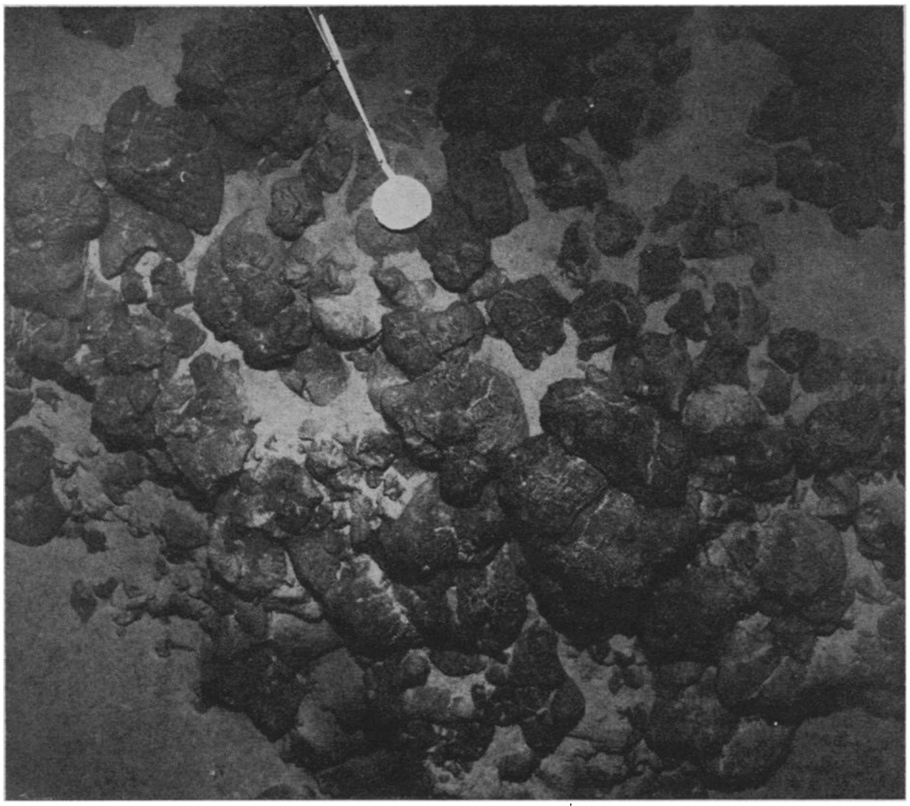

Fig. 3. Picture of the basaltic pavement showing pillow lavas. [Photo by E. Fisher]

clays and calcareous oozes in the Pacific, a rate of the order of at least 1 cm/10^3 years for the sediments accumulating on the rise seems reasonable. Under such circumstances, if the lava flows had been emplaced 10^6 or more years ago, they would by now have been covered by several meters of sediment. Lack of sediment cover suggests, therefore, that a reasonable upper limit for the age of the basalts in question is 10^6 years. This indirect estimate is substantiated by potassium-argon determinations of age on rocks from five locations along the outcrop which give ages of $< 10^6$ years (*8*). These concepts are in accordance with data which show thinning of sediment cover and increasingly younger age of the sediment as one moves toward the axis of the East Pacific Rise (*9*). The width of the axial band of basalt is similar to that of the axial positive magnetic anomaly observed in crossings of the rise at higher latitudes (*10*), which also suggests that the basalts were erupted since the last magnetic reversal, that is, since 0.8×10^6 years ago.

The fact that large volumes of fluid basalts are being outpoured from axial fissures along the rise may explain the absence of a central rift valley in the area we have surveyed: the rift valley is continuously kept filled by the lava flows. During periods of relative quiescence of the eruptive activity, tensional forces related to crustal spreading and subsidence of the thick basaltic pile at the ridge axis could result in the development of a rift valley such as is observed in the Mid-Atlantic Ridge.

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Solar Constant: First Direct Measurements

Abstract. *The solar constant was directly measured from an altitude of about 82 kilometers — apparently the first such determination. The total solar intensity was 136.1 milliwatts per square centimeter, or 1.952 calories per square centimeter, per minute—about 2.5 percent less than Johnson's derived value. Energy in the ultraviolet and visible regions (for λ less than 607 nanometers) was 7.0 percent less than that obtained by integration over Johnson's curve; for integral flux of λ greater than 607 nanometers there was almost perfect agreement. Seven supporting series of measurements from lower altitudes agreed extremely well with these results after correction for atmospheric extinction.*

The extraterrestrial flux of Sun's energetic radiation, integrated over all emission wavelengths and referred to one astronomical unit (defined as the mean Earth-Sun distance), is generally termed the solar constant of Earth. Earlier estimates of the total solar irradiance at the outer limit of Earth's atmosphere have been mainly derived, by extrapolation, from the classical pyrheliometric and spectral bolometric measurements made from high mountains. Additional information regarding the wavelength region unobservable from the ground, even from elevations ($\lambda < 295$ nm), was provided almost 20 years ago by use of rocket-borne spectrographs (*1*). The results, however, suffered from limitations of the then-experimental techniques in precision radiometry in the free atmosphere; the integrals ranged from 132 to 143 mw cm^{-2} (1.90 to 2.05 cal cm^{-2} min^{-1}) (*1*).

Recent attempts at precise measurement of the integral and spectral solar fluxes were made with large balloons, but the detectors remained in the ozonosphere (*2*); the results indicated (*3*) a value significantly lower than Johnson's (139.6 mw cm^{-2}) which has found most favor in the United States (*4*).

It has been pointed out (*5*) that knowledge of the extraterrestrial shortwave radiation flux, and of its spectral composition, is both important in astrogeophysical programs and a very necessary requirement for testing of spacecraft in space-simulation systems and for successful flight of vehicles. The basic object of a current program (*6*) is to make available a series of multichannel radiometers calibrated ultimately by exposure to Sun, at altitudes above the ozonosphere (greater than 50 km), from the X-15 rocket aircraft; the instrumentation has been described (*7*). Essentially the radiometer is a 12-channel model incorporating fast-response, high-sensitivity thermopiles of robust construction, plated after wire-winding, with associated quartz lenses and optical band-pass filters. Two channels record the total flux, two are equipped with broad-band filters (in combination subdividing the solar spectrum at 607 nm), and eight have narrow-band (interference) filters mainly covering the spectral range between 230 and 600 nm.

Our purpose is to summarize the first successful principal measurements made, during a flight by the X-15 (U.S. Air Force–NASA), on 17 October 1967, and those by a similar program with jet aircraft.

The X-15 was launched over Smith Ranch, Nevada, on a true heading of 187 deg toward Edwards Air Force Base, California (Fig. 1). At the peak altitude (approximately 84.5 km; 37.75°N, 117.35°W) the flight path was within 1 deg of the launch value upon which the precalculated radiometer roll and pitch angles depended. The radiometer "on-Sun" period was 81 seconds. The subperiod (23 seconds) selected for best measurements came soon after the peak, corresponding to altitude of 83 to 78 km and solar elevation of 28.3 deg. Ground-based radar located the aircraft and derived the ambient pressure. Radiometer temperature was monitored continuously (for example, − 32.5°C at 80 km). Solar exposure of the radiometer required no protective window. The final radiometer thermal zeros (before and after solar exposure) were derived from the record during the "pod-closed" periods, after consideration of the initial "pod-open" sky zeros. During the period selected as yielding the most accurate measurements, approximately 40 values of solar flux were obtained for each channel (the number of such values for the entire on-Sun period exceeded 1400). In-flight data were also telemetered to Edwards control (see Fig. 1).

It is believed that the flight yielded the first precise direct evaluation of solar intensities above the effective altitude of 5×10^{-3} torr. The principal measured fluxes (corrected to Earth mean distance) are (milliwatts per square centimeter): total, 136.1; OG1 filter, 101.6; RG8 filter, 73.4.

During preparation for the X-15 flight, six flights were made by a NASA B-57B over the Dayton-Columbus area, Ohio (40°N, 83°W), two in July and August 1966 and four in March 1967; the selected altitudes ranged from 11.5 to 15 km. In the 1966 series, the radiometer was exposed at or slightly above locally designated tropopause (mean, 13 km); the 1967 exposures were significantly above the tropopause (mean, 9.3 km). A seventh flight was made by a NASA CV-990 aircraft, at 12 km but below the tropopause, during October 1967 over the Pacific (11.5°N, 158.8°W).

On the B-57B flights the radiometer viewed Sun without intervening window; radiometer temperature (− 30°C was typical above 12 km) and amplifier-voltage reference were recorded. An optical sight for the pilot ensured proper solar orientation of the radiometric sensors. The signals were tape-printed on an integrating digital voltmeter in the observer's cockpit. In general, thermal zeros (before and after solar exposure) were obtained for each series of solar measurements, when the radiometer was temporarily out of the beam during the aircraft's circular flight, spiraling upward. Each series comprised from five to 25 solar readings per channel at constant altitude, depending upon the duration of exposure and the rate used for system integration; 21 such series were obtained. During the March 1967 operations, a special flight at speeds between 266 and 444 knots verified that the radiometer signals were immune to local fluctuations in pressure and wind; a related set of "off-angle" scans showed the effect of imperfect solar alignment.

Table 1 compares the results of the two B-57B programs. After correction for Earth mean distance, extinction by the remaining atmosphere, and unmeasured infrared radiation in the two principal filter channels, the agreement is striking: difference of each from mean; total flux, ±0.1 percent; filtered radiation, OG1 and RG8, ±0.5 and ±0.3 percent, respectively. As for corrections necessitated by the atmospheric layers above the aircraft, that for molecular (Rayleigh) scattering is based on tables incorporating a factor of 1.06 to account for the depolarization of

Table 1. Comparison of B-57B aircraft results in 1966 and in 1967.

Item	1966				1967			
	Total	Broad-band filters			Total	Broad-band filters		
		OG1	RG8	Mean		OG1	RG8	Mean
Wavelength (nm)	> 200	> 528	> 687	> 607	> 200	> 526	> 688	> 607
Flights (No.)		2				4		
Series of measurements (No.)		8				13		
Mean altitude (km)		13-1.5, + 2				13.5-1, + 0.5		
Mean solar elevation (deg)		67-4, + 2				43 ± 1		
Mean air mass (absolute)		0.20 ± 0.05				0.22 ± 0.03		
Total O_3 content (cm, normal temperature and pressure)		.355				.387		
Total H_2O above 100-torr level (mm)		.030 (est.)				.010†		
Measured fluxes (mw cm^{-2})	125.0	91.5	67.8		129.9	96.6	70.7	
		Corrections (%)						
Earth mean distance	+ 3.1	+ 3.1	+ 3.1		− 1.5	− 1.5	− 1.5	
Rayleigh scattering	+ 2.2	+ 1.0			+ 2.4	+ 1.1		
Ozone absorption	+ 2.7	+ 1.0			+ 3.5	+ 1.5		
Water-vapor absorption	+ 0.5	+ 0.7	+ 1.0		+ 0.3	+ 0.4	+ 0.6	
Unmeasured infrared	*	+ 3.5	+ 4.8		*	+ 3.5	+ 4.8	
		Total corrections (%)						
	+ 8.5	+ 9.3	+ 8.9		+ 4.7	+ 5.0	+ 3.9	
		Extraterrestrial fluxes (mw cm^{-2})						
	135.8	100.2	73.9	87.0	136.0	101.3	73.4	87.3

† Measured by radiosonde. * Estimated to be less than 0.2 percent beyond 5000 nm.

Table 2. Corrections (percentages) applied to measurements from CV-990 aircraft.

Item	Flux		
	Total	OG1	RG8
Earth mean distance	− 1.0	− 1.0	− 1.0
Rayleigh scattering	+ 2.2	+ 1.0	
Ozone absorption	+ 2.0	+ 0.7	
Water-vapor absorption (measured)	+ 0.3	+ 0.4	+ 0.5
Unmeasured infrared (window)	+ 3.3	+ 4.6	+ 6.0

asymmetric molecules (*8*). The corrections for ultraviolet radiation absorbed in the ozonosphere are computed from what are considered to be representative total atmospheric concentrations of ozone, vertically, which are based on the geographically nearest available simultaneous surface measurements and the generally established latitudinal distributions (*9*); Elterman's (*10*) treatment of the Vigroux absorption coefficients was employed, relating atmospheric opacity (and transmission) to altitude and wavelength. Precipitable water, above the aircraft, was either estimated or measured with infrared techniques whereby the filtered radiative integral was inverted to solve for transmission by water vapor (*11*). There was no evidence of the presence of aerosol (such as dust) in sufficient concentration above the altitudes of solar measurement, to affect the results significantly.

The CV-990 measurements on 22 October 1967 were made in a pressurized (to the equivalent of about 2.5-km altitude) aircraft fitted with a fixed quartz window for the radiometer. This arrangement necessitated a predetermined flight path to ensure that the solar beam, ideally, would be normal to both the aircraft window and the radiation sensors. But unsuitable weather compelled flight on an alternative course that introduced about 3.5-deg deviation of the beam from normal incidence to the window; a subsequent correction was made. A further complication was pronounced rolling of the aircraft during turbulence. Radiometer output was read (in millivolts) directly on a strip-chart potentiometric recorder that was calibrated in flight. The radiometer temperature was 25°C. The flight yielded a 20-minute series of measurements, but the total-flux channels were satisfactorily calibrated in flight with two of the group of working standard pyrheliometers. Solar elevation was 65.8 deg, corresponding to an absolute air-mass value of 0.21 at 12.1 km. These measurements are considered less accurate than those by the B-57B.

The factor 1.098 was established for correction for energy reflection and absorption by the window in the aircraft; other corrections to the solar measurements appear in Table 2. The corrected fluxes are 136.2, 100.9, and 73.6 mw cm^{-2} (total, OG1 filter, and RG8 filter, respectively); small filter corrections converted to the −30°C cutoff values of 527 and 687 nm, respectively.

Figure 2 shows the vertical profile of

Table 3. Solar constant of radiation; summary of aircraft measurements at altitudes of 12 to 15 and 78 to 83 km.

Measurement by	Milliwatts per square centimeter		
	Total flux (> 200 nm)	Ultraviolet and visible (< 607 nm)	Infrared (> 607 nm)
B-57B, 1966	135.8	48.8	87.0
B-57B, 1967	136.0	48.7	87.3
CV-990	136.2	48.9	87.3
Mean (weighted)			
	136.0	48.7_5	87.3
X-15	136.1	48.6	87.5
1. General mean, all flights			
	136.0_5	48.6_5	87.4
2. Johnson curve			
	139.6	52.3	87.3
Difference [(*1*−*2*)/*2*] (%)			
	-2.5_5	−7.0	+0.1

the atmosphere; the flight levels of the aircraft and the site of calibration of the instruments are indicated relative to the principal atmospheric regions. The calibration program for the radiometers has been described (*7, 12*). During these experiments it was customary to (i) compare two multichannel radiometers in the basic calibration program and (ii) conduct such calibrations before and after each set of flight operations. Calibration repeatability was generally within 0.2 percent.

With regard to the reliability of flight measurements, a study of the B-57B

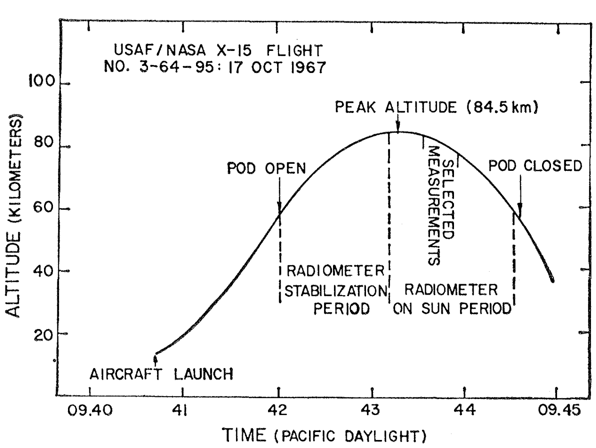
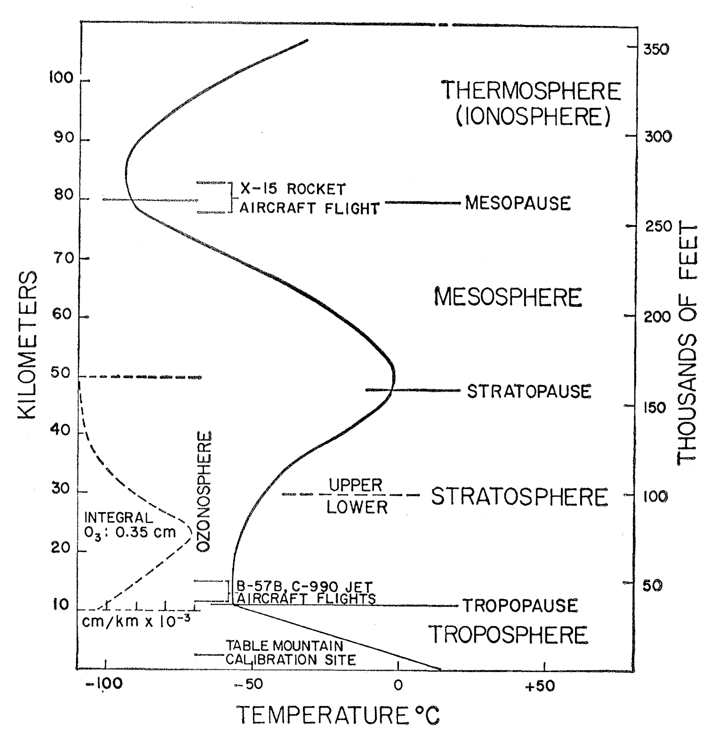


Fig. 1 (left above). Sequence of events aboard the X-15.

Fig. 2 (right). Standard atmospheric vertical profile (United States, 1962), showing the location of measurement of solar radiation.



raw signal data indicates that generally the values for channels 9 (OG1 filter), 10 (RG8 filter), and 11 (total flux) are within 0.3 percent of the mean for the on-Sun period. After analysis of the data (for example, application of temperature and zero corrections), the mean deviation of corrected signal data for comparable series of measurements is within 0.2 per cent. Scrutiny of the X-15 "selected measurement" data give repeatability figures of the order of ± 0.5 percent.

Table 3 summarizes the principal results from all eight flights. The mean deviations of the four sets of average values are rather remarkable: total flux, ± 0.1 percent; ultraviolet plus visible (that is, total minus infrared), ± 0.2 percent; and infrared, $\pm 0.1_5$ percent. The weighted means of all jet-flight series agree with the corresponding X-15 values within 0.2 percent on average. It is difficult to assess absolute accuracy as distinct from the different aspects of precision in measurement, but these figures suggest that the finalized values should be accurate within 1 percent. There is no added complication regarding the broad-band-pass filter channels since the filter factor for this type of filter is essentially the reciprocal of the main-band transmittance.

Comparison with the Johnson curve indicates that Johnson (*4*) overestimated the total flux by 2.5_5 percent; energy for wavelengths shorter than $\lambda = 607$ nm, by 7.0 percent. On the other hand, the values for $\lambda > 607$ nm are in almost perfect agreement. This significant difference for $\lambda < 607$ nm was confirmed in the analysis of the first series of narrow-band (interference) filter results from the 1966 flights. The weighted mean from five independent filter measurements, covering the spectral range from 295 to 595 nm, is lower by 7.5 percent than the Johnson integral (*7*). This material (and that from lower tropospheric levels) for the subsequent flights is now being evaluated. The B-57B measurements of total flux have been independently verified (*13*).

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27 May 1968

Glassy Objects (Microtektites?) from Deep-Sea Sediments near the Ivory Coast

Abstract. *Glassy objects of spherical, oval, dumbbell, teardrop, and irregular shapes have been found in a deep-sea sediment core taken off the Ivory Coast. They occur in a layer of sediment that was apparently deposited about 800,000 years ago. Their geographic location, appearance, and physical properties suggest that they are microtektites and that they are related to the tektite-strewn field of the Ivory Coast.*

Several hundred small (<1 mm) glassy objects have been found in deep-sea sediments from north of the Philippines, south of Sumatra and Australia, and southeast of Madagascar. On the basis of their geographic location, age of deposition, and physical properties, it has been suggested that these glassy objects are microtektites and that they represent a portion of the Australasian tektite-strewn field (*1*). The chemical composition of 60 of the glassy objects was determined by electron-microprobe analysis at the Goddard Space Flight Center (*2*). In general, they appear to be quite similar in their compositional trends to Southeast Asian and Australian tektites.

Recently, a search was undertaken to see if any glassy objects could be found in the deep-sea sediments near the Ivory Coast of Africa. A few hundred glassy objects were found in one core (V19-297) taken at 2°37′N and 12°00′ W. The appearance and physical properties of these glassy objects are similar to that of the Australasian microtektites.

Out of the 277 glassy objects recovered, approximately 90 percent are spherical in shape, and several hollow hemispheres were found. Most of the remainder are either oval or disc- or dumbbell-shaped (Fig. 1). Only two teardrop-shaped objects were found. In addition, fragments are very abundant. Like the Australasian microtektites, these glassy objects are mostly less than 1 mm in diameter; however, a few dumbbell-shaped objects are as long as 1.2 mm. They are brittle and break with a conchoidal fracture.

In transmitted light most (~70 percent) of the glassy objects are olive brown to olive green in color. A few are colorless, and the remainder are yellowish-green or dark brown to black. Thus, the color of these glassy objects is in contrast to the Australasian microtektites, which are mostly yellowish-brown (from the Wharton Basin) or colorless to yellowish-green; however, they are similar in color to the Ivory Coast tektites which, according to Vand (*3*), are brownish in thin section.

The surface texture of the glassy objects varies from glassy smooth to very irregular and badly pitted. Unlike the Australasian microtektites, these glassy objects appear to have undergone extensive solution which has resulted in surface markings that are not observed on the Australasian microtektites. Elongated bubble or solution pits, grooves, and flow lines are among the most abundant surface markings (Fig. 1). Like the Australasian microtektites and the Ivory Coast tektites, the glassy objects contain spherical bubble cavities, but no crystalline inclusions. Several of the glassy objects have elevated circular areas. In some instances, these