delta P = DELTAP = Differential pressure$ (15-23) Envelope mass, M<sub>e</sub> (ENVM):  $M_e = (\sigma_a + \rho_e(t) t_{ave}/t) S$   $\sigma_a = ADHE = Adhesive mass/m^2$   $\rho_e = SKIND = Density of envelope material kg/m^2 (mm)$   $t_{ave}/t = SKINR = Factor applied to envelope thick-ness for thickness variation$ (18) Tape mass, M<sub>T</sub> (TAPEM):  $M_T = N (GL) T_w (T_t) \rho_t$ 

> Assume: Tape width,  $T_w = 1.25$  inches = .0318 m Tape thickness,  $T_t = tape + tape$  adhesive = 4t

> > Tape density,  $\rho_t = \rho_e$

 $M_{T} = .0318(N) (GL) (4t) \rho_{e}$ 

=  $.127N(GL)(t)\rho_{a}$ 

N = NG = Number of gores

GL = GL = Gore length

(19) Add tape mass to envelope mass:

$$M_e = M_e + M_T$$

(20) Fin mass,  $M_F$  (FINM):

 $M_{\rm F} = r_{\rm f}M_{\rm e}$ 

 $r_f = FINMR = Ratio of fin mass to envelope mass$ 

- (21) Ballonet mass,  $M_B(BALNM)$ :  $M_B = r_B S(\alpha_a + \rho_e t/2)$
- (23) Total envelope mass, M<sub>e</sub> (ENVM):

$$M_e \sim M_e + M_B + M_F$$

Return to Main Program.

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58) Net lift, 
$$L_g$$
 (ALIFT):  
 $L_g = \forall b_h - M_e$   
 $b_h = HLIFT(IA) = Helium lift at altitude$ 

- (59) Aerodynamic drag, D(DRAG):
  - $D = qC_D^{\Psi \cdot 667}$  q = Q = Dynamic pressure  $C_D = CD = Drag coefficient$

This is propulsion power required out of the propeller. The program repeatedly used PREQ for computing component masses. Its value, however, depends upon the component being considered. For example, if PREQ is divided by propeller effiency, it becomes the power required out of the speed reducer. Its value is changed but the variable name is not. In specific instances where the power in or out of a component is a parameter to be used later, a new variable is defined and stored. (63) Propeller radius, R<sub>p</sub>(RP):

 $R_{r} = .45R$ 

The ratio of .45 of envelope radius is based on an approximation of the balloon wake which optimized propeller performance.

4.1.3.3 Power Source Equations. All component masses of the power source are computed within the power subroutine. Statement numbers listed here correspond to the compiler printout of the POWER subroutine included in Appendix A.

4.1.3.3.1 Combustion Engine Equations.

 $M_{BB} = B_p E_{EU}$   $B_p = BAT1 = Mass coefficient of primary storage$ battery

 $E_{BII} = BENGY = Back up energy$ 

(7) Engine mass, M<sub>E</sub> (TMM):

 $M_E = M_e P_{r \circ q} \rho_o / (\rho CR) + M_E$ 

M<sub>c</sub> = UMM1 = Engine mass/unit power out

 $\rho_{O}$  = SRHO = Standard sea level air density

 $\rho$  = RHO = Air density at altitude

CR = TURBOR = Turbocharger compression ratio

M<sub>E0</sub> = CMM1 = Engine mass at zero power ( Y intercept)

(8) Fuel mass, M<sub>f</sub> (FUELM):

 $M_{f} = sfc(P_{req})t_{os}$ sfc = SFCl = Specific fuel consumption for internal combustion engine

 $t_{os} = TS = Time on station$ 

(9) Fuel tank mass, M<sub>ft</sub> (TANKM):  $M_{ft} = R_{t/f} M_{f} + M_{fl} (.6L)$  $R_{t/f} = TMR1 = Ratio of tank mass to fuel mass -$ I.C. engines M<sub>f1</sub> = UFLM = Fuel line mass/unit length (10) Tail structure mass, M<sub>str</sub> (STRM):  $M_{str} = R_{str} (M_E + M_p + .9M_a) + M_{so}$ R<sub>str</sub> = STRMR = Ratio of structure mass to supported mass  $M_n = PROPM = Propeller and hub mass$  $M_a = ADDM1 = Additional mass required for engine$ operation  $M_{so} = CMM1 = Structure mass when supported mass =$ zero (Y intercept) (11) Wire mass, M<sub>w</sub> (TWIRM):  $M_{w} = .6L(N_1w_1 + N_2w_2)$  $N_1 = 2 = Number of wires$ 

 $N_2 = 3 = Number of wires$ 

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w<sub>2</sub> = WIRE2 = Mass coefficient of command unit to engine wire

4.1.3.3.2 Electric Power Source Equations.

(14) Speed reducer mass, M<sub>sr</sub>(SPRM):

M = SPR = Speed reducer mass/unit power out
P sr(out) = PREQ = Power out of speed reducer

(16) Motor mass, M<sub>m</sub> (TMM):

 $M_m = m_m P_m (_{out}) + C_m$   $m_m = UMM2 = Motor mass/unit power out$   $P_m (_{out}) = PREQ = Power required out of the motor$  $C_m = CMM2 = Motor mass at zero power (Y intercept)$ 

(17) Power into motor, P<sub>im</sub>(PIM):

 $P_{im} = P_{m(out)} / E_{m}$  $E_{m} = EM = Efficiency of motor$ 

(18) Required power out of power source, P<sub>req</sub>(PREQ):

Preq = Pim/Eps + Pss/Ess
Eps = ECPPS = Efficiency of control package for
power source
Pss = SUBPOW = Subsystem power required

E = ECPSS = Efficiency of control package for subsystem power

4.1.3.3.2.1 Fuel Cell.

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(20) Cell mass, 
$$M_C$$
 (CELLM):  
 $M_C = C_0 + C_1 V + C_2 V_2$   
 $V = VOLTFC = System voltage for fuel cell$   
 $C_0 = CFCM = Fuel cell mass at zero volts (Y inter-
cept)$   
 $C_1 = CELL1 = Coefficient for fuel cell mass/volt$   
 $C_2 = CELL2 = Coefficient for fuel cell mass/volt2$   
(21) Fuel mass,  $M_F$  (FUELM):

M<sub>f</sub> = afc P<sub>fc(out)</sub> t<sub>os</sub>D sfc = SFC2 = Specific fuel consumption of fuel cell
P<sub>fc(out)</sub> = PREQ = Power required out of fuel cell
D = DUTY = Duty cycle or ratio of operating time to mission time

Fuel mass is considered independent of the fuel cell and is printed separate of fuel cell mass.

(22) Fuel tank mass,M<sub>ft</sub>(TANKM):
 M<sub>ft</sub> = R<sub>t/f</sub><sup>M</sup>f
 R<sub>t/f</sub> = TMR2 - Ratio of tank mass to fuel mass

(23) Radiator Mass, M<sub>r</sub> (RADM):

Mr = mr<sup>P</sup>fc(out)
Mr = RAD = Radiator mass/unit power out of fuel
r cell

(24) Fuel cell mass,  $M_{fc}$  (TFCM):  $M_{fc} = M_{c} + M_{ft} + M_{r}$ 

4.1.3.3.2.2 Solar Array.

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(31) Power required from battery,  $P_{OB}$  (POB):  $P_{OB} = P_{im} (P_N/P_D) + P_{ss}/E_{ss}$  $P_N/D = PNBYPD = Ratio of power required at night to that of day$ 

(32-35) Secondary battery mass, M<sub>B</sub>(BATM): A battery mass is first computed based on the capacity

(amp - hr) of the battery. The charging current required to reach full charge during daylight hours is then computed. If it exceeds the maximum allowable charge current for the battery, the number of parallel strings is increased. The amount of increase is equal to calculated charge current divided by allowable charge current. Battery mass is now sized by charging current and not capacity.

(32) M<sub>R</sub>(BATM):

 $M_{B} = P_{OB}(B_{S}) \mathcal{P}_{N}/B_{CY}$ 

B<sub>g</sub> = BAT2 = Ratio of cell mass to cell voltage corrected for packaging losses. 1000 A

 $T_N = HRN = Hours of night$ 

B<sub>CY</sub> = BATCY = Battery capacity corrected for number of charge - discharge cycles.

(33) Charging current, I<sub>c</sub>(XIC):

 $I_c = B_{cy}/(T_s E_B)$   $T_g = HRS = Hours of sunlight$   $E_B = BCHEF = Battery charging efficienty = elec$ trical to chemical conversion

(35) Battery mass sized by charging current, M<sub>R</sub>(BATM):

 $M_{\rm B} = M_{\rm B} (I_{\rm C}/B_{\rm CC})$ 

B<sub>CC</sub> = BATCC = Maximum allowable charge current for battery

(39) If  $P_N/P_D$  is less than one, motor mass is increased for second motor,  $M_m(TMM)$ :

 $M_m = M_m + P_{im}(E_m) (P_N/P_D)m_m + C_m$ 

All variables as defined previously.

(40) Power required out of solar array, Posa(PREQ):

 $P_{OBB} = P_{req} + 1.22 P_{OB} E_B / ECP_B$ 

- 1.22 = Ratio of charging voltage to discharging voltage.
- $ECP_B = ECPB = Efficiency$  of control package for battery

(41) Solar array mass, M<sub>sa</sub>(TSAM):

Msa = PosaFg(msa+w4)
Fg = GEOF = Geometry factor
Msa = SA = Solar array mass/unit power out
w4 = WIRE4 = Interconnecting wire for solar array

4.1.3.3.2.3 Battery.

(46) Primary battery mass, M<sub>PB</sub>(TBATM):

 $M_{PB} = B_{p}(P_{req}T_{s} + E_{BU})$ 

All variables previously defined.

### 4.2 Analysis of Parametric Data

A series of graphs have been developed which summarize the computer output of the parametric study. These graphs, along with other pertinent information, were the basis for the selection of an optimum vehicle choice to meet the mission requirements. The basic power sources considered in this study; namely, solar cell array, fuel cell, battery, gas turbine, Diesel engine, and Wankel engine have been plotted. For reasons explained below and in Section 4.3, the most thorough comparison was made between solar cell array and fuel cell powered systems. By analyzing these graphs, comparisons can be made between these power sources to determine the most optimum system for a given set of conditions. In addition to the power source comparisons, these graphs show the parameters to which a particular system is most sensitive; such as, balloon material type and stress limit, free lift, coefficient of drag, and mission requirements (duration, altitude, speed, payload mass, and payload power). The system sensitivity to certain parameters is discussed in more detail in Section 4.2.2. Essentially then, this analysis has explored mission, feasibility, and construction parameters; and this analysis has helped to define the final mission requirements.

#### 4.2.1 Discussion of Graphs

The following graphs, Figures 4.3 - 4.9 were derived using a standard value for the basic design parameters. Generally one of these parameters was varied while the remainder were set at the standard values. The standard parameter values are:

Material type - biaxially oriented Nylon 6 Material stress limit - 8300 N/cm<sup>2</sup> Altitude - 21 km Free lift - 20% Coefficient of drag - .05 Duration - 7 days Payload mass - 90 kg Payload power - 0 W



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Figure 4.5 Effects of altitude on system design.

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Figure 4.7 Effects of using more than one material thickness on propulsion power and system mass.

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Solar Cell A/C\*18-21 km Vn/Vd = .5

Solar Cell A/C 18-21 km V//Vd = .2

Solar Cell 21 km

Solar Cell A/C 18-21 km

Fuel Cell A/C 18-21 km

Fuel Cell 21 km

\*A/C = Altitude Control with an average velocity of 7.7 m/s.

Note: All curves generated for nylon film with a stress of 12,400 N/cm<sup>2</sup>







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Figure 4.9 Effects of payload mass and power requirements on propulsion power.

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Velocity ratio - .333 (Solar cell array only)

Tank mass ratio - .5 (Fuel cell only)

Sunlight - 12 hr/day (Solar cell array only)

4.2.1.1 Discussion of Figure 4.3. The graphs presented in Figure 4.3 compare the propulsion power and system mass of all the basic concepts considered in this study contract. The power values shown represent the net power required out of the propeller to propel the airship forward; i.e., thrust multiplied times velocity. The mass versus duration and power versus duration curves appear similar because mass is proportional to the square root of the propulsion power cubed.

Since system power and mass are excessively large for a solar cell array system operating at 10.3 m/s (20 kn) air-speed, it was decided to fly 5.1 m/s (10 kn) at night and 15.4 m/s (30 kn) during the day to give a 10.3 m/s (20 kn) average for 24 hours. Thus, the solar cell array curves are shown with a  $V_N/V_D$  ratio of 10:30 ( $V_M/V_D = .333$ , see Figure 4.4). By flying at 5.1 m/s (10 kn) airspeed at night the battery mass required to operate the system while the solar cells are inoperable is reduced by a factor of 46. This reduces the system mass considerably as noted on the mass versus duration curve. Here the crossover with the fuel cell system is between 5 and 6 days, whereas on the power versus duration curve the crossover is at 18 days. This results because the power value furnished by the solar cell array must be sufficient for 15.4 m/s (30 kn) operation whereas the other concepts operate continuously at 10.3 m/s (20 kn).

On these base data curves the charge-discharge cycles for the batteries have been considered; and consequently, the solar cell array power and mass requirements increase slightly as the number of charge-discharge cycles for the batteries increase. On the power versus duration curve, three solar cell array curves are plotted for 10, 12, and 14 hours of sunlight to allow for operation of the solar powered airship at different latitudes and times of year. With 2 hours less sunlight the propulsion power required increases approximately 11% whereas with 2 additional hours of sunlight the propulsion power decreases approximately 8%.

The power required and the system mass are excessively high, as shown, for the battery case. The best available batteries 254 W-hr/kg (115 W-hr/1b) are presented. Batteries will not be considered in any of the other graphs since system size becomes too large beyond a one day mission.

The base data curves, as well as all remaining curves, show a fuel cell system utilizing a TMR value of .5; i.e., the tank mass is .5 times the fuel mass. The relative advantage of using a lightweight tank can be shown by using a TMR value of .85. For a 7 day mission, the power required drops by approximately .5 kW and system mass by approximately 20% for the TMR value of .5 as compared to .85.

The gas turbine, Wankel and Diesel engine curves are all hypothetically superior power sources in terms of propulsion power required and system mass. However, none of these power sources have been tested for high altitude operation. A development program would need to be performed in order to instill confidence in any of these systems, whereas the fuel cell and the solar cell array have been used for space flights with high reliability. Also, fuel cells and solar cells are available. The Wankel and Diesel curves are much lower than the gas turbine curve due to a lower specific fuel consumption, i.e., .024 kg/kW-hr (.4 lb/hp-hr) versus .73 kg/kW-hr (1.2 lb/hp-hr). All three of the internal combustion power sources would require either a ballonet or pump and valving scheme to maintain altitude as fuel is con-This would require additional power and system mass sumed. which has not been included in these curves. These curves consequently would be shifted higher on the graph to compensate for the additional power and mass. Since these power sources are not considered reliable or tested sources, this effort was not pursued.

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Discussion of Figure 4.4. Wind velocity is one of 4.2.1.2 the most sensitive parameters for any of the given systems. It has been decided that the most favorable winds exist at the 21 km (70,000 ft) altitude level. The first two graphs of Figure 4.4 show the effect of velocity on propulsion power and system mass. The velocity scale of the graphs is average velocity so that a comparison can be made between the two systems although the solar cell system has been designed to fly at higher velocities during daylight hours. For the solar powered system, power increases from approximately .5 kW at 5.1 m/s (10 kn) to approximately 3 kW at 7.7 m/s (15 kn), and from 7.7 to 10.3 m/s (15 to 20 kn) power increases from 3 kW to 13 kW. If the system size were constant, propulsion power would increase as the cube of the velocity; however, since the system necessarily grows larger to accommodate the increased propulsion system weight the power increases even more than the cube of the velocity.

The system mass for the solar cell nearly doubles between 5.1 and 7.7 m/s (10 and 15 kn) and triples between 7.7 and 10.3 m/s (15 and 20 kn). Beyond an average velocity of 10.3 m/s (20 kn) the system mass grows even faster.

The third graph of Figure 4.4 was plotted to determine the optimum flight velocity for day and night operation for a solar cell powered vehicle to obtain a 10.3 m/s (20 kn) average airspeed for a 24 hour period. By flying 15.4 m/s (30 kn) during the day, while the solar cells are powering the vehicle, and 5.1 m/s (10 kn) during the night, on battery power, system power and mass are minimized. However, this curve is relatively flat near the optimum velocity ratio and slight deviations from a  $V_{\rm N}/V_{\rm D}$  value of .333 would be acceptable.

4.2.1.3 Discussion of Figure 4.5. The three graphs of Figure 4.5 show the effect of altitude on propulsion power, mass, and skin thickness. As altitude is increased, less power is required due to lower density air. This, along with a lower superpressure which results because of the decreased absolute pressure, reduces the thickness of the envelope. As the envelope thickness decreases, the system mass consequently becomes lighter. By going from 18 to 21 km (60,000 to 70,000 ft) the propulsion power for a solar cell system decreases by approximately 25% (6,850 kg to 5,150 kg). But even more important is the decrease in skin thickness. The envelope skin thickness for a solar cell system drops from 390 µm (15.4 mil) to 220  $\mu$ m (8.7 mil). The 220  $\mu$ m (8.7 mil) material could possibly be manufactured by laminating two layers of nylon whereas the 15.4 mil material would require a quad-laminate. This would increase system mass slightly since two additional layers of adhesive would be required for the quad-laminate. The computer program assumed a bi-laminate material with one thickness of adhesive. By going to multi-laminate material the system mass would be even larger than the graph shows.

4.1.1.4 Discussion of Figure 4.6 The first graph of Figure 4.6 shows power versus maximum stress allowable for a solar cell array and a fuel cell system employing polyester and nylon films. As shown, either system is very sensitive to the type of and maximum allowable stress of the material. Both nylon and polyester have been plotted for stress levels from 8,300 to 12,400 N/cm<sup>2</sup> (12,000 to 18,000 lb/in<sup>2</sup>). This graph does indicate the need for a materials study; for example: if a nylon material with an allowable stress of 12,400 N/cm<sup>2</sup> (18,000 lb/in<sup>2</sup>) could be used an approximate savings of 65% could be realized in propulsion power for a solar cell system

as well as a substantial decrease in system mass.

The second graph of Figure 4.6 shows the sensitivity of the systems to the coefficient of drag, the parameter for which very little reliable data have been generated. All of the graphs in this series utilize a coefficient of drag of .05 which is based on analysis and past experience with a high altitude airship.<sup>10</sup>,<sup>14</sup> For a solar cell system, the graph shows propulsion power increasing 2.5 times as  $C_D$  increases from .04 to .06.

Free lift is another parameter to which the system is very sensitive as shown in the third graph of Figure 4.6. The minimum free lift required is dependent on the negative supertemperature. It was determined that the minimum free list should be 20% to maintain pressurization at the 21,000 m (70,000 ft) altitude level. Beyond 20%, as shown by the graph, system power requirements, as well as mass, grow very rapidly for either the solar cell or fuel cell vehicles.

4.2.1.5 Discussion of Figure 4.7. The graphs presented in Figure 4.7 compare the power and mass of the basic systems with the power and mass of systems which utilized more than one material thickness for the balloon construction. The yraphs show the tradeoff for both a solar cell array and a fuel cell system using either two or three material thicknesses. This requires a junction between the different thicknesses of material. Since stresses are highest near the largest diameter of the balloon and diminish near the ends, lighter gauge materials can be used at the nose and tail ends. This reduces the balloon mass and minimizes the system size. The two material thickness case would incorporate the thinner material at the nose, the heavier material through the midsection, and the thinner material again at the tail end. The same technique is used in the three material thickness case with two additional locations added to change material thickness. For a solar cell array powered system using two mater-ial thicknesses, a savings of 27% can be realized in system power and 37% in system mass. By going to three material thicknesses, a savings of 35% can be realized in system power and 48% in system mass. Thus, by varying the material thickness at discrete locations in the envelope a substantial savings in power and mass can be accomplished.

4.2.1.6 Discussion of Figure 4.8. The comparison with and without altitude control is shown in Figure 4.8 by the curves labeled A/C for altitude control. The altitude control curves are plotted using a velocity of 7.7 m/s (15 kn) since the

reason for using altitude control is to seek out a minimum wind field, whereas the curves without altitude control are plotted with a velocity of 10.3 m/s (20 kn). The solar cell array altitude control curves are plotted with V<sub>N</sub>/V<sub>D</sub> values of 5/25 10/20 to determine the most favorable comand bination of day-night velocities to obtain a 24 hour average of 7.7 m/s (15 kn). By flying 10.3 m/s (20 kn) during the day and 5.1 m/s (10 kn) at night the solar cell power and system mass are minimized. The propulsion power as well as mass for both solar cell array and fuel cell is substantially larger by incorporating altitude control. These curves were generated with a nylon material skin stress of 12,400 N/cm<sup>2</sup>  $(18,000 \text{ lb/in}^2)$  in order to obtain a solution. Also, altitude control complicates the system design and construction of the system.

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4.2.1.7 Discussion of Figure 4.9. Payload requirements in the range from 0 to 90 kg (0 to 200 lbm) and from 0 to 2 kW affect the fuel cell system propulsion power as shown in Figure 4.9. It should be recalled that the power values shown are in addition to the payload power, inefficiency losses, gimbal operation, and electronic system requirements. The payload mass has little effect as would be expected, since the 90 kg (200 lbm) payload mass is such a small part of the total system mass. The payload power variation does, however, make significant changes in the system propulsion power requirements.

#### 4.2.2 Sensitivity Analysis

An analysis was performed to determine the sensitivity of the system design to small changes in numerical values of all design parameters. The HASKV computer program was used to generate data for a one per cent variation of each parameter. Each parameter was varied independently, and all variations were taken as positive. Thus, parameter X became X +  $\Delta X = (1.01)$ . Except for X, all the other parameters were the same. A complete solution was required for each parameter that was varied. The system mass change,  $\Delta M$ , and absolute percentage change,  $|\Delta M/M|$ , were calculated. The following table gives the results of the analysis in order of decreasing sensitivity.

The most sensitive design parameter is the allowable material stress, SMAT, where a 1% increase reduces the system mass by over 4%. The next most sensitive design parameter is the envelope material density, SKIND, where a 1% increase will increase system mass by 3.7%. Material thickness factor, SKINR, significantly affects the system design. By constructing the envelope from different material thicknesses, as discussed in Section 4.2.1.5, a considerable savings in system mass can be realized. Parameters such as free lift, F, and supertemperature, SUPERT, greatly influence the system design as noted by the mass changes. Prediction of these parameters is very critical because of their influence on system mass. It is obvious that discretion must be used in all assumptions if a feasible system is to be designed.

Parameter Increased By 1%	Mass Change 	Absolute Mass Change 
SMAT*	-66.86 kg	4.01 %
SKIND	61.81	3.70
SKINR	55.83	3.35
F	43.55	2.61
SUPERT	27.30	1.64
SFC2	10.74	.644
CD	10.53	.631
PAYM	9.77	.585
SUBPOW	9.44	.566
TMR2	4.87	.292
CFCM	4.74	.284
FINMR	4.73	.283
CELL1	4.72	.283
VOLTFC	4.71	.282
ADHE	4.68	.280
PROP	4.65	.279
RAD	4.62	.277
UMM2	4.55	.273
STRMR	4.50	.269
FIN	4.08	.245
EPROP	- 1.65	.099
ESPR	- 1.65	.099
EM	- 1.53	.092
ECPPS	- 1.47	.088
ECPSS	58	.035
CMM2	.05	.0029
WIRE3	.05	.0029
BENG4	.03	.0018
CELL2	.02	.0012
CSTRM	.01	.00059

### \*See Section 4.1.2 for definition of nomenclature.

TABLE 4.1 SENSITIVITY OF SYSTEM MASS TO VARIOUS DESIGN PARAMETERS

#### 4.3 System Concept Choice

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The parametric study investigated concepts applicable to the system requirements. Other than the engineering analysis of the graphs there are several other factors which influence the choice of the system concept to be designed for the mission. The primary factors are cost, availability, reliability, vulnerability, and logistics. There is little specific information available at this time on any of these factors since this is a specialized design utilizing state-of-the-art components almost exclusively. However, general comments regarding the effect of each of these factors are discussed below. In addition to this discussion a System Concepts Comparison table, Table 4.2, has been compiled summarizing the primary factors and should be referred to.

Reliability of various system components and complexity of the entire system which determines feasibility is the most important choice factor. Solar cell arrays and fuel cells are proven and reliable power sources. Fuel cell operational designs encompassing environments ranging from undersea to outerspace and including underground use have been accomplished. Solar cells as well have a proven record for outerspace flights and have been used on a short duration powered balloon flight.<sup>10</sup>

Batteries are a very reliable power source; however, as discussed in Section 4.2.1.1, a battery powered vehicle becomes excessively heavy for flights beyond a one day mission.

Reliability of internal combustion engines and gas turbines has not been proved for altitudes above 12 km (40,000 ft). Above this altitude ignition cannot be assured and a turbocharger is required to maintain a high compression ratio. A heater may also be required for the fuel. These additional components would necessarily complicate the design of these power sources and decrease reliability. The internal combustion engine and gas turbine engine could someday prove to be the most favorable power sources for short duration (one week), but without a development effort they must be considered unreliable.

Cost is considered to be an important choice factor. However, there are other serious considerations. Since only parts of this system will be recoverable (see Section 5.5) it is necessary to compare the cost effectiveness of various system concepts under normal operational use. Of the various types of power sources considered it is highly likely that

SYSTEM CONCEPT (POWER SOURCE)	Advantages	DIBADVANTAGES	MANUFACTURING COSTS	AVAILABILITY	RELIABILITY
Solar Array	Extended duration for future development	Array likely not recoverable Cost			
		Complexity - Electronics	High	6 mo1 year	Good -
		System size large for 7 day duration			Face 110nt
Fuel Cell	Proven	Development necessary	Moderate	l year	Good -
	relledility	Fuel & Tanks - "Exotic"			excetteu <i>c</i>
		High light-off speed			
	System size	Unproven for high altitude	Low		The law Maria
Gas Turdine	minimized Cost	Development necessary	to Mođerate	T Act.	FAIT - GOOD
	COSC	Requires altitude stabili- sation			
		Gimbaling of engine			
*********		Reating may be required			
	System size	Unproven for high altitude			
Wankel	minimized	Development necessary	Low	6 mo.	Fair - Good
	Cost	Requires altitude stabili- Mation			
		Gimbaling of engine			
		Heating may be required			
	System size	Unproven for high altitude			
Diesel	minimized	Development necessary	Low	6 mo.	Fair - Good
	Cost	Requires altitude stabili- zation			
		Gimbaling of engine			
		Excessively large system			
Batteries	Simplicity	Cost	High	4 mo.	Excellent
		Structure design			

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# TABLE 4.2 SYSTEM CONCEPTS COMPARISON

the solar array would be most difficult, if not impossible, to retrieve. Since the solar cells are adhered to the balloon surface and cover a large area they cannot be detached in flight and the balloon itself is not considered retrievable. For long duration missions the economic problem is not as serious since the solar cell cost can be amortized over a longer period of time.

The fuel cell is considered recoverable; however, for safety reasons the tanks may be separated before being released from the balloon and parachuted separately. There is also a possibility that the fuel cell and tanks may be damaged upon impact. To keep from damaging the fuel cell a midair snatch recovery may be desirable.

All components of the internal combustion and gas turbine power sources are considered recoverable, but here again a snatch recovery may be required to eliminate impact damage.

Except for variations in power source costs all other components of the various systems, such as motors, reducers, telemetry, structures, propeller, etc., will incur similar expenses providing they are of the same size. It is generally conceded, however, that the smaller the system the lower the cost.

Availability of power sources and components is of prime consideration. Development of components must also be taken into account in the lead time necessary for procurement since the majority of the components are unique to the system design; and consequently, they are not off-the-shelf items. There are no major problems anticipated in procurement and no definite advantages of one type over another; however, actual procurement time necessary for the various power sources and components can only be estimated at this time.

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Vulnerability is not considered to be a very important factor for variations in system concept. Because of the fragile nature of the balloon itself, necessary design measures such as wear patches and protective coverings are required of any of the power source systems and components. Since the mission requirement is for a station keeping vehicle the system is not vulnerable to impact shocks associated with launches and landings.

The logistics involved will naturally affect the operational costs of the system. However, except for the fuel cell LO<sub>2</sub> and LH<sub>2</sub> logistics costs would not vary significantly between system concepts; and, as with vulnerability, logistics is not a very important factor in making a tradeoff between the systems.

In review of the System Concepts Comparison table and the graphical analysis, if it is assumed that all concepts are feasible, then reliability and cost are considered to be the most important factors. Since all of the low cost systems have unproved power sources these systems are being ruled out without an R & D program to develop a gas turbine, rotary piston, or Diesel engine.

As mentioned previously, the battery choice can be ruled out since it is not operationally feasible because of system size. The two remaining power sources, fuel cell and solar cell array, are considered the only feasible sources for a system.

The fuel cell concept appears attractive for missions up to one week in duration. Beyond one week the fuel cell system becomes increasingly large due to the additional fuel required to propel the system. As mentioned, the fuel cell is a very reliable, proven source with little development effort necessary. With operational restrictions and increased cost, the solar array powered vehicle is not considered as being competitive with the fuel cell powered system for short duration. It should be noted that for extremely long duration missions the solar array concept would be the only feasible choice.

The final choice then for this 7 day mission was the fuel cell powered vehicle. Even though the biaxially oriented nylon film has not been fully investigated it was decided to assume its use in the design because of the relative advantages of using this film as compared to polyester film. The parametric analysis reveals that employing altitude control is not justified and would compromise the reliability of the system. When altitude cannot be controlled a nominal altitude of 21.0 km (70,000 ft) is desirable for minimum winds. Also, skin thickness, power and mass requirements decrease as altitude increases so that 21.0 km (70,000 ft) is advantageous in optimizing the system as compared to 18.0 m (60,000 ft).

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## 5. SYSTEM DESIGN

The system design for the POBAL-S powered airship is based on the use of an aerodynamic shaped superpress re balloon meeting the following performance requirements\*.

Duration	7 day under continuous operation
Airspeed	Constant at 8.18 m/s (15.9 kn)
Altitude	Constant at 21 km (70,000 ft)
Payload Weight	890 N (200 1b)
Payload Power	Continuous 500 W

The airship is propeller driven with the power being supplied by a fuel cell through an electric motor. The overall airship is shown in Figure 5.1.

## 5.1 Vehicle

The POBAL-S vehicle consists of the balloon, which is the basic floating platform, along with the stern structure and gondola which provide mechanical support interfacing between the balloon and the components contained within these structures.

#### 5.1.1 Balloon

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The balloon is the inflatable member of the system. From a manufacturing and technology standpoint, the balloon is considered to include not only the basic envelope, or hull, but also the fins. These components are discussed below.

5.1.1.1 Hull. The POBAL-S hull is a Class C shape with a fineness ratio of 5.0. The inflated length is 113 m (371 ft) and the volume is  $29,270 \text{ m}^3$  (1,034,000 ft<sup>3</sup>). The primary envelope material is a biaxially oriented Nylon 6 film lamina-tion.\*\* The airship hull is shown in Figure 5.2.

The envelope load distribution for a pressurized aerodynamic shape hull is approximately that of a cylinder; longitudinal skin loading being about half the circumferential loading. In addition, the loading is proportional to the distance from the axis to the envelope, measured perpendicular to the envelope. Thus, the loads are maximum at the maximum

\*See footnote on page 7.

\*\*Tests were performed on this material and are reported on in Appendix B.



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PANEL		32 Cores	(103 htt)	PAREL 5:	52 Gores	(152 µm)	
PANTL	2:	40 Gores	(127 µm)	PANLL 6:	40 Gores	(127 µm)	
PATES	÷.	52 Gores	(152 µm)	FINEL 7:	32 Gores	(102 htt)	
PANEL	4 :	52 Gores	(203 um)				

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Figure 5.2 Envelope gore configuration.

diameter and minimum at the fore and aft ends. Minimum hull mass requires a material whose thickness can be varied to maintain a nearly constant stress over the length of the balloon.\* Skin thickness variation for the POBAL-S hull is accomplished by constructing the hull in seven sections using four different thicknesses. The four thicknesses required are obtained by using multiple laminations of 25.4  $\mu$ m (1 mil) material. Presently, 25  $\mu$ m (1 mil) is the maximum thickness available for biaxially oriented Nylon 6 in the 1500 mm (59 in) width. For the design stress of 9,825 N/cm<sup>2</sup> (14,250 lb/in<sup>2</sup>), the four laminates are 102  $\mu$ m (4 mil), 127  $\mu$ m (5 mil), 152  $\mu$ m (6 mil), 203  $\mu$ m (8 mil).

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The gore seals should be constructed as a butt seal with an outside tape 5.1 cm (2 inches) wide and inside tape 3.8 cm (1.5 inches) wide. Outside tape thickness will be 25  $\mu$ m (1 mil) greater than the inside tape thickness. A seal construction requirement is that the total tape thickness, excluding adhesive, be 25  $\mu$ m (1 mil) greater than the maximum laminate thickness being sealed. The fore and aft sections use a total tape thickness of 127  $\mu$ m (5 mil), the 127  $\mu$ m (5 mil) sections use a tape thickness of 152  $\mu$ m (6 mil), the 152  $\mu$ m (6 mil) sections use a tape thickness of 178  $\mu$ m (7 mil), and the center section uses a tape thickness of 229  $\mu$ m (9 mil).

The balloon should be assembled as described below. First, all sections are sealed leaving the bottom longitudinal seal open. Then the sections are sealed together still leaving the bottom seal open. A final trim is made to remove stress concentration points at junctions, and then the final longitudinal seal is made along the length of the balloon. End caps are finally installed. All external and internal attachments should be installed on individual gores prior to sealing of the gore. In instances where this is not feasible, attachments should be made as early in the assembly sequence as possible.

All loads on the balloon are carried by the balloon acting as a pressurized beam. The critical bending moment which causes the beam to buckle is<sup>7</sup>:

 $M_{\perp} = \Delta P \pi r^{\perp}$ 

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\*Hull mass would increase by 11% for the same hull constructed with longitudinal gores of a single 152  $\mu$ m (6 mil) laminate.

where  $\Delta P$  is the differential pressure and r is the radius of the cross section.

The force, F, required to buckle the balloon at any given section is:

 $F = M_{C}/L$ 

where L is the axial length from the section to the point where the force is acting. Substituting for  $M_C$  the equation becomes:

 $F = \Delta P \pi r^{5} / L$ 

Upon examination of the equation, it should be noted that  $\Delta P$  is constant for any section of the balloon. Also, since the radius is cubed, its influence on the maximum supportable load F is much greater than the lever arm L. Thus, it is reasonable to expect the critical buckling section to be located at the tail where r is small. This will occur at the tail since the radius approaches zero but must still carry the bending moment due to the stern structure and propulsion components.

The buckling force is calculated with the assumption that it acts at the gimbal axis, one meter aft of the balloon. A differential pressure of 238.5 N/m<sup>2</sup> (0.346  $10 \pm 10^{2}$ ) is used. This assumes an operating altitude of 21 km (70,000 ft), 20% free lift, and -10% supertemperature. This is anticipated to be the minimum pressure condition. Station 111.13 corresponds to the location, where the tail reinforcing battens terminate. At this location r has a value of 2.266 m (7.435 ft) and L has a value of 2.870 m (9.416 ft). Using these values, the critical buckling load is determined to be 3,038 N (683 lb). Since the actual applied load at the gimbal is only 801 N (180 lb), the margin of safety is 2.8. This is more than adequate to account for transient loading conditions.

If F is set equal 801 N (180 lb) the equation can be solved for the critical buckling pressure. Using a safety load factor of 1.5:

 $\Delta P_{crit} = (1.5) (801 \text{ N}) (L) / (\pi r^3)$ 

 $= 62.9 \text{ N/m}^2$ 

For the POBAL-S balloon at 21 km (70,000 ft) with 20%

free lift, 94.3 N/m<sup>2</sup> (0.37  $lb/in^2$ ) corresponds to a supertemperature of -12.6%. The margin of safety for -10% supertemperature is high, but because of the uncertainty in predicting minimum supertemperature, a pressure sensor should be used to shut the propulsion system down before critical buckling pressure is reached. A manual remote override should be provided in case the automatic switch malfunctions.

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1.1.1.

5.1.1.2 Fins. Fin sizing and location, as shown in Figure 5.1, is based on a scale model airship similar to POBAL-S.<sup>15</sup> Total surface area for the cross configured fins is 284.8 m<sup>2</sup> (3,066 ft<sup>2</sup>). The mean aerodynamic center is 48.88 m (150.5 ft) aft of the center of buoyancy.

The fins are constructed of biaxially oriented Nylon 6 material and consist of a 25  $\mu$ m (1 mil) membrane supported by two air inflated cones. The support cone material is 51  $\mu$ m (2 mil) thick. Physical dimensions of a fin are approximately 5.8 m (19 ft) by 12.2 m (40 ft). The base diameter of a cone is 1.32 m (4.33 ft), and the tip diameter is 0.20 m (0.66 ft).

The cones are separate of the balloon envelope and are pressurized by an air pump, Gast model 0330. Relief valves would be installed on individual fins or within the pressurizing system. The air pump can operate continuously, can pressurize to 68% of ambient pressure, and can develop a flow rate of 9.4 x  $10^{-4}$  m<sup>3</sup>/ sec (2 ft<sup>3</sup>/min) at no back pressure. Because constant pressure can be maintained, the problem of structural failure due to leakage is avoided.

Since the cones are air inflated separate of the balloon, the critical buckling section will be at the hull/fin interface, providing the cone pressure is always greater than the hull pressure. The maximum allowable differential pressure for an inflated cone is a function of the hoop stress. The hoop stress is '':

 $S = pR/(t \cos \theta)$ 

where p is the differential pressure, R is the radius of cir-

Airship Model with Stern Propellers, NASA TN D-1026, Langley Research Center, National Aeronautics and Space Administration. January 1962.

<sup>16</sup>Roark, Raymond J., <u>Formulas for Stress and Strain</u>, Mc-Graw-Hill. 1965. cumference, t is the material thickness and  $\Theta$  is the half cone angle.

The maximum allowable differential pressure is reached when the hoop stress equals the allowable material tensile stress,  $F_t$ . By rearranging the equation, the maximum inflation pressure is determined by:

 $p' = (F_t t \cos \Theta)/R'$ 

where the prime designates maximum values.

If the material is stressed to  $8,274 \text{ N/cm}^2$  (12,000 lb/ in<sup>2</sup>), the present conical configuration can withstand a differential pressure of  $6,305 \text{ N/m}^2$  (0.914 lb/in<sup>2</sup>). This is more than 1.3 times the ambient pressure at 21 km (70,000 ft). Maintaining a cone pressure greater than the balloon pressure is dependent upon the air pump and not limited by the material stress. Based on a supertemperature of 10%, the maximum balloon differential pressure will be 1,330 N/m<sup>2</sup> (0.193 lb/in<sup>2</sup>) or less than 0.3 times the ambient pressure.

Since the air pump performance is adequate to maintain a cone pressure greater than the hull pressure, the following analysis takes the hull/fin interface as the critical buckling section.

Air loads are assumed to be distributed as follows:

- 1. Fin aerodynamic loads are applied evenly along the quarter cord.
- 2. All loads are reacted at the base of the cones.
- 3. Deflection of the cone is computed for an evenly distributed load.
- 4. Skin friction drag of the membrane is neglected.

Since the lift force acts at the quarter cord, the forward cone reacts three-fourths of the load and the aft cone one-fourth. It is only necessary to show the integrity of the forward cone. Critical buckling force is dependent upon the balloon's minimum differential, and is given by:

 $F_b = M_c / .5L$ 

where  $F_b$  is the buckling force,  $M_c$  is the critical bending

moment, and L is the inflated length of cone (.5L is used since the load is assumed to be evenly distributed.

The critical bending moment, M, is:

 $M_{C} = \Delta P \pi R^{3}$ 

where  $\Delta P$  is the cone differential and R is the cone base cross section radius. Substituting for  $M_C$  the equation for critical buckling forces becomes:

 $F_{\rm b} = 2\pi R^3 \Delta P/L$ 

For the present configuration:

 $\Delta P = 2.38.5 \text{ N/m}^2 (0.0346 \text{ lb/in}^2)$ 

R = .66 m (2.2 ft)

L = 5.8 m (19 ft)

The critical buckling load is 73.8 N (16.6 lb). It is a vector sum of three-fourths of the fin lift and all of the aerodynamic drag acting on the cone. An approximate drag force is determined by assuming the cone to be a cylinder with a splitter plate having a  $C_D$  value of  $0.59^{1.7}$ . Based on frontal area and 8.158 m/s (15.86 kt) airspeed, the drag force is 9.5 N (2.1 lb). The critical lift force reacted by the cone is:

 $F_{LC} = (73.8^2 - 9.5^2)^{\frac{1}{2}}$ 

= 73.2 N (16.5 lb)

Since the cone reacts to three-fourths of the aerodynamic lift of the fin, the total lift generated by the fin,  $L_f$  is 97.7 N (21.9 lb). This load is the critical buckling lift for the fin.

A maximum allowable angle of attach for the fin can be calulated from:

 $L_f = qataS_t$ 

where q is the dynamic pressure, at is the fin lift curve

<sup>1</sup> Hoerner, Sighard F., Fluid-Dynamic Drag. 1958.
slope,  $\alpha$  is the fin angle of attack, and S<sub>t</sub> is the fin area.

The fins are expected to operate with a lift curve slope in the range of 1.7 to 2.9  $rad^{-1}$  (0.03 to 0.05 deg<sup>-1</sup>). This analysis assumes a value of 2.3  $rad^{-1}$  (0.04 deg<sup>-1</sup>) for  $a_t$ . In addition a 1.5 factor, n, is applied to the critical fin load as a transient condition.

For a velocity of 8.158 m/s (15.86 kn), the angle of attack must be less than 0.16 rad (9.1 deg) to prevent buckling. Since the fins are located on the balloon axis, the angle of attack limitation can be applied directly to the balloon. The additional control provided by the gimbaled thrust vector, should enable the autopilot to maintain an angle of  $\pm.052 \text{ rad}$  ( $\pm 3 \text{ deg}$ ). The fin design has a margin of safety near 2.0.

The deflection of the beam by the "Method of Dummy-Unit Loads" is evaluated as:<sup>18</sup>



where M is the bending moment in terms of x, m is the bending moment in terms of x due to a unit load acting at the section where y is to be avaluated, E is the modulus of elasticity, and I is the section moment of inertia.

For an evenly distributed load of "w" per unit length:

 $M = wx^2/2$ 

and for a unit load at the end point:

m = x.

Section moment of inertia for a thin film beam is:  $I = \pi r^{3}t$ 

where:

 $r = .1 + .56 x/L (x_0 is opposite cantilevered end)$ 

Bruhn,	E.F., Ana	lysis an	d Design	of	Flight	Vehicle
Structures,	Tri-State	Offset	Co., Cin	cinn	ati. 1	1965.

The integral becomes:

$$Y = \frac{L^{3}w}{2E\pi t(.56)^{3}} \int_{0}^{L} \frac{x^{3} dx}{(x + .1786L)^{3}}$$

For the design parameters, the integral yields a deflection of 0.043 m (0.14 ft). Based on test results from pressurized cylinder beams a deflection of 0.15 m (0.49 ft) to 0.23 m (0.75 ft) is predicted.<sup>7</sup> However, the loading condition was an end load versus an assumed distributed load. Classical beam analysis shows the end deflection due to a distributed load to be 37.5% of the deflection due to an end load condition. When this factor is applied to the values predicted by the tests, the deflection range is 0.056 m (0.18 ft) to 0.086 m (0.28 ft). This indicates that buckling will occur before any significant deflection takes place due to cone bending.

#### 5.1.2 Stern Structure

The stern structure houses the power train and the gimbal mechanism which controls the airship flight stability and direction. It is composed of three sections as shown in Figures 5.3 and 5.4. They are designed to react bending, torque, and thrust loads into the envelope. All of the framework is constructed from 6061-T6 aluminum tubing with 1.25 mm (0.049 in) wall. This alloy combines excellent weld properties with good machinability. The design is based upon an engineering stress analysis to show integrity of the structure. The analysis was modeled after a similar effort on a tail mounted gimbaled propeller system using a unit load solution in combination with expected loading conditions<sup>19</sup>. It is expected that the maximum load condition will result from gyroscopic moments and yaw forces on the propeller.

The stern assembly is attached by lacing the battens to the hull. This is a proven design but requires additional rigging time during launch. No attachment should be made to the termination ring since it is not a structural member but is included only to protect the envelope and maintain batten rigidity during launch.

<sup>1</sup>Soudry, J. G., <u>Structural Analysis Report</u>, <u>Silent Joe</u> <u>II Program</u>, GER 14356, Goodyear Aerospace Corporation, Advanced Research Projects Agency, Order No. 1255. 29 April 1969.



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Figure 5.3 Stern structure, side view.

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Figure 5.4 Stern structure, end view

# 5.1.3 Gondola

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The gondola houses the fuel cell with associated hardware and fuel tanks, the payload, the command telemetry system, control unit, and the autopilot. Pratt & Whitney derived the original design of the framework under a subsequent contract with the sponsor; and except for some changes in the framework, the design shown in Figure 5.5 is essentially identical to the original design<sup>20</sup>. One of the primary purposes of the expendable membrane support is to protect the fuel cell, associated hardware, and payload upon termination of the mission as discussed in Section 5.5. When the flight is terminated the entire gondola will be parachuted back to Since high winds may be encountered upon descent, earth. the impact vector may be as much as .79 rad (45 deg) causing the gondola to roll after impact. Thus, the parachute will be cut loose upon impact, preventing the gondola from being dragged. The landing shock of the gondola will be attenuated by the aluminum radiator panel, the crushable aluminum honeycomb base, the external frame, and the elastomeric shear mounts.

The water storage bag will be fabricated from  $1.7 \text{ N/m}^2$  (5 oz/yd<sup>2</sup>) urethane coated nylon fabric. This bag will store approximately .205 m<sup>3</sup> (45 gallons) of water which is to be discharged by the fuel cell.

The total weight is 5,007 N (1,126 lb) when the expendable membrane support, housekeeping electronics, and parachute are all accounted (See Section 5.1.4). The center of gravity of the gondola is located 35.9 m (118 ft) from the nose of the balloon as shown in Figure 5.1. The C.G. is maintained in the same position horizontally but shifts approximately 0.18 m (7.1 in) down as the fuel is consumed.

The gondola is suspended beneath the balloon by a distance equal to the height of the gondola in order to minimize drag and reduce the tension on the load lines. This results in the suspension lines pulling at an angle of .93 rad (53.5 deg) from the vertical as seen in Figure 5.6. The total load in the suspension lines is 8675 N (1950 lb) and one-half of this load is transmitted into each side of the

<sup>2</sup><sup>o</sup>Handley, L. M., <u>Study of Fuel Cell System for Powered</u> <u>Balloon</u>, PWA-4792, Pratt & Whitney Aircraft. Air Force Cambridge Research Laboratories, AFCRL-TR-73-0447. September 1973.



Figure 5.5 Gondola.





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balloon. To prevent overstressing of the envelope under pressurized conditions the hull in this area is designed with 203  $\mu$ m (8 mil) instead of 152  $\mu$ m (6 mil) material (See Figure 5.3).

Three load patches on either side of the gondola, as shown in Figures 5.1, 5.6 and 5.7, are used to hold the gondola. The load patches would be constructed from a high strength nylon fabric and would be adhered to the balloon skin using a liquid adhesive.\* The patch would be of a catenary type construction with nylon webbing sewn along the parabola to distribute the load uniformly throughout the patch. Load lines, which would be lightweight steel cables, would lead from a "V" ring on the patch to an eyebolt on the edge of the platform.

Seven additional patches, two on each side and three directly over the gondola, will be used during the launch sequence. These are shown in Figure 5.6 and are discussed further in Section 5.5.

#### 5.1.4 Weight Summary and Distribution

Table 5.1 summarizes the system weights; i.e., a breakdown of the weights of major vehicle components along with weights of components contained within the structure. The horizontal position of the center of gravity is also presented. The center of gravity distances are measured from the nose of the airship. The airship center of buoyancy is located at 49.9 m (164 ft) from the nose. Vertical alignment of the airship center of gravity to the center of buoyancy determines the gondola location. i

## 5.2 Propulsion Drive Train

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The propulsion drive train consists of the motor, speed reducer, and propeller with the electrical energy being supplied by the fuel cell which is discussed in Section 5.5.1. The framework which houses the drive train was discussed in Section 5.1.2. The following is a summary of the drive train power allocations:

\*Tests were performed to determine structural integrity of the patches. These tests are reported on in Appendix B.



Figure 5.7 Patches for gondela suspension.

Item Balloop	Weight* (N)	<u>C.G. (m)</u>
Fins Hull Total Balloon	168.7 <u>12,039.8</u> 12,208.5 (2,744.7 lb)	98.20 50.92 51.57 (169.20 ft)
Stern Structure Motor Converter Gimbal Motors Speed Reducer Structure Prop	34.3 222.7 3.9 68.7 192.3 <u>196.2</u> 718.1 (161.4 1b)	113.84 (373.51 ft)
Gondola Payload Housekeeping Electronics Fuel Cell H <sub>2</sub> Tank (Full) O2 Tank (Full) Water Bag (empty) Radiator Piping and Wiring Frame Structure Parachute Assembly Total Gondola	889.8 $290.4$ $636.1$ $685.0$ $1,650.2$ $22.2$ $97.9$ $66.7$ $348.1$ $311.0$ $5,007.4$ $(1,125.8  lb)$	35.9 (117.8 ft)
Wire, Gondola to Motor	216.8 (48.7 lb)	74.0 (242.8 ft)
Total System Weight	18,150.8 (4,080.7 1b)	49.9 (163.6 ft)

\*All weight calculations assume the acceleration due to gravity to be 9.81 m/s<sup>2</sup>. This estimates the gravitational forces to be 0.7% greater than actually experienced at float altitude.

TABLE 5.1 SYSTEM WEIGHT SUMMARY

Contraction (1).

	Input Power	Efficiency	Output Power
Motor	1.80 kW	75%	1.35 kW
Speed Reducer	1.35 kW	96%	1.30 kW
Propeller	1.30 kW	78%	1.01 kW

### 5.2.1 Propulsion Motor

The propulsion motor preliminary design was furnished by Lear Motors Corporation. Several motor vendors had been contacted, and this particular design appeared to be most advantageous. The prime factors in the selection of the propulsion motor, in addition to the normal considerations of power, speed, etc., were efficiency, weight, and high altitude capability. It was felt that the high altitude capability could best be provided by a brushless DC motor. Most brushless motors consist of an electronic unit and a rotating machine. It is beneficial to have the mass of the rotating machine very small in order to provide flexibility in the design of the gimbaled structure. The brushless concept fits this need nicely by having an electronic converter unit which may be located remotely from the rotating machine if desired. Also, the motor is very light weight and small in size. A specific advantage of the Lear Reno motor is the ability to start and stop the motor with a 0-5 VDC, TTL (transistor-transistor logic) compatible logic signal. This eliminates the heavy contactors required to start and stop other types of propulsion motors. It should be noted that this feature is available due to the use of transistors as switches in the electronic converter. A more powerful motor would necessitate the use of SCR's (silicon controlled rec tifiers), which are difficult to turn off, and thereby, require external circuity involving power losses and weight penalties.

The Lear design is not the DC to AC inverter driving an AC motor scheme used by many brushless motor manufacturers. Instead, a patented means of electronic commutation is employed. The efficiency of the Lear motor and electronics was the highest of all motors. The proposed design develops 1.35 kW (1.81 hp) at a speed of 1050 rad/s (10,000 rpm). The current drain is 60 A steady state at 30 VDC and 72A while starting.\* The start-up time of the motor under full

\*The design received from Lear Motors Corporation was based on 24 VDC operation. The value for current has been adjusted for 30 VDC operation. load is estimated to be three minutes maximum. Size 00 copper wire is proposed to carry current from the fuel cell to the motor. This wire has a weight of 5.9 N/m (0.404 lb/ft), and two wires are required. The efficiency of the motor, including its electronic converter, is 75%. The size of the motor is 12 cm dia x 12 cm (4.7 in dia x 4.7 in) and the converter is 32 x 32 x 16 cm (13 x 13 x 6.3 in). The total weight is 247 N (58 lb) and the heat sink requirements are 216 W at  $50^{\circ}$ C for the converter plus 245 W at  $90^{\circ}$ C for the motor. Figures 5.8 and 5.9 show physical characteristics of the motor and converter respectively. Performance characteristics are shown in Figure 5.10.

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## 5.2.2 Speed Reducer

A speed reducer with a reduction ratio of 133:1 is required to interface the 10,000 rpm motor with the 75 rpm propeller. Figures 5.11 and 5.12 illustrate the proposed belt type reducer. The Gates Rubber company was contacted for design information concerning sheave diameters, size of belts, belts per stage, and number of stages for optimum efficiency. The three stage reducer will have an operating life of 4000 hours at 96% efficiency. Maximum allowable temperature for continuous operation is  $82^{\circ}$ C. Physical size is estimated to be 36 x 34 x 18 cm (14 x 13 x 7.1 in) and the weight is estimated at 68.7 N (15.4 lb).

### 5.2.3

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Sensenich Corporation provided the aerodynamic design of the propeller to be used on POBAL-S. The design was based upon requirements furnished by Raven plus the flow distribution into the propeller disc area based upon tests performed on a tail powered airship model.<sup>15</sup>

The basic design details are as follows:

Number of blades3Diameter10.36 m (34.0 ft)Rotation speed75 RPMThrust119 N (26.8 lb)Efficiency78%Volume of each blade $0.3613 \text{ m}^3 (12.76 \text{ ft}^3)$ Surface area of each $7.273 \text{ m}^2 (78.29 \text{ ft}^2)$ 

Figure 5.13 shows the propeller outline with sections. The graphs of Figure 5.14 show the distribution of surface



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Figure 5.11 Speed reducer.

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BLADE SECTION AT % OF RADIUS

Figure 5.13 Propeller blade shape.



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area and volume elements of each propeller blade.

The fabrication design was derived at Raven Industries and is based upon past experience using two and three bladed light weight propellers. Because of the size of the propeller required to efficiently propel the airship at these altitudes it is essential that extreme weight saving techniques be used. Consequently, the propeller will be constructed utilizing 6.4 mm thick x 6.4 mm cell (.24 in thick x .25 in cell) Hexcell honeycomb of .018 mm (.0007 in) aluminum with face sheets of .051 mm (.002 in) Mylar and .127 mm (.005 in) aluminum as shown in Figure 5.15. Honeycomb design and construction is more detailed than other types of structure, however, it represents the best choice when a high stiffness to weight ratio is required. Until the fabrication technique is actually tested, the weight of the propeller cannot be accurately estimated, but based upon the recommended construction the estimated weight is 196 N (44 lb).



Figure 5.15 Propeller blade construction.

## 5.2.4 Thermal Analysis

A simplified thermal analysis has been performed to determine if special precautions will be necessary in controlling the operating temperature of the motor or speed reducer. The analysis accounted for heat dissipation only through radiation. Consequently, the temperature estimates are higher than would actually be experienced since convective and conduction heat losses are ignored. The motor, electronic converter, and speed reducer were considered as a single unit mounted on a common heat sink. The maximum allowable operating temperatures are  $90^{\circ}$ C for the motor,  $50^{\circ}$ C for the converter, and  $82^{\circ}$ C for the speed reducer. The radiating surface areas were estimated as  $452 \text{ cm}^2$  (70 in<sup>2</sup>),  $3072 \text{ cm}^2$  (476 in<sup>2</sup>), and  $3165 \text{ cm}^2$  (491 in<sup>2</sup>) respectively for a total of 6689 cm<sup>2</sup> (1037 in<sup>2</sup>).

The radiation impinging the unit is considered to be 1390 W/m<sup>2</sup> (129 W/ft<sup>2</sup>) solar, 119 W/m<sup>2</sup> (11 W/ft<sup>2</sup>) albedo, and 250 W/m<sup>2</sup> (23 W/ft<sup>2</sup>) terrestial. The absorption factor is estimated to be that of a white body, 0.22 for solar or albedo and 0.98 for terrestial.<sup>21</sup> The absorption area is considered to be one half of the total radiating area for solar and albedo radiation which results in heat inputs of 102 W solar and 9 W albedo. The absorption area for terrestial radiation is estimated to be 1510 cm<sup>2</sup> (234 in<sup>2</sup>) which results in 37 W terrestial input. The internal heat generated by the motor (with converter), and speed reducer is estimated to be 500 W. Thus, the total heat input is 648 W. Using an emittance of 0.92 for a white body at 50°C in the Stefan-Boltzman equation, the total radiating surface area required is estimated to be 11,410 cm<sup>2</sup> (1769 in<sup>2</sup>) which is almost twice the radiating area available.<sup>21</sup>

It appears that special precautions may need to be taken to avoid overheating any of the power train components. Several solutions can be considered, such as, separating the converter from the motor and speed reducer, shading the unit from solar radiation, using various coatings for thermal control, increasing the radiation area, or any combination of the above alternatives. However, a more exact analysis should be performed prior to incorporating any of these alternatives.

#### 5.3 Flight Control System

The purpose of the flight control system is two-fold; it keeps the airship stable, and it permits remote control of the flight course. Although lighter than air vehicles move slowly, they require some form of control to achieve stable flight. The flight control system consists of a twoaxis gimbal mechanism which is driven by an autopilot and associated sensors. The propulsion motor is mounted on a platform which is gimbaled to provide pitch and yaw devia-

"Van Vliet, Robert M., Passive Tomperature Control in the Space Environment, MacMillan & Co., 1965. tions. This structure is discussed in Section 5.4. Reversible electric gimbal motors drive rotary-to-translational actuators which are essentially independent of each other. A block diagram of the control system is shown in Figure 5.16. Each channel is a servo-system which reacts to an error signal that represents the difference between a desired attitude and the actual attitude. Also, rate damping is provided to prevent oscillations.

The estimated gimbal design characteristics are as follows:

Gimbal position range =  $\pm 0.785$  rad ( $\pm 45$  deg)

Maximum gimbal rate = 0.0524 rad/s (3 deg/s)

Maximum acceleration =  $0.00873 \text{ rad/s}^2 (0.5 \text{ deg/s}^2)$ 

Gimbal lever arm = 17.8 cm (7.01 in)

Gimbal friction torque = 2 Nm (1.47 ft-lb) @ 0.0524 rad/s

Gimbal static moment of inertia =  $167 \text{ Nms}^2$  (123 ft/lb/s<sup>2</sup>)

Propeller gyroscopic torque on gimbal = 81.6 Nm (60.2 ft-1b)

Gimbal position deadzone = 0.008 rad (0.458 deg)

Using these estimates, the preliminary design of the control system was completed. In the final design and stability analysis these values would be expected to change slightly. In the following sections each servo loop is examined in greater detail.

#### 5.3.1 Gimbal Mechanism

The gimbal mechanism of the control system contains the mechanical components represented in Figures 5.16 and 5.17. Mechanical parts include the gimbal motor, actuator, and position transducer. The yaw axis is formed by gimballing the propulsion assembly within the gimbal frame. A ballscrew operating between the frame and speed reducer housing provides yaw control. The pitch axis is made independent by gimballing the frame within the support structure. Pitch control is provided by a baliscrew operating between the support structure and a lever attached to the pitch shaft. The key factors in this mechanism are reliability and mini-



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Figure 5.16 Flight control system block diagram.



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Figure 5.17 Gimbal mechanism.

mum weight.

The gimbal motor chosen is a DC, permanent magnet, high speed motor with a reducing gearhead attached. The high speed motor with gearhead has a low starging threshold. good position accuracy, and moderate starting torque. Figure 5.18 is a representation of the gimbal position loop including the servo amplifier. The transfer function for the mechanical portion of this loop was developed as:<sup>22</sup>

$$\frac{\Theta_{\mathbf{G}}(\mathbf{S})}{\Theta_{\mathbf{m}}(\mathbf{S})} = \frac{K}{T^2 \mathbf{S}^2 + 2 \zeta T \mathbf{S} + 1}$$

where:

$$K = \frac{L}{KgK_{L}}$$

$$T = \sqrt{\frac{J_{\rm G}L^2}{2\pi\eta K_{\rm L}^2 K_{\rm S}}} = \frac{L}{2.51 K_{\rm L}} \sqrt{\frac{J_{\rm G}}{\eta K_{\rm S}}}$$

$$2\zeta T = \frac{K_{\rm D}L}{K_{\rm S}K_{\rm L}}$$

$$\zeta = \frac{K_{\rm D}L}{K_{\rm S}K_{\rm L}2\,\rm T}$$

 $\Theta$  = angular displacement

n = efficiency of the ballscrew

G = subscript denoting gimbal

J = moment of inertia

 $K_D$  = damping coefficient due to kinetic friction

 $K_{\alpha}$  = step down ratio of gearhead

<sup>22</sup> Beemer, Jack D., et al., <u>POBAL-S R & D Design Evalua-</u> <u>tion Report, Part II</u>, Report No. 0673006, Raven Industries, Inc. Air Force Cambridge Research Laboratories, Contract No. F-19628-73-C-0076. 6 July 1973.  $K_{r}$  = length of lever arm

 $K_{g} = twist of shaft$ 

S = the Laplacian operator

I = lead of the ballscrew (linear motion per revolution)

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m = subscript denoting motor

The total starting moment of inertia of the gimbal is:

 $J_{G} = J_{I} + J_{P}$ 

where  $J_I$  is the moment of inertia required to overcome the inertia of the gimbaled mass and  $J_p$  is the moment of inertia required to balance the gyroscopic torque forces caused by the gimbaling of the spinning propeller. Friction is assumed to be negligible at this point. The  $J_I$  term is estimated to be 167 Nms<sup>2</sup> (123 ft/lb/s<sup>2</sup>), and  $J_p$  is calculated to be 9347 Nms<sup>2</sup> (6895 ft-lb-s<sup>2</sup>) which yields a value of 5514 Nms<sup>2</sup> (7018 ft-lb-s<sup>2</sup>) for  $J_G$ .



Figure 5.18 Gimbal position loop.

The Kg factor represents a torsional displacement in the gearhead shaft and was computed to be  $3.90 \times 10^{-4}$  Nm/rad (251 ft-1b/deg). The K<sub>D</sub> parameter is a gimbal damping constant which is very difficult to predict. It is primarily dynamic friction of the gimbal bearings and will be highly dependent on lubricant and temperature. By estimating the required gimbal torque, T, to be 2 Nm (1.5 ft-1b) at an angular velocity,  $\omega$ , of 0.0524 rad/s (3.0 deg/s) K<sub>D</sub> is:

 $K_D = T_{\omega} = 38.2 \text{ Nms} (28.2 \text{ ft-lb-s})$ 

The ballscrew selected is Saginaw Steering Gear type 0500-0125-SGT. It has a lead of 3.13 mm/rev (0.124 in/rev), a 1.3 cm (0.5 in) diameter shaft, and must be at least 28 cm (11.0 in) long. At that length the ballscrew can withstand 4450 N (1000 lb) compression load and travel at 25.4 cm/s (10 in/s). The gimbal lever arm required is 17.8 cm (7.01 in) long, which means the travel rate would be approximately 0.93 cm/s (0.37 in/s) to achieve 0.0524 rad/s (3.0 deg/s). This is well within the rated capabilities of the ballscrew. The SGT series is a standard ground thread model which has a back-lash assumed to be tolerable. If deadzone is a problem in the final design, there are other ballscrew models available with preloading to further reduce backlash.

The motor-gearhead combination selected is a Globe Motors Part No. 54539-10 which has the following characteristics:

Input Voltage: 24 VDC

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No Load Motor Speed: 942 rad/s (8,996 rpm) Armature Inertia: 3.7 x 10<sup>-7</sup> Nms<sup>2</sup> (2.7x10<sup>-7</sup>ft 1b 5<sup>2</sup>) Input Current: 0.45 A Output Shaft Size: 0.794 cm (0.313 in) dia. x 1.27 cm (0.50 in) long Size: 3.175 cm (1.24 in) dia. x 7.34 cm (2.89 in) long Breakaway Voltage: 3.6 VDC Mass: 0.2 kg

Torque Ratio: 17

Speed Ratio: 27.94

Efficiency: 40%

Motor Torque: 0.00706 Nm (1 oz-in)

The motor speed at rated load is approximately 640 rad/s (6400 rpm). The actual gimbal rate produced with this design is 0.0681 rad/s (3.9 deg/s) which is greater than the minimum requirement 0.0524 rad/s (3.0 deg/s). The motor transfer function was calculated to be:<sup>22</sup>

 $\frac{\Theta(S)}{V(S)} = \frac{24.8}{S(1+0.445 S)} \frac{rad/s}{V}$ 

The most common feedback transducer used in servo loops is a potentiometer. These are normally high quality linear devices which are available from many manufacturers. The step-up gears are used to drive the position feedback potentiometer in order to economically get maximum resolution. Typically, single turn units have 4.71 rad (270 deg) of rotation, and the gimbal swing is 0.785 rad (45 deg) or a total of 1.57 rad (90 deg). Therefore, a step-up of 1:3 may be used. Referring to Figure 5.16 the feedback transducer output is to represent 0.785 rad (45 deg) of gimbal movement. The maximum output is  $\pm$  15 VDC. The analog of gimbal linear displacement,  $\delta_{\rm G}$ , is:

$$\delta_{\rm G}^{\rm d} = \frac{15V}{.785 \rm rad} \, \Theta_{\rm G}$$

where  $\Theta_{\mathbf{G}}$  is the gimbal angular displacement.

The servo amp gain must be sufficient to drive the motor when the maximum permissible gimbal error occurs. Since the maximum permissible position deadzone ( $\Delta \Theta_{\rm C}$ ) is assumed to be 0.008 rad (0.46 deg), and the breakaway voltage of the motor is 3.6 V, the approximate gain of the servo amplified ( $K_{\rm a}$ ) must be:

$$x_a = \frac{3.6V}{(\delta_G^2) (\Delta \Theta_G)}$$

This gain is within the current "state-of-the-art" for existing servo amplifiers. The open loop transfer function for this preliminary design can be summarized as:<sup>22</sup>

$$\frac{\delta_{G}^{*}(S) = K_{a}K_{m} L (3)V}{\epsilon(S)} = \frac{K_{a}K_{m} L (3)V}{K_{g} (2.35)K_{L}} \left( \frac{1}{\frac{J_{G}L^{2}}{2\pi K_{L}^{2}\eta K_{g}}} \frac{S^{2} + \frac{K_{D}L}{K_{g}K_{L}} S^{+1}}{\frac{S(1+0.445S)}{2\pi K_{L}^{2}\eta K_{g}}} \right)$$

where:  $K_a = 23.6$ 

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$$K_{m} = 24.8 \frac{rad/s}{V} (1420 \frac{deg/s}{V})$$

$$K_{g} = 3.90 \times 10^{4} \text{ Nm/rad } (502 \text{ ft-lb/deg})$$

$$L = 5.05 \times 10^{-4} \text{ m/rad } (2.89 \times 10^{-5} \text{ ft/deg})$$

$$V = 15 V$$

$$K_{g} = 27.94$$

$$K_{L} = 0.178 \text{ m } (0.584 \text{ ft})$$

$$J_{G} = 9514 \text{ Nms}^{2} (7018 \text{ ft-lb-s}^{2})$$

$$\eta = 0.9$$

$$K_{D} = 38.2 \text{ Nms } (28.2 \text{ ft-lb-s})$$

Several factors must be considered in the final design of the inner control loops in addition to any stability enhancement features:

1. A means must be provided to limit electrical power to the gimbal motor before the gimbal assembly reaches its mechanical limit.

- 2. Mechanical couplings must be designed to minimize deadzone and tests must be performed to determine the minimum gimbal displacement necessary to start the motor.
- 3. Circuits must be designed such that ground loops, oscillations, and hot spots are precluded.

## 5.3.2 Autopilot & Sensors

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The autopilot contains the circuitry that provides the gains, filtering and dampening necessary to insure stable flight. The autopilot for this vehicle consists of a pitch and yaw channel, both completely independent of each other.

A block diagram of the autopilot is shown in Figure 5.19. The time constants and gains are determined by a stability analysis of the complete control system (see Section 5.3.3). The block diagram indicates that both pitch and yaw channels. have similar computations. A sensor detects actual airship attitude which is subtracted from a desired attitude to form an error signal,  $\Delta \psi$ . The error signal is used as a direct input and as a derived rate signal by passing it through a high pass filter. The derived rate signal,  $\psi$ , becomes a rate damping factor when it is subtracted from the attitude error signal. The resultant is a gimbal command signal proportional to the attitude error and damped in proportion to the rate of change of the attitude error. A limiter is added to prevent the gimbal mechanism from trying to move beyond its mechanical, or electrical limits, and beyond the safety limits of the airship.

During developmental testing the autopilot should have gain changing circuitry incorporated for varying autopilot parameters in-flight. It is anticipated that all forward circuit gains, feedback gains, and lead/lag constants should be adjustable in 3 increments. Also, as shown in Figure 5.19, the airship may be flown manually by using radio command to apply the proper voltage directly to the gimbal motor. This manual control is intended only as a back-up function in case of autopilot malfunction. Mechanical relays are shown in the diagram for simplicity, but solid state devices would most Likely be used.

The autopilot unit may be mounted anywhere in the gondola but the pitch sensor and heading sensor should be located with some discretion. The pitch sensor should be mounted directly under, and as close as possible to, the longitudinal axis of the airship. This would minimize pitch errors due to possible rolling motions of the airship. Likewise, the magnetometer (heading reference) should be located directly under the longitudinal axis and as high as practical in the gondola to minimize roll effects. Some testing will be required to determine the effects of the gondola structure on the magnetometer accuracy.



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Figure 5.19 Autopilot block diagram.

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5.3.2.1 Pitch Control. The pitch control serves to keep the airship flying level as altitude is determined by the balloon buoyancy. If desired, the airship can be flown with a fixed pitch angle by applying a DC voltage offset to the pitch error input. The pitch sensor is chosen to be a gravity sensing electrolytic transducer such as the type EP10-750 by Hamlin, Inc. It has a range of ±0.21 rad (12 deg) and an analog of 20.1 VAC/rad (0.340 VAC/deg) for small angles, when excited with 12.5 VRMS at 400 Hz. The response time constant of this device is approximately 0.8 seconds; therefore, the transfer function of the pitch sensor is:

$$\frac{V_{AC}}{\Delta \Theta} = \frac{20.1}{1+0.8S} \frac{VRMS}{rad}$$

The output must be rectified and filtered to interface with the autopilot. A 12 ms low-pass filter will limit the peakto-peak ripple to less than 10% of the peak AC voltage. The average of DC output voltage would be 0.95 times the peak AC voltage or 1.34 times the RMS input voltage. This assumes an infinite load on the filter, which is not practical. However, amplifiers are available with very high input impedances; therefore, a loss factor of 0.9 is assumed. The low pass transfer function then becomes:

$$\frac{V_{DC}}{V_{AC}} = \frac{1.21}{1+0.012s}$$

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Yaw Control. The yaw control loop is similar to the 5.3.2.2 pitch except for the sensor and the heading command inputs. The heading sensor is assumed to be a magnetometer such as Schonstedt Instrument Company's UAM-53C-1. It has an output analog of 0.0210 Vm/A (1.67 V/oersted) and weighs 2.9 N (0.66 Its operating temperature range is +4.4 to +60°C; and lb). it may require a heater and thermostat unless it can be located near a heat source. Since field intensity and flux density are equal in a nonmagnetic medium, the output analog of the magnetometer is  $1.67 \times 10^4 \text{ V/T}$  (1.67 V/gauss). The earths magnetic flux density decreases as the inverse cube of the distance from the center of the earth. The earth radius is 6378 km (3963 mi) so an additional 21 km (13 mi) would cause a reduction in flux density of approximately one per cent.

The magnetometer is sensitive to the horizontal compon-

ent of magnetic flux which varies from  $5 \times 10^{-6}$  to  $4 \times 10^{-3}$ T (0.05 to 0.4 gauss) over the surface of the earth.<sup>23</sup> This indicates that the gain of the heading sensor signal will have to be selectable over a range of from one to eight in order to fly anywhere in the world. A hypothetical example: the horizontal component of flux density at Sioux Falls, South Dakota is about  $2 \times 10^{-5}$  T (0.2 gauss). The output voltage would range from zero to a maximum of 0.334 V. If the magnetometer is mounted with the X-axis aligned with the longitudinal axis of the balloon, the voltage would be:

 $V_v = 0.334 \sin \psi$ 

where  $\psi$  is the magnetic heading. The frequency response is 130 Hz at 0.5 gauss. The transfer function of the magnetometer is:

$$\frac{\mathbf{v}_{\mathbf{y}}}{\Delta \psi} = \frac{0.334\psi}{(\mathbf{S}^2 + \psi^2) (1 + 0.00122\mathbf{S})}$$

Since a sinusoid gives a decreasing voltage as  $\psi$  increases beyond 1.57 rad (90 degrees), the magnetometer output must be linearized by a heading signal generator circuit which is shown following the magnetometer (Figure 5.19). In the final design, the heading signal generator circuit would combine the signals from all three axes into a linearized signal. The transfer function of this source would likely be more complicated than the one above, but would be similar in form. This function would be combined with the remaining loop functions and used in the final stability analysis.

### 5.3.3 System Stability

If the airship is to perform properly in flight it must follow a stable flight path. This requires that the autopilot function so as to command the gimbal mechanism in a proper fashion. Because of the interface and mechanical components involved it is not only essential to check out the airship stability on the assumption that the autopilot is reacting as anticipated; but it is also essential to determine that the basic electronics are stable when under operation. Thus, system stability encompasses both airship performance and electronics operation.

<sup>2</sup><sup>3</sup>Handbook of Geophysics and Space Environments, Shea L. Valley, ed., Air Force Cambridge Research Laboratories. 1965. 5.3.3.1 Autopilot Stability. The method normally used to determine if the electronics circuitry of the autopilot is stable is to analyze the servo system with innermost loop and progress to the outer loop after the inner loops have been stabilized. The inner and outer loops are shown for the yaw channel in Figure 5.20. The innermost loop is actually a gimbal position loop and will be analyzed first.

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Figure 5.20 Heading control, yaw channel.

5.3.3.1.1 Gimbal Position Loop. This feedback loop is necesmary to permit the gimbal motor to accurately hold the gimbaled mass in the desired position and to move it in a stable manner.

Inserting values of the preliminary design into the transfer function shown in Section 5.3.1 one obtains:

 $\frac{\delta'_G}{\epsilon} = \frac{(23.6)}{(0.000589)^2} \frac{(1.02 \times 10^{-4})}{(0.00236)} \frac{(3)}{(0.000589)^2} \frac{(1+0.4455)}{(1+0.4455)}$ 

This loop is shown in Figure 5.21. The stability of the loop can be determined by applying the frequency analysis method to the open loop transfer function.

The above transfer function was analyzed by the computer program STABAN which is listed in Appendix C. A Bode plot of computer solution is shown in Figure 5.22. As shown, the inner loop is stable with a gain margin of about 106 db and a phase margin of approximately + 66 deg; therefore, equalization is unnecessary. It should be noted that normal stability analysis methods ignore the 180 degree phase shift through the amplifier. This means 180 degrees on the Bode plot really represents an in-phase signal (360 degrees) and is the critical point to examine.



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The inner loop can be reduced to a single path by using the relationship:

$$F = \frac{G}{I + GH}$$

In this case, G is the motor and gimbal mechanism, while H is the feedback potentiometer and associated gears. (See Figure 5.16). The forward loop transfer then becomes:

$$F = \frac{0.0524}{(\tau_1^2 S^2 + 2\zeta_1 \tau_1 S + 1) (\tau_2^2 S^2 + 2\zeta_2 \tau_2 S + 1)}$$
where:  $\tau_1 = 0.625$ 
 $\zeta_1 = 0.703$ 
 $\tau_2 = 5.88 \times 10^{-4}$ 
 $\zeta_2 = 0.00237$ 

The gimbal motor position loop may be represented by a single block containing this transfer function. This block may be used in further analysis of both the pitch and yaw channels.

5.3.3.1.2 Pitch & Yaw Control Loops. Combining the inner loop transfer function from the previous section and sensor details from Section 5.3.2., gives the diagrams shown in Figure 5.23. The undefined gains and time constants should be calculated when the airship transfer function is known. The theoretical derivation of the airship transfer function, must be performed to fully complete this analysis but is impractical without some empirical data from a scale model. The necessary values can then be calculated and the stability tested with the STABAN program. If the computer program indicated marginal stability, lead and/or lag filters should be added along with gain adjustments, and stability retested. This process should be repeated until the phase margin and gain margin are acceptable.

The yaw loop is the same as pitch except for the heading command signal input. The time constants required will undoubtedly be different than pitch due to differences in response to the airship. Only the y-axis transfer function is shown for the magnetometer but the x and z axes have similar functions. All three signals will be utilized by the heading signal generator to convert  $V_y$  into a linear signal.






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Airship Flight Stability. The aerodynamic charac-5.3.3.2 teristics of the airship with respect to stability in flight, are an important consideration since airships are naturally The gimbaling of the thrust vector is used to hold unstable. the airship on course and create "stable flight" character-The autopilot governs the motions of the gimbal istics. mechanism by a predefined gimbal position based upon heading and pitch error and error rate feedback signals. The most meaningful way to check the airship flight stability is to model the system with a computer and study its synthesized reactions to various hypothetical situations. Such a technique empolying a digital computer was used successfully for High Platform II.<sup>10</sup> The discussion here will be limited to the basic equations which were used and the results obtained.

The geometry used in the equation is shown in Figure 5.24. The basic equations which are used are of the form:

Sum of Forces = (mass) (acceleration)

 $\Sigma \mathbf{F}_{\mathbf{X}} = \mathbf{m}_{\mathbf{X}} \mathbf{a}_{\mathbf{X}}$  $\Sigma \mathbf{F}_{\mathbf{Y}} = \mathbf{m}_{\mathbf{Y}} \mathbf{a}_{\mathbf{Y}}$  $\Sigma \mathbf{F}_{\mathbf{Z}} = \mathbf{m}_{\mathbf{Z}} \mathbf{a}_{\mathbf{Z}}$ 

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Sum of Moment = (moment of inertia) (angular acceleration)

 $\Sigma M_{yy} = I_{yy} \stackrel{o}{\Theta} \\ \vdots \\ \Sigma M_{zz} = I_{zz} \stackrel{o}{\psi}$ 

Sum of forces in x direction equal mass times acceleration in x direction:

T  $\cos(\tau-\beta)\cos(\tau+\alpha) - D_a - D_H - D_V - (W-b)\sin\gamma = M_X v$ 

Sum of forces in y direction equals mass time acceleration in y direction:

-  $S_a - L_V + T \cos \delta \sin(\tau - \beta) = m_y \upsilon (\dot{\Phi})$ 

Sum of forces in z direction equal mass time acceleration in z direction:

-  $L_a - L_H - T \cos \tau \sin(\delta + \alpha) + (W-B) \cos \gamma = -m_z v \dot{\gamma}$ 

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T =	Thrust
W =	Weight Of Airship
B =	Buoyance Of Gas
C.B. =	Center Of Buoyance
C.M. =	Center Of Mass
Q.C. =	Quarter Chord
D =	Drag
L=	Lift
S =	Side Force
M =	Moment About Y Axis
N =	Moment About Z Axi
ν =	Velocity
<i>l</i> =	Length
a =	Hull (Airship)
H =	Horizontal Fin
V =	Vertical Fin
t =	Tail
G ≖	Gimbal

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Sum of moments about y axis equal moment of inertia times angular acceleration about the y axis:

 $M_a + M_t - L_a h \sin \alpha + D_a h \cos \alpha - L_H (l_t \cos \alpha + h \sin \alpha)$ 

+  $D_H$  (h cosa -  $L_t sina$ ) - T cost (h cos $\delta$  +  $\ell_G sin\delta$ )

- B h  $\sin \Theta = I_{VV}\ddot{\Theta}$ 

Sum of moments about z axis equal moment of inertia times angular acceleration about the z axis:

 $-N_a - N_t + l_t (L_V \cos\beta + D_V \sin\beta) - Tl_G \cos\delta \sin\tau = I_{ZZ} \ddot{\psi}$ 

These equations are used in conjunction with the basic autopilot/gimbal performance defined with the following equation:

$$\mathcal{E} = \mathbf{G}_{\mathbf{PE}} (\Theta - \mathbf{A}) + \mathbf{G}_{\mathbf{PR}} \Theta$$

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 $\tau = \mathbf{G}_{\mathbf{Y}\mathbf{F}}(\boldsymbol{\psi} - \mathbf{B}) + \mathbf{G}_{\mathbf{Y}\mathbf{R}} \boldsymbol{\psi}$ 

where G is the autopilot amplifier gain. (P denotes pitch, Y denotes yaw, E denotes angular error, and R denotes angular rate). A is the pitch correction, and B is the heading correction factor. When these equations demand that the gimbal respond outside of realistic capabilities, it is limited to its actual rate and limit stop capabilities. Also, each of the major terms in the aerodynamic equation needs to be expanded upon in terms of aerodynamic derivations, and coefficients dependent upon angular displacements or velocities. The result is that the equations in their more complex form allow for the solving of v,  $\Phi$ ,  $\gamma$ ,  $\Theta$ , and  $\psi$  if all other angles, their time derivatives, and the velocity have known values.

To start the simulation calculation, initial conditions are assumed for these other angles, time derivatives, and velocity. The autopilot/gimbal system will react to this initial condition by its electromechanical response which can be calculated. By using short time intervals it is valid to assume that all accelerations are constant over each time interval. New values of each of the initial conditions can be recalculated using equations in the forms:

$$\Theta_1 = \Theta_0 + \frac{\dot{\Theta}_0 + \dot{\Theta}_1}{2} (\Delta)$$

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 $\Theta_1 = \Theta_0 + \Theta_0 + \Theta_1 (\Delta)$ 

where  $\Delta$  denotes the time increment.

The procedure is repeated in an iterative manner to calculate values of  $\Theta$ ,  $\alpha$ ,  $\delta$ ,  $\psi$ ,  $\beta$ ,  $\tau$ , and  $\nu$  at discrete time intervals. The computer output then shows how the system is predicted to respond to a specific situation defined by the initial conditions. Examples of the system response are shown in Figure 5.25. The computer program, POSIM, and examples of its output are listed in Appendix D.

### 5.3.4 Heading Control System

For station keeping demonstration purposes it has been determined that a fairly crude navigation technique used in conjunction with a heading control capability would be suffi-Also, for the purposes of this effort, station keepcient. ing has been defined as remaining within 200 nautical miles of the ground command center. To accomplish this it is recommended that course heading changes be made from the ground station based upon flight vectors determined by radar posi-These heading changes would be made by the heading tioning. control unit diagrammed in Figure 5.26.

The autopilot is designed to operate by actuating the gimbal to cause the airship to hold the heading programmed as a reference. The same magnetometer which is used for yaw stability control is also used for heading control. The reference heading is derived from a tapped potentiometer driven by a reversible stepping motor. The station operator can steer the airship by sending only "turn left" or "turn right" commands to the stepping motor. The program heading can then be changed in increments of less than one degree and verified by telemetry.

The heading command output is a linear voltage whose magnitude represents the deviation from north and whose polarity indicates the direction of deviation. The motor and driver provide .031 rad (1.8 deg) increments. A gear type speed reducer would reduce the step size to .016 rad (0.9 deg). The power converter output is approximately 1 W and



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the efficiency of this type supply is typically about 65. Input power requirements are approximately 15 W peak. Assuming the heading would seldom be changed, the average power is estimated to be 1.5 W. Weight of this unit is estimated to be 5 N (1.1 lb).

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As seen from the above description, the heading control is simple and somewhat crude by spacecraft standards. As the winds may exceed twice the airspeed capability of the airship, and the area of station keeping made much smaller, it may be desirable to design an on-board, station-keeping, navigation system at a later date for such applications. For the present, this system will allow evaluation of airship performance and variations in the wind field at this altitude.

### 5.3.5 Command and Telemetry System

The command system for the early stages of this project shall consist of a VHF, Narrow Band, FM radio link. The transmitter is located at the ground control station and the receiver is aboard the airship. A block diagram of the radio command unit is shown in Figure 5.27. This unit is composed of building blocks found within the Raven TRAC system. The

command system described herein has been in use by Raven Industries for balloon-borne applications since 1968 with an excellent history and proven operation to the radio horizon as found in balloon applications.



Figure 5.27 Radio command system block diagram.

The commands required are presented in Figure 5.27. To provide maximum reliability, the termination commands have a "private line" (tone squelch) independent from the airship command squelch. This command system contains a binary decoder which allows the transmission of up to 32 commands by utilizing only 5 command tones from the ground station. To verify command reception, a command verification signal is available to modulate the telemetry transmitter. This jives the ground station operator an audio tone upon command execution.

The switch closures provided by the format matrix boards must be heavy duty contacts (2-3 A) to permit control with a minimum of complexity. The estimated power consumption is 1 W. The approximate physical dimensions of this unit are 18 x 24 x 15 cm (7.1 x 9.4 x 5.9 in) and the weight is estimated to be 23 N (5.2 lb).

During the first flights many parameters must be tele-

metered for real time evaluation. This will allow the ground crew to evaluate performance and make appropriate adjustments. Analog chart recordings are ideally suited for this application. The analog recordings, as opposed to digital, give a history of operation at a glance. This is ideal where signals are continuously changing and real time evaluation is required.

An FM-FM telemetry system operating in the L or S band is proposed. The components that make up a system such as this are off-the-shelf items. The system can easily be tailored to suit system needs and meet IRIG (inter-range instrumentation group) requirements. and the second of the second second second

The airborne electronics will consist of appropriate commutators feeding IRIG + 7-1/28 proportional subcarrier oscillators. The standard IRIG format will allow up to 11 channels of data. (Due to possible ranging data interference and the limited data bandwidth, channels 1-10 have not been considered.) These subcarriers than modulate an L or S band transmitter as required. The advantage of L or S band telemetry over lower bands is the ability to utilize subcarrier channels 20 and 21. Figure 5.28 is a block diagram showing the on-board telemetry system. The telemetry unit will require approximately 35 W of power including the transmitter. The estimated weight is 10N (2.2 lb) including signal conditioning requirements and case. A space allowance of 15 x 15 x 15 cm (5.9 x 5.9 x 5.9 in) should be made available for the telemetry unit.

### 5.4 Power Supply System

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POBAL-S requires electrical power to operate the power train, gimbal mechanism, autopilot, on-board telemetry/command system, housekeeping functions, payload, and internal electrical functions. The power supply system to accomplish this consists of the fuel cell, the interfacing control unit, and an emergency power supply to operate the telemetry/command system.

### 5.4.1 Fuel Cell System

Design of the hydrogen-oxygen fuel cell system was furnished by Pratt & Whitney in conjunction with a concurrent contract.<sup>29</sup> An output voltage of 30 V was selected early in the program to expedite the fuel cell design. The voltage choice was based on three factors: 1) a similar system designed at 30 V had previously been developed by Pratt & Whitney, 2)



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voltages needed to be limited to prevent any arcing problems during operation at 21 km (70,000 ft), and 3) by using components from existing fuel cell designs the airship size was minimized at a fuel cell voltage of approximately 30 V.

The fuel cell is to furnish 2.52 kW net terminal power for 7 days continuously. The characteristic curves are shown in Figure 5.29. The heat rejection rate of the fuel cell is 1170 W which is accomplished with a radiator/coolant unit operating at  $93^{\circ}$ C. The fuel cell can be started from its own residual power in approximately 14 minutes and can withstand a 100% overload for a short time without permanent damage.

Basically, the fuel cell system components include the fuel cell (consisting of the cell stack, values, coolant, pumps, condenser, heaters, piping, etc.), the liquid  $H_2$  and  $O_2$  in their respective storage tanks, the radiator, and the  $H_2O$  storage bag. Section 5.1.3 discusses how these components are contained within the gondola. The weight breakdown is as follows:

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Fuel cell		636.1 N
H <sub>2</sub> tank (empty		467.0
O <sub>2</sub> tank (empty)		244.6
H2		218.0
02		1405.6
H <sub>2</sub> O storage bag		22.2
Radiator		97.9
Piping and wiring		66.7
	Total	3158.1 N (710 1b)

5.4.2 Power Distribution and Control System

Power from the fuel cell is allocated as follows:

Payload			500	W
Autopilot,	celemetry,	gimbal,	etc. 220	W
NOCOL	T	otal	2520	W



Figure 5.29 Fuel cell characteristics.

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The control system provides the interface between the heavy duty power circuitry and sensitive electronic circuitry to provide proper power allocation. Referring to Figure 5.30 the power control and switching is located within the control system. All control functions are depicted as switches for clarity; however, solid state devices are desirable and should be incorporated in most areas.

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## Figure 5.30 Power distribution and control system block diagram.

The payload power was specified to be 500 W and furnished by the fuel cell. A TTL-compatible logic signal is furnished to the payload which is assumed to contain a switching device capable of controlling its 16.7 A current.

The voltage sensor and back-up power control shown performs an automatic switching function. This circuit connects the largest of the two voltages to the telemetry, command, and

navigation systems. Therefore, if the fuel cell voltage should drop below the battery voltage, indicating fuel cell failure, the back-up battery will automatically supply the required current. The voltage output of the fuel cell and current drain of the back-up battery are continuously monitored and coupled to the telemetry to alert the ground station operator should the back-up battery come "on-line" By using small regulators at each load, instead of one large regulator, improved filtering of switching transients and noise is achieved. By using sealed relays and solid state devices the control unit need not be pressurized. The volume of the control unit is  $11 \times 11 \times 11$  cm (4.3 x 4.3 x 4.3 in). The estimated total weight is 26 N (5.7 lb).

5.4.3 Emergency Power Supply

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A back-up battery as shown in Figure 5.30 provides backup power for the command, telemetry, heading control, and termination devices. This power supply is to provide minimum tracking, control, and telemetry for a 24 hour period in case of a propulsion system malfunction or a fuel cell failure. Should a failure occur, this can be extended to 48 hours by commanding the telemetry transmitter on and off as required. The average current to operate the telemetry unit, command unit, and attitude sensors is estimated to be 1.55 A.

The battery must also furnish power to fire the squibs at flight termination, energize relays, energize transducers, etc. These short pulses will not occur at any predictable frequency, nor at any particular time during the flight. In an attempt to insure that the required peak power is available for these intermittent loads, an additional 1 A of current was added to the battery requirement.

For high reliability it was decided to use a primary type battery. Acceptable solutions for the primary battery requirements were received from only two sources. The pertinent details are:

Vendor	Yardney	Chromalloy
Туре	Silver-Zinc	Lithium-Organic
Size	29.2 x 19.7 x 17.8 cm	34.8 x 31.8 x 30.2 cm
Weight	222 N	167 N
Heater power	12.4 W	9 W
Shelf Line	1 month	l year

Silver-zinc batteries are proven and offer the best reliability. Lithium-organic production experience is not well established at this time, but it is expected to improve in the future. The final battery choice should be made when a complete control unit design is accomplished.

### 5.5 Launch and Recovery

The POBAL-S vehicle as described above is a complex balloon system. The launch and recovery operation will be a difficult task and eventually must be considered a major task item.

### 5.5.1 Launch

The recommended launch technique for this vehicle is a "tail first" vertical launch utilizing a tow balloon under which the airship will ascend tail first. The primary reasons for this type of launch are to prevent damage to the propeller during lift-off and keep the heaviest weight concentration (gondola) near the bottom of the balloon to prevent surging of helium during ascent. A subtask of some future effort should be to demonstrate the launch concept under an experimental test.

The launch sequence is shown in Figure 5.31. The balloon should be laid out longitudinally with the stern structure positioned over the aft end. Approximately 4.6 m (15 ft) from the tail end the balloon should be clamped off so that only the tail will inflate to facilitate lacing the stern structure to the balloon. A crane would position and lift the stern structure as the inflation and lacing proceeds. The clamp would be released when lacing is completed.

The crane would have to raise the structure until the tow balloon is inflated and can support the airship tail. The tow balloon would have a buoyancy of approximately 1,480 N (333 lb). As the crane is released from the stern structure the tow balloon would hold the aft end of the airship vertical while inflation of the airship continues.

At approximately 30.5 m (100 ft) from the tail a triroller will have been clamped to the airship hull. The triroller is attached to two winches that will control the liftoff until the length of the airship is in the vertical position. In this manner, the gendola can be lifted slowly from the ground to avoid any snatch forces which would otherwise be encountered. When the entire balloon is clear of the ground and in the vertical position, the tri-roller clamp would be released.



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Figure 5.31 Launch sequence.

This launch technique requires two inflation valves. A valve would be located between the storn structure and the "tie off". The purpose of this valve is to inflate the aft cone for lacing of the battens to the airship. As the crane is released and the tow balloon begins to pick up the tail of the airship, a second valve which is located near the triroller would be opened. This valve is used to fill the balloon to its gross inflation.

The airship gross inflation would be 22,000 N (4,950 lb). This is the airship gross weight plus 20% free lift. The inflation gas is to be helium. The 20% free lift would be counteracted by 18% or 3,290 N (740 lb) of ballast which would leave 2% free lift in the system. The ballast and tow balloon would be released by a pressure sensing switch. The rate of ballast release would be adjusted to assure that the airship eases into final pressurization.

A total of 10% free lift would be required to launch this vehicle. Since the airship has 2% free lift remaining after accounting for the ballast, the tow balloon would require a buoyancy of 8% of the gross system weight or 1,480 N (333 lb). Thus, the two balloon serves two purposes; it holds the stern structure and tail of the airship in the vertical position during the initial states of inflation and ascent, and it provides the required free lift for ascent.

A level sensor would be attached to the stern structure as a safety device so that when the tow-line reaches a  $70^{\circ}$ lean-over angle (from the vertical), a time delayed squib and cannon assembly would release the tow balloon. This is redundant to the pressure switch. Since the tow balloon is not used to vent gas to the airship, its buoyancy is retained and it would continue to rise and clear the propeller once it is released. The airship will level out and ease into its float altitude of 21 km (70,000 ft) as ballast is released.

Figure 5.32 shows the gondola and load patches going through the complete ascent deployment sequence from the vertical to the horizontal position. In the initial stages of launch, as the gondola is vertical, the three launch patches directly over the gondola support the entire load. The load lines from these patches are secured on the plane of the center of gravity of the gondola. As the balloon begins to tip to the .79 rad (45 deg) position all seven of the launch patches, two on either side and three directly above the gondola, would share the weight of the gondola.

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Then as the balloon continues to tip into its final horizontal flight position the load is transferred from the launch patches to the six load patches, three on either side of the gondola; and the launch patch lines become slack.

5.5.2 Recovery

The POBAL-S gondola contains expensive equipment. The items within the gondola can be reused if a method of recovery is provided. The most reliable and least expensive method of accomplishing recovery is with the use of a parachute which would be actuated upon release of the gondola from the balloon. The gondola termination circuitry consists of a relay, fuse, and time delay. The termination would be accomplished by cutting the support lines with cutters containing two Dupont S-68, four grain squibs which are energized independently. By energizing the second squib shortly after the first, the reliability can be doubled. The recommended firing current is 0.6 A for 4 ms for each squib. If the second squib pulse is delayed for 4 ms, the current required would be 0.6 A for 8 ms per line cutter. Occasionally the terminals of the squibs will be shorted together by the detonation. Therefore, a fuse is used in the line to the primary squibs such that if one should short it would not jeopardize the firing of the back-up squibs. In order to prevent static build-up an SPDT relay should be used for the control interface so that the squib power lines are shorted together until actuated.

The decelerator system selected must limit the shock forces experienced by the gondola at parachute opening and at ground impact to an acceptable value. The parachute selected for use in this application must posses an "effective drag area" of 264 m<sup>2</sup> (2,840 ft<sup>2</sup>) to provide a 6.1 m/s (20 ft/s) impact velocity. A parachute of this size will weigh approximately 310 N (70 lb) and require a packing volume of  $0.059 \text{ m}^3$  (2.1 ft<sup>3</sup>).

The parachute utilized for this application must inflate reliably at the low dynamic pressure which would be experienced at the parachute deployment altitude, and it must provide stable descent. An unstable trajectory would result in a less predictable and usually higher rate of descent. In addition, if the parachute is oscillating, the possibility exists that the payload would not impact with the base in a horizontal orientation. If the payload impacts the ground at an angle, the shock attenuation material on the base of the package is less efficient and impact loads are increased.

The existence of surface wind increases the importance of using a stable, oscillation free recovery system. Surface winds impart a horizontal velocity to the descending gondola; and, if strong enough, these winds will cause the gondola to tumble or roll after ground impact. Impact loads can better be controlled if the package can be maintained upright during recovery. Preliminary analysis shows that if the recoverable load impacts the ground with its base horizontal, the upright orientation of the gondola can be maintained with winds up to 10.5 m/s (20.4 kn). However, if the payload and parachute are oscillating so that the base of the gondola impacts the ground at an angle of .35 rad (20 deg), the payload may overturn with winds above 5.1 m/s (10 kn).

Parachute designs such as the cross, disk-gap-band, and ringslot all provide stable descent. These designs will maintain an oscillation angle from the vertical of less than .17 rad (10 deg).

The parachute should be folded and packed in the gondola with the apex of the canopy to the top or open end. Parachute packing and rigging is then completed by attaching one one end of the lanyard (cord) to the apex of the canopy and the other end of the lanyard to a support structure in the airship. When recovery is initiated, the gondola and airship separate. As this separation occurs the lanyard would extract and deploy the parachute. When the complete parachute is deployed the lanyard would break, separating the gondola from the airship. The parachute is then free to inflate and support the vehicle to impact.

The length of the lanyard should be long enough to extend approximately 3 m (10 ft) below the airship to avoid canopy-with-airship contact during the deployment. Lanyard strength should be approximately 890 N (200 lb). This is sufficiently strong to insure extraction of the 310 N (70 lb) parachute without adding unnecessary weight to the airship for lanyard structural support.

The parachute can best be attached to the gondola using a four-legged bridle with one leg of the bridle attached near each corner of the gondola. This method of parachute attachment provides the most stable gondola orientation at ground impact.

Upon impact with the ground, a line cutter will be activated to cut the parachute from the gondola to preclude the possibility of the gondola being dragged.

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The stern structure is not designed for a parachute recovery and will be returned with the airship. Since there are no shock attenuators attached to the structure, nearly as much damage would be imparted upon impact using a parachute recovery as would be by remaining with the balloon. The additional design effort to salvage the stern assembly is not warranted as the salvageable hardware is a small part of the system cost.

As the gondola is released from the airship a rip panel would be opened. The rip cord used to open the panel would be attached to the top of the parachute. The cord would be long enough so that the parachute is fully deployed before the cord opens the panel. The rip panel would be located near the nose of the airship. As the gondola is released, the airship will tip nose up due to the weight of the stern structure assembly. This would allow the helium to vent rapidly as the airship descends with the stern assembly down.

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The task reported on in this text primarily consisted of a parametric analysis which resulted in a system concept definition for POBAL-S (a high altitude, superpressure airship) and the design of the airship. Also included was a brief historical discussion of powered balloons applicable to POBAL-S. The parametric analysis was presented in enough detail so that future extensions of the work performed here could be readily accomplished. The design was presented in enough detail so that it was shown to be feasible to fabricate, launch, and operate the POBAL-S system.

The types of systems analyzed included propeller driven superpressure airships powered by a solar cell array, a fuel cell, a battery, a gas turbine engine, and internal combustion engines. For mission durations of less than one week there are definite cost and design advantages of using a fuel cell powered vehicle. Combustion engine vehicles may also be applicable to the one week mission but a significant development effort to demonstrate feasibility would be required. Also, because of fuel consumption the engine concept presents design complications. For mission durations of two to three weeks the combustion engine should definitely be considered and an effort should be expended in developing such a concept. The fuel cell concept may have cost advantages for these durations, as compared to the solar cell array powered airship, but it is doubtful that such a system is feasible to launch because of its large size. For missions of extended duration (longer than one month) the solar cell array powered airship presents the only feasible alternative. However, in spite of its obviously high cost, such a vehicle could be developed under a single effort and fulfill all mission requirements. The primary disadvantage is that the solar cells are not recoverable. The cost per flight of this vehicle is then highly dependent on solar cell costs.

The analysis section of this report discussed the sensitivity of the system design to all design parameters. Also, the parametric curves indicate the dependency of system feasibility on various parameters. These analyses indicate that one of the major future efforts required leading to vehicle development is that of envelope material development. Other system design parameters such as film design stress limit, maximum supertemperature, required free lift, coefficient of drag, etc., must also be accurately determined. To minimize design complications, system size, and system costs and to maximize reliability any future development efforts

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should place great emphasis on accurate determination of these parameters.

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The chosen concept was for a vehicle capable of supporting an 880 N (200 lb) payload requiring 500 W continuous power at an altitude of 21 km (70,000 ft) for a 7 day duration. The airship to meet this mission requirement is to be fuel cell powered and operate at an 8.18 m/s (15.9 kn) airspeed. In the design it was assumed that a new biaxially oriented nylon film would be used as the envelope material; however, at the present time this film is not a proven superpressure balloon material. Other new materials should also be considered since conventional polyester film, even though it exhibits near minimum excursions in supertemperature extremes, does not have an acceptable strength-toweight ratio.

\*Appendix B reports test results of experimentation with biaxially oriented Nylon 6.

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 INITIAL, MAX, AND INCREMENT OF TIME LOOP COUNTER
 IN ALTITUUE CONTROL, 1500 M. A/C, 3000 H. A/C C+\* READ UNFORMATTED INPUTS (CONSTANTS FOR PARAMETRIC EWATIONS) VEHICLES C++ INITILIZE STANDARD SEA LEVEL PRESSURE AND DENSITY 3AUDM2,ADDM3,5A,GECE,IURDOR,SUBPOW,PNGYPD,YULISA,DUIY C\*\* ESTAULISH COMPUTED CUMPONENT MASSES IN COMMUN STORAGE **HARCH 1973** J&PO#, 4X, 6HPNBYPD/21X, 6HVOLT5A, 4X, 4HOUTY/// C++ PROGRAM MASKY SIZES HIGH ALTITUDE STATION KEEPING C++ STORE BALLOUN DESIGN PARAMETERS IN COMMON STORAGE C++ KRITE NAMES OF INPUT PANAMETERS IN 8 COLUMN ROWS C++ WRITE YALUE OF INPUT PARAMETERS IN & CULUMN ROWS •4HSFC1.6X.4HSFC2/21X.5HSTRMR.5X.5H INC DATA SPRES/101325.0/, SRHD/1.225/ BY KAVEN INUUSTRIES. HEIN.7X,3 I READ(1, 302, ENU=99) HEAD 18777. . 022748. . 018012/ ERT, 4X, 1H 1(2X,131) **WRITES3.302)HEAD** PRUGRAM HASKY FURMAT ( 20441 HRITE(3.305) LHRS, HRN, TS C + 1 = 0 = 1 = 2DEVELOPEC C\*\* IIT.MIT.NIT EURHAT() C++ [ND, MWD, N] C++ 11A, MIA, N **CSHWIRE** // READ DEVICE-AFCUI // PRIMT DEVICE-5203 [4X, 6HS **GAHSNA** C\*\* READ 200 290 302 5 21 10 2 2 13 A

Instruction     Instruction       Instruction <th></th> <th>1001 1001</th> <th></th>		1001 1001	
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Bit Michael (1)         Bit Michael (1)           1         10         10         15         16 <td< td=""><td>4 15 ALPHA=</td><td>0</td><td></td></td<>	4 15 ALPHA=	0	
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<ul> <li>MICHARGENICIA-27</li> <li>MICHARGENICA CARTINAL 11-1941111</li> <li>MICHEL 11000 FAULORY DI EXCORTINO</li> <li>MICHEL 11000 FAULORY DI EXCONTINAL 11-194111</li> <li>MICHEL 11000 FAULORY DI EXCONTINAL 11-194111</li> <li>MICHEL 11000 FAULORY DI EXCONTINAL 11-194111</li> <li>MICHEL 11000 FAULORY DI EXCONTINAL 11-1000-11-1000</li> <li>MICHEL 11000 FAULORY DI EXCONTINAL 11-1000-10-10-10-10-10-10-10-10-10-10-10</li></ul>	3 17 ALPHA=	1. IFT(IA)/HLIFT(IA-2)	
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8       313 FUNITIONAL PARTITIONAL TETTLAT PRESS, WHALLETTLAT, PARTITIONAL PARTITICANA PARTITIONAL PARTITICANA	C AND BALL	DON UTFFERENTIAL PRESSURE	
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0       00       06       64       44       44         1       VIND       2       54       440         2       0       04       44       46       27       47       44         3       C++       MUTE       410       VIND       2       24       44       44         3       C++       MUTE       VIND       41       47       44	27HUELT	1P=1F6+0+10H_NENIQN/A2)	
2       WWIND-25374 MUD         3       C+* WRIE KIND YENHOL:5         2       C+* WRIE KIND YEUGETY - KUD         3       IS FURNEJO-5         4       315 FURNEJO-5         5       C+* WRIE KIND YEUGETY - AUD         5       C+* WRIE KIND YEUGETY - AUD         5       C+* KEUTE TIFOLIKE FOR POWER SOURCE SPECIFIED         6       C007         7       TF-1117-N117         115-25-4017       TF-1117-N117         115-25-24       TF-1117-N117         115-217-2123-23-24       TF-1117-N117         115-25-24       TF-1117-N117         115-25-24       TF-1117-N117         115-25-24       TF-1117	0 00 88	LIND # MAD # MAD	
C** MRITE KINO VELOCITY AND DYNAMIC PRESSURE         315 FOURTE(1/712, SWIND-4)         CALL LINFOLVE         FOURTE(1/712, SWIND-4)         CALL LINFOLVE         FOURTE(1/712, SWIND-4)         CALL LINFOLVE         FOURTE(1/712, SWIND-4)         CALL LINFOLVE         FOURTE SALED         FOURTE SALED         CALL LINFOLVE         FOURTE SALED         FOURTE SALED         CONSTRUETING         FOURTE SALED         FOURTE SALED         CONSTRUETING         FOURTE SALED         FOURTE SALED         CONTSTRUETING         FOURTES SALEDON FADIUS = 100 R.         CONSTRUETING         CONTSTRUETING         FOURTES SALEDON FADIUS = 100 R.         CONSTRUETING         CONSTRUETING </td <td>VHIND</td> <td>= 2,5514 ∓ (kU) testenoune 5</td> <td></td>	VHIND	= 2,5514 ∓ (kU) testenoune 5	
315       FURNT(1/1X, SHNIMD-4         5       CALL INFO2(X)         5       CALL INFO2(X)         6       CALL INFO2(X)         6       CALL INFO2(X)         6       CALL INFO2(X)         7       CALL INFO2(X)         6       CALL INFO2(X)         7       CALL INFO2(X)         6       CONT IT-111-111-011         7       T1-111-112-012         8       T1-211-012         17       CALL SACCOM RADIUS = 100 M.         11       CALL SACCOM RADIUS = 100 M.         12       CALL SACCOM RADIUS = 100 M.         13       Z5 KENV         14       CALL SACCOM RADIUS = 100 M.         15       CALL SACCOM RADIUS = 100 M.         16       T12-10.123, 233, 24         17       CALL SACCOM RADIUS = 100 M.         17       CALL SACCOM RADIUS = 100 M.         18       CALL SACCOM RADIUS = 100 M.	C++ HRITE KI	ID VELOCITY AND DYNAMIC PRESSURE	
CALL INFOLICI         CALL INFOLICI         COLT FINEL         DONYS=IT         DAYS=IT         Contraction         ALLOON ANDIUS = 100 A.         ALOON         J=0         J=1         Con SHAPE CONPUTES BALLOON PANNETERS	-3 AL MRITE	1,315)VWIND=_64.2.64 M/SEF_64.22HD=_66.2.12H MEWINM/SP.K/1	
Ceve INFUZ PRIMIS. OUTPUT HEADING. FOR POWER SOUNCE SPECIFIED         6       077 IT=IIT.MIT.MIT         7       0.77 IT=IIT.MIT.MIT         8       17=10.00         9       17=10.00         10       23 MM-12.00         23 MM-12.0       23 MM-12.01         11       15=20.01         12       23 MM-12.00         13       25 MM-12.00         13       25 MM-12.00         14       26 TO 25         15       24 MM-12         16       20 TO 25         17       25 MM-12         16       100 M         17       25 KENVUDO         17       25 KENVUDO         18       100 M         10       10         12       26 KENVUDO         13       26 KENVUDO         16       15-1         17       2 CALL SHAFE (RENV)         17       2 CALL SHAFE (RENV)	5 CALL		
0       7       11=111.MIT.MIT         1       DaYS=1T       DaYS=1T         1       15=22.4.17       11=111.MIT.MIT         1       F15=2.4.17       12=2.23.24         2       MK=12.00       23         1       CU TO 25       25         2       24       MK=12.00         1       CU TO 25       25         2       24       MK=12.00         3       25       MKH=100.         4       R1=0       1         5       1=0       1         6       15=1       1         7       2.4L       SAMETERS         65       15=1       1         7       2.4L       SAMETERS         7       2.4L       SAMETERS	CAN INFUZ PR	INIS, OUTPUT HEADING FOR POWER SOURCE SPECIFIED	
7     DAY5-IT       8     115-22.4.11       15-22.4.11     15-22.4.11       15     21 HKN=12.0       16     21 KKN=12.0       17     25 HKN=12.0       18     512 HK       19     24 HKN=11       10     24 HKN=11       11     25 HKN=12.0       12     24 HKN=100       13     25 KHV=100       14     20       15     1=0       17     2 Call SHAFE (RENV)       18     15-1       19     15-1       17     2 Call SHAPE (RENV)       18     15-1       19     15-1       17     2 Call SHAPE (RENV)	10 11 CAELUIE	LITE LUOF	
9       IFIFN-11         10       23         11       10         12       24         13       25         13       25         14       10         15       21         15       21         16       10         17       26         15       15         16       15         17       2         15       15         15       15         15       15         15       15         15       15         16       15         17       2         17       2         17       2         25       5         17       2         26       5         5       15         17       2         26       5         17       2         17       2         26       5         26       5         26       5         26       5         26       5         20       1	T DAYS=1		
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99     Construction       91     VECPLANCENTIME.2004       92     VECPLANCENTIME.2004       93     VECPLANCENTIME.2004       94     VECPLANCENTIME.2004       95     VECPLANCENTIME.2004       96     VECPLANCENTIME.2004       97     VECPLANCENTIME.2004       96     VECPLANCENTIME.2004       97     VECPLANCENTIME.2004    <	51	AL 1FT=VOL+HL 1FT(1A)-ENVN	•
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<ul> <li>NEG-RADOL PERSON CONTRACT CONTROL</li> <li>NUMPORTON CIRCUM</li> <li>NUMPORTON CIRCUM</li> <li>NUMPORTON CIRCUMENT STRUTTON TO THE ST</li></ul>	29	DK AG=Q=CC+VOL++ 6666667	
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<ul> <li>B. FURNHORSEN</li> <li>B. FURNHORSEN</li> <li>C. B. FURNHORSEN</li> <li>C. B. REGURES CONNETION STERN. FOR SULF SUDDIES CONNELS.</li> <li>C. B. REGURES CONNETION STERN. FOR SULFICION EXEMPATIVANISTICION FERMINIALST</li> <li>C. B. LEODIN SYSTEM. FOR SULFICION. RECON NUST - NET LIFT - ALIFT</li> <li>C. B. LEODIN SYSTEM. FOR SULFICION. RECON NUST - NET LIFT - ALIFT</li> <li>C. B. LEODIN SYSTEM. FOR SULFICION. RECON NUST - NET LIFT - ALIFT</li> <li>C. B. LEODIN SYSTEM. FOR SULFICION. RECON NUST - NET LIFT - ALIFT</li> <li>C. B. LEODIN SYSTEM. FOR SULFICION. RECON NUST - NET LIFT - ALIFT</li> <li>C. B. LEODIN SYSTEM. FOR SULFICION. RECON NUST - NET LIFT - ALIFT</li> <li>C. B. LEODER STATE.</li> <li>C. B. LEODER STATE.</li> <li>A. STERNART STATE.</li> <li>A. STERNART STATE.</li> <li>A. STERNART STATE.</li> <li>A. B. LITI AND STATE.</li> <li>A. B. MITTEL, AND TSATE.</li> <li>A. B. MITTEL, AND AND AND AND AND AND AND AND AND AND</li></ul>	62	PR EQ=PREQ/EPRUP	
PRUDMENDING           PRUDMENDING           PRUDMENDING           Composition         Predmentation	63	RP=RENV4.45	•
<ul> <li>Call DUER (PRECAMERICA SPIG). APPOID</li> <li>Call DUER (CONVERTS) (PRECAMERICA SPIG). APPOID</li> <li>FRECHTER CONVERTS. ANS/O OF DUER TAX/ON THREATED POINTERNIA SECURE SOURCE</li> <li>FRECHTER (SPIG). AND THE PRESENT TIME LOOP IS COMPLETED.</li> <li>CALL CONVERTS. AND THE PRESENT TIME LOOP IS COMPLETED.</li> <li>CALLET - ALLET RESCALED (C)</li> <li>CALLET CONVERTS. AND THE PRESENT TIME LOOP IS COMPLETED.</li> <li>CALLET - ALLET RESCALED (C)</li> <li>CALLET - ALLET RESCALED (C)</li> <li>CALLET CONVERTS. AND THE PRESENT TIME LOOP IS COMPLETED.</li> <li>CALLET - ALLET RESCALE IS PAIRTED. AND THE PRESENT TIME LOOP IS COMPLETED.</li> <li>CALLET - ALLET RESCALE IS PAIRTED. AND THE PRESENT TIME LOOP IS COMPLETED.</li> <li>CALLED CONTRACT AND THE PRESENT TIME LOOP IS COMPLETED.</li> <li>CALLED CONTRACT AND THE PRESENT TIME LOOP IS COMPLETED.</li> <li>CALLED CONTRACT AND THE PRESENT TIME LOOP IS COMPLETED.</li> <li>CALLED CONTRACT AND THE PRESENT TIME LOOP IS COMPLETED.</li> <li>CALLED CONTRACT AND THE PRESENT TIME LOOP IS COMPLETED.</li> <li>CALLED CONTRACT AND THE PRESENT TIME LOOP IS COMPLETED.</li> <li>CALLED CONTRACT AND THE PRESENT TIME LOOP IS COMPLETED.</li> <li>CALLED CONTRACT AND THE PRESENT TIME LOOP IS COMPLETED.</li> <li>CALLED CONTRACT AND THE PRESENT TIME LOOP IS COMPLETED.</li> <li>CALLED CONTRACT AND THE PRESENT TIME LOOP AND THE PRESENT TIME LOOP IS COMPLETED.</li> <li>CALLET AND LEAST AND THE TREEM</li> <li>CALLET AND LEAST AND THE PRESENT AND R2. LOOP ALCH (2) AND COMPUTE AND R2. LOOP ALCH (2) AND COMPUTE AND R2. LOOP AND R2. LOOP AND R2. LOOP ALCH (2) AND COMPUTE AND R2. LOOP AND R2. LOOP ALCH (2) AND COMPUTE AND R2. LOOP ALCH (2) AND COMPUTE AND R2. LOOP AND R2. LOOP AND R2. LOOP ALCH (2) AND COMPUTE AND R2. LOOP AND R2. LOOP ALCH (2) AND COMPUTE AND R2. LOOP ALCH (2) AND COMPUTE AND R2. LOOP AND</li></ul>	3	PR UPM=PROPers	
<ul> <li>Consider Consults Computer Marker Marker Source Construction Frammary Automotestime Source Consults for Sulution, Recontauron-retainbary Marker Mar</li></ul>	65	CALL PUMEN (PREQ,ALENG,K,SRHO,HRHO)	
<ul> <li>REGUREG MASS MASS GALL COMPAYINGLY REAVIRATION FERMINALSTAN</li> <li>C. RALCONSTENT, FOR SULUTION, REGN MUST = WET LIFT = ALIFT</li> <li>C. RALLOND SYSTENT, FOR SULUTION, REGN MUST = WET LIFT = ALIFT</li> <li>C. RALSCUERE MASS MASS GALL COMPARENTS AND THE PRESENT TIME LOOP IS COMPLETED.</li> <li>C. A MESSAGE IS PRINTED, AND THE PRESENT TIME LOOP IS COMPLETED.</li> <li>C. A MESSAGE IS PRINTED, AND THE PRESENT TIME LOOP IS COMPLETED.</li> <li>C. A MESSAGE IS PRINTED, AND THE PRESENT TIME LOOP IS COMPLETED.</li> <li>C. A MESSAGE IS PRINTED, AND THE PRESENT TIME LOOP IS COMPLETED.</li> <li>C. A MESSAGE IS PRINTED, AND THE PRESENT TIME LOOP IS COMPLETED.</li> <li>C. A MESSAGE IS TRUPTOR TO ALITY</li> <li>C. A MESSAGE IS TRUPORTICICAL ALLONDOR TO ALITY</li> <li>C. A MESSAGE IS TRUPORTICICAL ALLONDOR TO ALITY</li> <li>C. A MESSAGE IS TRUPERTOR TO ALITY</li> <li>C. A MERSAGE IS TRUPERTOR TO ALITY</li> <li>C. A MERSAGE IS TRUPORTICICAL ALLONDOR TO ALITY</li> <li>C. A MERSAGE IS TRUPERTOR AL</li></ul>		C++ PDMER COMPUTES COMPUNENT MASSES OF POWER SOURCE	
Centre         Centre<	<b>66</b>	REGREREGN+PROPN+TNN+STRN+TWIRN+TBAIN+PAYN+AUTON+TERMM+BASTN	
C antoon System. For Sulution, Rean Nust - NET LIFT - ALIFT Systemeonetwork Fronter-ALTE-Read Fronter-Read Fronter-Read Fronter-ALTE-Read Fronter-Re	1	Cot REGULAED MASS = MASS OF ALL COMPONENTS REGULAED TO POWER, AND OPER	ATE
01         SYSNAREANCH           03         SYSNAREANCH           04         SYSNAREANCH           05         IF (ASSIGEF1.EE.1.0) GJ 03           17         Contrel 14.1.2.535. THAN REAN TOO M. AN UTERATION TAKES PLACE.           17         Contrel 14.1.2.1.2.0.010 01.           17         Contrel 15.1.2.0.010 01.           17         Contrel 15.1.2.0.010 01.           17         A ressate 15.4 PAINTED. AND THE PRESENT THE LODP 15. CUMPLETED.           17         A ressate 15.4 PAINTED. AND THE PRESENT THE LODP 15. CUMPLETED.           17         Restrict 01 151           17         Restrict 0.01 151           17         Restrict 0.01 151           17         Restrict 0.02 50           17         Restrict 0.01 151           17         Restrict 0.01 151           17         Restrict 0.01 151           17         Restrict 0.01 151           18         Restrict 0.01 151           19         Restris 4.00105           100		C BALLOON SYSTEM. FOR SULUTION, REQN MUST = NET LIFT = ALIFT	
00         01FFALTG-RECM           70         Cen IF AALTCH - RECM           71         FFE(ARSE IS PRATED, AUG) THE PRESENT TIME LOOP IS COMPLETED.           71         -5         FFE(ARSE IS PRATED, AUG) THE PRESENT TIME LOOP IS COMPLETED.           71         -5         FFE(ARSE IS PRATED, AUG) THE PRESENT TIME LOOP IS COMPLETED.           71         -5         FFE(ARSE IS PRATED, AUG) TAKES           73         -60         TO 54           74         -60         TO 54           75         -60         TO 54           76         -60         TO 54           77         -60         TO 54           78         -60         TO 54           79         -61         MITM NEG.           71         -7         -7           72         -60         TO 54           73         -60         TO 54           74         -7         -7           75         -60         TO 54           76         -64         MEMALINESCONTOSIS 15           77         -7         -7           78         -7         -7           79         -1         -1           71         -1         -1	67	SY SM=REQ4+ENVH	
00       [F10455104751.4.5.1.0.0]       60       17.1.4.5.1.5.1.1.0.1.5.1.0.0]         11       0.5       17.1.5.1.5.5.7.1.4.4.0.0       15.0.4.1.6.1.5.1.5.1.5.1.5.1.5.1.5.1.5.1.5.1.5	89	DIFF=AL [FT-REGM	
70       Cent IF ALLEF (15, LESS THM REGM FOR LOO M, R, NO ITERATION TAKES PLACE,	69	[f[A85(D[fF].LE.1.0) 60 TO 37	
1         Construct Service         State         No         DIFFAIL         Diffe         Diffe <thdiffe< th=""> <thdiffe< th="">         Diffe</thdiffe<></thdiffe<>	70	IF(D[FF)45,37,50	
1         C. A REJAGE ISPAINTED, AND THE PRESENT TIME LOOP IS COMPLETED.           72         1511-56-0100 TO a1           73         50-010           74         1515-51-01           75         60 TO 59           76         60 TO 59           77         50-01           78         60 TO 59           79         60 TO 2           70         20 State Natures           78         60 TO 2           79         60 TO 2           70         20 State           78         60 TO 2           79         61 ALET AND ALETARGA           70         20 State           79         61 ALET AND ALETARGA           81 ALET AND ALETARGA           81 ALET AND ALETARGA           82 ALET AND ALETARGA           81 ALET AND ALETARGA           82 ALET AND ALETARGA           81 ALET AND ALETARGA           82 ALETAND ALETARGA           82 ALUTANTESISTATA           83 ALETAND ALETARGA           82 ALUTANTESISTATA           84 ALUTANTESISTATA           82 ALUTANTESISTATA           82 ALUTANTESISTATA           82 ALUTANTESISTATA           82 ALUTANTESISTATA		Cee IF ALIFE IS LESS THAN REAM FOR 100 M. R. NO ITERATION TAKES PLACE	
71       45 [F(1.5, E(5, 0) L(5, -1)]         73       R1 + E(W)         74       40       170 59         75       60       170 59         74       60       170 51         75       60       170 51         76       16115, 50, 015, -11         77       244       171 101 154         78       REVERSIVE - 01155       110-P01MT BETWEEN - 110, 154         78       REVERSIVE - 011 105       150 - 01155         78       REVERSIVE - 011 105       150 - 01155         79       REVERSIVE - 011 105       110 - 0101 105         79       REVERSIVE - 011 105       110 - 0101 105         70       00 10 2       201 10 109         300       REVERSIVE - 0105       110 - 0101 105         80       300       10 10 109         81       21 10 109       301 10 109         82       RUN FULGS       100 10 109         83       ROUTO       100 10 109         83       ROUTO       100 10 109         84       REVERSIVE - REGUESTSMAREGE - 1500 MARP - 1700 - 1000 MAR - 1700 - 1000 MARP - 1000 - 1000 MAR		C A RESSAGE IS PRINTED, AND THE PRESENT TIME LOOP IS CUMPLETED.	
72     TIFIIS.GT.01 IS1       73     R1-FERW       74     C0 10 59       75     FILIS.AT.01 IS-1       76     FILIS.AT.01 IS-4       77     R2-REW       78     R0 401       79     G0 10 15       79     FILIS.AT.01 IS-4       76     R2-REW       77     FRAVERIAN       78     R0 401       79     G0 10 2       60     10 39, 391       70     60 10 2       71     R486105       78     60 10 3       79     60 10 3       70     60 10 3       71     R486105       73     FORMATI OPENINT REMARADIUSS       79     60 10 3       70     60 10 3       71     R4865       73     FORMATI OPENINT REMARADIUSS       81     21 G0 10 139, 399       82     21 G0 10 139, 399       83     21 G0 10 17       83     21 G0 10 17       84     21 G0 10 17       85     21 G0 10 17       86     10 17       81     21 G0 10 17       82     21 G0 10 17       83     21 G0 10 17       84     21 G0 10 17       85     21 G0 10 17<	11	45 IF(J.EQ.0)60 TO 61	
7.3       R1-REW         7.4       G0 TO 59         7.5       50 J=1         7.7       State Lexit Full Miss. Diff. R2= LAST R W13M POS. UIFF         7.8       RELVAST FRZ.M196.         7.8       State Lexit R with Miss.         7.8       State Lexit Rest.         7.8       State Lexit R with Miss.         7.8       Construct RS with Miss.         7.8       Construct RS with Miss.         7.8       Construct RS with Miss.         7.9       Construct RS with RS LEG GNNSIDERED ever/7M ALTET. FB. 2, 64.0 SMREQME.         8.0       State RAST Lines.         8.1       State State RAST Lines.         8.2       State State State RAST R	72	IF(IS,67.0) IS=+1	· · · · · · · · · · · · · · · · · · ·
74       60 010 59         75       50 401         76       15-11.01 15-1         77       57-861         78       57-861         79       60 10 2         79       60 10 2         70       332 FEUNATI : 00000000000000000000000000000000000	2	RI=REWV	•
15         50         94           17         FIELLT.0         15-1           17         RELEAT.0.0         15-1           18         RELEAT.0.0         15-1           19         RELEAT.0.0         15-1           10         REMEAT.0.0         15-1           11         RETEA.0.0         10-001ML           12         AF0.2//1         10-001ML           13         FORMATIC OFFFE MAX.SIZE CONSIDERED ###*/TH ALTET.ERGA           14         RETEA.0.0         100.30.3           15         Con TO 00.30.3         1000.0           16         41         MRTELA.500.00% ALEMG.SYSH.PREQ.TSKIN, ENVM, RP.TMM.FUELM.TEM.           15         Con TO 00         20100.7           16         41         MRTEL3.3501004% ALEMG.SYSH.PREQ.TSKIN, ENVM, RP.TMM.FUELM.TEM.           16         41         MRTEL3.350104% ALEMG.SYSH.PREQ.TSKIN, ENVM, RP.TMM.FUELM.TEM.           17         STRAT_LEGATOR.D.SALEMG.SYSH.PREQ.TSKIN, ENVM, RP.T	11	60 T0 59	
76       RFIES.LT.001       15-1         77       Core R1= LAST R WITH NES. DIFF. R2= LAST R WITH POS. DIFF       39         78       50       NEW AND-TAIL-162-RUL-90         76       ALLET ANO. REVAIL-162-RUL-90       AENVEL-101-80         78       61       MITTEL ANO. SCOM NEW RADUS.         61       MITTEL ANO. SCOM NEW RADUS.       BASE-2011         81       330       GO TO Z         82       61       MITTELS.3001ALTF-REGM         81       330       GO TO Z         82       5010MAT       SOURCE         845-27/1       AES-27/1         82       5010M FOUND - WITE REVORE         83       GO TO 15         845       35010MY SALENG-SYSAH, PEG-15KLN, ENVM, RP. THM, FUELM, TANKM,         845       251KM, THERR-POL-DARG         845       300 TO 17         845       300 TO 17         845       300 TO 17         845       41         845       8411E(5, 35010MY SALENG-SYSAH, PEG-15KLN, ENVM, RP. THM, FUELM, TANKM,         845       41         845       60         845       41         845       8411E(5, 35010MY SALENG-SYSAH, PEG, 15KLN, ENVM, RP, THM, FUELM, TFOH,         845 <td>75</td> <td>50 Jel</td> <td></td>	75	50 Jel	
17         R2=REM           78         95         RENVENT.HE.           78         95         RENVENT.HE.           78         95         RENVENT.HE.           78         50         TO 2         RMM           79         60         TO 2         RMM           79         60         TO 2         RMM         RAULET. REQM           79         60         TO 2         SIZE CONSIDERED         SAMA SIZE CONSIDERED           81         327         FOUNT FOR PAUS.SIZE CONSIDERED         SAMA SIZE CONSIDERED         SAMA SIZE CONSIDERED           81         327         GO         TO 139.139.11FT.REGM         SAMA RAULES.SIZE CONSIDERED         SAMA RAULE           81         327         GO         TO 139.139.11FT.REGM         REMVEN.RAUM.R.RELM.FILMEN.           82         20         TO 139.139.12FT.REGM         SAMA RAULE SUBMER.SUME.         SAMA RAULE           83         70         TO 10         SAMA RAULE RAUM.RAU.RAUM.RAU.RAUM.RU.RAUM.	16	IFIIS.LT.O) IS*1	:
Cene R1= LAST R WITH NEG.         DIFF         R2= LAST R WITH NEG.         DIFF         R2= LAST R WITH NEG.         DIFF         R2= LAST R WITH NEG.         DIFF         R3         R4         R4.01US IS NID-DIMT BETWEEN RI AND R2. LOOP BACK (2) AND CONDUTE         Convertive.stlite.	77	R2=RENJ	`` `
78       59 RENVERI-(42-R1)*.5         78       50 REV         79       60 T0 2         61       81 MITET AND REIMER RADUUS IS MID-PUINT BETWEER RADUUS IS MID-PUINT BETWEER RADUUS IS MID-PUINT BETWEER RADUUS IS MID-PUINT IS ALLET AND RADUEL MAD RADUEL RADUER RADUER RADUER RADUER RADUER RADUER RADUEL RADUEL RADUEL RADUEL RADUEL RADUER RADIER RADI		Cot RI= LAST R WITH NEG. DIFF. R2= LAST R WITH POS. UIFF	
79       Con NEU ADDIUS IS MID-PUINT BETWEEN RI AND R2. LOOP BACK (2) AND COMPUTE         79       CO TO Z       LIET AND REQM FOR NEW RADIUS.       NID-PUINT BETWEEN RI AND R2. LOOP BACK (2) AND COMPUTE         81       WRITE (3.330)ALTET:REGN       BAS 2/1)       SID ALTET AND REQMANDELET:REGN         81       MSID:RATI : GOTTO BAC       BAS 2/1)       SID ALTET:REGN         82       CO TO B       BAS 2/1)       SID ALTET:REGN         83       FOLD 10 493.3919414243); K       SID ALTET:REGN         83       SID 10 493.994.94414243); K       SID 2047         83       SID 10 493.94414243); K       SID 2047         83       SID 10 470.000 - WRITE RADEG, SYSN, PREG, TSKIN, ENVN, RP, TMN, FUELM, TAWN, N         84       SIRM. ILLICE, SUD 2002, SYSN, PREG, TSKIN, ENVN, RP, TMN, FUELM, TSAN, SITR, SIRM, SID 10 77         85       GO TO 77       SIRM, ILLICE, SYSN, PREG, TSKIN, ENVN, RP, TMN, TBATN, TSAN, SISTR, TELS, SID 2007, SYSN, PREG, TSKIN, ENVN, RP, TMN, TBATN, TSAN, SISTR, TELS, SISTR, TELS, SID 2007, SYSN, PREG, TSKIN, ENVN, RP, TMN, TBATN, TSAN, SISTR, TURN, POS, DEG TO 77         81       C BO TO 77       SIRM, SINN, RP, TMN, TBATN, TSAN, SISTR, TAR, SISTR, TAN, FUELM, TSAN, SISTR, TURN, POS, DEG SISTR, SISTR, SINN, RP, TMN, TBATN, TSAN, SISTR, TAN, SISTR, TURN, POS, SISTR, SISTR, SINN, SISTR, TURN, POS, SISTR, SISTR, TURN, POS, SISTR, TAN, SISTR, TURN, POS, SISTR, TAN, SISTR, TURN, FUELM, TSAN, SISTR, TURN, POS, SISTR, SISTR, TURN, SISTR, TURN, POS, SISTR, TURN, POS, SISTR,	. 81	59 RENV=R1+(X2-R1)*.5	
7       C       ALET       AND       REOM       FOR       MADIUS         79       61       WITE(5,330)ALIFT-REOM         81       WITE(5,330)ALIFT-REOM         81       WITE(5,330)ALIFT-REOM         82       C0       10         83       332       FORMATI'-OPENDA         83       31       G0       10         83       31       G0       10         84       332       FORMATI'-OPENDA       MALIENGS-SYSM-PREG-TSKIM-, ENVM-, RP., TMM, FUELM, TAKM,         85       31       G0       10       139, 139, 141, 142, 142, 142, 142, 142, 143, 144, 144, 144, 144, 144, 144, 144	-	COT NEW RADIUS IS MID-PUINT BETWEEN RI AND R2. LOOP BACK (2) AND COMP	JTE
78       6.0       10.2         81       6.1       ukriff(2,330)ALIFT.KEQN         82       5.0       10.1       0.4         82       5.0       10.1       0.4         83       5.0       10.1       0.4         82       5.0       10.1       0.4         83       5.0       10.1       0.4         83       5.0       10.1       0.1         84       5.0       10.1       0.1         85       5.1       10.1       1.4         85       5.1       1.0       1.0         85       5.0       10.1       1.4         85       5.0       10.1       1.4         8       4.1       11.1       1.0         8       2.5       11.1       1.0         8       2.5       11.1       1.1         9       50       1.1       1.1         10       17       1.1       1.1         8       2.1       1.1       1.1         10       17       2.0       2.1         10       17       2.1       2.1         10       17       2.1 <td< td=""><td></td><td>C ALLET AND REAM FOR NEW RADIUS.</td><td></td></td<>		C ALLET AND REAM FOR NEW RADIUS.	
B0         B1         B1         B2         B2<	£	<b>6</b> 0 10 2	
81       330 FORMATI TOFFF MAX SLAF LUNSTOFRED FFF (TH ALTET-FFB. 2) SAL SHARENET.         82       60 T0 (39.39.49.41,42.43) rK         83       31 G0. T0 (39.39.49.42.43) rK         84       39 HITEG 3.3501DAYS.ALENG.SYSA.PREG.TSKIN.ENVM.RP.TMM.FUELM.TAWM.         85       31 G0. T0 (39.39.43.46.65.5YSA.PREG.TSKIN.ENVM.RP.TMM.FUELM.TAWM.         84       35 RM.LIARN.EDP.DRAG         85       60 T0 T1         85       60 T0 T1         85       60 T0 T1         86       41 WRITE(3.3501)AYS.ALENG.SYSA.PREG.TSKIN.ENVM.RP.TMM.FUELM.TFCM.         81       42 WRITE(3.3501)ARS.ALENG.SYSA.PREG.TSKIN.ENVM.RP.TMM.FUELM.TFCM.         83       42 WRITE(3.3501)ARS.ALENG.SYSA.PREG.TSKIN.ENVM.RP.TMM.TBATM.TSAM.         84       42 WRITE(3.3501)ARS.ALENG.SYSA.PREG.TSKIN.ENVM.RP.TMM.TBATM.TSAM.         85       60 T0 T1         90       43 WRITE(3.3501)ARS.ALENG.SYSA.PREG.TSKIN.ENVM.RP.TMM.TBATM.TSAM.         85       72 GRAPTIALE         90       43 WRITE(3.3501)ARS.ALENG.SYSA.PREG.TSKIN.ENVM.RP.TMM.RP.TMM.TSAM.         91       53 GRAPTIAL         92       54 MAITELS.J.STATALENG.SYSA.PREG.TSKIN.ENV.RP.TM.RP.TM.TSAM.         93       43 WRITE(3.3501)ARS.ALENG.SYSA.PREG.STATALS.C.F.F.S.F.S.Z.F.S.F.S.F.S.F.S.F.S.F.S.F.S	8	61 WRITE(3, 330)ALIFT:REGN	
2       650 10 (39, 39, 39, 41, 42, 43), K         6       10 (39, 139, 39, 41, 42, 43), K         6       70 (10) (39, 33, 30) Day Sy, 41, 42, 43), K         8       59 MULTECD, 5000 Day Sy, 41, 42, 43), K         8       50 MULTECD, 5000 Day Sy, 41, 42, 43), K         8       60 T0 T0         7       60 T0 T0         8       41 MRITECD, 5000 Day SALEMG, SYSH, PREQ, TSKIN, SHVH, RP, TMH, FUELM, TFCM,         8       41 MRITECD, 5000 Day SALEMG, SYSH, PREQ, TSKIN, SHVH, RP, TMH, FUELM, TFCM,         8       42 MRITECD, 5000 Day SALEMG, SYSH, PREQ, TSKIN, SHVM, RP, TMH, FUELM, TFCM,         8       42 MRITECD, 5000 Day SALEMG, SYSH, PREQ, TSKIN, SHVM, RP, TMH, FUELM, TFCM,         8       42 MRITECD, 3500 Day SALEMG, SYSH, PREQ, TSKIN, SHVM, RP, TMH, FUELM, TSAM,         8       42 MRITECD, 3500 Day SALEMG, SYSH, PREQ, TSKIN, SHVM, RP, TMH, FUELM, TSAM,         9       60 T0 T1         9       51 NK, THRM, PUELM, TSAM,         9       51 NK, THRM, PUELM, TSAM,         9       51 NK, TRATH, TSAM,         9       51 NK, TAM, TAM, TRATH, TSAM,<	10	30 FORMAL OF A A SIZE CONSIDERED THE ALLE ALLE THE SAME WE	
<ul> <li>2 30 10 (39, 39, 41, 42, 43), K</li> <li>5 31 CO 10 (39, 139, 41, 42, 43), K</li> <li>5 9 MITE(3, 3501DAYS, ALENG, SYSM, PREG, TSKIN, ENVM, RP, TMM, FUELM, TANKM, 2518M, TMM, FUELM, TANKM, 2518M, TMIRE(3, 3501DAYS, ALENG, SYSM, PREQ, TSKIN, ENVM, RP, TMM, FUELM, TFCM, 2518M, TMIRE(3, 3501DAYS, ALENG, SYSM, PREQ, TSKIN, ENVM, RP, TMM, FUELM, TFCM, 2518M, TMIRE(3, 3501DAYS, ALENG, SYSM, PREQ, TSKIN, ENVM, RP, TMM, FUELM, TFCM, 2518M, TMIRE(3, 3501DAYS, ALENG, SYSM, PREQ, TSKIN, ENVM, RP, TMM, TBATM, TSAM, 2518M, TURM, P02-DRAG</li> <li>6 41 4017</li> <li>6 41 4017</li> <li>6 41 4017</li> <li>7 6 4017</li> <li>9 550 FURMITIES - 0.FR.S, ALENG, SYSM, PREQ, TSKIN, ENVM, RP, TMM, TBATM, TSAM, 2518M, TURM, P02-DRAG</li> <li>9 5518M, TURM, P02-DRAG</li> <li>9 55010AYS, ALENG, SYSM, PREQ, TSKIN, EMVM, RP, TMM, TBATM, TSAM, 5518M, TURM, P02-DRAG</li> <li>9 5518M, TURM, P02-DRAG</li> <li>9 55010AYS, ALENG, SYSM, PREQ, TSKIN, EMVM, RP, TMM, TBATM, TSAM, 60171</li> <li>9 55010AYS, ALENG, SYSM, PREQ, TSKIN, EMVM, RP, TMM, TBATM, TSAM, 60171</li> <li>9 55010AYS, ALENG, SYSM, PREQ, TSKIN, EMVM, RP, TMM, TBATM, TSAM, 60171</li> <li>9 55010AYS, ALENG, SYSM, PREQ, TSKIN, EMVM, RP, TMM, TBATM, TSAM, 60171</li> <li>9 55010AYS, ALENG, SYSM, PREQ, TSKIN, EMVM, RP, TMM, TBATM, TSAM, 60170</li> <li>9 5010000</li> <li>9 501000</li> <li>9 5010000</li> <li>9 50000</li> <li>9 500000</li> <li>9 500000</li> </ul>	;	AF8•2///	
53       37       50       10       139.39.39.41,524.31,51       50.46       57.49.15       50.46       57.40       10.40       40.46       57.40       10.40       40.46       57.80       10.40	22		
0.       59 krite(3, 35010xY5, ALENG, SYSR, PREG, TSKIN, ENVM, RP, TUM, FUELM, TANKM,         0.       53 FRM. JURN, POP, DRAG         0.       41 krite(3, 35010xY5, ALENG, SYSR, PREG, TSKIN, ENVM, RP, TMM, FUELM, TFCM,         0.       41 krite(3, 35010xY5, ALENG, SYSR, PREQ, TSKIN, ENVM, RP, TMM, FUELM, TFCM,         1.       23 FRM. JURN, POP, DRAG         1.       23 FRM, JURN, POP, DRAG         1.       25 FRM, JURN, POP, DRAG         1.       25 FRM, JURN, POP, DRAG         2.       25 FRM, FUELM, FOR, DRAG         2.       35 FUENTIELIS, JODDAYS, ALENG, SYSM, PREQ, TSKIN, ENVM, RP, TMM, FUELM, TSAM,         2.       25 FRM, FUEN, FOR, DRAG         2.       35 FUENTIELIS, JODDAYS, ALENG, SYSM, PREQ, TSKIN, ENVM, RP, TMM, TBATM, TSAM,         3.       42 MLTELIS, JODDAYS, ALENG, SYSM, PREQ, TSKIN, ENVM, RP, TMM, TBATM, TSAM,         3.       42 MLTELIS, JODDAYS, ALENG, SYSM, PREQ, TSKIN, ENVM, RP, TMM, TBATM, TSAM,         3.       53 FUENTINE         3.       54 MLT LOOSE	63	37 G0 T0 (39,39,39,41,42,43) rk	
8+       59       WRITE(3: 350) DAYS, ALENG: SYSH, PREG. TSKIN, ENVN, RP. TMM. FUELM, TAKIN,         85       60       T       7         85       60       T       7         85       60       T       7         86       41       WRITE(3: 350) DAYS, ALENG: SYSH, PREQ. TSKIN, ENVN, RP. TMM. FUELM, TFCM.         81       251RM. 141RM. FOP. DRAG         83       42       WRITE(13: 350) HRS, ALENG. SYSH, PREQ. TSKIN, ENVN, RP. TMM. FUELM, TFCM.         83       42       WRITE(13: 350) HRS, ALENG. SYSH, PREQ. TSKIN, ENVN, RP. TMM. FUELM, TFCM.         83       42       WRITE(13: 350) HRS, ALENG. SYSH, PREQ. TSKIN, ENVN, RP. TMM. TBATM, TSAM.         90       43       WRITE(13: 350) DAYS, ALENG. SYSM, PREQ. TSKIN, ENVN, RP. TMM. TBATM, TSAM.         90       43       WRITE(13: 350) DAYS, ALENG. SYSM, PREQ. TSKIN, ENVN, RP. TMM. TBATM, TSAM.         91       350 FURMATIFS. OF FR. 2, FI0. 2, FR. 3, FT. 4, FLO. 2, 2FT. 2, F9. 2, FR. 2, 2FT. 2, F8. 4, F8. 2, F8. 2, 2FT. 2, F8. 2, 2FT. 2, F8. 4, F8. 4, F8. 2, 2FT. 2, F8. 4, F8	-	C++ SOLUTION FOUND - WRITE PROPER OUTPUT FOR POHER SOURCE	
STRM. LMRM. FOP. DRAC         65       60       10       71         87       63       10       71         87       63       10       71         88       41       MRITE(3, 350) DAYS. ALEMG. SYSH. PREQ. TSKIN. ENVN., RP. THM. FUELM. TFCM.         87       63       10       71         88       42       MRITE(3, 350) HRS, ALEMG. SYSH. PREQ. TSKI A, ENVN., RP., THM., TBATM. TSAM.         89       53 TAN. FUELM., POP., DRAG.       55 TAN., TMM., TBATM., TSAM.         90       43 MRITE(3, 350) HRS, ALEMG., SYSM., PREQ., TSKI M., ENVN., RP., TMM., TBATM., TSAM.         91       350 FURMATIE(3, 0., FR.2, FI0.2, FR.3, FT. 4, FI0.2, 2. FT.2, F9.2, FR.2, FR.4, G.         91       350 FURMATIE(5, 0., FR.2, FI0.2, FR.3, FT.4, FI0.2, 2. FT.2, F9.2, FR.4, G.         93       60 TO T       70       80         94       60 TO 200       60 TO 200       81M.       MO.< 200       86 G.         95       59       59       CONTRUE       51M.       MO.< 200       86 G.	•	39 WRITE(3,350)DAYS,ALENG,SYSN,PREG,TSKIN,ENV,RP,TMM,FUELN,TANKH,	
<ul> <li>60 T0 77</li> <li>61 KITE(3,350)DAYS,ALENG,SYSH,PREQ,TSKIN,ENVN,RP,TNN,FUELN,TFCN, 63 T0 77</li> <li>63 T0 77</li> <li>63 T0 77</li> <li>64 KITE(3,350) HRS,ALENG,SYSH,PREQ,TSKIA,ENVN,RP,TNN,TBATN,TSAN, 25TAN,TMIRN,P0P,DRAG</li> <li>69 G0 T0 77</li> <li>70 T1 75,0,FE,2,F10,2,FE,3,F7,4,F10,2,2F7,2,F9,2,F8,2,2F7,2,F8,4, 71 55,0,FE,2,F10,2,FE,3,F7,4,F10,2,2F7,2,F9,2,F8,2,2F7,2,F8,4, 71 55,0,FE,2,F10,2,FE,3,F7,4,F10,2,2F7,2,F9,2,F8,2,2F7,2,F8,4, 71 55,0,FE,2,F10,2,F10,2,F1,4,F10,2,2F7,2,F9,2,F8,2,2F7,2,F8,4, 71 55,0,FE,2,F10,2,F10,2,F1,4,F10,2,2F7,2,F9,2,F8,2,2F7,2,F8,4, 71 55,0,FE,2,F10,2,F10,2,F1,4,F10,2,2F7,2,F9,2,F8,2,2F1,2,F8,4, 71 55,0,FE,2,F10,2,F10,2,F1,4,F10,2,2F7,2,F9,2,F8,4,5,4,5,4,5,4,5,4,5,4,5,4,5,4,5,4,5,4,</li></ul>		25 RM+ TUIRH+ POP. 0446	
60       41       MRTTEL(3, 550)5475, ALEMG, 5758, PREQ, 15KIN, ENVN, RP, IMM, FULLM, ITCM,         81       25184, 14174, FOP, 0R4G       25184, 14174, FOP, 0R4G         83       42       WETEL(3, 350) HR5, ALEMG, SYSH, PREQ, TSKIA, ENVN, RP, TMM, TBATM, TSAH,         89       60       10       7         89       60       10       7         90       43       METEL(3, 350) HR5, ALEMG, SYSH, PREQ, TSKIN, ENVN, RP, TMM, TBATM, TSAH,         90       43       METEL(3, 350) AR5, ALEMG, SYSM, PREQ, TSKIN, ENVN, RP, TMM, TBATM, TSAH,         90       43       METEL(3, 350) AR5, ALEMG, SYSM, PREQ, TSKIN, ENVN, RP, TMM, TBATM, TSAH,         91       350       FURMATIER, DER, DERAG         91       350       FURMATIES, OFFEL2, FIO.2, FEL.3, FT.4, FLO.2, 2FT.2, F9.2, FB.4,         92       77       GUTTOLE         93       60       10         94       60       10         95       59       CUNTINUE         96       510P	÷	60 10 11	
ET         CS         CS<	98	41 URIFE(3,350)DAYS,ALENS,SYSH,PREQ,ISKIN,ENVA,RP,IHH,FUELN,FUELN,	•••
81       42       WEITE(1)         83       42       WEITE(1)         74       251381.14134.007.0846       5844.0846.158114.608.1581.0846         89       60       17         90       43       WEITE(1)       53010475.04266.5784.0860.158114.6004.80         91       350 FURMAT(55.0.68.2, F10.2, F30.2, 2577.2, F9.2, F30.2, 2577.2, F3.4.4.6.6.6.6.6.6.6.6.6.6.6.6.6.6.6.6.6.		ZSIMI, IMIRA, POP, DRAG	
88       *2       WITE 19701 MSAG         89       60 T0 7         90       +3 WITE 132020 MSAG         91       350 FURMITE 145.00 FR.5 ALENG. SYSW. PREQ. TSKIN. ENVN., RP. TMN. TBATM. TSAM.         91       350 FURMITE 15.00 FR.2, F10.2, FS.3, F7.4, F10.2, 257.2, F9.2, F8.2, F8.4,         92       77 CGMTINUE         93       60 FO 200         94       60 T0 200         95       60 T0 200         96       510 LUNE         95       59 CUNTINUE         96       510 LUNE         96       510 LUNE			
89         60         10         71           90         43         MKITEI3-3300DAYS,ALENG,SYSM,PREQ.TSKIN,ENVN,RP.TMN,IBATN,ISAN,           90         43         MKITEI3-3300DAYS,ALENG,SYSM,PREQ.TSKIN,ENVN,RP.TMN,IBATN,ISAN,           91         350         FURMATIFS.0.FR.2.F10.2.F8.3.F7.4.F10.2.2F7.2.F9.2.F8.2.2F7.2.F8.4.           91         350         FURMATIFS.0.FR.2.F10.2.F8.3.F7.4.F10.2.2F7.2.F9.2.F8.2.2F8.4.           92         77         GGNTNUE           93         48         CONTRUE           94         60         70           95         59         CUNTRUE           96         510         NO200		♦2 MAILE(JS-2012 MAISASIENGS/21204-1241241245445474124544444444444444444444	•
90 43 WAITE 3: 3302DAYS, ALENG, SYSW, PREQ, TSKIN, ENVN, RP, TWN, TBATH, TSAM. 91 350 FURMAT (FS. 0, FR. 2, F10.2, FR. 3, F7. 4, F10.2, 2F7.2, F9.2, F8.2, 2F7.2, F8.4, 92 77 CGNTINE 93 88 CONTINE 94 80 TO 200 95 59 CUNTINE 96 510P 96 510P			
91         350         FURM.FIS.0.014.120.0130.014.010.010.010.010.010.010.010.010.01		AUTUS TATING STATE CASE PARA TATE CAME AN TAILY TAKEN TAKEN	
91 350 FURMATINE OF R. 2, F10.2, F8.3, F7.4, F10.2, 2F7.2, F9.2, F8.2, F8.4, 92 77 CGMTINUE 93 85 CONTINUE 94 60 TO 200 95 59 CUNTINUE 95 59 CUNTINUE 96 570P	8	40 MLICIST.DOUGATCHO.STSM.FKEG.ISKIN.CNV.V.C.MV.C.K.C.MV.C.MV.ISAIN.	
92 77 GGATINE 93 86 GORTANE 94 60 TO 200 95 59 CUNTINE 96 510P			
92 77 66411446 93 48 60411446 94 60 70 200 95 59 6041146 95 59 6041146 95 5100 96 5100	1	53U FUKEAI [ 73.4; Fe.2; TU.2; Fe.3; T.1.4; FU.2; F.1.4; F.4.4; F.4.4; Fe.4; F.4.4; Fe.4; Fe.4; Fe.4; Fe.4; Fe	
72 CH CONTINUE 94 EU TO 200 95 CALL LOUSE COMELETED. SIM. NO. 200 READS NEW CONTROL CARD 95 59 CUNTINUE 96 STOP	ç		
94 CONTRACT 94 CONTROL 95 CONTINUE 95 STOP 96 STOP	20		
95 CONTINUE 96 STOP 96 STOP	<b>.</b>		
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59         54         Curt Inuc           96         510P         200P		CITE ALL LUCE LURGE LURGER DIA. NU. CUP READS ARE CUMINUL CMU	
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000 TUTAL ENNORS FOR THIS COMPILATION 00 THE TUTAL CURE USED BY MASKY IS 13312 DECIMAL. 01 THE TUTAL CURE USED BY MASKY IS 13312 DECIMAL. 02 TTHE NOUVELAY CURE SIZE IS 16244 DECIMAL 04 TTOTAL NUMBER DF LIBLARY SECTORS REQUIRED IS 70 NAME-MASKY PACK-FORTRZ, WNIT-RI, RETAIN-T, LIBNARY-D

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SUBROUTINE INFUT (K) * SUBROUTINE INFOT PRINTS TYPE OF POMER SOURCE SPECIFIE 60 TO 11,2,3,4,5,6),K	L URITE(3,308)	305 FORMAT( "ONREC GAS TURBINE AS POWER SUURCE" / )	RETURN	2 WRITE(3, 309)	309 FORMAT("OTURBOCHARGED NANKEL AS PONER SOURCE"/)	RETURN	3 WRITE(3,310)	310 FORMAT("OTURBOCHARGED DIESEL AS POWER SOURCE"/)	RETURN	4 uk[TE(3r311)	311 FORMAT(*OFUEL CELL AS POWER SOUNCE*/)	RETURN	5 HR[TE(3,312)	312 FURMAT("OSOLAR CELLS AS POWER SOURCE"/)	RETURN	6 WKITE(3,313)	313 FURMAT("OBATTERIES AS POWER SOURCE"/)	RETURN	END	The second for This Scholl attom
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000 IDIAL ERRURS FOR THIS CUMPILATION OLIGA I TOTAL NUMBER OF LIBRARY SECTORS REGUIRED IS 5 NAME-INFOL "PACK-FORTR2;UNIT-RL,RETAIN-T,LIBRARY-R,CATEGONY-020

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320 FORMAT(2K; 4HDAYS, IX; 6HLENGTH, 6X; 4HMASS, 4X; 4HPREQ; 2X; 5HTSR[N; 6X; I4HHULL; 4X; 2HRP; 2X; 6HENGINE; 5X; 4HFUEL; 4X; 4HTANK; 4X; 3HSTR; 3X; 4HHIRE; 2 FOKMATT ZX, SHOAYS, EX, 6HLENETH, 6X, 4HMASS, 4X, 4HPAEQ, 2X, 5HFSKIN, 6X, 14HHXL, 4X, 2HAP, 3X, 5HND TOK, 5X, 4HFUEL, 3X, 4HTFCM, 5X, 3HSTR, 3X, 4HUIRE, 25X, 3HPQP, 2X, 6HTHXUST) FORMAT T & HOURS, IX, GHLENGTH, bX, 5HMASS, 4K, 4MPREQ, 2K, 5HTSKIN, 6K, AHMULL, 4K, 2HRP-3K, 5HMOTOR, 4K, 5HTBATN, 5K, 2HSA, 5K, 3HSTR, 3X, 4MLIRE, <u>326 FORMATT(2X,4HDAY5,1X,6HLENGTH,6X,4HMASS,4X,4HPREQ,2X,5HT5K[M,6X}</u> <u>A4HHULL,4X,2HRP;3X,5HMUTOR,6X,5HTBATM,5X,2HSA</u>,5X,3HSTR,3X,9MLIRE, 000 TOTAL ERRORS FOR THIS COMPILATION 1 TOTAL NUMBER OF LIBRAAY SECTORS REQUIRED IS 6 NAME-IMFOZ ,PACK-FORTR2+UMIT-RI,METAIN-T,LIBRAAY-R,CATEGORY-020 C++ SUBROUTINE INFUZ PRINTS COLUMN HEADINGS FOR OUTPUT DATA GO TO (1,1,1,1,2,3,4),K C++ WRITE COLUMN HEADS FOR IC ENGINE OUTPUT WRITE COLUNN HEADS FOR ALL BATTERY OUTPUT 4 MR[TE(3+326) WRITE COLUMN HEADS FOR SOLAR ARRAY OUTPUT WRITE COLUMN NEADS FOR FUEL CELL OUTPUT B5K, 3HPOP, 2X, 6HTHRUST) 25X, 3HPOP , 2X, 6HTHRUST1 25X, 3HPOP, 2X, 6HTHRUST) SUBROUTINE INFOZ (K) WRITE(3, 324) WALTE( 3, 320) 2 4R [TE(3, 322) RETURN FORMAT RETURN REFURN RETURN ŝ 322 . 3 1 601 10 -N 1 21 2 <u>r 1</u>7

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			LENESS RATIO GREATER THAN 1. USE CLASS C. S		۰.
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	)	C++ ALENG	E ENFLATED LENGTH OR DIANETER		• •
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		C++ TSKIN	* SKIN THICKNESS		
ł			ENVELOPE NASSFINAL VALUE CONVITED [5]	DTAL NUL MASS	
			ursek ur vonca 2006 EcilGTH		
		C++ TAPEH	= HASS OF SEALING TAPES		
		C++ F184 =	- HASS OF HURZ. AND VENT. FINS		
		Cet SALW	= BALLUMET NASS		
		CAN BASEN	* BALLAST MASS		
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-4	SUBROUTINE POWER (PRE4, ALENG, K, SRH0, RHO)
	Cee SUBRUUTINE POMER CUMPUTES MASS OF POWER DEPENDENT COMPUNENTS 
~	CURRUN BUREFERANTITEATER MIREL MIREL,
	2CELL2,CELL1,CFCM3RAD,TMR1,TMR2,SFC1,5FC2,5FRRR,C51KM,UFLM,AUUK2, 
~	COMPACE SPACE STATE CANDER STATE STA
•	IHRSPHRN-TS
•	EAR COMPUTE COMPONENT HASSES FOR SC ENGINE
L.	20 TEATM=BATH=BATH
	PREQ=PREQ=SUBPUL/CFCPS
~ (	THE HUMS THE REGARDANCY (KING) LARBOX STATES
8 9	TACHTST CONTRACTOR 64ALENG
ē	SIAMSSIAMS 4 THAT ROPH ADDAT 49146 49146
	TW [KM=ALENG+664[2.*W]RE1+3.*W]RE2]
2	PEGGE-TANKA+FUELM+AUDAL
-	rae converse component masses common to electrical systems
71	21 SPRH-SPR+PREQ
	PR 64=PR 64/55PR
16	TMM≍UMM2≠PREG+CMM2
17	pim=pkEc/EM
18	
61	IFIK-512'42950 AND AND AND AND AND AND AND AND AND AND
	Let Luticity Longerty Longerty - CERLIN WAS PAULTED FOR
	LULL SFLARS (00174PJM/EC2954SUBPOW/ECPSS)
2	TANKATINATION
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4- 16 1-4-19	I FIGHCLEINT I SANATAMAN THERM 2. THERE 33 AAAALENG FP [ M/YDL] FC
200	
	JBATM=BATJ#BENGY arria=treatmatconmaannm2
ŝ	Ces Compute Compunent MASSES FUX SOLAR CFLLS.
30	25 HaS=24,s=HRN
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	int states and the states of
ŝ	FEAALCC-XIC 266,28,28
M	Z6 BAIM=GATH+XIC/BATCC
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5	I TRWSTARSPIREMEMANUSCECKAC
9	12 PKEG=PREG+1,225P0b/16CP8+BCHEF1
4	TSAM=PREDETEIDE ESA+KikE4)
42	THIRPASS ENGEL STATEMENT FLOORENESS FOR THE STATEMENT OF
41	STARESTRANDER STRANDERSTRANDERSTRANDERSTRANDERSTRANDERSTRANDERSTRANDERSTRANDERSTRANDERSTRANDERSTRANDERSTRANDERS
	Cat COMPUTE COMPONENT MASSES FOR ALL BATTERY CASE
\$	20 ISAT HABAT LAARAAT JAAR MALA
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FURTRAN IV VEROL/NEDOL

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11253+2++014/241543	SPRN+PNUPN+ADDH3+.5}+CSTRN	ENG			· ·	
48 TNERM=ALENG+(,64)	5-AMETANASERNES	50 REGM=TSAM+SPKN+AD	51 RETURN	52 ENG		

NEKE-PUMER PACK-FORTR2.UNIT-RI.RETAIN-T.EIBARY-E.CATEGOR-020 000 TOTAL EURORS FOR THIS COMPLATION OLIO3 I TOTAL NUMBER OF LIBRARY SECTORS REGUTRED IS-

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ECPSS CMN2	VOLTEC SFC2. GEOF	<b>PNBYP</b> D
ECPPS UMA2	BENGY SFC1 SA	-SKINR SUBPON
ECPB CMA1	NIRE5 TMR2 ADCM3	FLANK TURBOK
BATCY	MIRC4 IMR1 AUDM2	6LC PAYN
BATCC SPR	KAD RAD	FLN TERNM
BATZ SCOP	CFCM CFCM	ADHE AUTOM
6ATL 6400	MIREI CELLI	SHAT
BCHEF	CELL2	SK IND SUPERT VOL ISA

0.88999998E+00 0.43500004E+01 0.85500002E+00 0.6000010E-02 0.61999999E-01 0.8999998E+00 0.9700003E+00 0.899999E+00 0.75999999E+00 0.38699999E+01 0.9499999E+00 0.000000E+00 0.8079999E-01 0.12110000E+02 0.8689994E+01 0.4079999E+01 0.75900000E+00 0.3800001E-02 0.5000000E+00 0.000000E+00 0.3300000E+02 0.36899996E+01 0.4079999E+01 0.24699999E+00 0.11000000E+01 0.3200000E+02 0.8159998E+01 0.45239997E+01 0.31000000E+02 0.83999996E+01 0.3000000E+02 0.246999999E+00 0.11000004E+01 0.52200001E+01 0.45239998E+01 0.31000000E+01 0.773000002E+00 0.3000000E+01 0.114999999E+00 0.11000004E+01 0.52200001E+01 0.45239998E+01 0.22799999E+01 0.3000000E+01 0.114999996E+01 0.52200001E+01 0.52200001E+01 0.45239997E+01 0.224999999E+01 0.30000000E+01 0.114999999E+00 0.11000004E+01 0.52200001E+01 0.45239997E+01 0.2249999999E+01 0.30000000E+01 0.114999999E+00 0.11000004E+01 0.52200001E+01 0.45239997E+01 0.224999999999E+01 0.30000000E+01 0.114999999E+00 0.11000004E+01 0.52200001E+01 0.45239997E+01 0.224999997E+01 0.32700005E+00 0.30000000E+01 0.114999999E+00 0.11000004E+01 0.52200001E+01 0.45539997E+01 0.244999999E+01 0.30000000E+01 0.1149999995E+00 0.11000004E+00 0.45400000E+01 0.45539997E+01 0.2249999999E+01 0.3000000E+01 0.1149999995E+00 0.11000004E+00 0.52200001E+01 0.45539997E+01 0.2249999995E+01 0.30000000E+01 0.114999999E+00 0.11000004E+00 0.45400000E+01 0.35699997E+01 0.906999997E+01 0.244999998E+01 0.3000000E+01 0.1140999995E+00 0.444999997E+00 0.45400000E+01 0.455399997E+02 0.10000005E+00 0.37000000E+01

SOLAR CELLS AS POWER SOURCE

NTOM/N2	•	
1331. NE		THRUST 446.65 465.69
DELTAP= ]		P0P 6.3986 7.1921
6/M3 E		H [RE 13.02
07487 K		518 24.22 25.04
RHD		SA 202.64 211.03
EKTOW/M2		18ATH 67.92 86.75
4678. W		N010R 94.26 07.93
PRESS=	_	RP 5.22 5.22
65 KG/N3	NEW TON/ SQ. M	HULL 1519.45
FT=.064	8-93 1	TSKIN 1.1866
RS HLI	5	PRE9
LOOD. METE	444 M/SEC	MASS 2042.78
1TUDE= 2	HIND=15.4	LENGTH 115.97
AL T		HOURS 16.
* *	1	

483.14 521.01 588.04

in

25.79 14. 10.26

18-85 235.69 265.50

97.93 5.43 101-29 108.59 121.51

5.33

101.09 1911.29 2287-64

0.1905 5.252 0.1940 6.426 0.2015 1.503 0.2141

2296.88 2572.29 2172.94

> 120.61 133-06

29

18.41

3063.89

50-10 25.35 06.41

> 5.5 5.99

<del>son</del>ásky≎¢ run 60 4/LR80-2 Battery, VN/VD ≈ 10/30 ↔ User Poner = 100 natts

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机合物器 机外线器 化微量子 "你不是你的女子,想要我一些不是一些是一种思想,却是我不是不能的?""你说,你们你你是我一点,是我不是你们们们们的那些我说了,可是你不可以能知道,你不不是你?""你是你不是

ECPSS CMN2 VOLTEC	SFC2 GEOF CD	PNBYPD
ECPPS UMA2 NENGY	SFCL SA SKINR	SUBPON
ECPB CMMI MIRES	T MK2 AUDH3 F INNR	TURBOR
BATCY UMMI WIRE4	THRI AGUN2 GLC	PAYN
BATCC SPR WIRE3	KAU Aŭdmi Fix	TERMA
6AT2 ESPR HIRE2	UFLH VFLH AOHE	AUTUM
BATI PROP Virei	CSTRN SRAT	DUTY
BCHEF EPROP EM	STRING	

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**0.43999998E+00 0.43500504E+01 0.8550002E+00 0.60000010E-02 0.61999999E-01 0.89999995E+00 0.9700003E+00 0.4079999E+00 0.75999999E+00 0.38699995E+01 0.9499999E+05 0.0000000E+00 0.80799997E-01 0.12110000E+32 0.86899995E+01 0.40799995E+01 0.75000000E+02 0.38000501E-02 0.5000008E-03 0.8000001E+00 0.33300000E+01 0.12110000E+32 0.86899995E+01 0.40799995E+01 0.246999995E+02 0.13000000E+01 0.50000008E-03 0.8000001E+00 0.33300000E+01 0.12110000E+32 0.86899995E+01 0.40799995E+01 0.11999995E+00 0.11000000E+01 0.52000001E+01 0.45299997E+01 0.4520000E+01 0.72700000E+01 0.73000002E+00 0.3600000E+00 0.11499995E+01 0.877088E+08 0.43300013E+02 0.5000000E+01 0.40299997E+01 0.22700000E+01 0.444999998E+01 0.30000000E+01 0.11499995E+01 0.877088E+08 0.43300013E+02 0.5000000E+01 0.104599995E+01 0.227000002E+01 0.444999998E+01 0.30000000E+01 0.11499995E+00 0.11000002E+00 0.45500001E+01 0.45299997E+01 0.45299997E+01 0.227000002E+00 0.30000002E+00 0.11499995E+00 0.11000002E+00 0.455000000E+01 0.455099997E+01 0.452999995E+01 0.227000002E+00 0.30000000E+01 0.10000002E+00 0.199999999E+00 0.45500001E+01 0.455099997E+01 0.452999995E+01 0.227000002E+00 0.30000000E+01 0.100000002E+00 0.19999999E+00 0.45500001E+01 0.455099997E+01 0.2000000E+01 0.227000002E+01 0.50000002E+01 0.50000000E+01 0.100000002E+00 0.199999999 0.100000002E+00 0.19999999 0.10000000E+01 0.45500000E+01 0.455099997E+01 0.9000999995E+01 0.2000000E+01 0.45999999E+00 0.50000000E+01 0.10000000E+01 0.19999999 0.116000000E+01 0.45500000E+01 0.4550999997E+01 0.9000999997E+02 0.10000000E+01 0.45999999E+00 0.37000000E+01 0.10000000E+03 0.45900000E+01 0.4550999997E+01 0.900000E+01 0.45999999E+00 0.37000000E+01 0.10000000E+03 0.19999999E+00 0.45500000E+01 0.4550999997E+02 0.10000000E+01 0.14999999E+00 0.370000000E+01 0.10000000E+03 0.10000000E+01** 

SOLAR CELLS AS POVER SOURCE

	i				
	IHRUST	458.04	473.23	492.95 536.36	607.62
	904	7.0740	7.3712	2440-1	1486.9
	NIBE	13.49	14.32	15.95	20.32
	STR	24.71	25.53	28-06	31.10
	- SA	209.63	216.25	244.52	276.21
; - -	TBATA	75.37	96.09	166.06	259.48
	MOTOR	\$6°45	103-76	111.55	125-29
	RP	82*5	5 ° °	5.72	6.03
NENTON/SQ.	HULL	1578-66	1776.95	1996.68	2402.46
3.93	NIXSI.	0.1689	0.1966	0.2044	0.2176
å	PRED	610-41	15.788	140°11	19.249
444 N/SEC	HASS	04°4177	2388.91	2687.04	3239.48
N1ND=15	TENGTH	110 87	122-19	127-08	135.25
	HDURS	14.	12-	10.	
 2					

DELTAP= 1331. NEWTON/N2

RH0=.07687 KG/M3

PRESS= 4578. NEWTON/M2

HLIFT=.0645 KG/N3

ALTITUDE= 21000. NETERS

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••HASKV## RUN 60 4/LR80-2 JATTERY# YN/V0 = 10/30 -- USER PUNER = 200 HATTS

•	ECPSS CMM2	VOLTEC	SFC2	GEOF	00	DAPPO
-	ECPPS	BENGY	SFCI	SA	SKINR	SUBPON
	ECPB	WIKE5	THR2	ADDM3	FINNE	TURBOR
!	BATCY	HIRE4	THRI	ADDMZ	5	MAN
	BATCC SPR	, WERES	RAÚ	ADOML		LERAN
	BAT2 Espr	HLP.E2	CFCH	UFCM ABIT	At'15	AUIUN
	8AT1 P4UP	WIKEL	CELLE	CSIKH -	CUAL L	DUTY
	BCHEF EPRUP	5	CELLZ		101010	VOLTSA
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 0.4350000€+01
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SOLAR CELLS AS POWER SOURCE

NEWTON/N2		-	1	2		6	
131.		THRUS	5-125	496.9	517.9	563.4	645.4
DELTAP=		504	7.2814	7.6745	3699.5	8. 7025	9.9689
6/H3		<b>NIRE</b>	14.07	15.18	16-12	14.21	22.19
07487 K		STR	25,28	26.38	27.28	29.22	32,70
RHO*		SA	219.06	230.38	240.34	260.58	297.04
NENTON/M2		TBATM	89.19	114.28	140-08	197°C4	307.32
4678.		MOTOR	÷0°65	103.95	108-01	116.78	132.59
PRESS=		КР	5.36	5.50	5.62	5-86	6.27
45 KG/H3	ENTON/SQ.M	HULL	1645.48	1792.05	1895.30	2147.52	2630.24
(FT=_06	8.93	<b>NIXSI</b>	1.1917	.1968	1.2009	~2002°(	1.2243
KS HL	4	PAEQ	15.308 0	15.097 C	16.749 0	18.169 0	20.701 0
000. METI	44 N/SEC	HASS	2214.54	2395.18	2549.93	2893.11	3547.42
1TUDE= 21	VLND=15.4	LENGTH	119.14	122-31	124-88	130.25	139.40
ALT	-	HOURS 1	16.	14.	12.	.0	•
<u>a</u> _	2						

4+HASKY++ RUN 60 4/1...0-2 BATTERY+ VN/VD = 10/30 -- USER PDHER = 500 MATTS

ECPSS	CANZ	VULTFC	SFC2	GEOF	<b>CO</b>	Derand	
ECUPS	UMM2	BENGY	SFCL	SA	SKINR	NUMBUS	
ECP8	CMM1	4 [ 4 E S	T MK-2	ADDM3	FINMR	TURBOR	
BATEY	LMML	<b>MERE4</b>	LMRI	ADDMZ	GLC	PAY	
BATCC	5.PR	HIREJ	RAU	AUDMI	FIN	TERMM	
BATZ	ESPR	WIRE2	CFCM	UFLX	ADHE	AUTUM	
118	PRUP	WIREL	CELLI	CSTRM	SHAT	u.	Aind
BCHEF	EPRCP	EN	CELLZ	STRMR	SKIND	SUPERT	VOLTSA

0.6199999996-01\_0.89799998E+00\_0.9700003E+00\_0.89999998E+00 0.60000010E-02 0.85500002E+00 0.89999998E+00\_0.43500004E+01\_

SOLAR CELLS AS POWER SOURCE

LIF1=.0645 KG/M3 PRESS= 4578. NEWION/M2 RHO4.07487 KG/M3 DELTAP= 1331. NewION/M2	= 8.93 NEWTON/SQ.M	TSKIN HULL RE MOTOR TBATH SA STR WIRE POP THRUST	0.2015 1911.29 5.64 108.59 151.73 253.68 71.41 16.25 8.0465 521.01	0.2074 2084.58 5.80 114.55 158.25 267.42 28.73 17.67 8.5240 551.93	0.2127 2245.71 5.95 120.06 206.15 280.13 29.94 19.01 8.9654 580.51	0.2237 2610.44 6.26 131.93 289.31 307.52 32.56 22.02 9.9166 642.10	
.[FT=40645 KG/M3 PR	- 8.93 NEWTON/SQ.M	TSKIN HULL	0.2015 1911.29 5.	0.2074 2084.58 5.	0.2127 2245.71 5	0.2237 2610.44 6.	
111UDE= 21000. HETERS HI	wind=15.444 M/SEC Q	LENGTH MASS PREQ	125.24 2571.84 17.679	128.91 2604.73 18.637	132.20 3025.13 19.523	139.04 3519.08 21.432	
¥ 	14	HDURS	16.	14.	12.	10.	•

##HASKV## RUN 40 ----ASE DATA. ALL SYSTEMS ---

ECPSS C4M2 VOLITFC SFC2 GEOF CD PNBYPD
ECPPS UPPA BENGY SFCI SA SA SVBPOW
ECPB CVMI AIRE5 AUDM3 FINMQ FINMQ
ВАТСҮ UMV1 AIRE4 ADDM2 GLC FAVM
BATCC SPR WIKF3 WIKF3 AUDAL AUDAL FIN
BALL PRUP NIKEL CELLI CSTR4 SMAT F
RCHEF EP LID EM STRMA STRMA STRMA STRMA VILTSA

u; 759979797F=00 0.8709995F401 u.1000030E+01 u.448u0uu5E=07 u.61999999E=01 0.8993998E+00 0.9700003E+00 0.8999998E+00 u.759979797F=00 0.7E697939F401 u.10000306F41 0.20000006E+07 u.83399090E+01 u.12110000E+02 0.83999997E+01 0.40799995F401 0.75699999E+07 0.10000030E+01 0.3200000038E-03 n.8000001E+01 0.33990000E+02 0.30900000E+02 0.83999997E+00 0.35000000E+02 0.11499999F401 0.8737034E+04 0.454903001E+01 0.45799997E+01 0.227000005E+01 0.73000002E+00 0.35000000E+02 0.11499995F401 0.87737034E+04 0.454903001E+01 0.45799997E+01 0.227000005E+01 0.73000000E+01 0.37000000E+01 0.11499995F401 0.87737034E+04 0.454903001E+01 0.45599997E+01 0.22709999995E+01 0.12000000E+01 0.5000000E+00 0.11499995F401 0.87737034E+04 0.454903001E+01 0.45599997E+01 0.22709999999996+01 0.37000000E+01 0.11499995F401 0.87737034E+04 0.454903001E+01 0.45599997E+01 0.227099999995E+01 0.130000000E+00 0.11499995F401 0.87737034E+04 0.45790000E+01 0.45599997E+01 0.2270900000E+00 0.35000000E+00 0.11499995F401 0.87737034E+04 0.45790000E+01 0.45599977E+01 0.2270900000E+01 0.2270000000E+01 0.11499995F401 0.87737034E+00 0.455400000E+01 0.4559997E+01 0.40599997E+01 0.2270000000E+01 0.50000000E+01 0.11499995F401 0.87737034E+00 0.455400000E+01 0.4559997E+01 0.405999995E+01 0.410000000E+01 0.50000000E+01 0.11499995F401 0.87737034E+00 0.455400000E+01 0.35699997E+01 0.40599997E+07 0.10000000E+01 0.2770000000E+01 0.11499995F401 0.87737034E+00 0.455400000E+01 0.35699997E+01 0.40599997E+07 0.10000000E+01 0.50000000E+01 0.50000000E+01 0.11499997E+01 0.455400000E+01 0.35699997E+01 0.40599997E+07 0.10000000E+01 0.5000000E+01 0.37000000E+01 0.11499997E+01 0.455400000E+01 0.35699997E+01 0.40599997E+07 0.10000000E+01 0.50000000E+01 0.37000000E+01 0.11499997E+01 0.455400000E+01 0.35699997E+01 0.40599997E+07 0.10000000E+01 0.50000000E+01 0.37000000E+01 0.1149997E+01 0.455400000E+01 0.35699997E+01 0.40599997E+07 0.10000000E+01 0.2170000000E+01 0.370000000E+01 0.1149097E+01 0.4554000000E+01 0.45540997E+01 0.4059997E+07 0.10000000E+01 0.455409997E+01 0.370000000E+01 0.3569999

FUEL CELL AS PUMER SURCE

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<u>HL:FT=+0645 KG793 PRESS= 4678+ NEWT04782 RHD=+07487 KG/R3 DELTAP= 1331+ NEWTUN/NZ</u> ALTITURE - 21000. 451EKS

							.			-	
THRUST	310 310		+10+	67.269	893.03	1192.17	1535.45	1012.45		1.2022	28.9.43
dÜd		1112-6	4.7555	651159	9.2461	12.2746	15.8091	10 0100		2076-67	29.6509
Aler A	06.91	21.91	38.29	c4.26	16.601	L58.78	312-08		17.076	14.344	E1'965
STR		14.33	19.40	25.05	32.10	40-34	64.75		10.00	64.21	85.56
TECH	10.001	276.31	14.914	25. 108	1296.54	1984.61	70.05.15		41 • gn14	5615.34	18*29+2
FUEL	101.02	01E	673.11	T265.14	2174.49	3461.24	5108.00		1478.94	10361.07	13914.75
MUTUR	66°¢2	41.56	59.45	-80.HT	109-80	144.43	20 70		231-15	284.52	11.646
RР	5.49	6.61	7.96	9.46	11.10	72.01			16.25	14.09	19.88
HULL	1931.63	3349.12	5839 <b>.</b> 20	- 9775. 48	15778.79	24105.00			49708.25	67917.19	90-15-06
<b>TSKI</b> V	1961-0	U.2363	0.2546	1357	1000	0144 0		0.014V	6282.0	6.6463	3.7106
PxEQ	4.152	5.464	B.656	17.707	16 778	22 246	063433	5 · · · · · · · · · · · · · · · · · · ·	36.067	44.415	53.683
NASS	F0.19E5	4146.54	7245.32	19.17141	1.1.4.6.6.4.6	78 UTUUE	60° 06 006	10"12654	62UB3.58	84875.94	12:279211
LENGTH	122.07	145.85	174-83				10407	16*226	361.94	401-70	34-144
DAYS	. [	<b>9</b>			• • •		• • •	-12	24.	27.	30.
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\*\*HASKY\*\* RUN 40 --BASE DATA, ALL SYSTEMS --

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消費な物格がないなどであるとなるとなったないないないないないないでがないない。現代に、海洋などの自然ないたいにいなるのでは、またいで、それがないというないないないないないない。それの言葉など、「「「「」

- E6733	CHM2	VOL TFC	SFC2	GEOF	3	flak Bid
	2MP2	BENGY	SFCI	SA	SK I NR	SUBPOW
ECPB	CYM	W[RES	TMRZ	<b>ADUN3</b>	FILME	TURBUK
DAIL 7	LMMU	<b>WIRE4</b>	THRI	<b>ADDM2</b>	219	PANA
BRICC	SPR	<b>WERE3</b>	RAD	ADDML	k i J	TEK HEL
BATZ	ESPR	WIREZ	CFC	UFL	ADHE	AUTOR
TING	60X4	WIREL		CSTRM	SMAT	<u> </u>
BCHEF	92.3P	a di	TELLZ	STRMK	SKIND	VIIL TSA

0.75090000E+00 0.3800000E+02 0.50003008E-03 6.8000000E+00 0.333000007E+00 0.30900000E-02 0.8999997E+00 0.37000000E+02 0.24699999E-02 0.10000000E+01 0.32000000E+02 0.81599997E+01 0.63000021E-01 0.50000000E+00 0.44099992E+01 0.3000000E+00 0.19999999E+01 0.1100000E+01 0.32000000E+02 0.81599997E+01 0.45299937E+01 0.5000000E+01 0.3000000E+01 0.11499996E+01 0.87737098E+08 0.4390001E-01 0.85500000E+01 0.104599937E+01 0.24999997E+01 0.10000000E+01 0.5000000E+01 0.11499996E+01 0.87737098E+08 0.4390001E-01 0.855000000E+01 0.104599937E+01 0.249999997E+01 0.10000000E+01 0.5000000E+01 0.11499996E+01 0.87737098E+08 0.4390001E-01 0.85500000E+01 0.104599937E+01 0.249999997E+01 0.10000000E+01 0.5000000E+01 0.100000002F+00 0.19999999E+00 0.45400000E+01 0.35699997E+01 0.90699997E+02 0.100000000E+01 0.5000000E+01 0.136999995+01 0.448000055=02 0.619999945=01 0.89999985+00 0.97000005+01 0.899999995=01 0.1360000005+01 0.00000005=00 0.807999945=01 0.89999985+00 0.9547999995=01 0.435000046+01 10+366666986\*00 0\*3866566651\*0 0-1100007E+01

0.10400005F+C3

CFLL AS POWER SOURCE FUEL

A-16

XLTTUDE= 21000, WETERS HLTFT=.0645 KG/H3 PRESS= 4678, NEWTGH/H2 RNG=.07487 KG/H3 DELTAP= 1331, MEMTUN/M2

							-																	
	THRUST	35.20	1.2	37,34	38.62	59-92						101-12	111.67	124.23	137.98			TueilCT		219.97	282.38	360.41	46 <b>1.3</b> 5	SRS. RO
	404	2181.0	0.1876	0.1922	9861-0	0.2055			a'Gd	1941		0-7806	0.8623	0.9593	1.0655					2+2649	2.9074	3.7107	4.7553	E.037
	MIRE	18.0	0.85	0.85	0.93	16.*0		·				3.92	4.55	5.34	6.25					12.58	18.30	26.39	<b>58.2</b> 9	11.75
	STR	6.18	6.26	6.31	6:39	6.45			212			6.00	86.33	5.82	96.90			e Ta		11.80	13.83	16.30	19 <sub>e</sub> 40	- 31 - 10 -
	TFCN	84-38	84.13	87.66	16.10	96.17			N D L L		CC* 001	116.06	134.41	156.61	182.78	: :		1574		160-07	230.52	332.23	479.57	JO CEY
	FUEL	56.6	17.06	26.39	32.28	40-61			1911		34.51	63.41	97.69	139.24	184.43		,			107.67	229-56	-09-27	673.11	11.02.01
	MOTOR	61.6	6.22	6.28	6.35	6.43			401.0M		12.16	13.01	13.94	15,05	16.25					29.48	37.32	46.51	54.45	
-	2	4.39	4.47	4.53	69.2	4.68	ł	-	90		¥. 12	4.97	5.27	5.50	5.80		<del>,</del>	6		5.49	6.22	7.03	7.46	
ter townso.	нигг	92.266	1045.55	1082.93	1139.37	1197.78		4ENTON/SQ.	1000		1230.43	1429.88	1656.43	1942.77	22.72.72		VENTON/SQ.			1931.63	Z803.52	4030.59	5R39.20	
1 66°0 =0	PREQ TSKEN	0.343 0.1571	0.395 0.1593	0.<03 0.1618	0.415 0.1646	0.427 0.1673		Q= 2.23	DBED TCPT4		1.334 0.1689	1.458 0.1775	1.615 0.1800	1.791 0.1968	1.943 0.2074		0= 3.97 I	1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1	ATUCH POXA	4.152 0.1904	5.314 0.2225	6.767 0.2514	8.656 U.2846	TA 642 A 3305
148 H/SEC	MASS	15.9121	1234.37	1333.17	1402.05	1473.52		722 P/SEC	1) 10		1514.01	1760.49	2042.59	2396.13	2005.18		296 X/SEC	4466	CCMM	23-1-93	34.54.15	64*5064	1245,82	61 22 21
4 IND= 5	DAYS LENGTH	3. 97.66	5. 99.31	7. 100.59	92.201 .F	11. 104.60		4{VÙ= 1*	NAVE FREED		5. 104.9B	5. 110.35	115.97	9. 126.31	11. 124.91		r [40=10.		HINT'L CALL	3. 122.07	5. 115.31	7. 156.25	9. 176.25	25 201 11
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	wine 54.25 54.25 111.62 1210.21 3366.58 591.75	
۰,	SIR 25-05 37-15 53-37 74-13 90-99	
	TFCM 360.00 726.98 1359.33 2355.29 3789.69	
	FUEL <b>552.49</b> 950.22 950.22 3773.79 6345.06	
	MOTCIR 89.62 142.79 215.61 310.54 425.80	
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REFTON/SO.M	HULL 4240.08 8704.77 16353.61 28452.68 45920.19	HENTON/SO.I
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SIX WINE TC: TWUS 15.33 302.96 28.3254 1834.0 138.41 809.13 54.5232 3530.3 224.861732.05 90.7702 3877.8 394.963242.13137.5485 8906.5 461.225426.73195.907312555.5	
RP         NOTUK         FUEL         TFCM           10.57.327.96         1329.34         1155.54           14.67         627.51         4267.45         3008.76           15.951041.97         993.55         6376.70           23.301576.04         19349.1611277.43           27.672221.26         33334.6913602.96	
PREO TSKIN HULL 51.286 0.3740 13651.42 98.669 0.5245 36362.68 184.227 0.6761 17965.75 248.332 0.8331 1.328.38	
DATE LENGTH MASS 3. 234.00 15990.48 5. 326.02 45372.72 1. 420.65 91462.19 9. 517.62 1018006.06	0/20/20/2 70*510 *11

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\*\*HASKV\*\* RUN 40 -- BASE DATA, ALL SYSTEMS ---

1.11								
	EQ 55	CMM2	VOLTEC	SFC2	GEOF	3	DARYPD	
	ECTTS	CHIN2	GENGY	SFCI	8A	SKING	NOAROS	
1	ECPB	CANL	NIKES-	TRKZ	AUDH3	FIRE	TURBUR	
	BATCY	INNU	WIRE4	THRE	ADDM2	GLC	PAYN	
	BATCC	SPR	HLRE3	RAD	ADORI	FIN	TERRE	
	8412	ESPR	<b>WIRE2</b>	CFCH	UFLM	ADHE	AUTUM	
	BATT	PRUP	WIREL	CELL	CSTRM	SHAT	  +	
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	I			I			I	

0-1386666669 0\*44800006E-07 0.61999999E-01 0.8999998E+00 0.9700003E+00 10+3666669E1\*0 0.43500004E+01 0.110999997E+01 0 104000000E+03 **A-**18

FUEL CELL AS POLER SOURCE

KHU=,12067 KG/A3 DELTAP= 2135, MENIUN/MZ HLIFT=1039 KG/M3 PRESS= 7505, WEHLON/M2 ALTITUDE= 18000. HETEKS

				1				1		E.	
	THRUST	268.96	359.51	479.52	633.26	823.95	1665. NENTON/H2		ı	THRUST	239.97
	40 <b>4</b>	Z691*Z	3.7015	4.9371	6.520I	8.4834	DELTAP=			Ð	2-4708
	MIRE	13.40	20.71	31.90	24-84	71-86	(G/H3			NIRE	12.71
	SIR	12.40	15.12	18.60	22.96	28.25	07526 K		1.	STR	J1.96
	TFCM	EE-6/1	273.27	17.41	11.629	929.80	RH0=.			TECH	167.93
	FUEL	92-161	291.61	543.42	921.31	1463.52	NENTON/12			FUEL	117.27
	MOTOR	35.74	46.40	60+53	15.63	101.08	. 5924.			ROTOR	37.33
	RР		5.53	6.39	1.34	8.37	PRESS=		-	RP	5.09
	HULL	2037.1	3141.60	4R30.R7	1371.63	10857.68	21 KG/M3		RENTON/ SQ. I	нис	1937.12
	<b>TSKIN</b>	5-2746	0.31/3	0.3664	1127.0	0.4803	[FT=,08		50.05	LISKIN	0.2303
1 7	PREQ	190.2	6. 750	8.985	848-11	15.399 (	RS HL		÷,	PRED	420.4
-210 H13EC	MASS	2534.66	3917.11	6034.45	90° a 516	13591.59	19500. MFT		.296 M/SEC	SAM	2406.00
	JAYS LENGTH	3. 106.32	5. 122.92	7. 141.97	9. 163.15	11. 186.10	ALTITURE=		01=Ut:] M	MAS LENGTH	3. 113.04
	-					-				[	

407.71 529.88 681.07 313.85 5.4556 7.0122 3.2315 1078 41.71 60.73 19.02 28.15 17-10 20-70 25-04 14.26 539.15 781.65 247.97 366.96 171.60 254,89 452.54 +1.03 52.( d 66.40 84.26 6.63 7.56 8.57 5.82 2891.90 4269.25 6316.22 9200.46 5.900 0.2634 7.648 0.3002 9.923 0.3422 12.738 0.3880 3598.56 5327.64 7894.09 11502.98 190.43 1.34 29.27 ċ

DELTAP= 1331. NEWTON/42 RHU=+07487 KG/M3 PRESS= 4678 . NE4T0%/MT HLIFT: J045 KG/33 ALTITUDE= 21000. PFTERS

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-	THRUST 219.97	262.38	360-41	58°546		1053. NEVT			THRUST	257-16	325.24	512-34					•	•.	۰.					۱,			т. , М	, 1- , 1- , 1- , 1- , 1-	•	
	POP 2.2649	\$206.2	3.7107	6.0323		DELTAP= 1			-00-	2.6478	3,3486	5.2750			•	. 11	•	1	•	• .	•	••••			•			•		1.1
	HFRE 12.58	06.81	26.39	54-70	•	G/H3			ALRE	12.66	25.53	19-05			÷					•	•	.:	•				•	1		÷
	STR 11_60	-13.85	16530	19-40		05681 K			STR	11.78	15.86	51.15									,		· ·	· · ·		• ,	• 1 ·	:		·
	TFCM 140-07	230.52	332.23	419.57		RHG.	•		TFCN	153.70	307.08	606.70			•									:,			I			
	FUEL	229.56	12.904	613.11		IENTON/N	•		FUEL	08.90	369.66	599.21		•			•													
	MDT OR	37-32	46.51	54.45	CA+C1	3700. 1	•.		AUTOR	28.07	42.37	51-45	Į.	4		·			,				ŗ							
	ž		7.03	7.95	96.6	PRESS=			0	20.01	7.54	8.41 9.46																' <u>'</u> .		
EMTON/SC.M	ниг	1931.63 2403.53	4036.19	05.99.50	<b>8335</b> •67	FKG/M3		ENTOR/SU-		1980.LN	3936.04	5578.74																		
N 19.6	I SK I N	.1964	\$152	2646	.3205	FT=.050		-3.12		1581	J.1845 J.2131	0. 2674																		
=0	PREQ	4.152 0	0 115 c	8.656 0	10.966 U	RS HLT		<b>5</b> 0		PKEG 3.850 (	4-844 ( 6-112 (	7.06																		
JAC WICEL	#ASS	2381.73	3464.15 4005 40	7245.92	10353. 52	2500. METE		JUK BUSEL		2396.27	3397.45	6859-84 0552.81																		
01-011	ENGTH	122.07	138.31	176.88	199.72	11UDE= 2		- 01-01-0		LENGTH 132.57	148.93	10/																		
-	DAYS		. .,		11.	1	į			DAYS	5		• • •					<b>A-</b>	19											

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#### APPENDIX B

#### MATERIAL TESTING

A biaxially oriented nylon 6 film was chosen as the candidate material from which the laminated film for hull construction was to be fabricated. This type of film was unproven for balloon use; and consequently, testing of the film was required. Also, tests were required to demonstrate the structural integrity of patches and seal junctions used in the de-Thermoplastic adhesive tapes had previously been design. veloped for this film and it was intended that a significant portion of the tests be conducted on seals and seal junctions using these tapes. However, it was discovered that these tapes did not have sufficient shear strength for the intended use. Two additional procurements of sealing tapes were made, but after extensive testing the adhesive characteristics could not be improved. Consequently, the efforts to perform tests on the thermoplastic adhesive tapes were abandoned.

For the patch tests, a liquid adhesive, Adcote 102A, was successfully used. Patches of the fan and parabolic design, as shown on the following page, were tested both from a straight pull and at an angle of  $45^{\circ}$ . The fan patches were sealed to laminate with a 1 inch wide seal around the entire patch whereas the parabolic patches utilize a "T" tape with the base of the tape as the seal area. The results of these tests are listed in the table below. Limitations of the test







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PARABOLIC PATCHES

equipment prevented any of the patches from being tested to ultimate strength. However, the results obtained in most cases are three to four times the actual loading that the patches would encounter in a launch or flight condition.

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	LAMPIC L	-8-	- FAI UI	- 16213

NG .	PATCH DESCRIPTION	TYPE OF TEST	TENSION-POUNDS	OBSERVATIONS
1	24" FAN PATCH SEALED ON 3 PLY Nylon Laminate, 4 webbings in Patch	STRAIGHT PULL	1600	PATCH AND LAMINATE IN-TACT, NO TEARING OF WEBBINGS FROM PATCH FABRIG, DISTRIBUTES LOAD EVENLY.
1 2	24" FAN PATCH SEALED ON 3 PLY NYLON LAMINATE, 4 WEBBINGS IN PATCH	PULLED AT 450	1000	TOP HALF OF PATCH TAKES MAJORITY OF LOAD A SLIGHT TEARING OF WEBS FROM FABRIC AT "DA RING ATTACHMENT.
3	24" FAN PATCH SEALED ON 3 PLY Nylon Laminate, 4 webbings in Patch	STRAIGHT PULL	1 350	NO SIGNS OF PATCH OR LAMINATE FAILURE.
•	30" FAN PATCH SEALED ON 4 PLY Nylon Laminate, 5 webbings in Patch	STRAIGHT PULL	1000	PATCH AND LAMINATE IN-TAGT.
5	30" FAN PATCH SEALED ON 4 PLY Nylon Lamimate, 5 webbings in Patch	PULLED AT 450	1250	PATCH AND LAMINATE IN-TAGT.
-6	24" PARABOLIC SEALED ON 3 PLY Nylon laminate	STRAIGHT PULL	1 350	ENDS OF PATCH CURL TO CENTER DUE TO UNI- AXIAL TEST, LEG OF "T" TAPE STRETCHES APPROX 1" FROM BASE THROUGH MIDDLE 1/3 OF PATCH.
7	24" PARABOLIC SEALED ON 3 PLY. Nylon laminate	PULLED AT 45 <sup>0</sup>	1200	REINFORCEMENT WEBBING ALONG SLOPE OF Curve begins to tear from Fabric Around Attachment Point.
8	24" PARABOLIC SEALED ON 3 PLY- Nylon Laminate	STRAIGHT PULL	1250	LEG OF "T" TAPE STRETCHING BASE THROUGH CENTER 1/3 OF PATCH - SLOPE OF CURVE NEEDS TO BE INCREASED TO ALLEVIATE THIS.
9	36" PARABOLIC SEALED ON 4 PLY Nylon Laminate	STRAIGHT PULL	800	36" PARABOLIC HAS A GREATER SLOPE AND THUS DISTRIBUTES LOAD INTO LAMINATE MORE EVENLY. TEST TERMINATED AT BOO LBS. DUE TO MAL- FUNCTION OF EQUIPMENT.
10	36" PARABOLIC SEALED ON 4 PLY Nylon Laminate	PULLED AT 45°	600	WEBBING TEARS FROM FABRIC AT LOAD ATTACH- MENT - NEED HEAVIER FABRIC & WEBBING.

Both patch designs appear to distribute the load into the laminate, on which it is sealed, quite uniformly considering this was a uniaxial and not a biaxial test. The fan patch exhibited higher loadings than the parabolic at the 45° pull without any paring of the fabric or webbings in the patch.

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The tearing, however, could be alleviated by using heavier fabric and webbing in the patch design.

Earlier ultraviolet radiation exposure tests had shown that the biaxially oriented nylon 6 film exhibits much less degradation in strength and ductility after exposure than does comparable polyester film. Samples were exposed under a GE H12T3, 750 W UV lamp at a nominal distance of 14 inches from the lamp. Exposure times of 9 hours and 16 hours were used. Tensile strengths and ultimate elongations were determined from strip tensile tests performed at  $-60^{\circ}$ C with an initial jaw distance of 2 inches and a separation rate of 2 inches/minute. The results are as follows:

ULTRAVIOLET DEGRADATION TESTS

		Tensil	e Stre	ngth(lb)	Elongation (%)							
Material	Orien- tation	After	ехроя	ure of	After exposure of							
		<u>0 hr</u>	<u>9 hr</u>	<u>16 hr</u>	<u>0 hr</u>	<u>9 hr</u>	<u>16 hr</u>					
1 mil nylon 6	TD	41.2	33.1	7.3	36.8	21.0	0					
sxy mil poly- ester	TD	30.6	18.9	6.3	29.5	3.1	0					
1 mil nylon 6	MD	42.1	32.5		35.8	14.3						
4x4 mil poly- ester	MD	36.8	14.3		31.0	1.9	چە ئون ئچ					

Tests have consistently shown the nylon film to be superior; but as the table shows after enough exposure the nylon, like the polyester, will degrade to an unusable state.

Water absorption by the nylon film can be an important factor to consider Tests have been performed to determine the changes in weight, tensile strength, and ultimate elongation of the film as affected by relative humidity. Samples were stored at room temperature at 0, 50, and 100% relative humidities and were tested after 7 days and 30 days. Most of the change occurred after 7 days, but additional change can be detected after 30 days. The 30 day results are summarized below. For the tensile tests the jaw distance was 3 inches with separation rates of 2.0, 0.5, and 0.2 inch/min corresponding to testing temperatures of 21, -25, and -70°C.

#### EFFECTS OF WATER ABSORPTION TESTS

· · · · ·	0% RH	50% RH	1.00% RH
Thickness, um	25.1	26.1	26.0
Weight, g/m <sup>2</sup>	29.1	31.9	32.0
Specific gravity (calculated)	1.16	1.22	1.23
M.D. Tensile Strengths, 1b, @	:		
21°C	31.0	29.1	27.1
-25°C	29.6	29.4	30.5
-70°C	34.6	34.5	37.3
T.D. Tensile Strengths, 1b, @	:		
21°C	34.0	32.0	30.3
-25°C	33.6	31.4	32.9
-70°C	38.2	36.2	35.4

(cont.)

#### EFFECTS OF WATER ABSORPTION TESTS (cont.)

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	<u>0% RH</u>	50% RH	100% RH
M.D. Elongation, 8, 8:			
21°C	68	69	74
-25°C	48	47	58
-70°C	42	41	46
T.D. Elongation, %, 0:	•		
21°C	72	68	73
-25 °C	50	48	57
-70°C	47	39	34

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A variety of stress/strain tests were performed using the 25  $\mu$ m film. During this testing it became obvious that the nylon film exhibited unstable creep characteristics. Further, it was determined that the creep characteristics were very difficult to predict as a result of variations in the film properties and because of the sensitivity of these characteristics to temperature. There were significant differences between identical tests and anomalies between similar tests performed at different temperatures. The following table summarizes the nominal results obtained from the biaxial creep tests.

#### BIAXIAL CREEP TESTS

		Elon	Jation (%)
Stress 1b/in <sup>2</sup>	Temperature ( <sup>O</sup> C)	Initial Value	After 4 Hours of Creep
12,000	-70	3	4
14,000	-70	بند شن نید	8
14,000	-33	4	5
8,000	-25	2.	4
10.000	-25	5	7
14.000	-25		20
8.000	<b>–10</b>	5	25
10.000	-10	2	9
7.000	<b>O</b>	. 8	+ 725
10,000	21	7	12

The uniaxial dead load tests also showed creep instabilities which are difficult to predict. The following lists are some typical examples:

Stress	Temperature			Elonga	tion (%	<u>}</u>	
(lb/in <sup>2</sup> )	(°C)		a	fter te	st time	s of	
		<u>0 hr</u>	<u>3 hr</u>	<u>24 hr</u>	<u>51 hr</u>	<u>96 hr</u>	<u>168 hr</u>
10,000	21	10	15	18	25		
14,000	21	18	22	27	33		35
14,000	-33	3				10	
21,000	-33	7				17	

UNIAXIAL DEAD LOAD CREEP TESTS

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Except for the creep instability, the biaxially oriented nylon 6 film would function as a good superpressure balloon material. All other characteristics including handling, pinholing, permeability, spectral transmittance and reflectance, etc., are excellent; and this film should be analyzed further for possible use as a fiber reinforced gas barrier.

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APPENDIX C

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	C STUTION FOR ANY PROPAGATION OF THE PROPAG	
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<pre>&amp;&lt;= K(1) # 2.K(2) # 2.K(5) # 2.K(5) # 7.K(7) # 7.K(7) # 7.K(8) Ga(h=Galiv+20.0# aL0G10(K) Ga(h=Galiv+20.0# 5.5 \$ * 4.0G10(K) PH1=PH1=500.73.1 \$ 4.10/2.0 = 5.5 \$ * 9.0 \$ 0.0 # 7. T(5) 3.201 \$ % \$ 0.0 \$ 0.0 \$ 0.0 \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$</pre>	<pre>&amp;&lt;= K(1) * E K(2) * Z K(3) = K K(4) * Z K(5) * T K(6) * T K(1) * X (1) G A (1 = G A (Y + 20, C * A L UG 10 G A (Y) E A (1 = G A (Y + 20, C * A L UG 10 G A (Y) E H = P H = P H = P + 20, T * 20 - E X S * 90.0 A (1 = G + 1 * 0.4 E G A (Y) + 7 * 5 X + 6 A (Y) = * F E • 1 * 0 B • 5 X + P H = * F 9 * 2 * A K T ( 1 * 2 G G A = * F 0.3 * 4 G J (Y = * F E • 1 * 0 B • 5 X * P H = * F 9 * 2 * A K T ( 1 * 2 G G A = * F 0.3 * 4 G J (Y = * F E • 1 * 0 B • 5 X * P H = * F 9 * 2 * A K T ( 1 * 2 G G A = * F 0.3 * 4 G J (Y = * F E • 1 * 0 B • 5 X * P H = * F 9 * 2 * C = C * 1 * C = C * A K C A TH S C O # P I A C A I V = * F E • 1 * 0 B • 5 X * P H = * F 9 * 2 * C = C * D = C * C * P I A C A I A = * F 0 * C * 0 * C * 0 * C * 0 * C * 0 * C * 0 * C * 0 * C * 0 * C * 0 * 0</pre>	<pre>#&lt;= # [1 * 2.4 (2) * 2.4 (4) * 2.4 (5) * 1.4 (6) * 7.4 (1) * 7.4 (8) Galt=Galt*= 20.0* * 2000 0 (a) Galt=Galt*= 20.0* * 2.0 = 0.5 (a) # = 1.4 = 2.0 (3.1 + 1.0 / 2.0 = 5.5 * 9.0 0 (b) # = 1.4 = 1.4 / 2.0 = 5.5 * 9.0 0 (c) # = 1.4 = 1.4 / 2.0 = 5.5 * 9.0 0 (c) # = 1.4 = 1.4 / 2.0 = 5.5 * 9.0 0 (c) # = 1.4 = 1.4 / 2.0 = 5.5 * 9.0 0 (c) # = 1.4 = 1.4 / 2.0 = 5.5 * 9.0 0 (c) # = 1.4 = 1.4 / 2.0 = 5.5 * 9.0 0 (c) # = 1.4 = 1.4 / 2.0 = 5.5 * 9.0 0 (c) # = 1.4 = 1.4 / 2.0 = 5.5 * 9.0 0 (c) # = 1.4 = 1.4 / 2.0 = 5.5 * 9.0 0 (c) # = 1.4 = 1.4 / 2.0 = 1.5 0 (c) # = 1.4 = 2.4 / 5.5 = 1.4 / 5.0 = 1.5 0 (c) # = 1.4 = 2.4 / 5.5 = 1.4 / 5.0 = 1.5 0 (c) # = 1.4 = 2.4 / 5.5 = 1.4 / 5.0 = 1.5 0 (c) # = 1.4 = 2.4 / 5.5 = 1.4 / 5.0 = 1.5 0 (c) # = 1.4 = 2.4 / 5.5 = 1.4 / 5.0 = 1.5 0 (c) # = 1.4 = 2.4 / 5.5 = 1.4 = 2.5 0 (c) # = 1.4 = 2.4 / 5.5 = 1.4 = 2.5 0 (c) # = 1.4 = 2.4 / 5.5 = 1.4 = 2.5 0 (c) # = 1.4 = 2.4 / 5.5 = 1.4 = 2.5 0 (c) # = 1.4 = 2.4 / 5.5 = 1.4 = 2.5 0 (c) # = 1.4 = 2.4 / 5.5 = 1.4 = 2.5 0 (c) # = 1.4 = 2.4 / 5.5 = 1.4 = 2.5 0 (c) # = 1.4 = 2.4 / 5.5 = 1.4 = 2.5 0 (c) # = 1.4 = 2.4 / 5.5 = 1.4 = 2.5 0 (c) # = 1.4 = 2.4 / 5.5 = 1.4 = 2.5 0 (c) # = 1.4 = 2.4 / 5.5 = 1.4 = 2.5 0 (c) # = 1.4 = 2.4 / 5.5 = 1.4 = 2.5 0 (c) # = 1.4 = 2.4 / 5.5 0 (c) # = 1.4 / 5.5 0 (c) # = 1.4 / 5.5 0 (c) # = 1.4 / 5.5</pre>	:
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<pre>#A. T. T. M. /pre>	FORVETT UNESAFTFORT, VAU/S',5%, GAIN=',F8.1, D6',5%, PHI=',F3.2' FORVETT UNESAFTFORT TO FELLETTAENDIG TO 100 GUTO 105 FORUS FOR THIS COMPLETICS FAUNS FOR THIS FOR THIS FOR THE FOR	MARTEL STATE AND	
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PLCE-MECUL         EVICE-S203         IEWICE-S203         IEWICE-S204         IEWICE-S204         IEWICE-S204         IEWICE-S204         IEWICE-S204         IEWICE-S204         IEWICE-S204         ARANS IS 1340M.255(1.0.000.0017.0017.00117.111.2.0013         ARANS IS 13410M.3013         ARANS IS 13410M.3014         ARANS IS 13410M.3014         ARANS IS 1340M.3014         ARANS IS 1340M.125         ARAN IS 1340M.125         ARAN IS 1340M.125         ARAN IS 1340M.125         ARAN IS 1340M.126	101 201 13 L 40C 101	•	AN. 		TA.	HI, 3=PSI	LETA									1																		••• • • • • • • • • • • • • • • • • • •	[ N= 1 +	,10X,				/16%.	Χ,	
EVICE-MECUI         EVICE-MECUI         EVICE-MECUI         EVICE-MECUI         EVICE-MECUI         EVICE-S203         FROGRAM POSIM         ISAL (5GLL, 6GAL, 15AL, 6GAL, 15AL, 16AL, 15AL, 14AL, 15AL,		• •	CDI T.ELT.ELG.HZ.GSA.63 GHTL.GVTL.SUMFZ.SUMFX.		≈2HI • 5=PSI • 6=TAU • 7=THEI	TH TINE 1=GAMA, 2=P	ITH TIME l=PSI.2=THE	INTIAL LEKU AKKATS TPUT	HT.					ITEST		L	I C N/ SFC	BAL DEG/SEC	ENT OF TIME SEC	HER PRINT OUTS	CK GAIN F cath	GAIN	NIN										g	2,8X, TRIM PITCH ANGLE-	EC/15X, PITCH ERROR GAI	YAN ERROR 6214=+ . F6.24		REMENT + 1 + 5 - 2 / 21X+		PYNAMIC EQUALIONS	6X, 'LMASS= 'EL4.7/16X	
EVICE-AFCUI EVICE-AFCUI FROGRAM POSIM COMMON A0(8)+8 IGSAL, 6SALR, 6SALR			0(4). CD0,CD1,CD01, MR,6SHT,6SVT,6HTM,6VTM	VELO, LOUP , B, LINE, L, ITE	1 1841 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	IS FIRST DERIVATIVE WI	IS SECOND DERIVATIVE N	RAY IN DEGREES FOR OU	TRAIGHT AND LEVEL FLIG	.01745329,51.29578/	991 TI TLE			0,THR,8,TMAX,DIT,LOOP	2151	S, YMASS, ZMASS, YYI, ZZI	FRUTEU, TKU, MEAU, AT, KA INITIAL VELOCITY I	ANGULAR RATE OF GIM	DIFFERENTIAL INCREM	NUMBER OF LOOPS BET	AUTOPILOI PIICH EXK	AUTOPILOT YAN ERROR	AUTOPILOT YAN RATE (	INPUT HEADING TRIM PITCH ANGLE									E . A Y . R A T F . PFG . PRG . VFG . VI	"INPUT HEADING=" F6.	L RATE= F5.2.8H DEG/St	RATE GAIN=' + F6.2/15X		"DIFFERENTIAL TIME IN	- 1 60 Ami - 1 A 1 2 (2 - 9 1 4 - 5 1 1 4 - 5 2 4 4 - 5 2 4 4 - 5 2 4 4 4 5 5 4 4 4 4 4 4 4 4 4 4 4 4 4	BALLON PARAMETERS FOR	1/16X, 'YHASS= ',E14.7/1	(6X+*IZZ= **EL4.7)
		EVICE-MFCUI DEVICE-5203 PROGRAM POSIM	COMMON A0(8) .8 1654L,654L8 .654	22MGM, YHGM, THR.	IN ARAY IS 1-	B=DELTA B ARAAY	4=THETA C ARMAY	AN ARATS HILL A AN ARAY IS AO A	* INITIALIZE FOR S	DATA RAD.DEG/0	99 READ( 1.4. END=9	4 FORMATI 2044)	2 COMMATCOCIO 01	READ(1,2) VEL	2 FORMAT(SF10.0.	READ(1,3) XMAS	The ALLO	RATE =	- 110		9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9	YEG =	YAG =	HEAD = AY =	T00= 0.0	VELD0 = 0.0	BX([]=0.0	6 BO(1)=0.0	00 7 [=1,6	D B L-1-2	CO(1)=0.0	8 CX([]=0.0	WRITE(3,4)TITL( WRITE(3,5)HFAU	5 FORMATI . 0. , 20X,	A/ 31X, GIMBA	DF6.2.6X, PITCH	WKITE(3,11) DI	11 FURMAT ( 10+ 20X	WRITE(3.12) XM	12 FORMAT( . 0 20X.	A'XHASS= ',E14.7	IZ SIJ I ZAJ 8

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FORTAM IN VEROL/HODDL

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22	GARC= RATE* OIT
11) v 11) r	6CLM1 = 45. # KAU
	DIFFICAUT KAU 14 MRTTF[1.45]
25	45 FURMAIL 11///13X.* TIME*.8X.* TRETA*.7X.*ALPHA*.7X.*OELTA*.7X.*051*.
	A9X, BETA ; 6X, 'TAU', 9X, 'VEL'//)
	OU DU EALFLUUP
1	VELDZ= SUNEX / XMASS
27	BX(1)= SUMEZ /(ZMASS + VELQ)
<b>4</b> 3	BX(2)= SUMFY ((YMAS5 * VELO)
14	CK(1)£ 2MQK / 225 CK(2)= YM(H / VVE
14	
	AFTX= AFEC + 1AFTD0 +AFTDX1+H1
9	BX(4)=_B0(4)_+(Co(2)_+CX(2))_#HT
5	$\Delta X(T) = \Delta G(T) + (BO(4) + BX(4)) + HT$
7:	DA131# 50165 / +(COL1 + +CA11) #41
	AX1312 AV121 + FRAC11 + FXX(1) AV12
15	AX(4)= 40(4) +(80(2) +8X(2)) +H
ž	<u> </u>
55	AX[2]= AX[4] -AX[5]
-94 -	AX[8]= PEG= [AX[7]-AY] + PRG= BX[4]
25	AX(6)= YEG# [AX[5]-BY1 + YRG #5X[3]
5	
50	TTARONIANAN TAUTUTA ANAN'I
61	
62	A ELO=YELX
63	00_23_1=Je8
\$	23 A0( [) = AX( [)
6 4 6	24 (141) - 24 (140) - 24 (140) - 24 (140) -
2.7	
5	25 CO(1)=CX(1)
69	100=100 +011 +0*000159
70	IF(ITEST-1) 30,68,30
11	68 FF(LDOP-(L+1)) 30,69,30
1	
: 2	71 FURMAT(" FIRST DERIVATIVE WITH TINE
	2'PHI= 'sEls.T.5X.'PSI= 'sEls.T.5X.'THETA= 'sEls.T/' SECOND DERIVAT
	3IVE WITH TIME
25	LIWE=LINE + 4
-16	30 CUNTINUE
11	00 31 [=1,8
87	31 AN(1)=40(1)+0E6
	3.5 CHARTELESS I LUCANI (LIARILITANIS) ANIS) ANIS) ANIS I ANIS
3	JL FURNA I LLAD OF LLOJI     MISEL   ME + 1
82	IE(THAX-T00) 99.99.35
10 10	35 IF(LINE-50) 64,14,14
	999 STOP
3	END

2017年、1917年の1917年1月1日には、1917年の1917年1月1日には、1917年の1917年に、1917年の191

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# FURTRAN IV VEROI/MODDI

000 TOTAL EKRORS FUK THIS COMPILATION 00 I THE TOTAL CORE USED BY POSIM IS 13312 DECIMAL. 01 I THE STANT CONTRUL AUDRESS OF THIS MUDULE IS 0000. 02 I THE NON-OVERLAY CORE SIZE IS 15375 DECIMAL 04 I TOTAL NUMBER OF LUMARY SECTORS REGUIRED IS 72 1 NAME-POSIM PACK-FORTR2.UNIT-R1.RETAIN-I.LLUMARY-D

0L100 E 0L101 E 0L102 E 0L104 E

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2         CCMMCN ADDELNET(A).         CD0.CCI LOD T.COIT.CLT.ELT.ELC.WC.5.0ME 2.5.0M           3         VVE - VELO E.C.SAME C.SAME C.SA	CUMMON A0181, BC141 ZZMUM, YEON, TER, VELO VV = VELC +* 2. ANG= SQRT(ANG2) ANG= SQRT(ANG2) ANG= SQRT(ANG2) ANG= SQRT(ANG2) ANG= SQRT(ANG2) ANG= SQRT(ANG2) ANG= VELO + GSAM + APMA= VV + GSAM + APMA= VV + GSAM + APMA= VV + GSAM + APMA= VV + GSAM + VTD= VV + GVTL + VTD
C     CLARLAN AND STORY AND ST	165.AL.       05.AL.
223000       Contract restances of contract restance restance restance restance restance restance restance restanc	LESAL * CARK * CARK * CANK * C
3       VG = VE • VE       VG = VE • VE         5       AGG2 = AOL11 • V       V         6       AGG2 = AOL11 • V       V         7       AGG2 = AOL11 • V       V         9       AGG2 = AOL11 • V       V         10       AGG2 = AOL11 • V       SGA = CG01 + AOC11         11       AGG2 = CSAL + VV + (-AOL12)       AGG2         12       AGG = GSAL + VV + (-AOL2)       AGG2         13       ATG2 = SGAL + VV + (-AOL2)       AGG2         14       ATG2 = VELO + GSAM = AOL13       AGG2         12       AGG = GSAL + VV + (-AOL2)       AGG1         13       YTL = VV + GAT + AOL13       AGG1         14       ATG2 + VF + GAT + (-AOL2)       AGG1         15       ATG2 + VF + GAT + AOL13       AGG1         16       YTL = VV + GAT + AOL13       AGG1         17       VF + GAT + AOL13       AGG1         18       VT12 + VV + GAT + AOL13       AGG1         19       VTL + VV + GAT + AOL13       AGG1         11       VT12 + V + GAT + AOL13       AGG1         11       VT12 + V + GAT + AOL12       AGG1         11       VT12 + V + GAT + AOL12       AGG1         12       VT12 + V + GAT + AO	ZZENG FE
3       W1= VEL0       501(1)***********************************	VV= VEL0 ** Z. +0         ANG22 × 20(1)**2. +10         ANG4 S2R TANG2 +         ALG4 = GSAL * A0(1) *         ALG4 = GSAL * A0(1) *         ALG4 = GSAL * CSA * GSAR * CLO         ADG4 = VEL0 * GSAR * CLO         APAG4 = VV * GSAR * CLO         APAG4 = VV * GSAR * CLO         APAG4 = VV * GSAR * CLO         APAG5 = GSAL * VEL0 * GSAR * CLO         APAG5 = CSAL * VEL0 * GSAR * CLO         APAG5 = VV * GVIL * A         VTD= VV * GVIL * (+ 1 + A)         VTD= VV * GVIL * (+ 1 + A)         VTD= VV * GVIL * (+ 1 + A)         VTD= VV * GVIL * (- 1 + A)         VTD= VV * GVIL * (- 1 + A)         VTD= VV * GVIL * (- 1 + A)         VTD= VV * GVIL * (- 1 + A)         VTD= VV * GVIL * (- 1 + A)         VTD= VV * GVIL * (- 1 + A)         VTD= VV * GVIL * (- 1 + A)         VTD= VV * GVIL * (- 1 + A)         VTD= VV * GVIL * (- 1 + A)         VTD= VV * GVIL * (- 1 + A)         VTD= VV * GVIL * (- 1 + A)         VTD= VV * GVIL * (- 1 + A)         VTD= VV * GVIL * (- 1 + A)         VTD= VV * GVIL * (- 1 + A)         VTD= VV * GVIL * (- 1 + A)         VTD= VV * (- 1 + A)         VTD= VV * (- 1 + A)
6       AddC2= A01(1)=*2.*A01(2)=*2.         7       Add-CSAL = A01(1)         9       AA=CSAL = A01(1)         9       ADF= VELO = CSAH = B01(4)         11       ADF= VELO = CSAH = B01(4)         12       ASB= CSAL = VV = (CDO = COI = AMC2)         13       ANB= SSAL = VV = (CDO = COI = AMC2)         14       ANFE = VELO = CSAH = B01(4)         12       ASB= SSAL = VV = (CDO = COI = A012)         13       ANBE = VELO = CSAH = A0111         14       HL= VV = GNT = (CDO = COI = A012)         15       HT= VV = GNT = (CDO = COI = A012)         16       HT= VV = GNT = (CDO = COI = A012)         17       HT= VV = GNT = (CDO = COI = A012)         18       VTD= VV = GNT = (CDO = COI = A012)         19       VTD= VV = GNT = (CDO = COI = COI = A012)         19       VTD= VV = GNT = (CDO = COI = COI = A012)         10       VTD= VV = GNT = (A012)         11       VTD= VV = GNT = (A012)         12       VTD= VV = GNT = (A012)         13       VTD= VV = GNT = (A012)         14       VTD= VV = GNT = (A012)         15       VTD= VV = GNT = (A012)         16       VTD= VV = GNT = (A012)         17       VTD= VV = GNT = (A012)         18<	ANG2= A0(L19*2, +40 ANG2= SGRT(ANG2) ANG= SGRT(ANG2) ADF= VV * 65AL * 00(4) ADF= VV * 65AL * 0 APA= VV * 65AL * V *(- ASB= 53AL * V *(-) APA= 53AL * V *(-) SUMFY= 53AL * (-) SUMFY= 53AL * (-) APA= 54A+40+47 SUMFY= 53AL * (10,0) SUMFY= 54A+40+40+40+40+40+40+40+40+40+40+40+40+40+
<ul> <li>MAGE SQRT[AMGZ]</li> <li>AMGE SQRT[AMGZ]</li> <li>AMACSALR * 001(1) * VELO</li> <li>AMACSALR * 001(1) * VELO</li> <li>AMACSALR * 001(1) * VELO</li> <li>AMACSAL * VY * 653A * AO(1)</li> <li>AMACSAL * VY * 663A * 40013</li> <li>AMACSAL * VY * 654A * 40013</li> <li>AMACSAL * V * 654A * 40013</li> <li>AMACSAL * V * 654A * 40014</li> <li>AMACSAL * V * 654A * 40013</li> <li>AMACSAL * V * 64AA * 404A</li> <li>AMACSAL * V * 66AAA * 40012</li> <li>AMACSAL * V * 66AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA</li></ul>	ANG= SQR T(ANG2) ALG= GSAL * AO(1) * ALG= GSAL * AO(1) * ADF= VV * 65A * (C APMA= VV * 65AM * APMA= VV * 65AM * APMA= VV * 65AM * APME= VELO * 65AM * APME= VV * 65AM * APME= VELO * 65AM * APME= VV * 65AM * APME * APME * APME * APME *
6         Alacost         # 0(1) * WE           7         Aufs W * 65A * (L00 + C01 * AM62)           8         Aufs W * 65A * (L00 + C01 * AM62)           11         Aufs W * 65A * (L00 + C01 * AM62)           12         Abb W * 10 * 2013)           13         ANBE W * 65A * (L00 + C01 * AM62)           14         Aufs V * 65A * 4 * 4 * 100           15         Aufs W * 65A * (L00 + C01 * A013)           16         MUL W * 65A * (L001 + C01 * A012) * 201           17         HD W * 65A * (L001 + C01 * A012) * 201           18         HT W * 65A * (L001 + C01 * A012) * 201           19         HT W * 65A * (L001 + C01 * A012) * 201           11         VTD W * 65A * (L001 + C01 * A012) * 201           12         Auts K & 65A * (L001 + C01 * A012) * 201           13         WT W * 65A * (L001 + A012) * 201           14         WT W * 65A * (L001 + C01 * A012) * 201           15         HT W * V + 64T * A012) * 201           16         WT = W * 65A * 65A * (L001 + C01 * A012) * 201           17         WT = W * 65A * 65A * (L001 + C01 * A012) * 201           22         DeLC05 = C051A0(11) * 201           23         AL PC05 = C051A0(11) * 201           24         VAA001 * 71 * 4 * 1000           25         AL PC05 = C0	ALA=GSAL * 40(1) * ALA=GSAL * 40(1) * ADF= VV * 65A * 6 APNA= VV * 65A * 6 APNA= VV * 65A * 6 APNA= VV * 65A * 1 APNB= VV * 65AL * V * (- APNB= VV * 6 + 1 APNE= VV * 6 + 1 APNE= VV * 6 + 1 APNE= VV * 6 + 1 APDE= COS(40(1)) APPE= COS(40(1)) APPE= ALA+AL4+H1 SUMFY= SIN(40(2)) APDE= ALA+AL4+H1 SUMFY= AFA+S0+VTB FVA= ELT* + APDE
7         ALG= GSALR * B01(4) * YEL0           8         ADMA= VV * 65A.* 400(1)           10         APMA= VV * 65A.* 400(1)           11         SSB = 65A.4.* 4V * 65A.* 400(1)           12         ASR = 55A.0.* 400(1)           13         ASR = 55A.0.* 400(1)           14         APRE- VV * 65A.* 400(1)           15         APRE- VV * 65A.* 400(1)           16         VIL = VV * 64NL * A0(1)           17         APRE- VV * 65A.* 400(1)           18         VIL = VV * 60NL * A0(1)           19         VIL = VV * 60NL * 400(1)           10         VIE = VV * 60NL * 400(1)           11         VIE = VV * 60NL * 400(1)           19         VIE = VV * 60NL * 400(1)           10         VIE = VV * 60NL * 400(1)           11         VIE = VV * 60NL * 400(1)           12         VIE = VV * 60NL * 400(1)           13         AIFONS         COSI * 400(1)           14         VIE = VV * 60NL * 400(1)         AIFONS           15         AL FONS         COSI * 400(1)           16         VIE = VV * 60NL * 400(1)         AIFONS           17         VIE = VV * 60NL * 400(1)           18         VIE = VVE * 4100(1)           18         <	ALG= GSALR * 80(4) ADF= VV * 65A * 10 ADF= VV * 65A * 10 ADF= VV * 65A * 10 ASB= 65AL * VV * 10 ASB= 65AL * V * 10 ASB= 55AL * V * 10 ASB= 55AL * V * 10 APRE= VV * 65AN * 10 APRE= VV * 65H1 * 10 HTL= VV * 10 HTL= VV * 10 HTL= VV * 10 HTL= VV * 10
9       ADF= VV = 65A * (C00 + C01 + ADC2)         10       APMA= VV = 65A * 4 C0(1)         11       ASB= 65AL * V * (-AO(2))         12       ASB= 65AL * V * (-AO(2))         13       APME= VE 0 = 65AM * AO(1)         14       APME= VE 0 = 65AM * BO(1)         15       APME= VE 0 = 65AM * BO(1)         16       APME= VE 0 = 65AM * BO(1)         17       APME= VE 0 = 65AM * BO(1)         18       APME= VE 0 = 65AM * BO(1)         19       HT= VE 0 = 65AM * BO(1)         11       HTD= VE 0 = 65AM * BO(1)         12       APME= VE 0 = 65AM * BO(1)         13       HTD= VE 0 = 65AM * BO(1)         14       HTD= VE 0 = 65AM * BO(1)         15       HTD= VE 0 = 65AM * BO(1)         16       VT = VE 0 = 65AM * BO(1)         17       HTD= VE 0 = 65AM * BO(1)         18       VT = VE 0 = 65AM * BO(1)         19       HTD= VE 0 = 65AM * BO(1)         10       VE = 670 * 610 * 601 *	ADF= VV * 65A * (C ADA= VV * 65A * (C APMG= VELO * 65AM * A5B= 65AL * VV *(- ASR= 55AL * VELO APMB= VV * 65AM *! APMB= VV * 65AM *! APMB= VV * 65AM *! HTL= VV * 64H *(- HTL= VV * 65YT * ( HTD= VV * 65YT * (- HTD= VV * (-))
9       GPMA= VY & GSAM & AO(1)         10       APPAG = GSAL & V * GSAM & AO(2)         11       APAG = GSAL & V * GAN & EAO(2)         12       APPAG = GSAL & V * GAN & AO(1)         13       APPAG = GSAL & V * GO(1)         14       HUL= VV & GHT & COO(1 + G)1 * AO(1)         15       HUL= VV * GHT & COO(1 + G)1 * AO(1) * * * * * * * * * * * * * * * * * * *	APMG= VELO * 65AM *         APMG= VELO * 65AM *         ASR= 53LR * VV * 61         ASR= 53LR * VV * 61         AVME= VELO * 65AM *         AVME= VELO * 65AM *         AVME= VV * 65M *         HTL= VV * 65M *         HTH= VV * 64M *         HTH= VV * 64M *         BETCUSE COSIA0601         BETCUSE COSIA061         BETCUSE COSIA061         BETCUSE COSIA061         SUMFZE ALA+ALU+HT         SUMFZE ALA+ALU+HT         SUMFZE ALA+ALU+HT         SUMFZE ALA+ALU+HT         FIVE HT +         FIVE HT +         FIVE HT +         FIVE HT +
10         2010         55.01         * V * 5 (-6012)           11         ASSE 55.44         * V * 5 (-6012)           12         ASSE 55.44         * V * 6 (-65.012)           13         APME= VEL 0 * 50.013           14         HUE= VE 0 * 55.04         * 6.012)           15         HUE= VE 0 * 55.04         * 6.011         * 0011           16         VIL= VV * 55.04         * 6.001         + 6.012           11         HUD= VV * 55.04         * 6.011         + 0.012           18         VID= VV * 55.04         * 6.011         + 0.012           19         HIE= VV * 6.011         * 6.011         + 0.012           10         VID= VV * 55.014         * 6.011         + 0.012           11         VID= VV * 55.014         * 6.011         + 0.012           12         VID= VV * 55.014         * 6.012         + 0.012           19         VID= VV * 55.014         * 6.012         + 0.012           11         VID= VV * 55.012         * 0.012         + 0.012           12         VID= VV * 6.014         * 0.012         + 0.012           12         VID= VV * 6.012         * 0.012         + 0.012           12         VID= V * 6.014         * 0.0	AFNQ=         VELO         GSAL         *         V         *         C         M         C         M         C         M         C         M         C         M         C         M         C         M         C         M         C         M         C         M         C         M         C         M         <
11       558.6 554.8 * V * 6(-12)       50(3)         12       558.4 5 * 70(2)       50(3)         13       ATHE = VV * 651.4 * 40(2)       50.11 * 40(1)         14       ATHE = VV * 651.4 * 70(2)       50.11 * 40(1)         15       HTE = VV * 651.4 * 5001 + 501.1       5001 + 501.1         16       VTL = VV * 651.4 * 5001 + 501.1       5001 + 501.1         19       HTE = VV * 651.4 * 5001 + 501.1       5001 + 501.1         19       HTE = VV * 651.4 * 5001 + 501.1       5001 + 501.1         20       VTH = VV * 651.4 * 500.1       5001 + 501.1         21       10.055 * 6051.00(0)       5001 + 501.2         22       11.055 * 5051.00(1)       5001 + 501.2         23       84.7005 * 6051.00(1)       5001 + 501.2         24       ALPCOS = 6051.00(1)       5001 + 501.2         25       501.100 + 100.1       100.2         26       514.000 + 100.1       100.2         27       501.010.1       500.5         28       501.010.1       500.5         29       501.010.1       500.5         21       501.010.1       500.5         22       501.010.5       501.010.5         29       501.010.5       501.010.5     <	ASR= 55AL * V *(- ASR= 55AL * V *(- ASR= 55AL * VELO APMB= VV * 65AM *( HTL= VV * 6HL * 6 HTL= VV * 6HL * 6 HTD= VV * 65Y1 * ( VTD= VV * ( VTD=
12       ASB 53AL * W * 55AL * W * 5013         13       AYMB * W * 65AL * W * 1011         14       HIL * W * 65AL * M * 1011         15       HIL * W * 65AL * M * 10011         16       VIL * W * 65AL * M * 10011         17       HID * W * 65AL * M * 10011         18       VID * W * 65AL * M * 10011         19       HID * W * 65AL * M * 10011         19       HID * W * 65AL * 10011         19       HID * W * 65AL * M * 10011         19       HID * W * 65AL * M * 10011         19       HID * W * 65AL * M * 10011         20       VH * KALOHIL         21       DELCOS* COSIGNOIN         22       BERCOS* COSIGNOIN         23       ALPSH* SIN(AOLI)         24       ALPSH* SIN(AOLI)         25       ALPSH* SIN(AOLI)         26       FINT         27       SUMF* ALQHIL+HR* FAUCOS * SIN(AOLI)         28       SUMF* ASAASANTO * HAR ALQHIN         29       SUMF* ASAASANTO * HAR ALQHIN         21       SUMF* ASAASANTO * HAR ALQHIN         22       SUMF* ASAASANTO * HAR ALLOND * SUMA         23       SUMF* ASAASANTO * HAR ALLOND * SUMA         24       ALALAUANIA         27       SUMF* ARCOS	ASRE CAL * V * C ASRE 53LR * V * C AYNE - VEL * C AYNE - VEL * G AYNE - VEL * G ATL = V * G HT = C HT = V * G HT = C HT =
12       Axme "Stark * CLU" * B0(2)]         13       Arme: Ve GSM: * B0(3)         14       HTL= VV * GSM: * B0(2)         15       HTL= VV * GSM: * B0(2)         16       HTD= VV * GSM: * CD01 * CD11 * A0(2)**2.)         18       VTD= VV * GSM: * CD01 * CD11 * A0(2)**2.)         19       HTm= VV * GSM: * CD01 * CD11 * A0(2)**2.)         10       HTD= VV * GSM: * CD01 * CD11 * A0(2)**2.)         11       VTD= VV * GSM: * CD01 * CD11 * A0(2)**2.)         12       DVTD= VV * GSM: * A0(1)         20       VTD= VV * GSM: * A0(1)         21       TAUCOS= COS(A0(1))         22       BFTCOS= COS(A0(1))         23       BFTCOS= COS(A0(1))         24       AFTRE * A012)         25       GE(COS= COS(A0(2))         26       SUMFA= ALAALQHTL+TRR* FAUCOS * SIM(A0(2)) + A0(1))         27       SUMFA= ALAALQHTL+TRR* FAUCOS * SIM(A0(1)) + A0(1))         28       BFTCOS= COS(A0(1)) + A0(2) + A1ACOS(A0(1))         29       SUMFA= ALA+ALQHTL+TRR* FAUCOS * SIM(A0(1)) + A1COS         29       SUMFA= ALA+ALQHTL+TRR* FAUCOS * SIM(A0(1)) + A1COS         29       SUMFA= ALA+ALQHTL+TRR* FAUCOS * SIM(A0(1)) + A1COS         20       SUMFA= ALA+ALQHTL+TRR* FAUCOS * SIM(A0(1)) + A1COS         29       SUMFA= AL	ANNE "534" * 46 LU AVRE "54M * 46 LU AVRE VELO * 65AM * HTL = VV * 611 * 1 HTD = VV * 65H * 1 HTD = VV * 65H * 1 VTH * 1 VTH = VV * 65H * 1 VTH * 1 VTH *
13       APMB= W* 6 GAM* 8-00(3)         14       APME= V* 6 GAM* 80(3)         15       HT= V* 6 GAM* 80(3)         16       HT= V* 6 GAM* 80(3)         17       HT= V* 6 GAM* 80(3)         19       VTD= V* 6 GAM* 80(1)         20       VTD= V* 6 GAM* 8-0012)         21       VTD= V* 6 GAM* 8-0012)         22       UTD= V* 6 GAM* 8-0012)         23       BETCOS= COS(A0(1))         24       ALPCOS= COS(A0(1))         25       ALPCOS= COS(A0(1))         26       GSIAAL1         27       SUMC2         28       SUM (ACC2)         29       SUM (ACC2)         20       SUM (ACC2)         21       SUM (ACC2)         22       SUM (ACC2)         23       SUM (ACC2)         24       ALPCOS = GOS(A0(1))         25       SUM (ACC2)         26       SUM (ACC2)         27       SUM (ACC2)         28       SUM (ACC2)         29<	AVMB= VV & GSAM *1 AVME= VV & GSAM *1 HTL= VV & GVTL *( HTD= VV & GVTL *( HTD= VV & GSVT *( VTD= VV &
1+       APRE- VELO * GSNR * 60(13)         15       VTL= VV * 6(NT * 1001 + 011)         16       VTD= VV * 6(NT * 1001 + 011)         17       NTD= VV * 6(NT * 1001 + 011)         18       VTD= VV * 6(NT * 1001 + 011)         20       VTH= VV * 6(NT * 1001 + 011)         21       NTD= VV * 6(NT * 1001 + 0012)         22       D5(1055 c05(1001 + 012))         23       BETCUS= C05(10(0))         24       APSGNS c05(10(1))         25       SUSTS = SIN(A0(1))         26       SUSTS = SIN(A0(1))         27       SUSTS = SIN(A0(1))         28       SUSTS = SIN(A0(1))         29       SUSTS = SIN(A0(1))         29       SUSTS = SIN(A0(2))         2005       HTR+ DELCUS = HTR+ DELCUS         21       SUSTS = SIN(A0(2))         29       SUSTS = AA+ALO+HTL+ HTR+ TAUCOS         2005       HTL+ ALLO+TLL+ HTR+ TAUCOS         21       SUST         22       SUST         23       SU	AVR.F VELO * 65ANR HTL= VV * 6HTL * A HTD= VV * 6FIT * ( VTD= VV * 65VT * ( HTD= VV * 65VT * ( TDD= VC * 50SA0(2)] BETCOS= COSA0(2)] BETCOS= COSA0(2)] A PCOS= COSA0(2)] A PCOS= COSA0(1)] A PCOS= COSA0(1)] A PCOS= COSA0(2)] A PCOS= COSA0(1)] A PCOS= COSA0(1)] A PCOS= COSA0(2)] A PCOS= COSA0(2)
15       MTL= W* 64TL * A0111         16       MTL= W* 65TL * (4012)         17       MTD= W* 65TL * (4012)         19       WTD= W* 65TL * 4012)         20       WTH= W* 65TL * 4012)         21       TAUCOS         22       DSLC055         23       BETCOS         24       APFOS         25       ALPGOS         26       COSTAO(6)         27       SUMTA         28       SUMACOS         29       SUMACOS         20       SUMACOS         21       SUMACOS         22       SUMACOS         23       BETCOS         24       SUMACOS         25       ALPGOS         26       SUMACOS         27       SUMACOS         28       SUMACOS         29       SUMACOS         20       SUMACOS         21       ALPCOS         22       SUMACOS         23       SUMACOS         24       ALPCOS         25       SUMACOS         26       SUMACOS         27       SUMACOS         28       ILAALQOS     <	HTL= VV * 6HTL * A <u>VTL= VV * 65HT * 1</u> <u>VTD= VV * 64HA * 1</u> <u>VTD= VV * 64HA * 1</u> <u>TAUC05= C05140(61)</u> <u>DELC05= C05140(61)</u> <u>ALPC05= C05140(61)</u> <u>ALPC05= C05140(411)</u> <u>ALPC05= C05140(41)</u> <u>ALPC05= C05140(411)</u> <u>ALPC05= C05140(41)</u> <u>ALPC05= C0</u>
16       VTL= VV e GVT, *(-A0(2))         17       VTD= VV * GSHT * (CD0T + CD1T * A0(1)**2.)         18       VTD= VV * GSHT * (CD0T + CD1T * A0(2)**2.)         19       HTM= VV * GSHT * (-A012)         20       VTD= VV * GST * (-A012)         21       DELC05= COSAG0(6)         22       TAUCOS= COSAG0(1)         23       BEFC05= COSAG0(1)         24       AL PSIN= SIN(A0(2))         25       AL PSIN= SIN(A0(1))         26       SUSES= SIN(A0(1))         27       SUMFZ= ALAALQUHIL+THR TAUCD5         28       AL PSIN= SIN(A0(2))         29       SUMFZ= ALAALQUHIL+THR TAUCD5         21       SUMFZ= ALAALQUHIL+THR TAUCD5         22       SUMFZ= ALAALQUHIL+THR TAUCD5         23       SUMFZ= ALAALQUHIL+THR TAUCD5         24       AL PSIN= SIN(A0(2))         25       SUMFZ= ALAALQUHIL+THR TAUCD5         26       SUMFZ= ALAALQUHIL+THR TAUCD5         27       SUMFZ= ALAALQUHIL+THR TAUCD5         28       SUMFZ= ALAALQUHIL+THR TAUCD5         29       SUMFZ= ALAALQUHIL+THR TAUCD5         21       SUMFZ= ALAALQUHIL+THR TAUCD5         22       SUMFZ         23       SUMFZ         24       SU	VIL         VV         6 VIL         4(-           HJD         VV         6 SHI         4(-           VTDD         VV         6 SHI         4(-           TAUCOS         COS AGO(6)         1         4(-           DELCOS         COS AGO(6)         1         1           AL PCOS         COS AGO(2)         1         1           AL PCOS         COS AGO(2)         1         1           AL PCOS         COS (AO(1))         1         1           AL PCOS         SIN(AO(2))         1         1           SUMF2         ALA +AL4+H10+H10+H10+H10+H10+H10+H10+H10+H10+H10
17       HFD= VV * 65N1 * (CDOT + CDIT * A0(1)**2.)         18       VTH= VV * 65N1 * (CDOT + CDIT * A0(2)**2.)         20       VTH= VV * 65N1 * (-012)1         21       TAUCOS- COSIA0(6)         22       VALL         23       VALL         24       VALL         25       VALL         26       SIN(a0(1))         27       SUM52= COSIA0(1)         28       SUM52= COSIA0(1)         29       VALL         29       SUM52= ALA+LU+HTL+THR* TAUCOS         29       SUM52= COSIA0(1)         29       SUM52= SIN(a0(1))         29       SUM52= SIN(a0(1))         29       SUM52= ALA+LU+HTL+THR* TAUCOS         29       SUM52= SIN(a0(2))         20       FRAMA         21       SUM52= ALA+LU+HTL+THR* TAUCOS         22       SIN(a0(2))         23       SUM52= SIN(a0(2))         24       ALPCOS         25       SIN(ACCOS)         26       SIN(ACCOS)         27       SUM52         28       SIN(ACOS)         39       FARA         40       FALA         29       LA         20	HJD= VV * 65Hf * ( VTH= VV * 65Yf * ( VTH= VV * 65Yf * 4 VTH= VV * 65Yf * 4 VTH= VV * 65Yf * 4 VTH= VV * 65Yf * 4 DELCOS= COS A0(6)] BETCOS= COS A0(6)] ALPCOS= COS A0(1)] ALPCOS= COS A0(1)] BETSN= SIN(40(1)) BETSN= SIN(40(1)) BETSN= SIN(40(1)) BETSN= SIN(40(1)) CUMFZ= ALA+LQ+HTL SUMFZ= ALA+LQ+HTL SUMFZ= ALA+LQ+HTL SUMFZ= ATA+S0+VTC FPM= HTA+TTO+VTCM FVM= ELT*(-VTL* BE
18       VTD= VY & GSV1 * (CDUT * GDIT * AG(2)+*2.1         19       HTH= VY & GSTA * (CDUT)         20       VTH= VY & GSTA * (CDUT)         21       TAUCGS= CG5(A0(8))         22       DELCOS= CG5(A0(1))         23       BETCOS= CG5(A0(1))         24       APSIN= SIN(A0(1))         25       GS1(A0(1))         26       GS1(A0(1))         27       SUNFZ= ALAALUHHTLFIR* TAUCGS * SIN(A0(8)+A0(1))         28       APSIN= SIN(A0(2))         29       SUNFZ= ALAALUHTLFIR* TAUCGS * SIN(A0(6))+A0(1))         29       SUNFZ= TARALUHTLFIR* TAUCGS * SIN(A0(6))+A0(1))         29       SUNFZ= TARALUHTLFIR* TAUCGS * SIN(A0(6)) +A0(1))         29       SUNFY= ASRASB+VTL*FIR* DELCGS * SIN(A0(6)) +A0(1))         29       SUNFY= ARAALUHTL*TIR* TAUCGS * SIN(A0(6)) + ELT* ALPSIN         30       KFELT * ALPCOS = ALPSIS         31       FFN= ELT*VTE* BEFTCOS * SIN(A0(6)) - AO(2))         32       SUNFY= ALPCOS + HTN + UELCOS * SIN(A0(6)) - AO(2))         33       YNDH= FPN + APNA + VNA + NK+ SALACOS         34       FFI FET       JL+17         35       JL       FFI FET       JL+17         36       IFI FET       JL+17       JSONFY       JSONFY         35	VTD= VV * 65VT * ( HTA= VV * 67TR *( TAUCOS= COSAG(61) TAUCOS= COSAG(61) BETCOS= COS(60(1)) BETCOS= COS(60(1)) ALPCOS= COS(00(1)) ALPCOS= C
19     HTM= VV = GMTM = -A0121       20     VTM= VV = GMTM = (-A0121)       21     TAUGOS= COS(A00(8))       22     DELCOS= COS(A0(1))       23     BEFCOS= COS(A0(1))       24     ALPSIN= SIM(A0(2))       25     ALPSIN= SIM(A0(2))       26     COS(AA(1))       27     SUMFZ= TAAALu+HTL+TMR* TAUCOS       28     ALPSIN= SIM(AO(2))       29     SUMFZ= SIM(AO(2))       29     SUMFZ= SIM(AO(2))       29     SUMFZ= SIM(AO(2))       20     AFECOS(A0(1))       29     SUMFZ= SIM(AO(2))       20     A(ELT)       21     FMM       22     SUMFZ= SIM(AO(2))       23     SUMFZ= SIM(AO(2))       24     SUMFZ= SIM(AO(2))       25     SUMFZ= SIM(AO(2))       26     SUMMA       27     SUMFZ= SIM(AO(6))       28     FELT       29     SUMFZ= SIM(AO(2))       29     SUMA       20     SUMFZ       21     FELT	HIME VV * GHIM * A VTHE VV * GVTM * A TAUCOSE COSTAG(6)] DELCOSE COSTAG(6)] ALPCOSE COSTAG(6)] ALPCOSE COSTAG(1) ALPCOSE COSTAG(2) ALPCOSE COSTAG(1) ALPCOSE COSTAG(2) ALPCOSE COSTAG(1) ALPCOSE COSTAG(2) ALPCOSE COSTAG(1) ALPCOSE COSTAG(2) ALPCOSE
20       VTM= VV * GVTM *(-A0(2))         21       TAUCOS= COS(A0(6))         22       DELCOS= COS(A0(1))         23       BETCUS= COS(A0(2))         24       ALPCOS= COS(A0(2))         25       BETCUS= COS(A0(2))         26       COS(A0(2))         27       DELCOS= COS(A0(2))         28       SUMFZ= ALALUHLETHR* TAUCOS         29       SUMFZ= ALALUHLETHR* TAUCOS         20       SUMFZ= ALALUHLETHR* TAUCOS         21       SUMFZ= ALALUHLETHR* TAUCOS         22       SUMFZ= ALALUHLETHR* TAUCOS         29       SUMFZ= ALALUHLETHR* TAUCOS         21       SUMFZ= ALALUHLETHR* TAUCOS         23       SUMFZ= ALALUHLETHR* TAUCOS         24       FTM= ELTALUTH BETCOS         29       SUMFZ= ALALUHTER* BETCOS         31       FTM= ELTALUTH BETCOS         32       ZMOM= ATMR* ATMS-THR* DELCOS         33       TANDF * ALPCOS         34       FTM= ELTALUTH BETCOS         35       IA LOFS         36       IA LOFS         37       TAUDF         38       FTM= ALPCOS         39       IA TAU         31       IA LOFS         35	VTH= VV * 6VTH *(- TAUCOS= COSAG(6)1 DELCOS= COSAG(6)1 DELCOS= COS(40(8)] BETCOS= COS(40(8)] ALPCOS= COS(40(1)) ALPCOS= COS(40(1)) ALPCOS= COS(40(1)) SUMFZ= ALA+ALQ+VTU SUMFZ= ALA+ALQ+VTU FVH= ELT * ALPCOS(40( SUMFZ= ALA+VTO*FU FVH= ELT*(-VTL* HE FVH= ELT*(-VTL* HE
21       TAUCOS= COS(AU(8))         22       DELCOS= COS(AU(8))         23       BETCOS= COS(AU(1))         24       ALPCOS= COS(AU(1))         25       ALPCOS= COS(AU(1))         26       SETSIN= SIN(AO(1))         27       SUMFY= ALA+ALQ+HTL+THR* TAUCOS         28       SUMFY= ALA+ALQ+HTL+THR* TAUCOS         29       SUMFY= ARA+ALQ+HTL+THR* TAUCOS         29       SUMFY= ARA-ASB+HTL+THR* TAUCOS         29       SUMFY= ARA-ASB+HTL+THR* TAUCOS         20       FPM= HTN+(HTD+VTD* BETCOS         29       SUMFY= ARA-ASB+HTL+THR* DELCOS         20       FFM= ELT**(-VTL* BETCOS         21       SUMFY= ARA-ASH*TH* DELCOS         23       YNUM= FPM         31       FFM= APRA-ANX95+FW         50       FFM= ELT**(-VTL* BETCOS         31       FFM         700       ALPCOS         32       ZUMON         33       L+ADF         34       LF(1000         35       IF (1000         36       IF (1000         37       IAMM         38       IFF(11000         39       IFF(11000         31       IAMA <t< th=""><th>TAUCOS= COStAG(6)] DELCOS= COS(40(8)) BETCOS= COS(40(1)) ALPCOS= COS(40(1)) ALPCOS= COS(40(1)) BETSIN= SIN(40(1)) BETSIN= SIN(40(1)) BETSIN= SIN(40(1)) BETSIN= SIN(40(1)) BETSIN= SIN(40(1)) BETSIN= SIN(40(1)) SUMFZ= ALA+ALU+HT SUMFZ= ALA+ALU+HT FPM= HTM+HTD+VTBM FYM= ELT*(-VTL* BE</th></t<>	TAUCOS= COStAG(6)] DELCOS= COS(40(8)) BETCOS= COS(40(1)) ALPCOS= COS(40(1)) ALPCOS= COS(40(1)) BETSIN= SIN(40(1)) BETSIN= SIN(40(1)) BETSIN= SIN(40(1)) BETSIN= SIN(40(1)) BETSIN= SIN(40(1)) BETSIN= SIN(40(1)) SUMFZ= ALA+ALU+HT SUMFZ= ALA+ALU+HT FPM= HTM+HTD+VTBM FYM= ELT*(-VTL* BE
22       0ELC05= C05(40(8))         23       BETC05= C05(40(1))         24       ALPC05= C05(40(1))         25       BETC05= C05(40(1))         26       BETSN= SIN(40(1))         26       BETSN= SIN(40(1))         27       SUMF2= ALA+ALU+HIL+THR* TAUC05         28       SUMF2= ALA+ALU+HIL+THR* TAUC05         29       SUMF2= ALA+ALU+HIL+THR* TAUC05         29       SUMF2= ALA+ALU+HIL+THR* TAUC05         29       SUMF2= ALA+ALU+HIL+THR* TAUC05         29       SUMF2= ALA+ALU+HIL+THR* TAUC05         20       FPM= HTM+HID++TUP & BETC05         30       FFM= HTM+HID+HID+HID+HID+HID         31       FPM= HTM+HID+HID+HID+HID         32       SUMF7= ALPC05         33       LFM=ALPC05         31       FVA         52       SUMA         32       NUUM= FPM + APPA + ALPC05         33       L+MOD         34       FLIFE ALPC05         35       L4         36       FLIFE ALPC05         37       L4         38       LFL10-DPC1         39       LFL10-DPC1         31       L6         35       L6         36	DELC05= C05(40(8)) BETC05= C05(40(8)) ALPE05= C05(A0(2)) ALPE05= S05(A0(1)) BET51A= S1N(A0(1)) BET51A= S1N(A0(1)) BET51A= S1N(A0(2)) SUMF2= ALA+ALQ+HTL SUMF2= ALA+ALQ+HTL SUMF2= ALA+ALQ+HTL SUMF2= ALA+ALQ+HTL SUMF2= ALA+ALQ+HTL FYM= ELT * ALPC05_ *HE FYM= ELT*(-VTL* BE
23       BETCUSE COSIA0(1)         24       ALPCOSE COSIA0(1)         25       ALPCOSE COSIA0(1)         26       SUMFZE ALA+ALU+HTL+FHR* FAUCOS *SIMIAO(8)+A0(1))         27       SUMFZE ALA+ALU+HTL+FHR* FAUCOS *SIMIAO(8)+A0(1))         28       SUMFZE ALA+ALU+HTL+FHR* FAUCOS *SIMIAO(8)+A0(1))         29       SUMFZE ALA+ALU+HTL+FHR* FAUCOS *SIMIAO(8)+A0(1))         29       SUMFZE ALA+ALU+HTL+FHR* FAUCOS *SIMIAO(1))         29       SUMFZE ASA+ASB+VTL*FHR* ALPSIM         29       FPME HTN+HUTD+VTD* BETCOS         30       A[ELT * ALPCOS         31       FVME ELT*(-VTL* BETCOS         32       ZMGMF = ATRA+ATMS* FVMTTM* UELCOS         33       FVME = ALT*(-VTL* BETCOS         34       FFU       ALPCOS         35       I       ALDE         36       IF(1002-L)       IT,16,17         37       I       FAULA       ALPCOS         36       IF(11551-1)       IT,16,17       SIMAAQ3         37       I       FAULA       ALPCOS         36       IF(11551-1)       IT,16,17       SIMAAQ1         37       I       FAULA       ALPCOS         36       IF(11551-1)       IT,16,17       SIMAA <th>BETCUS= COS(A0(2)) ALPCOS= COS(A0(2)) ALPCOS= COS(A0(1)) ALPCOS= COS(A0(1)) BETSIN= SIN(A0(1)) BETSIN= SIN(A0(1)) SUMFZ= ALA+AL4+HT SUMFZ= ALA+AL4+HT SUMFZ= ALA+AL4+HT FVM= ELT * ALPGUS_ +HT FVM= ELT*(-VTL* BE</th>	BETCUS= COS(A0(2)) ALPCOS= COS(A0(2)) ALPCOS= COS(A0(1)) ALPCOS= COS(A0(1)) BETSIN= SIN(A0(1)) BETSIN= SIN(A0(1)) SUMFZ= ALA+AL4+HT SUMFZ= ALA+AL4+HT SUMFZ= ALA+AL4+HT FVM= ELT * ALPGUS_ +HT FVM= ELT*(-VTL* BE
25       ALPCOS= COS(AQ(1))         25       ALPCOS= COS(AQ(1))         26       BEFSIM= SIN(AQ(1))         27       SUMFZ= ALALUHILTHRR* TAUCOS       *SIN(AQ(8)+AQ(1))         28       SUMFZ= ALALUHILTHRR* TAUCOS       *SIN(AQ(8)+AQ(1))         29       SUMFZ= ALALUHILTHRR* TAUCOS       *SIN(AQ(6))-AQ(2))         29       SUMFZ= ALALUHILTHRR* DELCOS       *ELT* ALPSIN         20       A(ELT * ALPCOS       *HTP* LIT* ALECOS(AC(6))-AO(2))       *(HID * ALPCOS         31       FYM= ELT* ALPCOS       *HTP* LIT* ALPCOS       * (HID * ALPCOS         32       ZNON= ATMAYNÖFFYN-THR* DELCOS       * SIN(AO(6)) * ELS* ALPSIN         33       YNUM= ATMAYNÖFFYN-THR* DELCOS       * ELT* ALPSIN         33       YNUM= ATMAYNÖFFYN-THR* DELCOS       * SIN(AO(6)) * ELS*         33       YNUM= ATMAYNÖFFYN-THR* DELCOS       * ELT* ALPSIN         33       YNUM= ATMAYNÖFFYN-THR* DELCOS       * ELT* ALPSIN         34       FT       # ALPCOS       * ELT* ALPCOS         35       IA       FT       * ALPCOS       * ELT* ALPSIN         36       IF       IF       * ALPCOS       * ALPCOS       * ELT* ALPSIN         37       IA       IF       * ALPCOS       * INA       * ALPCOS	ALPCOS= COS(A0(1)) ALPCOS= COS(A0(1)) BEFSTM= SIN(A0(2)) BUMEY= ALA+ALQ+HT SUMEY= ALA+ALQ+HT SUMEY= ASR+AS8+YT FPM= ELT+(-VTL= HE FYM= ELT+(-VTL= HE
25       AL PSIN= SIN(AO(1))         26       BEFSIN= SIN(AO(2))         27       SUNFX= ALA+LQ+HTL+HR* FAUC05       \$SIN(AO(8)+AO(1))-ADF-HID-VT0         28       SUNFX= ALA+SLV+LFLR* FAUC05       \$SIN(AO(8)+AO(1))-ADF-HID-VT0         29       SUNFY= ALA+SLV+LFL*HR* FAUC05       \$SIN(AO(6))-AO(2))         29       SUNFY= ASA+SLVL*HR* DELC05       \$KIN(AO(6))-AO(2))         20       A[ELT * ALPGOS       \$KIN + DELC05       \$SIN(AO(6)) - AO(2))         30       A[ELT * ALPGOS       \$KIN + DELC05       \$KIN(AO(6)) + ELS         31       FYN= AFNA *APNG. *AFNG. *ALPC05       \$SIN(AO(6)) + BEISIN) + TAJC05       \$SIN(AO(6)) + BEISIN) + TAJC05         31       ZNON= ATR3+A7N5       \$KIN + DELC05       \$SIN(AO(6)) + BEISIN) + TAJC05       \$SIN(AO(6)) + BEISIN) + TAJC05         31       ZNON= ATR3+A7N5       \$KIN + ADEC05       \$SIN(AO(6)) + BEISIN) + TAJC05       \$SIN(AO(6)) + BEISIN) + TAJC05         32       ZNUN= FPN.       ALPC05       \$HIR + TAJC05       \$SIN(AO(6)) + BEISIN) + TAJC05         33       I+ADF       HZ       ALPC05       \$SIN(AO(6)) + BEISIN) + TAJC05         33       I+ADF       HZ       \$SIN(AO(6)) + ALQ) + BEISIN) + TAJC05       \$SIN(AO(6) + BEISIN) + TAJC05         34       I+ADF       HZ       I+ADF       ALPC05 <td< th=""><th>AL PSIN= SIN(A0(1)) BEISIN= SIN(A0(2)) BUMF2= ALA+ALQ+HTL SUMFX= THX+CDSIAO( SUMFY= ASR+ASB+VTL FPN= HTM+(HTD+VTB= AIGLT * ALPGUS_ *H2 FYM= ELT*(-VTL* BE</th></td<>	AL PSIN= SIN(A0(1)) BEISIN= SIN(A0(2)) BUMF2= ALA+ALQ+HTL SUMFX= THX+CDSIAO( SUMFY= ASR+ASB+VTL FPN= HTM+(HTD+VTB= AIGLT * ALPGUS_ *H2 FYM= ELT*(-VTL* BE
26       BETSIN= SIN(AG(2))         27       SUNFZ= ALA+ALQ+HTL+THR* TAUCOS *SIN(AO(8)+AO(1))-ADF-HTD-VTO         28       SUNFY= ASA+ALQ+HTL+THR* TAUCOS *SIN(AO(8)+AO(1))-ADF-HTD-VTO         29       SUNFY= ASA-ASB+VTL+THR* DECLOS *SIN(AO(8)+AO(1))-ADF-HTD-VTO         20       FPN= HTN+(HTD+VTD* BETCOS 1+COS(AO(6)) + AD(2))         30       F(ELT * ALP,COS       +HZ* ALPCOS - (HZ* ALPSIN)         31       FYN= ELT*(-VTL* BETCOS + (HTD * ALPCOS + VTD)* BETSIN) +         32       ZNGM= ATMR+ATA+ALP-THR* TAJCOS*( HZ* ALPSIN)         33       ZNGM= ATMR+ATA+ALP-THR* TAJCOS*( HZ* ALPSIN)         33       ZNGM= ATMR+ATA+ALP-THR* TAJCOS*( HZ* ALPSIN)         33       ZNGM= ATMR+ATA+ATHR* TAJCOS*( HZ* ALPSIN)         34       IF(ITEST-I) 17.14, 17         35       IA       IA         36       IF(ITEST-I) 17.14, 17         37       I6       FUMA (JZ,ZZ), AHALM, 7Z, SHALM, 7Z, SHALMA+GX, GAMPA         35       IA       IF(ITEST-I) 17.14, 17         36       I5       ICUDS+I       I7.14, 17         37       I6       FUMA (JZ,ZZ), SHALM, 7Z, SHALM, 7Z, SHALM+GX, GX, GAMPA         37       I6       IF(IZEST-I) 17.14, 17         37       I6       IF(IZEST-I) 17.14, 17         36       I5       I7Z, SHAMAPA, 7Z	BE ISIN= SIN(A0(2))       BUMFZ= ALA+ALQ+HTL       SUMFX= ALA+ALQ+HTL       SUMFY= ASR+ASB+VTL       SUMFY= ASR+ASB+VTL       FPM= HTM+(HTD+VTB*       A[ELT * ALPCGS_ *HS       FYM= ELT*(-VTL* BE
27       SUMF2= ALA+ALQ+HTL+THR* TAUCO5       *SIM(AQ(B)+AQ(1))         28       SUMFY= JYM*COS(AQ(6)-AQ(2)) = COS(AQ(B)+AQ(1)))       29       SUMFY= JYM*COS(AQ(6)-AQ(2)) = COS(AQ(B)+AQ(1)))         29       SUMFY= ASRASSAULETHR* DECCOS       * (H2* ALPCUS)       - (H2* ALPCUS)       - (H2* ALPCUS)         30       FFM= HTM+HTD+HTD* BETCOS       + (H2* ALPCUS)       - (H2* ALPCUS)       - (H2* ALPCUS)       - (H2* ALPCUS)         31       FYM= ELT*(-VTL* BETCOS       + H2* ALPCUS       - (H2* ALPCUS)       - (H2* ALPCUS)       - (H2* ALPCUS)         32       ZMGME = ATM2+ATM3+FYM - THM* UELCOS       + SIM(AQ(6))       + EL5       - (H2* ALPCUS)       - (H2* ALPCUS)       - (H2* ALPCUS)         33       TVHUME = FPM + APPMA + ALPCUS - HHR* UELCOS       + SIM(ALA+ALQ) - (H2* ALPCUS)       - (H2* ALPCUS)       - (H2* ALPCUS)       - (H2* ALA)	SUMFZ= ALA+ALQ+HTL SUMFY= ASR+AS0+4TL SUMFY= ASR+AS0+VTC FPM= HTM+{HTD+VTC0 A{ELT # ALEPGOS_ +HE FYM= ELT#(-VTL# BE
28     SUMFX=     THR*CUTO*TO     COSTA0(5)-AD(1))-ADF-HTD-VTO       29     SUMFY=     ASC+ASB+VTC+THR*     DELCOS     * SIMIAD(5)-AD(2))       30     FPM=     HTM*CUTO+VTD*     BETCOS     * (HID * ALPCOS     - HTD*VTO       31     FVM=     ELT*     ALPSIN     - (HID * ALPCOS     - HTD*VTO       32     ZMOM=     ATEX+     HAP*     ALPSIN     - (HID * ALPCOS     - ELT*     - ELT*       32     ZMOM=     ATEX+     AND     - APAG     - APAG     - APAG     - APAG     - APAG       33     TANDF     A PANA     - APAG       33     TANDF     A REI     TATER     - LPCOS     - FLIF*     - ELT*     - ELT*     - ALPSON       33     TATER     A RADO     - APAG       34     FFI     IF     - APAG     - APAG </th <th>SUMFX= JHR*COS(20) SUMFY= ASR+AS6+VTL SUMFY= ASR+AS6+VTL FPM= HTM+HTD+VTB# FVM= ELT*(-VTL* HE FVM= ELT*(-VTL* HE</th>	SUMFX= JHR*COS(20) SUMFY= ASR+AS6+VTL SUMFY= ASR+AS6+VTL FPM= HTM+HTD+VTB# FVM= ELT*(-VTL* HE FVM= ELT*(-VTL* HE
29       SUKFY= ASR+ASB+VTL*TRR* DELCBS       *SIM130(5)-A0(2)         30       FPM= HTM+1HTD+VTD* BETCOS       +HIR       +	SUNFY= ASR+ASB+VTL FPM= HTM+(HTD+VTB+ FLT * ALPUDS_ +H2 FVM= ELT*(-VTL* BE
30       FPM= HTM+(HTD+VTD* BETCOS ) * (HZ* ALPCOS - ELT* ALPSIM)         31       FYM= HTM+(HTD+VTD* BETCOS + HTD)* BETSIM) +         32       AFELT* ALPCOS - HHZ* ALPSIM )         32       ZWWH= ETT* ALPCOS + HTM + METCOS + VTD)* BETSIM) +         33       ZWWH= ETT* ALPCOS - HHZ* ALPSIM *         33       ZWWH= ETT* ALPCOS - HHZ* ALPCOS + VTD)* BETSIM) +         33       ZWWH= ETT* ALPCOS - HHZ* ALPCOS * SIM(AO(6)) * ELG         33       I+ADF* HZ* ALPCOS - THR* TAJCOS*E HZ* BLECOS * ELG*SIM6AO         34       IF(ITEST-I) 17,16,17         35       I& IE(1000-L) 17,16,17         36       IS hRITE(3,16)         37       I.6 FURMAT (JZX,5HALM)7X,3HALQ,7X,5HAPMA.6X,6HAPMA.6X,6HAPMA.6X,6HAPM         37       I.6 FURMAT (JZX,5HALM)7X,5HSUMFX,5X,6HAPMA.6X,6HAPMA.6X,6HAPMA.6X,6HAPM         37       I.6 FURMAT (JZX,2HALM)7X,5HSUMFX,5X,6HAPMA.6X,6HAPMA.6X,6HAPM         38       JRTIE(3,16)         39       JRTIE(3,10,20)         31       I.4 HW, VTM,5UMFZ,5UMFZ,5UMFY,5PA,6YMAPMA.6X,6HAPMA.6X,6HAPMA.6X,6HAPMA.6X,6HAPMA.6X,6HAPMA.6X,6HAPMA.6X,6HAPMA.6X,6HAPMA.6X,6HAPMA.6X,6HAPMA.6X,6HAPMA.6X,6HAPMA.6X,6HAPMA.6X,6HAPMA.6X,6HAPWA.6X,6HAPMA.6X,6HAPWA.6X,6HAPWA.7X,6HAPMA.6X,6HAPWA.7X,6HAPMA.6X,6HAPWA.7X,6HAPWA.7X,6HAPWA.7X,5HAPWA.7X,5HAPWA.7X,5HAPWA.6X,6HAPWA.7X,5HAPWA.6X,6HAPWA.7X,6HAPWA.6X,6HAPWA.7X,5HAPWA.6X,6HAPWA.7X,5HAPWA.6X,6HAPWA.6X,6HAPWA.7X,6HAPWA.6X,6HAPWA.7X,6HAPWA.7X,6HAPWA.7X,6HAPWA.7X,6HAPWA.7X,5HAPWA.7X,5HAPWA.7X,5HAPW	FPM= HTM+(HTD+VTD* <u>A</u> {ELT * ALPGOS_ +H2 FVM= ELT*(-VTL* BE
A[ELT * ALPUOS       +H2* ALPSIN       -         31       FYM= ELT*(-VIL* BETCOS + (HID * ALPCOS + VTD)* BETSIN         32       ZMGM= AYM2+YN3+FYM-TMR = APLCOS + (HID * ALPCOS + VTD)* BETSIN         33       ZMGM= AYM2+XN3+FYM-TMR = ALPCOS + VTD)* BETSIN         33       ZMGM= AYM2+XN3+FYM-TMR = ALPCOS + VTD)* BETSIN         33       I+ADF* H2* APPA * APPA * APPA         34       IF(ITEST-1) 17.14,17         35       14. FE(LOUD-L) 17.14,17         35       14. FE(LOUD-L) 17.14,17         35       14. FE(LOUD-L) 17.14,17         35       14. FE(LOUD-L) 17.14,17         36       15. KRITE(3.16)         37       16. FUMMT (//ZLX, 3HALA, TX, 3HALQ, TX, 3HADF, TX, 4HAPMA, 6X, 4HAPMA, 6X, 4HAPMA         37       16. FUMTA (//ZLX, 3HALA, TX, 3HALQ, TX, 3HADF, TX, 4HAPMA, 6X, 4HAPMA, 6X, 4HAPMA         37       16. FUMTA (//ZLX, 3HALA, TX, 5HSUMF, 5X, 5HSUMF, 6X, 6HAPMA, 6X, 6HAPMA         38       1.7X, 3HAIRA, 7X, 5HSUMF, 7X, 5HSUMF, 6X, 6HILL, TX, 3HUL, TX, 3HUL, Y, 5M         39       1. KRITE(13.16)       AA_AALA, AA, 7X, 5HSUMF, 7X, 6HAPMA, 6X, 6HAPMA, 7X, 5HAPMA,	AFELT + ALPUDS +HZ FYM= ELT+F-VTL+ BE
31       FYNE ELT*(-VTL* BETCOS +(HTD * ALPCOS + YTD)* BETSIM) +         32       ZNGNE AYRX-AYX5+FYN-THX* DELCOS * SIM(AO(6)) * ELS         33       I+ADF       APRL + APPL + APPL         33       I+ADF       APRL + APPL + APPL         34       IF(ITEST-I) 17,16,17       BELCOS* ELG*SIM(A)         35       15       IF(100P-L) 17,16,17         35       15       IF(100P-L) 17,16,17         36       15       IF(120P-L) 17,16,17         36       15       IF(120P-L) 17,16,17         36       15       IF(120P-L) 17,16,17         36       15       IF(1202-L) 17,16,17         37       16       FUNMAT (/ZUX),3HALA,7X,3HALQ,7X,5HAPHALALA,7X,5HAPHALALA,7X,5HAPHALA,7X,5X,5HAPHALA,7X,5HAPHALA,7X,5X,5HAPHALA,7X,5HAPHALA,7X,5HAPHALA,7X,5HAPHALA,7X,5HAPHALA,7X,5HAPHALA,7X,5HAPHALA,7X,5HAPHALA,7X,5X,5HAPHALA,7X,5HAPHALA,7X,5HAPHALA,7X,5HAPHALA,7X,5HAPHALA,7X,5HAPHALA,7X,5HAPHALA,7X,5HAPHALA,7X,5X,5HAPHALA,7X,5HAPHALA,7X,5HAPHALA,7X,5HAPHALA,7X,5HAPHALA,7X,5HAPHALA,7X,5HAPHALA,7X,5HAPHALA,7X,5HAPHALA,7X,5HAPHALA,7X,5HAPHALA,7X,5HAPHALA,7X,5HAPHALA,7X,5	FYR= ELT+(-VTL+ BE
<ul> <li>32 ZMGWE ATYRRANYSGFFYM-THRE DELCOS &amp; SIN(AO(6)) &amp; ELG</li> <li>33 YMUWE FPM + APMA *APMGHZE AIPSIN # (AIA-ALQ) - FENCESINE</li> <li>34 IF(ITEST-1) 17,14,17</li> <li>35 IS (FILCOPE-L) 17,14,17</li> <li>36 IS (FILCOPE-L) 17,14,17</li> <li>36 IS (FILCOPE-L) 17,15,17</li> <li>36 IS (FILCOPE-L) 17,15,17</li> <li>37 IG FURMAT (//21X,344LA,7X,344LQ,7X,344DF,7X,944DPMA,6X,644DPM</li> <li>37 IG FURMAT (//21X,344LA,7X,344LQ,7X,344DF,7X,944DPMA,6X,644DPM</li> <li>38 IS (FILCOPE-L) 17,15,17</li> <li>39 MRITE(3,10,40)C,444ZMM,5X,554SUMFLZZX,54SUMFY,5X,544ZMM</li> <li>39 MRITE(3,442ADM,6X,444YM,7X)</li> <li>39 ULHFM,VTM,SUMFZ,SUMFY,FPM,FPM,FPM,2MDM, YMDM</li> <li>39 LIHF,VTM,SUMFZ,SUMFY,FPM,FPM,FPM,FWM,ZMDM,YMDM</li> <li>39 LIHFM,VTM,SUMFZ,SUMFY,FPM,FPM,FVM,ZMDM,YMDM</li> </ul>	
33       YNUM= FPR + APMA + APMA, -H.Z.A. PSIM, *(ALA+ALQ) - F*H2*5INL         34       IF41FEST-1) 17,14,17         35       16 EF(L00P-L) 17,14,17         36       15 NRITE(3,10,17,14,17         36       15 NRITE(3,10,17,14,17         36       15 NRITE(3,10,17,14,17         36       15 NRITE(3,10,117,14,17         36       15 NRITE(3,10,1217,344LA,77,344LQ,77,544APMA,657,544APMA,657,544APMA,657,544APMA,657,544APMA,657,544APMA,657,544APMA,657,544APMA,657,544APMA,657,544APMA,657,544APMA,657,544APMA,657,544APMA,657,544APMA,657,544APMA,657,544APMA,657,544APMA,657,544PMA,757,554,544PMA,757,554,544PMA,757,554,544PMA,757,554,544PMA,700M,77,544PMA,777,544PMA,574PMA,574,540PM7,754,540PM7,574,540PM7,7544PMA,774,540PM,740PM,11,47         39       141F6,174,544PMA,650MF7,570MF7,570M7,770,544PMA,470M         39       141F6,174,544PMA,650MF7,570M57,570M7,770M,740M         39       1,11F6,174,50M52,50M57,570M57,570M57,570M67,570M67,570M67,570M67,570M67,570M7,570M1,770M0,740M         39       1,11F6,174,770,500F2,500M57,570M57,570M57,570M67,570M67,570M67,570M67,570M67,570M67,570M67,570M67,570M57,570M7,570M67,570M7	ZHGH= AYMR+AYX6+FY
140F*       H2* ALPCOS       TAUF       TAUCGS*f       H2* DELCOS       ELG*SIMfAQ         34       IF(ITEST-L)       17,14,17         35       14       IF(ITEST-L)       17,14,17         35       15       IC(109-L)       17,15,17         35       15       RITE(109-L)       17,15,17         36       15       RITE(1,200-L)       17,15,17         31       16 <furmat< td="">       1/21X; JHALA,7X; JHALQ,7X; JHADF,7X; GHAPMA.6X, GHAPMA.6X, GHAPMA         31       1.7X, JHAN,7X; JHALA,7X; JHALQ,7X; JHADF,7X; GHAPMA.6X, GHAPMA.6X, GHAPMA         32       1.7X, JHAN,7X; SHALA,7X; SHAUR,6X, GMFY,5X; SHWFLA_IX; SHSUMFY,5X, SHUPA,6X, GHAPMA         38       JHFYN,7X, GHARAN,7X, SHSUMFY,5SH,9MFY,5X, SAWFX,5X, SH         38       JHFYN,7X, SUMFZ,6X,6X, SUMFY,FPN,FPN,2X,0M,YMO,0M,0M,0M,0M,0M,0M,0M,0M,0M,0M,0M,0M,0M,</furmat<>	YHUN= FPR + APMA +
34 IF(ITEST-1) 17,14,17 35 If IF(100-L) 17,15,17 36 IS KRITE(3)16) 37 I6 FUKIT (J21X; J4LA, TX, 3HALQ, TX, 3HADF, TX; 4HAPHA, 6X, 4HAPHA, 6X, 4HAPHA, 6X, 4HAPHA, 6X, 3HAPL, 1X, 3HAPL, 2, 7X, 3HHEM, 7X, 5HX MB/221X, 4HA YMK, 6X, 3HHFL, 1X, 3HUTL, 1X, 3HD 2. 7X, 3HHEM, 7X, 2HV TM, 7X, 5HSUMFZ/SIX, 5HSUMFY, 5X, 5HSUMFY, 5X, 3H 38 MKTLL, 7X, 3HHEM, 7X, 4HAZMM, 6X, 4HYMMF, 6X, 3HHTL, 1X, 3HUTL, 1X, 3HD 38 MKTLE13,1) A.A.ALQ, ADF, 4HAYMMF, 5HSLMFX, 5X, 5HSUMFY, 5X, 3HSUMFY, 5X, 4HZM, 7X, 5HSUMFY, 5Y, 5X, 5HSUMFY, 5X, 4HZM, 7X, 5HSUMFX, 5X, 5HSUMFY, 5X, 4HZM, 7X, 5HSUMFX, 5X, 5HSUMFY, 5X, 5HSUMFY, 5X, 5X, 5X, 5HSUMFY, 5X, 5HSUMFY, 5X, 5X, 5HSUMFY, 5X, 5X, 5X, 5HSUMFY, 5X, 5X, 5X, 5X, 5X, 5X, 5X, 5X, 5X, 5X	L+ADF+ HZ+ ALPCOS
35         16         IF(LOUP-L)         17.415.417           36         15         FMINTE(1/21X)-3HALA,7X,3HALQ,7X,3HADF,7X,9HAPMA,6X,6HAPMA,6X,6HAPMA,5X,6HAPMA,5X,6HAPMA,5X,6HAPMA,5X,6HAPMA,5X,6HAPMA,5X,6HAPMA,5X,6HAPMA,5X,6HAPMA,5X,6HAPMA,5X,6HAPMA,5X,6HAPMA,7X,2HAPMA,7X,5HSUMFZ,2X,2HAPMA,5X,6HAPMA,7X,5HSUMFZ,2X,3HALL,1X,3HALL,1X,3HALL,1X,3HALL,1X,3HALL,1X,3HALL,1X,3HALL,2X,7X,6HIRM,7X,5X,6HAPMA,7X,5HAPMA,1X,7HAPMA,7X,5X,6HAPMA,7X,5X,6HAPMA,7X,5X,6HAPMA,7X,5HAPMA,5X,6HAPMA,7X,5X,5X,6HAPMA,7X,5X,5HAPMA,7X,5X,7X,6HAPMA,7X,7X,7X,7X,7X,7X,7X,7X,7X,7X,7X,7X,7X,	IF([TEST-1) 17,14,
36       15       kr [Te(3, 16)         37       16       FUKMAT (//21X, 3HALA, 7X, 3HALQ, 7X, 3HADF, 7X; 4HAPMA, 6X, 4HAPMA, 7X, 3HUTL, 7X, 3HUTL, 7X, 3HUTL, 7X, 3HUTL, 7X, 3HUTL, 7X, 3HUTL, 7X, 5HSUMFY, 5X, 6HAPMA, 7X, 4HAPMA, 7X, 5HSUMFY, 5X, 6HAPMA, 6X, 4HAPMA, 7X, 5HSUMFY, 5X, 6HAPMA, 7X, 5HSUMFY, 5X, 4HAPMA, 7X, 5HSUMFY, 5X, 4HAPMA, 7X, 5HSUMFY, 5X, 4HAPMA, 7X, 5HSUMFY, 5X, 6HAPMA, 7X, 5HSUMFY, 5Y, 5HSUMFY, 5Y, 7X, 5HSUMFY, 5Y, 7X, 5HSUMFY, 5Y, 5HSUMFY, 7X, 5HSUMFY, 5X, 6HAPMA, 7X, 5HSUMFY, 5Y, 7X, 5HSUMFY, 5HSUMFY, 5Y, 7X, 5HSUMFY, 7X, 5HSUMFY, 5Y, 7X, 5HSUMFY, 7X, 5HSUMFY, 7X, 5HSUMFY, 7X, 5HSUMFY, 7X, 5HSUMFY, 5X, 7X, 5HSUMFY, 7X, 5HSUMFY, 5X, 7X, 5HSUMFY, 5X, 7X, 7X, 5HSUMFY, 7X, 7X, 5HSUMFY, 7X, 7HSUMFY, 7X, 7HSUMFY, 7X, 7HSUMFY, 7X, 7HSUMFY, 7X,	14 IF(LOUP-L) IT, 15.15.1
37 16 FURMAT (//21X; 3HALA, 7X, 3HALQ, 7X, 3HADF, 7X, 5HAPMA, 6X, 6HAPMA, 7X, 7X, 7X, 6HAPMA, 7X, 7X, 6HAPMA, 7X, 7X, 6HAPMA, 7X, 7X, 7X, 7X, 7X, 7X, 7X, 7X, 7X, 7X	IS KRITE(3, 16)
1.7X,3H45R,1X,5H4XM9/21X,4H4YM6.6X,3HHFL_TX,3H9IL_TX,3H9I 2.7X,3HHFW,7X,2HVTW,7X,5HSUMF2/21X,5HSUMFX,5X,5HSUMFY,5X, 3 3HFYM,7X,4AAAUM,6X,64XM0MF2/21X,5HSUMFX,5X,5HSUMFY,5X, 38 HKITE13,51,ALAAAU2,4DF4XM90,4584,5XM6.4YM8.4HIL.V 1,HFM,VTM,5UMFZ,5UMFY,5PM,5YM,2M0M,YMOM 1,HFM,VTM,5UMFZ,5UMFY,5PM,5YM,2M0M,YMOM 1,HFM,VTM,5UMFZ,5UMFY,5PM,5YM,2M0M,YMOM 1,HFM,VTM,5UMFZ,5UMFY,5PM,5YM,2M0M,YMOM 1, RETURN 40 L7 RETURN	16 FURMAT (//21X, 3HAL
2.7X,34HEM,7X,24VEM,7X,5HSUMFZ/2IX,5HSUMFX,5X,5HSUMFY,5X, 3.3HFYM,7X,4HZMOM,6X,4HYMOM/) 38 UKITEL3.*1.ALA.ALQ.ADF.APMJ.APMQ.ASB.ASB.AYMB.AYMB.HTL.V 1.HEM,VTM,SUMFZ,5UMFZ,5UMFT,FPM,FYM,ZMOM,YMOM 39 L.INE= L.INE + 9 40 L7 RETURN 40 L7 RETURN	1.7X.3HA5R.2X.4HAY
3 3HFYM,7X,4HZMOM,6K,4HYMOM/) 38 JKLIEL3+*1 ALA_ALQLADE_APMJ_APMQ_ASB_ASB_AYMB_AYMB_HIL.V 1,HIM,VIM,SUMFZ,SUMFZ,SUMFY,FPM,FYM,ZMOM,YMOM 39 LINE= LINE + 9 40 LI RETURN 40 LI RETURN	2.7X, 3HHTM, 7X, 2HVTH
38 HKITE(3,*) ALA.ALQ.ADE.APMG.ASB.ASR.AYMB.AYMB.HIL.V 1.Hfm,vim,sumfis.Sumfie.	3 3HFYN, TX, 4HZNON, 6
I.HFM.VTM.SUMFZ.SUMFZ.FPM.FY.FPM.FYM.ZNDM.YMOM 39 L.INE= L.INE + 9 40 L7 RETURN 40 L7 R.	HRITE(3,*) ALA.ALC
39 LINE= LINE + 9 40 LI RETURN 1	L.H.F.Y.TH, SURFZ, SUP
40 17 RETURN	LINE= LINE + 9
270 Can	L7 RETURN
	END

000 TOTAL ERRORS FUR THIS CUMPLIAILUN 04.103 [ TOTAL NUMBER OF LIBRARY SECTORS REQUIRED IS 13 MAME-FORCE "PACK-FORTR2"UNIT-RI,RETAIM-1,LIBRARY-R,CATEGORY-020

CUMUITION CORUM 1 -- INITAL YAM ANDLE = 3 DEG \*\* FEEDBACK CUNTROL

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ENPUT HEADING U.OU TRIM PITCH ANGLE 0.00

GIMBAL RATE 3.00 DEG/SEC PITCH ERRUN GAINE 1.00 YAM ERRON GAINE 1.00 YAM RATE GAINE 1.00

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UIFFERENTIAL IINE INCREMENT= 0.20 INITIAL VELULIT= 7.78 THRUST= 122.70

SND					
EUNTI					
DYNAHIC					
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METERS	10+30	12E+04	12E+04	101	+01
PARA	40730	12110	12110	0000	0000E
ILLUN	0-2	0. ¢	0.4	80Z.	<b>1.268</b>
ЪÅ	4ASS=	=224+	: A 5 5 =	<b>ΓΥ</b> = 0	C = 2 1
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KEL	1.17	7.17	1.11	7.77	7.77	11.1	1.77	1.17	1.17	7.70	7.76	7.70	7.76	7.76	1.76	7.76	7.76	1.76	7.76	7.70	7.76	7.76	7.76	1.70	7.76	7.76	7.76	11.1	1.1	1.17	1.77	71.77	1.72	11-1	1.1	1.77	11.1	1.77	11.1	1.11
TAU	2.98094	2.94371	2.90259	2.80059	2.81878	2.11754	2.73697	2.69711	2.65793	2.61942	2.58157	2.54434	2.50773	2-47170	2.43625	2.40136	2.36701	2,33319	2。29989	2.26709	2.23479	2.20298	2.17164	2.14077	2.11035	2.08038	2-05084	2.02174	1.99307	18406.1	<b>1.</b> 93696	I. 90951	1.88246	L.85579	1.82952	1.80361	1.7780E	1.75292	1.72812	1.70367
BFLA	-2.71953	-2.47816	-2.31244	-2.16200	-2.07121	-1.97359	-1.88010	-1.90704	-1.73526	-1.66988	-1.61014	-1.55543	-1.50519	-1.45891	-1.41618	-1.37660	-1.33984	-1.30559	-1.27359	-1.24361	-1.21543	-1.18887	-1.16376	-1.13996	+6711.1-	-1.09578	-1.07519	-1.05547	-1.03055	-1 -01835	-1.00081	-0.94387	-0.96749	-0.95162	-0.93022	-0.92125	-0.90669	-0.89251	-0.87867	-0.86517
ISA	21166-2	2.90170	2:9229.5	2.84150	2.83955	2.79815	2,75725	2.71704	2.01752	2.63863	2.60050	2.56296	2.52633	2.48971	79863.2	2.41380	2.35413	2.35010	2.31554	2.28149	2.25094	2.21839	16781.5	2.15020	2-12556	2.09536	2.00561	2.03529	2.00741	1.97896	1,95038	1.92323	86468.1	1.80913	1.84265	1.81655	1.79385	1.76550	1.74052	1°71589
DELTA	0,04093	0-00202	0.00283	U.00341	0.00373	0.00398	6.00404	0,00400	0.00JH3	0.00370	6.00347	0.00322	0.00294	0.04265	0.00237	0.00208	0.00179	0.01151	0.00124	0.00098	0.00074	0.00050	0.00028	C.00008	-6.00012	-0-030	-0-00047	-0,00062	-0.00077	15000-0-	-0.00103	-0-00115	-0.00126	-0.00135	-0.00145	-0-04153	-0.00161	-0.00168	-0.00L74	-0*00180
АЦРНА	-0* 00195	-0.00614	-0.00151	-0.01161	-0.01238	-0.01220	-0.01133	-0.01001	-0.00343	-0.00073	-0.00500	-0.04332	-0.00173	-0.00027	0.00105	0.00221	0.0322	0.00408	0.04479	0,00536	0.00581	0.00415	0.00639	0.00655	0.00662	0.00663	0.00658	0.00649	0.00635	0.00619	0.00600	0.00579	0.00556	0.00533	0.00509	0.00485	0.00461	0.00437	0.00413	0.00390
lite la	0.00053	0.15Z	0.00243	u.0u312	0-00359	0.00388	0.0401	0.60402	0.00394	0.00379	94 <u>600</u> .0	0.00335	U.CU2U3	0.00280	0.00251	0.00422	0.00193	G.0U165	0.00138	0.00LLL	0.00086	0.00062	0.00039	0.00018	-0*00002	-0.00021	-0.06038	-0.00055	-0.00070	-0.00084	-0.0U397	-0.00109	-0*100-0-	-0.00130	-6-00140	-0.0149	-0.00157	-0.00164	-0.06171	-0.00177
IIAt	2.00015	4.00030	0.0045	3.00061	10.90076	12-00041	14.00105	16.00121	18.0vi33	20.00L45	22.00157	24.60169	26.00182	28.00194	34.04206	32.00218	34.00230	36.00243	30.03255	40.00267	42.00279	44.00291	46.00304	43.00316	50.00325	52.00340	54.00352	56.00365	56.00377	00.00J29	10400-23	04.00414	00-00420	68.00438	70.00450	72.00462	74.00475	76-00437	78.00499	80.00511

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Section States

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VEL	7.78610 7.78640	7.78671	101 81.1	7.78731	7.78761	1.78791	7.78323	7.78350	7.78879
TAU	0.35033 0.93742	0.92419	0.91115	0.89830	0.88563	0.87314	0.36083	0.84868	<b>C-8</b> 3672
BETA	-0.47620 -0.46943	-0.40276	-0.45019	-0.44471	-0.44332	-0.43702	-0.43082	-0.42470	-0.41867
PSI	1.95763 0.94412	- 08Ccv.J	0-91757	0.90475	0.89197	0.87939	0.86693	0.85475	0.84279
1)- LTA	12200°0+ 22200°0+		-0.00219	-0.00213	-6.04217	-0.04215	-0.00214	-0°01313	-0-06212
ALPHA	-0*00005 -0*00005	-0.0000	-0.00011	-0.00014	-0.00015	-0,00017	-0.00019	-0.00021	-0+00622
Тне IA	-0+0423 -0+0422	-0.0421	-0.00219	-0.00218	-0.00217	-0.00216	-0.00215	-0.00213	-0.00212
T 1 ME	lož.01012 264.01024	166.01036	156.01048	1/0.01060	1.2.01073	1/4.01085	176.01097	176.01109	136-01122

CHADIFICH LOTRUN I -- IS ULGAFL HEADING CHANGE

INPUT HEADING= 15.00 TRIM PITCH ANGLE= 0.00

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GIMBAL AAFE= 3.00 UEG/SEC PITCH ERKUR GAIN= 1.00 YAM ERRDR GAIN= 1.00 YAM ERRDR GAIN= 1.00 YAM RATE WAIN= 1.00

UTFFERENTIAL TIME INCREMENT= 0.20 INTTAL VELUCITY= 7.78 THRUST= 122.70 . .

FIERS FUR UTNAMIC EQUALLUNS	+0+	+0+	+04	77	10																																			
BALLUN PARAM	XMASS= 0.2407500	YMASS= 0.4121102	ZMASS= 0.4121102	IYY= 0.2680u00E+	12Z= 0.2680000E+																																			
VEL	7.78039	7.78023	1.77309	7.77757	7.77565	7.77316	7.77001	7.76620	27131.1	7.75663	7.75058	7.74485	T.73429	7.73140	7.72422	T.71683	7.70929	7.70166	7.659397	7.68628	7.67862	7.67103	7.66355	7.65619	7.64.897	7.64192	7.63506	7.62839	7.62193	7.61568	7.60965	7.60385	7.59827	7.59293	7.58782	7.58294	7.57829	7.57387	7.56968	7.56571
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TAU	-5,99999	-11-99997	-14.75432	-14.57794	-14-39306	-14-20571	-14.01815	13.83129	-13.64548	-13.46091	-13.27769	-13.09590	-12.91562	-12,73691	-12.55981	-12.38440	-12.21072	-12.03680	-11.86869	-11.70042	-11-53402	-11.36952	-11.20695	-11.04631	-10.88761	-10.73086	-10.57608	-10.42325	-10.27239	-10.12348	-9.97653	-9.83153	-9.68846	-9.54732	-9.40811	-9.27079	-9.13537	-9.00182	-8.87013	-8.74028
BETA	0.00533	0.14480	0.5128G	1.05834	1.62624	2.15353	2.62304	3.03471	3.30479	3.69687	3.96054	4.18591	4.37757	4* 53954	4.67537	4.78816	4.84062	4.55515	5.01383	5.05853	5.09085	5.11224	5.12398	5.12716	5.12280	5.11177	5.09485	5.07273	5.04604	5.01532	4.98106	4.94370	4.90362	4.86119	4.81670	4.77044	4.72266	4.67357	4°62338	4.57227
P S I	0.00757	U.05339	21221-0	0.33507	0.51434	0.70076	0.66813	1.07530	1.20162	1,44631	1.63070	1.81320	1.99423	2.17373	2.35163	2.52789	2.70244	2.87524	3.04525	3.21544	3.34277	3.54822	3.71175	3.67336	4.03303	4.19375	4 • 34651	4.50032	4.65216	4 *8U205	86676*7	5.04596	5.23999	5.38209	5.5227	5.66054	19691.5	5.93139	6.06401	6.1947B
UELTA	-0-(~020	-0.00021	0.00035	0.00120	0.11222	0.00344	0.00492	0.00663	0.00469	0.01097	1.01334	+8CT0*0	0-01840	0-02095	0*12345	0.02584	0.02809	0.03018	0.03206	0.03375	0.03521	0.03645	U.03746	0.03325	0.03893	0.03920	0.04937	0.03936	0.03918	0,05384	0.03836	0.03774	10160.0	0.03618	0.03526	65460-0	0.03318	0.03205	0, 03088	0.02967
AL PHA	0.0042	6.00095	-0.00022	-6.00327	-0-00696	-0.01104	-0.01564	-0.02036	-0.02063	-0.03279	-0.03908	-0.04525	-0.0104	-0.05624	-0.06068	-0.06423	-0.06683	-0°06843	-0.06905	-0.06870	-0.06746	-0,00540	-0.06260	-0.05916	-0.05517	-0.05074	-0.04596	-0.04093	-0.03572	-0.03041	-0,02509	-0.01980	-0.01461	-0.00456	-0.00469	-0.00004	0.00437	0.00853	0-01241	0.01601
THE LA	-0.00011	-0.00022	10000-0	U.00078	0.06171	0.00283	0.00418	0.00000	0.00/68	0.06961	u.01213	0.01458	0.01712	0.01968	u.02220	U.U2465	6.02697	0.02914	0.03112	16260.0	0.03448	U.03583	0.03695	0.03786	0.03854	0.03401	U.03429	0.03937	0.03427	0.03901	0.03660	U.03a05	u.03738	0.03660	0.03572	<b>0.03</b> +75	0.03372	0.03262	0.03146	72020.0
TIME	2.00015	4.00030	6+000-0	8.0006I	10.00076	12.00031	14.00106	16.00121	18-60133	20.00145	22.60157	24.00169	20.0182	23,00194	30-00206	32.00218	34+00230	36+00243	Jo.00255	+6.00267	42.00279	16200.444	40-00304	45.0U315	50.00J28	>2.00340	24.00352	30.00365	24.0U377	64E00.04	62.0U401	64.GU414	66.0u426	60-00438	70.00450	72.00462	74-00475	16.00487	78-20499	80.00511

D-12

VEL	1.56195	7.55442	7.55513	7.55199	7.54907	7.54636	7.54384	7.54151	7.53936	7.53739	7.53559	7.53396	7.53249	7.53117	7.53001	7.52900	7.52813	7.52740	7.52680	7.52633	7.52598	7.52575	7.52564	7.52563	7.52574	7.52594	7.52624	7.52664	7.52712	1.52769	7.52835	7.52908	7.52989	7.53078	7.53173	7.53275	7.53383	7,53497	7.53617	7.23140
TAU	-8.61227	-8.48606	-8.36164	-8.23900	-8-11810	-1+99895	-7.88150	-7.76574	-7-65167	-7.53925	-7.42847	-7.31929	-7.21172	-7.10571	-7.00126	-6.89834	-6.79694	-6.69702	-6.59858	-6.50158	-6.40603	-6.31198	-6.21913	-6.12775	-6.03772	-5.94903	-5.86166	-5.77559	-5.69079	-5.60725	-5.52496	-5.44389	-5.36404	-5.28537	-5.20787	-5.13152	-5-05632	-4.98224	-4.90926	-4.83730
BETA	4.52040	4.40790	4.41493	4.35L58	4.30796	4.25417	4.20028	4.14636	15260**	4.03878	3.98521	3.93185	3.87875	3.82594	3.77346	3.72135	3.66963	3.61832	3.56744	3.51703	3.46708	3-41762	3.36867	3.32071	3.27228	3.22488	3.17802	3.13169	3.08591	3.04068	2.99602	2.95190	2.90834	2.86532	2.82287	2.78096	2.73962	2.69882	2.65857	2.61830
154	6.32371	56044-0	6.57613	b.69366	6.82143	6.94146	7.05976	7.17637	1.29128	1.40452	7.51612	7.62610	7.73447	7.84127	7.94650	8.05019	8.15235	8.25301	<b>8.35219</b>	8.44.330	8.54618	8-64103	6.73448	8.82655	8.91725	9.00651	9-03464	9.18136	9.26680	9.35097	9.43348	9.51555	9-59602	9.67528	75 Ec7. 9	9.83029	90906"6	9.98071	10.05424	10.12657
DFLfA	U.U7443	0.02716	0.02589	U.02460	0.02332	0.02203	0+02075	0.01949	0.01824	0.01761	0.01579	0.01460	0.01343	0.01229	0.01113	0.01009	0.00904	0.00801	0.00701	0*00604	01500.0	0.00419	0.00332	0.00247	0.30165	0.000H6	60000-0	-0.20064	-0.00135	-0.00203	-0.00268	-0.00331	-0*00391	-0.449	-0.00504	-0.00557	-0.00.08	-0.00656	-0-00.703	-0.00747
VH4TV	0°01333	0.02235	0.02510	0.02756	0.02976	0.03169	16620-0	0.03481	0.03603	C. 03703	0.03784	0.03845	0.03890	0.03919	7.03933	0.03934	0.03923	106£0.0	0.03870	0.03829	6.03781	0.03726	0.03665	0.03598	0.03528	0.03453	0.03375	0.03295	C.03213	0.03129	0.03044	C.02958	0.0287E	0.02785	0.02698	0.02612	0.02527	0.02442	0.02358	0.02275
ThelA	02905	0.02179	0.02652	0.02524	0.02390	0.02267	0.02139	0.02012	0.01866	0.01762	0.01640	0.01>20	0.61402	0.01286	01174	0.01064	0.00557	0.00852	0.00751	0.00653	0.00557	0.00465	0.00376	0.00289	0-00206	0.00125	0-00048	-0.00027	-0.00099	-0.00169	-0.00235	-0.00299	-0.00361	-0.00420	-0.00476	-0.00531	-0.00582	-0.00632	-0.00679	-0.00725
1146	£560.24	64.00536	84400.08	<b>84.00560</b>	90.00572	92.00584	194.00.49	90.00609	98.00621	100.00533	102.00645	104.00658	100.03670	108.00682	110.00094	112.00706	114.00719	116.00731	116.00743	120.00755	124.00768	124.00780	L20=00792	124.00804	130.00616	132.00629	134.00841	136.00853	134.00865	140.03877	142.00890	144.00902	146.00914	146.00926	150.0038	152.00951	124.00363	156.00975	158.00987	160.00999
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VEL	7.53873	7.54008	7.54148	7.54293	7.54442	7.54595	7.54751	7.54912	7.55075	7.55242
TAU	-4.76655	-4.69678	-4.62806	-4.56036	-4.49367	-4.42798	-4.36326	-4.29951	-4-23671	-4.17485
<b>BETA</b>	2.57970	2.54108	2.50300	2.46544	2.42843	2.39193	2.35595	2.32049	2.28554	2.25109
ISd	10.19303	10.25332	10.33756 IU	10.40579	10.47237	10.53916	10.60+36	10.66860	10.73187	10.79420
DELTA	-0.07 <i>8</i> 9	-0.00829	-0.0056R	-0-00404	-0.00339	-0.00972	-0*01003	-0.01033	-0.01061	-0.01087
ALPHA	0,02194	6.02114	0.0.35	0.01958	0.01883	0.01609	0.01736	0.01666	0.01597	0.510.0
THETA	-0.00768	-0.00609	-0.00249	-0.00686	-0.00922	-0.00955	-0.00988	-0.01018	-0.01047	-0.01074
TIMÉ .	162.01012	164.01024	166.01036	165.01048	170.01060	172.01073	174-01085	176.01697	178-01109	180.01122

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