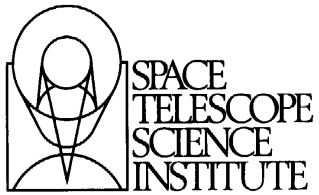
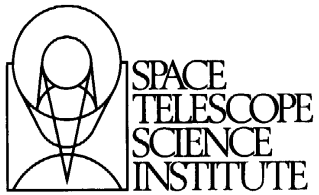


NGST Mission Simulator

Larry Petro/STScI

April 27, 2001

Overview



- Objectives
- Models
- Tools & products
- The future

NMS Objectives

- Support development of the DRM science program
  - Goal: exposure times accurate to ~20% (throughput & backgrounds ~15%)
- Support design parameter sensitivity studies
  - System level representation of design characteristics
  - Absolute accuracy less important
- Provide a user-controllable tool
  - No hard-coded parameters
  - User-editable & supplied input data files

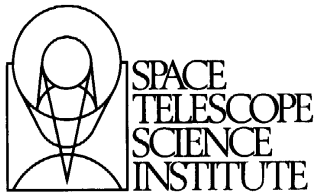
NMS models

- Signal detection
- Throughput
- Background
- Image quality
- Spacecraft ephemeris
- Surveys
- Observing overheads
- Scheduling algorithm (for MET)

NMS model features

- Wavelength dependence of all quantities, 0.5 - 30 μm (Six octaves)
  - Throughput
  - PSF sharpness
  - Detector quantum efficiency
  - Background
- Computes exposure time, S/N, sensitivity, and overheads
  - Fine time-mesh evaluation of all quantities
- Representation of survey mission
- Values of parameters in baseline OTA & ISIM files based upon GSFC Yardstick design

Signal detection model



- Photometric matched filter (Wiener filter)
  - Optimal detection, uniquely defined
  - Does not require specification of aperture size
  - Defines "image sharpness"
- Signal proportional to
  - OTA & SI throughput, detector QE
  - Bandpass per pixel (defines "spectral resolution" of camera and spectrograph)
- Background, detector, and target noise
  - Flat-field noise not represented

S/N definitions

$$S/N = t_{\exp} s_{t\arg} \Big/ \sqrt{N_{eff} S_{bkg} + s_{t\arg} t_{\exp}}$$

$$S_{bkg} = s_{dark} t_{\exp} + n_{read} \sigma_{read}^2$$

$$N_{eff} = \sqrt{N_{sharp}^2 + N_{t\arg}^2 + N_0^2}$$

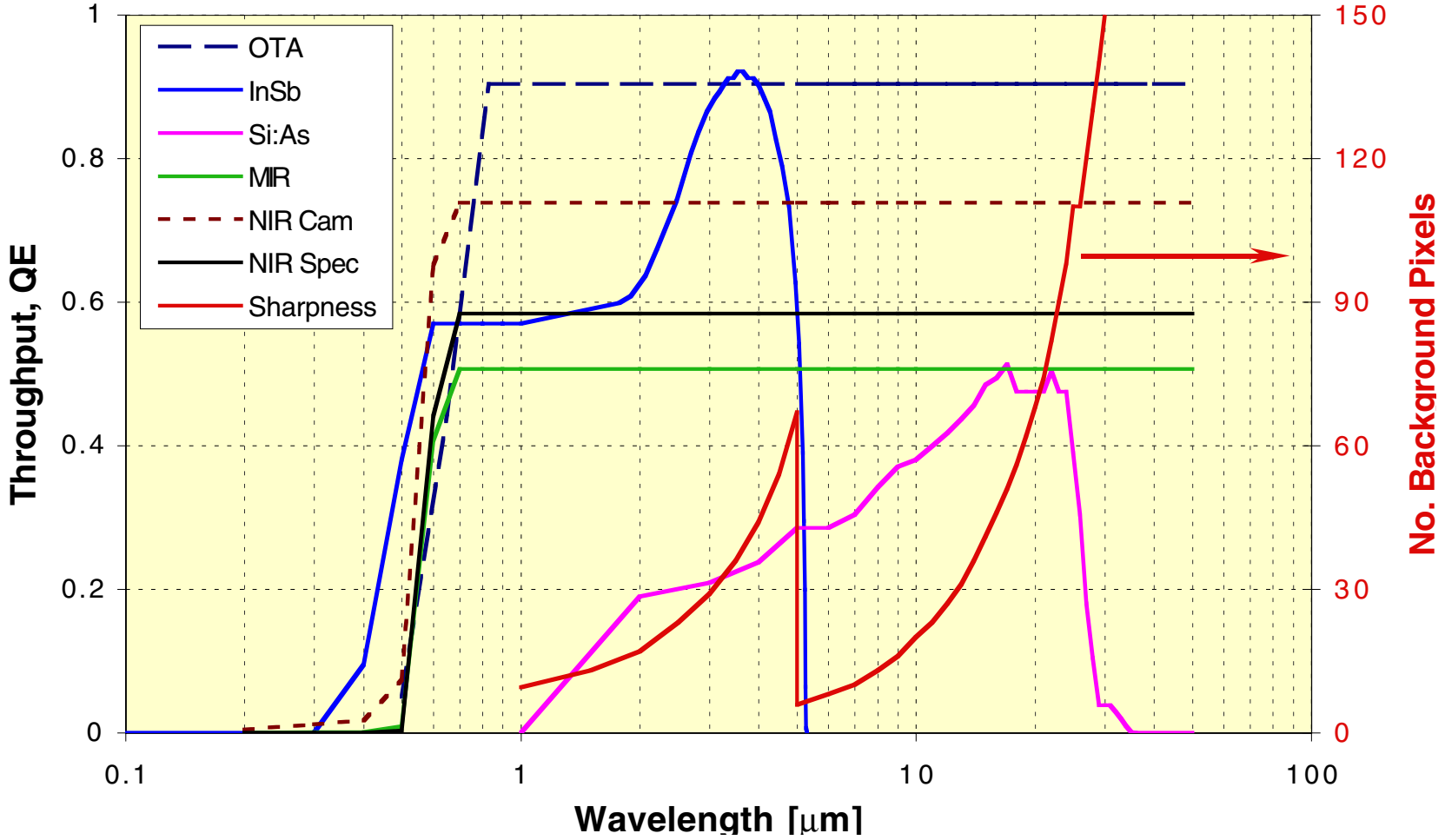
$$N_{sharp} = \int PSF^2 d\Omega \Big/ \Omega_{pix}$$

$$s_{t\arg} = S_\nu A_{tel} \eta_{tot} \nu / SPR$$

Throughput

- OTA
  - Number of surfaces (5 in GSFC Yardstick)
  - Gold reflectivity (GSFC & Astro. Quantities)
- ISIM
  - Total throughput for each SI specified in user-supplied, wavelength dependent vector
    - Spectrometer slit loss included in total
  - Values in baseline input file for GSFC Yardstick
    - Gold reflectivity
    - Nominal lens and filter mean transmission
    - Nominal grating efficiency
- Detector quantum efficiency
  - InSb and Si:As for GSFC Yardstick

NGST Throughput



Background

- Zodiacal Light
- Scattered light (sunshield, stars, ZL)
- Thermal emission
- Detector noise
- *Not modeled*
  - Infrared cirrus (not significant $\lambda < 30$ μm)
  - Local backgrounds (*i.e.*, host galaxies, stellar PSF)
  - Earthshine, moonlight (scheduling will mitigate)

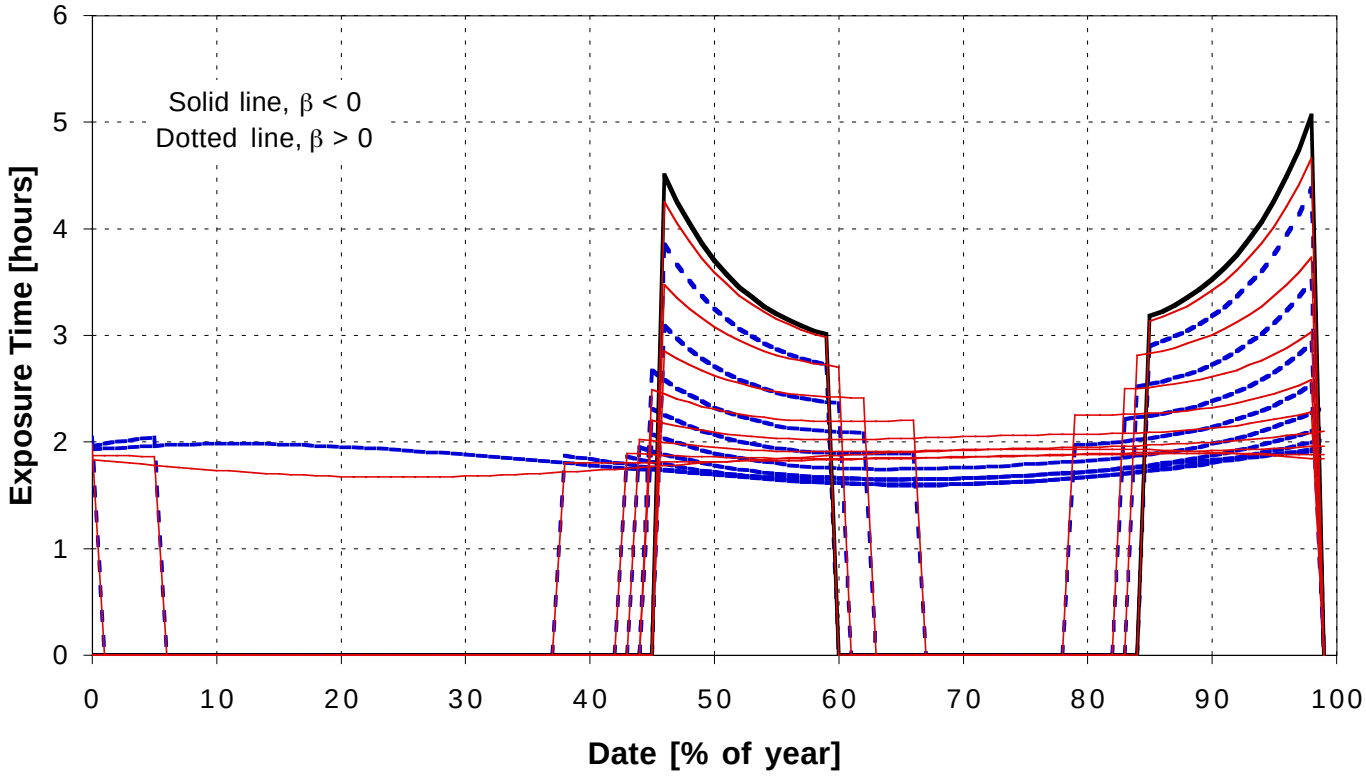
Zodiacal Light

- Model represents COBE/DIRBE obs. (E. Wright code)
- Interplanetary dust scatters and re-radiates sunlight
  - Scattering important in NIR (< 4 μm)
  - Thermal emission important in MIR (> 4 μm)
- Distribution of dust
  - Centered on Sun
  - Density decreases slowly with distance from Sun
- For a given target, surface brightness varies with day of year

Zodiacal Light (cont'd)

NIR-ACCUM Image

(m_{AB}=31, λ=2.0 μm, $\lambda/\Delta\lambda$=5, S/N=5)



Scattered light model

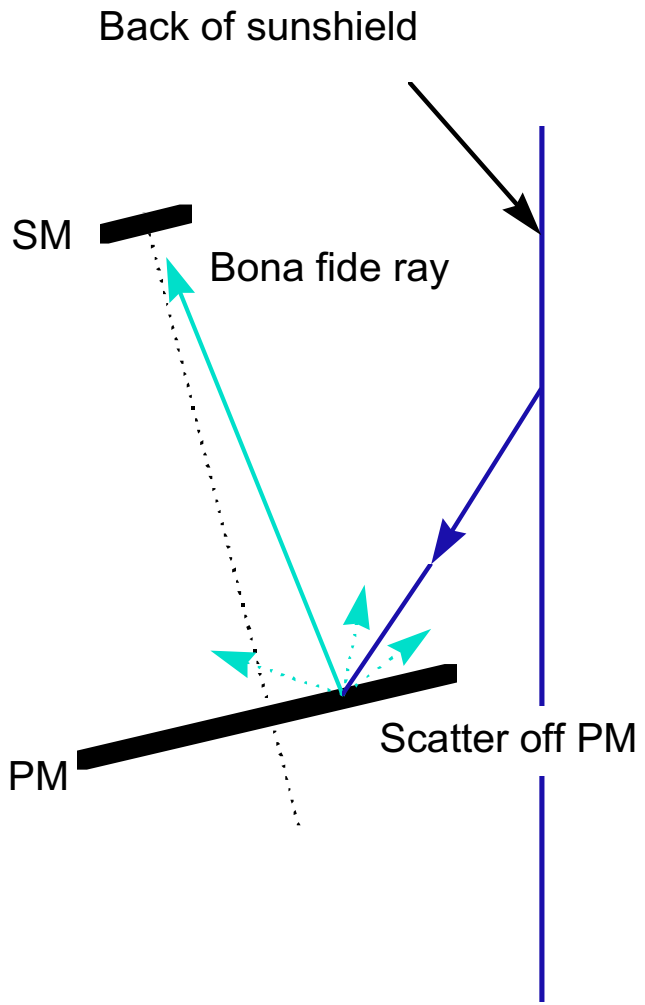
- Scattering of sunshield thermal emission, Zodiacal Light, and starlight
- Apply basic radiometry: $\propto dAd\Omega\cos\theta\cos\varphi I_{src}BRDF$
- Finite element representation
  - Sunshield temperature distribution
  - Primary mirror modeled as N segments (8 in baseline)
  - Secondary mirror is 1 segment
- Mirror scattering BRDF
  - Represents dust & microroughness
  - Fits Spyak & Wolfe calculations
  - Wavelength dependent
- Blockage by mirrors and sunshield computed

Sunshield thermal emission

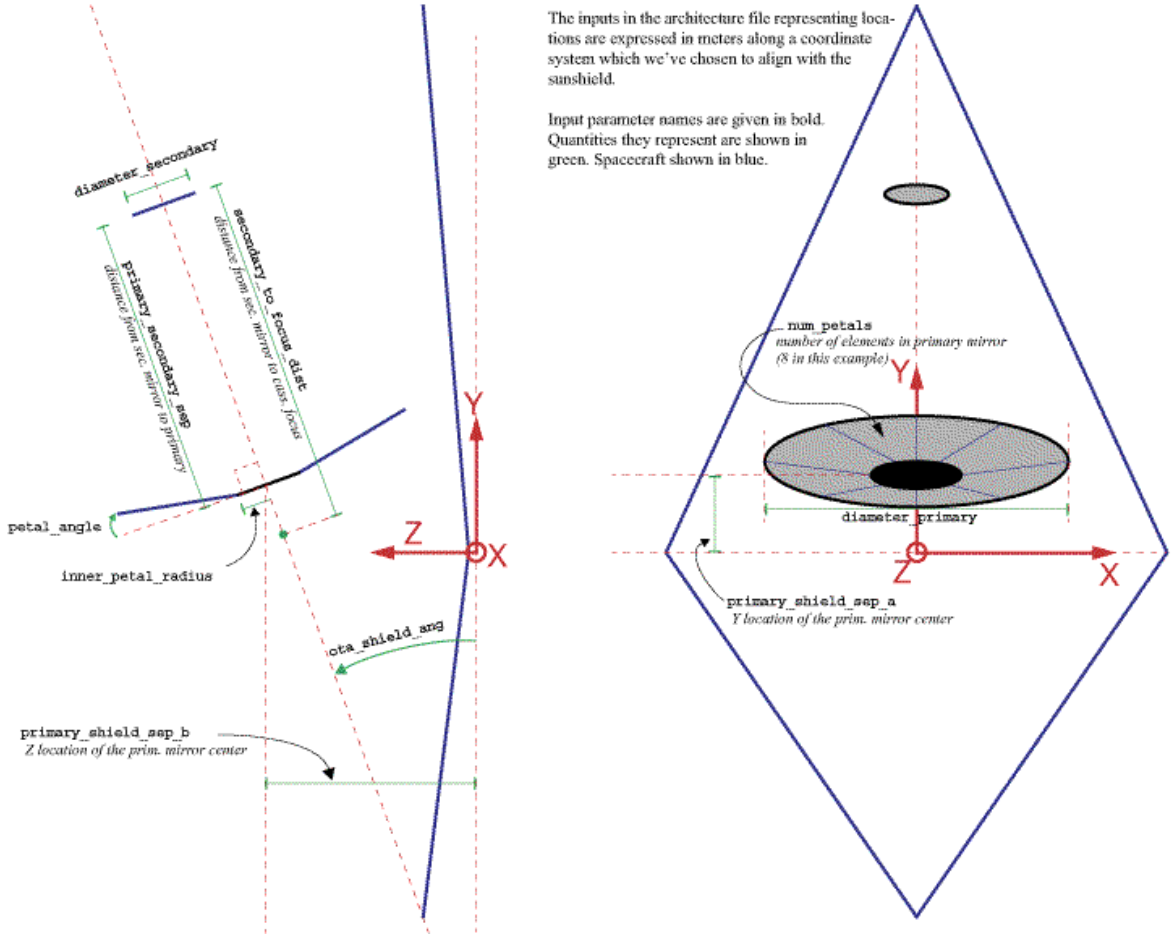
- Six-layer sunshield transfers some heat to the back surface
  - Temperature is ~100 K
- Temperature varies as

$$T^4 \propto \cos\theta_{Sun} / d^{0.5}$$

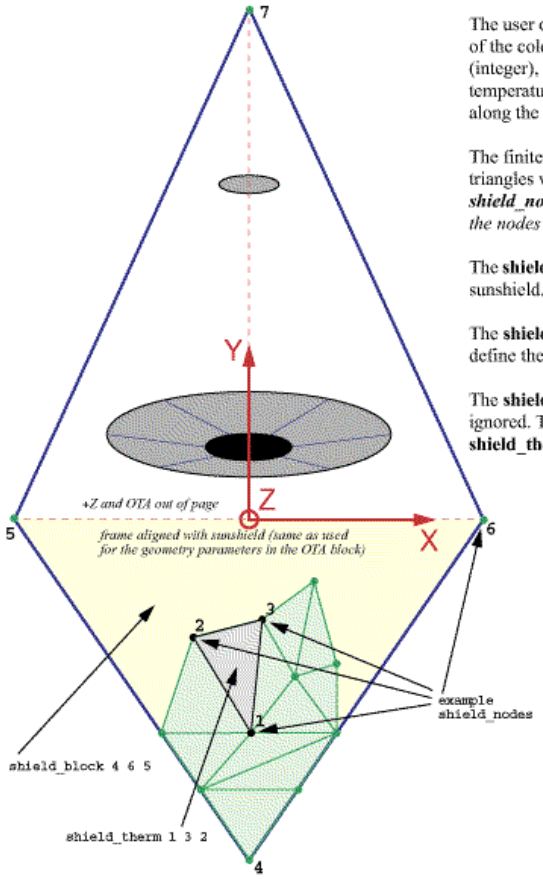
- Nominal roll for start of each visit



Definitions of "OTA" Parameters in NMS Space & Telescope File



Definitions of Sunshield Elements in NMS Space & Telescope File



The user defines any number of "**shield_node**". These are points along the surface of the cold side of the sunshield. Each **shield_node** is supplied a unique identifier (integer), its X,Y,Z location in meters, and the beginning-of-life and end-of-life temperatures of the shield surface at that point. They may be distributed in any way along the shield back.

The finite elements (**shield_therm** or **shield_block** records) are then defined as triangles with corners comprising three shield_nodes. *The listing of the **shield_node** identifiers in the **shield_therm** and **shield_block** records must specify the nodes counter-clockwise as seen from the cold side of the sunshield.*

The **shield_therm** elements are used to calculate backgrounds originating from the sunshield.

The **shield_block** elements are used for sky blockage calculations and need only define the perimeter of the sunshield.

The **shield_node** records used by **shield_block** have their temperature fields ignored. The same **shield_node** may be used in both a **shield_block** and **shield_therm** definition.

Example:

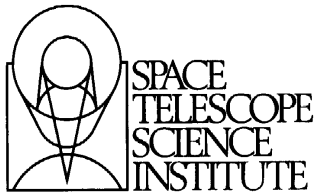
```
                #   X    Y    Z    BOL (K) EOL (K)
shield_node     1   x1   y1   z1    50      65 ;
shield_node     2   x2   y2   z2    68      88 ;
shield_node     3   x3   y3   z3    70      91 ;
shield_node     4   x4   y4   z4     0       0 ;
shield_node     5   x5   y5   z5     0       0 ;
shield_node     6   x6   y6   z6     0       0 ;
shield_node     7   x7   y7   z7     0       0 ;


shield_therm 1   3    2 ;
shield_block 4   6    5 ;
shield_block 6   7    5 ;
etc...
```

Scattered sky & Zodiacal Light

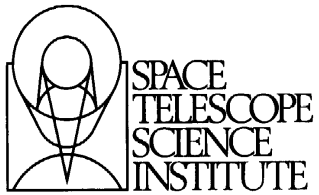
- Sky (starlight)
  - COBE/DIRBE measurements are tabulated
    - 2.6° cells
    - Six DIRBE wavelengths (1, 2, 3.5, 5, 12, 25 μm)
  - Uses lookup in angle, interpolation in wavelength
- Zodiacal Light
  - Uses COBE/DIRBE model for specific direction & wavelength

Thermal emission



- Primary and secondary mirror represented by grey-body emission
- Temperature of each mirror separately specified
- Emissivity supplied by user as wavelength dependent vector

Detector noise



- Dark current
  - Proportional to integration time
- Readout noise
  - Fixed amount per image frame
  - Frame time limited by Cosmic Rays and pixel well-depth
  - Dependence on number of Fowler samples is not modeled
  - Simplified representation not optimal for MIR due to rapid filling of pixel wells by observatory thermal background
- Values in baseline ISIM file are from feasibility Detector WG studies

NGST Backgrounds

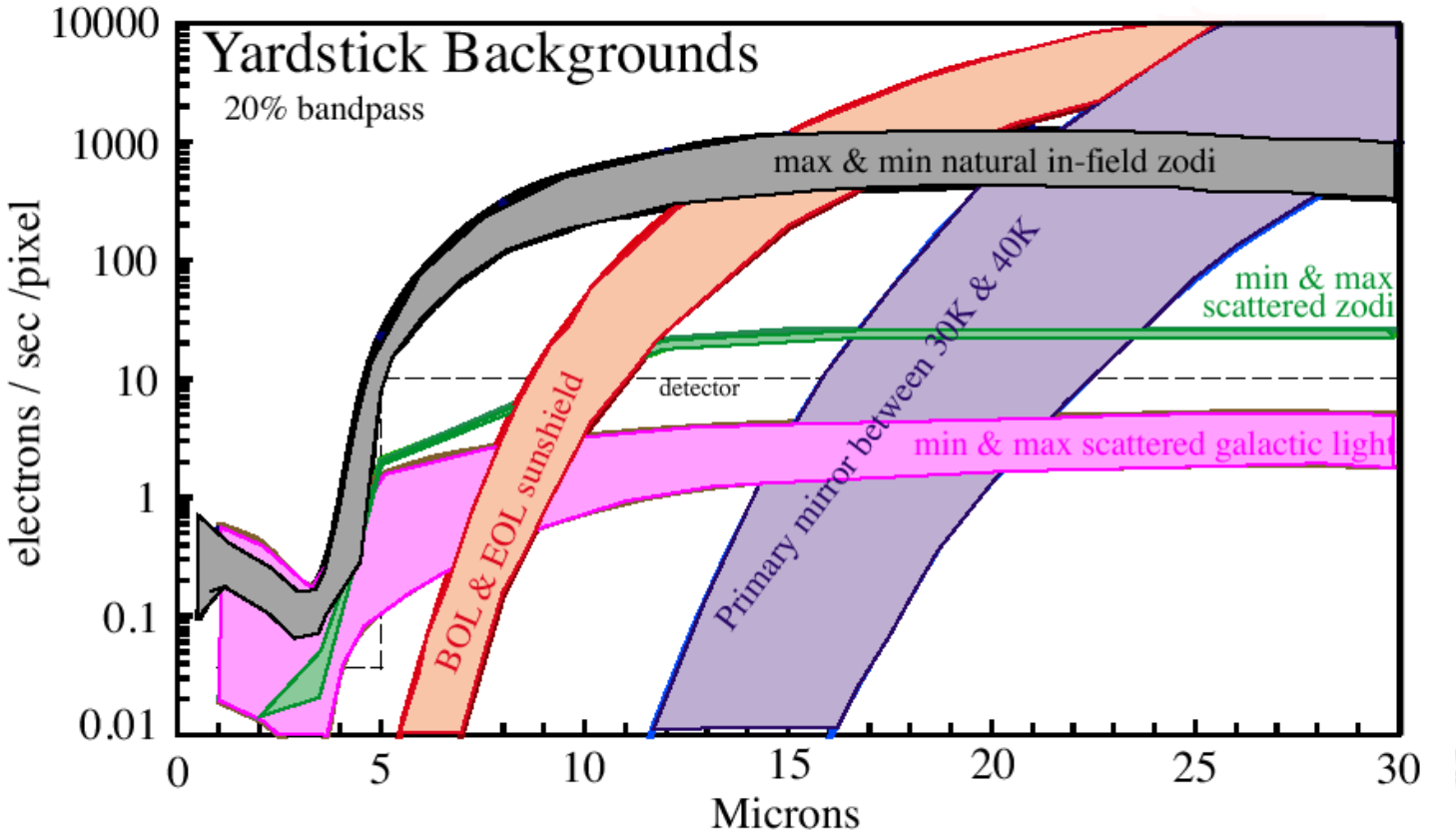
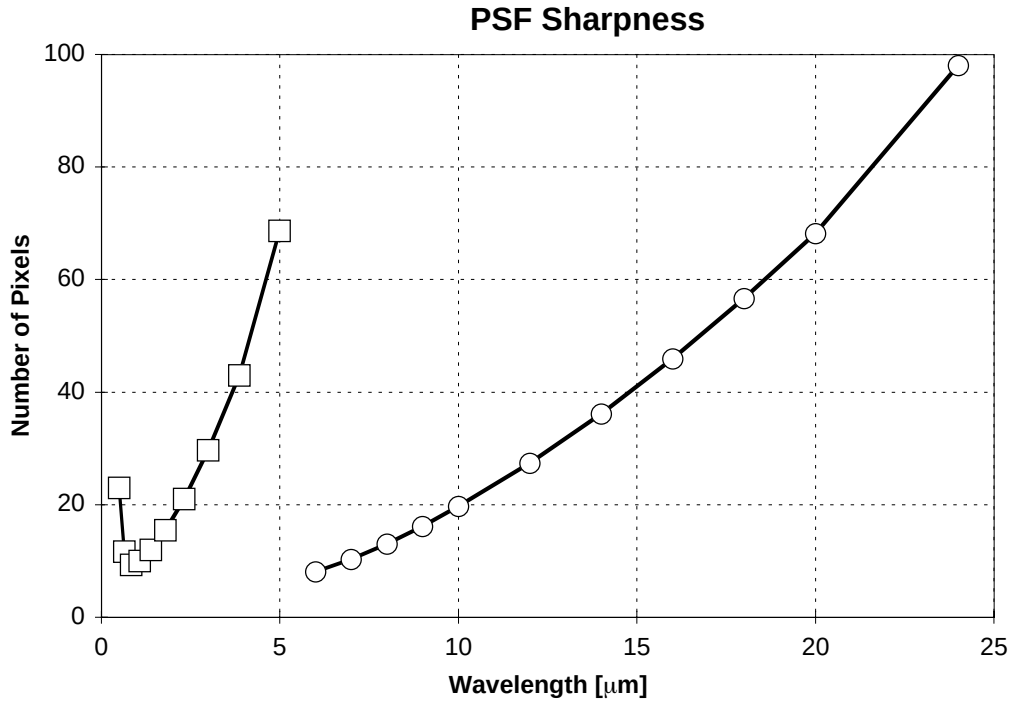


Image quality

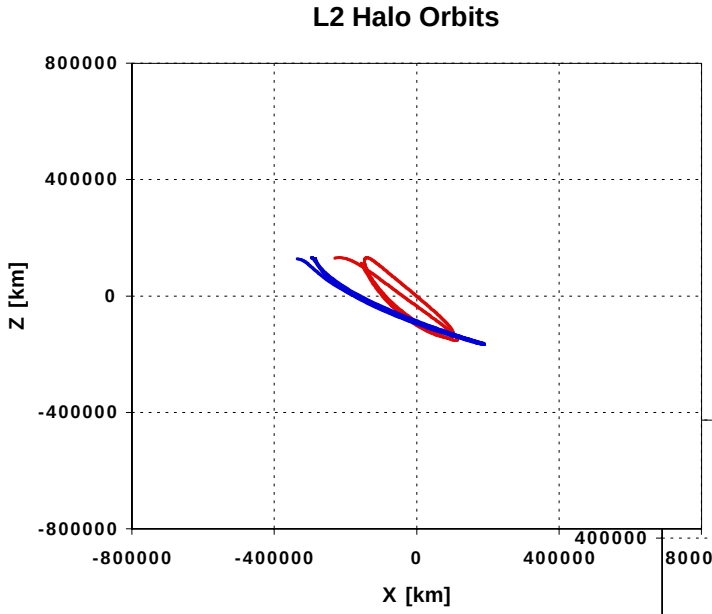
- PSFs from wavefront simulations by J. Trauger
  - Hex-segment primary mirror
  - Scaled HST WFE
  - λ_{crit} = 1.5 μm

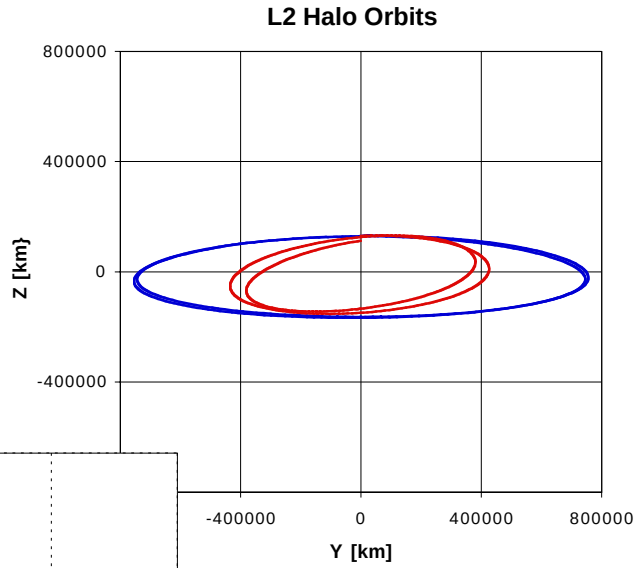


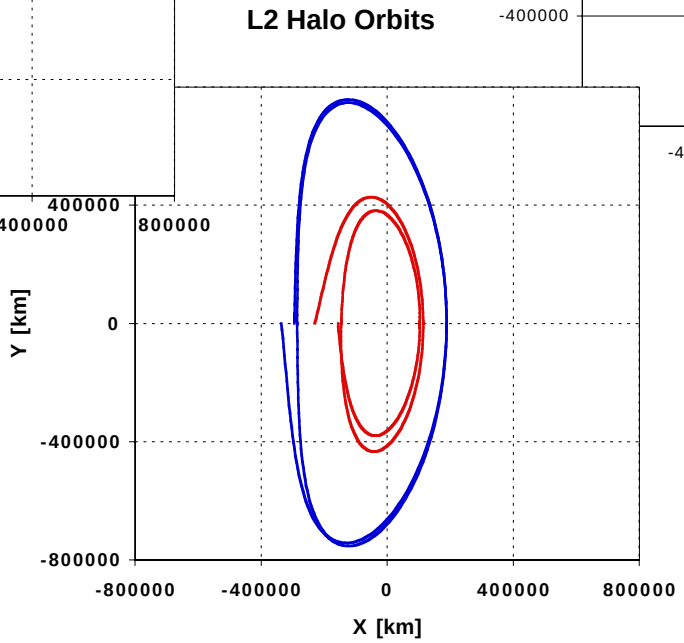
Spacecraft ephemeris

- Employed for Zodiacal Light background, sun-pointing restrictions
- Ephemerides pre-computed with HST MOSS
  - L2 Halo (large & small)
  - 1 x 1, 1 x 2, 1 x 3, 1 x 4, & 1 x 5 AU
  - 1 x 1 AU: 10°, 20°, & 30°, inclined
  - See Release Notes for v1.9
- Or, user may supply the ephemeris

Examples of L2 Halo Orbits





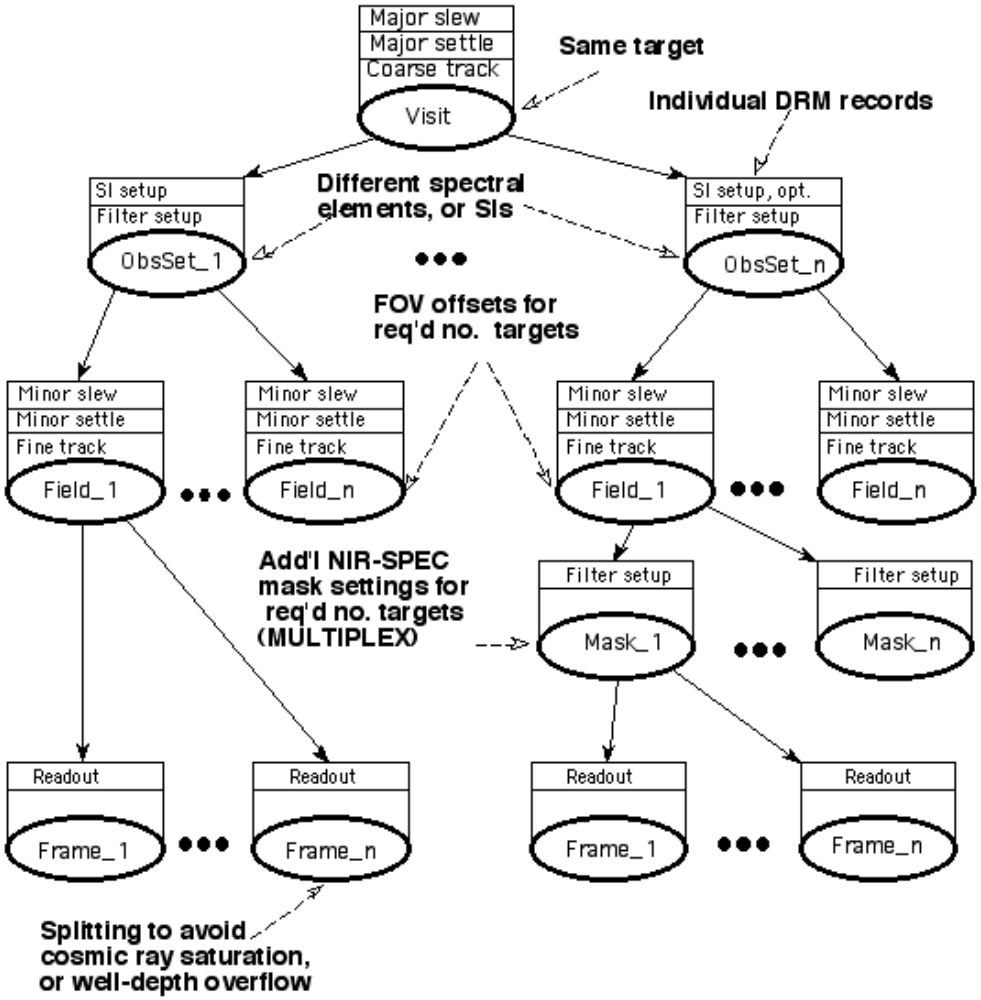


Survey model

- Wide, diffraction-limed FOV of NGST and survey nature of science programs is accounted
  - Number of required targets
  - Surface number density of targets
  - SI field of views
    - Cameras
    - Multi-object spectrograph
      - Number of targets per exposure is limited
  - Exposure time per target

Overhead model

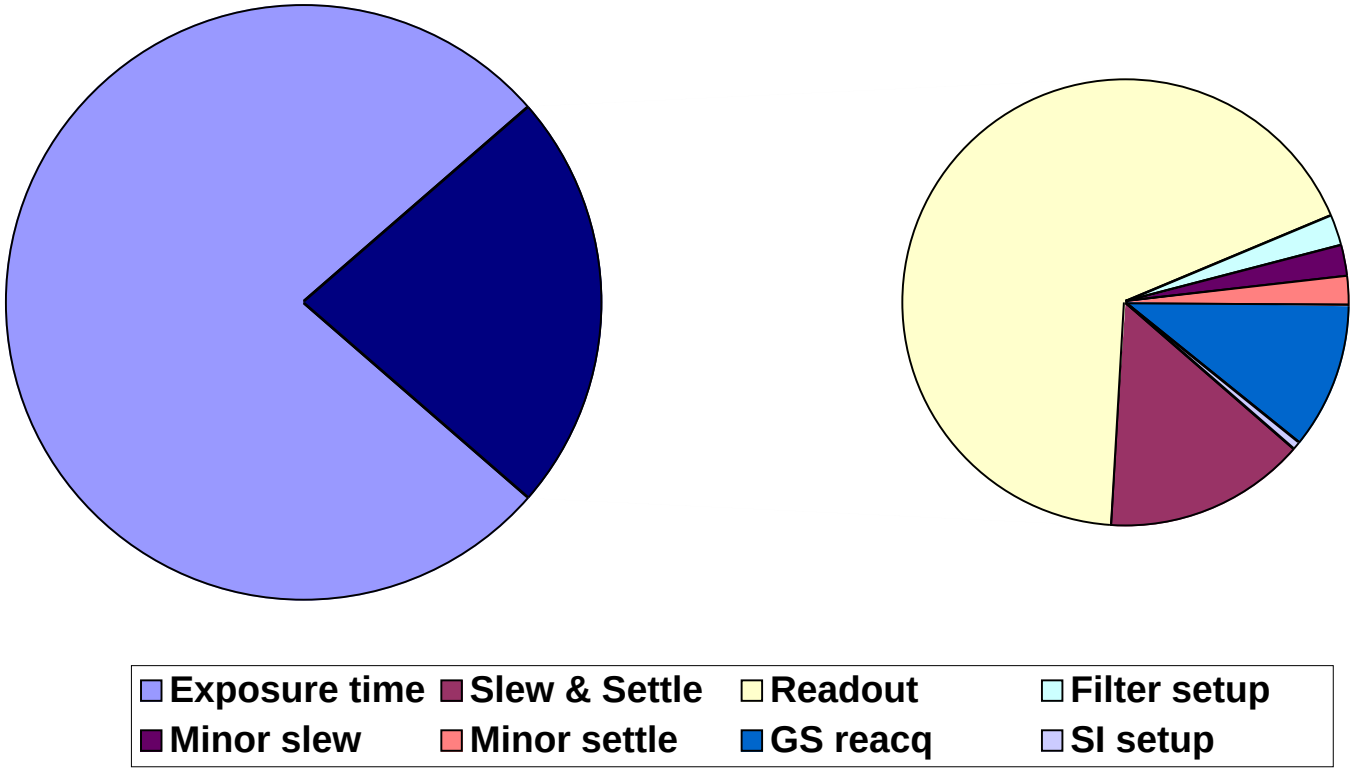
- Hierarchical accounting
- Slew, settle, Tracker Acq, SI setup, filter setup, readout, GS Acq, small angle maneuver, SAM settle
- Fowler sampling for detector data frames
- *Not included*
  - Calibration (SIs, WFE)
  - Housekeeping (momentum, orbit)
  - Solar flares
  - Safings



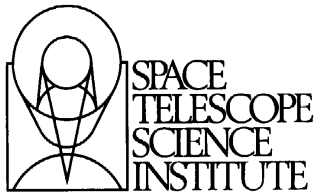
NMS exposure splitting and overhead model

6-16-1999
LDP

Observing activity distribution (by Mission Elapsed Time)



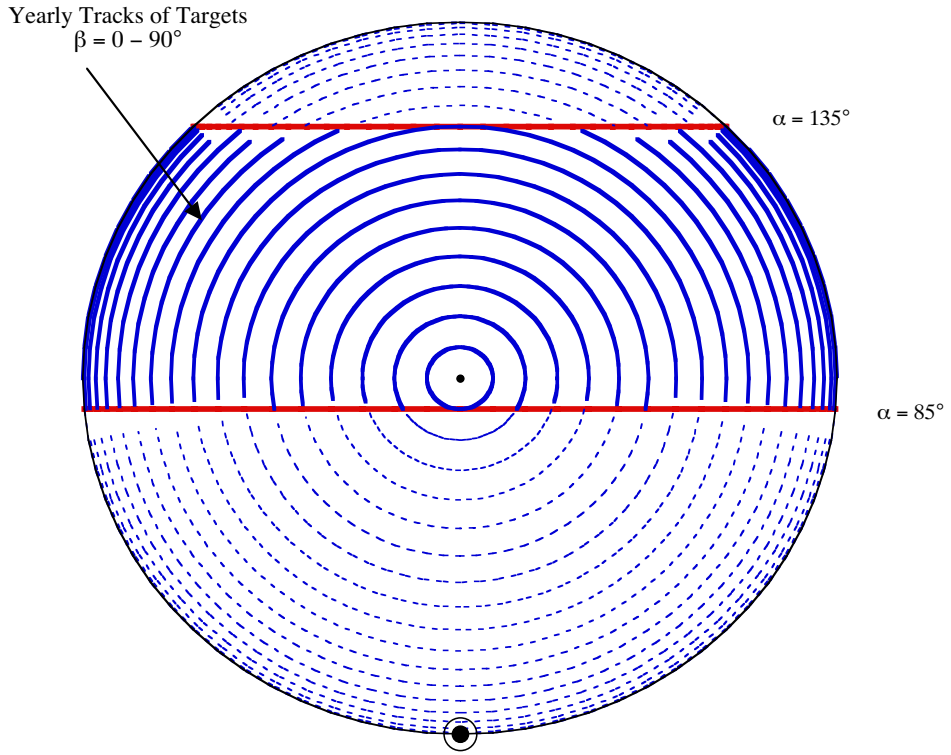
Scheduling



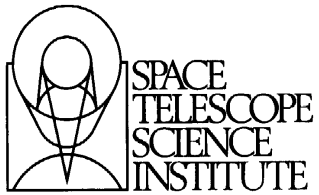
- Greedy algorithm
- Evaluate observation MET on mission mesh
- Scoring metrics
  - Greatest ratio
  - Greatest difference
- Pointing restrictions enforced

Sun angle restriction characteristics

- Visibility windows repeat on a yearly cycle
- Duration and number of windows is a function of target ecliptic latitude
  - $\beta > 85°$ Continuous (one-year) visibility
  - $45° < \beta < 85°$ One window and one gap per year
  - $\beta < 45°$ Two windows and gaps per year



Validation of NMS



- Scattered sunshield background compared to APART
- Zodiacal Light matches COBE/DIRBE measurements
- PSF sharpness function anchored to Trauger calculations
- Sanity checks vs. other simulators

NMS user interface

- Web browser
  - Immediate
  - Batch submission
- Command line (with user-installed S/W)
- Data files (all can be supplied by the user)
  - OTA/Spacecraft
  - ISIM
  - Science Program
  - Ephemeris
  - Sky intensity
- Parameter variations (supplied by user)

Tools & products

- ETC (Min, max, median)
- S/N (Min, max, median)
- Sensitivity (Min, max, median)
- MET (scheduled observations)
- Parameter variations
  - Sum of minimum MET

The future

- Evolution of a scientist's planning tool
  - Background reports
  - Improved ISIM model
  - Inclusion of models from other ETCs
- Update baseline input files
  - Downselected architecture
  - MISC MIR SI
  - Selected NIRCAM & NIRSPEC
- Maintenance of design parameters and models
- Operations studies
  - Scheduling and guide star availability