AGENDA

Committee Meeting - December 5, 1969

The Solar Constant and the Solar Spectrum

9:15 A.M.	-	Opening Remarks - M. P. Thekaekara
9:30 A.M.	-	C. Duncan - Radiation Scales
9:45 A.M.	-	Dr. R. Gast - Earlier Data
10:15 A.M.	-	Coffee Break
10:30 A.M.	-	Dr. A. Drummond - The Eppley Results
11:00 A.M.	-	Richard Willson - The J.P.L. Data
11:20 A.M.	-	Dr. D. Murcray - The Balloon Data U. of Denver
11:45 A.M.	-	LUNCH
1:00 P. M.	-	C. Duncan - NASA 711 - Thermophysics Branch Data
1:30 P. M.	-	M. P. Thekaekara - NASA 711 - Thermodynamics Branch Data
2:00 P. M.	-	Discussion
3:00 P. M.	-	Adjourn - Visit to the Labs

7/2/69 Called Gast. He agreed - Called Duncan Mook.
Mook says see with Hardgrove whether IES has any money for Gast's travel.

Talk with Hardgrove, President, I.E.S. R.R. Bouché
Endevco Corporation, 801 S. Arroyo Pkwy, Pasadena,
Cal 91109, Technical Vice-President Elect, IES
is in charge of Environmental Series Hand books to be published by IES.

Committee Chairman for "Solar Radiation" is
Gerald A. Bruno, La Casa de Bella Vista, 3424
North Monterosa Ave, Altadena, Cal. 91001

IES has no funds for travel of committee members,
~~this~~ asks members to get Corporate support before accepting appointment.

Duncan: Knows Bruno — I should try to go to the Tri-Society Meeting in Los Angeles in September

Hardgrove wants the description of the Solar radiation Committee's field of interest to be improved - to be less hardware oriented. Suggest

The Solar Radiation Committee is concerned with ~~the establish defini~~ radiation effects on space systems. It seeks to establish the space environment solar ~~radiation~~, ~~that is,~~ the ~~defini~~ ~~zero air mass solar~~ irradiance both total and spectral. ~~and~~ Solar simulation laboratory apparatus is used to study the effects of this environment on various materials, components and space vehicles. Special Consideration

Duro-Test Corp. 3424 N. Monterosa Ave
Altadena, Cal 91001

is required for the establishment of a total irradiance standard detector, spectral irradiance standards, & and the use of optical systems and instrumentation in the measurement of irradiance in solar simulators.
Spoke and sent it on to Duncan
Called Muneray - OK to be committee member
Stair suggests all recently obtained values should be plotted - Our Unit, Stair, Arvesen.
In charge of the ~~book~~ ~~is~~ Hand book is Richard C. Navarin
U S Army Materiel Command, Wash. DC 20315
Phone 9-0x2-0460 or 112-0460

11/6/69 I mailed yesterday to 6 Committee members - Gast, Muneray, Drummond, Stair, Lane, Willson the memo of 10/30/69 & enclosures - Mills says appointment as "Consultant without fee" will enable NASA to meet travel expenses.

11/7 Spoke to Muneray - He hasn't yet got the papers - I will call later -
Spoke to Gast - ~~Has~~ He just got the papers - I will call in the afternoon
Spoke to Stair - Just got - Travel for Langley? - I will call later.
Spoke to Willson: To tell him I am sending him the form for Consultant.
He is going on Wed for balloon flight Returning next Monday.

11/11 Spoke to Muneray - I will send travel vouchers -
Has strong feelings about range 2 to 20μ - Feels his value is higher accuracy - Drummond's high because of anvole.

11/19 Talked to Scholes at Eppley Drummond will be back next week - Hickey will be coming for the Langley

meeting.
I spoke with Gast. He is not sure our λ value is right. Errors of the order of 3 or 4 Å (I say, I agree)
Ozone absorption - ~~Did to~~ Dr Elterman's work is not a precision job - He ~~did~~ gave values for 15° - Should use - 44°. Drummond's aperture was 15°. Sky brightness was considerable. Gast would give as much weight to Murray's as to mine & Drummond's combined - Deduct 0.3% from my value.
I spoke with Lane. He has no problem with travel funds. JPL cone gives 139 & Angstrom gives 135.8. There is a difference in View factor On 990 the difference was 1.7% on Table Mountain the difference is 2.3%.

11/21/61 Presented a report at the meeting of the East Coast Group - LRC. Mook said ours is the only committee which has funding for travel.

~~ASTM~~ Joint Committee on Solar Simulation will present "Recommended practice for Solar Simulation" — There are 11 sections. IES SRSC East Coast has 6 tasks Second of these is our committee. Apparently these tasks are not part of the material to be included in "Recommended practice."

Notes taken during the LRC meeting 11/21/69.

μεγαλύτερη προσπάθεια για το καλύτερο

Call - Wornum - 75W 20 kW - accumulating used lamps -

25 people present. for the meeting

Twightwood — 12 to 14 ~~clear~~ no clouds.

Temperature 75 - 80° - Hickey - 1% spread in NIP's

½% standard deviation - PacRad -

Saerad Kendalls -

Plamondon's Boa ~~radio~~ Marmier values agree.

Plamondon believes that he has a value of the solar Constant - with great accuracy

Kostkowski - Round Robin Spectral Irradiance Measurements - 3 labs 3 lamps -

~~At~~ At least a month between measurements - Measure at 5 wavelengths

Redstone Newark AFB

Optronics

Eppley

Indicated

Drift

Let .25	2.4 μ							
λ	mean difference (1) Labs - NBS		mean difference between any two labs	L_1 L_2	SD			
.25	Redstone	Eppley -2.5%	Optr. -1.9	4.5		.5 %	L_1 1.1	L_2 -.2	L_3 +.2
.45	~~Kodak~~ 2.4	-2.5	-.9	4.9	NBS	.8	.4	.7	+.3
.65	1.5	-2.3	-1.5	3.8		1.5	.3	.9	.2
.9	1.3	+1.4	-1.1	3.4		.5			
2.4	2.9	+1.0	+1.1	2.9		.9	.6	.4	.3

Apparent drift over 15 hours was 0.4%

(1) gives value of Irradiance obtained by the lab — NBS value of Irradiance.

Youden

~~Eaton~~ Industrial Vol. 15 May 1959

~~Aug~~ Average drift is 0.4%.

If we are interested in absolute values probably not ~~more~~ less than 12%

7 or 8 primary standards at NBS.

Geist

A thermal detector - A self-calibrating detector.

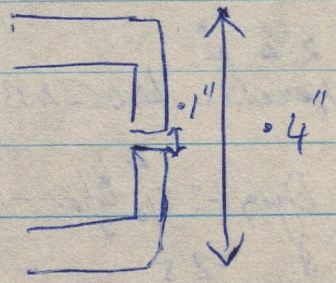
Direct Measure temp difference Δt } Δt

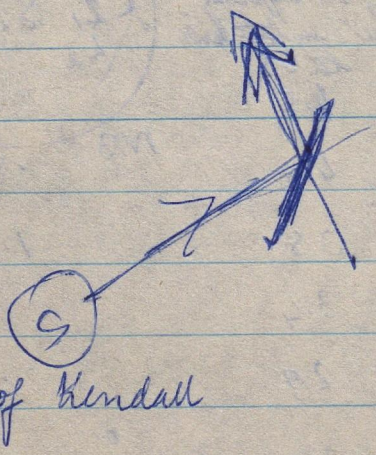
Measure electrical power }

Indirect % of power ~~dissipated~~ absorbed in the heater to that dissipated

% of radiant energy absorbed to that incident

Determine to what extent there is equivalence between radiant and electrical heating.





Pascal of Kendall

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940 EAST NORTHWEST HIGHWAY MT PROSPECT ILLINOIS 60057
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CLEARBROOK 5-1561
SOLAR RADIATION SIMULATION COMMITTEE
PLEASE ADDRESS REPLY TO

IES SOLAR RADIATION COMMITTEE ANNUAL MEETING MINUTES

The annual meeting was called to order by the chairman, Charles Duncan at 2:00 PM on Thursday 29 April 1971 at the Biltmore Hotel in Los Angeles, California. The meeting was conducted as a simultaneous annual and executive sub-committee meeting. The chairman and membership chairman, Fritz Benning, determined that a quorum was present. F. Benning recorded the minutes in the absence of Jim Webb who was unable to attend.

I. Committee Officer Reports

The chairman distributed copies of the annual report of the committee to those present and asked for comments. (Copy included as an attachment). No comments were made which required any changes in the annual report. The annual report has been forwarded to the IES Technical V.P., Dr. Ray Bouche of Endevco.

Fritz Benning, membership chairman, reported that an updated membership list will be available for distribution near the end of May, 1971.

Gene Borson reported on the recent reorganization of ASTM Committee E-21 on Space Simulation. Sub-Committee 7 has become an official part of the committee and is titled "Solar Simulation". All members of this IES SRC are members of E-21.70 Sub-committee of ASTM. The ballots which will be used in the future for approval of tasks performed by this joint committee will be the standard ASTM ballots. Two efforts are presently being conducted by this joint committee: (1) Recommended Practice for Solar Simulation for Thermal Balance Testing of Spacecraft; and (2) Engineering Standard for the Solar Constant and Solar Spectrum.

II. Recommended Practice for Thermal Vacuum Testing

This task was the subject for one of the colloquia at the annual meeting. Most of the sections are near final form. Comments from the audience at the colloquium session were noted by the responsible section leaders for possible inclusion into their respective sections.

The recommended practice will include all definitions of special terms which are a part of the Recommended Practice.

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The Los Angeles Working Group volunteered to hold a local meeting on 17 May to perform a final editing job on the sections before the Practice is sent to committee members for a vote. This editing will not attempt to modify the technical content of the sections but rather to make the Practice read more smoothly and to place all items in each section which properly belong in that section.

The Recommended Practice is to be mailed to all members for a vote about 15 June, 1971. All section leaders should forward a reproducible copy of their sections to Gene Borson before 1 June, 1971.

III. Solar Constant and Solar Spectrum

This task was also the subject of a colloquia session at the annual meeting. Based on the material presented at the colloquium and the comments from the audience, this task is now near completion.

This task is scheduled for a vote of the committee about 15 June 1971. A final copy of the proposed engineering standard is to be forwarded to C. Duncan by 1 June, 1971.

IV. Future Tasks

A new task "Aerospace Technology Relevant to Ecological Studies" was approved. Dr. William Kline of the Smithsonian Institution was suggested as possible chairman for this task. Other members of the task section will include Malcolm Lillywhite, Dave Orbock, and Fritz Benning.

Also approved was the publicizing of aerospace facilities which might be of use to ecological studies. Members of this committee who have suggestions on this subject should forward them to the Publicity Chairman, Wayne Moore of Spectrolab. Moore will prepare a series of news releases from these suggestions. A second task, "Total Irradiance Calibrations and Detectors for 20 Solar Constants Irradiance Levels" was approved and will be headed by Dr. Andrew Drummond of Eppley Labs. Other members of this task section include Ray Kruger, Dick Willson and Jim Kendall.

The committee also plans to hold at least one colloquia session at the annual meetings in the future. The material covered by each of these colloquia will be assembled and published in book form as a series of monographs - The first of these will be the "Solar Constant and Solar Spectrum".

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V. Miscellaneous

Radiometer intercomparison measurements may be performed at Mauna Loa, Hawaii in the future. Dr. Drummond will keep the committee informed of progress. The JPL intercomparisons at Table Mountain may or may not be continued. Dick Willson of JPL should be contacted by those who have an interest in these intercomparisons. Willson also has copies of the report on the 1970 intercomparisons.

Terry Hershey is to coordinate the efforts of the Government Industry Committee on High Energy Light Sources with the tasks performed by this committee, specifically, the working sub-groups on Safety Considerations.

VI. Announcements

ASTM is sponsoring a meeting on 25-28 June 1972 in Los Angeles which will include sessions on Test Methods, Aerospace, and non aerospace applications of Aerospace Technology - Additional details can be obtained from Gene Borson of the Aerospace Corporation.

The Sixth IES/AIAA/ASTM Space Simulation Conference has been scheduled for the 1st week of May, 1972 in New York City. IES is the host society for this meeting. Charles Duncan has been appointed technical program chairman and encourages each of you to submit papers for this meeting. This will be held the same week as the IES annual meeting. The IES annual meeting will be the first part of the week and the Space Conference the latter part - One registration fee will cover both meetings. Additional details may be obtained from Charles Duncan of NASA/GSFC. A copy of the call for papers is included as an enclosure.

The meeting adjourned at 4:30 PM.

F. N. Benning
Secretary

Attendees

F. Benning - Spectrolab
E. Borson - Aerospace Corp.
A. Drummond - Eppley
C. Duncan - NASA/GSFC
G. Gallagher - MIT Lincoln
J. Griffith - JPL
T. Hershey - Spectrolab
E. Laue - JPL
A. Lunde - Boeing
A. Matel - Hughes
D. Orbock - Sperry-Rand
J. Yuen - N. R. L.

Enclosures

Annual Report less enclosures
Call for papers IES/AIAA/ASTM Space Simulation Conference

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SOLAR RADIATION SIMULATION COMMITTEE

PLEASE ADDRESS REPLY TO
Charles H. Duncan
Code 762.4
NASA/Goddard
Space Center
Greenbelt, Md 20771

Annual Report

April 1970 - March 1971

I. Officers and Chairman of Sub-Committees

New officers were nominated and elected during this period. These officers, sub-committee chairman, and section chairman are shown on Enclosure 1. The term of office for the elected officers is two years. New officers will be elected in the even numbered years and shall take office on 1 July of the even-numbered years.

II. Committee Reorganization

A survey of the membership of the committee was conducted during this period. The information from this survey was used to formulate a set of bylaws. These bylaws were adopted on 1 July 1970. Copies of the bylaws have been distributed to all members. A copy of the bylaws is included as Enclosure 2.

III. Membership

An intensive effort to recruit new members has been in progress this year. A membership application form was prepared and mailed to prospective members. This effort has resulted in approximately 30 new members being added to the committee. The membership of the committee is now 107. These members represent 12 government agencies or laboratories, 35 industrial companies, 4 universities, and 2 consultants. 52 of the total are contributory members, 15 are consultaltory members and 40 regular members. A copy of the membership application is included as Enclosure 3 and the membership list as Enclosure 4.

IV. Current Tasks

Seven tasks are presently in progress. Two of these are very comprehensive and require considerable effort. These tasks are:

1. Recommended Practice for Solar Simulation for Thermal Balance Testing

2. Engineering Standard for the Solar Constant and Solar Spectrum;

3. Establishment of Total Irradiance Standard Detector;

4. Spectrum Evaluation Criteria for Solar Simulations;

5. Operator-User Test Data Interface for Solar Simulation Tests;

6. Calibration and Standardization of Total Irradiance Detector; and,

7. Establishemnt of test Data Format and Collection of Data on Spectral Irradiances of Radiant Energy Sources and Solar Simulation.

V. Tasks Under Consideration for Next Year

Four tasks are being considered for next year, these are:

1. New uses for Solar Simulation Facilities;

2. Solar Simulation Technology Applicable to Ecological Studies;

3. Total Irradiance Calibrations and Detectors for 20 solar constants; and,

4. Material for book on "Solar Simulation Optics and Radiometry".

VI. Work Accomplished in this Reporting Period

The work which has been accomplished by the committee during this reporting period is:

1. Organization and conduct of two sessions at 16th Annual Meeting in Boston, Mass.;

2. Workshop on "Radiometry" organized and conducted at 16th Annual Meeting of IES;

3. Organization and conduct of two session at 5th ASTM, IES, AIAA Space Simulation Conference in Gaithersburg, Md. in September 1970;

4. Workshop on "Solar Simulation for Thermal Balance Testing of Spacecraft" organized and conducted at 5th Space Conference;

5. Organization of two colloquia and two regular sessions for 17th Annual Meeting of IES in Los Angeles, Calif.; and

6. Established joint working group with ASTM committee E-21 on Space Simulation, and AIAA Thermophysics and Ground Test Committees.

VII. Work to be Completed During Next Reporting Period

The work scheduled for completion during the next reporting period is:

1. Publication of IES document on "Solar Simulation Testing";

2. Publication of IES document on "Solar Constant and Solar Spectrum";

3. Preparation in final form of "Recommended Practice of Solar Simulation for Thermal Balance Testing of Spacecraft" which will then be adopted by ASTM;

4. Preparation in final form of "Engineering Standard for the Solar Constant and Solar Spectrum" which will then be adopted by ASTM; and,

5. Organize and conduct sessions at the 6th IES-AIAA-ASTM Space Conference and the 18th Annual Meeting of the IES.

VIII. Meetings of the Committee

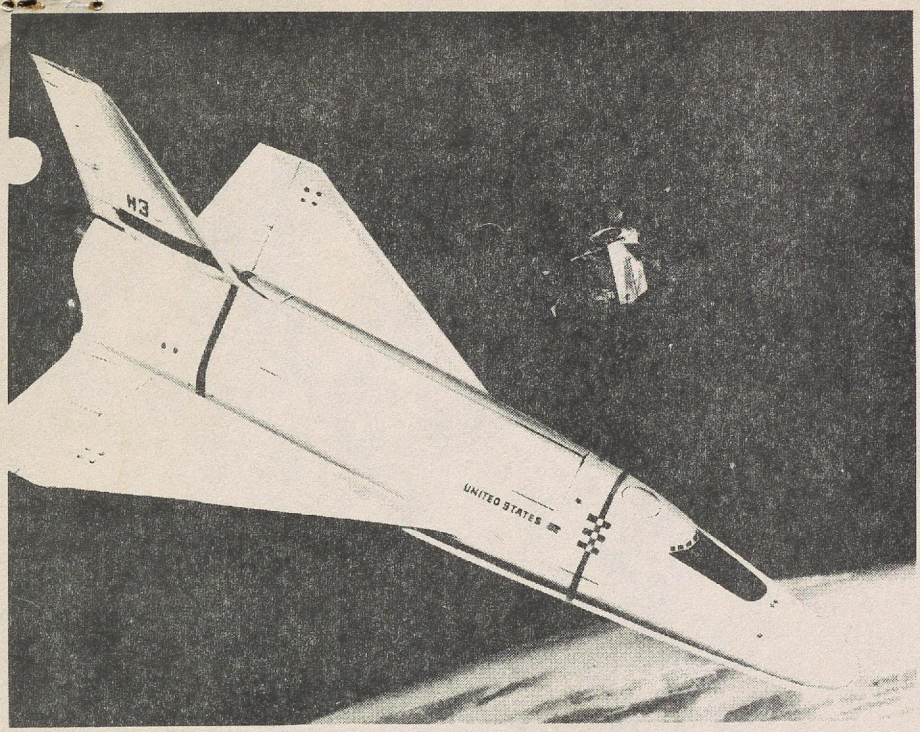
The annual meeting of the committee for 1970 was held in Boston, Mass. during the 16th IES Annual Meeting. An addition meeting was held at NBS during the 5th Space Simulation Conference. The 1971 Annual Meeting is scheduled during the 17th IES Annual Meeting is Los. Angeles, California.

The EAST sub-committee held a two day meeting at Lewis Research Center in Cleveland, Ohio on 11 and 12 June 1970. Another meeting was held at Goddard Space Flight Center on 16 March 1971.

The WEST sub-committee holds monthly meetings in the Los Angeles area.

Charles H. Duncan

Charles H. Duncan
Committee Chairman



CALL FOR PAPERS

IES - AIAA - ASTM SPACE SIMULATION CONFERENCE

APRIL 30 - MAY 4, 1972

AMERICANA HOTEL

NEW YORK CITY, NEW YORK

"Space — The Unlimited Challenge"

PURPOSE

The purpose of this technical conference is to provide for a meaningful exchange of information on advances in the space simulation field. Major emphasis will be placed on ingenuity and new techniques.

SUBJECT MATTER

I. Environmental Simulation

Papers are invited that deal with test techniques in the following areas:

a. Powered Space Flight Dynamics
b. Solar Radiation
c. Measurement and Instrumentation
d. Facility Design Involving Novel and Unique Solutions
e. Predictive Testing

II. Long Term Efforts

Papers are invited that deal with the long term efforts of:

a. Weightlessness
b. Exposure to Radiation
c. Changes attributable to combinations of any of the environmental stresses

CONFERENCE SCHEDULE

This will be the sixth conference sponsored by this tri-society cooperation and it is scheduled 18 months after the fifth conference to provide time for more new subject material.

This conference will be held adjacent to, but not a part of, the IES 18th Annual Meeting. The technical program of the conferences will be coordinated to prevent overlapping and, the attendees will be able to combine the two meetings and the IES Annual Environmental Equipment Exposition, the largest of its kind.

WHAT TO SUBMIT

I. A Cover Letter Containing:

a. The name and address of the author's organization and his position in the organization including department or section.

b. A statement that the paper has not previously been published or presented.

II. Three copies of a 200 word abstract or the completed paper. Abstract to include:

a. Complete title of proposed paper.
b. A concise statement of the problem or objective covered.
c. An indication of the scope and methods of approach.
d. A summary of important conclusions with a statement of data used to substantiate conclusions.

III. Submission of abstract is required on or before 15 August 1971. Authors are urged to submit their material at their earliest convenience. Authors will be informed of acceptance by October 1971. Complete papers due by 20 December 1971. Time should be budgeted for clearance procedure.

IV. Abstracts and related correspondence should be addressed to:

TECHNICAL PROGRAM COMMITTEE,
SPACE SIMULATION CONFERENCE
INSTITUTE OF ENVIRONMENTAL SCIENCES
940 EAST NORTHWEST HIGHWAY
MT. PROSPECT, ILLINOIS 60056
(312) 255-1561

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Philadelphia, Pa. 19103

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Miller -

IES SOLAR RADIATION COMMITTEE NATIONAL MEETING

Time: 2:00 PM - 16 September 1970

Place: NBS Lecture Room A

I. Proposed Engineering Standard for Solar Constant and Solar Spectrum

II. Recommended Practice for Solar Simulation for Thermal Balance Testing of Spacecraft

III. 17th IES Annual Meeting at Los Angeles 26-30 April 1971

IV. New Business

V. ADJOURN

20 ~~15~~ Oct To mail MPT Data package Duncan

~~15 Nov East Coast approval~~

30 Oct IES, SRC Mailing

VOTES From East Coast Group

15 Nov 80% have to vote - 2/3 of that have to approve

30 Nov IES SRC Mailing - Progress Report from Duncan

No changes can be made between Oct 20 & Nov 30

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SOLAR RADIATION SIMULATION COMMITTEE

PLEASE ADDRESS REPLY TO

Code 762
NASA Goddard Space
Flight Center
Greenbelt, Maryland 20771

September 4, 1970

TO: Committee Membership

FROM: National Chairman

SUBJ: Proposed Engineering Standard for Solar Constant and Solar Spectrum

I have been on leave and travel since the end of July. During this time, some controversy has arisen among members of this committee over the proposed engineering standard for the solar constant and solar spectrum which is being prepared by Section E-2 of the EAST Sub-Committee.

In order for the membership to be informed of the various viewpoints in this controversy, I am enclosing a copy of several letters and memos I have received since the end of July. These are: letters from John Arvesen, Eric Laue, and Richard Willson, and two memos from Dr. M. P. Thekaekara.

I would direct the attention of all members to Article IX, Section 1 of the Bylaws of this committee. This specifically states that each proposed new or revised standard must be approved by two-thirds of the sub-committee sponsoring the work before submission to the membership Chairman via the Solar Standards Chairman for letter ballot of the whole committee. In this particular case, the EAST sub-committee has to approve the standard before it can be submitted to the full committee. However, discussions among members other than the sub-committee section members involved is encouraged before new or revised standards are submitted for ballot. In view of the great interest in this particular effort, a special meeting of the whole committee will be held in conjunction with the 5th Space Simulation Conference as shown on Page 10 of the enclosed announcement. The agenda will include this item along with several others. If you are unable to attend this meeting and wish to express your viewpoint, write me a letter by return mail and I will present these at the meeting.

One point I would emphasize regarding paragraph 3 of Arvesen's letter is that it is not necessary to wait for action by NBS on Spectral irradiance standards since relative intensity curves of the solar spectrum are currently available which can be made absolute by application of the value of the solar constant using either the method of Johnson and the Smithsonian Institution or other acceptable spectrographic methods.

See you in Gaithersburg in September.

Charles H. Duncan
National Chairman

Enclosures:

- Arvesen Letter
- Laue Letter
- Willson Letter
- Two memos of Thekaekara
- Space Simulation Conference Program
- Agenda for Committee Meeting

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
AMES RESEARCH CENTER
MOFFETT FIELD, CALIFORNIA 94035

REPLY TO
ATTN OF: STP:234-1

August 17, 1970

Charles H. W. Duncan
NASA/Goddard Space Flight Center
Code 762
Greenbelt, Maryland 20771

Dear Mr. Duncan:

As members of the IES Solar Radiation Committee we are presently charged with the responsibility of considering the establishment of a Standard of the Solar Constant and Solar Spectrum. I am herein forwarding to you for your consideration a copy of a paper delineating the results of our independent investigations.

Of considerable importance to committee action regarding adoption of a Standard for the Solar Spectrum is the fact that the National Bureau of Standards is presently working on redefining the primary Standard of Spectral Irradiance. This redefinition would affect all prior spectral irradiance values based upon the Standard. The proposed Standard for the Solar Constant would not be affected because its value is based upon independent total radiometric measurements.

I recommend that committee action on establishment of a Standard for the Solar Spectrum be postponed until the National Bureau of Standards has issued a corrected scale for the Standard of Spectral Irradiance and that consideration be given at that time to all available data.

John C. Arvesen
Member
IES Solar Radiation Committee

JET PROPULSION LABORATORY California Institute of Technology 4800 Oak Grove Drive, Pasadena, California 91103

August 20, 1970

Dr. Matthew P. Thekakara
% NASA Goddard Space Flight Center
Greenbelt, Maryland 28771

Dear Doctor Thekakara:

As indicated in todays telephone conversation, enclosed is a copy of the J. Plamondon SPS article. While the data presented is substantially correct, additional analysis of the instrument's test data has resulted in a slight decrease in the reported solar irradiance and also a reduced error band. Mr. Plamondon is preparing a paper which details the design, calibration, and flight data reduction details. Unfortunately, the desired "turn off" the sun manuever is not scheduled for Mariner VII until December, 1970. The spacecraft is still heavily involved in the Einstein gravity experiment and other mapping work. Mariner VI cannot be rotated off the sun because the storage batteries are no longer functioning.

The data points in Fig. 12 are all that are available during the flight since the space tracking network was diverted for other operations.

It is regrettable there is confusion concerning the JPL efforts. Please bear with us until the matter is satisfactorily resolved. I also recognize that you as chairman can decide that the Solar Irradiance Committee work has been completed. In view of the current activity in these fields; for example, the enclosed letter, it might be wise to request a reconsideration of this effort as, if, and when the various puzzles have been reasonably explained.

Sincerely,

Eric G. Laue

EGL:slw
Enclosures
cc: C. Duncan
R. Willson

Telephone 354-4321 Twx 213-449-2451

JET PROPULSION LABORATORY *California Institute of Technology • 4800 Oak Grove Drive, Pasadena, California 91103*

August 12, 1970
Refer to 371-RCW:kam

Dr. M. P. Thekackara
Chairman; IES Committee on the Solar Constant
and the Solar Spectral Irradiance
Code 322
NASA, Goddard Space Flight Center
Greenbelt, Maryland 20771

Dear Dr. Thekaekara:

The lack of response to the dissenting point of view expressed by E. Laue, J. Kendall, and myself to you prior to the Boston IES meeting necessitates the re-iteration of my position on the past function and proposed conclusions of the committee on the Solar Constant and Solar Spectral Irradiance.

The committee has held but one meeting. If there have been others, I have not been included. I feel that a comprehensive evaluation of the many recent experimental measurements of Solar Irradiance requires more of the committee's time.

Questionaires were sent out persuant to the meeting, in which the committee members were asked to give weights to a list of solar constant determinations. Some of the values listed had not been discussed previously in the committee meeting, and others were incorrect representations of the values reported by the experimenters. Some of the questionaires appear to have been discarded in your final published analysis, since measurements given non-zero weights by myself and others were not included.

The majority of the solar spectral irradiance model proposed by you at the Boston IES meeting was based on only two experiments--your CV-990 measurements and the X-15 filter measurements. Suggestions that the committee consider other recent solar spectral irradiance measurements, such as those of J. Arvesen and D. Murcray, have not been implemented to my knowledge.

The present proposed solar constant and spectral irradiance model makes heavy use of the GSFC-NASA 711 experiment. Four of the eight solar constant values considered in your final analysis are from this one experimental effort. The vast majority of the solar spectral irradiance measurements used are those of the same GSFC effort. The GSFC-NASA 711 measurements should be included in the committee's recommendations in a proportion commensurate with their merits relative to other measurements. There are numerous other measurements to be considered.

I would like to have a better understanding of the rationale producing the solar constant and spectral irradiance model presented by yourself at the

Telephone 354-4321 *Twx 213-449-2151*

Boston IES meeting. Presumably, these quantities are meant to represent a cross section of committee point-of-view. At the present time this does not seem to me to be the case. In the interest of gaining some form of consensus, I am requesting that the following additional committee action be taken prior to acceptance and publication of its conclusions. The committee members should be supplied with copies of all questionaires and any additional material the chairman feels appropriate. Comparisons can then be made between your proposed solar constant and spectral irradiance model and the recommendations contained in the questionaires. Discrepancies between a direct use of the questionaire weightings and your proposed weightings should be resolved to the satisfaction of the entire committee.

Sincerely yours,

Richard C. Willson

cc: John C. Arvesen; Charles H. Duncan; Eric G. Laue; Fritz N. Benning; Jon Geist; Conrad P. Mook; Eugene N. Borson; John R. Hickey; Dr. David G. Murcray; Andrew J. Drummond; James M. Kendall, Sr.; Dr. Paul Gast; Dr. Henry J. Kostkowski; Raymond Kruger

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SOLAR RADIATION SIMULATION COMMITTEE

PLEASE ADDRESS REPLY TO

Dr. M. P. Thekaekara
Code 322, GSFC
Greenbelt, Md., 20771
September 4, 1970

Memorandum

To: Dr. R. P. Gast, Dr. A. J. Drummond, Dr. D. G. Murcray, Mr. E. C. Laue, Mr. R. C. Willson.

From: M. P. Thekaekara

The letter of Mr. Richard C. Willson, dated August 12, 1970, gives me the occasion to review some of the work done by the Committee on the Solar Constant and Zero Air Mass Solar Spectral Irradiance. The task was well defined: to propose values of the solar constant and the solar spectrum. There was a deadline to be met: the IES meeting at Boston, April 12 - 16, 1970.

That deadline is now long past; values endorsed by the six members of the committee were proposed. I might regard myself as holding a defunct chairman's job.

A questionnaire was distributed on December 30, 1969. Two questions were asked in the questionnaire: 1) What are the relative weights to be given to the values of the solar constant proposed by different authors? 2) Is the NASA 711 curve adequate? What changes would you suggest?

I had also requested comments, and had agreed that the comments and the weights you give would be confidential. What Mr. Willson wants me to do would go counter to this agreement. I, for one, feel great reluctance in spreading broadcast my criticisms of the work of other people for all of whom I have a high personal regard. Such publicity would generate more heat than light. But if several of you wish it otherwise, I shall be happy to send a copy of your comments back to you for editing before publication.

As for the first question about the solar constant there were plenty of comments, hardly any for the second question about the spectrum.

There was a fair degree of agreement among Dr. Drummond, Dr. Murcray, Dr. Gast and myself about the relative weights to be assigned. Dr. Murcray was of the view that all ground based values being integrals of the spectral curves and being based on different spectral standards should be rejected. Dr. Gast and I agreed with him, and to a certain degree also Dr. Drummond, though he gave a high weight to Labs and Neckel. Cary 14 value was excluded for the same reason that it was an integral.

The six values of weighted averages were 135.0, 135.1, 135.1, 135.7, 136.7 and 137.9.

The value 135.3 was chosen by Dr. Drummond and myself as being a good compromise, one that might be accepted by the entire scientific community with a high degree of confidence. Discussions on the phone with Dr. Gast and Dr. Murcray made it plain that they would be quite agreeable to this value. Later I called Mr. Willson and Mr. Laue and they too agreed to this value being presented as the recommendation of the committee. This was done during the week of February 17.

Next came the question what relative weights should be assigned to the different published values. The numbers finally chosen were such as to give 135.3 as the weighted average and to reflect the opinions of most of the members. The relative weights had also to be such as to sound reasonable to an outside public. A straight average of the weights we had assigned would not have given 135.3.

Mr. Willson refers to new values being listed, incorrect representations and omissions. I presume the new values he refers to are those of Kondratiev and Plamondon. They were brought up at the meeting of December 5, Kondratiev by Dr. Drummond and me, Plamondon by Mr. Laue, "because of the publicity it had received."

Incorrect representation probably refers to Mr. Willson himself. In December we had a published value 139.0 from JPL TR 32-1365; in the answer to the questionnaire in January he had 138.2; I heard that the value was further revised downwards later on.

The omissions from the final list are the integrals of spectral curves and Mr. Willson's own value. For the integrals the case seemed clear. For Mr. Willson's value, the case was far from clear. There was no firm value we could cite at that time. A JPL committee was studying the question. The 2.2%

correction to the IPS scale was a moot question. If a value above 138 was cited for Mr. Willson there was no plausible set of weighting factors we could assign to the rest of the values so as to derive a final 135.3. Mr. Laue tells me there is a firm value now, 137.0. But in March, a simple omission seemed more courteous than trying to defend a low weighting factor.

Thus we are left with 8 values. Four of these are from independent experiments of GSFC NASA 711. They are assigned a total weight of 22, compared to 34 for the other four.

Next came the question of spectral irradiance. Dr. Drummond had supplied some very extensive data. They were based not only on the X-15 but on several flights of CV990 and B57-B. They had the great advantage of being in a scale independent of the NBS spectral standards.

Dr. Murcray also gave some valuable information in the IR. They were based not only on his findings but on those of many others. The extension of the table beyond 20μ was made on the basis of these data. There was very close agreement between the NASA 711 table and Dr. Murcray's values at the 6 wavelengths he listed in the range 4 to 20μ. Leaving the NASA 711 table unchanged in this range was the result of a discussion of the data between Dr. Murcray and myself. Thus it is not true that Dr. Murcray's values were not used; they were a rather striking confirmation of our I-4 data.

Nor is it true that the Cary 14 data (Arvesen, Griffin and Pearson) were not considered. In fact a detailed comparison with the GSFC curve was made. Cary 14 data were punched on cards and a normalized ratio graph was plotted. The agreement was close over most of the range. A striking exception was the range 0.525 to 0.675μ. I had pointed this out at the December 5 meeting and said that probably the GSFC curve may have to be shifted upwards in this range. That was my thinking till the middle of February 1970 when Dr. Drummond's data arrived. In this range the Eppley - JPL data were almost exactly in agreement with the GSFC data. On reexamining the curves due to the four GSFC instruments in this range it was found that all four were in close agreement, crossing each other at several points.

Shifting the GSFC curve upwards in any range would have entailed lowering it everywhere else so as to keep to the integral value of 135.3. This would have been an unacceptable change in the data of all the five GSFC spectral irradiance instruments. The integral value of the GSFC spectral curve prior to normalization had been 135.25.

The question of the Cary 14 data came up at the IES meeting in Boston. The difficulties were pointed out by Dr. Drummond, Mr. Duncan and myself.

The method of building up the proposed spectral curve was discussed with each of the committee members prior to the IES - Boston meeting, and it was endorsed by all.

Mr. Willson had written in his letter of January 9: "I will have solar spectral distribution information in the near future, but have nothing to contribute at present." I do not recall receiving any such information.

One final word: it is not true that there was no response to the letter which Mr. Laue, Mr. Willson and Mr. Kendall wrote to me prior to the Boston IES meeting. The letter did not seem to me as expressing a dissenting point of view. Mr. Laue and I discussed it on the phone and he told me that the letter need not have been written, and I should disregard it, that no reply was needed, and that he would communicate to Mr. Willson the gist of our conversation.

M. P. Thekaekara

M. P. Thekaekara

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UNITED STATES GOVERNMENT

Memorandum

TO : Mr. Charles H. Duncan, Head
Radiometry Section, Thermophysics Branch

DATE: 9/1/70

FROM : Dr. Matthew P. Thekaekara
Thermodynamics Branch

SUBJECT: Solar Constant and Solar Spectrum

This brief memo is with reference to the letter which Mr. Arvesen sent to you as also to several others including myself about the proposed standard values of the solar constant and zero air mass solar spectral irradiance. You were one of those mainly responsible for setting up this task group. We had a rather well-defined though difficult problem: to propose these standards. We had also a deadline to meet: i.e., IES Meeting in Boston in April 1970.

Two points were raised in Mr. Arvesen's letter, that his data from the Cary 14 should be considered and that in view of the possible revision of spectral irradiance standards of the NBS the proposed solar curve should await further corrections.

As for the first point, the Cary 14 results were carefully considered. In fact, until the filter data of Eppley -JPL became available in February, the GSFC curves from the four instruments and the Cary 14 curve were the only ones available from high altitude measurements. The differences were in the range 0.525 to 0.675μ. Elsewhere the agreement was well within the range of error of the different instruments. In the range around 0.6μ where the four GSFC curves crossed each other and the Cary 14 curve was distinctly higher, the filter data were in almost exact agreement with the final GSFC curve.

The proposed standard curve is based on two independent scales, one referred to the NBS quartz iodine lamp and the other referred to IPS 56. The Eppley JPL data are from a radiometer calibrated on IPS 56 and the filter factors are computed from transmittance curves and an idealized source spectrum. Thus, there is no dependence on the NBS spectral irradiance scale.

The IPS 56 has been accepted internationally. No attempts have been made to compare the NBS spectral standard with similar standards used in laboratories outside the U.S. Attempts at a revision of the NBS spectral standard had been begun in 1966; no results have yet been announced. It is difficult to say how many years more it will take before an international spectral irradiance standard can be established. It has been a long standing custom in spectroscopy to insist on agreement between three independent laboratories before a standard is accepted.

Meanwhile should we be satisfied with the Johnson value of 139.5 mw cm^{-2} for the solar constant? Should the solar spectral curve continue to be a 6000°K blackbody curve in the IR as was proposed by Parry Moon in 1940 and was adopted by F. S. Johnson?

The values which were proposed in April 1970 at the IES Meeting were based on data which were thought the best available at that time. No new data has since been published.

Matthew P. Thekaekara

Matthew P. Thekaekara

This arrived after letter was written
Dr. Drummond is the Solar Standards Chairman
for our Committee

PHONE (401) 847-1020

THE EPPLEY LABORATORY, INC.
SCIENTIFIC INSTRUMENTS
NEWPORT, R.I. 02840 U.S.A.

3 September 1970

Mr. John C. Arvesen
Member, IES Solar Radiation Committee
NASA
Ames Research Center
Moffett Field, California 94035

Attention: STP:234-1

Dear John,

Thank you for your letter dated 17 August 1970 in which you recommend the postponement of IES Solar Radiation Committee action on the establishment (but which I prefer to call endorsement) of a standard of extraterrestrial spectral irradiance.

I must very strongly oppose such a suggestion. But it is quite clear that you misapprehend the real position. This in no way reflects upon you and probably many of our other colleagues. The spectral curve which Dr. Thekaekara and I have proposed was only finalized in May, when we submitted a joint paper to "Nature". This contribution has been accepted, but we do not believe that it will appear much before the end of the year since we still await proofs. Also, the related (and more detailed) paper, by me, was only presented, to a limited audience, at the Leningrad COSPAR Meeting at the end of May. Therefore, there is not yet been any real widespread dissemination of the material contained in these papers.

My reasons for opposing your proposal are as follows:

(a) The spectral reference advocated by Dr. Thekaekara and me is based not solely on Goddard monochromator results referenced to NBS spectral standards of irradiance, but also on the Eppley-JPL aircraft filter radiometry

programs conducted over several years and referenced to IPS;

(b) The integral under this curve has been adjusted to fit what we believe is the best acceptable value to date of the solar constant of radiation;

(c) This value does not depend in any way upon NBS radiometric standards.

For your information, I therefore give below three tables extracted from my COSPAR paper (with change of numbering).

Table 1. High-altitude measurements of the solar constant: 1961-1969

Source		Solar Constant mW cm^{-2}
Murcray	Univ. of Denver	133.8
McNutt and Riley	GSFC	134.3
Duncan and Webb	GSFC	134.9
McNutt and Riley	GSFC	135.2
Plamondon	JPL	135.3
Kondratyev et al.	Univ. of Leningrad	135.3
Kruger	GSFC	135.8
Drummond et al.	Eppley-JPL	136.0
Mean (weighted)		135.3

Table 2. Eppley-JPL principal aircraft broad bandpass filter measurements

Year	Month	NASA Aircraft	Series	λ(nm)	OG1 >526	RG8 >688	Mean >607	Total -Mean <607
					mW cm^{-2}			
1966	July-Aug.	B-57B	8		100.2	73.9	87.0	49.0
1967	March	B-57B	13		101.3	73.4	87.3	48.7
1967	October	X-15	1		101.6	73.4	87.5	48.5
1967	October	CV-990	1		100.9	73.6	87.3	48.7
1968	June-Aug.	CV-990	11		100.9	73.3	87.1	48.9
Mean (5 sets with 34 series)					101.0 ±0.4	73.5 ±0.3%	87.2	48.8

Table 3. Eppley-JPL aircraft narrow bandpass filter measurements and GSFC corresponding monochromator etc. results

λ(nm)	E-JPL	GSFC	E-JPL / GSFC	λ(nm)	E-JPL	GSFC	E-JPL / GSFC
	mW cm^{-2}				mW cm^{-2}		
235-344	5.52	5.24	1.05	508-592	14.9	14.7	1.01
272-322	2.78	2.58	1.08	535-603	12.1	11.6	1.04
295-365	6.99	6.29	1.11	565-631	12.1	10.9	1.11
298-344	4.22	3.88	1.09	595-645	8.83	7.89	1.12
334-403	7.78	7.63	1.02	603-663	10.3	9.24	1.11
355-430	10.1	10.2	0.99	603-697	15.0	14.1	1.06
410-474	11.8	11.9	0.99	631-697	10.3	9.62	1.07
430-490	11.5	11.8	0.97	645-700	8.47	7.91	1.07
446-500	10.6	10.8	0.98	697-963	28.2	28.1	1.00
490-565	13.3	13.7	0.97	1250-2000	17.3	18.0	0.96

Mean agreement (20 wavelength intervals) E-JPL:GSFC = ±5%

Note: E-JPL values underlined are derived differentially from adjacent pairs of broad bandpass filters; other E-JPL values are from narrow bandpass interference filters

You will observe that the agreement between the filter and monochromator data is remarkably good. Allowing for the different measurement, calibration and extratrapolation to zero air mass problems, Dr. Thekaekara and I consider that the best reliability which we can place upon absolute energy values derived for such generally small wavelength intervals is somewhat better than ±5 per cent; and this is born out by the results integrating all these uncertainties. It is doubtful whether the present NBS standards of spectral irradiance can be trusted to better than this figure in many of the bandwidths tabulated above.

I personally believe that this proposed spectral standard is the best obtained so far, that there would appear

to be little opportunity to properly contest the curve until a satellite measurement program becomes realistic, and that we should not wait for such an indefinite period before putting our affairs, in this respect, in order.

Sincerely yours,

A. J. Drummond
Chief Scientist
Member
IES Solar Radiation Committee

AJD:am

PROPOSED NEW ENGINEERING STANDARD FOR THE SOLAR CONSTANT AND ZERO AIR MASS SOLAR SPECTRAL IRRADIANCE

By: Matthew P. Thekaekara
NASA, Goddard Space Flight Center

APPENDIX

The following is an appendix to the paper of the same title printed in the Proceedings of the 16th Annual Meeting of the IES.

The values from Table I considered for a final weighted average are given below. They are in units of milliwatts cm^{-2}. After each value is given in parentheses the relative weighting factors assigned to it on a scale of 0 to 10.

U. of Denver Balloon	133.8	(4)
GSFC Å 6618	134.3	(3)
GSFC Å 7635	134.9	(3)
GSFC Hy-Cal	135.2	(8)
JPL Mariner Cone	135.3	(10)
U. of Leningrad Balloon	135.3	(10)
GSFC Cone	135.8	(8)
JPL-Eppley X-15, NASA 711	136.0	(10)

The weighting factors are based on evaluations and criticisms offered by members of the committee.

Maximum weight is given to the values obtained from the JPL Mariner, Leningrad Balloon, and Eppley-JPL Aircraft, since the final values in each case are based on a large mass of data. A high degree of reliability is assigned also to the values given by GSFC Hy-Cal and GSFC Cone. These represent two independent scales; a large number of data points were considered; a careful technique of extrapolation to zero air mass was utilized.

The U. of Denver Balloon value is also worth serious consideration. That it is so low points to some of the basic problems of radiometry in general and solar radiometry in particular. The two GSFC Angströms yielded relatively fewer data points and hence are given less weight.

The proposed value of the solar constant, which is the weighted average of the eight above values is 135.3 mW cm^{-2} or 1.940 calories min^{-1} cm^{-2}.

The estimated error is ±2.1 mW cm^{-2} or ±0.03 cal min^{-1} cm^{-2}. We believe that this estimate of error, 1.5%, is quite conservative, considering the large amount of high altitude measurements on which it is based. This revised value of the solar constant is 3.1% lower than the Johnson value of 2.0 cal min^{-1} cm^{-2} which used to be accepted formerly.

For the zero air mass solar spectral irradiance practically all the available data apart from those of the GSFC experiments on board NASA 711 Galileo are deduced from ground based measurements. They were not considered to be sufficiently significant to modify the NASA 711 curve. The high altitude data recently made available by A. J. Drummond form a notable exception. They are based on the Eppley-JPL measurements made with a multichannel filter radiometer carried on board X-15, B57B and Convair 990. Over most of the spectral range the results are in close agreement with the GSFC data. The differences are well within the experimental uncertainties of the two sets of measurements.

In the wavelength ranges where several of the Eppley-JPL filters are in agreement in showing a slightly different value from those of GSFC, a weighted average of the two sets of data was taken. This produces a small revision of the GSFC curve in the wavelength range 0.3 to 0.70μ and increases the integrated area under the curve, the solar constant, from the GSFC value of 135.1 to the new proposed standard, 135.3 mW cm^{-2}.

The proposed standard for zero air mass solar spectral irradiance is presented in tabular form in Table IV and graphically in Figure 7. The following differences between Table III from NASA 711 and the revised Table IV should be noted The energy in the range 0 to 0.12μ is 0.6 microwatt cm^{-2}; it is based on the findings of H. E. Hinteregger.[37] In the range 0.12 to 0.2μ Table III was based on the NRL data, which both Heath[32] and Parkinson and Reeves[38] have found to be about 2.5 times too high. The values have hence been adjusted downwards. In the range 0.22 to 0.30 the correction to NRL data assumed for Table III have been confirmed by Heath and hence no changes were made. The Eppley-JPL data were used, as stated earlier, for the corrections in the range 0.3 to 0.70μ. The maximum changes are +2.3% at 0.34μ, -0.7% at 0.45μ and +1.6% at 0.63μ. In the range 0.70 to 20μ the spectral irradiance values of NASA 711 have been retained. The few entries for wavelengths between 20μ and 1 mm are based on the combined data of many different observers as quoted by Shimabukuro and Stacey.[39]

More detailed information about the new proposed standard of zero air mass solar spectral irradiance will be available in a monograph to be published by the committee on "Solar Electromagnetic Radiation" in the series "NASA Space Vehicles Design Criteria."

REFERENCES

37. H. E. Hinteregger, private communication, to be published in Ann. de Geophysique, 1970.

38. W. H. Parkinson and E. M. Reeves, private communication, to be published in Solar Physics, 1970.

39. F. J. Shimabukuro and J. M. Stacey, Astrophys. J. 152, 777 (1968).

TABLE 7

Solar Spectral Irradiance - Proposed Standard Curve

λ - Wavelength in microns

P_λ - Solar spectral irradiance averaged over small bandwidth centered at λ, in Watts $cm^{-2}\mu^{-1}$

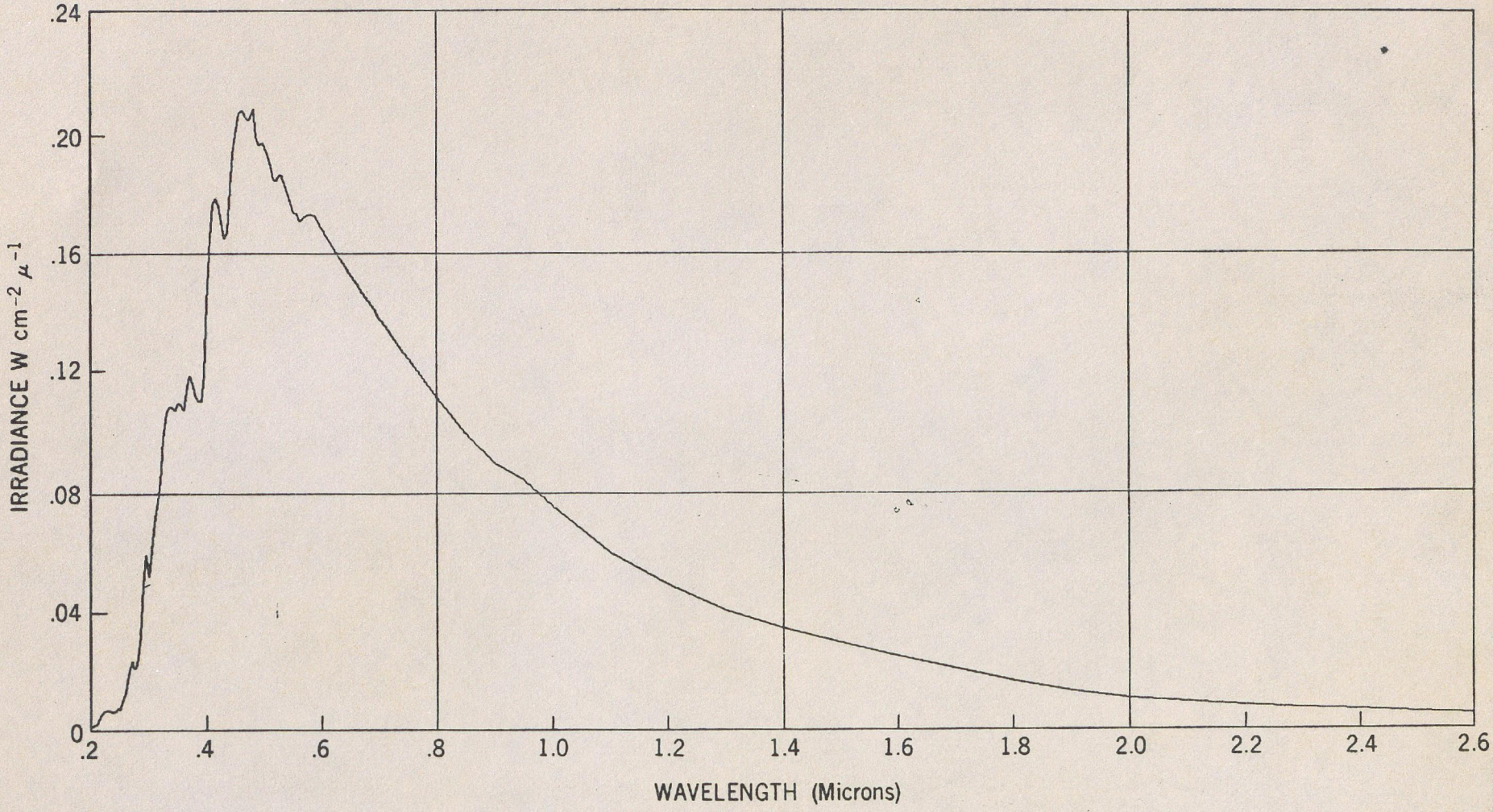
A_λ - Area under the solar spectral irradiance curve in the wavelength range 0 to λ, mW cm^{-2}

D_λ - Percentage of the solar constant associated with wavelengths shorter than λ

Solar Constant - 135.30 mW cm^{-2}

λ	P_λ	A_λ	D_λ	λ	P_λ	A_λ	D_λ	λ	P_λ	A_λ	D_λ
.120	.000010	.00059992	.00044	.475	.2044	25.6001	18.921	2.4	.0064	129.695	95.858
.140	.000003	.00072999	.00053	.480	.2074	26.6296	19.681	2.5	.0054	130.285	96.294
.150	.000007	.00077999	.00057	.485	.1976	27.6421	20.430	2.6	.0048	130.795	96.671
.160	.000023	.00092999	.00068	.490	.1950	28.6236	21.155	2.7	.0043	131.250	97.007
.170	.000063	.00135999	.00100	.495	.1960	29.6011	21.878	2.8	.00390	131.660	97.3103
.180	.000125	.00229999	.00169	.500	.1942	30.5766	22.599	2.9	.00350	132.030	97.5838
.190	.000271	.00427999	.00316	.505	.1920	31.5421	23.312	3.0	.00310	132.360	97.8277
.200	.00107	.010984	.0081	.510	.1882	32.4926	24.015	3.1	.00260	132.645	98.0383
.210	.00229	.027784	.0205	.515	.1833	33.4214	24.701	3.2	.00226	132.888	98.2179
.220	.00575	.067984	.0502	.520	.1833	34.3379	25.379	3.3	.00192	133.097	98.3724
.225	.00649	.098584	.0728	.525	.1852	35.2591	26.059	3.4	.00166	133.276	98.5047
.230	.00667	.131484	.0971	.530	.1842	36.1826	26.742	3.5	.00146	133.432	98.6200
.235	.00593	.162984	.1204	.535	.1818	37.0976	27.418	3.6	.00135	133.573	98.7238
.240	.00630	.193559	.1430	.540	.1783	37.9979	28.084	3.7	.00123	133.702	98.8192
.245	.00723	.227384	.1680	.545	.1754	38.8821	28.737	3.8	.00111	133.819	98.9056
.250	.00704	.263059	.1944	.550	.1725	39.7519	29.380	3.9	.00103	133.926	98.9847
.255	.0104	.306659	.226	.555	.1720	40.6131	30.017	4.0	.00095	134.025	99.0579
.260	.0130	.365159	.269	.560	.1695	41.4669	30.648	4.1	.00087	134.116	99.1252
.265	.0185	.443909	.328	.565	.1705	42.3169	31.276	4.2	.00078	134.198	99.1861
.270	.0232	.548159	.405	.570	.1712	43.1711	31.907	4.3	.00071	134.273	99.2412
.275	.0204	.657159	.485	.575	.1719	44.0289	32.541	4.4	.00065	134.341	99.2915
.280	.0222	.763659	.564	.580	.1715	44.8874	33.176	4.5	.00059	134.403	99.3373
.285	.0315	.897909	.663	.585	.1712	45.7441	33.809	4.6	.00053	134.459	99.3787
.290	.0482	1.09715	.810	.590	.1700	46.5971	34.439	4.7	.00048	134.509	99.4160
.295	.0584	1.36365	1.007	.595	.1682	47.4426	35.064	4.8	.00045	134.556	99.4504
.300	.0514	1.63815	1.210	.600	.1666	48.2796	35.683	4.9	.00041	134.599	99.482195
.305	.0603	1.91740	1.417	.605	.1647	49.1079	36.295	5.0	.0003830	134.63905	99.511500
.310	.0689	2.24040	1.655	.610	.1635	49.9284	36.902	6.0	.0001750	134.91805	99.717708
.315	.0764	2.60365	1.924	.620	.1602	51.5469	38.098	7.0	.0000990	135.05505	99.818965
.320	.0830	3.00215	2.218	.630	.1570	53.1329	39.270	8.0	.0000600	135.13455	99.877723
.325	.0975	3.45340	2.552	.640	.1544	54.6899	40.421	9.0	.0000380	135.18355	99.913939
.330	.1059	3.96190	2.928	.650	.1511	56.2174	41.550	10.0	.0000250	135.21505	99.937220
.335	.1081	4.49690	3.323	.660	.1486	57.7159	42.657	11.0	.0000170	135.23605	99.952742
.340	.1074	5.03565	3.721	.670	.1456	59.1869	43.744	12.0	.0000120	135.25055	99.963458
.345	.1069	5.57140	4.117	.680	.1427	60.6284	44.810	13.0	.0000087	135.26090	99.971108
.350	.1093	6.11190	4.517	.690	.1402	62.0429	45.855	14.0	.0000055	135.26800	99.976356
.355	.1083	6.65590	4.919	.700	.1369	63.4284	46.879	15.0	.0000049	135.27320	99.980199
.360	.1068	7.19365	5.316	.710	.1344	64.7849	47.882	16.0	.0000038	135.27755	99.983414
.365	.1132	7.74365	5.723	.720	.1314	66.1139	48.864	17.0	.0000031	135.28100	99.985964
.370	.1181	8.32190	6.150	.730	.1290	67.4159	49.826	18.0	.0000024	135.28375	99.987997
.375	.1157	8.90640	6.582	.740	.1260	68.6909	50.769	19.0	.0000020	135.28595	99.989623
.380	.1120	9.47565	7.003	.750	.1235	69.9384	51.691	20.0	.0000016	135.28775	99.990953
.385	.1098	10.0301	7.413	.800	.1107	75.7934	56.018	25.0	.000000610	135.29328	99.995036
.390	.1098	10.5791	7.819	.850	.0988	81.0309	59.889	30.0	.000000300	135.29555	99.996718
.395	.1189	11.1509	8.241	.900	.0889	85.7234	63.358	35.0	.000000160	135.29670	99.997568
.400	.1429	11.8054	8.725	.950	.0835	90.0334	66.543	40.0	.000000094	135.29734	99.998037
.405	.1644	12.5736	9.293	1.000	.0746	93.9859	69.464	50.0	.000000038	135.29800	99.998525
.410	.1751	13.4224	9.920	1.100	.0592	100.675	74.409	60.0	.000000019	135.29828	99.998736
.415	.1774	14.3036	10.571	1.200	.0484	106.055	78.385	80.0	.000000007	135.29854	99.998928
.420	.1747	15.1839	11.222	1.300	.0396	110.455	81.637	100.0	.000000003	135.29864	99.999002
.425	.1693	16.0439	11.858	1.400	.0336	114.115	84.342	1000.0	0	135.30000	100.000000
.430	.1639	16.8769	12.473	1.500	.0287	117.230	86.645				
.435	.1663	17.7024	13.083	1.600	.0244	119.885	88.607				
.440	.1810	18.5706	13.725	1.700	.0202	122.115	90.255				
.445	.1922	19.5036	14.415	1.800	.0159	123.920	91.589				
.450	.2006	20.4856	15.140	1.900	.0126	125.345	92.642				
.455	.2057	21.5014	15.891	2.000	.0103	126.490	93.489				
.460	.2066	22.5321	16.653	2.100	.0090	127.455	94.202				
.465	.2048	23.5606	17.413	2.200	.0079	128.300	94.826				
.470	.2033	24.5809	18.167	2.300	.0068	129.035	95.370				

SOLAR SPECTRAL IRRADIANCE (NASA STANDARD)



PROPOSED SPECIFICATION FOR THE SOLAR CONSTANT AND AIR MASS ZERO SOLAR SPECTRAL IRRADIANCE

These pages should replace page 8 (table 5), page 9 (table 6) and page 10 (figure 1) of the "Proposed Specification for the Solar Constant and Air Mass Zero Solar Spectral Irradiance" distributed for ballot to membership in September 1971. All values and symbols have been changed to SI units in conformity with ASTM recommendations.

IES Solar Radiation Committee
ASTM Space Simulation Committee E-21
AIAA Thermophysics Committee
AIAA Ground Test Committee

INSTITUTE OF ENVIRONMENTAL SCIENCES
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SOLAR RADIATION SIMULATION COMMITTEE

10 November 1971

PLEASE ADDRESS REPLY TO
NASA/GSFC
Code 762
Greenbelt, MD 20771

TO : Committee Membership

FROM: National Chairman

I. The minutes of the Joint Meeting with ASTM Committee E-21.70 held in Los Angeles, CA on 5 & 6 October 1971 are enclosed. Both the Recommended Practice and Engineering Standard were approved by this Committee. More details are in the minutes.

II. The IES has approved the printing of the "Colloquium on Solar Radiation" proceedings which were presented at the IES Annual Meeting in Los Angeles in April 1971. These will be printed in the standard book size with hard covers and will sell for approximately $10. Dr. A. J. Drummond of Eppley Laboratories is coordinating this effort.

III. The program for the IES-AIAA-ASTM Sixth Space Simulation Conference is nearly finalized. Approximately 75 papers are presently planned for presentation. This conference will be held at the Americana Hotel in New York City on 1-3 May 1972. The IES Annual meeting will be held at the same hotel on 2-4 May 1972. The Government Industry Committee on High Energy Light Sources also plans to hold its semi-annual meeting on 4&5 May 1972. This committee will hold its annual meeting on 3 May. ASTM Committee E-21 also plans to meet during this week. There should be something of interest for everyone, so make your plans now to attend. Preliminary program announcements will be mailed by IES early in January 1972.

IV. Dick Nichols, IES Technical Vice-President, has appointed me Manager, Physical Science Division of the IES Technical Committees effective 1 November 1971. This is a new position created by the revision of the constitution and by-laws earlier this year. Terry L. Hershey, the Vice-Chairman (WEST) has agreed to assume the duties of National Chairman of the committee until the new officers are elected in 1972. Also, Tony Matel of Hughes Aircraft Company has agreed to assume the duties of Vice-Chairman (WEST) during this period.

V. I wish to thank each of you for your support and efforts on committee activities during my term as National Chairman.

Charles H. Duncan

Charles H. Duncan
National Chairman

Enclosures

Joint Meeting - Subcommittee 7, Solar Simulation of Committee E-21, Space Simulation of ASTM; with IES Solar Radiation Commiteee and AIAA ground test and Simulation.

October 5 & 6, 1971
International Hotel
Los Angeles, California

Joint Committee Chairman - Terry Hershey

A. Review of final draft of "Recommended Practice for Solar Simulation for Thermal Vacuum Testing of Spacecraft" and final vote before submission to E-21 Committee.

The committee reviewed all comments (written and oral) concerning the final draft and resolved all items. Several changes in wording, corrections to units, and clarifications were made to each section. The section co-ordinators were asked to submit these final changes to C. Duncan at GSFC for assembly into document.

The subcommittee formally voted to accept the Recommended Practice and submit it for ballot to the E-21 Committee.

Tentative data for ballot is mid-November, with schedule for printing of approval Practice in time for IES Annual Meeting, May 1972.

B. Review of final draft of "Proposed Engineering Standard for the Solar Constant and Solar Spectrum" and final vote before submission to E-21 Committee.

The committee resolved all comments concerning the proposed specification and made a few minor changes in wording. Spectral irradiance was defined more explicitly and agreement was made to use the ANSI standard nomenclature, E_{λ}. The specification was adopted by unanimous vote and will now go to E-21 Committee for final ballot.

C. The ASTM booklet on form and metric units practice guide were suggested as documents for the committee's use in future activities.

ATTENDANCE LIST

October 5, 1971

J. Richmond	NBS
J. Griffith	JPL
T. Hershey	Spectrolab
C. Maag	COMSAT
C. Duncan	NASA/GSFC
F. Benning	Spectrolab
J. Castle	Spectrolab
E. Laue	JPL
R. Kruger	NASA/GSFC
B. Replogal	NASA/GSFC - Brown & Root
T. Francis	Spectrolab
F. Trebel	RAE
T. Hollingsworth	NASA/GSFC
J. Brystrom	ASTM Headquarters

October 6, 1971

J. Richmond	NBS
M. Thekaekara	NASA/GSFC
F. Benning	Spectrolab
R. Kruger	NASA/GSFC
C. Duncan	NASA/GSFC
B. Replogal	NASA/GSFC - Brown & Root
R. Hammel	TRW
C. Wilkinson	MC-DAC

TABLE 6

SOLAR SPECTRAL IRRADIANCE - PROPOSED STANDARD CURVE ABRIDGED VERSION

λ - WAVELENGTH IN μm

E_λ - SOLAR SPECTRAL IRRADIANCE AVERAGED OVER SMALL BANDWIDTH CENTERED AT λ, IN $W \cdot m^{-2} \cdot \mu m^{-1}$

$D_{o-\lambda}$ - PERCENTAGE OF THE SOLAR CONSTANT ASSOCIATED WITH WAVELENGTHS SHORTER THAN λ

SOLAR CONSTANT - 1353 $W \cdot m^{-2}$

λ	E_λ	$D_{o-\lambda}$	λ	E_λ	$D_{o-\lambda}$	λ	E_λ	$D_{o-\lambda}$
0.12	.1	4×10^{-4}	0.43	1639	12.47	0.90	891	63.37
0.14	.03	5×10^{-4}	0.44	1810	13.73	1.00	748	69.49
0.16	.23	7×10^{-4}	0.45	2006	15.14	1.2	485	78.40
0.18	1.25	1.7×10^{-3}	0.46	2066	16.65	1.4	337	84.33
0.20	10.7	8.1×10^{-3}	0.47	2033	18.17	1.6	245	88.61
0.22	57.5	0.05	0.48	2074	19.68	1.8	159	91.59
0.23	66.7	0.10	0.49	1950	21.15	2.0	103	93.49
0.24	63.0	0.14	0.50	1942	22.60	2.2	79	94.83
0.25	70.9	0.19	0.51	1882	24.01	2.4	62	95.86
0.26	130	0.27	0.52	1833	25.38	2.6	48	96.67
0.27	232	0.41	0.53	1842	26.74	2.8	39	97.31
0.28	222	0.56	0.54	1783	28.08	3.0	31	97.83
0.29	482	0.81	0.55	1725	29.38	3.2	22.6	98.22
0.30	514	1.21	0.56	1695	30.65	3.4	16.8	98.50
0.31	689	1.66	0.57	1712	31.91	3.6	13.5	98.72
0.32	830	2.22	0.58	1715	33.18	3.8	11.1	98.91
0.33	1059	2.93	0.59	1700	34.44	4.0	9.5	99.06
0.34	1074	3.72	0.60	1666	35.68	4.5	5.9	99.34
0.35	1093	4.52	0.62	1602	38.10	5.0	3.8	99.51
0.36	1068	5.32	0.64	1544	40.42	6.0	1.8	99.72
0.37	1181	6.15	0.66	1486	42.66	7.0	1.0	99.82
0.38	1120	7.00	0.68	1427	44.81	8.0	.6	99.88
0.39	1098	7.82	0.70	1369	46.88	10.0	.25	99.94
0.40	1429	8.73	0.72	1314	48.86	15.0	4.9×10^{-2}	99.98
0.41	1751	9.92	0.75	1235	51.69	20.0	1.6×10^{-2}	99.99
0.42	1747	11.22	0.80	1109	56.02	50.0	3.8×10^{-4}	100.00

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Paper No. 82

PROPOSED SPECIFICATION FOR THE SOLAR CONSTANT AND AIR MASS ZERO SOLAR SPECTRAL IRRADIANCE

IES Solar Radiation Committee and ASTM Space Simulation Committee E-21

FOREWORD

This Specification for the Solar Constant and Air Mass Zero Solar Spectral Irradiance resulted from a joint effort between the Institute of Environmental Sciences Solar Radiation Committee and the American Society for Testing and Materials Committee E-21 on Space Simulation. It was the subject of a colloquium session held at the 17th Annual Meeting of the Institute of Environmental Sciences at Los Angeles, California, 26-30 April, 1971. The material upon which this specification is based is now in the process of being published by the IES as a case bound book which will be titled "The Solar Constant and Solar Spectrum."

Members of the two committees and other interested persons have contributed to this specification by offering comments and suggestions. The task originated in the East Sub-Committee of the IES Solar Radiation Committee and was assigned to a sub-committee section which consisted of the following individuals:

Dr. Matthew P. Thekaekara,
Chairman - NASA/Goddard Space Flight Center
Dr. Andrew G. Drummond - Eppley Laboratory
Dr. P. Rupert Gast - Air Force Cambridge Research Laboratories
Eric G. Laue - Jet Propulsion Laboratory
Dr. David G. Murcray - University of Denver
Richard C. Willson - Jet Propulsion Laboratory

The document is planned for eventual publication by ASTM in the Book of Standards. The present reproduction of this document is the draft as approved by the IES Solar Radiation Committee. The document now has to be voted on by ASTM and may be revised before it appears in the ASTM Book of Standards.

It is printed in this proceedings to give it a wider distribution among those who may find it useful in their work.

Charles H. Duncan
Chairman, IES Solar Radiation
Committee

1. SCOPE

1.1 This specification defines the solar constant and the zero air mass solar spectral irradiance for use in thermal analysis, thermal balance testing, and other tests of spacecraft and spacecraft components and materials.

1.2 This specification is based upon data from experimental measurements made from high altitude aircraft, balloons, spacecraft, and the Earth's surface. The stated accuracies are based on the estimated accuracies of the measurements, calibrations, and radiometric scales.

2. DEFINITIONS OF TERMS

2.1 Air Mass (Optical Air Mass). The ratio of the path length or radiation through the atmosphere (l_m) at any given angle, Z°, to the sea level path length toward the zenith (l_z)

$$AM = \frac{l_m}{l_z} \cong \sec Z^\circ, \text{ for } Z^\circ \leq 62^\circ.$$

Symbol: AM1 (Air Mass One), AM2 (Air Mass Two).

2.2 Air Mass Zero. The absence of atmospheric attenuation of the solar irradiance at one astronomical unit from the Sun. Symbol: AM0.

2.3 Astronomical Unit. A unit of length defined as the mean distance between the Earth and the Sun, 149,597,890 ±500 Km. Symbol: AU.

2.4 Irradiance at a Point on a Surface. Quotient of the radiant flux incident on an element of the surface containing the point, by the area of that element. Symbol: E: Unit: Watt per square meter, $W \cdot m^{-2}$.

2.5 Irradiance, Spectral. The irradiance per unit wavelength interval at a specific wavelength, or as a function of wavelength. Symbol: E_λ. Unit: $W \cdot m^{-2} \cdot \mu m^{-1}$.

2.6 Integrated Irradiance. Spectral irradiance integrated over a specific wavelength interval from λ_1 to λ_2.

Symbol: $E_{\lambda_1-\lambda_2}=\int_{\lambda_1}^{\lambda_2} E_\lambda \, d\lambda$ Unit: $W \cdot m^{-2}$

2.7 Additional definitions will be found in E349.

3. SOLAR CONSTANT

The solar constant, based on the average of the values shown in Table 1, is:

$1353\ W \cdot m^{-2}$. Estimated Error: $\pm 21\ W \cdot m^{-2}$.

Table 2 summarizes the results in different units and Table 3 presents the total solar irradiance at various planetary distances from the Sun.

4. SOLAR SPECTRAL IRRADIANCE (AIR MASS ZERO)

The zero air mass solar spectral irradiance is based on data from the NASA 711 research aircraft experiments[1,2,3] (see Table 4) with additions and revisions based on other recent measurements[16]. Previously compiled solar spectral irradiances were based on ground based measurements[17 to 25] and some measurements from rockets[26]. Spectral irradiance data from the NASA Ames Research Center[27] were not included because of calibration uncertainties. Further discussion on the methods of calculation and historical information can be found in References 3, 16 and 28 to 31.

Table 5 presents the solar spectral irradiance in tabular form for the range 0.12 to 1000μm. The first column gives the wavelength (λ) in μm; the second gives the spectral irradiance (E_λ) at λ in $W \cdot m^{-2} \cdot \mu m^{-1}$; the third gives the total irradiance for the range 0 to λ ($E_{0-\lambda}$) in $W \cdot m^{-2}$; and the fourth gives the percentage of the solar constant associated with wavelengths shorter than λ, ($D_{0-\lambda}$).

Table 6 presents an abridged version of Table 5. Figure 1 plots the Standard Solar Spectral Irradiance.

The irradiance in the range 0 to 0.12 μm (nearly $0.006\ W \cdot m^{-2}$) is based on Hinteregger's results[32]. In the 0.14 to 0.20 μm range, the values are based on Naval Research Laboratory data[17, 26] that have been adjusted downward because of data by Heath[33] and Parkinson and Reeves[34]. In the range 0.20 to 0.30 μm, the values of the Goddard Space Flight Center curve have been retained because of confirming Nimbus satellite data[33]. The Epply-JPL data were used for revision in

Table 1

SOLAR CONSTANT

Platform	Detector	Year	Solar Constant $W \cdot m^{-2}$	Reference
NASA 711 Aircraft	Hy-Cal Pyrheliometer	1967	1358	1,2,3
NASA 711 Aircraft	Ångström 7635	1967	1349	1,2,3
NASA 711 Aircraft	Ångström 6618	1967	1343	1,2,3
NASA 711 Aircraft	Cone Radiometer	1967	1358	1,2,3
Soviet Balloon	U. of Leningrad Actinometer	1961-1968	1353	4,5
U. of Denver Balloon	Eppley Pyrheliometer	1969	1338	6,7
Eppley-JPL High Altitude Aircraft	Eppley Pyrheliometer	1966-1968	1360	8-13
Mariner VI & VIII Spacecraft	Cavity Radiometer	1969	1353	14
JPL Balloon	Cavity Radiometer	1968-1969	1368	15
Average Estimated Error			1353 ±21	

the range 0.3 to 0.7 μm[9-13]. The 20 to 1000 μm range[9-13, 16] irradiances were computed from the combined data on the brightness temperature of the Sun from many different authors as quoted by Shimabukoro and Stacey[35].

Table 2

THE SOLAR CONSTANT
(Conversion Factors)

Solar Constant = 1353 $W \cdot m^{-2}$ (± 21 $W \cdot m^{-2}$) [preferred unit]
= 0.1353 $W \cdot cm^{-2}$
= 135.3 $mW \cdot cm^{-2}$
= 1.353×10^{6} $erg \cdot cm^{-2} \cdot sec^{-1}$
= 125.7 $W \cdot ft^{-2}$
= 1.940 $cal \cdot cm^{-2} \cdot min^{-1}$ (± 0.03 $cal \cdot cm^{-2} \cdot min^{-1}$)
= 0.0323 $cal \cdot cm^{-2} \cdot sec^{-1}$
= 429.2 $Btu \cdot ft^{-2} \cdot hr^{-1}$
= 0.119 $Btu \cdot ft^{-2} \cdot sec^{-1}$
= 1.937 Langleys $\cdot min^{-1}$
The calorie is the thermochemical calorie-gram and is defined as 4.1840 absolute joules. The Btu is the thermochemical British thermal unit and is defined by the relationship: 1 Btu (thermochemical)/(°F x lb) = 1 cal · g (thermochemical)/(°C x g).
The Langley, however, is defined in terms of the older thermal unit the calorie · gm (mean), i.e., 1 Langley = 1 cal · g (mean) · cm^{-2}; 1 cal · g (mean) = 4.19002 joules.

Table 3

SOLAR IRRADIANCE AT THE PLANETS

Planet	Solar Irradiance $W \cdot m^{-2}$		
	Mean	Perihelion	Aphelion
Mercury	9029.0	14309.0	6211.0
Venus	2586.0	2621.0	2551.0
Earth	1353.0	1399.0	1309.0
Mars	583.0	709.0	487.0
Jupiter	50.0	55.2	45.5
Saturn	14.9	16.6	13.4
Uranus	3.68	4.07	3.34
Neptune	1.496	1.500	1.493
Pluto	0.870	1.556	.555

Table 4

SPECTRAL IRRADIANCE INSTRUMENTS ON BOARD THE NASA 711 GALILEO RESEARCH AIRCRAFT, USED FOR OBTAINING THE GSFC CURVE OF SOLAR SPECTRAL IRRADIANCE
(References 1, 2, 3)

Instrument	Energy Detector	Type of Instrument	Aircraft Window Material	Wavelength Range (μm)
Perkin-Elmer Monochromator	1P28 Tube, Thermocouple	LiF Prism LiF Prism	Sapphire Sapphire	0.3 - 0.7 0.7 - 4
Leiss Monochromator	EMI 9558QA, PbS Cell	Quartz Double Prism	Dynasil Quartz Dynasil Quartz	0.3 - 0.7 0.7 - 1.6
Filter Radiometer	Phototube	Dielectric Thin Films	Dynasil Quartz	0.3 - 1.2
P-4 Inter-ferometer	1P28 or R136 PbS Cell	Soleil Prism Soleil Prism	Infrasil Quartz Infrasil Quartz	0.3 - 0.7 0.7 - 2.5
I-4 Inter-ferometer	Thermistor Bolometer	Michelson Mirror	Irtran 4	2.6 - 15

Table 5

SOLAR SPECTRAL IRRADIANCE - PROPOSED STANDARD CURVE

λ - Wavelength in micrometers

E_λ - Solar spectral irradiance averaged over small bandwidth centered at λ, in $W \cdot m^{-2} \cdot \mu m^{-1}$

$E_{o-\lambda}$ - Integrated solar irradiance in the wavelength range o to λ, in $W \cdot m^{-2}$

$D_{o-\lambda}$ - Percentage of solar constant associated with wavelengths shorter than λ.

Solar constant - 1353 $W \cdot m^{-2}$

Note: lines indicate change in wavelength interval of integration.

λ	E_λ	$E_{o-\lambda}$	$D_{o-\lambda}$	λ	E_λ	$E_{o-\lambda}$	$D_{o-\lambda}$	λ	E_λ	$E_{o-\lambda}$	$D_{o-\lambda}$
.120	.100	.0059992	.00044	.525	1852	352.591	26.059	1.70	202	1221.23	90.261
.140	.030	.0072992	.00053	.530	1842	361.826	26.742	1.75	180	1230.78	90.967
.150	.07	.0078	.00057	.535	1818	370.976	27.418	1.80	159	1239.25	91.593
.160	.23	.00938	.00068	.540	1783	379.979	28.084	1.85	142	1246.78	92.149
.170	.63	.01360	.00100	.545	1754	388.821	28.737	1.90	126	1253.48	92.644
.180	1.25	.02308	.00169	.550	1725	397.519	29.380	1.95	114	1259.48	93.088
.190	2.71	.04280	.00316	.555	1720	406.131	30.017	2.00	103	1264.90	93.489
.200	10.7	.10989	.00811	.560	1695	414.669	30.648	2.10	90	1274.55	94.202
.210	22.9	.27785	.02053	.565	1705	423.169	31.276	2.20	79	1283.00	94.826
.220	57.5	.67985	.05024	.570	1712	431.711	31.907	2.30	69	1290.40	95.373
.225	64.9	.98585	.0728	.575	1719	440.289	32.541	2.4	62.0	1296.95	95.8580
.230	66.7	1.31485	.0971	.580	1715	448.874	33.176	2.5	55.0	1302.80	96.2903
.235	59.3	1.62985	.1204	.585	1712	457.441	33.809	2.6	48.0	1307.95	96.6710
.240	63.0	1.93560	.1430	.590	1700	465.971	34.439	2.7	43.0	1312.50	97.0073
.245	72.3	2.27385	.1680	.595	1682	474.426	35.064	2.8	39.0	1316.60	97.3103
.250	70.4	2.63060	.1944	.600	1666	482.796	35.683	2.9	35.0	1320.30	97.5838
.255	104	3.06660	.2266	.605	1647	491.079	36.295	3.0	31.0	1323.60	97.8277
.260	130	3.65160	.2698	.610	1635	499.284	36.902	3.1	26.0	1326.45	98.0383
.265	185	4.43910	.3280	.620	1602	515.469	38.098	3.2	22.6	1328.88	98.2179
.270	232	5.48160	.4051	.630	1570	531.329	39.270	3.3	19.2	1330.97	98.3724
.275	204	6.5716	.4857	.64	1544	546.899	40.421	3.4	16.6	1332.76	98.5047
.280	222	7.6366	.5644	.65	1511	562.174	41.550	3.5	14.6	1334.32	98.6200
.285	315	8.9791	.6636	.66	1486	577.159	42.657	3.6	13.5	1335.73	98.7238
.290	482	10.9716	.8109	.67	1456	591.869	43.744	3.7	12.3	1337.02	98.8192
.295	584	13.6366	1.0078	.68	1427	606.284	44.810	3.8	11.1	1338.19	98.9056
.300	514	16.3816	1.2107	.69	1402	620.429	45.855	3.9	10.3	1339.26	98.9847
.305	603	19.1741	1.4171	.70	1369	634.284	46.879	4.0	9.5	1340.25	99.0579
.310	689	22.4041	1.6558	.71	1344	647.849	47.882	4.1	8.7	1341.16	99.1252
.315	764	26.0366	1.9243	.72	1314	661.139	48.864	4.2	7.8	1341.98	99.1861
.320	838	30.0216	2.2188	.73	1290	674.159	49.826	4.3	7.1	1342.73	99.2412
.325	975	34.5341	2.552	.74	1260	686.909	50.769	4.4	6.50	1343.4141	99.291507
.330	1059	39.6191	2.928	.75	1235	699.384	51.691	4.5	5.90	1344.0341	99.337331
.335	1081	44.9691	3.323	.76	1211	711.614	52.595	4.6	5.30	1344.5941	99.378721
.340	1074	50.3566	3.721	.77	1185	723.594	53.480	4.7	4.80	1345.0991	99.416045
.345	1069	55.7141	4.117	.78	1159	735.314	54.346	4.8	4.50	1345.5641	99.450413
.350	1093	61.1191	4.517	.79	1134	746.779	55.194	4.9	4.10	1345.9941	99.482195
.355	1083	66.5591	4.919	.80	1109	757.954	56.023	5.0	3.83	1346.3906	99.511500
.360	1068	71.9366	5.316	.81	1085	768.966	56.834	6.0	1.75	1349.1806	99.717708
.365	1132	77.4366	5.723	.82	1060	779.694	57.627	7.0	.99	1350.5506	99.818965
.370	1181	83.2191	6.150	.83	1036	790.174	58.401	8.0	.60	1351.3456	99.877723
.375	1157	89.0641	6.582	.84	1013	800.419	59.158	9.0	.380	1351.8356	99.913939
.380	1120	94.7566	7.003	.85	990	810.434	59.899	10.0	.250	1352.1506	99.937221
.385	1098	100.3016	7.413	.86	968	820.224	60.622	11.0	.170	1352.3606	99.952742
.390	1098	105.7916	7.819	.87	947	829.799	61.330	12.0	.120	1352.5056	99.963459
.395	1189	111.5091	8.241	.88	926	839.164	62.022	13.0	.087	1352.6091	99.971108
.400	1429	118.0541	8.725	.89	908	848.334	62.700	14.0	.055	1352.6801	99.976356
.405	1644	125.7366	9.293	.90	891	857.329	63.365	15.0	.049	1352.7721	99.980199
.410	1751	134.2241	9.920	.91	880	866.184	64.019	16.0	.038	1352.7756	99.983414
.415	1774	143.0366	10.571	.92	869	874.929	64.665	17.0	.031	1352.8101	99.985964
.420	1747	151.8391	11.222	.93	858	883.564	65.304	18.0	.024	1352.8376	99.987997
.425	1693	160.4391	11.858	.94	847	892.08	65.934	19.0	.02000	1352.8596	99.989623
.430	1639	168.7691	12.473	.95	837	900.50	66.556	20.0	.01600	1352.8776	99.990953
.435	1663	177.0241	13.083	.96	820	908.79	67.168	25.0	.00610	1352.9328	99.995037
.440	1810.	185.7066	13.725	.97	803	916.90	67.768	30.0	.00300	1352.9556	99.996718
.445	1922	195.0366	14.415	.98	785	924.84	68.355	35.0	.00160	1352.9671	99.997568
.450	2006	204.8566	15.148	.99	767	932.60	68.928	40.0	.00094	1352.9734	99.998037
.455	2057	215.0141	15.891	1.00	748	940.18	69.488	50.0	.00038	1352.9800	99.998525
.460	2066	225.3216	16.653	1.05	668	975.58	72.105	60.0	.00019	1352.9829	99.998736
.465	2048	235.6066	17.413	1.10	593	1007.10	74.435	80.0	.00007	1352.9855	99.998928
.470	2033	245.8091	18.167	1.15	535	1035.30	76.519	100.0	.00003	1352.9865	99.999002
.475	2044	256.001	18.921	1.20	485	1060.80	78.404	1000.0	.00000	1353.0000	100.000000
.480	2074	266.296	19.681	1.25	438	1083.66	80.109				
.485	1976	276.421	20.430	1.30	397	1104.75	81.652				
.490	1950	286.236	21.155	1.35	358	1123.63	83.047				
.495	1960	296.011	21.878	1.40	337	1141.00	84.331				
.500	1942	305.766	22.599	1.45	312	1157.23	85.530				
.505	1920	315.421	23.312	1.50	288	1172.23	86.639				
.510	1882	324.926	24.015	1.55	267	1186.10	87.665				
.515	1833	334.214	24.701	1.60	245	1198.90	88.611				
.520	1833	343.379	25.379	1.65	223	1210.60	89.475				

Table 6

SOLAR SPECTRAL IRRADIANCE - PROPOSED STANDARD CURVE ABRIDGED VERSION

λ - WAVELENGTH IN μm

E_λ - SOLAR SPECTRAL IRRADIANCE AVERAGED OVER SMALL BANDWIDTH CENTERED AT λ, IN $W \cdot m^{-2} \cdot \mu m^{-1}$

$D_{o-\lambda}$ - PERCENTAGE OF THE SOLAR CONSTANT ASSOCIATED WITH WAVELENGTHS SHORTER THAN λ

SOLAR CONSTANT - 1353 $W \cdot m^{-2}$

λ	E_λ	$D_{o-\lambda}$	λ	E_λ	$D_{o-\lambda}$	λ	E_λ	$D_{o-\lambda}$
0.12	.1	4×10^{-4}	0.43	1639	12.47	0.90	891	63.37
0.14	.03	5×10^{-4}	0.44	1810	13.73	1.00	748	69.49
0.16	.23	7×10^{-4}	0.45	2006	15.14	1.2	485	78.40
0.18	1.25	1.7×10^{-3}	0.46	2066	16.65	1.4	337	84.33
0.20	10.7	8.1×10^{-3}	0.47	2033	18.17	1.6	245	88.61
0.22	57.5	0.05	0.48	2074	19.68	1.8	159	91.59
0.23	66.7	0.10	0.49	1950	21.15	2.0	103	93.49
0.24	63.0	0.14	0.50	1942	22.60	2.2	79	94.83
0.25	70.9	0.19	0.51	1882	24.01	2.4	62	95.86
0.26	130	0.27	0.52	1833	25.38	2.6	48	96.67
0.27	232	0.41	0.53	1842	26.74	2.8	39	97.31
0.28	222	0.56	0.54	1783	28.08	3.0	31	97.83
0.29	482	0.81	0.55	1725	29.38	3.2	22.6	98.22
0.30	514	1.21	0.56	1695	30.65	3.4	16.6	98.50
0.31	689	1.66	0.57	1712	31.91	3.6	13.5	98.72
0.32	830	2.22	0.58	1715	33.18	3.8	11.1	98.91
0.33	1059	2.93	0.59	1700	34.44	4.0	9.5	99.06
0.34	1074	3.72	0.60	1666	35.68	4.5	5.9	99.34
0.35	1093	4.52	0.62	1602	38.10	5.0	3.8	99.51
0.36	1068	5.32	0.64	1544	40.42	6.0	1.8	99.72
0.37	1181	6.15	0.66	1486	42.66	7.0	1.0	99.82
0.38	1120	7.00	0.68	1427	44.81	8.0	.6	99.88
0.39	1098	7.82	0.70	1369	46.88	10.0	.25	99.94
0.40	1429	8.73	0.72	1314	48.86	15.0	4.9×10^{-2}	99.98
0.41	1751	9.92	0.75	1235	51.69	20.0	1.6×10^{-2}	99.99
0.42	1747	11.22	0.80	1109	56.02	50.0	3.8×10^{-4}	100.00

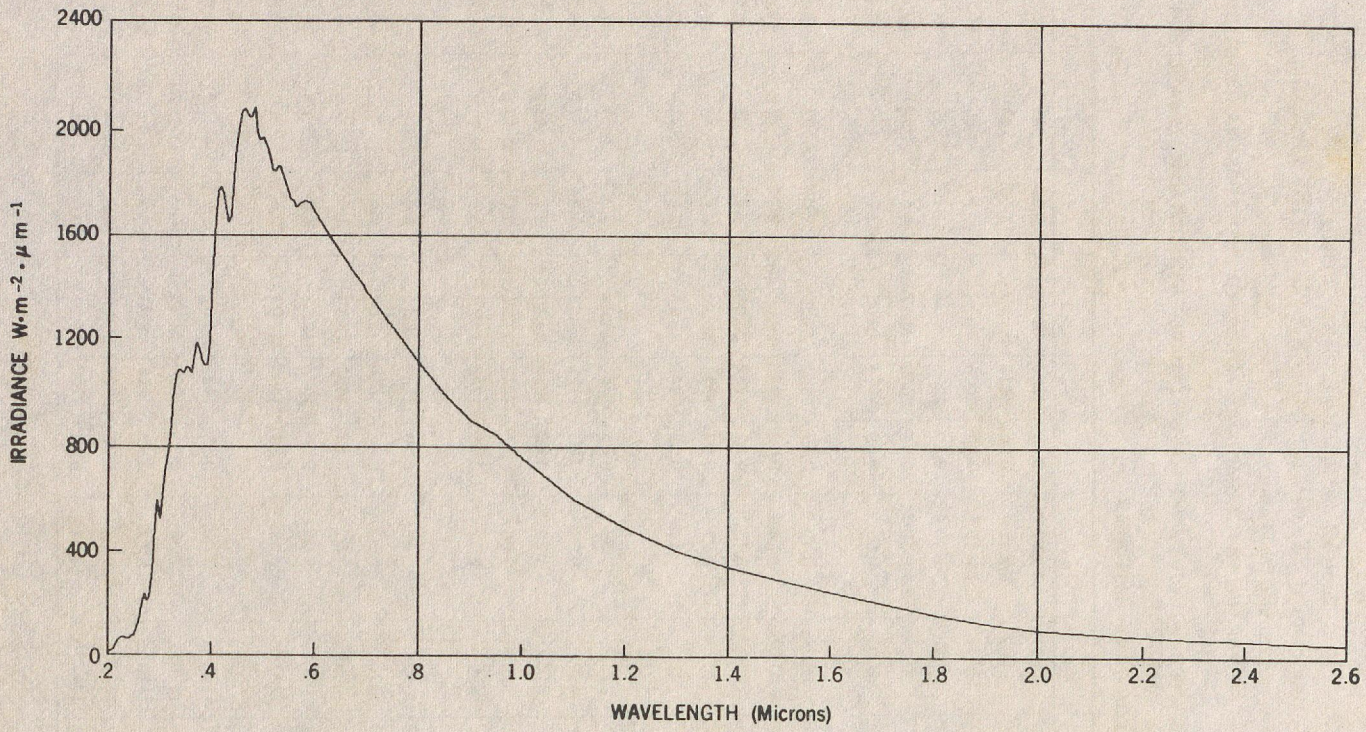

Figure 1. Solar Spectral Irradiance.

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ADVANCE SCHEDULE OF ACTIVITIES

ASTM COMMITTEE E-21 ON SPACE SIMULATION

DISNEYLAND HOTEL, ANAHEIM, CALIF.

APRIL 3-4, 1973

TUESDAY, April 3, 1973*

4:00pm	Subcommittee E21.70 on Solar Simulation	T. L. Hershey
6:00pm	E-21 Executive Subcommittee	E. N. Borson

WEDNESDAY, April 4, 1973*

9:00am	E-21 Orientation Session (All members and friends of E-21 are urged to attend this session for discussion with ASTM Headquarters representatives).	E. N. Borson
10:30am	Subcommittee E21.50 on Contamination	R. T. Hollingsworth
1:30pm	Subcommittee E21.70 on Solar Simulation	T. L. Hershey
4:30pm	E-21 Main Committee (All members and friends of E-21 are urged to attend).	E. N. Borson

*(E-21 meetings have been scheduled to try to avoid conflict with the IES sessions most applicable to the E-21 people expected to attend.)

E-21 SUBCOMMITTEES MEETINGS ELSEWHERE

E21.60 on Thermal Radiation Properties — D. F. Stevison

Scheduled to meet in July 1973 with the AIAA 8th Thermophysis Conference. Those interested should contact D.F. Stevison, Chairman E21.60, WPAFB, Ohio (513-255-2110)

E21.80 on Ablation — G. F. Wright, Jr.

Scheduled to meet in May 1973 at Langley Field, Va. Those interested should contact G. J. Wright, Jr., Chairman E21.80, Sandia, Albuquerque, N. Mex. (505-264-7363).

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SOLAR RADIATION SIMULATION COMMITTEE

PLEASE ADDRESS REPLY TO

March 13, 1973

Textron, Inc.
Box 4158
San Fernando, Calif. 91342

TO: Committee Membership

FROM: Terry L. Hershey

SUBJECT: Annual Meeting

The regular annual meeting of the Solar Radiation Committee will be held on Tuesday afternoon April 3, 1973, from 4:00 p.m. to 6:00 p.m. at the Disneyland Hotel Convention Center.

The meeting room will be posted on the announcement board located in the IES registration area.

In addition to reviewing a progress report of existing SRC tasks, and outlining new tasks, we will be electing officers for the coming year. See the enclosed ASTM E-21 schedule for additional information.

See you in Los Angeles.

Terry L. Hershey
Chairman

Enclosure

-- CALL FOR PAPERS --

AIAA-NASA/ASTM/IES SEVENTH SPACE SIMULATION CONFERENCE

November 12, 13, 14, 1973 Abstract Deadline: April 30, 1973

The seventh in the series of Tri-Society Space Simulation Conferences will be held at the International Hotel, Los Angeles, on November 12-14, 1973. This conference is sponsored by the American Institute of Aeronautics and Astronautics (AIAA - Host Society), the American Society for Testing and Materials (ASTM), the Institute of Environmental Sciences (IES), and the National Aeronautics and Space Administration (NASA). This series of meetings reflects the mutual interests of the AIAA Technical Committee on Ground Testing and Simulation, the ASTM Committee E-21 on Space Simulation and the IES Committee on Solar and Planetary Radiation Simulation.

The purpose of these conferences is to provide an international forum for the exchange of meaningful and useful information on advances in space simulation technology. The scope of this conference has been expanded to include all aspects of space simulation now existent, as well as those aspects proposed for future research, development, test and evaluation. This includes all the technologies involved in simulating space environments and the interactions of such environments with man and matter. Special emphasis will be given to activities relating to Space Shuttle, Skylab, the joint U.S./Russian space mission, and other challenging missions such as Helios and various outer-planet programs.

Papers are solicited in all of the above subject areas. Papers which emphasize advances in the fidelity and reliability of space simulation techniques, applicability to the current and future generations of space vehicles, and those which relate to applications of space simulation technology to other fields are especially desired. Candidate session titles may include, but are not limited to:

Contamination Detection and Control
High Energy Light Sources
Space Simulation Facilities
Behavior of Materials
Predictive Testing
Testing of Very Large Specimens
Scale Model Testing
Habitability/Manned Effects
Weightlessness/Zero Gravity/Reduced Gravity
Accelerated Time Testing
Exposure to Exotic Atmospheres
Combined Environments/Synergistic Effects
Thermal Techniques
Thermal Control Materials
Solar Simulation and Radiation
Spacecraft Tests
Novel or Unique Facility Utilization
Ablative Re-entry Materials
Computer Simulation
Radiometry/Optics
Vacuum Measurements/Mass Spectrometry
Validity of Solar Extrapolation

(over)

Papers on subjects within the broad scope of the conference, but not suggested above, will, of course, also be considered. The conference format will include invited papers as well as those submitted in response to this call. All papers must be unclassified.

The proceedings of the past two conferences were published as casebound U.S. Government Special Publications, one by the National Bureau of Standards (NBS) and one by the National Aeronautics and Space Administration (NASA). This policy will be continued for this conference. As a co-sponsor of this conference, NASA will publish all accepted papers in such a volume, which will be available for distribution at the conference. These publications receive world-wide distribution to many diverse technologies through U.S. Government Printing Office channels.

Abstracts of 500 - 800 words covering a proposed paper, prepared in accordance with instructions appearing on page , should be submitted in triplicate no later than April 30, 1973 to the Technical Program Chairman:

R. E. (Zeke) King (MS 31-2)
McDonnell Douglas Astronautics Co.
5301 Bolsa Avenue
Huntington Beach, California 92647
(714) 896-2170

Notification of acceptance will be mailed to authors by June 4, 1973. Photo-ready manuscripts of accepted papers will be required no later than July 16, 1973.

General inquiries or suggestions concerning this meeting should be addressed to the General Chairman:

George J. Frankel (05/383)
Grumman Aerospace Corporation
Bethpage, L.I., N.Y. 11714
(516) 575-9113