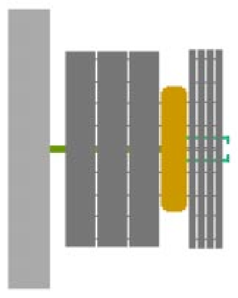


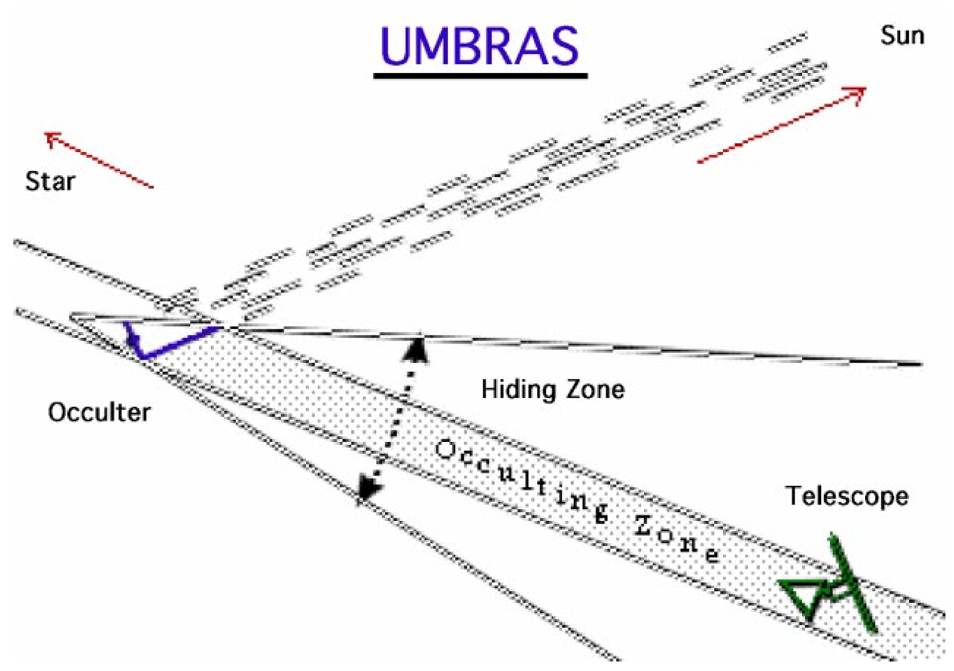
Enhancing NGST Science: UMBRAS

http://www.stsci.edu/~jordan/umbras/

What is UMBRAS?

UMBRAS (Umbral Mission Blocking Radiating Astronomical Sources) is a spacecraft designed to interpose itself between a space-based telescope and bright astronomical targets. In addition to blocking light from the target, light in the PSF is redistributed, and better contrast at small angular separations is achieved for faint objects. This will enable more powerful planet searches around nearby stars, and allow other NGST science goals to be enhanced.

Observing Configuration of UMBRAS & NGST



The diagram at left shows the relative configuration of UMBRAS and the space telescope. UMBRAS interposes itself between target star and telescope to block the light, literally placing the telescope in the umbra of the star.

The screen shade sits 'atop' the occulting screen and shields the occulting screen from direct sunlight. The spacecraft bus is hidden behind the occulting screen from view by the telescope (in the 'Hiding Zone'), allowing the telescope to see only the dark unilluminated side of the occulting screen.

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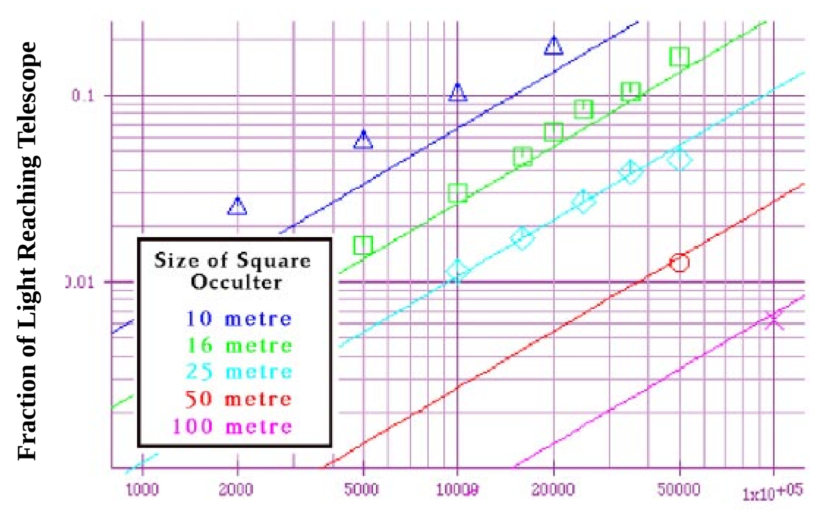
Special thanks to Karla Peterson, AURA, for suggesting the acronym *UMBRAS*.

What can UMBRAS achieve?

A number of groups have done studies on the effectiveness of an occulter at reducing light from a star. Our study assumed a centred, square occulter with an 8-metre telescope. The data for average light reduction at 1.6 μ is plotted at right. More in-depth studies show that light reduction is not uniform across the field and the occulter produces its own diffraction spikes depending upon occulter shape, size and distance. As a result of the diffraction spikes, there are localized regions where the light is far below the average values indicated here.

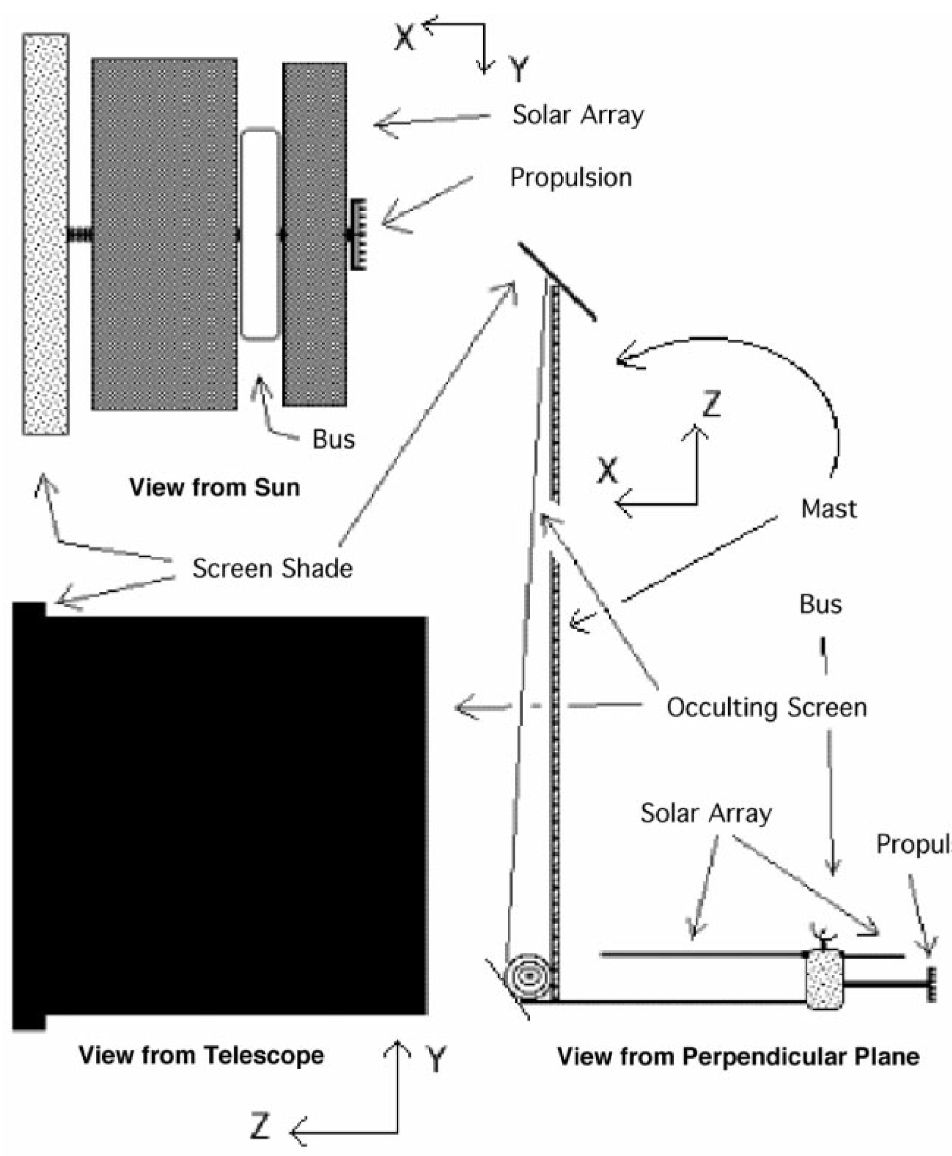
A central goal of UMBRAS is to produce an image showing an extrasolar planet--not sinusoidal curves on a graph which is how current indirect evidence of planets outside our solar system is presented.

Square Occulter Light Reduction at 1.6 μ



Lines show Copi & Starkman's aperture-independent 'nulling factor'. Data points are the result of Schroeder's numerical simulations of light reduction over a centred, circular 8-metre aperture.

What might UMBRAS look like?



Major Occulter Components:

- **Screen Shade**
- **Occulting Screen**
- **Screen Pedestal & Boom**
- **Spacecraft Bus**
- **Propulsion Module & Boom**
- **Solar Arrays**

This preliminary SPIDER design employs a 16 x 24 metre unfurling MLI screen which is shaded from the sun during observations by a shack-roof *screen-shade* that prevents any illumination of the telescope-ward side of the occulting screen. SPIDER maintains a fixed orientation during the observation to achieve this, using ACS thrusters mounted on the bus and propulsion boom to achieve the necessary stationkeeping requirements.

Larger occulting screens block more light at greater ranges. To accomplish this and not violate payload bay restrictions with an MLI screen, an alternate design using an interlaced telescoping Screen-Shade (extending in the y-direction) to create a 30-metre wide occulting screen appears possible.

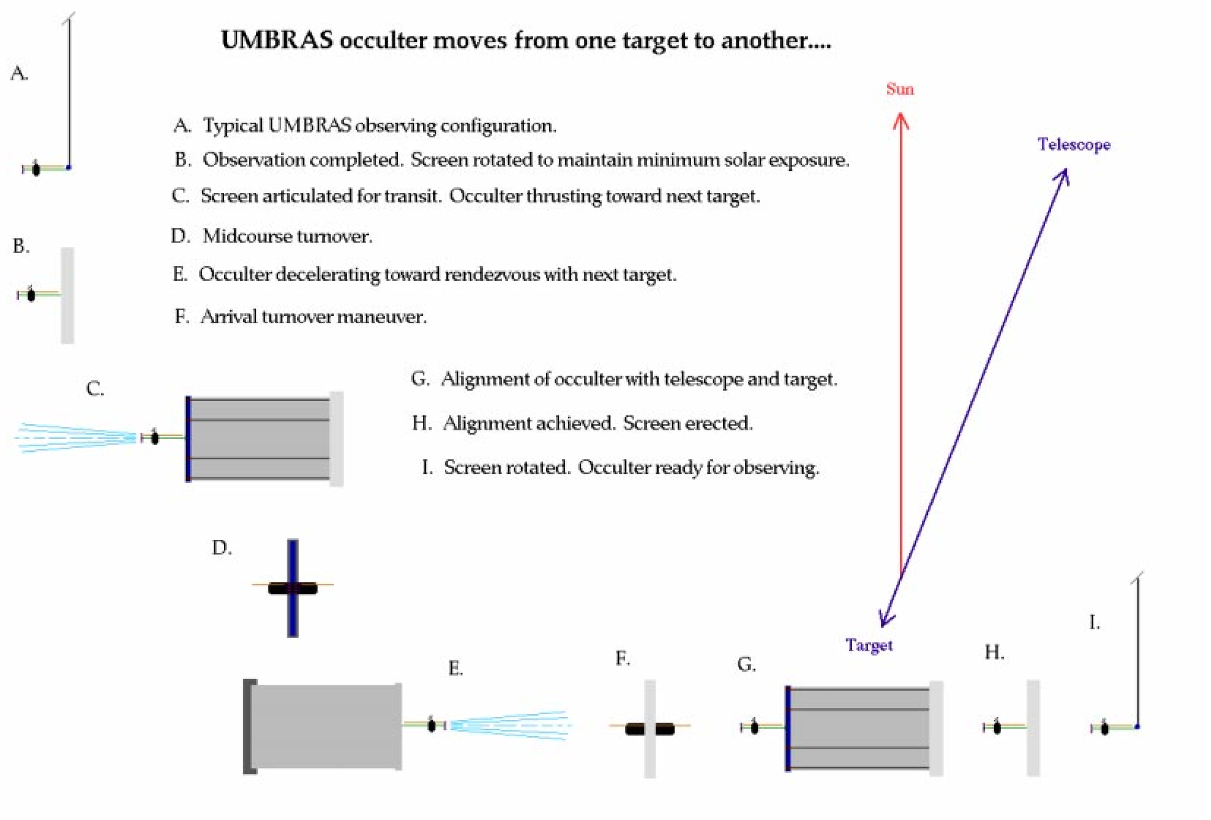
UMBRAS operation is compatible with NGST

An operations concept has been developed which allows the occulter spacecraft (SPIDER--Solar Powered, Ion-Driven Eclipse Rover) to move from target to target and offer significant observation rates while using only a small fraction of NGST observing time.

The diagram at right shows the major phases of an NGST-class occulter moving from one target station to another.

Like NGST, UMBRAS cannot operate/observe at NGST's antisolar point. Operation near the 'quadrature ring' is preferred, because the *occulting screen* must be visible to the telescope and present as large of an aspect as possible, yet remain shielded from the sun by the *screen shade*.

Preliminary assessment shows that stationkeeping can be performed to keep the relative position of NGST and occulter stable during observations.



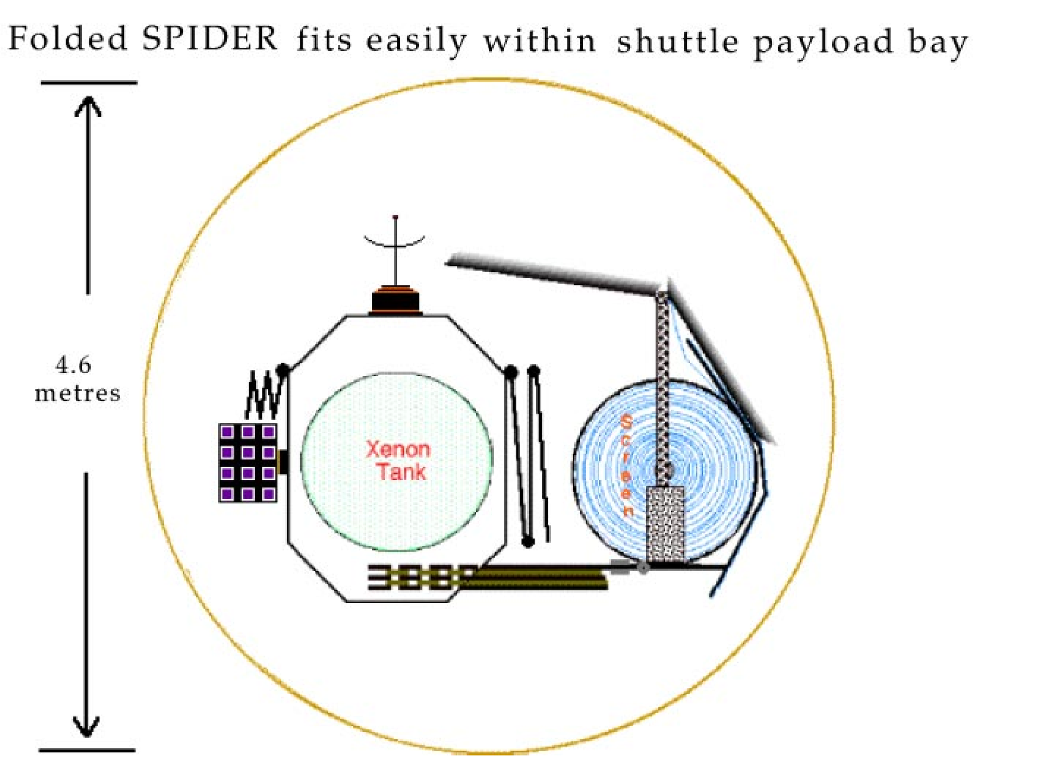
- ***Occulting Screen*** **unfurled from 'window shade' cassette on** ***Screen Pedestal.***
- **Controlled 1-time unfurling of** ***Screen*** **&** ***Propulsion Boom*** **deployment.**
- **Bistems or coiled** ***Astromasts*** **for shade/screen support.**
- ***Screen Pedestal*** **articulates for:**
  - **Transit to provide symmetry for thrust control.**
  - **Observations to hide bus/array/propulsion from telescope view.**
- ***Propulsion Module*** **on boom minimizes contamination & interference.**
- ***Attitude Control System*** **mounted on** ***Bus*** **and** ***Propulsion Module*** **for torquing.**
- ***Sun Shade*** **shields screen from direct solar exposure during observations.**
- **Xenon propellant tanks stored in bus.**
- **Three-axis stabilization for stationkeeping, maneuvering, & transits.**

How will UMBRAS get to NGST?

Depending upon actual spacecraft mass, UMBRAS can be delivered to NGST by various launch & delivery options.

If UMBRAS' mass is under 6 tonnes, a shuttle deployment with 4 staged PAM DII solid motors attached to SPIDER (2 at each end of the bus) can give it escape velocity from LEO. If its mass is more, then in addition to the 4 solid motors, prolonged SEP (solar-electric propulsion) thrusting & lunar swing-by can allow Earth-escape. Alternately, an IUS atop a Titan IV, Proton, or Ariane can boost the lighter UMBRAS to station, with an Atlas Centaur G boosting a heavier UMBRAS.

The occulting craft fits within a Titan IV fairing or STS payload bay as shown below. Once on-orbit, after the solid boosters have been expended and staged, the occulter will deploy SEP propulsion boom, solar arrays, screen shade, occulting screen, and screen-pedestal boom. Once unfurled, SPIDER will proceed toward rendezvous with NGST in a manner similar to the depiction in the operations diagram above.



Mass & Power Estimates/Limits for UMBRAS Missions

	D-class 2-year & 1-metre telescope Mass / Power / Dimensions:	N-class 6-year & 8-metre telescope Mass / Power / Dimensions:
Payload:		
extensible screen	25 kg (5m x 5m, 10 layers)	360 kg (30m x 30m, 4 layers)
shade	10 kg	60 kg
screen cassette	30 kg	90 kg
bus-screen boom	50 kg	70 kg
pedestal & support structure	50 kg	50 kg
support structure & masts	~100 kg	~80 kg
Payload subtotal:	*265 kg*	*710 kg*
Bus + Array:		
Structure:		
array support	< 20 kg (4m x 8m)	< 50 kg (6m x 14m)
bus	< 100 kg (1.5m x 1.5m x 4m)	< 200 kg (1.5m x 1.5m x 9m)
Battery : (NiH2, 450 W-hrs)	< 10 kg	< 10 kg
Power Production:		
Arrays (GaAs @ 16%)	280 kg {7kW} (8m x 4m)	600 kg {15 kW} (12m x 6m)
Power Control & Conversion	300 kg	680 kg
Propulsion:		
NSTAR @92mN (eff =.85)	102 kg [2 x 2.3 kW] (6 total)	408 kg [6 x 2.3 kW] (24 total)
Power Conditioning / Control	120 kg [~0.6 kW] (4 units)	300 kg [~1.5 kW] (10 units)
ACS (16 UK-10 @25mN)	< 120 kg (4 x 0.7 kW)	< 120 kg (4 x 0.7 kW)
Xe propellant storage tanks	~ 130 kg (440 kg Xe)	~1200 kg (4000 kg Xe)
Xe pressure & feed system	50 kg [100 W]	50 kg [100 W]
ACS aux (16 cold gas @5N)	< 40 kg [100 W]	< 40 kg [100 W]
4 cold-gas, tank+feed system	< 100 kg	< 100 kg
Attitude determination & control:		
sun sensors	~ 2 kg [< 12W] (4 units)	~ 2 kg [<12 W] (4 units)
star trackers	~ 30 kg [< 80 W] (4 units)	~ 30 kg [< 80 W] (4 units)
gyros & reaction wheels	~ 50 kg [< 300 W] (6 units)	~ 150 kg [< 600 W] (6 units)
Communications:		
Ranging	< 30 kg [< 100 W] (2 units)	< 50 kg [< 100 W] (3 units)
Communications	~ 60 kg [< 120 W] (2 units)	~ 60 kg [< 120 W] (2 units)
Metrology locator telescope or laser position sensor	~100 kg [~ 50 W]	~ 100 kg [~ 50 W]
Command, Control & Data I/O:	< 20 kg [25 W]	< 20 kg [25 W]
Thermal Control:-	--	?
Bus + Array subtotal	*< 1644 kg*	*< 4170 kg*
Dry mass:	< 1929 kg	< 4880 kg
Margin ~ 20% (total dry mass):	~ 390 kg	~ 980 kg
Total mass (inc. propellant):	**< 2760 kg**	**< 9860 kg**

Preliminary estimated maximum mass and power requirements for D- and N-class SPIDER occulters for UMBRAS missions.

D-Class missions are useful for 1-2 metre diameter telescopes (Discovery class).
N-Class missions are useful for very large space telescopes (NGST-sized).
The above estimates are believed to be conservative upper limits for the UMBRAS concept. Explorer-class missions are under study (< 1-metre diameter telescopes).

Can UMBRAS be built?

UMBRAS was designed with *existing technology,* and does not assume any advances in either delivery systems or manufacturing techniques. SPIDER could be built *today.*

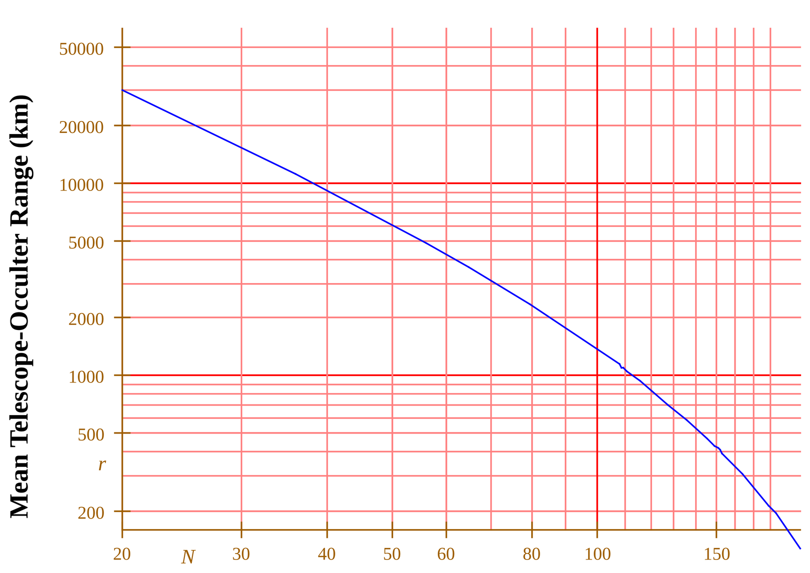
XIPS

2-6 30-cm NASA/Hughes NSTAR Xenon-ion Propulsion units can move UMBRAS from station to station.

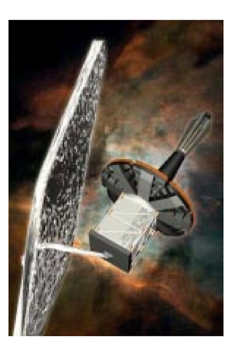
Advances in accelerator cathode composition may increase grid lifetime and reduce the number of auxiliary thrusters SPIDER must carry, and therefore its mass.

Several designs for occulting screens have been discussed in the literature. UMBRAS, as presented here, uses a conventional multi-layer insulation (MLI) approach. A possible benefit to MLI is that with the proper MLI composition, observations using UMBRAS could be taken at wavelengths approaching 5-microns.

The Effect of Range upon Maximum Observing Rate



The number of targets which NGST can observe using SPIDER depends strongly upon the sequencing strategy and the *mode* the occulter is used in (Telescope-Occulter range). The above graph of maximum achievable targets/year assumes a 10-tonne, fully fueled SPIDER using 6 NSTAR thrusters moving at an attitude to optimize solar array exposure between uniformly distributed targets. No advances in weight-savings from future technology developments are presumed in this design.



SPIDER will be *power-limited* in its ability to produce thrust, therefore science goals which may not optimize target-to-target movement for minimum time and maximum power production, will fall below this curve.

Comments/Questions:
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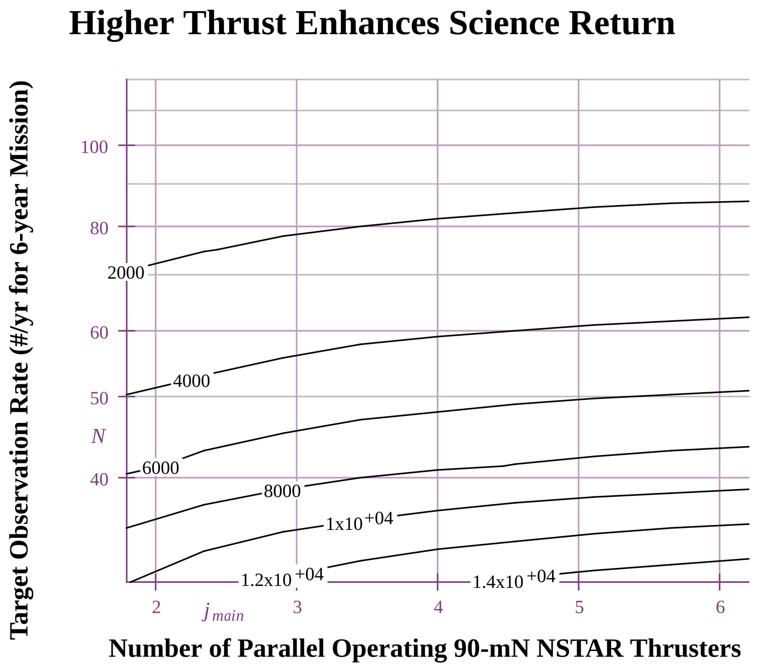
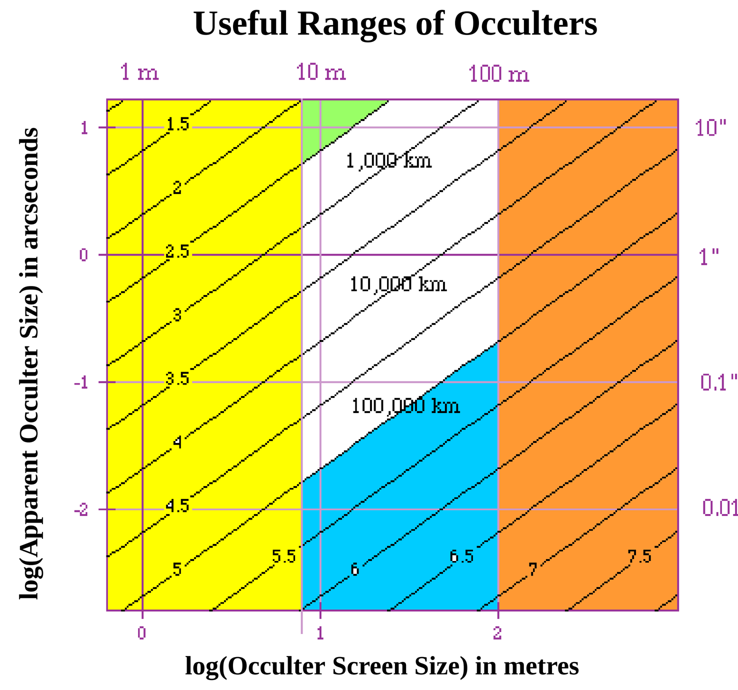
What Operational Constraints will UMBRAS have?

Since SPIDER will be limited in thrust by the amount of solar power that can be produced, there is a limit to UMBRAS acceleration, and therefore time transiting between targets. Depending upon the required science goals for the targets chosen for observing, trade-off studies can be conducted to determine the number of thrusters and size of the solar array needed to achieve those goals.

Higher Thrust Enhances Science Return



Useful Ranges of Occulters

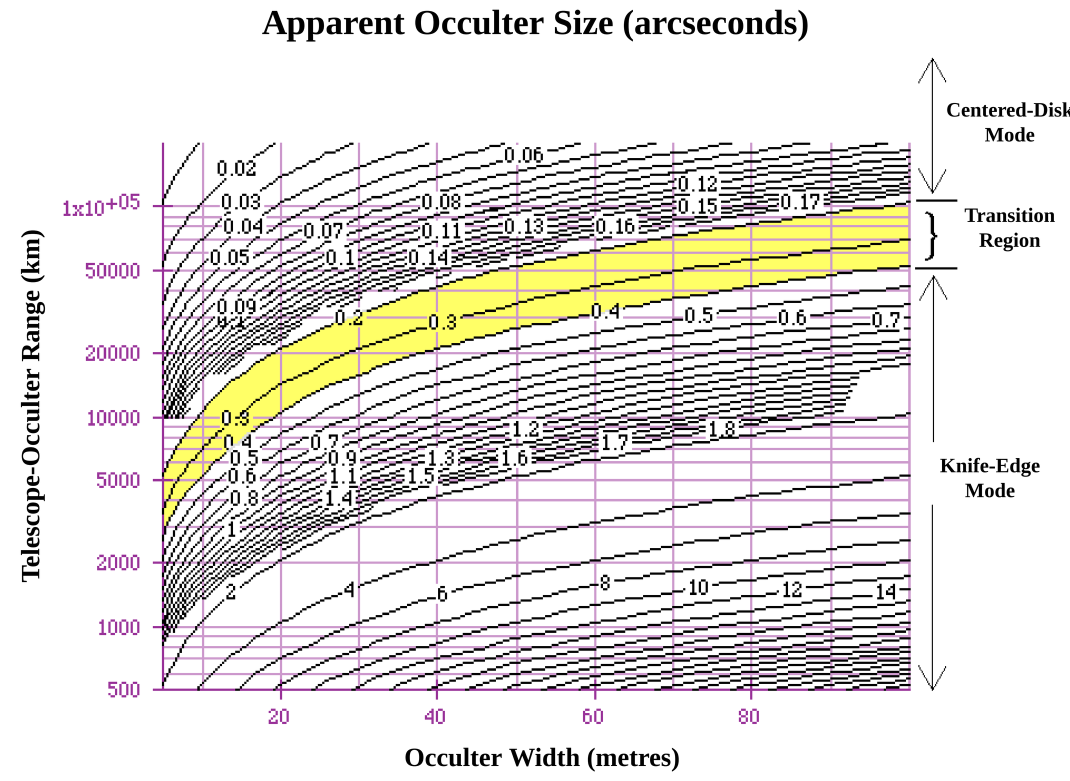


The graph above shows the approximate useful operating range of a solar-electric propelled occulter with the colored regimes delineating the useful bounds.

- In the yellow region, the occulter is too small to block the aperture.
- In the orange region, the occulter screen is too large and unwieldy.
- In the blue region, the occulter is so far away that significant target observation rates are hard to achieve and stationkeeping becomes difficult for ion propulsion due to differential gravitational drift.
- In the green range, stationkeeping deadband limits become increasingly more severe.

The screen will present various sizes during occultation work depending on screen size and proximity of SPIDER to the telescope. Either a 'knife-edge' or 'centered-disk' mode can be used to block light from a bright target.

Apparent Occulter Size (arcseconds)



Free-flying occulters are not a new idea--L. Spitzer, G. Woodcock, and others have explored the concept's utility and design before. UMBRAS offers an alternate and more complete design option that can be built using existing techniques. While not part of the currently funded NGST systems design, UMBRAS offers a way to enhance the science output from NGST.