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Exotech Systems, Inc.

October 15, 1972

National Aeronautics and Space Administration
Headquarters
Planetary Quarantine Office
Washington, D. C. 20546

Attention: Lawrence B. Hall Code SL

Subject: Second Quarterly Progress Report, Contract NASw-2372, Scientific and Technical Services for Development of Planetary Quarantine Measures for Automated Spacecraft.

Gentlemen:

This letter constitutes the second quarterly progress report summarizing work for the period July 1 through September 30, 1972, on the contract cited above.

Emphasis during this reporting period was placed on the following activities:

- PQ requirements analyses relating to SSB and LSC meetings and reports
- Preparation of material for the Spacecraft Sterilization Technology Seminar, San Francisco, July 18–19, 1972, and
- Activities related to the review of the PQ Plans for Viking '75.

I PROGRESS AND STATUS

Progress on all thirteen (13) tasks of the contract is summarized in terms of factual data, status and progress. A separate analysis section provides an interpretation of results and recommendations for further action.

Task 1 Evaluation of the Impact of Changes in Planetary Quarantine Requirements

The Planetary Quarantine Officer, with the assistance of the AIBS PQ group (formerly called PQAP) and the SSB, as requested, continuously reviews and reassesses quarantine requirements and constraints imposed upon space flight projects. Under this task, evaluations are conducted to support the justification and establishment of these requirements and to estimate their implications upon flight projects.

Work performed during this reporting period related principally to the continuing review by members of the Space Science Board of PQ constraints imposed upon flight projects. In addition to values for the probability of microbial growth for Mars and Jupiter, other specifications, such as dry heat sterilization characteristics, have been reviewed as has the basic PQ approach which requires compliance with firmly-established standards.

We have compiled pertinent data to assist the PQO in requesting and evaluating these reviews. Specifically, we have assessed the feasibility of the SSB committee's proposed "intermediate approach," an attempt to eliminate the need for a dry heat terminal sterilization cycle for Viking (see PQ-405). Supporting data will be provided to the PQO in November for discussion with members of the SSB.

The possible impact of PQ constraints upon payload reliability remains of concern to the SSB, the LSC and the AIBS PQ group. Clarification of the relationships between quality assurance standards, hardware costs and PQ constraints has been requested regarding spaceflight programs such as Viking.

A more detailed assessment of the "intermediate approach" will be delivered during the next quarter. In addition, we will summarize and assess the current plans of the Viking '75 project for terminal heat decontamination.

Task 2 - Maintain and Operate the Planetary Quarantine Document System

The Quarantine Document System (QDS) is an indexed file of material pertinent to the review of flight project quarantine plans and operations. This task covers the operation, maintenance and updating of the system.

The collection experienced continued growth and use. During the reporting period, 40 documents were added to the collection bringing the total to 440.

Utilization of the QDS has increased significantly in supporting evaluations and analyses performed both by Exotech and the PQO's staff. Use by other groups has been nil; however, requests for information are expected as the existence of the system becomes more generally known.

A need for greater indexing detail for the vastly increased size of the QDS was accommodated by re-indexing the entire collection using an expanded keyword listing. This task was completed during the reporting period.

Under this task, there is continuing effort to acquire pertinent documents and other source materials to develop and maintain adequate information, both historical and current, on PQ-related activities of the various government agencies and contractors.

Task 3 Microbial Contamination Logs

COSPAR has asked each launching nation to supply it with information on all planetary missions that will permit the maintenance of a contamination log. The microbial contamination log fulfills this requirement and is submitted to the PQO for presentation to the COSPAR PQ Panel at its annual meetings. This task covers the maintenance of logs for actively-studied planets of biological interest and the timely submission to the PQO of pertinent contamination data.

The status of planetary contamination logs is as follows:

Mars	Revision	December 31, 1971
Venus	Revision	December 31, 1971
Jupiter	Original Version	June 30, 1972

In-flight data on Pioneer 10 and operational data from Mariner 9 is being compiled for future updating of the Jupiter and Mars logs.

Task 4 Maintenance of Allocation Bank

The United States and the Union of Soviet Socialist Republics plus other launching nations have each been allotted a portion of the total probability of contamination of each planet of our solar system based on an estimate of the total number of missions to be flown by each nation. From these data, the Planetary Quarantine Officer makes pre-launch allocations of the probability of contamination allotted to each launched spacecraft. Following the space flight, unexpended portions of the allocation to any mission event that is completed successfully may be recaptured and redistributed by the Planetary Quarantine Officer to follow-on missions.

To assist the Planetary Quarantine Officer in making the most liberal allocation consistent with COSPAR policy to each United States mission, Exotech maintains relevant data for all US flights launched to date.

A summary of the current status of the allocation banks for Mars, Venus and Jupiter is as follows:

	Total US Allocation	Expended to Date	Allocated to On-Going Missions	Apportioned Against Balance of Projected Missions
Venus	50×10^{-5} *	0.001×10^{-5}	14×10^{-5}	36×10^{-5}
Mars	44×10^{-5}	1.6×10^{-5}	20×10^{-5}	22×10^{-5}
Jupiter	50×10^{-5} *	0.00002×10^{-5}	6.4×10^{-5}	44×10^{-5}

*In absence of official estimates, we have arbitrarily assigned 50% of total COSPAR upper bound of 1×10^{-3}.

The above table reflects the recent allocation increase to Viking '75 (PQ-439).

The Allocation Bank is a part of the PQ Status Board which will be completed during the next reporting period.

Task 5 Creation and Maintenance of List of Approved Parameters

Uniformity of policy and document review can be facilitated by a listing of parameters employed by flight projects in validating compliance with PQ requirements. This task covers the preparation of such a listing with definitions and approved numerical values or ranges.

Two categories of parameters have been identified and are recommended to be monitored under this task. These are:

(1) PQO issued parameters (includes those specified by the PQO, such as D values, P(r), etc., as well as those determined or recommended by others and submitted to the PQO for issuance to flight projects).

(2) PQO approved parameters (includes parameters described and enumerated by flight projects and submitted in project plans for PQO approval. Examples include: P(uv) for Project X, P(I) for Project Y, etc.).

A listing of candidate parameters in both categories was presented in the last quarterly report. These were further evaluated during this reporting period. Twenty-two (22) parameters of the 1st category were documented and submitted to the PQO as PQ-439. Supporting technical material was attached to facilitate the review of these data.

The second category will be similarly treated during the next reporting period. The data will be arranged to facilitate comparisons between flight projects.

Task 6 Preparation of Technical Information Memo

The Planetary Quarantine Technical Information Memo (TIM) is a brief, informal newsletter containing summaries of research results of note, meetings, significant travel plans, policy decisions, changes in personnel, initiation of new research tasks, and management deadlines. It is submitted to ninety-five (95) people involved in the PQ program.

Issues prepared during the reporting period and their lead articles were:

No.	Date	Article
2	June 19	COSPAR Meeting
3	July 12	Water Activity
4	August 2	Spacecraft Seminar
5	September 15	LSC Meeting

Future issues will cover standardized terminology, review of PQ specifications, trends in PQ and other topics of interest to those involved in the program.

Task 7 Evaluation of Flight Project Quarantine Plans

Implementation of PQ requirements by flight projects is effected through a set of plans and related documents by which PQ-related tasks are guided and controlled. The purpose of this task is to support the PQ Officer in his review and evaluation of these documents to ensure flight project compliance.

During the reporting period, support was provided in the continuing review of the terminal sterilization program planned for Viking '75. The approach proposed by Viking is the use of dry heat in terminal decontamination, with the oven temperature selected within the range of 100° C to 113° C based upon a pre-terminal assay of surface burden. The possible impact of recent heat inactivation tests was assessed and moisture control needed to achieve the specified microbial reduction was compared with existing requirements (NHB 8020.12). It was determined that compliance with the moisture specification of NHB 8020.12 would provide the stated kill rates (see figures 1 & 2).

We are summarizing the proposed Viking terminal decontamination program for presentation to members of the SSB.

A proposed schedule for the submission to the PQO of PQ documentation required of NHB 8020.12 was prepared and submitted to the PQO with a recommendation that its features be included in the forthcoming revision to NHB 8020.12.

The preliminary PQ Plan for Mariner Venus Mercury 1973 was reviewed. Comments are contained in PQ-452 and PQ-453.

Figure 1

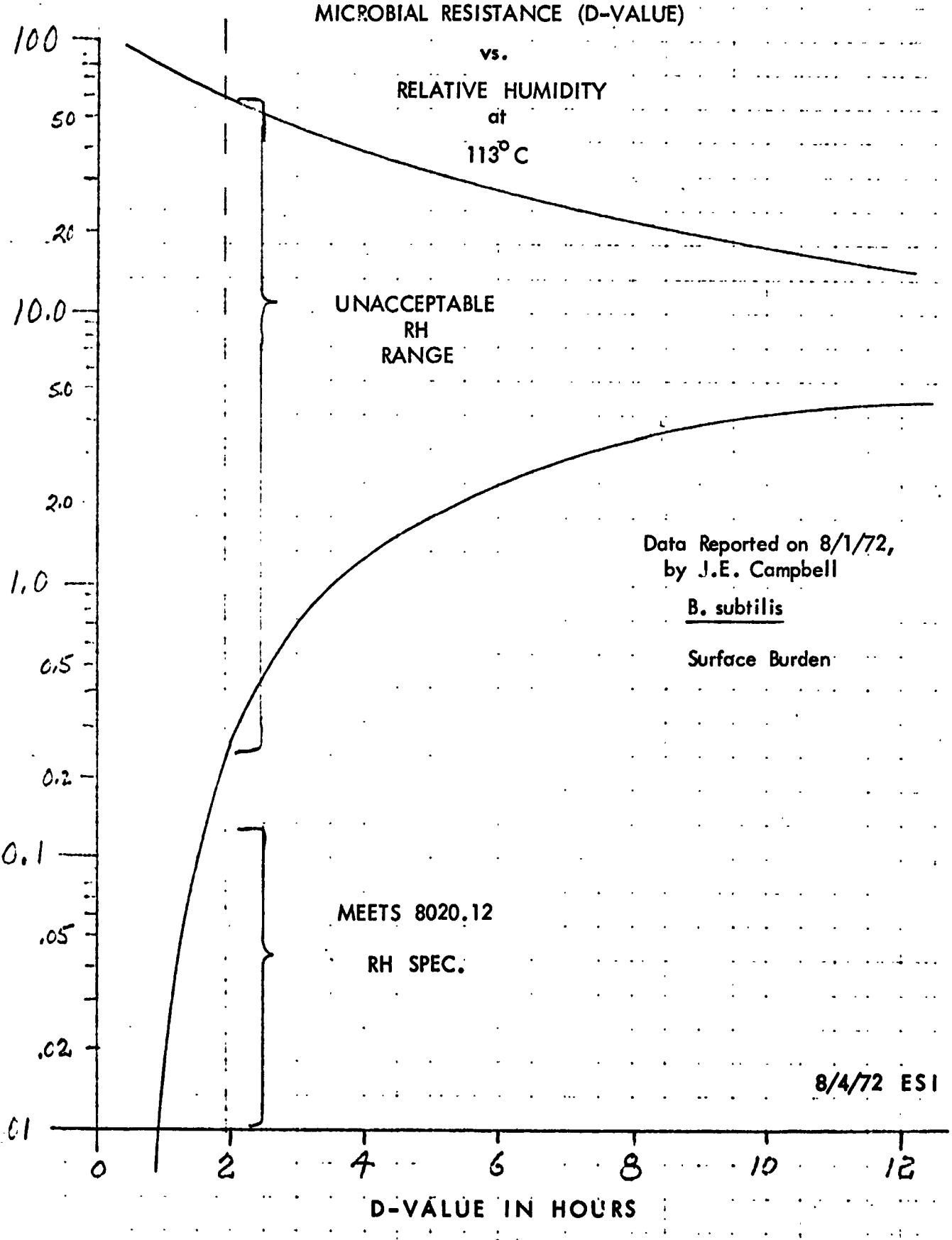
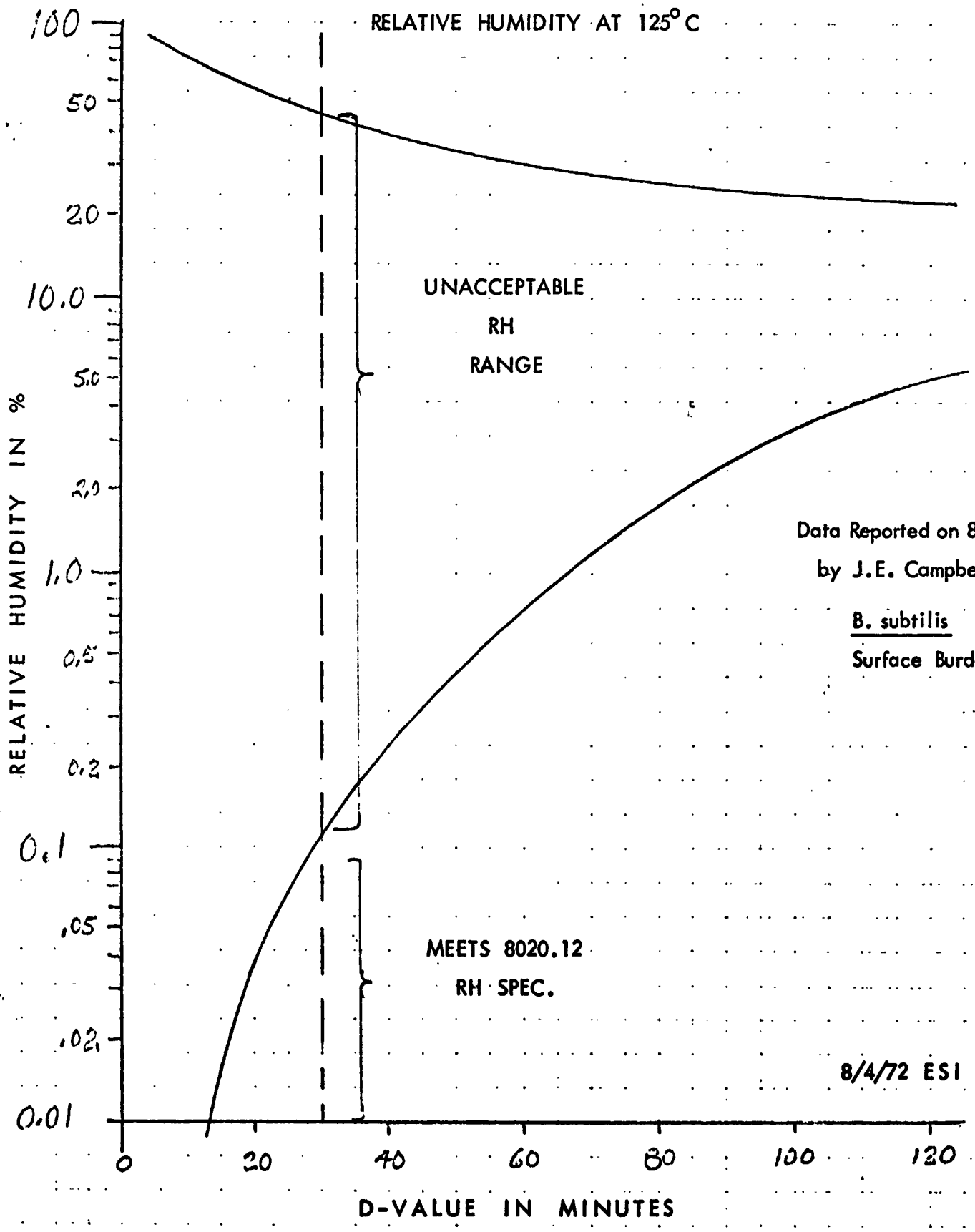

MICROBIAL RESISTANCE (D-VALUE)
vs.
RELATIVE HUMIDITY
at
113° C
100
50
20
10.0
5.0
2.0
1.0
0.5
0.2
0.1
.05
.02
.01
UNACCEPTABLE
RH
RANGE
MEETS 8020.12
RH SPEC.
Data Reported on 8/1/72,
by J.E. Campbell
B. subtilis
Surface Burden
8/4/72 ESI
0
2
4
6
8
10
12
D-VALUE IN HOURS

Figure 2

MICROBIAL RESISTANCE (D-VALUE)

vs.

RELATIVE HUMIDITY AT 125° C



Task 8 Supporting Analysis of Planetary Quarantine Sterilization Parameters

This task is directed toward the establishment of more definitive PQ parameters which can be utilized in flight project implementation of PQ requirements without undue conservatism. Parameters reviewed during the reporting period included:

D values
Z value
P(r) parameters
P(vt)

D and Z values were reviewed in the light of recent inactivation tests. Appendix A presents pertinent RH scaling data.

Values for release parameters are being reviewed with impact data from tests conducted at the White Sands Missile Range. This work is continuing.

Space survival data, including vacuum and temperature, was reviewed in the course of compilation of the material for Chapter IV of Foundations of Space Biology. The adequacy of the current value of 1.0 for P(vt) was verified.

The feasibility of expressing flight project allocations in terms of the number of viable terrestrial organisms (VTO's) was assessed (PQ-451) at the suggestion of Dr. Hall. It is recommended that this system be adopted for future missions. Further work will be performed on this approach and a sample analysis based upon the VTO concept will be submitted during the next reporting period.

Task 9 Preparation of Technical Presentations

This task relates to the preparation of written and graphic materials for publications, briefings and speeches on PQ subjects.

During the report period materials relating to the following presentations and documents were prepared and delivered:

- L.B. Hall, "A Decade of Development in Sterilization Technology by the United States Space Program," presented at the Industrial Sterilization Conference, Amsterdam, September 1972.

- S. Schalkowsky and I. Jacoby, "Safety Margins in the Implementation of Planetary Quarantine Requirements," AIBS, San Francisco, July 1972.

- L.B. Hall, Editor, "Planetary Quarantine Principles, Practices and Problems," Chapter IV, Foundations of Space Biology and Medicine.

A major effort during this reporting period was the preparation of Chapter IV of "Foundations of Space Biology and Medicine" to combine the U.S. and the English translation of the U.S.S.R. versions with rough drafts of material by U.S. authors on new topics not included in previous publications.

A review draft of the document was completed and submitted for comments. These comments are now being compiled, revisions are in process, illustrations are being completed and the bibliography is being revised to comply with specifications. The final manuscript is scheduled for completion by 1 November 1972.

Task 10 Technical Support at Meetings

Under this task, Exotech provides technical support for the PQO as may be required at meetings of the Life Sciences Committee, COSPAR, flight project planetary quarantine working groups, experimenters, and others.

Technical support provided by Exotech during this reporting period included meeting and pre-meeting consultation and discussions relating to the following meetings:

—	LaRC/Bionetics/USPHS/NASA Hdqs.	9/1/72
—	Life Sciences Committee	9/8/72
—	AIBS Sterilization Seminar	9/18–19/72
—	AIBS PQ Group	9/20–21/72

Task 11 Support of Technology Transfer

In addition to the elements of technology transfer support relating to tasks 9 and 10, the effort required herein involves serving as a source of PQ technology information upon referral of inquiries by the PQO and assisting in the development of the agenda for meetings of the PQ group.

During the reporting period there were no requests from outside the PQO and his staff for technology information. Assistance was provided, however, in the development of the agenda for the PQ group meetings scheduled for San Francisco July 20–21 and Atlanta, Oct. 5–6.

Task 12 Preparation of Planetary Quarantine Schedule

Contract Modification #1 dated October 2, 1972 requested that PQ schedule information be supplied as part of the Technical Information Memo. Activity under this task will henceforth be reported as part of Task 6.

Task 13 Integrated Resumes of NASA Research

There was no activity under this task during this reporting period. Candidate topics for treatment during the remainder of the contract are discussed in the subsequent Analysis Section.

II ANALYSIS

This section provides the results of analyses and assessments conducted during the reporting period. It interpretes the results and discusses possible impacts of this work on the PQ program. The material is ordered in terms of the significance of the results and the need for management decision.

1. Activities of SSB

A reorganization of the SSB committee which, at NASA's request, reviews PQ matters is necessitating the compilation and presentation of material relating to the development and operations of the PQ Program. To the extent that these information requests of the SSB are intended to orient and familiarize new members with little prior PQ association, they serve a useful purpose and are to be encouraged. Unfortunately, the information exchange provides the opportunity to argue basic program philosophy and to bring up discarded issues long considered to have been resolved.

Such a situation is currently faced by the PQO, who anticipates the need to justify the basic program precept of the application of firm constraints (traceable to COSPAR recommendations or state of scientific knowledge) with mechanisms for implementation and verification of compliance measures. Background data including historical information is being assembled to support program decisions and operations. Uncertainty, which may exist in the enumeration of certain parameters, is not to be confused with lack of a definitive program rationale.

It is a fact, however, that increased knowledge of survival characteristics and of planetary environmental parameters has permitted and hopefully will continue to permit the relaxation in PQ constraints. The point has now been reached where options other than dry heat decontamination have become worthy

of consideration even for vehicles intended to reach planetary surfaces. This relaxation does not obviate the need for PQ, nor does it necessarily make the job easier. In some situations, for example, there now may exist several options for spacecraft treatment, each of which should be evaluated by the flight project in developing its PQ plan.

To facilitate this task, future PQ allocations can be stated in terms of VTO's (see PQ-451) and the capabilities and limitations of optional decontamination techniques should be further defined. Regarding the latter, we recommend that research be sponsored in laser decontamination and that state-of-technology reviews be considered of cleaning techniques using such agents as formaldehyde, hydrogen peroxide, and isopropyl alcohol. We are preparing specific recommendations along these lines for PQO consideration.

2. Viking Sterilization Cycle

We are defining the project-proposed approach for PQO review with members of the SSB. Our description will include an evaluation of the assumptions made and the uncertainties associated with selected parameter values. The feasibility of the approach will be assessed and any shortcomings identified. Worst case situations will be probed to ascertain whether the maximum envelop of terminal sterilization conditions now proposed by the VPO is sufficiently conservative to insure acceptable results.

We are particularly concerned regarding the techniques for derivation of estimated burden levels and the local moisture profile in the oven and will treat these areas in detail.

3. Jovian Parameters

Confusion exists with respect to the interpretation of the statement made at the COSPAR meeting at Leningrad, relating Outer Planet and Martian parameters. This simplification is probably susceptible to significant criticism because of recent developments in the estimates of planetary environment parameters. We suggest attention be devoted to the evaluation of P(g) and other survival parameters for all Jovian planets. This appears to be a reasonable issue to address to the SSB.

4. Parameter Enumeration

Recent Martian data should be reviewed in confirming the value of P(g). Again, the SSB could be helpful in assessing the impact of Mariner 9 results.

Consideration should be given to a transit-time reduction factor applicable to surface burdens of non-sterilized vehicles. We intend to compile reported fall out data to identify a possible approach.

We are prepared to discuss each of the above items with you at your earliest convenience and establish a work schedule to accommodate your priorities associated with these items and other on-going tasks.

Please advise if additional information is desired.

Very truly yours,

EXOTECH SYSTEMS, INC.

Edward J. Bacon

EJB:hj

Attachment: Appendix A

APPENDIX A

DERIVATION OF STERILIZATION TEMPERATURE RELATIVE HUMIDITIES

PROBLEM: To compute RH at selected temperatures which are equivalent to NHB 8020.12 specification: "The moisture content of the sterilizing gas shall be less than 25% relative humidity at the standard conditions of 0°C and 760mm Hg pressure". (Page 8).

DEFINITION: Relative Humidity - The ratio of the density of water vapor present in the gas to the density which would saturate at the existing temperature. It is also the ratio of the pressure of the water vapor present to the pressure of saturated water vapor at the same temperature. 1/

DATA: Density of saturated stream 2/

temperature	density (kg/m^3)
0	0.00485
104	0.683
113	0.908
125	1.299

CALCULATIONS:

1) Vapor density of 25% RH mixture at 0°C and 760 mm Hg is:

$$25\% \times 0.00485 = 0.00121 \text{ kg/m}^3$$

2) RH @ 113 is ratio of (1) above to that needed to saturate:

$$RH_{113} = \frac{0.00121}{0.908} = 0.134\%$$

3) Similarly

$$RH_{104} = \frac{0.00121}{0.683} = 0.177\%$$

$$RH_{125} = \frac{0.00121}{1.299} = 0.0933\%$$

1/ Eshbach, Handbook of Engineering Fundamentals, Page 7-90.
2/ Handbook of Chemistry & Physics, Properties of Saturated Stream, p E-14

°F	°C	°F	°C
213	100.58	231	110.56
214	101.11	232	111.11
215	101.67	233	111.67
216	102.22	234	112.22
217	102.78	235	112.78
218	103.33	236	113.33
219	103.89	237	113.89
220	104.44	238	114.44
221	105.00	239	115.00
222	105.56	240	115.56
223	106.11	241	116.11
224	106.67	242	116.67
225	107.22	243	117.22
226	107.78	244	117.78
227	108.33	245	118.33
228	108.89	246	118.89
229	109.44	247	119.44
230	110.00	248	120.00

°F	°C	°F	°C
249	120.56	267	130.56
250	121.11	268	131.11
251	121.67	269	131.67
252	122.22	270	132.22
253	122.78	271	132.78
254	123.33	272	133.33
255	123.89	273	133.89
256	124.44	274	134.44
257	125.00	275	135.00
258	125.56	276	135.56
259	126.11	277	136.11
260	126.67	278	136.67
261	127.22	279	137.22
262	127.78	280	137.78
263	128.33		
264	128.89		
265	129.44		
266	130.00		

°F	D		
	S	M	E
213	7.30	14.59	72.96
214	6.87	13.73	68.65
215	6.46	12.92	64.59
216	6.08	12.15	60.77
217	5.72	11.43	57.18
218	5.38	10.76	53.80
219	5.06	10.12	50.62
220	4.76	9.52	47.63
221	4.48	8.96	44.82
222	4.22	8.43	42.17
223	3.97	7.93	39.68
224	3.73	7.47	37.33
225	3.51	7.02	35.14
226	3.31	6.61	33.05
227	3.11	6.22	31.10
228	2.93	5.85	29.26
229	2.75	5.51	27.53

°F	D		
	S	M	E
247	0.92	1.84	9.20
248	0.87	1.73	8.65
249	0.81	1.63	8.14
250	0.77	1.53	7.66
251	0.72	1.44	7.21
252	0.68	1.36	6.78
253	0.64	1.28	6.38
254	0.60	1.20	6.00
255	0.57	1.13	5.65
256	0.53	1.06	5.32
257	0.50	1.00	5.00
258	0.47	0.94	4.71
259	0.44	0.89	4.43
260	0.42	0.83	4.17
261	0.39	0.78	3.92
262	0.37	0.74	3.69
263	0.35	0.69	3.47
264	0.33	0.65	3.27

°F	D		
	S	M	E
230	2.59	5.18	25.90
231	2.44	4.87	24.37
232	2.29	4.59	22.93
233	2.16	4.31	21.57
234	2.03	4.06	20.30
235	1.91	3.82	19.10
236	1.80	3.59	17.97
237	1.69	3.38	16.91
238	1.59	3.18	15.91
239	1.50	2.99	14.97
240	1.41	2.82	14.09
241	1.33	2.65	13.25
242	1.25	2.49	12.47
243	1.17	2.35	11.73
244	1.10	2.21	11.04
245	1.04	2.08	10.39
246	0.98	1.95	9.77

°F	D		
	S	M	E
265	0.31	0.61	3.07
266	0.29	0.58	2.89
267	0.27	0.54	2.72
268	0.25	0.51	2.56
269	0.24	0.48	2.41
270	0.23	0.45	2.27
271	0.21	0.43	2.13
272	0.20	0.40	2.01
273	0.19	0.38	1.89
274	0.18	0.36	1.78
275	0.17	0.33	1.67
276	0.16	0.31	1.57
277	0.15	0.30	1.48
278	0.14	0.28	1.39
279	0.13	0.26	1.31
280	0.12	0.25	1.23