Glenn Schneider
Steward Observatory
University of Arizona
http://nicmosis.as.arizona.edu:8000
“If it develops nothing else of novelty, the recent solar eclipse can fairly lay claim to be the first astronomical event to be observed from an airplane.

Although the flight and observation made at Fort Sill, Okla., were not undertaken with any serious scientific objective in view, it was at least demonstrated that we may eventually look to the aviator for work of value in connection with eclipses.”
While most of the undertakings of eclipse time call for a solid foundation, which can hardly be looked for even in the plane of the future, the aviator can at least free the astronomer from his complete subjection to clouds and other superficial weather phenomena.

We may, therefore, look for more general use of planes in connection with subsequent eclipses.”
Reasons for Employing Aircraft To Observe Total Solar Eclipses

1. Deployment/Relocation
   TSE 22 December 1870 - Jules Jannsen escapes the siege of Paris by balloon to observe eclipse in Algeria.

2. Cloud obscuration avoidance
   Stratosphere: Virtually assured; Polar Stratosphere: 99.99%

3. Totality Prolongation
   Record (by far) to date: TSE 1973 - Duration ~ 74 minutes

4. Sky Transparency
   Improved (Reduced Particulate Scattering)

5. Sky Darkness
   Improved (Higher Contrast Coronal Visibility to Larger Radii)
Reasons for Employing Aircraft To Observe Total Solar Eclipses

6. Astronomical Seeing
   Improved ("r_naught" decreases with increasing altitude)

7. Atmospheric Turbidity
   Reduced (Vorticity & Sheer decline in power with altitude)

8. Panchromatic Visibility
   Improved (IR and UV "windows" open up)

9. Unparalleled Horizon Reach and Observational Vista
   Apparent Horizon 367 km (228 miles) distant @ 35,000 ft

10. It’s just plain neat (cool, keen, fun, da bomb [oops]…)
    If you haven’t done one yet…what are you waiting for???
    … and think of those frequent flyer miles.
FOLLOWING 1st FLIGHT - MORE TSE FLIGHT PROPOSALS TO USNO:

1919 - Prof. D. P. Todd: aircraft observations

1923 - Col. J. Millis (retired): aircraft observations

- pioneer aerial photographer
- “father of airborne astronomy”
- early balloon-borne aeronaut*
- in situ tropopausal temperature measurement
- 1st photograph of Earth’s curvature (1930)
- record balloon ascent Explorer II 72,395 ft with Cpt. O. Anderson at Rapid City, S.D. (11 Nov 1935)

*Stevens, W. S., National Geographic, Dec 1926, 755: “Exploring the Earth’s Stratosphere”
De Havilland DH-4B

Objective: Determine Centerline Location from Air

Method: Aerial Eclipse Photography, 30 photographs exposed

Result: none successful in imaging the eclipse

Synopsis: “no valuable results were secured”

- F.B. Little, 1925, Popular Astronomy, 33, 239

Albert William Stevens

1st (in a series) of airborne eclipse flights
FOLLOWING 1st FLIGHT - MORE TSE FLIGHT PROPOSALS TO USNO:

1919 - Prof. D. P. Todd: aircraft observations

1923 - Col. J. Millis (retired): aircraft observations

1925 - Col. J. Millis: dirigible* observations

“It was the idea of Colonel Millis that the TOP of the airship could be used as a platform for apparatus and observers…

Much skepticism was evinced as to the desirability of attempting so unusual a method of observing the eclipse as a serious scientific undertaking…”

- F. B. Little, USN
TSE: 24 January 1925
US Navy Airship “Los Angeles”
Altitude: 4,500 ft.
Deployment: 41.0°N, 71.5°W
100 mile E of Montauk Pt., NY

DISADVANTAGE: Inability to ascend high to “over-ride” clouds.

Objectives:

- Secure Photographs & Drawings of Solar Corona
- Obtain Spectroscopic Observations (Bureau of Standards)
- Record Contact Timings
- Observe and Document Color Effects
- Observe Shadow Bands
- Observe “possible comets & other objects”
- Observe “any other unusual appearances”
TSE: 24 January 1925

US Navy Airship “Los Angeles”

“upon consultation with those familiar with the the construction and use of airships, it became immediately evident that the top surface is not a suitable place for… apparatus… {or} personnel”.

“As it was, the one person assigned to duty in the cockpit has his face and fingers frozen while securing pictures of the eclipse.”
SPECTROGRAPHIC CAMERA

TSE: 24 January 1925

US Navy Airship “Los Angeles”

TOTAL SOLAR ECLIPSE OF JANUARY 24, 1925. SPECTROGRAM OF CHROMOSPHERE AND CORONA

a Helium
b Chromosphere
c Corona
The Tragic End of the Dirigible Eclipse Observing Concept
The Observation of the Eclipse by Airplane [Napa, Sonoma]

“...the eclipse ... so near the border line between annular and total it appeared well worthwhile... to observe from an airplane at considerable altitude.

“...the shadow track was so very narrow its exact location was in doubt.

Greatest Eclipse: 29.6°N, 121.2°W
Path Width*: 1.1 km
Duration*: 1.4 sec

*no limb corrections

Map source: F. Espenak- sunearth.gsfc.nasa.gov/eclipse/eclipse.html
TWO AIRCRAFT @ 10,000 ft

1) Lt. W. Bobzien, Pilot (CMD)
   Sgt. S. Bush, Photographer
   SUN: 20” EFL f/3.5 K-6 Camera

2) 1st Lt. H. Wallace, Pilot
    M. H. Jeffers, Photographer
    SHADOW: 3.5” EFL f/1.85 box camera

“...it was possible the advancing shadow cone would be seen many miles away, and the pilot of a plane might have time to alter the line of flight so as to get into the shadow…”

“...a photograph of the corona... would suffer less from scattered light... at high altitude {due to} less air, dust, and water vapor between Sun and camera.

“...airplane would afford {a} point of vantage from which to effectively observe the Moon’s shadow on the ground.

“Two minutes before totality was due… the region over the Pacific to the SW as getting very dark…”

“At this time the visual search for the expected half-mile wide umbral shadow was begun. This was *unsuccessfully* looked for up to the moment when it was realized that the eclipse was central, and that the shadow, *what there was of it*, was at hand.”

“It seems safe to say, now, in the Sonoma region the umbra did not exist.”
TSE 28 April 1930
USNO Eclipse Expedition
Honey Lake, California
Duration of Totality: 1.4 s

Vought O2U-1 Corsair

Objective: Determine exact Centerline of eclipse.

Method: Cinematography of Shadow

Result: Recorded Approach Of Lunar Shadow

Application: Corrections to Lunar Almanac
TSE: 31 August 1932
Army Air Corpse/NGS Expedition
27,000 ft over New Hampshire, USA

OPERATED THREE CAMERAS
+ Obtained time-resolved series of approaching lunar shadow
+ Obtained IR filtered images of solar corona
- One camera tangled in Oxygen hose

"From Five Miles Above the Earth's Surface, the National Geographic Society-Army Air Corps Survey Obtained Successful Photographs of the Moon's Shadow."

Stevens, A. W., National Geographic, (Nov) 1932, 62, 581.

Photographing the Eclipse of 1932 from the Air
*During the Total solar Eclipse of 28 April 1930
*RCAF Operation Eclipse*

Royal Canadian Air Force/Canadian Radio Wave Propagation Cmte.:

- 4 Aircraft: Spitfire, Mitchell, Anson(2)
- 17,000 ft. to 34,000 ft.
- 7 Aerial Cameras (6 automated operation) + 1 motion picture camera
- Aircraft fitted with special (plate glass) windows
- **Visual & Infrared** photographs of corona & prominences
- **Spectroscopic & Polarization** measurements
- First spectroscopic observations from heavier-than-air aircraft

*Multi-Spectral, Multi-Modal, Temporal PHYSICAL SCIENCE*
“Observations should be made in an open aircraft, not through an aircraft window… extra light scattering at the window will entirely vitiate the advantage of high altitude observations.

In making the observations… if was found most convenient to fold the aircraft door back and mount the camera in the open doorway.

The aircraft used was a special Lincoln capable of flying to an altitude of 43,000 ft.

Physiological difficulties made it inadvisable to attempt observations from this height … 30,000 ft was chosen to give the best compromise between sky darkening… aircraft stability and observer alertness…
Eclipse Observations: Lat = 61 23.9’N, 1° 34.6’W

404 mm EFL Multi-Lens Occulting/Baffled Camera

8 images on one 12”-sq. Ilford HP3 plate.

4 for direct intensity measurements:
  f/9 (14° x 28° FOV), f/20, f/49, f/130

4 for polarization: 2-f/9, 2-f/20
  quad pol. 2 cm in front of film
  parallel & perpendicular to ecliptic

Exposure time: 1 min., start CII + 30s
  for darkest sky

Guiding Error: 10’ over 1m exposure.
Remember this number:

\[ ~10^{-11} \text{ @ 25° ecliptic elongation} \]

**Fig. 6.**—Brightness variation of solar corona along ecliptic (which is practically coincident with solar equator).
Fig. 9.—Polarization of the solar corona. The measures refer to those parts of the corona within 20° of the ecliptic.
CORONAL/Zodical Light INTENSITY

**Fig. 10.** Variation of brightness of solar corona and zodiacal light with distance from the Sun. The zodiacal light data are taken from the work of Roach et al.
Scandinavian Airlines "Torolf Viking" at 15,000 ft near Lifjell in Telemark in the south of Norway “Anti-Sun Side” - Johnny Björnulf, Raun Conradi

http://www.ufo.se/blogg/index.php?entry=entry061006-010324
20 June 1955: First Dedicated Eclipse “Chase” With A Jet Aircraft

- T-33 Jet (Trainer)
- Totality Ground Duration: 7m 09s (Philippines)
- Aircraft Ground Speed ~ 600 mph
- Totality Duration from Air: 12m 15s
NASA/Ames’s Sheldon Smith (Physics Branch) & Ray Torrey (Guidance & Control Systems Branch) built a gyro-stabilized camera* for airborne (DC-8) observations of TSE 1963, shown here on the Ames Convair 990 “Galileo” (one of 13 experiments) carried to TSE 1965 in the South Pacific.

The Cold War: A Golden Age For Airborne Coronaphiles

The Tragic Beginning of the USAF/AEC Eclipse Observing Concept
<table>
<thead>
<tr>
<th>Date</th>
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<tr>
<td>24 Sept 1963</td>
<td>Ratified by Senate in U.S.</td>
</tr>
<tr>
<td>10 Oct 1963</td>
<td>Entered into Force</td>
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**PROHIBITS:** “Nuclear weapons test or any other nuclear explosion in the atmosphere, in outer space, or under water.”

U.S. CONGRESS AUTHORIZES 4 Part “Test Readiness Program” including: “improvement of monitoring capability vis-à-vis Sino-Soviet Nuclear technology.”

LEADS TO the acquisition of three AEC partnered USAF NC-135 (modified B707) aircraft operated by Los Alamos, Sandia, and Livermore research facilities as “flying laboratories.”
AEC 1964 REPORT: Weapons test diagnostics from aircraft were so successful ground facilities on Eniwetok and Christmas Island were obviated.

SCIENTISTS LOBBIED AEC to obtain permission to use aircraft also to study ionospheric E and B fields, cosmic rays, and SOLAR ECLIPSES, arguing such missions would augment the TRP simulation exercises.

High-flying, long-range jet aircraft ... could be used as observation stations for extraterrestrial phenomena and would have a tremendous advantage over ground facilities. Jet aircraft capability would place researchers above the clouds that often negate ground observation, and above 80% of the earth’s atmosphere, whose dust and water vapor scatters light and degrades data.

For instance ... meaningful measurements of the solar corona, which are impossible from the ground because of water vapor that blocks the infrared end of the solar spectrum, could be made from the aircraft.
AEC APPROVES!

30 May 1965 (Pago Pago, American Samoa)

Ken Williamson, Don Liedenberg, Walt Wolff of Los Alamos Lab operating the “The Rube” - a multi-function telescopic imager, photometer, and interferometer over the South Pacific during the 30 May 1965 TSE.
Los Alamos
PI: Art Cox:
Instrument: “The Rube”

TSE: 30 May 1965/ 12 Nov 1966
The “Rube”

Ken Williamson, Don Liedenberg, Walt Wolff on The NC-135 TSE 1965 American Somoa Flight

TSE: 30 May 1965/ 12 Nov 1966
AEC APPROVES!

30 May 1965 (Pago Pago, American Samoa)

John Kuruzovich, Jose Llamas, John Barsic & Lyle Porter of Sandia National Lab operating the “Holy Cow” manual tracking infrared spectrograph over the South Pacific during the 30 May 1965 TSE.

CORONAL EMISSION LINE PROFILE OBSERVATIONS AT TOTAL SOLAR ECLIPSES

I: Airborne Instrumentation and Results*

D. H. LIEBENBERG
LASL, University of California, Los Alamos, N.M. 87545, U.S.A.

(Received 7 July, 1975)

“A 25-cm aperture f/8.0 telescope was operated aboard a U.S. Air Force - Energy Research and Development Administration aircraft at the 30 May 1965 and 12 November 1966 total solar eclipses…

TSE: 30 May 1965/ 12 Nov 1966
AEC APPROVES!

30 May 1965 (Pago Pago, American Samoa)

AIRBORNE SPECTROGRAPHIC OBSERVATIONS OF THE SOLAR ECLIPSE OF NOVEMBER 12, 1966

John G. Conway
Lawrence Radiation Laboratory, University of California, Berkeley

William F. Morris and C. Frederick Andrews
Lawrence Radiation Laboratory, University of California, Livermore

Two spectrographs were flown.
Ca II, H & K lines observed at 2 Rsun.
T(5303; Fe XIV) = 2.5MK
T(6374; Fe X) = 1.8MK,
Limb-to-corona intensity profiles ----->
"As the mission proceeded, those on the 135 watched in disbelief as the SST streaked by and above at 55000 ft."

"We mounted a quick & dirty mission… intensity data out to 20 solar radii were collected." (37,000 ft. over North Dakota)

"The RGFE camera used again for TSE 1980 produced a marvelous photograph of a hydrodynamic eruption from the sun's surface that formed a huge bubble in the corona."

"Lilliquest was on his back, still struggling to center the disk as totality approached…"
TSE 1979: Charles Keller

“We mounted a quick & dirty mission… intensity data out to 20 solar radii were collected.” (37,000 ft. over North Dakota)

TSE 1980: Bob Jeffries, Charles Keller, Brook Sanford, Paul Mutschlener, Joe Montoya & Carl Lilliquest

The RGFE camera used again for TSE 1980 “produced a marvelous photograph of a hydrodynamic eruption from the sun's surface that formed a huge bubble in the corona.”

“Aas the mission proceeded, those on the 135 watched in disbelief as the SST streaked by and above at 55000 ft.”
Contemporaneous with the USAF/AEC Eclipse mission (TSE 1966): Gemini 12 was launched on 11 November 1966 at 20:46:33 UT and inserted into a 160.8 x 270.6 km Earth orbit at 20:52:40. Two phasing maneuvers using the Gemini Agena Target Vehicle secondary propulsion system were accomplished allowing the spacecraft to rendezvous with the November 12 total eclipse over South America at 9:20 a.m. EST with the crew taking pictures through the spacecraft windows.
TSE: 30 JUNE 1973
Concorde 001 F-WTSS/375
Mach 2.05 @ 16.2—17.7 km
Las Palmas to Ft. Lamy
74 minutes of totality!

Special Purpose Windows:
- crystal quartz
- composite Irtran-2
- (2) fused quartz
TSE: 30 JUNE 1973
Concorde 001 F-WTSS/375
Mach 2.05 @ 16.2—17.7 km
Las Palmas to Ft. Lamy
74 minutes of totality!

Special Purpose Windows:
- crystal quartz
- composite Irtran-2
- (2) fused quartz

- Far-IR Chromospheric Emission (250 $\mu$m to 2 mm)
  Michelson spectral interferometer,
  liquid-He cooled InSb detector

- Coronal near/mid- IR Emission (2-3, 4-5, 9-13 $\mu$m)
  liquid-N$_2$ cooled InSb photoconductive detectors,
  liquid-He cooled Ge bolometer

- Time-Resolved Coronal Imaging (<1.4R, <15R)
  Film cameras with 180mm, 1.52m, 3m EFL

- High Resolution Coronal 5303Å Emission Line Imaging
  FP pressure-scanned (0.05Å) interferometer - vidicon
Many wavelength bands obscured from earth are accessible from aircraft.
**NASA’s Learjet Observatory**

*45,000 ft standard operation*

1954: “Observations should be made in an open aircraft, not through an aircraft window…”

29 cm IR Telescope built by Frank Low (used multiple times in late 1960’s-70’s)
Demonstrated likelihood of significant inhomogeneities in the lower chromosphere with size scales $\sim 1000$ km

* Clark & Boreiko, 1982, 76, 117.
“At least 1,000 planes were in the air along the path of totality; some airports were so jammed that a number of eclipse viewers never got off the ground in time.”

- Life (Apr 1979)
NASA astrophysicist astronauts (then candidates) Sally Ride & Steve Hawley photograph TSE 1979 from a T-38 @ 43,000 ft.

“We thought up the trip as a good training opportunity to do science in an operational environment - like we hoped to get to do on Shuttle one day.”

-S. Hawley 17JUL2007

1918: “Although the flight… not undertaken with any serious scientific objective…demonstrated that we may… look to the aviator for work of value in connection with eclipses”.

In flight photo by Steve Hawley
NASA’s Kuiper Airborne Observatory*
C-141A Aircraft, 14 km ceiling, 6,000 mile range

92 cm telescope
1 to 500 µm spectral range

*1974 — 1995
NASA’s Kuiper Airborne Observatory
far-IR/sub-mm Observations of TSE 31 July 1981

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SUBMILLIMETER EXTENSIONS OF THE SOLAR LIMB DETERMINED FROM OBSERVATIONS OF THE TOTAL ECLIPSE OF 1981 JULY 31

C. Lindsey, E. E. Becklin, J. T. Jefferies, and F. Q. Orrall
Institute for Astronomy, University of Hawaii

M. W. Werner
NASA Ames Research Center

AND

Ian Gatley
United Kingdom Infrared Telescope
Received 1982 July 7; accepted 1982 September 10
“We present the first results of a lunar occultation of the solar limb made from the Kuiper Airborne Observatory in the 30, 50, 100, and 200 µm continuum during the total solar eclipse of 1981 31 July.

We find the solar limb to be extended at the longer wavelengths up to 1000 km higher than predicted from smooth plane-parallel chromosphere models.

Results at both 2nd and 3rd contact show the infrared limb extensions to be approximately 0.8”, 1.5”, 2.5”, and 3.0” above the visible limb in the 30, 50, 100, and 200 µm bands, respectively.

A possible interpretation proposes chromospheric fine-structure inhomogeneities of greater density than presently incorporated in models of the middle chromosphere.”
“We dedicate this work to David A. Barth, the chief pilot for the KAO during the eclipse observation, who tragically lost his life while test-flying an aircraft a few weeks after the successful completion of our program. Our observations required operation of the KAO aircraft at its performance limit, and we therefore depended very much on his skill. We were very fortunate not only in having the benefit of his outstanding ability, but also for the real pleasure of his personal acquaintance during his involvement with our program.”
The 1970’s - Egalitarian E-Flights

TSE 1972 - RELOCATION

paradigm shift

TSE 1974 - In Situ OBSERVING

“Then you flew your Lear jet up to Nova Scotia to see the total eclipse of the sun”

Ansett Airlines Eclipse Flight - Perth, Australia

Images Courtesy of Wendy Carlos
"t"SE 1986 would be my 12th Total Solar Eclipse - but would it be Total?

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Eclipse Predictions by
Fred Espenak,
NASA's GSFC
hSE 28 Apr 1930
California
1.4 s Totality

Vought O2U-1 Corsair

A PERSONAL “FIRST FLIGHT”:

Cessna Citation II

“the eclipse … so near the border line between annular and total it appeared well worthwhile… to observe from an airplane at considerable altitude.

“…the shadow track was so very narrow its exact location was in doubt.

- W. H. Jeffers (1930)

hSE 03 October 1986 (19:05:19.0 UT)
“Gang-of-Nine” Eclipse Expedition
North Atlantic, southwest of Iceland
Stationary Observer Totality Duration:
0.0 s MAX (Meeus 1966) @ Sea level*
-0.2 s (Espenak 2001) @ 44,000 ft/19:05:19

* @ max eclipse, altitude = 6°
@ 44 kft/max ecl., d(moon) + 0.7” wrt MSL
1985 - “CENTERLINE” S/W

Topocentric
Lunar
Limb
Corrections
(Data: A. Fiala)

Atmospheric Refraction Models

VAX/11-750 RSX APL11

(not exactly portable...)

hSE 03 October 1986 (19:05:19.0 UT)
“Gang-of-Nine” Eclipse Expedition
North Atlantic, southwest of Iceland

PREDICTION ISSUES
circa 1985-86:
Pre-Computation
hSE 03 October 1986 (19:05:19.0 UT)          PREDICTION ISSUES  
“Gang-of-Nine” Eclipse Expedition           circa 1985-86: 
North Atlantic, southwest of Iceland         LIMB PROFILE

A. Fiala (USNO): This is a new program - I don't know exact Scale!
hSE 03 October 1986 (19:05:19.0 UT)
“Gang-of-Nine” Eclipse Expedition
North Atlantic, southwest of Iceland

PREDICTION ISSUES
circa 1985-86
ATMOSPHERIC REFRACTION

1.9’ but model dependent
hSE 03 October 1986 (19:05:19.0 UT)
“Gang-of-Nine” Eclipse Expedition
North Atlantic, southwest of Iceland

PREDICTION ISSUES
circa 1985-86
PRE-GPS

Inertial Navigation
Gyro Bias Error
Secular Accumulation:
~ 1 per 1000 km of flight
So, How Did We Do?

Top Left to Bottom Right
(3 fps)
TSE: 22 July 1990

Joe Rao’s coup d’air
Trans-Air Airlines 403
L-1011: Honolulu-> S.F.

32,000 ft, Finnair DC-9
Over Joensu, Finland

41 min. “delay”
nets 360 PAX 71s Totality

80 s of totality, 90 PAX on-board

Photos: Fred Espenak
NASA’s Hubble Space Telescope
“Observes” TSE 11 July 1991

1m 04s of Totality from 602 km AMSL

@ Maximum Eclipse:
  Magnitude = 1.0351
  \( \frac{r_{\text{moon}}}{r_{\text{sun}}} = 1.0746 \)
  “Antumbral” depth = 95.4%

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HUBBLE SPACE TELESCOPE -- IN THE UMBRA!
NASA’s Hubble Space Telescope
“Observes” TSE 11 July 1991

HUBBLE SPACE TELESCOPE -- IN THE UMBRA!
TSE: 30 June 1992 - South Atlantic

Only landfall: Coastal Uruguay With Sun on Horizon

Unobscured Viewing Probability: ≤ 5%

What to DO?…

TODAY THE COMMERCIAL AIRLINE PILOT, DECIDES NOT TO FLY TO RIO AS SCHEDULED!

HE DOESN'T WANT TO SEE RIO! HE WANTS TO SEE THE SOLAR ECLIPSE!
1992 - EFLIGHT S/W (UMBRAPHILE/CENTERLINE derivative)
Eclipse Flight/Shadow Intercept & Real-Time Navigation

*High Precision “Moving Platform” Dynamical Computation of TSE Ephemerides, Global & Local Circumstances.*
- Topocentric Lunar Limb Corrections
- Atmospheric Refraction Models

*TSE: 30 June 1992*

1st Implementation: Mac PB 170 MacOS 7 APL/68000
Digression: The Evolution of “EFLIGHT”

In Situ OPERATIONAL PEDIGREE:
TSE 30 June 1992
DC-10 Eclipse Flight
Digression: The Evolution of “EFLIGHT”

In Situ OPERATIONAL PEDIGREE:
TSE 30 June 1992
DC-10 Eclipse Flight

6m 15s @ 41,000 ft
(Ground Duration: 4m 37s)
Digression: The Evolution of “EFLIGHT”

In Situ OPERATIONAL PEDIGREE:
TSE 30 June 1992
DC-10 Eclipse Flight

2001, 2003, 2008...
...Into the Wild Blue Yonder!

SUPERSONIC

FASTER!, HIGHER!, LONGER!
“Our attention was focused on flying… when the red glow of the instruments panel filled the cockpit that we realised that the sunlight had gone. It had become a dark night and the sky was filled with stars all round… At 80,000 feet… the sky appears grey… because of the absence of dust, air and water molecules. But this time, during totality, the sky suddenly turned inky dark without notice…

At a speed of Mach 2.5, we got to see about 90 seconds of totality, while those on ground got to see only 55 seconds.”
TSE 11 August 1999
MIG-21
13,000 m, 1650 kph

Coordinated Air + Ground Photographic Program

nIR corona (EIR + yellow blocker; 630 - 930 nm) to 18 solar radii
82 film rolls, 1184 frames: 15 VIS&IR spectral regions
761 frames of eclipse 13 IR films
423 calibration frames

Registered Coronal Images to 23 R(sun)
TSE 11 August 1999
and a MIG-29
(0 m, 0 kph)

“experiments… were not possible… due to weather conditions (the MIG-29 was stopped by the control tower during take off, not because it could not take off, but because that, if something wrong happened, it could not land safely nowhere in the area).”

-Vlad Popa, 17 July 2007

Institute for Space Sciences
Bucharest, Romania

PROJECT
Neutrino Oscillation with Telescopes during the Total Eclipse
TSE 11 August 1999
and a Flock of Concordes

BA 9091C
BA 9099C
AF 4500
Christine McGourty, BA 9091:
“Before take-off there was a rehearsal of the seat-switching that had to be performed to get those on the left hand side of the plane over to the right and back twice during totality.”
“There was a stunning view of the partial eclipse. But it wasn't easy to see, appearing quite small and so high in the sky that many people were on their knees between their own seat and the one in front, twisting their necks round and peering up out of the tiny window. Totality was something it seemed only the lucky ones were able to witness.”
John Beckman: "Because of the small windows and the angle, you could never get your eye in the right position to see totality while the plane was in level flight. It was only when it did a few wiggles in the air that you could see totality… I saw about 10 seconds of totality. It was obviously disappointing and I'd hoped to see several minutes."
EFLIGHT SS 2001

Modifications for $V_{\text{aircraft}} > V_{\text{umbra}}$

2001 - EFLIGHT SS (for TSE 21 June 2001)

Modified for Concorde/Supersonic Flight Intercept

PowerMac PB/G3-G4 MacOS 9 APL/Level II
Eclipse Circumstance Calculator and Aircraft Navigation Aide
Specifically designed to address the problem optimally intercepting the moon's shadow from a moving aircraft.

PEDIGREE:
- 21 June 2001 Planned 1 Hour Totality With Ill-Fated AF Concorde
EFLIGHT SS 2001
Eclipse Circumstance Calculator and Aircraft Navigation Aide
Specifically designed to address the problem optimally intercepting the moon's shadow from a moving aircraft.

PEDIGREE:
- 21 June 2001 Planned 1 Hour Totality With Ill-Fated AF Concorde

The Tragic End of Concorde
Eclipse Observing Concept

25 July 2000
AF Flight 4590
Clementine Lunar-Orbital Circum-Solar Imaging While In Moon’s Shadow

Blackwell 1954

Hahn 2002, Icarus 158 350
EFLIGHT 2003 X (MacOS X)

Fully Integrated for TSE 23 Nov 2003...

Fully compliant with CDU I/O & FMS interface requirements of modern aircraft systems

PowerMac PB G4 MacOS X APL X

Boeing 747-400 ER
EFLIGHT 2003 X (MacOS X)
Eclipse Circumstance Calculator and Aircraft Navigation Aide
Specifically designed to address the problem optimally intercepting the moon's shadow from a moving aircraft.

23 November 2003 - ANTARCTICA:
Planning and Real-Time Navigation Croydon/QANTAS QF 2901
Planning S&T/Lan Chile LC 8001
## EFLIGHT X Tabular Output

### Co-Moving “Local Circumstances” from Moving Aircraft

#### U.T. Intercept: 22:44:00 | TOTALITY DURATION = 2m 34.7s
Flight Altitude: 35000ft

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**Time Correlated Aircraft Track, Centerline, and Umbra Intercept Data**

#### Selected WAYPOINTS

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**FMS INPUT**  
**“READ-BACK”**
NHK (Japan) Real-Time HDTV

Gulfstream-II @ 10 km aMSL
Launch: Novolazarevskaya
What’s Next? -- NASA/DRL SOFIA
Stratospheric Observatory for Infrared Astronomy

The SOFIA Telescope has a 2.5 m diameter clear aperture (comparable in size to the Hubble Space Telescope’s 2.4 m)

The SOFIA Aircraft will operate from 39,000—45,000 ft, 3—4 8hr flights per week over 20 years. Mission deployable
Prof. Eric Becklin (UCLA), SOFIA Chief Scientist, was on Aloha Airlines 243…

USRA receiving Federal Aviation Administration’s Part 145 Repair Station Certification, April 27, 2005

4-26-1988 After 89,080 flight cycles on a 737-200, metal fatigue lets the top go in flight.
The Tragic End of the SOFIA Eclipse Observing Concept??

National Aeronautics and Space Administration
President’s FY 2007 Budget Request

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FY 2008 Budget Estimates

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SOFIA
1st Flight
04/26/2007
Successful

1st Science Operations -- 2008-9?
But Not (yet; 2010-11?) Solar Enabled…
But FIRST! -- TSE 01 August 2008
2m 51s +/-10s of Totality
From the Pristine, Clear, and Particulate Free Skies
of the High Polar (81°–83°) North from 35,000+ feet

Airbus 330-200
At high polar latitudes, the tropopausal boundary between the troposphere below (where "weather occurs") and the stratosphere is only 6—9 km AMSL (compared to 12—17 km at mid and low latitudes).

Polar stratospheric clouds can only form at <-78° C, i.e., during the polar winter, making the probability of cloud-free eclipse viewing nearly 100%.

C. Long, NOAA/NWS ->
But FIRST! -- TSE 01 August 2008
2m 51s +/-10s of Totality
From the Pristine, Clear, and Particulate Free Skies of the High Polar (81°–83°) North from 35,000+ feet

In the AoO, aerosol scattering of sunlight by airborne particulates is extremely low, resulting in exceptionally dark skies during totality, enabling eclipse viewing with significantly enhanced image contrasts.

Moreover, the airmass along the line-of-sight to the Sun is significantly reduced (by ~ 75%), resulting in exceptional sky transparency, greatly reduced atmospheric turbidity, and significantly better astronomical "seeing".
**But FIRST! -- TSE 01 August 2008**

2m 51s +/-10s of Totality

From the Pristine, Clear, and Particulate Free Skies of the High Polar (81°–83°) North from 35,000+ feet

In the AoO, the duration of totality will be increased by appx. 40s over the “ground”, with the Sun comfortably positioned and optimally oriented for observations on the starboard side of the aircraft.
But FIRST! -- TSE 01 August 2008
2m 51s +/-10s of Totality
From the Pristine, Clear, and Particulate Free Skies
of the High Polar (81°–83°) North from 35,000+ feet

http://nicmosis.as.arizona.edu:8000/
ECLIPSE_WEB/ECLIPSE_08/TSE2008_EFLIGHT.html

http://www.tq-international.com/
NorthPoleFlight2008/NPFlighthome.htm