EFLIGHT X - Eclipse Flight Planning & Navigation S/W: Making Every Second Count!

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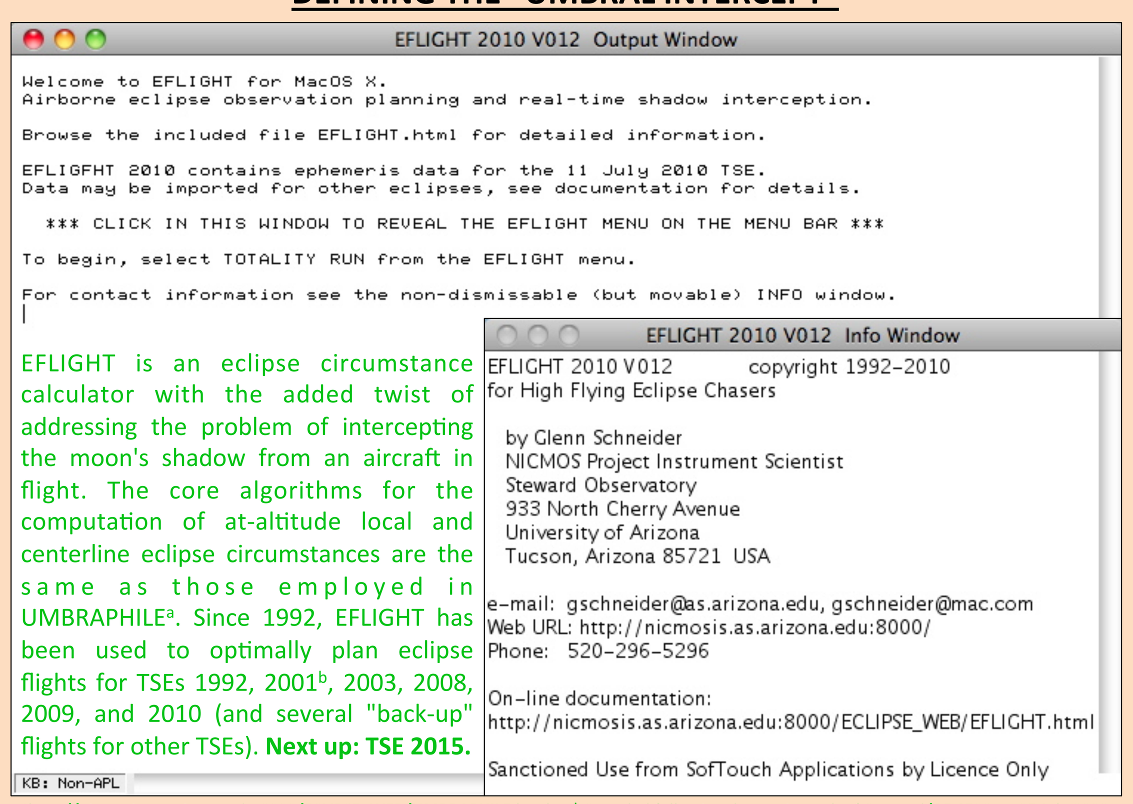
TOP 10 REASONS TO OBSERVE TSEs FROM JET AIRCRAFT

DEPLOYMENT/RELOCATION FLEXIBILITY To Find the BEST Spot in the Area of Operations for Observing	**CLOUD OBSCURATION AVOIDANCE** Clear Skies Virtually Assured
TOTALITY PROLONGATION Aircraft Speed Extends the Duration of Totality	**SKY TRANSPARENCY** Significantly Improved — Lower Particulate Scattering
SKY DARKNESS Much Higher Coronal Contrast, Visibility to Larger Distance	**IMPROVED ASTRONOMICAL "SEEING"** "r_naught" Decreases with Increasing Altitude
REDUCED ATMOSPHERIC TURBIDITY Vorticity & Sheer Decline in Power Above Tropopause	**MORE PANCHROMATIC TRANSMISSIVITY** IR and UV "Windows" Open Up or are Extended
UNPARALLELED HORIZON REACH & OBSERVATION VISTA Apparent Horizon ~ 400 km distant, depressed 3.5° @ 40,000 ft.	**ESTHETIC, ETHERIAL, EXPERIENCE** There is nothing quite like it...

WHY EFLIGHT?

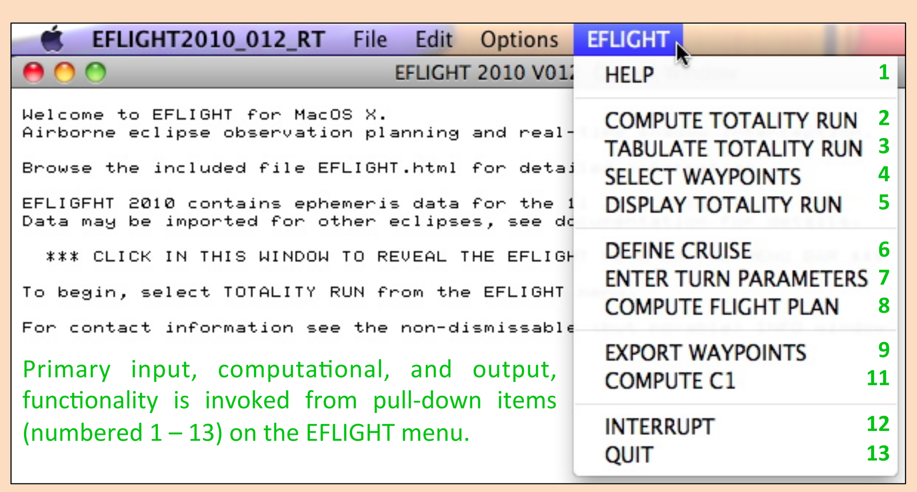
Hitting a moving target (the moon's shadow) from a moving platform (a high speed aircraft) is intrinsically not too complex a problem, though it certainly is non-trivial. To do so, successfully, while optimizing an aircraft flight intercept to strike a desired balance between duration, observability (e.g., line-of-site restrictions due to aircraft windows), cost, and other constraints, must be approached with both care and rigor. By 1992, the availability and capabilities of portable (aka "laptop") computers had so rapidly evolved, that eclipse flight optimization and *re*-planning in reaction to *in situ* conditions became possible. As a result, the first version of EFLIGHT, an integrated eclipse flight planning and navigation S/W package, was engineered for the then fledgling Macintosh PowerBook 100 series laptop computers, and then successfully used to navigate a DC-10 precisely through the path of the 30 June 1992 eclipse. Since then, EFLIGHT has evolved into a fully integrated airborne eclipse observation planning and navigation tool. Many of its current capabilities are illustrated here. Got an airplane?

DEFINING THE "UMBRAL INTERCEPT"



EFLIGHT is an eclipse circumstance calculator with the added twist of addressing the problem of intercepting the moon's shadow from an aircraft in flight. The core algorithms for the computation of at-altitude local and centerline eclipse circumstances are the same as those employed in UMBRAPHILE[a]. Since 1992, EFLIGHT has been used to optimally plan eclipse flights for TSEs 1992, 2001[b], 2003, 2008, 2009, and 2010 (and several "back-up" flights for other TSEs). **Next up: TSE 2015.**

[a] http://nicmosis.as.arizona.edu:8000/ECLIPSE_WEB/UMBRAPHILE.html [b] Canceled following the tragic crash of Concord/AF 4590 on 25 July 2000.



Primary input, computational, and output, functionality is invoked from pull-down items (numbered 1 – 13) on the EFLIGHT menu.

1 COMPUTE TOTALITY RUN – INPUT DIALOG

- Specifies the Universal Time (with one second granularity) at which the aircraft is to be concentrically located in the moon's shadow. → U. T. Mid-Eclipse = 192000 (hhmmss)
- Non-central mid-eclipse intercept: displacement from centerline (CL). → Intercept CL 0 (km / mi / nm) toward Sun
- Computation time window ± UT of mid-eclipse for Totality Run. → Time Window = 7 7 Min.
- Aircraft true AIRSPEED in units of distance/hr (unit per CL displacement). → True Air Speed = 447.39 /hr
- At mid-eclipse fly: (a) specified heading, (b) perpendicular Sun LOS to optimize passenger window viewing (best near the points of local noon/midnight), (c) parallel to shadow motion to maximize duration of totality (at path extrema requires flying "across the shadow"). → Fly Aircraft Heading = 122.36 Deg. / Fly Perpendicular to Sun / Fly Parallel to Shadow
- Aircraft altitude above mean sea level (in feet) at mid-eclipse. → Altitude in feet AMSL = 39000
- Expected Winds Aloft at UT/Location of mid-eclipse. → WIND from 270 Deg., Speed = 55
- Border pad in latitude/longitude for graphical display output window. → Autoscale + 1.2 Deg.
- Time granularity for CL computation and graphical display (right: CL and aircraft latitude/longitude tabulation/display output format). → Display Time Resolution: 1s 5s 10s 30s; Output Format: DDD.xxxxx DDDMMSS.x DDDMM.xxx
- Graphical output inter-frame cadence. / Coordinate display format. → Display Frame Delay = .05 s
- Export time-correlated waypoints to ASCII (text) file. → Export Waypoint Table
- Real-Time simulation: synchronize UT with offset to system clock. → RT SIMULATION
- Size of graphical display window w.r.t. default. → Graphics Scale = 100 °/°

CANCEL OK

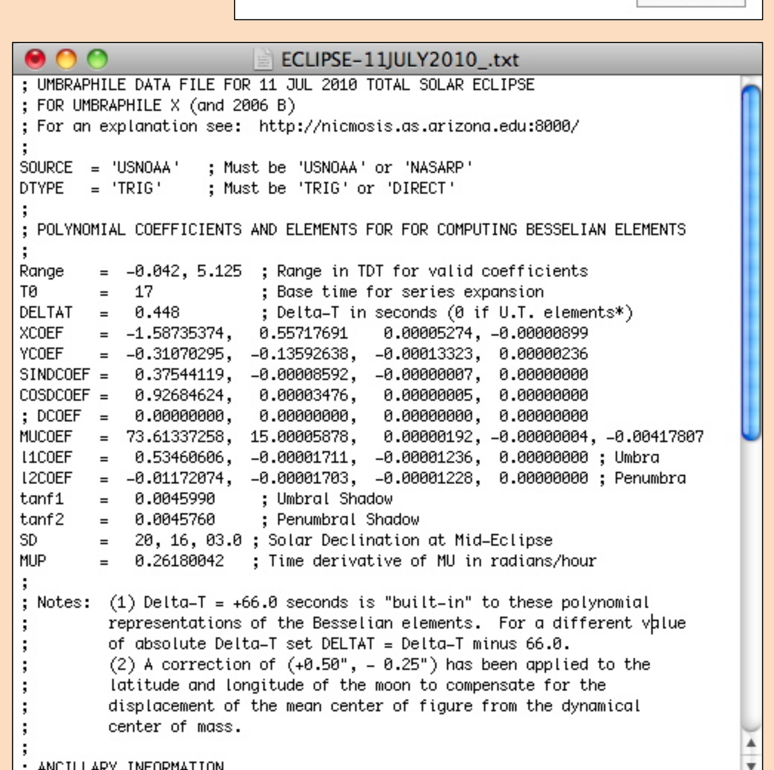
1 COMPUTE TOTALITY RUN OPTIONAL BESSELIAN ELEMENT FILE IMPORT & COMPUTATION UT RANGE AND CADENCE

Start Time	191259.0	HHMMSS.f
End Time	192701.0	HHMMSS.f
Increment	000001	HHMMSS.f
Altitude	11887.2	meters

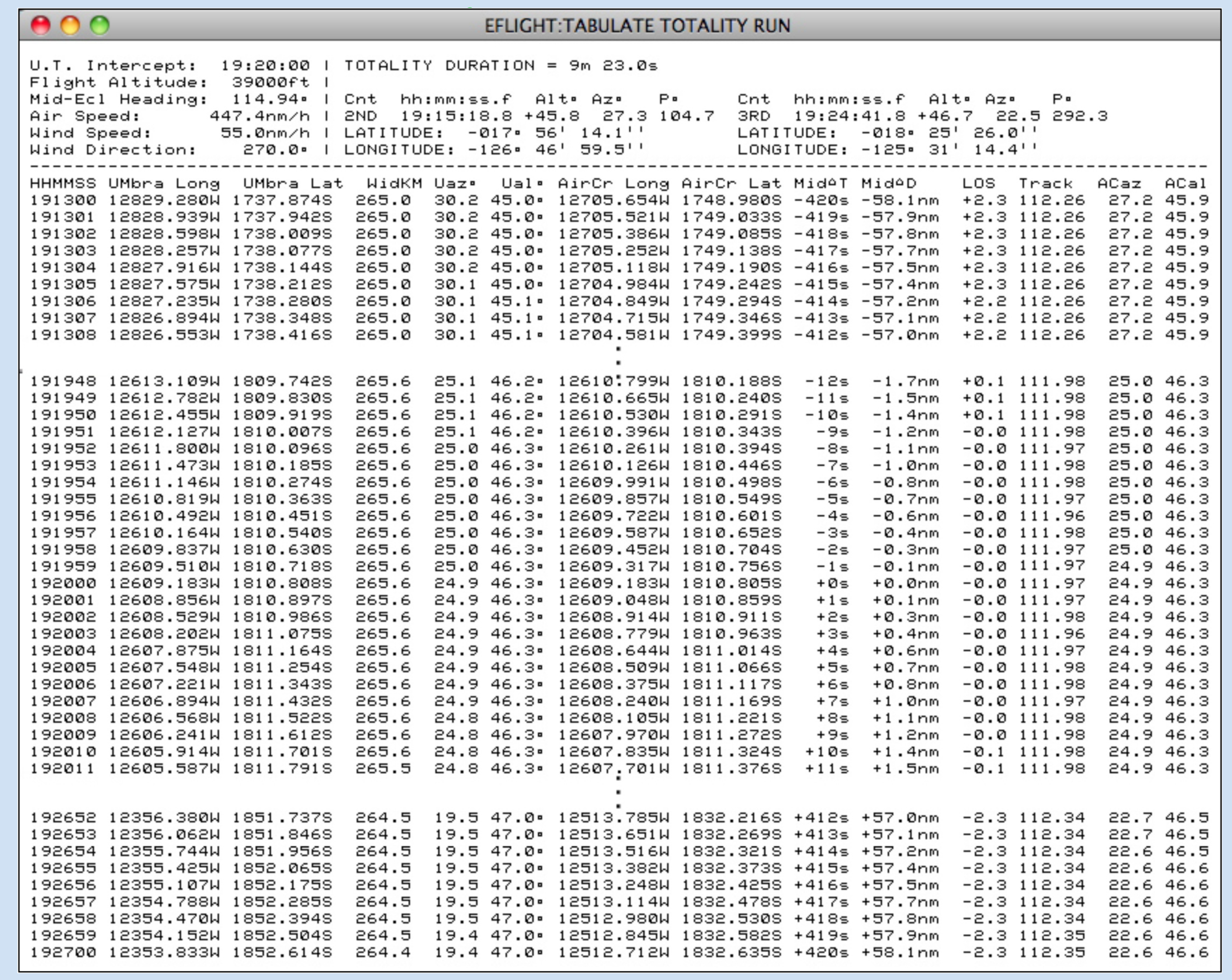
Read Data File

CANCEL OK

Besselian Element ASCII File Format (common format for UMBRAPHILE S/W)



THE "TOTALITY RUN"



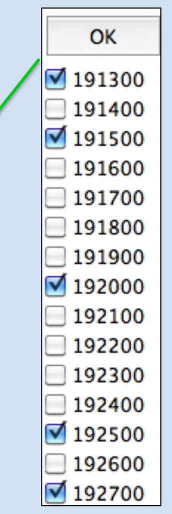
"Local" circumstances for contacts II and III are computed for specified mid-eclipse UT intercept, air speed, direction, winds aloft and altitude.

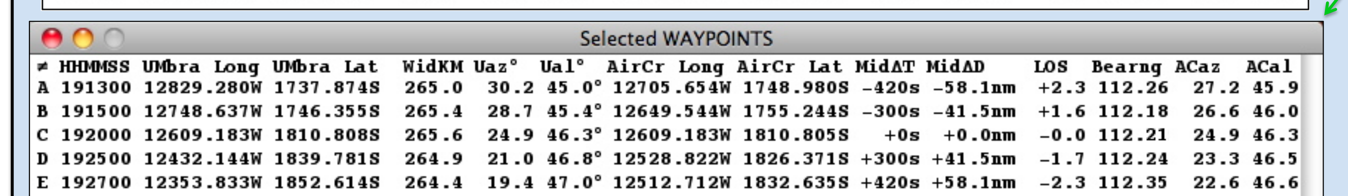
UT correlated position (long./lat.) of umbra shadow axis at height AMSL, shadow width (km), solar azimuth & altitude angle from umbra center with aircraft long./lat.,time and distance (in seconds and km) to mid-eclipse intercept, solar Line-of-Site deviation from window normal angle, aircraft track (w.r.t. true north), solar azimuth and altitude angle from aircraft.

4 SELECT (NAVIGATION) WAYPOINTS

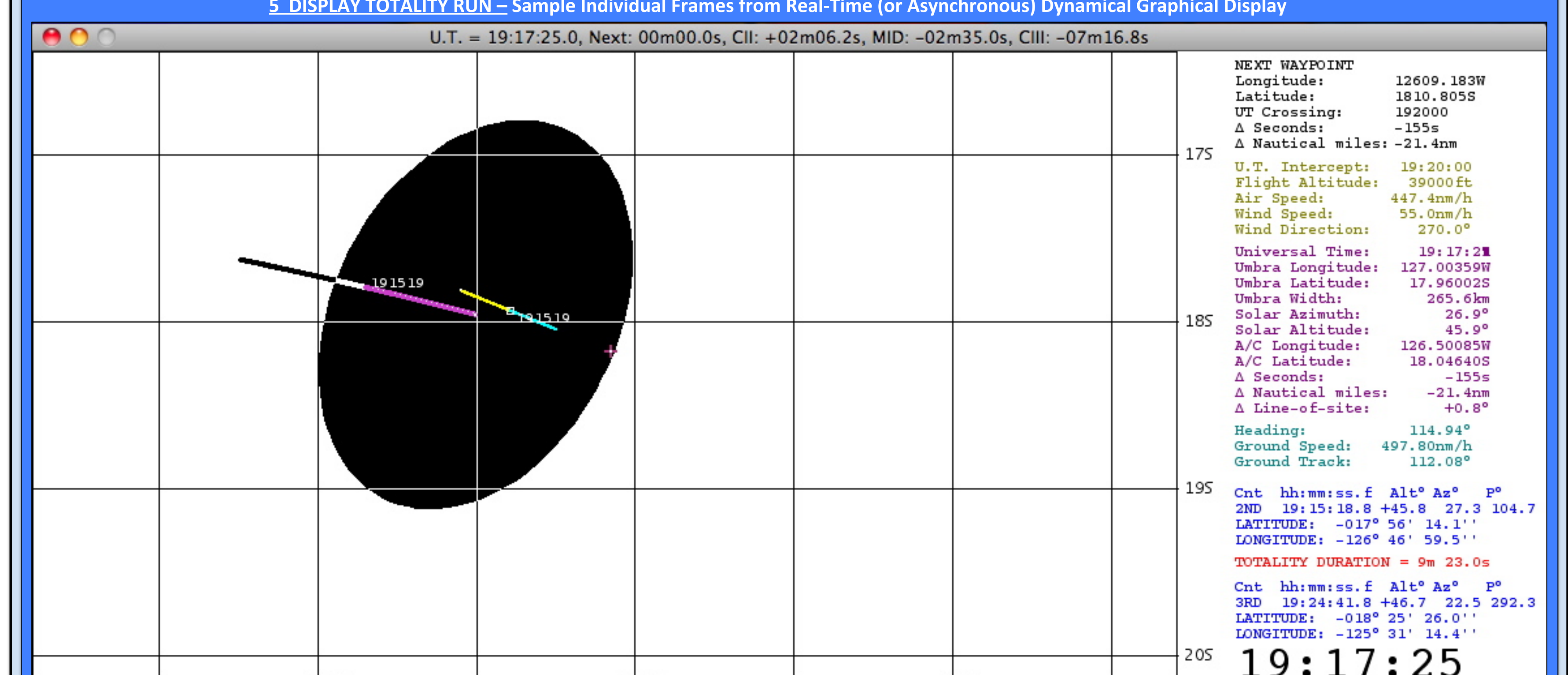
Waypoint Selection Time Granularity: 1s 5s 10s 30s 60S

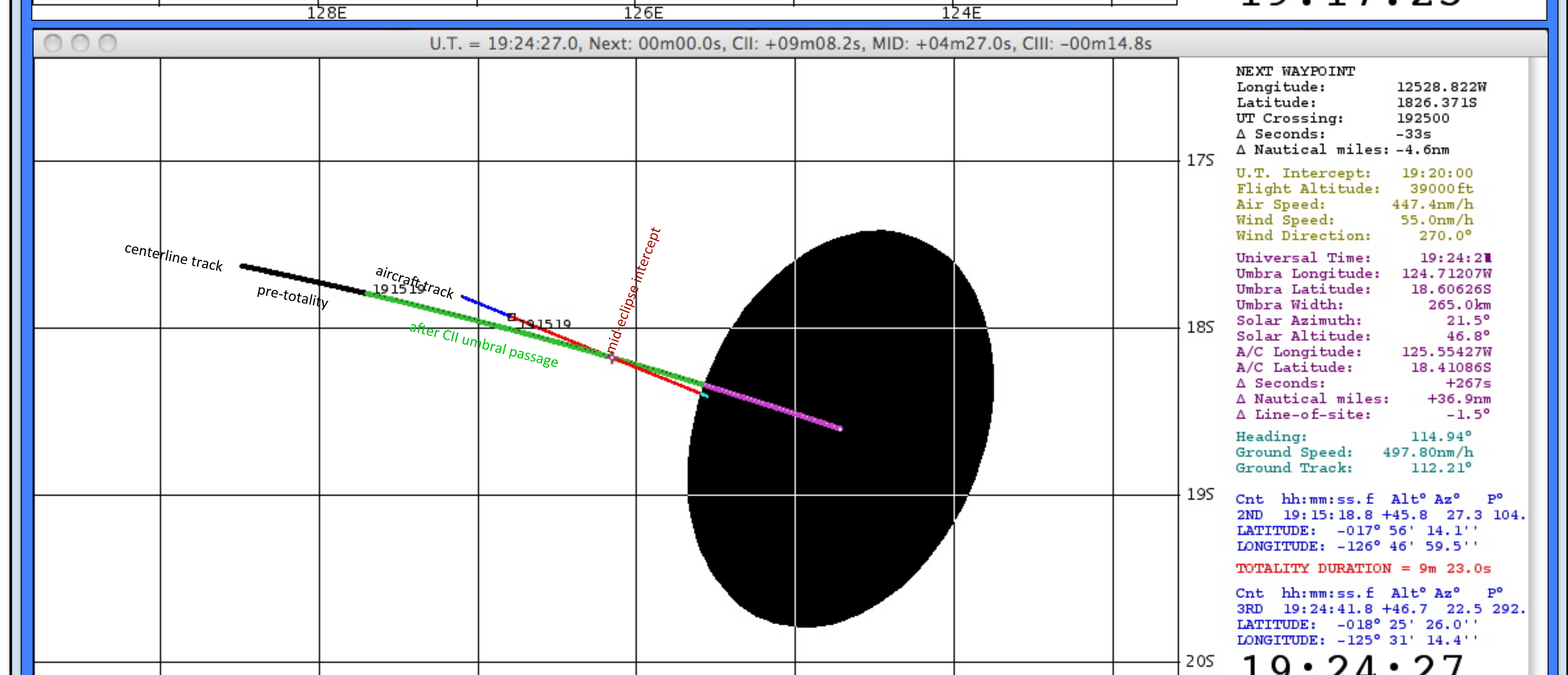
CANCEL OK





5 DISPLAY TOTALITY RUN – Sample Individual Frames from Real-Time (or Asynchronous) Dynamical Graphical Display





END-TO-END EFLIGHT PLANNING

6(a) DEFINE CRUISE – from airport to pre-CII shadow viewing leg by great circle or by navigation waypoints.

- Compute Cruise Waypoints Via Great Circle from/to Airport
- Manually Enter Cruise Waypoints (e.g. on Standard Airway)

CANCEL OK

		DDMM.ff	N/S		DDDMM.ff	E/W
CR1	PAPAE	1820.00	S	Longitude	14500.00	W
CR2	PEBRO	1900.00	S	Longitude	14000.00	W
CR3	PATIA	1915.00	S	Longitude	13500.00	W
CR4	PATUI	1920.00	S	Longitude	13000.00	W

CANCEL OK

6(b) DEFINE CRUISE – anticipated winds aloft for all primary at-altitude flight legs

SPECIFY WINDS ALOFT BEFORE/AFTER TOTALITY RUN

ANTICIPATED WINDS ALOFT		nM/h	Deg
PAPAE > PATIA	Outbound Cruise 1st Half	35.0	240.0
PATIA > SVITS	Outbound Cruise 2nd Half	50.0	260.0
SV1 > SV2	Ingress Shadow Viewing	55.0	270.0
TR1 > TR2	TOTALITY RUN	55.0	270.0
SV3 > SV4	Egress Shadow Viewing	55.0	270.0
CR4 > CR5	Inbound Cruise Leg 1	40.0	250.0
CR5 > CR6	Inbound Cruise Leg 2	40.0	225.0

CANCEL OK

7(a) ENTER TURN PARAMETERS – entry of aircraft performance during constant radius turns

CONSTANT RADIUS (RF) TURNS

Bank Angle (Degrees)	15.0
Turning Radius (nM)	10.90
Fixed Rate (Deg/sec)	0.6666
Entry+Exit (Seconds)	8.0

CANCEL OK

7(b) ENTER TURN PARAMETERS – A/C nose deviation angle during shadow viewing to keep windows in fuselage shadow

For INGRESS Shadow Viewing Leg SV1 -> SV2:

Orient Aircraft NOSE 2.0 deg. WEST of Solar Azimuth at SV2

CANCEL OK

8 COMPUTE FLIGHT PLAN – additional end-to-end inputs

TAKE-OFF > START CRUISE, END CRUISE > LANDING

Airport Latitude 1732.40 (DDMM.ff) S Longitude 14936.68 (DDDMM.ff) W

Take-off to Cruise PAPAE 38.16 minutes, 268.0 nM

CR6 Cruise to Landing 24.00 minutes, 150.0 nM

SHADOW VIEWING LEG DURATION (Nearst UTC Minute)

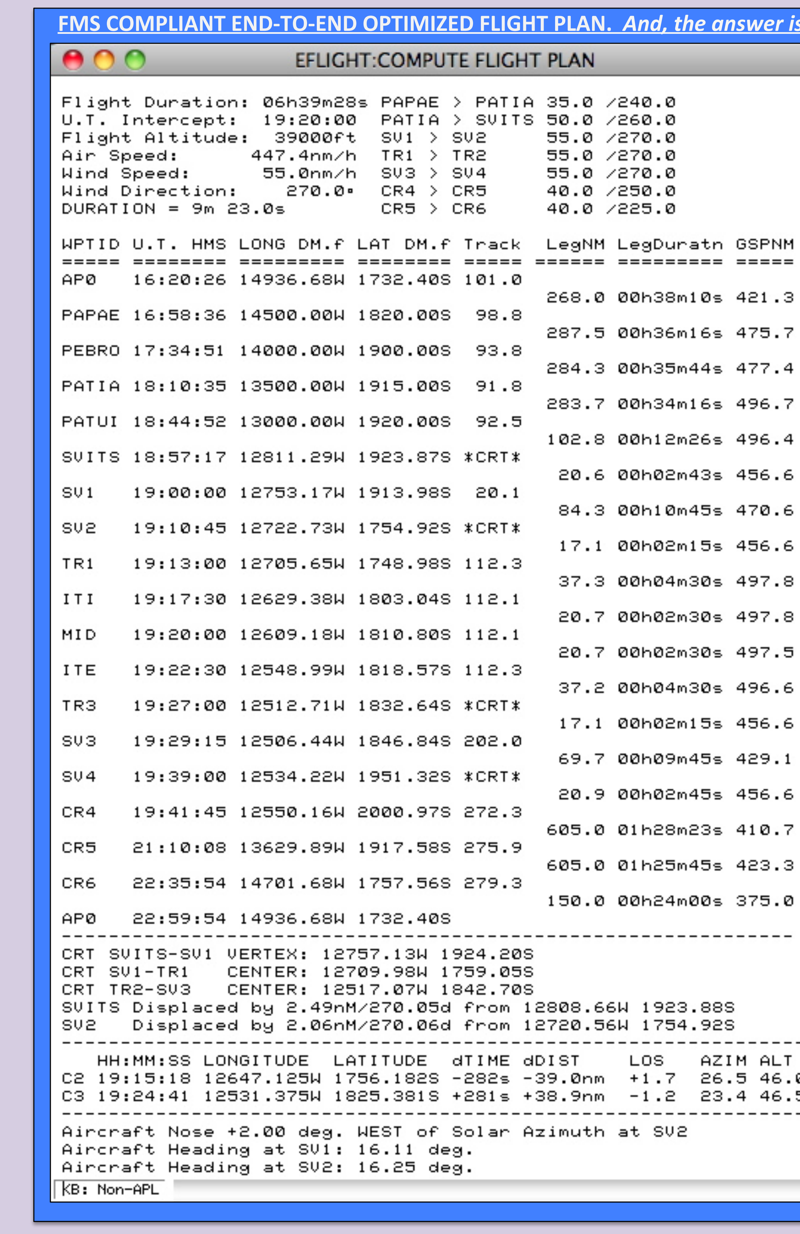
Ingress (SV1 > SV2) 10 minutes Egress (SV3 > SV4) 9 minutes

ADDITIONAL INTRA-TOTALITY WAYPOINTS

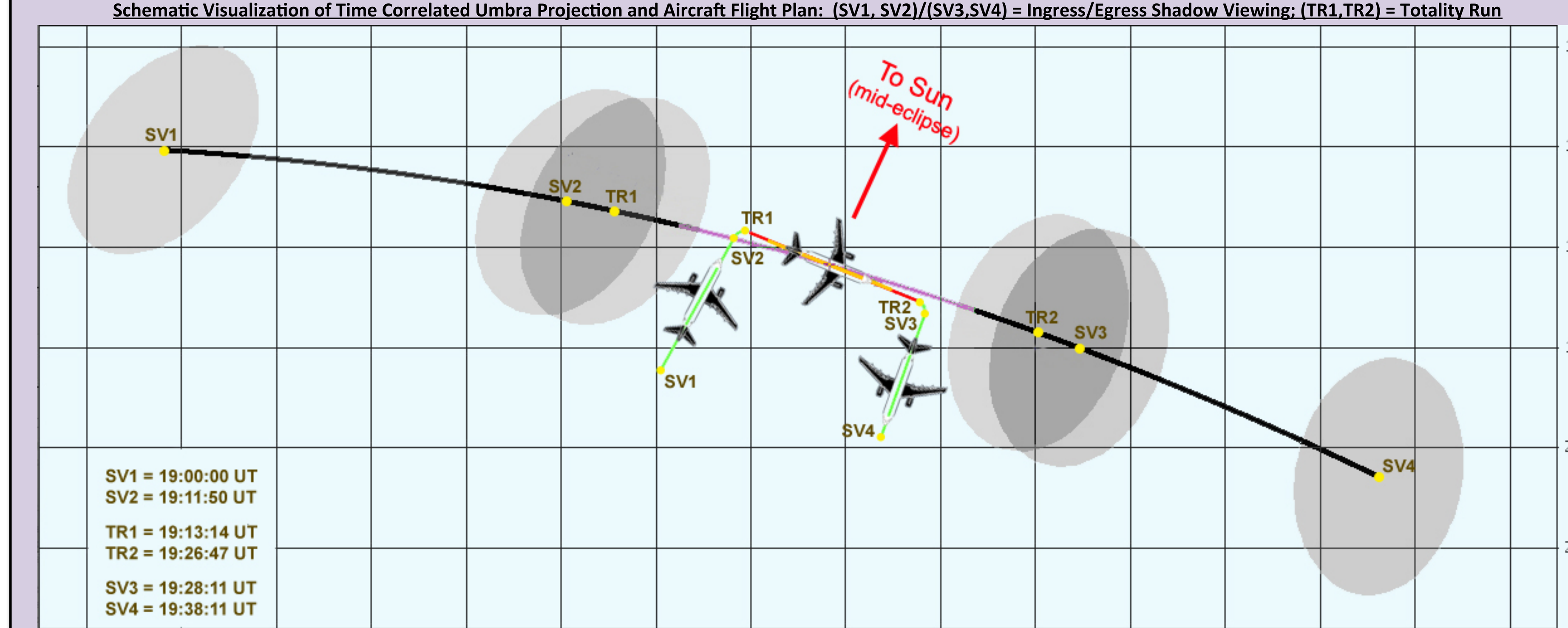
at MID-Eclipe +/- 2.5 minutes

CANCEL OK

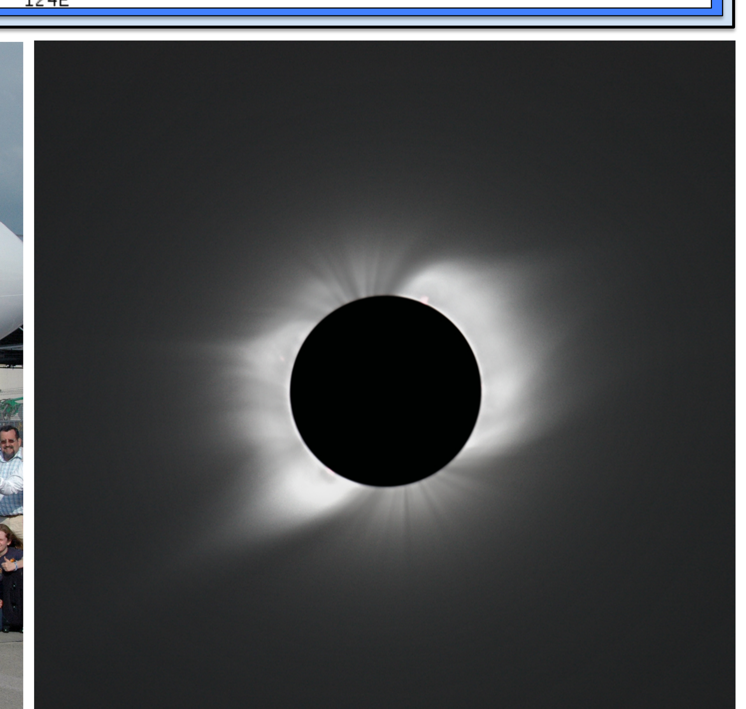
FMS COMPLIANT END-TO-END OPTIMIZED FLIGHT PLAN. *And, the answer is…*



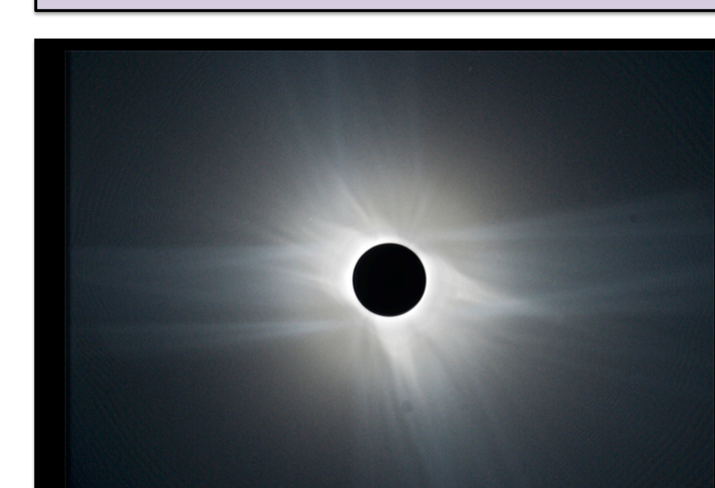
Schematic Visualization of Time Correlated Umbra Projection and Aircraft Flight Plan: (SV1, SV2)/(SV3,SV4) = Ingress/Egress Shadow Viewing; (TR1,TR2) = Totality Run

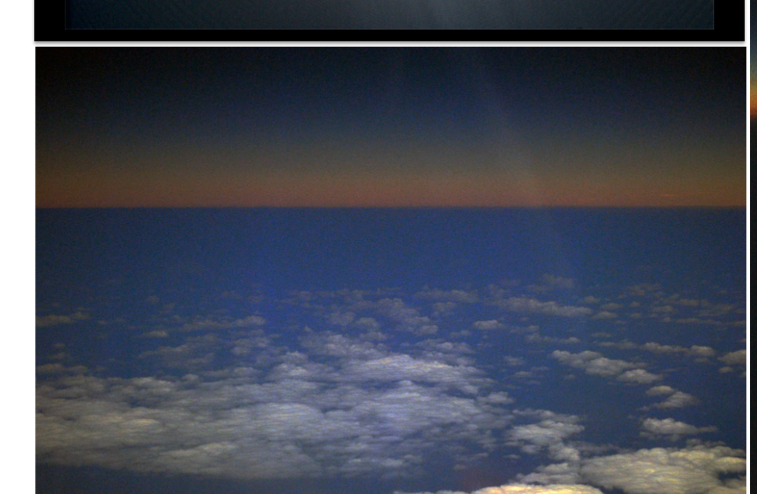


BACK ON THE GROUND AFTER TSE PLANNED & EXECUTED WITH EFLIGHT 2008 (2m 52s TOTALITY, 82.6°N)

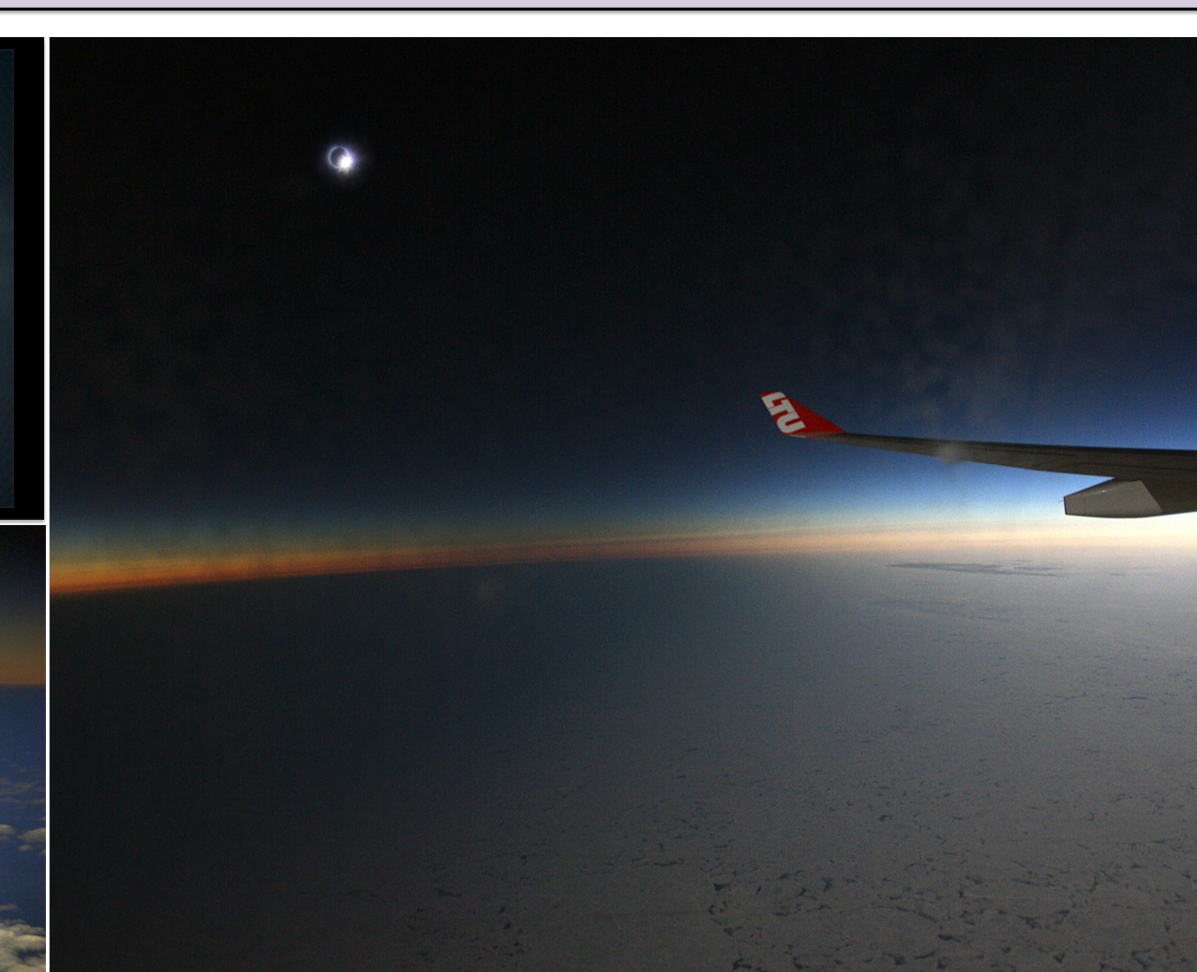


TSE 2008 HIGH CONTRAST/DARK SKY CORONA FROM 36,000 FT. AMSL





EFLIGHT 2010 SHADOW INTERCEPT: MID-TOTALITY & UMBRA APPROACH



TSE 2008 CII: STUNNING VIEW OF THE SKY ABOVE AND SEA-ICE BELOW ENABLED BY EFLIGHT PRECISION NAVIGATION