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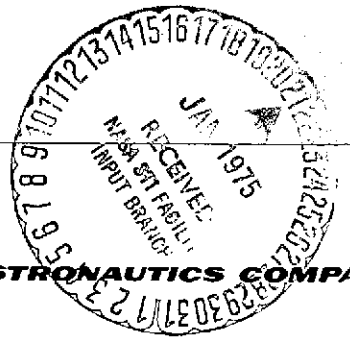
GENERALIZED ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEM COMPUTER PROGRAM (G189A) CONFIGURATION CONTROL

PHASE II FINAL REPORT
Contract NAS9-13404



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3 DECEMBER 1974

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FOREWORD

The work described in this report was performed by the Biotechnology and Space Sciences Department of the Engineering Division, McDonnell Douglas Astronautics Company - Western Division, Huntington Beach, California. J. R. Jaax, Crew Systems Division, National Aeronautics and Space Administration, Johnson Space Center (JSC) was the contract technical monitor. S. W. Nicol was the project manager for McDonnell Douglas. R. L. Blakely was responsible for performing the G189A computer program configuration control effort and major assistance was provided by R. E. McEnulty.

SUMMARY

This final report documents the work performed during Phase II of contract NAS9-13404, Generalized Environmental Control and Life Support System Computer Program (G189A) Configuration Control. Phase II of the contract covers the period from 1 November 1973 to 31 October 1974. During this period the following items of significance were accomplished.

1. The G189A simulation of the Shuttle Orbiter ECLSS was upgraded in the following areas:

   a. The G189A component configuration was changed to represent the current Orbiter 102 configuration. (The DFI equipment, present on 101, was not simulated.)

   b. The two gas controller characteristics were modelled for the Orbiter and the payload crew compartments and the logic required to equalize pressure differences, which can exist at the time of hatch opening, was developed.

   c. The data required to do a transient Shuttle Orbiter and payload crew compartment simulations were incorporated.

   d. Two interface subroutines; ELØAD and QLØAD, which allow transient electrical power profile data generated by the Mission Planning and Analysis Division (MPAD) Spacecraft Electrical Power Simulator (SEPS) program, Reference 1, to be automatically read and entered into the G189A Shuttle ECLSS simulation as heat load data, were developed and made operational.

   e. Three diagrammatic printout subroutines, which utilize the computer printer to print loop schematics of the Shuttle ECLSS overlaid with computed system performance data such as component flow rates, heat load temperatures, gas pressures, etc., were developed and utilized for efficient presentation of analysis results.

The current status of the G189A Shuttle Orbiter ECLSS simulation was documented and is included as Attachment No. 1 of this report. The status report provides a detailed discussion of the various models and their assumptions and presents the latest study results obtained from these models.

2. Four master program libraries of the G189A computer program were prepared and are being maintained for the NASA/GSE computer system. An Exec 8 and Exec II version of the G189A standard program library are available on tape. Two separate versions of the G189A program library, modified with logic and routines applicable only to Shuttle Orbiter ECLSS simulations, are maintained on tape for use on the Exec II system.

3. Several new subroutines were added to the G189A program library and several existing subroutines were modified to improve their capabilities. (Addendum No. 2 to the G189A Program Manual will be published separately. This addendum provides the documentation changes required to update existing G189A Program Manuals, Reference 2.)

4. A number of special analyses were performed in support of Shuttle ECLSS performance studies, configuration modification studies and payload support capability and interaction studies.

1.0 INTRODUCTION

The G189 Generalized Environmental Control and Life Support System Computer Program was initially conceived and developed by MDAC in 1964. It was initially delivered to NASA/JSC in 1965 under contract NAS9-4090. Since this time a number of program revisions and developments have occurred as a result of work performed in-house and in conjunction with other NASA contracts. The Crew Systems Division, CSD, of NASA/JSC has been instrumental in the development of this program into a valuable ECLSS simulation tool. This contract, NAS9-13404 - Generalized Environmental Control and Life Support System Computer Program (G189A) Configuration Control, provides a method for updating and maintaining the G189A program library and documentation for all program users. The effort also involves (1) providing instruction and recommendations for the use and application of the program, (2) developing new subroutines and logic required for new simulations, (3) supporting special analyses required by CSD, and (4) conduct studies to define and understand the interaction of the Shuttle ECLSS and proposed payload ECLSS and ECS designs. The following section describes in detail the progress made under the various tasks described in contract NAS9-13404 for the Phase II portion of the contract.

2.0 REPORT OF PHASE II PROGRESS

The Phase II progress on tasks 1-11 as described in contract NAS9-13404 is reported below.

2.1 Task 1, Formulate Master Programs

Four unique master program libraries of the G189A computer program were prepared and maintained for the NASA/JSC computer system during Phase II of this contract. An Exec 8 library tape of the standard G189A program (library for general simulation use) was prepared in January 1974 for use on the UNIVAC 1110 computer. (This library has not been updated recently because the Exec II system has provided more efficient turnaround.) An updated version of the standard G189A program library tape and two special Shuttle ECLSS simulation program library tapes were prepared for

use on the UNIVAC 1108 Exec II system computer. These library tapes and other G189 tapes available at NASA/JSC are described in more detail in Section 2.2.

2.2 Task 2, Maintain Library

The following tapes are being maintained at NASA/JSC for the G189/G189A program and simulation library.

Description	Tape No.	Reserved by	Version Date	Operating System
1. G189A Subroutine Library Tapes - Standard Version (Provided for general simulation usage):				
a. EXEC II Tapes	V04848 & V15190	McEnulty/MDAC	9/74	EXEC II
b. EXEC 8 Tape	X01421	Blakely/MDAC	1/74	EXEC 8
2. Shuttle Orbiter ECLSS Simulation:				
a. G189A Subroutine Library Tapes - Special Versions:				
Mission Phase Analysis via Card Input of Component Heat Load Data - Shuttle/Space-lab Two Gas Controller Interactions with Hatch Open/Close Logic	V13433 & V16714	McEnulty/MDAC	9/74	EXEC II
Transient Mission Analysis via Interface with MPAD Spacecraft Electrical Power Simulator (SEPS) Program to Provide Transient Electrical Heat Dissipations - Shuttle/Payload Two Gas Controller Simulation	V13930	Blakely/MDAC	11/74	EXEC II

Description	Tape No.	Reserved by	Version Date	Operating System
b. Basic Case Data - Shuttle Reference Mission 2, OV102	V07545 & V11806	McEnulty/MDAC	9/74	EXEC II
3. SSP Water Waste Management System Simulation:				
a. G189A Subroutine Library	V07003	Ayotte/HSD	10/72	EXEC II
b. Basic Case Data	V07024	Ayotte/HSD	10/72	EXEC II
4. SSP 12 Man Simulation with Molecular Sieve				
a. G189 Subroutine Library (old program)	V07006	Ayotte/HSD	7/71	EXEC II
b. Restart Data	V07012	Ayotte/HSD	7/71	EXEC II
5. Apollo Block II Command Module ECS Simulation				
a. G189 Subroutine Library (old program)	E02663	Cox/LEC	9/69	EXEC II
b. Basic Case Data - Earth Orbit	E02695	Cox/LEC	9/69	EXEC II

2.3 Task 3, Provide Recommendations

Contact has been maintained between active G189A program users at NASA/JSC, NASA/MSFC, and MDAC-W to provide recommendations regarding use of master program library tapes, program subroutine modifications, and routine peculiarities or limitations.

2.4 Task 4, Provide Instruction

Contact has been maintained between active G189A users at NASA/JSC, NASA/MSFC, and MDAC-W to provide briefings on new options and subroutines being developed and to aid in debugging program errors.

2.5 Task 5, Provide Program Modifications

Several component subroutines and general program modifications have been made and several new subroutines have been prepared for use with the Shuttle ECLSS simulation during Phase II of this contract. Details on these changes are documented in Addendum No. 2 to the G189A Program Manual and will be published separately. The major subroutine and program changes are outlined below in Section 2.5.1 and 2.5.2.

2.5.1 G189A Subroutine Library - Standard Version

General Program Modifications:

1. An option was added which allows a single variable flag, KSTEDY, to be used to force steady state solutions to be performed for all components during a transient run. (This option can be used to speed psuedo-steady state convergence of a system simulation during transient runs for various portions of a simulated mission.)

2. The universal print flag, KCHOUT, was modified to allow two additional printout options: (1) A printout of the A, B, and R arrays for each component only after component solution and (2) a printout of each component's V array data as it was stored after the component's solution.

3. The utility subroutine, ESTIM, was modified to use a new independent variable value of $X_1 = 0.1$ if the old independent variable was $X_1' = 0.0$ and a parallel line condition (non-converging functions) or the initial use of the subroutine occurred. (The original coding set $X_1 = 1.05\ X_1'$ under those conditions.)

Component Subroutine Modifications:

CMAN - Modified to store each crewman's heat storage rate, heat generated by shivering, and metabolic rate in the component's V array data. An option was also provided to allow each crewman's metabolic rate to be specified directly by V array data input if so desired.

FAN - Modified to allow a constant volume flow in cubic feet/minute and an associated heat dissipation in watts to be specified in the component's V array data. (The original coding allowed only constant mass flow as an option.)

PUMP - (Identical to FAN modifications.)

New Subroutines:

HAFCEE - A utility subroutine to be used as a re-estimator during iterating calculations. HAFCEE is used to estimate the convergence point of two functions which have a common independent variable with specific predefined upper and lower limits. This routine can serve as an alternate to subroutine ESTIM under the above conditions.

2.5.2 G189A Subroutine Library - Shuttle Orbiter ECLSS Version

The general program and component subroutine modifications discussed in Section 2.5.1 were also incorporated in the Shuttle Orbiter ECLSS Version of the G189A Subroutine Library. New subroutines developed specifically for the Shuttle simulations are discussed below. GPØLY1 and GPØLY2 logic for particular Shuttle cases are discussed in the Status Report, Attachment No. 1.

New Subroutines:

ARSGAS - A special purpose subroutine which utilizes the UNIVAC 1108 high speed printer to produce a schematic representation of the Shuttle Atmospheric Revitalization System (ARS) gas loop components included in the current G189A simulation. The components are labelled with their proper name and number and overlaid with the simulation computed results (temperatures, flow, heat fluxes, pressures, etc.) to provide an efficient and simple presentation of the data. (Examples of the printed schematics are contained in the Status Report, Attachment No. 1.)

ARSH2O - A special purpose subroutine similar to ARSGAS except that it produces a schematic representation of the Shuttle ARS water loop components.

FCL - A special purpose subroutine similar to ARSGAS except that it produces schematic representation of the Freon Coolant Loop (FCL) components.

ELØAD - A special purpose subroutine which reads and stores transient electrical load profile data tape produced by the Mission Planning and Analysis Division's (MPAD) Spacecraft Electrical Power Simulator (SEPS) program, Reference 1. The electrical load data are converted to heat loads by ELØAD and stored in an equipment load table whereby a particular location in the table corresponds to a particular Electrical Equipment List (EEL) number as grouping. The subroutine also uses the next SEPS tape data set time point so that the G189A program may modify its time step to provide the proper computational time period between electrical load updates.

QLØAD - A special purpose subroutine which sums the proper groupings of electrical heat loads, stored by ELØAD, and inputs these data into the current G189A Shuttle ECLSS simulation components.

R718 - A utility subroutine which determines the fluid properties of water at a specified temperature or the integrated values over a specified temperature range. The equations used are applicable in the 32° - 260°F temperature range and are based on data published by ASHRAE in 1973.

The Freon fluid properties subroutine, F21, developed under Phase I of the contract was upgraded during Phase II so that the calculated values produced would be in agreement with the data currently being used for Shuttle radiator analyses.

2.6 Task 6 - Establish System Schematic Configurations on Master Programs

The current G189A Shuttle Orbiter ECLSS simulation basic case data are maintained on-tape as described in Section 2.2. These basic case data stored on tape are modified via card input for each of the three analyses discussed in the Status Report, Attachment No. 1. The three G189A analyses described in the Status Report are: (1) a simulated transient run using steady state mission phase heat load data obtained from RI in April 1974 for Reference Mission 2, Payload B, (2) a transient run used to checkout the two gas control and hatch opening logic for the integration of Shuttle and Spacelab, and (3) a series of transient runs for Reference Mission 2, option 1 covering mission phases 1-7, 8-12, and 15-20 utilizing electrical load power profile data generated by the MPAD SEPS program. The G189A component schematic representative of the Shuttle Orbiter ECLSS together with listings of the simulation input data and GPOLY logic, microfilm (SD 4060) plots of the computed transient data, and loop schematic printouts of the computed results, are included in Attachment No. 1.

2.7 Task 7, Support Special Analyses

A number of special analyses were performed during Phase II of this contract. A summary list of these analyses and their associated documentation is provided below:

1. Feasibility of integrating the Shuttle APU water boilers and the ECLSS water evaporative heat sink device functions, Reference 3.

2. Preparation of performance and weight penalty data associated with Orbiter ECLSS support of Shuttle Payloads, Reference 4.

3. Weight tradeoff study - water storage versus radiator panels for short duration Shuttle missions (0-8 hrs), Reference 5.

4. Cabin and water loop equipment temperatures resulting from a single Freon loop operation abort case when water loop sublimators are eliminated, Reference 6.

5. Feasibility study for reconfiguration of the Shuttle ECLSS to provide water loop cooling for the majority of the liquid cooled equipment, Reference 7.

6. Study of Shuttle radiator cavity effects upon the effective solar absorptivity and infrared emissivity of the cavity panel thermal control surfaces, References 8 and 9.

7. Study of Shuttle cabin oxygen enrichment due to the use of the open loop diluter/demand regulator oxygen system proposed for OV101, Reference 10.

2.8 Task 8 - Maintain Status Reports

The first issue of the G189A Shuttle Orbiter ECLSS Simulation Status Report, Reference 11, was published in June 1974. This report will be updated periodically. Attachment No. 1 of this final report contains the second issue of the status report which documents the capabilities and assumptions incorporated in the current G189A Shuttle Orbiter Simulation model and discusses the analyses performed using the model.

The status report and the monthly activity reports, Section 2.9, were transmitted to the following list of interested G189A program users located at key locations with whom liaison has been maintained.

1. Bob Balinkas 203/623-8012
   Mail Stop 1A-2-6
   Hamilton Standard
   Windsor Locks, Connecticut 06096

2. Buford Beadle 205/532-1623
   Mail Stop 190
   Teledyne-Brown Engr.
   Research Park
   Huntsville, Alabama 35812

3. Dr. D. E. Cagliostro 415/965-6190
   NASA/Ames Research Center
   Moffett Field, California 94035

4. Sam Clonts 205/453-3828
Mail Stop EP45
NASA/MSFC
Huntsville, Alabama 35812

5. John Jackson 714/896-2910
A3-250-AJCO-M.S. 13/3
MDAC-West
Huntington Beach, California 92646

6. Ben Fulbright 713/483-5181
Bldg. 13, Mail Code EZ
NASA/JSC
Houston, Texas 77058

7. Sutton L. Graham 713/488-5660
Beta Building
MDTSCO-Houston
16915 El Camino Real
Houston, Texas 77058

8. Jim Jaax 713/483-4941
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NASA-JSC
Houston, Texas 77058

9. Stu Nicol 714/896-2310
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Houston, Texas 77058

11. Marion Peeples 314/232-7862
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Level 3, M.S. 68
MDAC-East
Box 516
St. Louis, Missouri 63166

12. Woodrow Ryan 205/453-2350
Computer Sciences
8300 Whitesburg Dr.
Huntsville, Alabama 35812

13. Wylie Ward 205/532-1623
Mail Stop 190
Teledyne - Brown Engineering
Research Park
Huntsville, Alabama 35812

2.9 Task 9 - Provide Monthly Activity Report

Monthly activity reports containing information on revised program library tapes, new program features and options, new data tapes, computer operations problems, and monthly progress on contract task items were prepared and distributed to all interested G189A program users, Section 2.8 list.

2.10 Task 10 - Additional Provisions

G189A program library tapes were made available to D. J. Russell, Boeing Aerospace Company for use in support of the Crew Appliance Study, contract NAS9-13965.

2.11 Task 11 - Analytical Studies

A Spacelab two gas control and hatch opening simulation together with a payload crew compartment and payload interface heat exchanger have been incorporated into the G189A Shuttle Orbiter ECLSS simulation and utilized to perform several analyses which are documented in the G189A Status Report, Attachment No. 1.

3.0 CONCLUSIONS

The G189A program configuration control concept has proven to be effective in organizing and controlling the use and modification of the program and its simulations. Interested users have been identified and communications between these personnel have been established. This effort has resulted in the orderly development of the program and provides a central focal point for determining program inadequacies and errors, providing consultation and problem solutions, and distributing new updated versions of the program library.

The G189A Shuttle Orbiter ECLSS simulation prepared during Phase I of this contract has been continuously modified and upgraded throughout Phase II. Its current configuration, capabilities, and analyses results are described in detail in the G189A Status Report included as Attachment No. 1 to this final report.

The G189A Shuttle ECLSS simulation has been utilized for both steady state and transient analyses during this report period. The modelling within the simulation is consistent with the current state of development for the orbiter ECLSS. The simulation represents the active freon, water, and gas loops and is capable of performing consumable analysis calculations for potable water, ammonia, oxygen, nitrogen, and hydrogen. Transient electrical heat dissipations are automatically extracted from Reference Mission electrical power timeline data tapes prepared by the Mission Planning and Analysis Division. Transient cabin and gas constituent analyses are performed. The heat exchangers, coldplates, and heat sink devices currently use steady state solution techniques, however, these components can be easily transformed into transient models when final design configurations become fixed. (Estimates of the various Shuttle heat exchanger dynamic responses, Reference 12, indicate that steady state solutions are adequate for these components.) Transport lag or pressure drop analyses are not included presently, however, this information is becoming available and will be added in the future.

The G189A Shuttle Orbiter ECLSS simulation provides a basic model which can be easily upgraded as hardware development and testing proved and/or modified to perform special studies. The steady state and transient mission phase analyses have provided valuable system performance data to CSD subsystem managers during the past report period and additional Reference Mission analyses are planned for the future.

REFERENCES

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4. Orbiter ECLSS Support of Shuttle Payloads, J. R. Jaax, et. al., ASME Paper 74-ENAs-22, July 1974.

5. Tradeoff Study Water Storage versus Radiator Panel Weight for Short Duration Missions (0-8 hr), informal data transmitted, R. L. Blakely to D. W. Morris, April, 1974.

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9. Shuttle Radiator Cavity Effects Study, R. L. Blakely, MDAC Memo 74-MDAC-W-2, (to be published).

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12. Estimation of Dynamic Response of Heat Exchangers, M. R. Ruemont, R. I. Internal Letter SEH-ITA-74-154, 23 October 1974.