



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
GODDARD SPACE FLIGHT CENTER  
GREENBELT, MARYLAND 20771

August 25, 1972

Mr. Bruce Hartel  
Mail Code 1610,  
Martin Marietta Corporation  
P. O. Box 179  
Denver, Colorado 80201

Dear Mr. Hartel:

I am enclosing my comments on "Monitoring the total and spectral irradiance of the Sun from the ASF." On the phone I had discussed this with you. It took longer time in writing than I had planned. Perhaps you may be able to make some use of this in your September 20-21 presentation. And if I can be of any help with slides or some other way please let me know.

I am sending to Dr. R. D. Hudson a copy of this as also of Murray Mitchell's paper.

Some notes on Table 4.1 of Baseline Summary meant for your consideration are typed separately. No copy of this is being sent to Dr. Hudson.

In the Baseline Summary, p. 21, you speak of in-situ measurement of the ambient. I fully agree with you that this is beyond the scope of the present study. But, I think, it is of importance to all experimenters that the spacecraft management group look into this carefully. Dr. Kovar discussed it at the September 70 conference. Recently I had occasion to examine this problem; a brief paper (Paper 68 of SP 298) was written;

I am enclosing a copy. Perhaps the experimenters can make a strong case with the Spacecraft Management that contamination monitoring is an essential housekeeping function.

Sincerely,

*M. P. Thekaekara*

M. P. Thekaekara

P.S. I am looking forward to seeing you at the Houston meeting.

## Appendix 1

### Baseline Summary, ASF, Suggestions

The following suggestions might be considered for the next edition, if any, of Table 4.1, pp. 18 sqq. 2.1.1 'Total solar' should preferably be 'Solar total and spectral.' In 2.1.1 the wavelength range should be 1250 to 3500A and not 2000 to 3500A; otherwise the region 1250 to 2000 will be left uncovered. It is a region where NRL data are 2 to 3 times higher than more recent data, and the Sun apparently has a great variability. It is an important region for atmospheric physics. Resolution should be 12 to 35A. Radiance level is given as  $\geq 12$  MR; should be  $\geq 1.4 \text{ W m}^{-2} \text{ nm}^{-1}$ . Rayleigh is a useful radiance unit for an extended object of low energy output. Solar energy should rather be expressed in irradiance units at 1 A.U. You may also want to consider changing the title of column 4 to Irradiance and Radiance levels.

3.2.2 Change title to 'Solar, total and spectral'; that will help to show that the spectral distribution is an essential parameter. Range and resolution were inadvertently omitted in this line. If  $\lambda/d\lambda$  is 100, resolution might be put as 35 to 100A. But it should be noted that a prism instrument does not give a constant  $\lambda/d\lambda$ . If the slit width is set to give  $\lambda/d\lambda$  100 at 5000A, it will be 300 at 3000A, drops to 40 around 11000A and increases to 130 at 26000A. Irradiance range 2.5 to  $.4 \text{ W m}^{-2} \text{ nm}^{-1}$  is more correct. Field of view of  $1^\circ$  might be too much a constraint; it can be increased, thereby decreasing the constraint on pointing accuracy.

These notes on field of view and resolution apply also to line 4.2.2. The irradiance level is  $.8$  to  $.002 \text{ W m}^{-2} \text{ nm}^{-1}$ . Should wavelength range be restricted to  $\lambda < 3\mu\text{m}$ ? A Michelson interferometer can conveniently be used up to or even beyond  $15\mu\text{m}$ . Resolution should be the same as for measurement of clouds and terrain emission.

A line 5.2.2, Solar total and spectral, in the range 50 to  $15\mu\text{m}$  might be added. Entry in the 4th column of 5.2.1 seems to be a typist's error. Lines 5.7.2 and 6.5.3 show solar studies under

astronomy. Perhaps this was quite intentional, making it a secondary objective. This is the wavelength range of Earth emitted radiance and one where solar data are most scarce and highly discordant. The question of the relative importance of solar total and spectral measurements in this range might deserve a closer look.

M. P. Thekaekara  
Code 322  
NASA/GSFC



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
MANNED SPACECRAFT CENTER  
HOUSTON, TEXAS 77058

REPLY TO  
ATTN OF: TN2

September 8, 1972

Mr. M. P. Thekaekara  
Code: 322  
Goddard Space Flight Center  
Greenbelt, MD 20771

Dear Colleague:

Due to a scheduling problem the conference to discuss the results of the Atmospheric Science Facility Preliminary Design Study has had to be postponed from the September 20 date given in my previous letter. This conference is now rescheduled for October 11-13, 1972. The conference details, and the Martin-Marietta presentation will be sent to you under separate cover.

I sincerely regret the inconvenience that this change of date will have caused some of you and look forward to seeing you on October 11.

Sincerely,

Robert D. Hudson  
Advanced Programs  
Office

**MARTIN MARIETTA CORPORATION**

**DENVER  
DIVISION**

POST OFFICE BOX 179, DENVER, COLORADO 80201 TELEPHONE (303) 794-5211

19 October 1972

Dr. Matthew P. Thekaekara  
National Aeronautics and Space Administration  
Goddard Space Flight Center  
Greenbelt, Maryland 20771

Dear Dr. Thekaekara,

Thank you for your attendance at the Atmospheric Science Facility conference in Houston and the contributions which you made. We specially appreciated the presentation which you made on the measurement of the total energy and spectral distribution of the solar constant.

During one of the discussions it was mentioned that you were compiling a bibliography of the publications that resulted from the Convair 990 flight to measure the solar constant. We would appreciate receiving a copy of the bibliography along with a description of prism spectrometer that you have been developing.

Sincerely,

MARTIN MARIETTA CORPORATION

*Edward C. Mangold*  
Edward C. Mangold

*Mail Stop No. 1610*

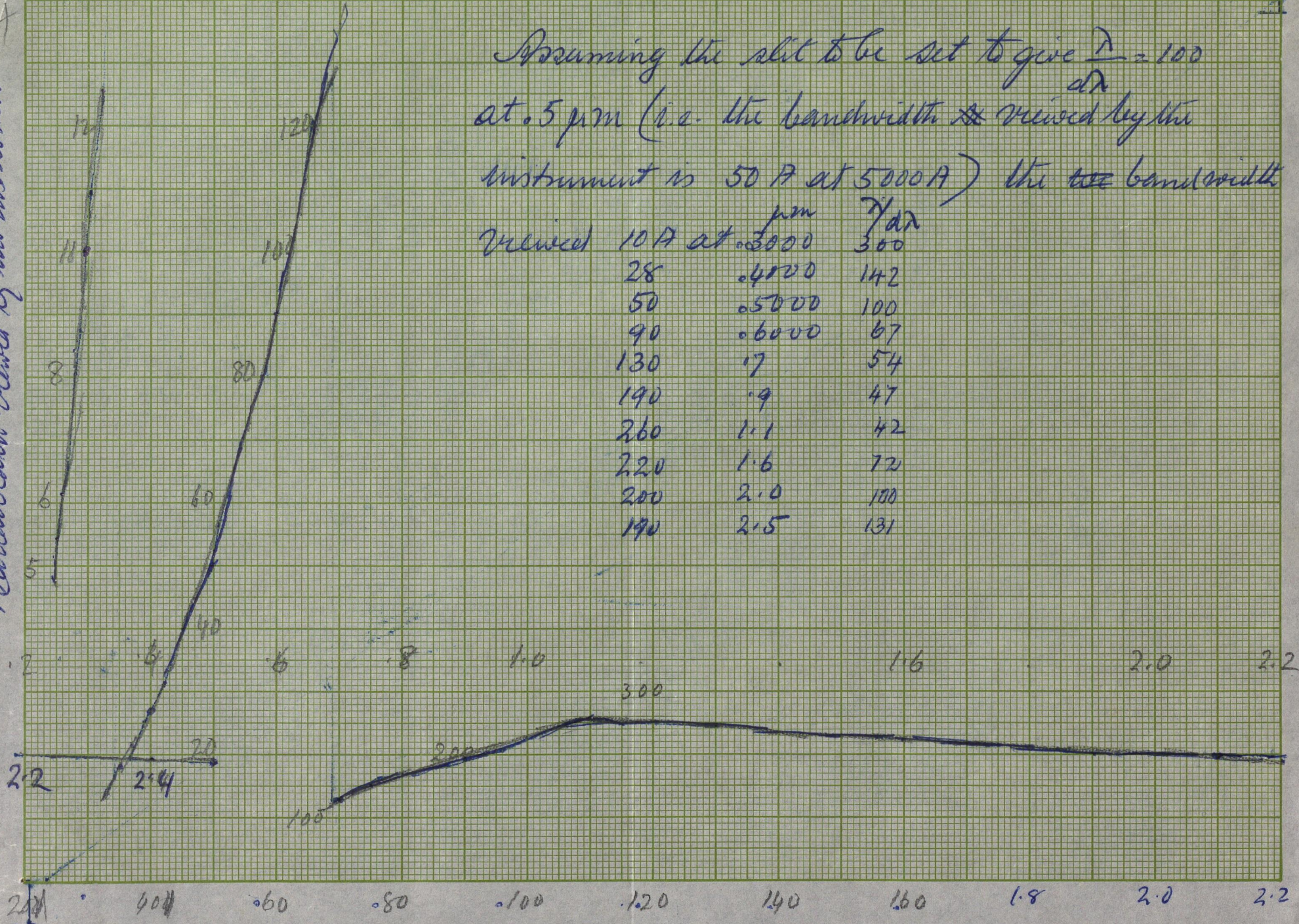
*Sent Copy of paper  
New York paper  
R 351*

ECM:su

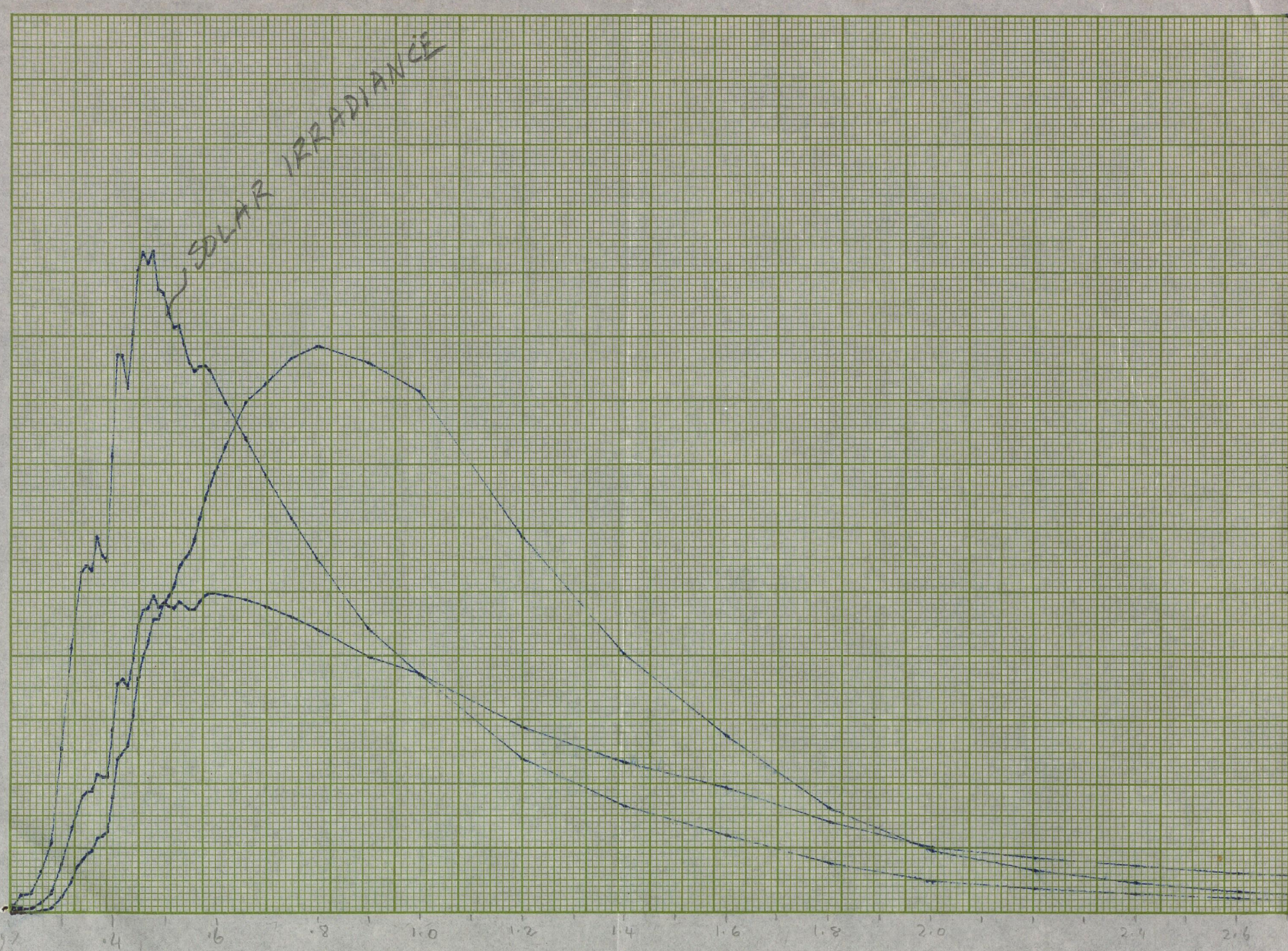
Bandwidth viewed by the instrument

Assuming the slit to be set to give  $\frac{\Delta}{\lambda} = 100$  at  $0.5 \mu\text{m}$  (i.e. the bandwidth ~~is~~ viewed by the instrument is  $50 \text{ \AA}$  at  $5000 \text{ \AA}$ ) the ~~total~~ bandwidth

viewed	$\mu\text{m}$	$\frac{\Delta}{\lambda}$
10 $\text{ \AA}$	0.3000	300
28	0.4000	142
50	0.5000	100
90	0.6000	67
130	.7	54
190	.9	47
260	1.1	42
220	1.6	72
200	2.0	100
190	2.5	131



SOLAR IRRADIANCE



100

50

L. H. Meredith  
Assistant Director

November 10, 1972

Herman E. LaGow  
Director of Systems Reliability

Shuttle Sortie Study

In response to your memo of October 18, 1972 on the Shuttle Sortie Study, I concur in the need for such a study and urge that this Directorate be directly involved. Toward that end I propose Mr. W. H. Meyer of the Test and Evaluation Division as the Directorate representative.

Attached is a specific proposal to study the Solar Constant and Solar Spectrum prepared by Dr. Thekaekara.

Herman E. LaGow

Attachment

300/HEL:JCH:di

cc:


320/J. C. New

312/H. Maurer

✓ 311/M. P. Thekaekara

326/W. R. Forlifer

316/W. H. Meyer



October 18, 1972

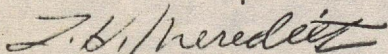
*from the office of the Director*

TO: Directors of

SUBJ: Shuttle Sortie Study

The results of the Space Shuttle Sortie Workshop held at the Center in August make it appear that the sortie mode has a number of potential uses. Furthermore, our extensive experience in the flight experiment area and in the balloon, sounding rocket, and small satellite system areas suggests that the Center has unique capabilities for defining such systems. Serious consideration is being given to initiating a study of a shuttle sortie mission. Such a study would complement the studies of payloads, such as EOS, that use the shuttle for launching and retrieving payloads.

While the published proceedings of the shuttle sortie workshop form a starting point for defining the objectives for such a sortie study they cover the total spectrum and do not focus on the particular aspects of interest and concern to the people at Goddard. Before initiating such a sortie study it is important to identify the study objectives and ground rules that people at Goddard think are important and also those areas of Goddard that are particularly interested in participating in such a study. I would appreciate receiving any comments you or your people have on this subject by November 10.



L. H. Meredith  
Assistant Director

-1257

## The Space Shuttle

Nixon issued statement on 2/5/72 that US has decided to proceed on the space shuttle. It is recoverable and can be reused 100 times. Operating costs will be  $\frac{1}{10}$  - Repair + servicing of satellites. In manned flight by '78. "We must sail sometimes with the wind and sometimes against it; but we must sail, and not drift, nor lie at anchor."

Space shuttle will be an airplane like orbiter, size of DC-9. Payloads 15' diam, 60' long, 65,000 lb., Fuel in an external tank which will be jettisoned in orbit. Orbiter operates in space for a week. Tank can be recovered. Crew of 4. May increase to 12. Will assemble modules in space. There will be several launch sites. The shuttle will carry the Tug which is to be built by the Europeans. Horizontal flight testing in '75, first manned orbit flight in '77 or '78. Tug can go to synchronous orbit and return to Earth orbit. If Tug is done in the US it will be in '83 to '85 period. Back to the moon after the nuclear tug is developed.



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
MANNED SPACECRAFT CENTER  
HOUSTON, TEXAS 77058

REPLY TO  
ATTN OF: TN2

September 22, 1972

Dear Colleague:

This package contains additional information on the Atmospheric Science Facility Conference to which you were invited. The conference is scheduled for October 11-13, 1972, at the NASA-Manned Spacecraft Center. We have enclosed here:

- (1) An agenda for the conference.
- (2) A list of motels in the NASA-MSC area.
- (3) A progress summary on the Atmospheric Science Facility prepared by Martin Marietta.
- (4) A form to indicate your response to the review of the Atmospheric Science Facility.

If you plan to attend the conference and are flying into Houston's Intercontinental Airport, we recommend you take a flight to the NASA-MSC area by Houston Metro Airlines. This commuter service takes about fifteen minutes and saves about a one hour drive.

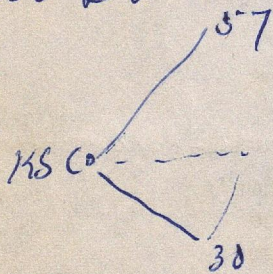
You will need to be badged at our Visitor Registration Building at the Southwest gate of the Manned Spacecraft Center on the first day of the conference. Car passes can also be obtained at the same place. The conference is being held in the Building 31 Conference Room (Room #193) on the MSC site.

We are requesting that you return the form indicating your participation of the review of the current status of the Atmospheric Science Facility.

Mockup shows how big it is. Morning - li shuttle, afternoon, the payload. - Be critical  
Horton  
Have a fairly good idea of what the payload should be. But is it the right thing.

Jack Heberling. Shuttle program office.  
Indefinite bet. expts to shuttle is not fixed.  
Shuttle is a transportation system.

- 78 16 On 78 only R&D flights
- 9 15 No expts planned till 79 -
- 80 24 But payloads for 79 must be identified by 78 in advance.
- 81 30 But for '85, '84 period only one year lead time is needed.
- 82 40
- 83 60 Initially 7 day sortie mission
- 84 60 Later 30 day mission
- 85 60 200 ft long  
5 million pounds at lift off  
H<sub>2</sub>O tank jettisoned at 100 m.  
200°K outside 130°K inside



- Baseline 2x2mm
- But 10 possible.
- Hot + Cold food - 4
- 4 man flight deck.
- Sleep station below flight deck.
- Payload Bay 15 ft diam x 60 ft long
- Sound 145 decibels max.
- Temp - ~~7~~ bet. -100 F to 200 F

- 25 KBPS ~~dedicated~~
- 256 KBPS maximum (kilobits p.s.)
- 3 H<sub>2</sub>O fuel cells each 8 kW at 30V DC
- Communications and switching at GSE

All attitude control by monometal hydrazine thrusters.  
305 pointing control can be held for 2 days.  
No spinning for equalization of temp.

BRUCE HARTEL  
73, 74 Instrument development

75, 76 Prototype evaluation

77, 78 Flight hardware

78 on flights

Dec 75 Prototype cluster flies in CV990

Dec 78 Early flight in shuttle

Task V Instrument preliminary development

Final report to be issued ~~later~~ in December.

Frizl Conf. 40; Questionnaire  
Vink etc 130 - 2nd Conf. 40

Data format digital  
Onboard storage - high order language  
Ground-based scientist involvement

Dr. Lee - NOAA.

Hutchison, Harrel, Wangold  
Investigator - data specialist  
Instrument specialist - Flight crew of 4

Even people would mean 24 hr operation

1) Minimum configuration -

3 clusters on pallets

2) Or main cluster in retractable chamber

It is possible to devise a set of common instruments which can perform a large variety of jobs. There is a space for more good furnished equipment.

I am looking forward to seeing you at the conference or receiving your written comments on the enclosed Martin report if you are unable to attend.

Sincerely,

James Robbins, for

Dr. Robert D. Hudson

Deputy Chief Physics Branch

4 Enclosures

ASF  
Cosmic Ray Facility  
Auroral Observatory  
Small Astronomical Telescope

Who is to control the facility?  
There should be a ~~control~~  
advisory committee.  
Payload 3000 lb. Shuttle capability  
is 40 000 lb.

Planetary & Earth Sciences  
Division  
Physics Branch

Interference filter  $10.6 \mu$   $\frac{3}{18}$  A half  
width.

Michaelson

Note about ~~Inter~~ Polarization  
type interferometer

Mass Spectrometer - Skylab has  
dropped it.

Precipitating particles are as important  
as solar radiation

Probably a 4th cluster for laser  
beam - Electron field

Apollo type \$20 000 per lb

Funding next year may be  
considerably less.

Enhance projects WILLIAM ROBERTS

Bill Maloney of MSC wants to MSC  
SKYLAB

know how  
write a 2 page letter about what they  
want to do - 16 people in the group - Stanford  
Penn St. Smithsonian NOAA  
Contractors are industry -

see from Oklahoma

Dan Swint TN-2 in charge  
of tape editing -

Mr. Dennon wants a copy of  
the text

MOTELS IN NASA-MSC AREA

Holiday Inn - NASA  
1300 NASA Boulevard Number 1  
Telephone: (713) 333-2500

Ramada Inn  
2020 NASA Boulevard Number 1  
Telephone: (713) 332-3551

Nassau Bay Motor Inn  
1600 NASA Boulevard Number 1  
Telephone: (713) 488-3402

*x \$14.00 Single Rm.  
RESERVED 9/27/72  
10 to 13*

Sheraton Kings Inn  
1301 NASA Boulevard Number 1  
Telephone: (713) 488-0220

ATMOSPHERIC SCIENCE FACILITY CONFERENCE  
NASA-MANNED SPACECRAFT CENTER

AGENDA

OCTOBER 11, 1972 - Bldg. 31 Conference Room - MSC

Registration	8:30 - 9:00 A.M.
Welcome - Mr. Anthony J. Calio	9:00 - 9:15
Introduction - Dr. Robert D. Hudson	9:15 - 9:30
Presentation on Shuttle Capabilities - Mr. Jack C. Heberlig	9:30 - 10:30
Break	10:30 - 10:45
Tour of Shuttle Mock-Ups	10:45 - 11:45
Lunch	11:45 - 1:00 P.M.
ASF Presentation - Martin Marietta	1:00 - 2:00
Break	2:20 - 2:35
ASF Presentation, Continued	2:35 - 3:15
Tour of ASF Mock-Ups	3:15 - 4:30
Cocktail Party (Nassau Bay Motor Inn)	5:30 - 7:30

OCTOBER 12, 1972 - Bldg. 31 Conference Room - MSC

Discussion Session I: Scientific Goals and Objectives	8:30 - 9:30 A.M.
Discussion Session II: Main Instrument Cluster	9:30 - 10:30
Break	10:30 - 10:45
Discussion Session II, Continued	10:45 - 11:45
Lunch	11:45 - 1:00 P.M.

Discussion Session II, Continued	1:00 - 3:00 P.M.
Break	3:00 - 3:15
Discussion Session III: Solar Monitors Group	3:15 - 4:30
Discussion Session IV: Observer Previewer Group	4:30 - 5:00

OCTOBER 13, 1972 - Bldg. 31 Conference Room - MSC

Discussion Session V: Data Management, Manned Participation, Overall Configuration, Future Activity	8:30 - 10:00 A.M.
Break	10:00 - 10:15
Discussion Session V, Continued	10:30 - 11:30

✓ 90

Monitoring of the Total and Spectral Irradiance  
of the Sun from the Atmospheric Science Facility \*

by

M. P. Thekackara

INTRODUCTION

Two important documents have recently been issued on the Science Objectives of the Atmospheric Science Facility, Preliminary Baseline Summary of March 1972 and Baseline Summary of May 1972. Comments on these summaries have been requested from the scientific community. The comments offered here are concerned mainly with one particular aspect of the science objectives, one part of the observational program of the ASF, namely the measurement of incoming solar irradiance, both total and spectral, in the wavelength range which contains most of this energy. Other aspects of the Science objectives include studies of the albedo and emitted radiation of the Earth atmosphere system, aurora and airglow, solar radiance in the XUV and for IR ranges. Considerable research has been done in these areas from rockets and unmanned satellites over the past twelve years; the talents of many have been brought to this effort; instrumentation at high levels of sophistication have been built. The ASF is the first major effort in the U. S. space program to include as an important and integral part of its science objectives the monitoring of solar energy and its spectral distribution in the wavelength range where the Sun exerts most influence on the Earth.

The Preliminary Baseline Summary states: "Associated with monitoring the radiation emitted or reflected from the Earth is the determination of the solar constant and its distribution into spectral components" (PBS p. 4). In the listing of experiments (PBS pp. 7 and 8) solar spectrophotometry is included in the four wavelength ranges, .03 to .125 $\mu$ m, .125 to .35 $\mu$ m, .35 to 1.0 $\mu$ m and 1.0 to 5.0 $\mu$ m. More specific details about these measurements are given in Table 4.1 of Baseline Summary (BS pp. 18-20). The wavelength resolution of  $\lambda/d\lambda$  equal to 100 which we had suggested in the questionnaire response of January 13 has been adopted in PBS and BS as an acceptable

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\*Presented at the Atmospheric Science Facility Conference,  
Manned Spacecraft Center, Houston, Texas, October 12, 1972

*This is an earlier paper for your info - for your file*

*JM*

minimum. The Baseline Summary states: "The requirement for simultaneous measurements over several wavelength ranges was expressed quite strongly, both at the 1970 Scientific Objectives Conference and by subsequent correspondence with the scientific community. In addition, low resolution monitoring of the incoming solar flux (solar constant) in support of the airglow and Earth radiation budget experiments is required, which would involve the use of a unique, independently pointable instrument for that purpose" (BS pp. 20-21).

#### JUSTIFICATION FOR THE SOLAR MEASUREMENT PROGRAM

Since solar irradiance measurement in the visible and near IR has not hitherto been attempted from satellites, the scientific justification of such a program needs to be elaborated more fully. The wavelength range proposed for spectral irradiance measurement is what would be scanned by a prism monochromator; the prism material being quartz or lithium fluoride. The lower limit is about  $0.2\mu\text{m}$ ; the upper limit is about  $2.5\mu\text{m}$  for a quartz prism and  $4\mu\text{m}$  for a lithium fluoride prism. Assuming for the solar constant and the solar spectral irradiance the design values proposed in the NASA Space Vehicles Design Criteria monograph, NASA SP 8005 (Reference 1), of the total solar irradiance at one astronomical unit,  $1353 \text{ Wm}^{-2}$ , only  $13 \text{ Wm}^{-2}$  is outside the range  $0.2$  to  $4\mu\text{m}$ ,  $0.01\%$  of the solar constant is below  $.2\mu\text{m}$  and one percent above  $4\mu\text{m}$ . The solar constant would be monitored with an absolute cavity radiometer, an Ångström compensated strip pyrhelimeter or some similar instrument calibrated on the International Pyrhelimeter Scale IPS 56.

In discussing this solar irradiance experiment it is well to recall the remarks made by Dr. A. E. Porter about Expts T025 and T027 proposed for Skylab A to monitor contamination. He said: "The two experiments are constantly in danger of being dropped off the spacecraft. They don't contribute to Earth resources; they don't pickup lunar rocks; they are totally unglamorous; they cost money; and they take up time and space." (Reference 2) All this is true also about measuring the energy of the Sun. Besides, there are other objections often raised. Has not the Sun's energy been measured for over half a century? Is it not known with sufficient accuracy? Why go to a satellite for what can be measured from the ground? Similar objections were raised already in 1961 when Dr. Hanel proposed a spherical blackbody to measure the solar constant.

(Reference 3). Several improved versions of this detector were built, but the experiment failed to get approved for any satellite. These objections continue to be raised though the answers to them are fairly simple and straightforward. In the ASF Scientific Objectives Conference solar spectrophotometry was mentioned as a possibility, but the wavelength range proposed at that time was only in the UV 1100 to 4000Å and in the IR 20 to 300  $\mu\text{m}$  (ASF Preliminary Analysis, December 1971, p. 5). Including the whole spectral range of solar irradiance is a most welcome change introduced in the PBS and BS.

#### ATMOSPHERIC PHYSICS OBJECTIVES

It must be emphasized that the solar measurements on board the ASF are in support of the Earth oriented measurements. The objective is atmospheric physics, not solar physics. We are in full agreement with the major goals in atmospheric research as stated in the B.S. "The ASF should be designed to perform experiments that are in accordance with national goals," (BS p. 12). These experiments are intended mainly for extending the ability to make useful prediction of weather, monitoring contaminants and source and sink mechanisms for the timely topic of air pollution, studying the Earth's radiation balance and long range climatic effects, understanding the dynamics of the atmosphere and the physical and chemical processes in the upper atmosphere. Five objectives have been identified as primary, namely, airglow, radiation budget, aerosols, atmospheric structure and minor constituents and pollution, (BS p.14). For all of these objectives and experiments, solar irradiance, total and spectral, is the most important input parameter.

Fig. 1 Airglow is induced by the Sun's irradiance at certain wavelengths. The radiation balance of the earth has the Sun's energy as the input. Aerosols and pollutants are studied by what they absorb and scatter from sunlight and absorption and scattering have a strong spectral dependence. It is solar irradiance which dominates the physical and chemical processes in the atmosphere. The major parameter for numerical simulation through atmospheric models and forecasting mesoscale phenomena is the Sun's input energy. To cite a simple example, a NASA Space Vehicles Design Criteria monograph (Reference 4) cites from an early publication by Von der Haar the following figures for global annual average for the radiation budget of the Earth-atmosphere system: incident solar,  $349 \text{ Wm}^{-2}$ ; reflected solar,  $105 \text{ Wm}^{-2}$ ; Earth emitted IR,  $230 \text{ Wm}^{-2}$ , which gives a net

\* Note: 349 is 1/4 of the Johnson value of 1396

radiation budget of  $14 \text{ Wm}^{-2}$ . The incident solar irradiance is based on the now obsolete value published in 1954 by Johnson. If instead the NASA design value of the solar constant (Reference 1)  $1353 \text{ Wm}^{-2}$ , is adopted, the annual average incident solar irradiance is  $338 \text{ Wm}^{-2}$ , and the net radiation budget falls to  $3 \text{ Wm}^{-2}$ .

#### SPECTRAL DISTRIBUTION IN THE VIS/IR

The energy incident on and measurable by the ASF belongs to three main categories: incident solar and reflected solar both on the sunlit side of the Earth and Earth emitted IR all around the globe. The Baseline Summary divides this energy into six wavelength ranges. It is instructive to find what is the relative distribution of the energy in each range. The distribution is shown in table I. Only two significant figures are given for the percentages of spectral distribution.

Table I  
Energy Distribution by Wavelength Range

Wavelength Range		Percentage of irradiance in the wavelength range due to		
From	To	the Sun	Earth reflected solar energy	Earth emitted IR
300	1250A	.0004		
1250	3500A	4.5	near zero	
3500	10000A	65	80	near zero
1	$5\mu\text{m}$	30	20	.4
5	$15\mu\text{m}$	.47	near zero	53
15	$150\mu\text{m}$	.019		45
150	$\infty \mu\text{m}$	.0004		2.1

fig.2

The percentages for direct solar irradiance are based on NASA design values of Ref. 1. The detailed spectrum of Earth reflected and Earth emitted IR varies considerably according sky and terrain conditions, but the percentages in the ranges listed remain about the same. The values given here were obtained by integrating the areas under the spectral curves given in Ref. 4, figure 1

for Earth reflected (from solid stratus cloud formations, Convair 990 data) and figure 5 for Earth emitted IR (from mid-latitude ocean, Nimbus 4 data). The percentages for solar and Earth IR irradiance are also shown graphically in figure 2 which is reproduced from figure 4.1 of BS (p.17) with two narrow vertical bars added, to the left for solar irradiance and to the right for Earth emitted IR. The height of the bars is on a relative (0 to 1) scale, normalized to the maximum percentage, visible/near IR for solar irradiance and long wave IR for Earth emitted IR. All wavelength ranges are represented at approximately the same level of emphasis in the BS for both primary and secondary experiments. This is not true for the relative distribution of energy. Though the solar energy in the XUV and for UV ranges is quite small, a relatively greater emphasis on experiments is placed because of the interest in the effects of the high energy photons on the upper layers of the atmosphere and the well-known large variations in solar flux.

No direct measurements of the Sun from the spacecraft would be necessary if we know to a sufficiently high order of accuracy the values of the solar constant and solar spectral irradiance and we also know that they are truly constant and independent of all other variable solar phenomena. It would be sufficient to adopt the values available in literature, for example, the NASA design values, and apply the corrections for the seasonal changes in Sun-Earth distance. Nor would the solar measurements be highly necessary if it were known that the changes in solar irradiance are minimal and have little or no effect on the atmospheric phenomena which are being studied.

#### UNCERTAINTY IN IRRADIANCE VALUES

But, as a matter of fact, the solar constant and the solar spectral irradiance are not known very accurately, they are subject to variations over undetermined ranges and these variations have an effect on the Earth-atmosphere system apparently far in excess of the magnitude of the variation. These are the three main reasons for making direct measurements of the Sun concurrently and in the same spectral bands as the measurements directed towards the Earth and the atmosphere.

6

Measurements of the solar constant have been made over a long period of time, starting from the pioneering work of Pouillet in 1838. In 1906 Hahn's standard work on Meteorology published without preference three values of the solar constant which were currently proposed. In the now preferred units of  $Wm^{-2}$  they were Pouillet's 1230, Langley's 2140 and Angström's 2790. The margin of uncertainty has diminished significantly since then, but even now the solar constant is not known to an accuracy at all comparable to that of other physical constants, velocity of light, electron charge, Planck's constant and the like. In 1954 F. S. Johnson derived the value  $1395 Wm^{-2}$  which was accepted as definitive, at least in the United States, till recently when measurements made at high altitudes led to a lower revised standard,  $1353 W.m^{-2}$ . This figure has been accepted as the NASA design value (Reference 1) and has been proposed as standard value for testing in the Book of Standards of the American Society for Testing Materials (Reference 5). The estimated error in this value is  $\pm 1.5$  percent. This has been based on nine values derived from extensive series of independent measurements made by different types of total irradiance detectors from high altitude platforms, Convair 990, B.57 B, balloons, X-15 and Mariner space probe. These nine values vary between a minimum of 1338 and a maximum of 1368, a range wider than the error limits assigned by the individual experimenters to their values. Most of these determinations required troublesome corrections for the residual atmosphere and water vapor above the aircraft or balloon, transmittance of the window material and other causes.

fig.3 The standard spectral irradiance curve is based mainly on the results obtained by a group of experimenters from NASA/GSFC. They used four instruments for  $\lambda$  0.3 to  $4\mu m$ , two monochromators, Perkin-Elmer and Leiss, a filter radiometer and a polarization type interferometer, but not all of them covered the whole range. The instruments were mounted in a Convair 990 jet aircraft. The solar spectrum was scanned at an altitude of 11.6 km. At this altitude the residual absorbents are 20% of the permanent gases and about 0.1% of the total water vapor content of the atmosphere. Hence the measurements are significantly more accurate than at ground level. However, the spectral curves obtained by the different instruments were not identical as shown in Figure 4. The data from a Cary 14 flown by NASA/Ames are also shown in the figure; these data were not

Table 2  
(Page 18)

Fig. 4

used in the derivation of the standard curve because of calibration difficulties. The differences between the Perkin-Elmer, Leiss and filter radiometer in the ranges .45 to .65 $\mu\text{m}$  and .85 and 1.05 $\mu\text{m}$  are relatively large. Another set of data on which the standard curve is based was obtained by the Eppley-JPL team in several series of flights on board Convair 990, B-57B and X-15 rocket aircraft. The instruments were filter radiometers which give the integrated solar energy over the transmittance band of each filter. The Eppley-JPL values and the values obtained from the weighted average of the NASA/GSFC curves as also the ratio of these values are given in Table III. Of the 20 spectral bands, 11 have ratios between 0.95 and 1.05; the other 9 ratios lie outside this range and four of them are greater than 1.10. These differences among the data of the GSFC instruments and between the GSFC weighted curve and the Eppley-JPL data may be due to instrumental errors, errors in the extrapolation to zero air mass and uncertainties in the spectral irradiance standards. The GSFC experimenters used 1000 W quartz iodine lamps as calibration standards. The Eppley-JPL standard was the Ångström pyrheliometer (IPS 56 scale) and the spectral sensitivity of each channel was computed using the transmittance function of the filter. The standard solar spectral curve was derived by modifying the GSFC curve over the range 0.3 to 0.7 $\mu\text{m}$  in the light of the Eppley-JPL results and normalizing it to the value  $1353\text{Wm}^{-2}$ .

Fig.5

TABLE III

Eppley-JPL Filter Radiometer Measurements with Corresponding  
Results from GSFC Solar Spectral Curve

$\lambda$ (nm)	mW cm <sup>-2</sup>		<u>E-JPL</u> <u>GSFC</u>
	<u>E-JPL</u>	<u>GSFC</u>	
235-344	5.52	5.24	1.05
272-322	2.78	2.58	1.08
295-365	6.99	6.29	1.11
298-344	4.22	3.88	1.09
334-403	7.78	7.63	1.02
355-430	10.1*	10.2	0.99
410-474	11.8	11.9	0.99
430-490	11.5*	11.8	0.97
446-500	10.6	10.8	0.98
490-565	13.3*	13.7	0.97
508-592	14.9	14.7	1.01
535-603	12.1*	11.6	1.04
565-631	12.1*	10.9	1.11
595-645	8.83	7.89	1.12
603-663	10.3*	9.24	1.11
603-697	15.0*	14.1	1.06
631-697	10.3*	9.62	1.07
645-700	8.47	7.91	1.07
697-963	28.2*	28.1	1.00
1,250-2,000	17.3	18.0	0.96

\* Values derived differentially from adjacent pairs of broad bandpass filters; other E-JPL values are from narrow bandpass interference filter measurements.

Differences of considerably greater magnitude have been observed between the standard curve and earlier solar curves proposed by other authors. These differences are shown graphically in figs. 6 & 7. The X-axis is wavelength in  $\mu\text{m}$ ; the Y-axis is the ratio  $k P'_\lambda / P_\lambda$ , where  $P'_\lambda$ ,  $P_\lambda$  are the irradiance according to one of the earlier curves and the standard curve respectively and  $k$  is a normalizing constant which makes the area under the other curves equal to that under the standard curve for the spectral range common to both. This mode of presentation permits the differences in spectral irradiance to be studied independently of the differences in solar constant. The relatively high values of the ratio for Johnson in the visible and for Nicolet at  $2\mu\text{m}$  and the low values for Nicolet and for Labs and Neckel in the visible and near UV are particularly worthy of note.

Fig.6,7

#### VARIABILITY OF SOLAR ENERGY OUTPUT

A closely related problem is the variability of the values of the total and spectral solar irradiance. At the NCAR Seminar on "Possible Responses of Weather Phenomena to Variable Extra-Terrestrial Influences," J. M. Mitchell presented a review paper entitled "The Solar Inconstant." A copy of that paper is included here. (Reference 5) The author says (p. 157): "I think it is a curious thing - I am tempted to use the word shocking, but I don't think I need to say that - that in the year of our Lord 1965 and in the year of our Satellite 7, going on to 8, we have yet to put an instrument into space above the atmosphere to find out once and for all whether the solar constant is changing along with all the other features on the Sun that we know are changing." And a little later, (p.158): "Clearly we should be giving highest priority in our space program to any promising scheme to get an accurate measure of the radiative temperature of the Sun over all wavelengths."

Fig.9

The author presents a large mass of observational data in support of these statements. He shows that there is a real possibility that the energy received by the Earth-atmosphere system from the Sun is variable and that such changes have an effect on many terrestrial phenomena and mainly on the weather. The data include the wintriness index of the northern hemisphere sea-level pressure pattern, the annual frequency of Etesian winds in Athens, the annual march of temperature in different cities of Europe, changes in meridional sea level

pressure, etc. There are many changes in the Earth-atmosphere system which have a strong correlation with changes in the Sun, in the number of sun spots, the rotation of the Sun, and non-periodic types of solar activity.

Several attempts have been made to determine the variation of the solar constant with the eleven year solar cycle. The most extensive data are those of the Smithsonian Institution. But the difficulties due to atmospheric corrections and the changes in radiation scales prevent an exact evaluation of the magnitude of the change. Kondratyev and his co-workers at the University of Leningrad (Reference 6) have analyzed the data from their balloon measurements over a period of six years. They conclude that the maximum value of the solar constant coincides with Wolf numbers 80 to 100, and that the solar constant decreases by 2 to 2.5 percent during sunspot maximum and minimum. A slightly different conclusion emerges from the data of the Lowell Observatory Solar Variations Project where the photometric magnitude of outlying planets Neptune and Uranus were measured relative to the magnitude of the background stars. During a cycle of sunspot number change from 2 to 200, the blue magnitude of Neptune changes by 0.2, which is equivalent to a change in the solar constant of 1.4%. Mitchell shows that this figure is in agreement with net long term trend in the Smithsonian data over the period 1925 to 1951.

If there are changes in the total energy emitted by the Sun, there is no reason to suppose that these changes affect all spectral regions uniformly. The known changes in the UV range below 3000A are quite inadequate to explain the changes in the solar constant. The sunspots are at a relatively lower temperature of 4000 K. The blackbody curve of 4000K is obviously red-shifted compared to that of 6000K. During a sunspot maximum, if the radiation from the rest of the solar surface remains the same, the solar constant should be less, not greater than during a sunspot minimum. If the solar constant is greater during sunspot maximum, as is apparently the case, greater sunspot activity is accompanied by higher temperatures outside the sunspots. The combined effect on spectral distribution would be quite different from that during sunspot minimum.

The changes in solar irradiance in the UV below 2500 A and in the microwave range between 2 cm and 10 m have been well established.

They vary by a factor of two or three in the UV and over a far wider range in the microwave range. The irradiance due to the Lyman -  $\alpha$  emission is  $5 \text{ ergs cm}^{-2} \text{ s}^{-1}$  and is subject to vary by 20 or 30 percent. Lyman -  $\alpha$  accounts for about two-thirds of all the energy below  $1250\text{\AA}$ . The changes in the range of greatest solar output,  $3000\text{\AA} < \lambda < 4 \mu\text{m}$  are not likely to be of this order of magnitude; nor can we assume that the changes are as small as in the solar constant itself. While there is a great deal in literature about changes in the solar constant and their effects on weather, there is hardly any mention of changes in the spectral distribution. The reason is not that changes do not exist, but they are totally unknown and unexplored. Ground based measurements of the solar spectral irradiance cannot yield the accuracy needed for detecting changes and relating them to solar events and cycles. Detailed spectral measurements from high altitude aircraft have been reported by only one group of researchers, the NASA/GSFC team, and these measurements were made over a limited two week period.

#### EFFECTS ON THE EARTH ATMOSPHERE SYSTEM

That the Earth-atmosphere system reacts to changes in the input energy of the Sun is a well established fact. The density of the ozone layer changes from day to night. The changes in the ionization layers of the upper atmosphere and their dependence on solar phenomena have been studied in great detail because of their direct consequences for radio communication. The geomagnetic disturbances have a periodicity of 27 days superposed on an eleven year period in agreement with the rotational and Wolf number cycles of the Sun. Long period correlation with sunspot cycle has been observed in such weather related phenomena like the water level in rivers and lakes, annual growth rings of petrified and living trees and the advance and retreat of glaciers. There are also the other data cited by Mitchell as mentioned earlier.

None of these effects is dependent solely on the total input energy, the solar constant; they are strongly wavelength dependent. The atmosphere is far from being a neutral density filter; nor is the land and ocean surface of the Earth an achromatic absorber. The Earth albedo spectrum is different

from the solar spectrum. Ozone production is due to the UV, as also erythematous effects. Photosynthesis essential for all life support, is due to two wavelength bands centered at 4400 and 7500 Å. Other resonance phenomena are the photomorphogenic responses like seed and flower development, shape and size of leaves, plant height, movement of leaves (as in the mimosa); the associated wavelengths are 6600 and 7300 Å. Absorption by water vapor with all its major effects on the making of weather is in narrow wavelength bands, all of them beyond 7000Å, which is the more poorly known part of the solar spectrum. Specific wavelengths are responsible for the atmospheric dissociation of the molecules of oxygen, nitrogen and water vapor.

Most of the instruments on board the Atmospheric Science Facility are directed towards the Earth. They measure the energy radiated by the Earth-atmosphere system in all wavelength bands. All the energy they measure is what the Earth and atmosphere receive from the Sun and reradiate either at the same wavelength or a longer IR wavelength. Any changes, cyclic or non-cyclic in the Sun cause corresponding changes in the radiation received by Earth atmosphere system, with 8 minutes lag for photon flux and about 16 hours lag for corpuscular flux. Solar events such as flares cause corpuscular emission of which the effects are observed in aurorae, geomagnetic disturbances, changes in cosmic ray flux, increase in ionization of the D layer, possibly localized heating of the atmosphere. Changes in photon flux though small apparently act as a trigger mechanism which upsets a delicate energy balance and causes large scale meteorological effects.

#### CONCLUSION

Thus it is seen that it is of extreme importance that the Atmospheric Science Facility should measure the solar radiant flux simultaneously with the measurements by instruments directed towards the Earth and the atmosphere. Both the solar constant and solar spectral irradiance should be monitored. This can be done with sufficient accuracy from the ASF since the instruments and data tapes are recoverable and calibration with reference to irradiance standards can be made in flight and after flight. Thus we can eliminate the serious uncertainties due to residual atmosphere as in high altitude aircraft and to detector degradation as has been experienced in the UV sensors

of Nimbus and IR Sun sensors of ERTS. Solar irradiance data should be made immediately available to the other experimenters on board who have their instruments directed towards the Earth. Specifications as to wavelength resolution, field of view, pointing accuracy, etc., as given the Baseline Summary (pp.18,19) are adequate; but perhaps these may need a closer study as experiment design progresses.

In this connection it is well to note that not only the ASF but also other atmospheric science programs are planning to make solar irradiance measurements. There is a growing awareness in the scientific community of the need of this type of measurement. Of special interest is the Complex Atmospheric Energetics Experiment (CAENEX). It is being conducted by the Soviet Commission of the Global Atmospheric Research Program (GARP). The general aim of CAENEX is to investigate the flux and flux divergences in a closed volume in the troposphere, using aircraft and balloons, supplemented by satellite and surface measurements (Reference 7). The proposed program of observations and calculations has eight sub-headings, the first of which is "Observations of the solar constant and its possible variations." The program will be extended over a period of five years. A pilot study was made in the fall of 1970. This program does not, however, include any detailed study of the solar spectral irradiance. A second subprogram of GARP, the GARP Atlantic Tropical Experiment (GATE) also plans to measure the solar input flux, but the experimental details have not yet been fully specified.

The experiment proposed for the Atmospheric Science Facility will probably be the first major attempt to measure the total and spectral solar irradiance over the entire wavelength range with sufficient degree of accuracy and resolution. It will provide the answer to a number of questions which have often been raised but never answered about solar terrestrial relationships. It will also be an essential contribution to the five primary objectives of the ASF, in particular to radiation budget and atmospheric pollution.

1. Anon, Solar Electromagnetic Radiation, NASA SP 8005, NASA, Washington, D. C., May 1971, pp. 13,14.
2. Anon, ASF Scientific Objectives Conference, Transcript. p. 1-16.
3. R. A. Hanel, "An Instrument to Measure the Solar Constant from a Satellite," NASA TN D-674, April 1961.
4. Anon, Earth Albedo and Emitted Radiation, NASA SP 8067, NASA, Washington, D. C., July 1971, p.8.
5. IES Solar Radiation Com. and ASTM Space Simulation Committee, "Proposed Specification for the Solar Constant and Air Mass Zero Solar Spectral Irradiance" in NASA SP 298, pp. 955-968, NASA, Washington, D. C. 1972.
6. J. M. Mitchell, "The Solar Inconstant," NCAR Technical Note TN-8, pp. 155-174, NCAR, Boulder, Colorado, 1965.
7. K. Ya. Kondratyev and G. A. Nikolsky, Q.J. Roy Meteor Soc. 96, 509 (1970).
8. J. London in "Proceedings of the Miami Workshop on Remote Sensing," Boulder, Colorado, July 1971, p. XV.

MEASUREMENT OF TOTAL AND SPECTRAL SOLAR  
SPECTRAL IRRADIANCE OUTSIDE THE ATMOSPHERE.  
NECESSARY FOR STUDIES OF

AIR GLOW

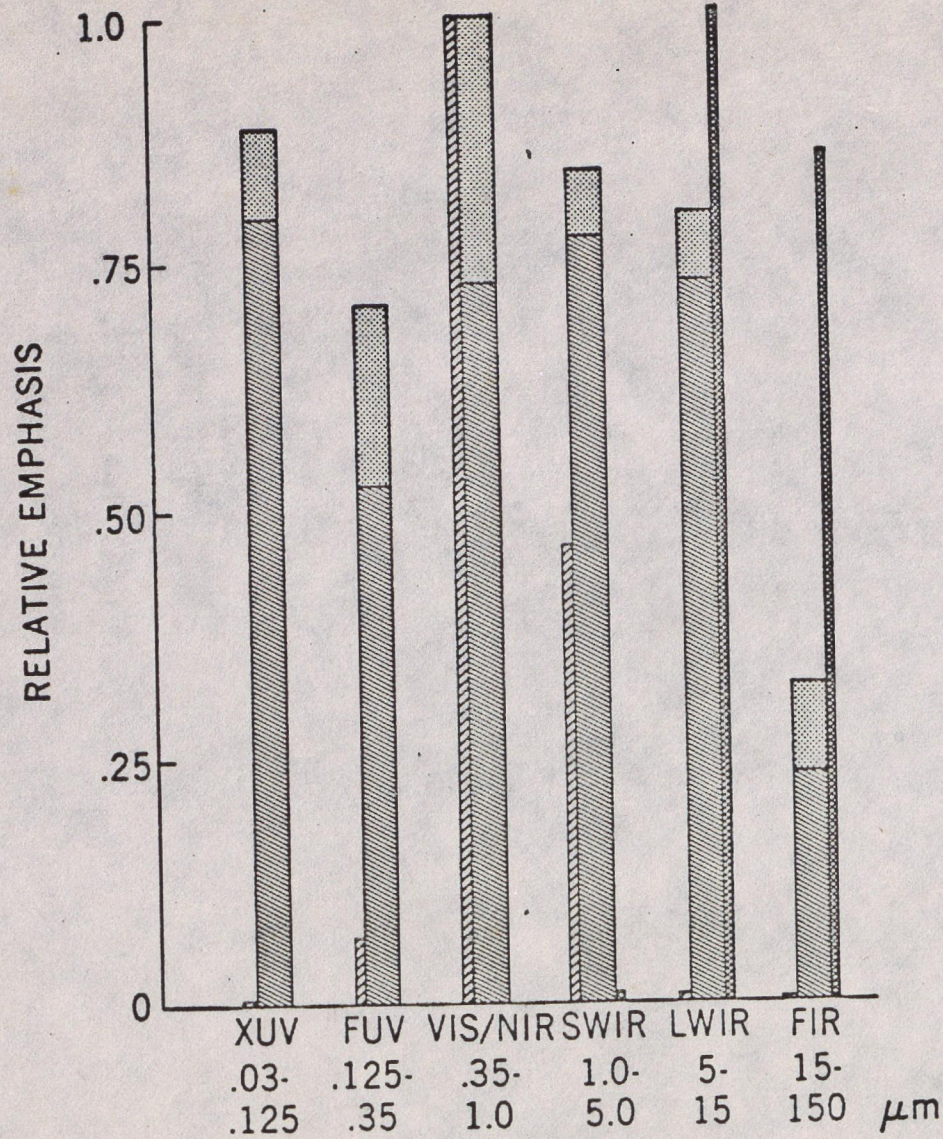
RADIATION BUDGET

AEROSOL SCATTERING

ATMOSPHERIC STRUCTURE

ATMOSPHERIC POLLUTION

*Fig 11*



EXPERIMENTS AND ENERGY DISTRIBUTION  
VERSUS WAVELENGTH REGION.

PRIMARY  
EXPERIMENTS

SECONDARY  
EXPERIMENTS

SOLAR SPECTRAL  
IRRADIANCE

EARTH EMITTED  
RADIANCE

Fig. 2

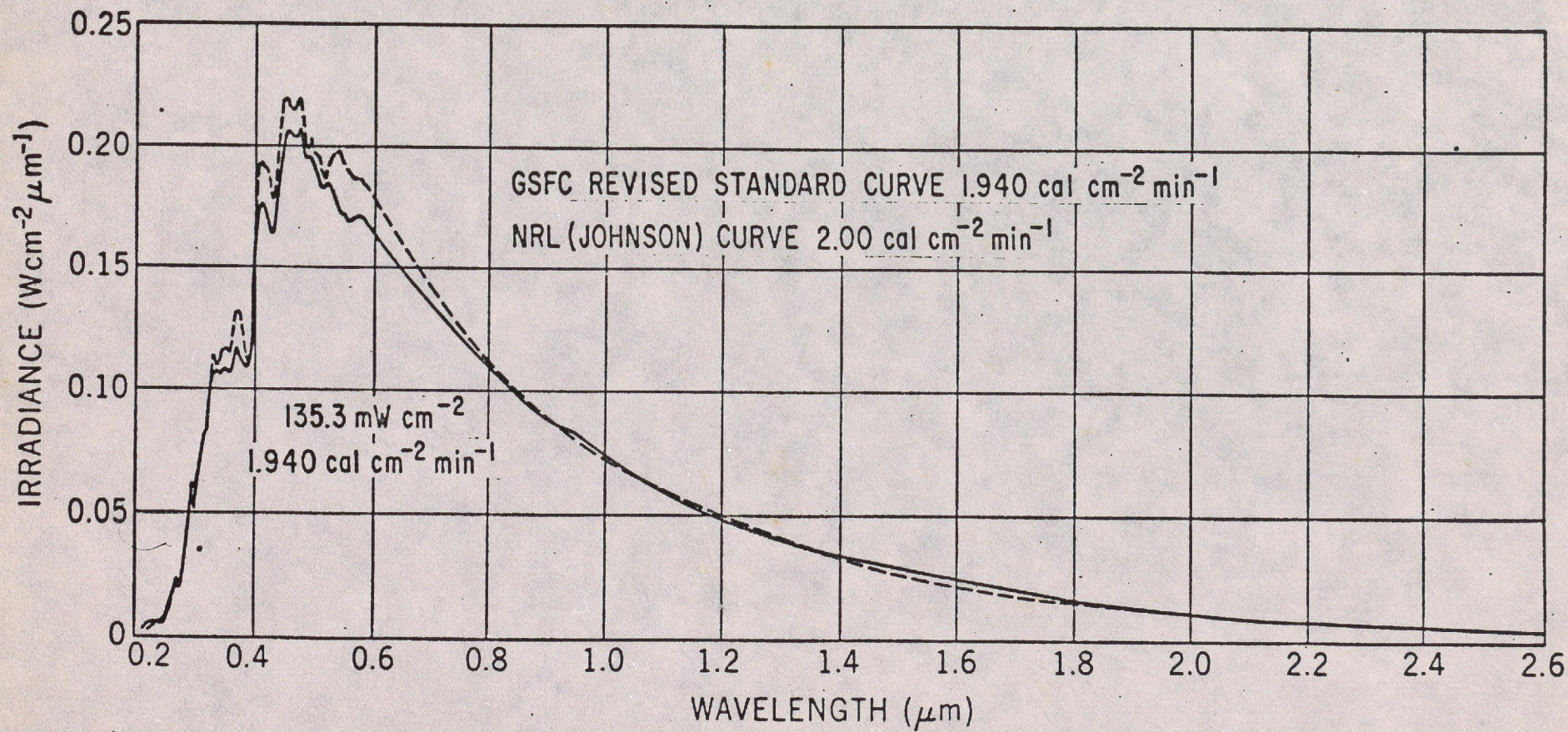


Fig 3

λ - Wavelength in micrometers

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

$E_{0-\lambda}$  - Integrated solar irradiance in the wavelength range 0 to λ, in  $W m^{-2}$

$D_{0-\lambda}$  - Percentage of solar constant associated with wavelengths shorter than λ

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

Note: lines indicate change in wavelength interval of integration

λ	$E_{\lambda}$	$E_{0-\lambda}$	$D_{0-\lambda}$	λ	$E_{\lambda}$	$E_{0-\lambda}$	$D_{0-\lambda}$	λ	$E_{\lambda}$	$E_{0-\lambda}$	$D_{0-\lambda}$
.115	.007	.0025	.0001	.510	1442	324.926	24.015	1.55	267	1196.109	87.665
.120	.900	.0044	.0002	.515	1433	374.214	24.701	1.60	249	1198.707	88.411
.125	.007	.0070	.0005	.520	1433	343.379	25.129	1.65	223	1210.609	87.475
.130	.007	.0071	.0005	.525	1452	352.591	26.059	1.70	202	1221.234	89.761
.140	.030	.0073	.0005	.530	1442	361.826	26.742	1.75	180	1230.784	90.767
.150	.070	.0074	.0005	.535	1418	370.976	27.414	1.80	159	1239.259	91.593
.160	.230	.0093	.0006	.540	1743	379.979	28.084	1.85	142	1246.784	92.149
.170	.630	.0136	.0010	.545	1754	388.821	28.737	1.90	126	1253.484	92.644
.180	1.250	.0230	.0016	.550	1725	397.519	29.390	1.95	114	1259.484	93.088
.190	2.710	.0428	.0031	.555	1720	406.131	30.017	2.00	103	1264.909	93.489
.200	10.7	.1098	.0081	.560	1635	414.669	30.648	2.1	90	1274.559	94.2024
.210	22.9	.2778	.0205	.565	1705	423.169	31.276	2.2	79	1283.009	94.8269
.220	57.5	.6798	.0502	.570	1712	431.711	31.907	2.3	69	1290.409	95.3739
.225	64.9	.9858	.0728	.575	1719	440.289	32.541	2.4	62	1296.959	95.8580
.230	66.7	1.3148	.0971	.580	1715	448.874	33.176	2.5	55	1302.809	96.2903
.235	59.3	1.6298	.1204	.585	1712	457.441	33.809	2.6	48	1307.959	96.6710
.240	63.0	1.9356	.1430	.590	1700	465.971	34.439	2.7	43	1312.509	97.0073
.245	72.3	2.2738	.1680	.595	1682	474.426	35.064	2.8	39	1316.609	97.3103
.250	70.4	2.6306	.1944	.600	1666	482.796	35.683	2.9	35	1320.309	97.5838
.255	104.0	3.0666	.2266	.605	1647	491.079	36.295	3.0	31	1323.609	97.8277
.260	130	3.6516	.269	.61	1635	499.284	36.902	3.1	26.0	1326.459	98.0383
.265	185	4.4391	.328	.62	1602	515.469	37.098	3.2	22.6	1328.889	98.2179
.270	232	5.4816	.405	.63	1570	531.329	37.270	3.3	19.2	1330.979	98.3724
.275	204	6.5716	.485	.64	1544	546.899	37.421	3.4	16.6	1332.769	98.5047
.280	222	7.6366	.564	.65	1511	562.174	37.550	3.5	14.6	1334.329	98.6200
.285	315	8.9791	.663	.66	1486	577.159	37.657	3.6	13.5	1335.734	98.7238
.290	482	10.9716	.810	.67	1456	591.869	37.744	3.7	12.3	1337.024	98.8192
.295	584	13.6366	1.007	.68	1427	606.284	37.810	3.8	11.1	1338.194	98.9056
.300	514	16.3816	1.210	.69	1402	620.429	37.855	3.9	10.3	1339.264	98.9847
.305	603	19.1741	1.417	.70	1369	634.284	37.879	4.0	9.5	1340.254	99.0579
.310	689	22.4041	1.655	.71	1344	647.849	37.882	4.1	8.70	1341.1641	99.12521
.315	764	26.0366	1.924	.72	1314	661.139	37.864	4.2	7.80	1341.9891	99.18618
.320	830	30.0216	2.218	.73	1290	674.159	37.826	4.3	7.10	1342.7341	99.24124
.325	975	34.5341	2.552	.74	1260	686.909	37.769	4.4	6.50	1343.4141	99.29150
.330	1059	39.6191	2.928	.75	1235	699.384	37.691	4.5	5.92	1344.0351	99.33740
.335	1081	44.9691	3.323	.76	1211	711.614	37.595	4.6	5.35	1344.5986	99.37905
.340	1074	50.3566	3.721	.77	1185	723.594	37.480	4.7	4.86	1345.1091	99.41678
.345	1069	55.7141	4.117	.78	1159	735.314	37.346	4.8	4.47	1345.5757	99.45127
.350	1093	61.1191	4.517	.79	1134	746.779	37.194	4.9	4.11	1346.0049	99.48299
.355	1083	66.5591	4.919	.80	1109	757.994	37.023	5.0	3.79	1346.3999	99.51219
.360	1068	71.9366	5.316	.81	1085	768.966	36.834	6	1.8200	1349.2049	99.71950
.365	1122	77.4366	5.723	.82	1060	779.694	36.627	7	.9900	1350.6099	99.82335
.370	1181	83.2191	6.150	.83	1036	790.174	36.401	8	.5850	1351.3974	99.88155
.375	1157	89.0641	6.582	.84	1013	800.419	36.158	9	.3670	1351.8734	99.91673
.380	1120	94.7566	7.003	.85	990	810.434	35.899	10	.2410	1352.1774	99.93920
.385	1098	100.3016	7.413	.86	968	820.224	35.622	11	.1650	1352.3804	99.95420
.390	1098	105.7916	7.819	.87	947	829.799	35.330	12	.1170	1352.5214	99.96462
.395	1189	111.5091	8.241	.88	926	839.164	35.022	13	.0851	1352.6224	99.97209
.400	1429	118.0541	8.725	.89	908	848.334	34.700	14	.0634	1352.6967	99.97758
.405	1644	125.7366	9.293	.90	891	857.329	34.365	15	.0481	1352.7524	99.98170
.410	1751	134.224	9.920	.91	880	866.184	34.019	16	.037100	1352.7950	99.98485
.415	1774	143.036	10.571	.92	869	874.929	33.665	17	.029100	1352.8281	99.98730
.420	1747	151.839	11.222	.93	858	883.564	33.304	18	.023100	1352.8542	99.98923
.425	1693	160.439	11.858	.94	847	892.089	32.934	19	.018600	1352.8751	99.99077
.430	1639	168.769	12.473	.95	837	900.509	32.556	20	.015200	1352.8920	99.99202
.435	1663	177.024	13.083	.96	820	908.794	32.168	25	.006170	1352.9454	99.99596
.440	1810	185.706	13.725	.97	803	916.909	31.768	30	.002970	1352.9683	99.99765
.445	1922	195.036	14.415	.98	785	924.849	31.355	35	.001600	1352.9797	99.99850
.450	2006	204.856	15.140	.99	767	932.609	30.928	40	.000942	1352.9860	99.99997
.455	2057	215.014	15.891	1.00	748	940.184	30.488	50	.000391	1352.9927	99.99946
.460	2066	225.321	16.653	1.05	668	975.584	27.105	60	.00019100	1352.9956	99.99967
.465	2048	235.606	17.413	1.10	593	1007.109	24.435	80	.00006160	1352.9981	99.99986
.470	2033	245.809	18.167	1.15	535	1035.309	21.519	100	.00002570	1352.9990	99.99992
.475	2044	256.001	18.921	1.20	485	1060.809	18.404	120	.00001260	1352.9994	99.99995
.480	2074	266.296	19.681	1.25	438	1083.884	15.109	150	.00000523	1352.9997	99.99997
.485	1976	276.421	20.430	1.30	397	1104.759	11.652	200	.00000169	1352.9998	99.99999
.490	1950	286.236	21.155	1.35	358	1123.634	8.047	250	.00000070	1352.9999	99.99999
.495	1960	296.011	21.878	1.40	337	1141.009	4.331	300	.00000034	1352.9999	99.99999
.500	1942	305.766	22.599	1.45	312	1157.234	0.530	400	.00000011	1352.9999	99.99999
.505	1920	315.421	23.312	1.50	288	1172.234	0.639	1000	.00000000	1353.0000	100.00000

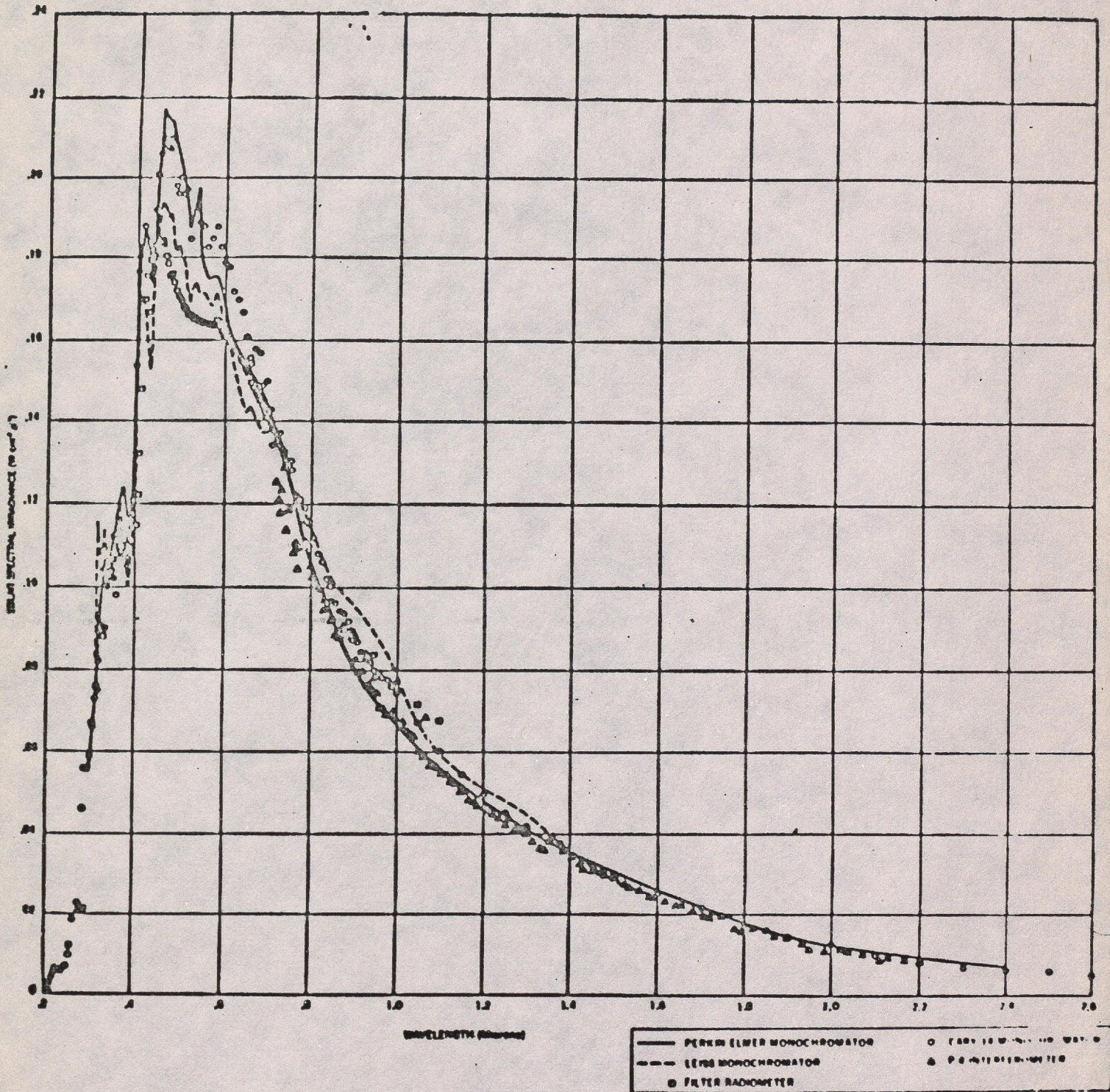


Figure 2. Solar spectral irradiance curves obtained by the different instruments on board Convair 990 in August 1967.

# EPPLEY/JPL SOLAR DATA COMPARED TO GSFC DATA

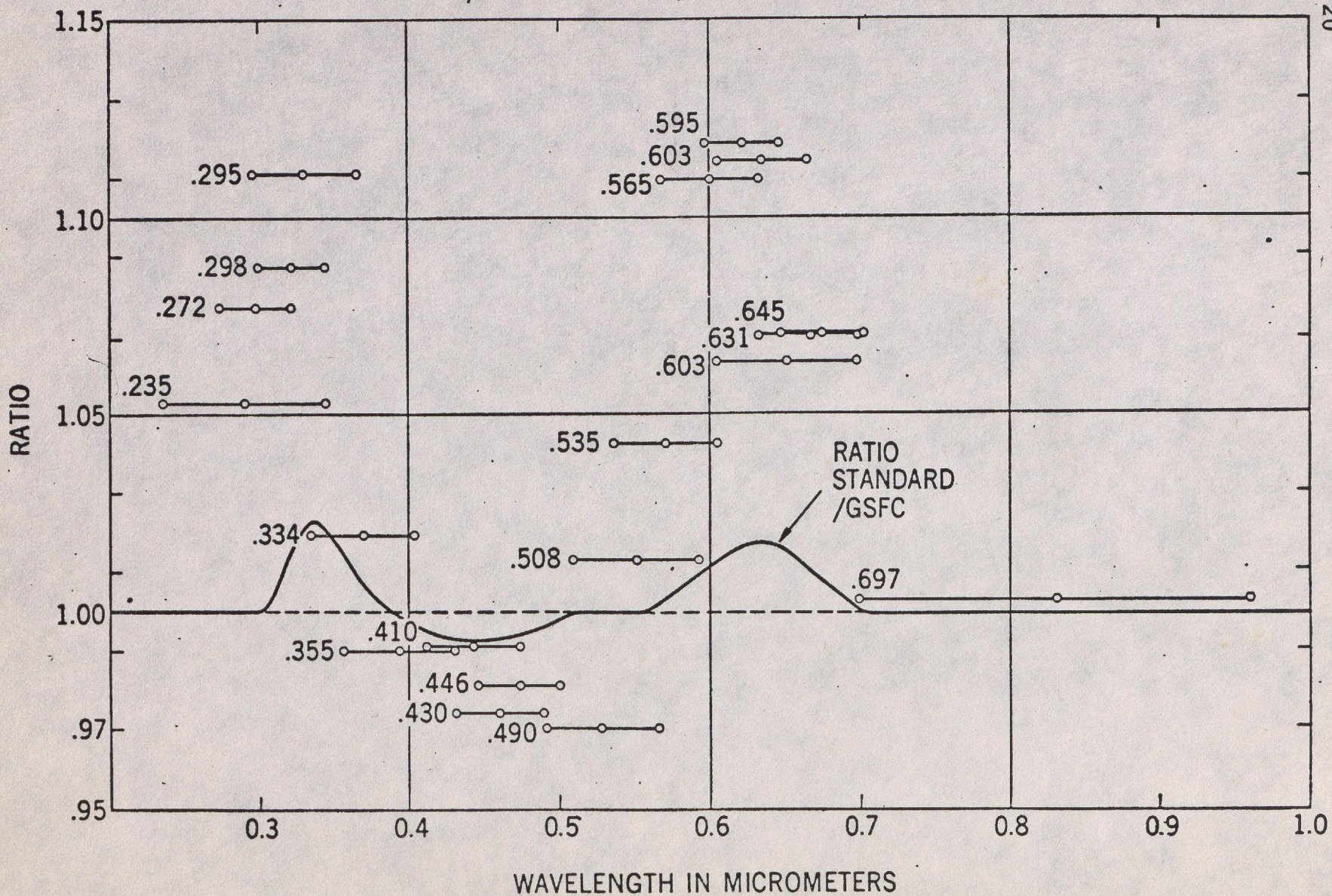


Fig. 5

# COMPARISON WITH SOLAR CURVES OF JOHNSON AND LABS & NECKEL

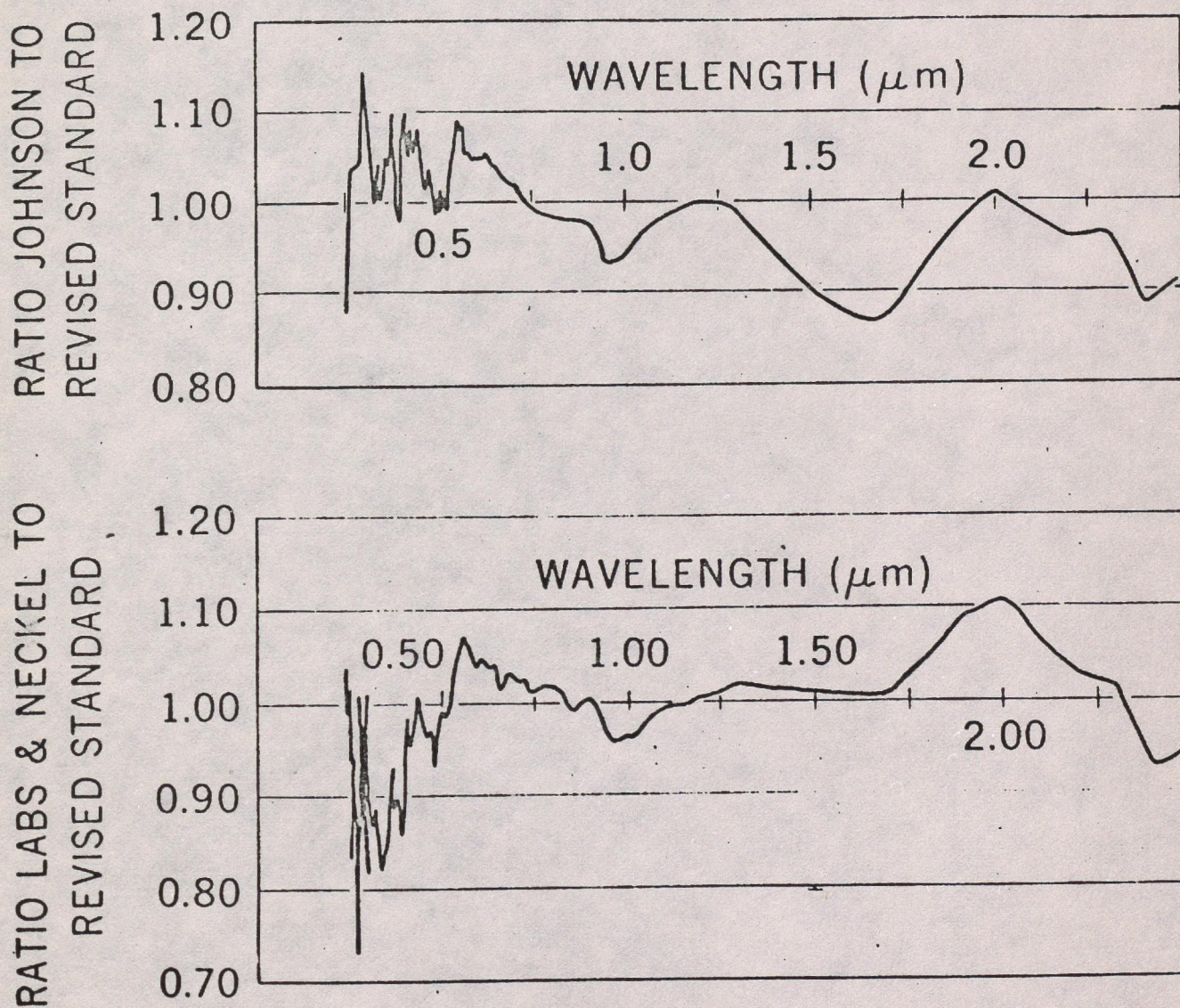


Fig 6

# COMPARISON WITH SOLAR CURVES OF NICOLET, STAIR & GSFC NASA 711

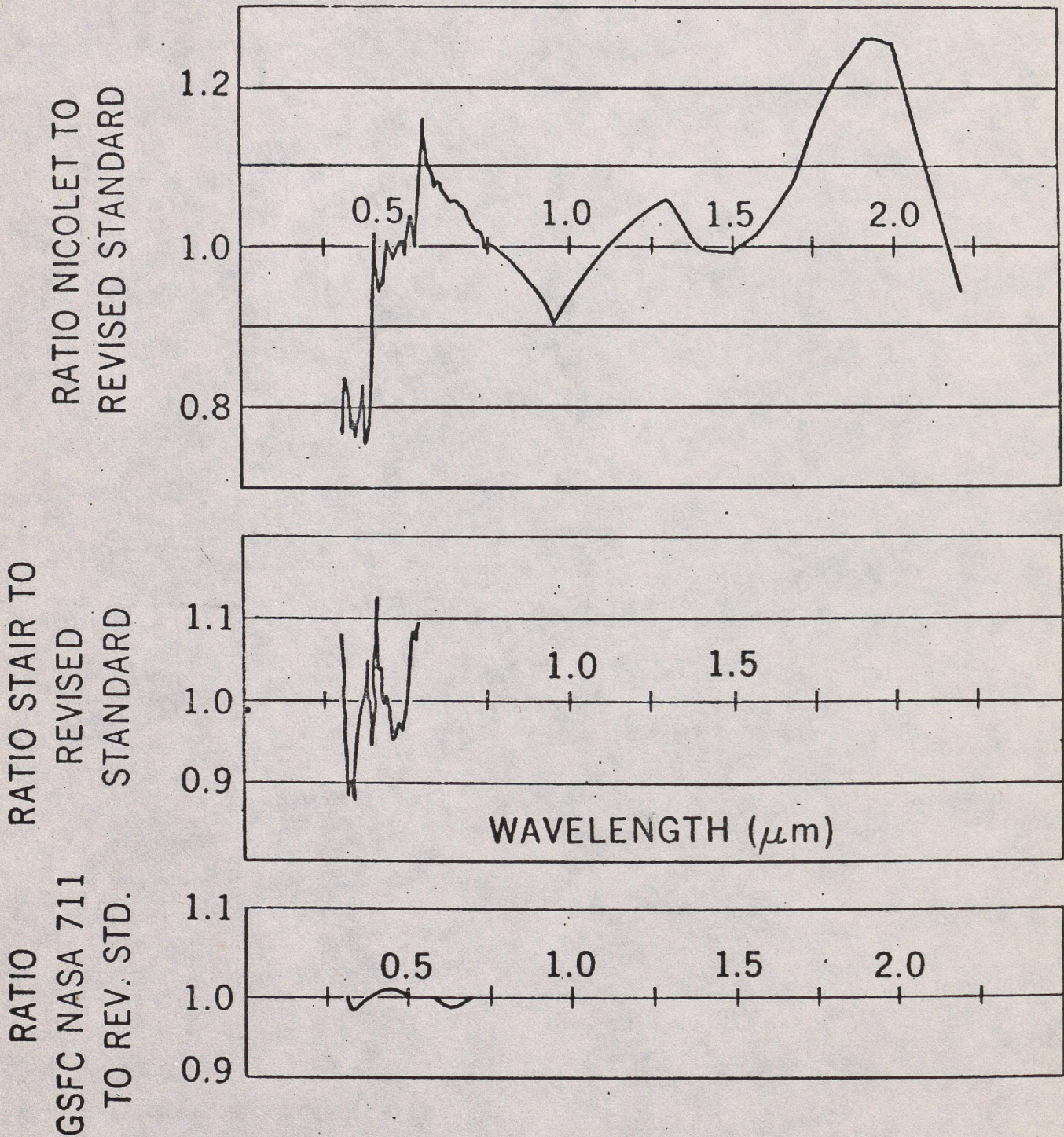


Fig 7

SOLAR CONSTANT: NRL VALUE  $1395\text{Wm}^{-2}$

NASA DESIGN STANDARD  $1353\text{Wm}^{-2}$   
 $\pm 1.5\%$

BASED ON VALUES RANGING FROM  
1338 TO 1368

SOLAR SPECTRUM UNCERTANITY

SCATTER AMONG GSFC CV 990  
SPECTRAL CURVES

DIFFERENCES BETWEEN GSFC AND  
EPPLEY-JPL DATA

OTHER SOLAR CURVES WIDELY DIFFERENT.

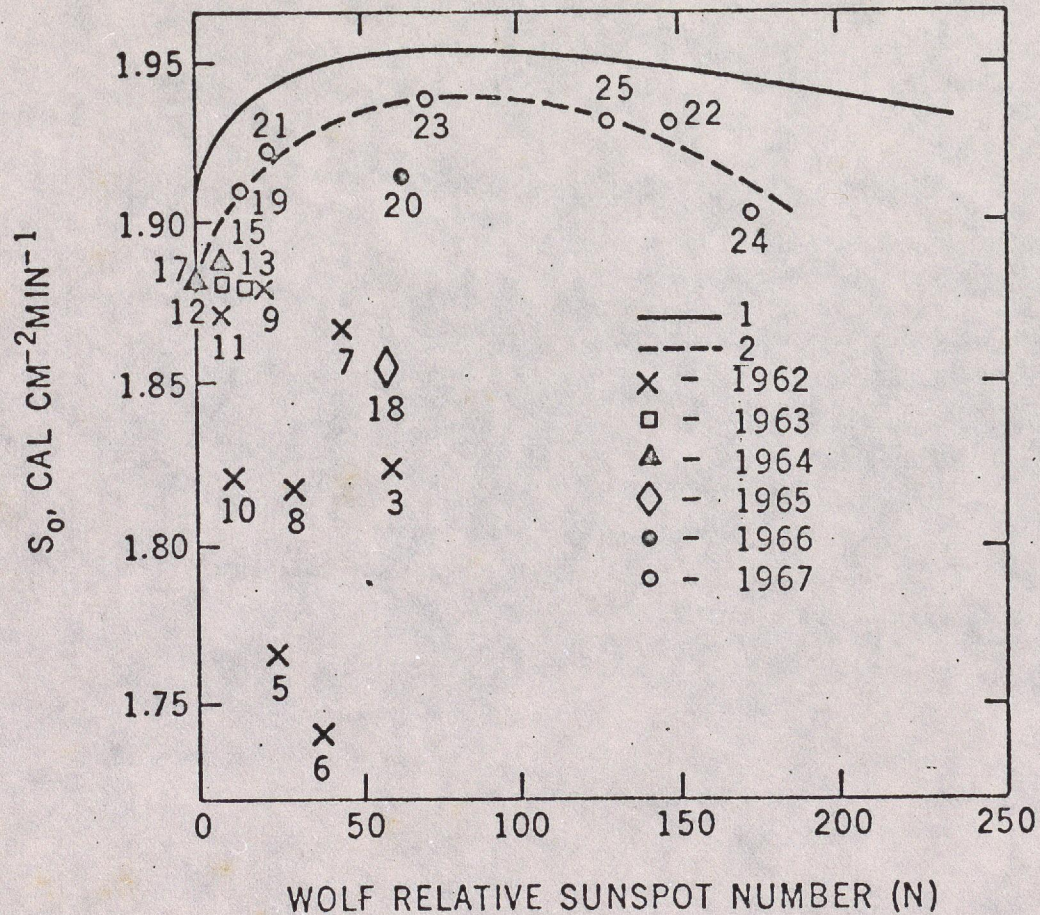
SPECTRAL VARIATIONS UNEXPLORED  
AND UNKNOWN

*Fig 8*

## SOLAR CONSTANT AND SOLAR SPECTRUM

- 1) ARE NOT KNOWN ACCURATELY
- 2) ARE SUBJECT TO VARIATIONS OVER UNDETERMINED RANGES
- 3) AFFECT THE EARTH-ATMOSPHERE SYSTEM THROUGH THESE VARIATIONS

*Fig 9*



1. THE  $S_0(N)$  DEPENDENCE OBTAINED BY ÅNGSTRÖM (SMITHSONIAN SCALE OF DIRECTLY MEASURED VALUES; DIFFERS FROM THE INTERNATIONAL PYRHELIOMETRIC SCALE OF 1956 BY +0.2 PER CENT).
2. THE  $S_0(N)$  DEPENDENCE FROM LENINGRAD DATA (INTERNATIONAL PYRHELIOMETRIC SCALE OF 1956).

Fig. 10

INFLUENCE ON THE EARTH-ATMOSPHERE SYSTEM

SUNSPOT CYCLE, SOLAR ROTATION,  
DIURNAL CYCLE ON

ETESIAN WINDS

WINTRINESS INDEX

ANNUAL MARCH OF TEMPERATURE

MERIDIONAL SEA LEVEL PRESSURE

GROWTH RINGS OF TREES

OZONE DENSITY

GEOMAGNETISM

GLACIER MOVEMENT

*Fig 11*

UNITED STATES GOVERNMENT

# Memorandum

TO : Dr. L. H. Meredith  
Assistant Director

FROM : Dr. M.P. Thekaekara  
Test and Evaluation Division

SUBJECT: Shuttle Sortie Study

DATE: November 3, 1972

## 1. Solar Constant and Solar Spectrum

In response to your memorandum of October 18, 1972, our group welcomes the opportunity to offer our comments on the Shuttle Sortie Study. We are particularly interested in participating in such a study. An objective of prime importance to our group is the monitoring of the solar constant and the extraterrestrial solar spectrum.

In 1967 our group made a series of flights in the CV 990 jet aircraft at 11.6 km. We measured the total and spectral irradiance of the Sun with a wide variety of instruments. The data obtained from these flights became the main basis for developing revised values of the solar constant and its spectral distribution. These values have since become a standard for usage at a national and international level, replacing the older standard which had been proposed by the Naval Research Laboratory in 1954.

*few*  
*of solar energy*  
No attempts (by any of the satellite experimenters) have been made to determine the solar constant and its spectral distribution from outside the atmosphere. A few solar irradiance studies have been made in the X-ray and UV ranges which account for less than half percent of the total energy of the Sun. The major problems in measuring the energy in the whole wavelength range are that sensors tend to degrade, instrument packages cannot be retrieved for post-flight calibration and sufficient degree of accuracy cannot be attained.



SUBJECT: Shuttle Sortie Study

## 2. Space Shuttle an Ideal Platform

The space shuttle in the sortie mode with flight duration of six to thirty days affords the opportunity for making a more precise evaluation of the Sun's energy. As was pointed out by C. W. Matthews, Associate Administrator of NASA, at the Sortie Workshop (Proceedings Vol. I, p. 1-30) the sortie mission is an analog to the Convair 990 airborne laboratory. The severe limitations of size and weight of satellite experiments are no longer a handicap. The wavelength range of special interest is from 0.2 to 4 $\mu$ m. This range contains all but one percent of the Sun's energy. Adequate precautions can be taken for calibration with reference to standards both during flight and after flight. State-of-the-art radiometric standards for both total and spectral irradiance can be carried on board. The entire solar disc or any special surface features can be studied with adequate field of view and pointing accuracy. On board participation by the experimenter permits selection of special problem areas on the disc, unusual solar events or specific spectral regions of greater variability. The main objective is the energy output of the whole Sun and its spectral distribution, and the variability of these quantities with periodic changes of the Sun such as rotation and sunspot cycles and non-periodic changes such as flares and prominences. These can be studied almost continuously with a highly automated but retrievable experimental package, requiring minimal attention from the on-board scientist.

## 3. Summary of Appendix I, Atmospheric Science Facility

As Appendix I to this memorandum is enclosed a paper which discusses in greater detail this problem, in so far as it relates to one of the working groups of the Shuttle Sortie Workshop. The Atmospheric and Space Physics working group developed the concept of an Atmospheric Science Facility (ASF) as a candidate module for the Space Shuttle Sortie mode and requested comments from the

SUBJECT: Shuttle Sortie Study

scientific community. This paper is a presentation which was made at the ASF conference in October 1972. It gives a detailed justification for monitoring the energy of the Sun in the wavelength range where most of that energy lies. The reasons given are 1) the solar constant and the solar spectrum are not known with an acceptable degree of accuracy, 2) they are subject to variations over undetermined ranges, and 3) they affect the Earth-atmosphere system through these changes. There is a great deal in literature about the variations in the solar constant, though the results of different authors are not in agreement. There is hardly anything in literature about the variations in spectral distribution in the range between the UV around  $0.3\mu\text{m}$  and the microwave region. This is not because changes do not exist but because they are totally unknown and unexplored. There is a growing awareness in the scientific community of the need of such measurements, as evidenced by the plans for the GATE program and the Soviet CAENEX program.

#### 4. Importance to Other Discipline Areas

As stated above this paper deals with the question of solar energy from the viewpoint of the Atmospheric and Space Physics working group. A strong case can be made - we shall not attempt to ~~x~~ it here - for such measurements from the viewpoint of many of the other working groups. All the reasons given here are equally applicable for Meteorology and Atmospheric Environmental Quality. This group plans for measurement of the solar constant with half percent accuracy (Proceedings Vol. II, p. 7-6) but does not mention the spectral distribution. Space Technology discusses (p. 1-J-1) the physics and chemistry laboratory in space; solar radiation along with zero-G and vacuum is its unique environment. Solar concentrators are among the sources of energy for Materials and Space Manufacturing (p. 2-10). For the discipline areas of Earth and Ocean Physics, Oceanography, Earth Resources

SUBJECT: Shuttle Sortie Study

and Surface Environmental quality, Planetary Astronomy, Infrared Astronomy, etc., the solar irradiance is a primary source of calibration, and the energy measured by their instruments is mainly that reflected or scattered from the solar energy. For UV and Optical Astronomy the Sun is a star, the brightest and the nearest. And for Solar Physics the precise monitoring of the total and spectral irradiance of the Sun is of the greatest importance. An answer might be found for the question often raised but never answered whether the Sun is a variable star.

#### 5. Conclusion

*II* We enclose here as Appendix *II* I a monograph of the NASA Space Vehicles Design Criteria series, SP 8005, entitled "Solar Electromagnetic Radiation." The design values presented here were generated mainly from the flights of Convair 990. We believe that the experience gained in obtaining these data and the inputs received subsequently from users of these data in many different discipline areas can be of advantage for the proposed study of the shuttle sortie mission.

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