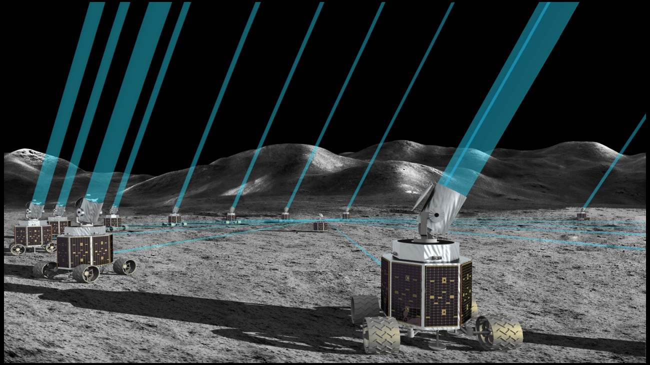
The Artemis-enabled Stellar Imager (AeSI): UV/Optical Interferometry from the Lunar Surface

NRL Colloquium - 2025 February 13

NASA Innovative Advanced Concepts



(Britt Griswold/GSFC)

ARTEMIS-ENABLED STELLAR IMAGER
AeSI
A NASA Innovative Advanced Concept Study

Dr. Kenneth Carpenter

NIAC Fellow 2024
HST Operations Project Scientist; RST Ground System Scientist
NASA Goddard Space Flight Center

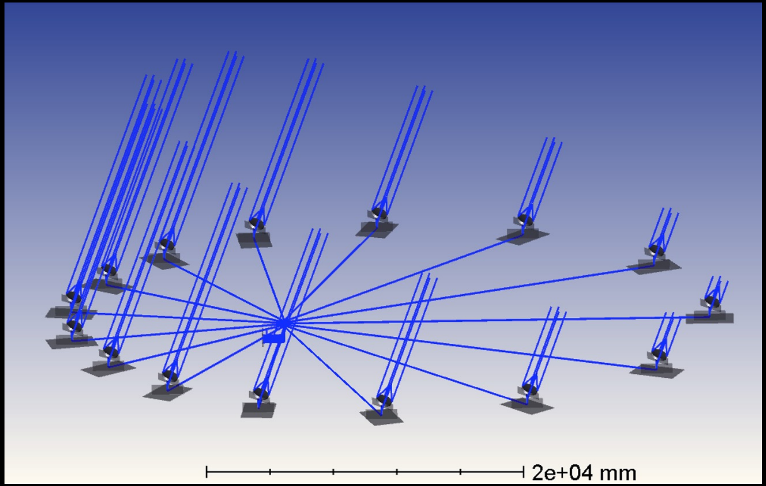
Introduction

Objectives of our Study

Assess whether we can build and operate, in collaboration with the human Artemis Program, **a long-baseline UV/Optical interferometer** on the lunar surface

Determine whether it is competitive with the free-flying *Stellar Imager (SI)*

Enable the study of our Universe at Ultra High Definition in the UV/Optical (~200x HST ang. Res.)



Impacts of our Study

Boldly expands the realm of the possible – many studies of free-flying space interferometers exist, but there are only limited studies of lunar designs (only radio).

Begins the technical journey toward resolving surface features and weather patterns on the nearest exoplanets and enabling an entire fleet of space interferometers observing from the x-ray to the far-infrared.

AeSI Team

Mission concept under development by NASA/GSFC in collaboration with experts from Industry, Universities, and Astronomical Institutes

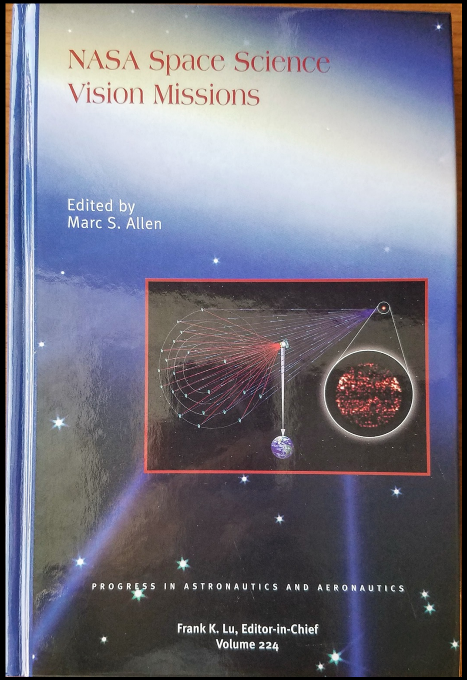
Ken Carpenter	NIAC Fellow, Mission Implementation Lead, IDC Coordinator
Tabetha Boyajian	Ground Interferometry Expert
Michelle Creech-Eakman	Ground Interferometry Expert
Margarita Karovska	Science Definition Co-Lead
David Leisawitz	Space Interferometry Expert
Jon Morse	Senior Advisor, Lunar Science & Infrastructure
Dave Mozurkewich	Lead System Engineer, Time Evolution of Observatory
Sarah Peacock	Science Definition, Study Co-Mgr, Outreach Co-Lead
Noah Petro	Artemis Expert
Gioia Rau	Science Definition Co-Lead, Study Co-Mgr., Outreach Co-Lead
Paul Scowen	Science Definition

Breann Sitarski	Optical Engineer
Gerard van Belle	Interferometry Expert, Mission Design Lead
Jon Brashear	Grad. Student, Science/AI
Derek Buzasi	Astereoseismology
Jim Clark	Mechanical Engineer
Erik Wilkinson	System Engineer
Julianne Foster	System Engineer
Buddy Taylor	Mechanical Engineer
Walter Smith	Mechanical Engineer
Qian Gong	Optical Engineer
Bruce Dean	Optical Engineer/WS&C, AI/ML
Len Seals	Scattered Light/Optical Engineer
David Kim	Power Systems Engineer

Why put Interferometers in Space or on the Moon?

Required for studying the Universe in high-definition over a broad range of colors and times.

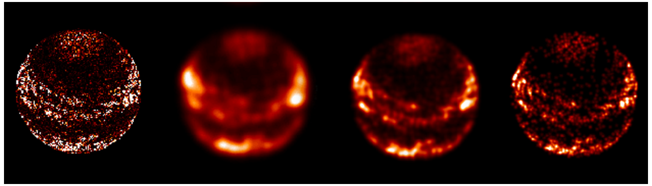
- Broader wavelength coverage
- Higher angular resolution
- Observe continuously over long time periods
- More stable environment
- No atmosphere, no turbulence, beams coherent over larger scales



What Can We See with a UV/Opt. Space-Based Interferometer?

Solar-type star at 4 pc in CIV line

Model SIsim images

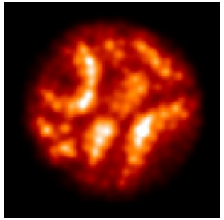


Baseline: 125m 250m 500 m

Evolved giant star at 2 Kpc in Mg H&K line

Model

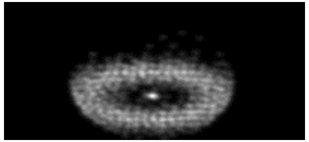
SIsim image (2mas dia)



Baseline: 500 m

SI imaging of planet forming environments: magnetosphere-disk interaction region

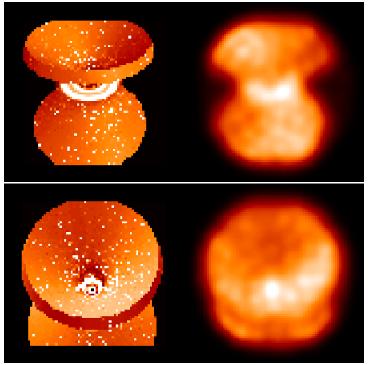
0.1 mas



SI simulation in
Ly α–fluoresced H2 lines

Baseline: 500 m

SI imaging of nearby AGN will differentiate between possible BELR geometries & inclinations

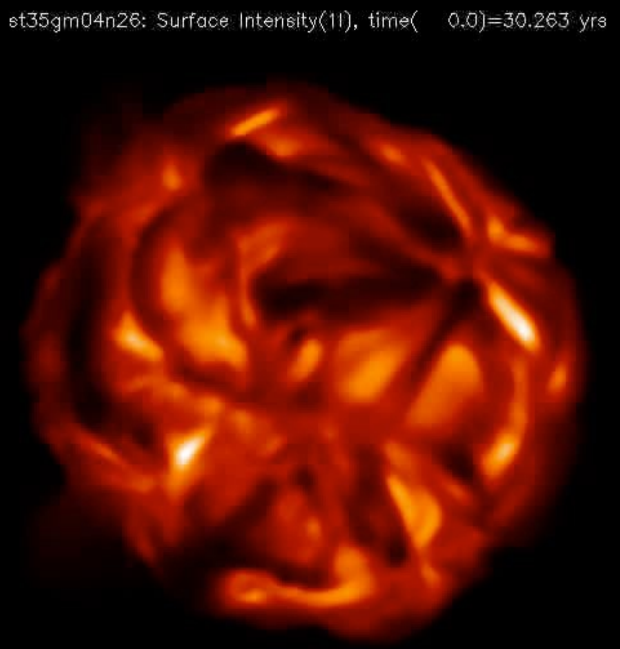


0.1 mas

model SI simulations in CIV line
(500 m baseline)

A long-baseline. UV/Opt. space interferometer will see motions of and *within* objects on astonishing timescales

- nearby stars will move across the sky as we watch
- physical processes will be directly visible
  - mass transfer in binaries
  - pulsation-driven surface brightness variations and convective cell structures in giants & supergiants
  - jets in young solar systems



Free-flying (SI) vs. Lunar (AeSI) Option

Pierre Bely et al.[1] (1996): **unless there is a pre-existing infra-structure on the lunar surface,** it is easier and better to build a large space interferometer as a free-flyer.

[1] "Kilometric baseline space interferometry," Proc. SPIE 2807, Space Telescopes and Instruments IV, (12 October 1996)

2005:

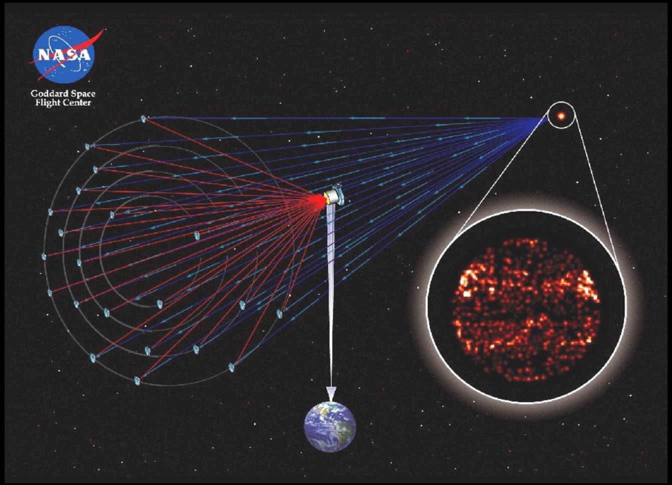
"Vision Mission" (VM) Concept for a free-flying, long-baseline, UV/optical space interferometer called *Stellar Imager (SI)*

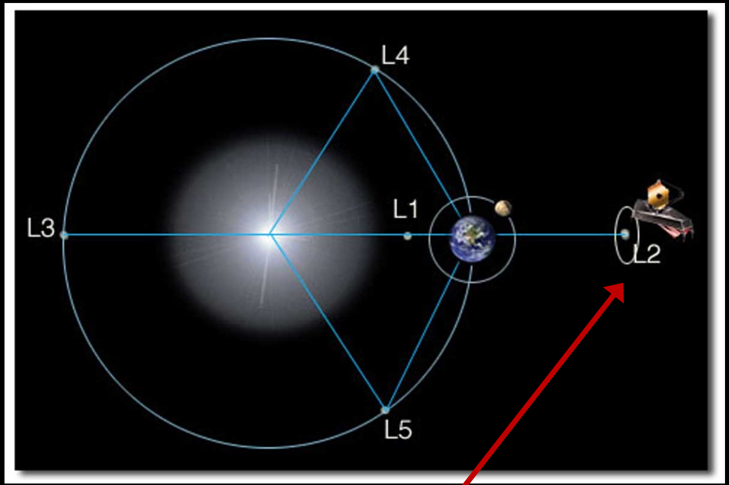
Now the Artemis Project plans to put humans and their infrastructure on the Moon within the next decade. It is time to consider in detail the lunar option!

2024:

A new concept, derived from *SI* but intended for construction on the lunar surface and operated in conjunction with the human Artemis Program called *Artemis-enabled Stellar Imager* (AeSI)

Original SI Concept: 2005 Vision Mission (VM) Study





- A 0.5 km diameter UV-optical Interferometer near Sun-earth L2
- 30 primary mirrors, controlled by 1 hub; ***200x the angular resolution of HST***
- Significant Technology Challenges:
  - •Precision formation-flying of ~ 30 spacecraft & Precision metrology over multi-km baselines
  - •Autonomous Control of entire system & How do we test on ground before launch?

Learn more about Stellar Imager here: https://hires.gsfc.nasa.gov/si/

With the Artemis Project on track to put humans and their infrastructure on the Moon, it is time to fully consider the lunar option!

First Step: NASA Innovative Advanced Concepts (NIAC) Phase 1 Study

NIAC
NASA Innovative Advanced Concepts

NIAC Phase I 2024 Fellows

Principal Investigator (Fellow)	Institution	Year	Study Title/Abstract	Presentation	Poster	Email Author
NIAC PHASE I FELLOWS						
Benner, Steven	Foundation for Applied Molecular Evolution	2024	Add-on to Large-scale Water Mining Operations on Mars to Screen for Introduced and Alien Life	VIDEO	PDF	sbenner@ffame.org
Bickford, James	Charles Stark Draper Laboratory	2024	Thin Film Isotope Nuclear Engine Rocket (TFINER)	VIDEO	PDF	jbickford@draper.com
Carpenter, Kenneth	NASA Goddard Space Flight Center	2024	A Lunar Long-Baseline Optical Imaging Interferometer: Artemis-enabled Stellar Imager (AeSI)	VIDEO	PDF	Kenneth.G.Carpenter@nasa.gov
Cabauy, Peter	City Labs, Inc.	2024	Autonomous Tritium Micropowered Sensors	VIDEO	PDF	peter.cabauy@citylabs.net
Eubanks, Marshall	Space Initiatives, Inc.	2024	Swarming Proxima Centauri: Coherent Picospacecraft Swarms Over Interstellar Distances	VIDEO	PDF	tme@space-initiatives.com
Landis, Geoffrey	NASA Glenn Research Center	2024	Sample Return from the Surface of Venus	VIDEO	PDF	geoffrey.a.landis@nasa.gov
McQuinn, Matthew	University of Washington, Seattle	2024	Solar System-Scale VLBI to Dramatically Improve Cosmological Distance Measurements	VIDEO	PDF	mcquinn@u.washington.edu
Pattabhi Raman, Aaswath	University of California, Los Angeles	2024	Electro-luminescently Cooled Zero-boil-off Propellant Depots Enabling Crewed Exploration of Mars	VIDEO	PDF	aaswath@ucla.edu
Romero-Calvo, Alvaro	Georgia Tech Research Corporation	2024	Magnetohydrodynamic Drive for Hydrogen and Oxygen Production in Mars Transfer	VIDEO	PDF	acalvo9@gatech.edu
Rothschild, Lynn	NASA Ames Research Center	2024	Detoxifying Mars: The Biocatalytic Elimination of Omnipresent Perchlorates	VIDEO	PDF	LynnJ.Rothschild@nasa.gov
Sprenger, Ryan	Fauna Bio Inc.	2024	A Revolutionary Approach to Interplanetary Space Travel: Studying Torpor in Animals for Space-health in Humans (STASH)	VIDEO	PDF	ryan@faunabio.com
Zha, Gecheng	Coflow Jet, LLC	2024	Mars Aerial and Ground Global Intelligent Explorer (MAGGIE)	VIDEO	PDF	gecheng@yahoo.com

ent.com/event/c3bf8346-776e-49dd-a45a-b74db57c2c29/websitePage:62aed4de-2e00-4397-8c11-0f9fa20e143b

PM POSTERS - 2024 NIAC Symposium

Zhang, Beijia	MIT Lincoln Laboratory	2024	LIFA: Lightweight Fiber-based Antenna for Small Sat-Compatible Radiometry	VIDEO	PDF	beijia@ll.mit.edu

NIAC Phase II-II 2024 Fellows

NIAC PHASE II FELLOWS						
Arumugam, Darmindra	NASA Jet Propulsion Laboratory	2023	Quantum Rydberg Radar for Surface, Topography, and Vegetation	VIDEO	PDF	darmindra.d.arumugam@jpl.nasa.gov
Balaban, Edward	NASA Ames Research Center	2024	Fluidic Telescope (FLUTE): Enabling the Next Generation of Large Space Observatories	VIDEO	PDF	edward.balaban@nasa.gov
Clements, Brianna	Howe Industries	2024	Pulsed Plasma Rocket (PPR): Shielded, Fast Transits for Humans to Mars	VIDEO	PDF	brianna@howeindustries.net
Eades, Michael	Ultra Safe Nuclear Corporation - Space	2023	The Nyx Mission to Observe the Universe from Deep Space – Enabled by EmberCore, a High Specific Power RadioisotopeElectric Propulsion System	VIDEO	PDF	m.eades@usnc-tech.com
Knapp, Mary	MIT Haystack Observatory	2024	The Great Observatory for Long Wavelengths (GO-LoW)	VIDEO	PDF	mknapp@mit.edu
Lubin, Philip	University of California, Santa Barbara	2023	PI – Planetary Defense	VIDEO	PDF	lubin@deepspace.ucsb.edu
Perrault, David	MIT	2023	Silent, Solid-State Propulsion for Advanced Air Mobility Vehicles	VIDEO	PDF	djperrea@mit.edu
Polidan, Ronald	Lunar Resources, Inc.	2023	FarView Observatory – A Large, In-Situ Manufactured, Lunar Far Side Radio Array	VIDEO	PDF	rpolidan@lunarresources.space
Polly, Stephen	Rochester Institute of Technology	2024	Radioisotope Thermoradiative Cell Power Generator	VIDEO	PDF	sjpvpr@rit.edu
Rothschild, Lynn	NASA Ames Research Center	2023	A Flexible, Personalized, On-Demand Astropharmacy	VIDEO	PDF	LynnJ.Rothschild@nasa.gov
Schaler, Ethan	NASA Jet Propulsion Laboratory	2024	FLOAT – Flexible Levitation on a Track	VIDEO	PDF	ethan.w.schaler@jpl.nasa.gov
Sultana, Mahmooda	NASA Goddard Space Flight Center	2024	ScienceCraft for Outer Planet Exploration (SCOPE)	VIDEO	PDF	mahmooda.sultana@nasa.gov

t.com/event/c3bf8346-776e-49dd-a45a-b74db57c2c29/websitePage:62aed4de-2e00-4397-8c11-0f9fa20e143b

M

POSTERS - 2024 NIAC Symposium

NIAC Phase III Fellows						
Rothschild, Lynn	NASA Ames Research Center	2024	Mycotecture off Planet: En route to the Moon and Mars	VIDEO	PDF	LynnJ.Rothschild@nasa.gov

High Level *AeSI* Phase 1 Study Schedule

March	April	May	June	July	August	September	October	November	December
3/19&20 : NIAC Phase 1 Orientation						9/10-12: NIAC Symposium			
	Internal Team work and preparation for IDC Study								
	Pre-meetings with IDC								
					Hybrid architectural study with IDC, MDL, IDL				
						Address IDC recommendations, complete Team Tasks and Final Report			
								Initial Prep for Phase II	

March 19-20	NIAC Phase 1 Orientation
April - July	Internal Team Work and Preparation for IDC Study
April - July	Pre-meetings with IDC
mid July/mid August	Hybrid architectural study with IDC, MDL, IDL
Sept 10-12	NIAC Symposium
Sept - Dec	Address IDC recommendations, complete Team Tasks and Final Report
Nov/Dec	Initial prep for Phase II

Requirements for Prime Science Goals

UV/Optical Imaging of astrophysically interesting targets with 0.1 mas resolution. Optical system to be optimized for observing from 1200-6600Å, in multiple UV pass bands of 2-10Å width and broadband optical light.

Imaging stellar activity using emission from the outer atmosphere:

•Image nearby main-sequence & giant stars with at least 1,000 resolution elements on their surface, in outer atmospheric UV emission lines; =>*baseline >500 m for a solar-type star at 4 parsec*.

•Construct images within ~1% of the stellar rotation period, i.e. 6 h for a star like the Sun or 2.5 hours for star with P-2.5 days; *requires efficient reconfiguration and/or a large number of array elements*

•Compile ~ 30 images within one stellar rotation; requires optimized target lists & efficient repointing.

•*Revisit stars during 3-6 month intervals, spanning > 5 yrs; requires a long life, and replaceable components.*

Imaging stellar interiors with asteroseismic techniques:

•Achieve 30 resolution elements on stellar disks with 1 min. cadence, in a broad passband in the optical; *requires at least 9 optical elements, with meter-class collecting areas.*

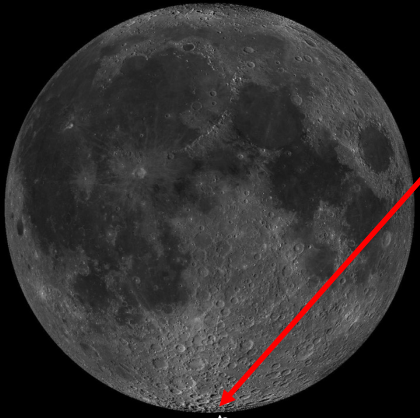
•Continuous observations for ~one rotation, with a duty cycle better than ~ 90%; requires stable environment.

Imaging of stars and extended complex sources such as star- and planet-forming regions, accretion disks and jet-forming regions, interacting binaries, super massive black hole environments, etc. Image frequency components to be high enough for complex sources, and point spread function with well-defined core areas.

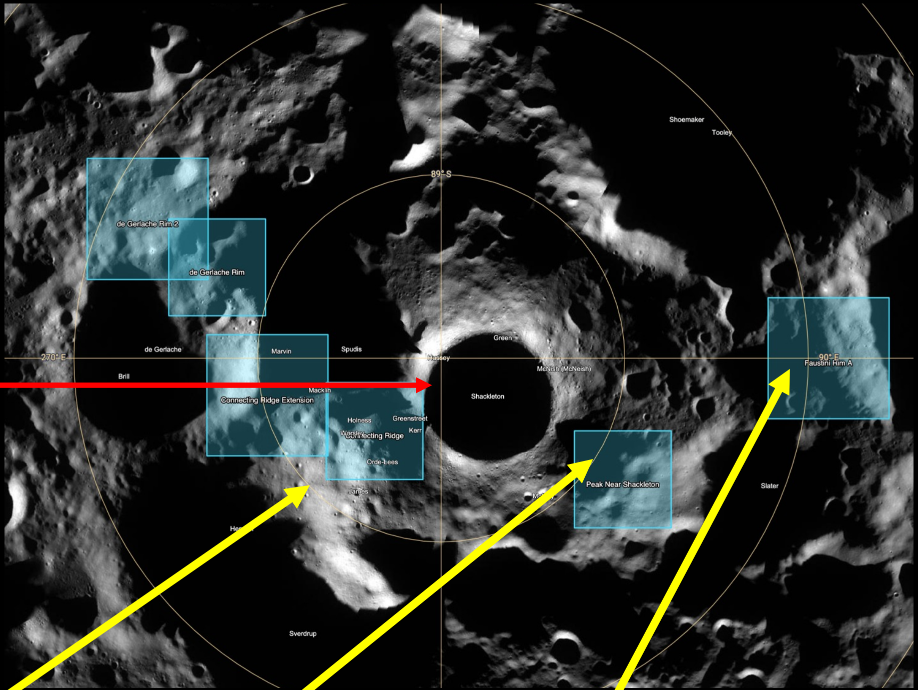
Design Requirements

Parameter	Value	Notes
Maximum Baseline (B)	1 km (adjustable)	Outer array diameter
Diameter of Mirrors	1 - 2 m (1 m currently)	Up to 30 mirrors total
λ-Coverage	UV: 1200 – 3200 Å Optical: 3200 – 6600 Å	Wavefront Sensing in optical only
Spectral Resolution	UV: 10 Å (emission lines) UV/Opt: 100 Å (continuum)	
Operational Location	Lunar Surface, near Artemis	
Operational Lifetime	10 yrs	
Angular Resolution	50 mas – 208 mas (@1200–5000Å)	Scales ~ λ/B
Typical total time to image stellar surface	< 5 hours for solar type < 1 day for supergiant	
Imaging time resolution	10 – 30 min (10 min typical)	Surface imaging
Seismology time res.	1 min cadence	Internal structure
# res. pixels on star	~1000 total over disk	Solar type at 4 pc
Minimum FOV	> 4 mas	
Minimum flux detectable at 1550 Å	5.0 x 10^{-14} ergs/cm^2/s integrated over C IV lines	10 Å bandpass
Optical Surfaces Control	Actuated mirrors to mm-nm level	
Phase Corrections	to λ/10 Optical Path Diff.	
Aspect Control/Correct.	3 mas for up to 1000 sec	LOS mainten.

Some illustrative candidate ***Artemis-enabled Stellar Imager (AeSI)*** sites near some of the original candidate Artemis base locations.



Shackleton Crater
South Pole

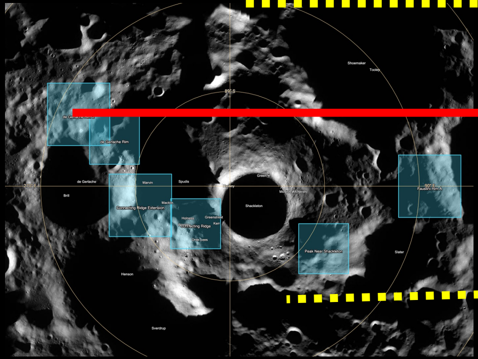


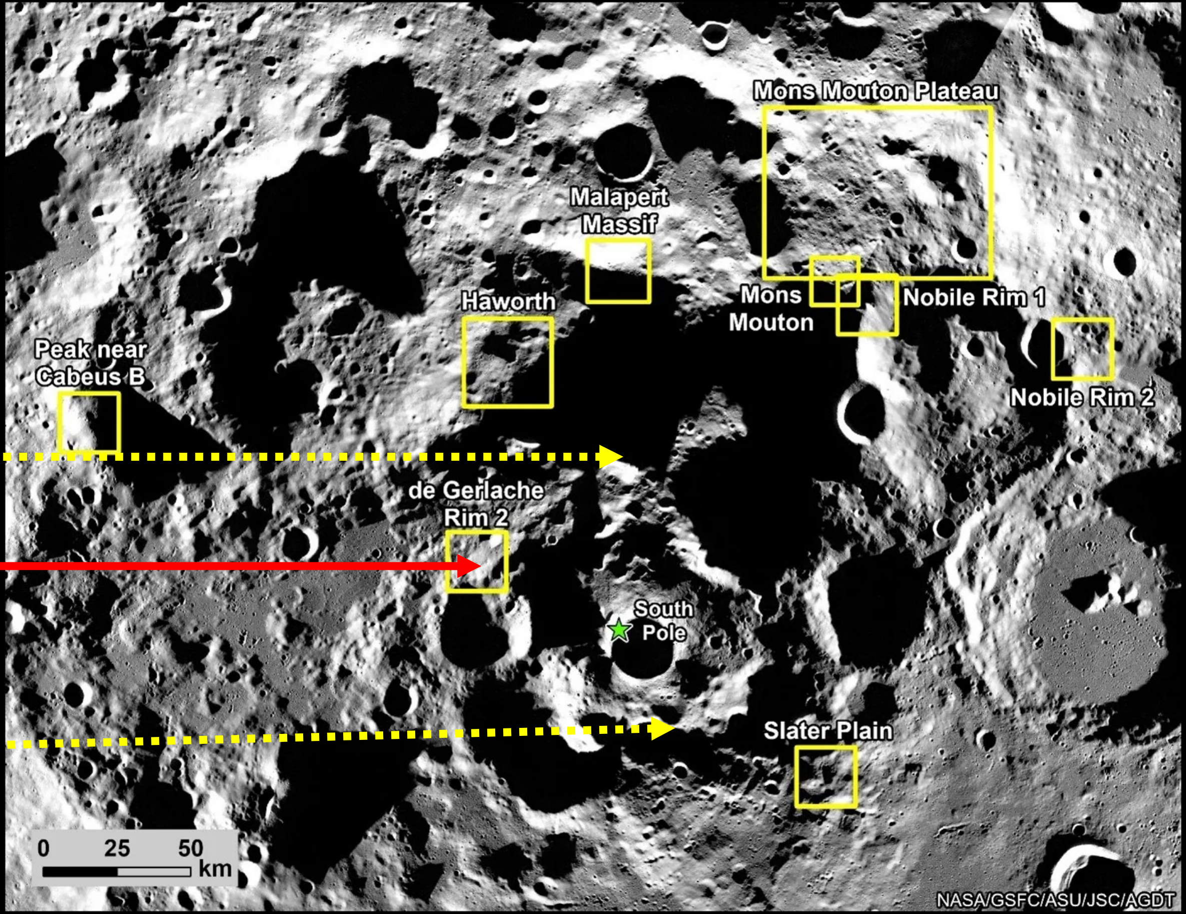
Candidate AeSI Sites near: Connecting Ridge, Peak Near Shackleton, and Faustini Rim A

Note: Equally good sites can be found near the "new 9" candidate Artemis base locations.

“New 9” Artemis Candidate Sites

- Range further from South Pole (better for AeSI)
- Have 1 site in common with original list: “de gerlache Rim 2” (red line)



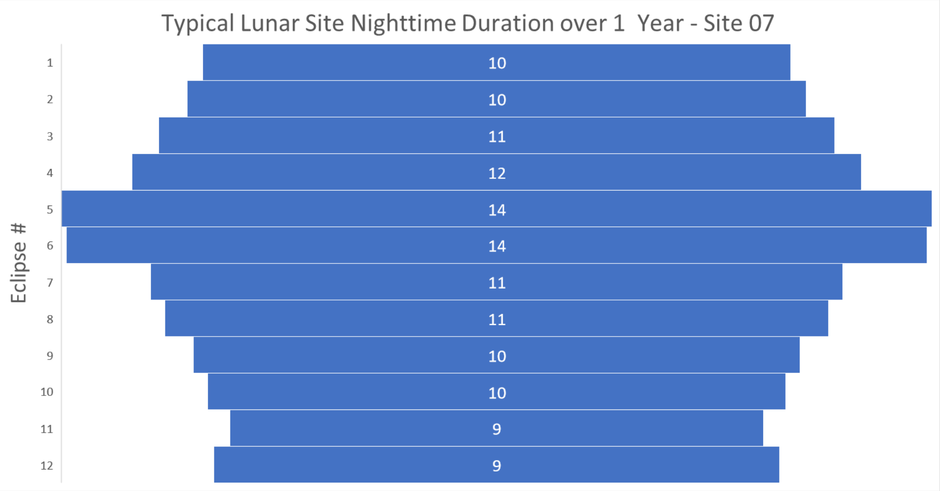


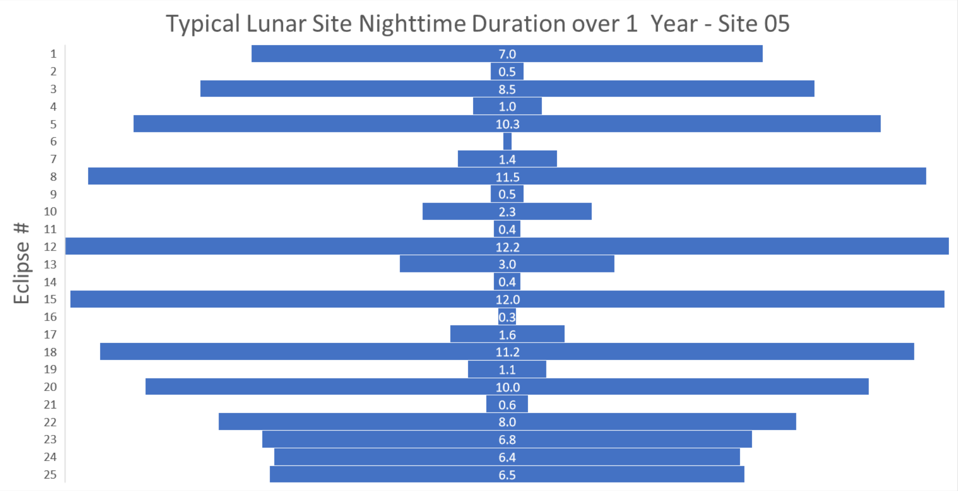
Solar Illumination Varies a *Lot* Near the Lunar South Pole!!!

- From Heritage Analysis from Erwan Mazarico

Site 07. No midnight sun. Seasonal variation in nighttime duration: 9-14 days

Site 05: Both midnight sun and blockage during the day. Seasonal variation (7-13 days) and shorter duration shadowing (0.1-3 days)

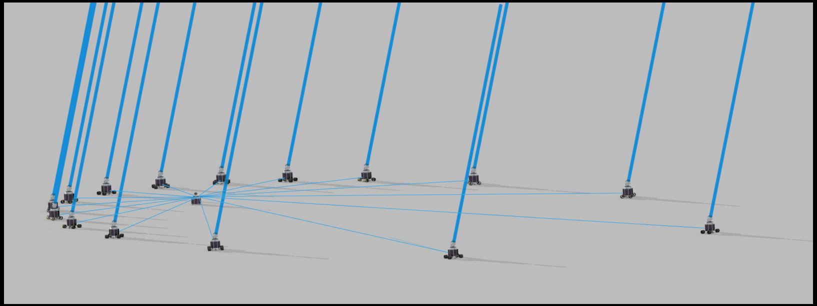


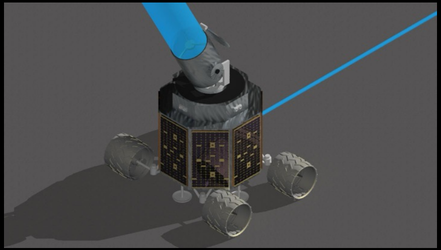


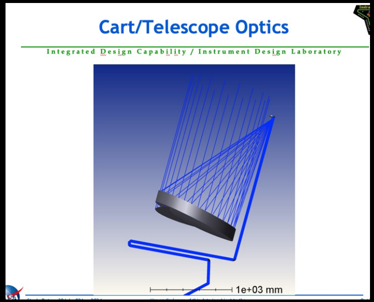
Baseline Design: GSFC Integrated Design Center (IDC)

Stage 1: 15 rovers, elliptical array to avoid long delay-lines. 1 km major-axis

Stage 2: 30 rovers, enhanced hub







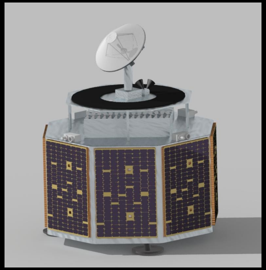
Mirror Station: artist's concept (B. Griswold) and internal optics (IDC/D. Mozurkewich)

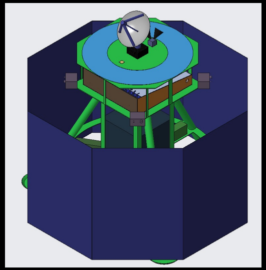
IDC: Engineering Study

- Systems
- Mechanical Design
- Optical Design
- Communications
- Thermal
- Power

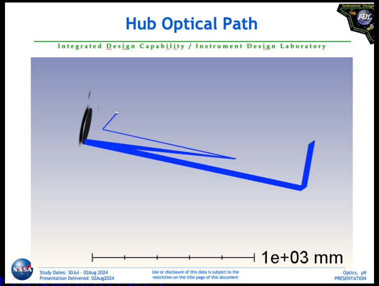
Conclusion: Feasible!!!

IDC provided many good recommendations for further studies and technology development.



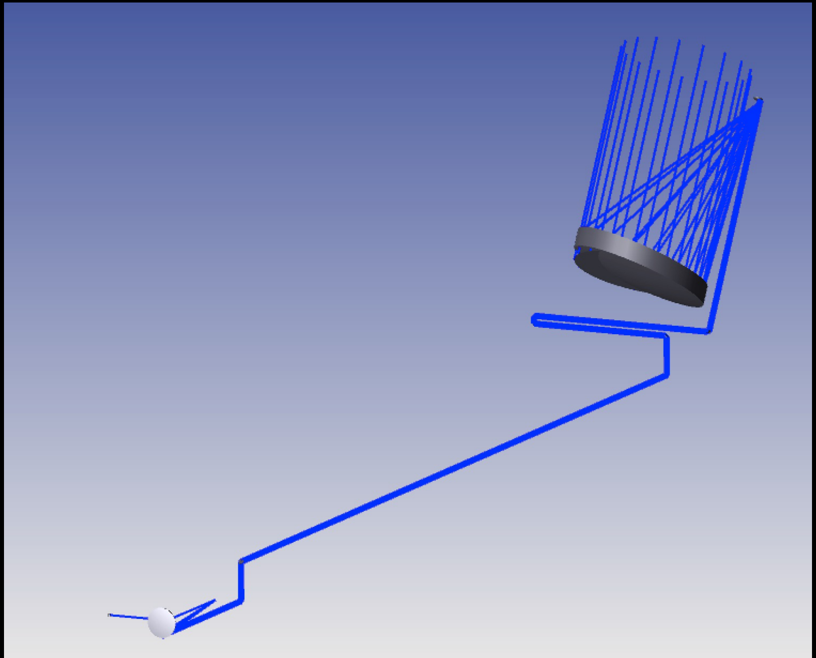


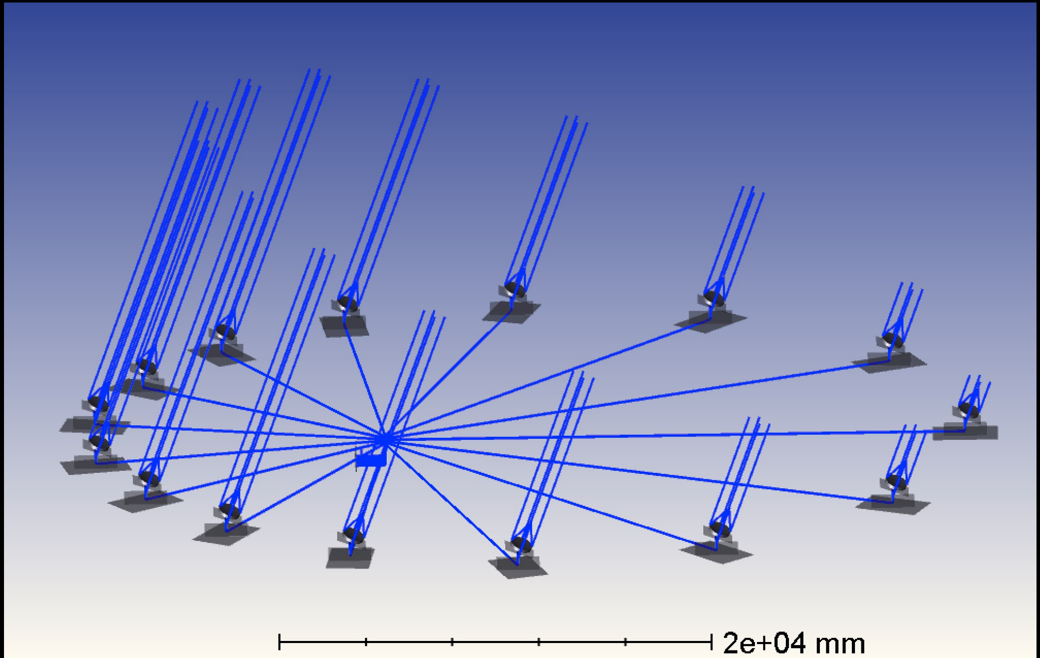
Hub: artist's concept (B. Griswold) and internal details/ optics (IDC & D. Mozurkewich)



(Britt Griswold/GSFC)

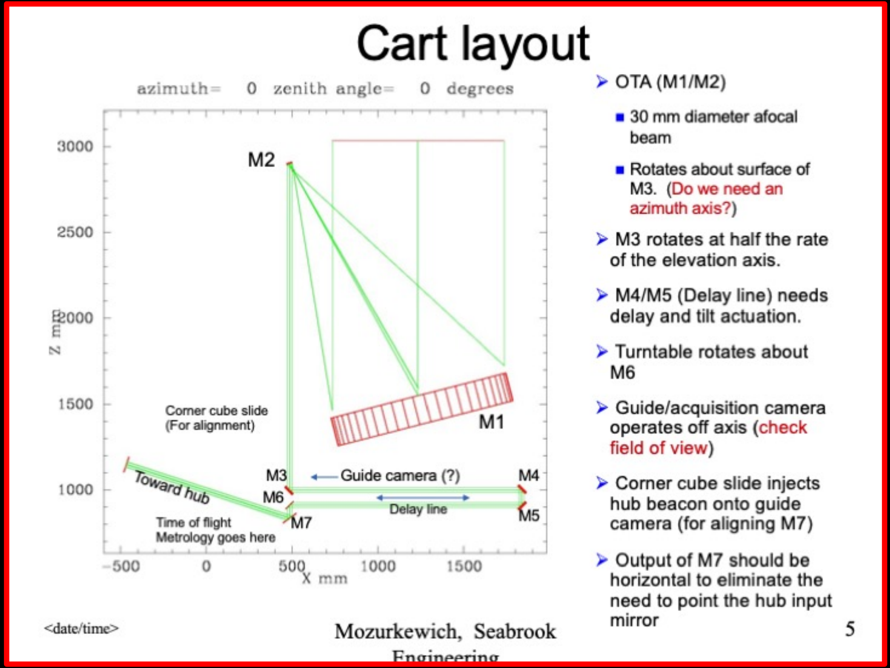
Optical Layout and Array Configuration

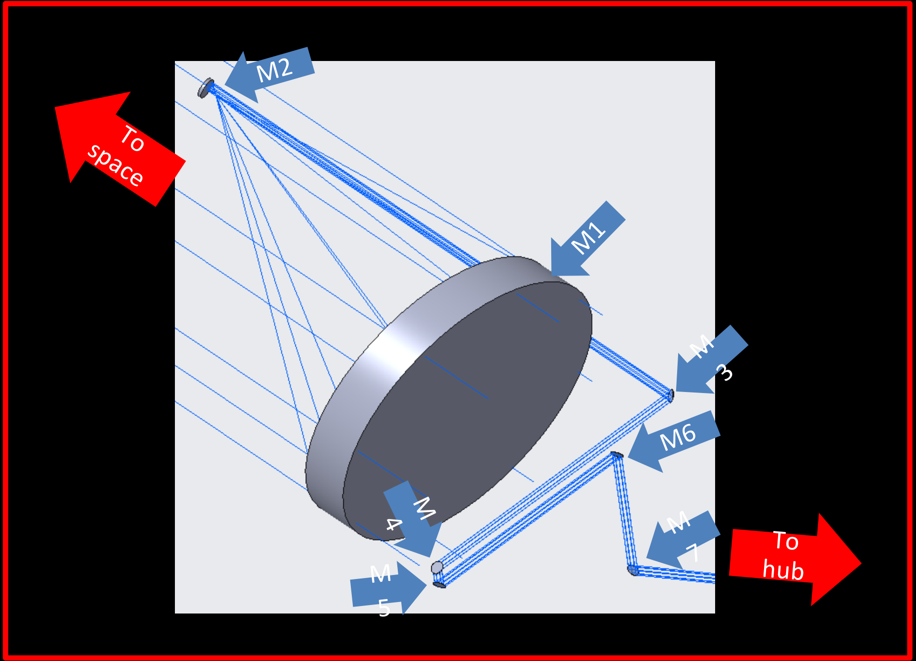




Cart Optical layout

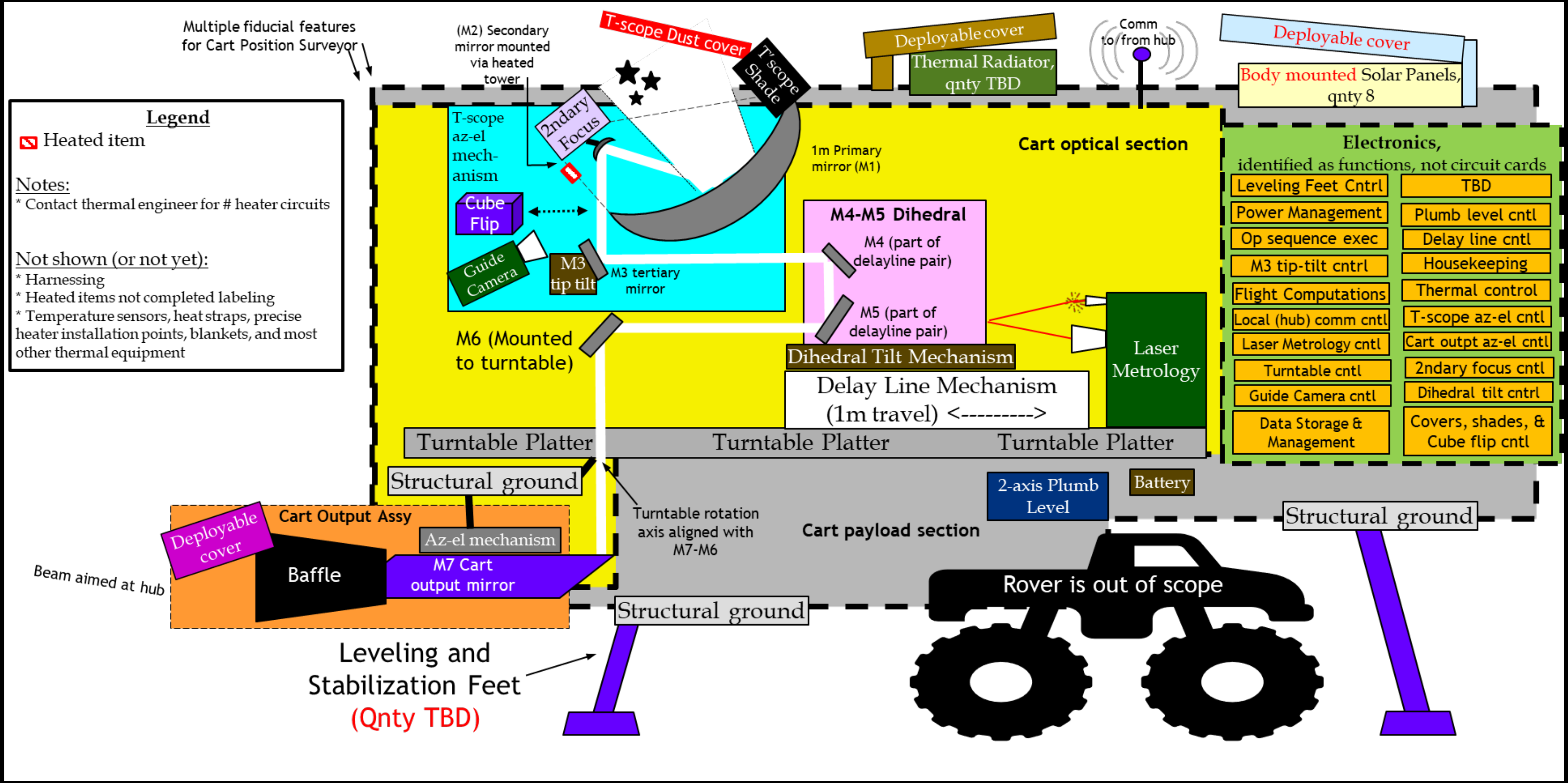
Bert Pasquale/D. Mozurkewich 31 July 2024



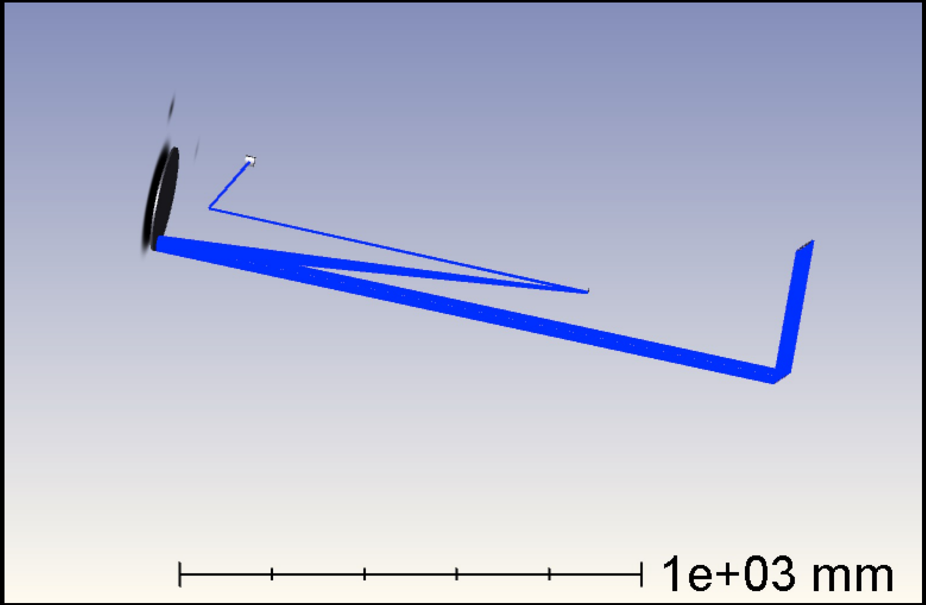


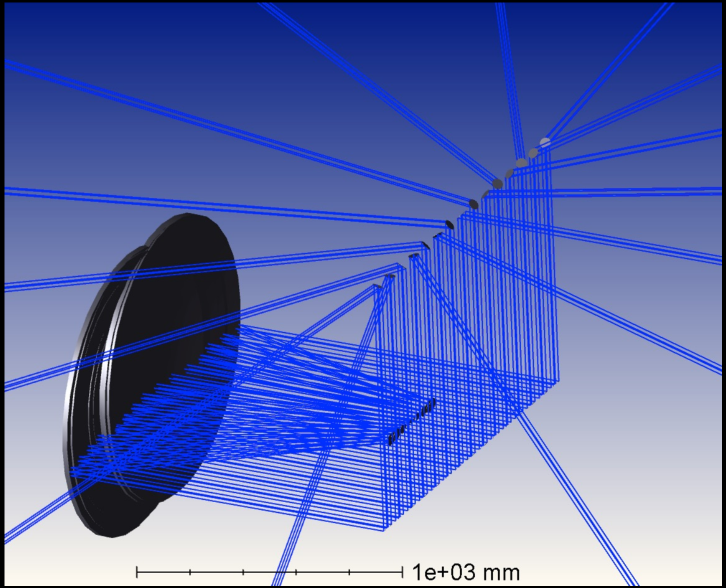
Architecture Diagram – Cart

Schematic representation – does not represent actual layout



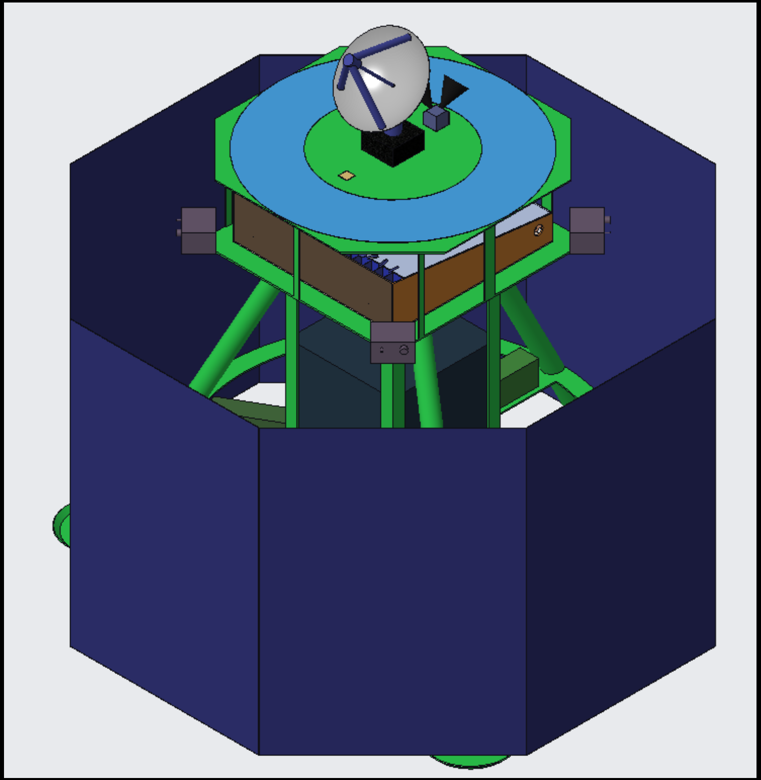
Hub Optical Layout



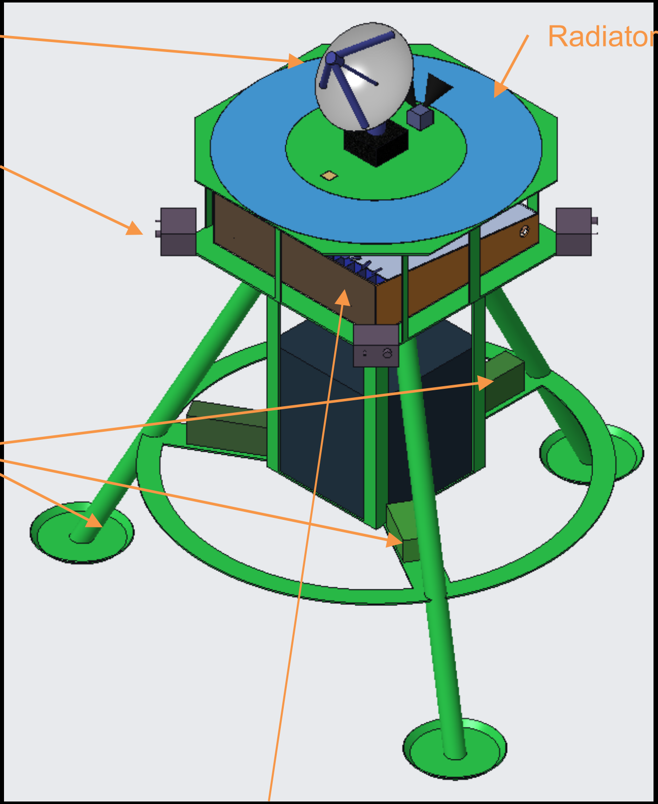


Hub Schematics

GSFC IDC 31 July 2024

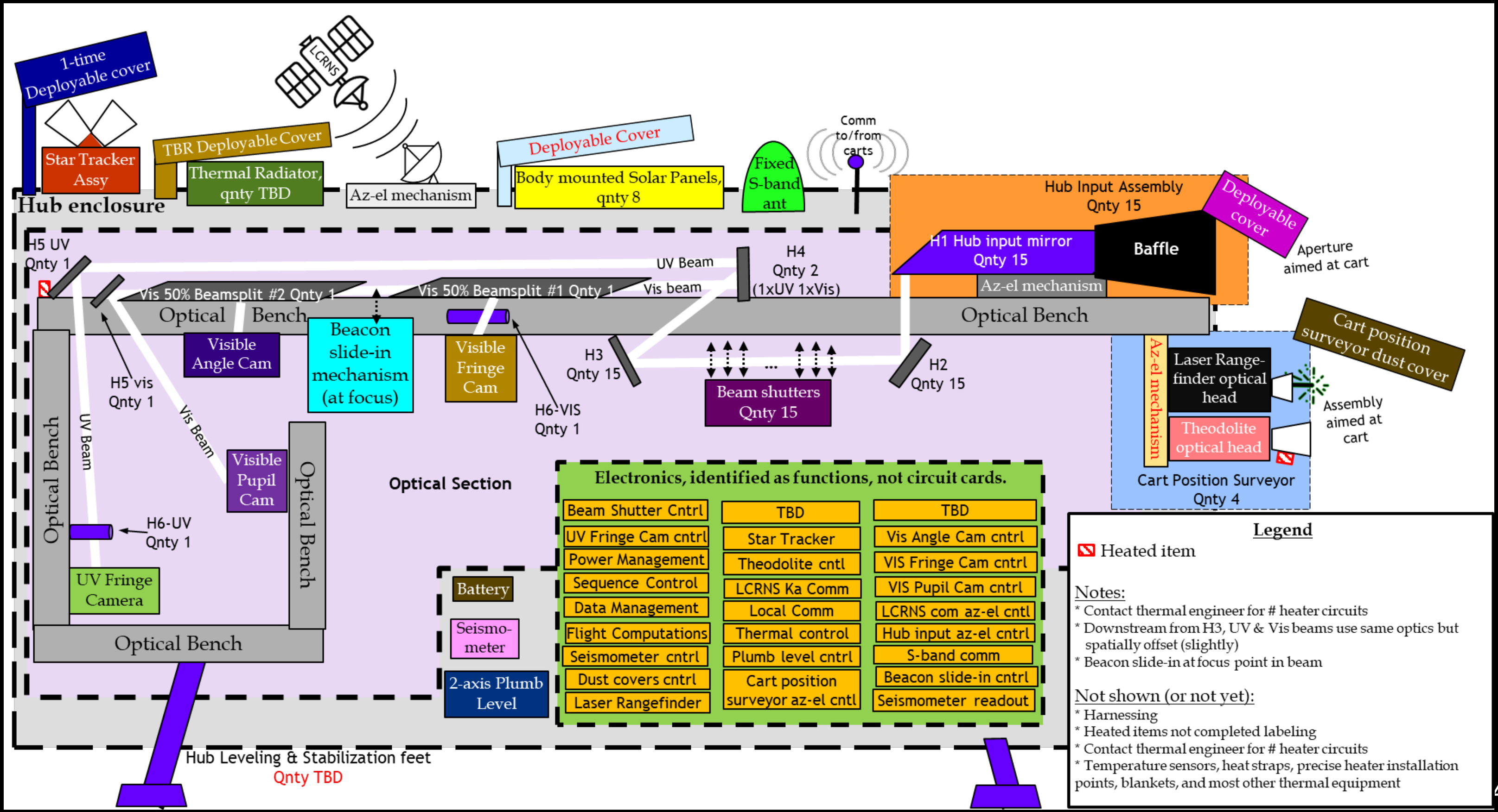


~4.5m tall X 4.3m wide X 4.3 m deep



Architecture Diagram – Hub

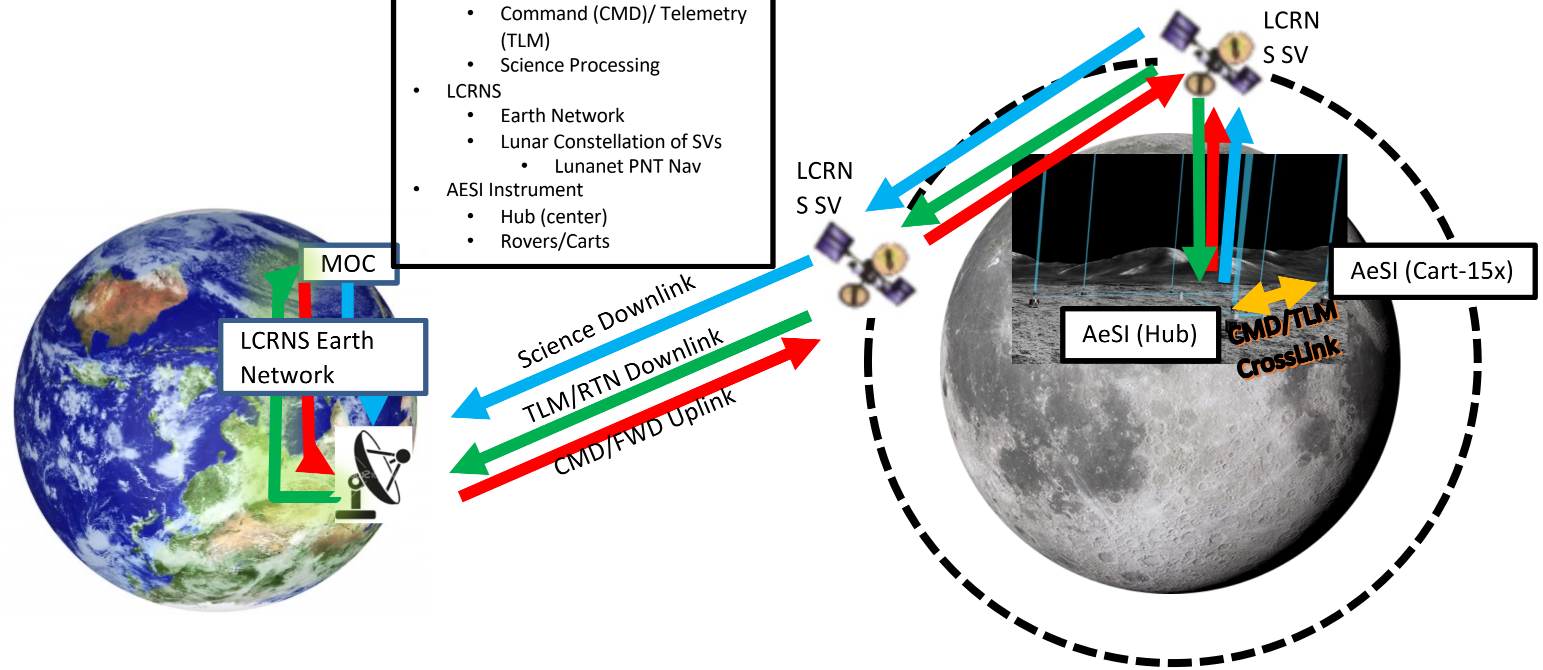
Schematic representation – does not represent actual layout



Notional AeSI Mission Architecture (GSFC IDC)

Key Mission Elements

- MOC
    - Command (CMD)/ Telemetry (TLM)
    - Science Processing
- LCRNS
    - Earth Network
    - Lunar Constellation of SVs
        - Lunanet PNT Nav
- AESI Instrument
    - Hub (center)
    - Rovers/Carts



Launch and Lunar Landing

- The launch & transportation to the lunar surface near an Artemis base camp is one of the primary contributions of Artemis to AeSI.

- Candidate launch vehicles include:
  - Starship (used in baseline design)
  - New Glenn
  - SLS

Deployment

- Need to transport the observatory components from the landing site to the interferometer site and configure them for initial commissioning and observing.

- The array elements are on carts which are capable of moving across the lunar surface to enable array-reconfigurations during operations and may be able to make the trip from the landing site to the observatory site
  - though it may be safer and better to move multiple carts on a larger transport rover if such is available from the Artemis Program.

- hub will require such transportation, as it is not designed to be mobile

- Once the interferometer components are roughly in place, the commissioning program will take charge of the more precise positioning needed for operations.

Typical AeSI Instrument ConOps

This assumes it follows a small survival period and AeSI is already commissioned long ago (note that length of day/night will vary)

1. Init and Configure Instrument

- Hub (Always Fixed)
  - Boot up computer and initialize electronics; Bring optical system temperatures to observation setpoint(s)
- Boot up computer and initialize electronics
  - Move rovers and point optical system towards target; Point outgoing mirrors at hub
- Bring optical system temperatures to observation setpoint(s)
- Both - Actuate dust covers and anything else implemented for the survival period. TBC - Check list of motion requirements for anything else

2. Configure for Observation

- Hub: Point optical system incoming mirrors at rovers; make internal adjustments inside the hub optical path?
  - coarse setting on delay lines, ranging between elements
- Hub & Rover: Find fringe and set delay lines (may/will require more rover and optical system moves, if so do some re-pointing; Active tracking
- Calibration? Yes, image calibrator (star) before and after. move delay line?

3. Perform Observation

- Observe/read detector 8 hr planning baseline with multiple readouts– move delay lines and optical system to track the target (this will also occur during prior steps).
- Rovers will move for long observations (including month-long asteroseismology observations) and for reconfigurations.

4. Post-observation configuration

- If another observation is planned immediately after, repeat at step 2.
- If a data transmission to Earth is mandatory after the last observation, it must be added.
  - No criticality to latency of receiving data on the ground – driven by data evaluation (validate data first, then delete from recorder) and other constraints

Observation Scenarios

- Observing plan depends substantially on whether we can operate through both daylight and nighttime hours
  - If solar powered, would observe mostly during day with batteries providing survival heater power and perhaps some limited-time observing at night
  - If nuclear powered (fission surface reactor), could operate day and night
- Normal mode operations
  - Observe a series of targets (solar type stars, AGN, symbiotic stars), obtaining sub-milli-arcsec UV/optical still images
  - Observe selected targets to view spatio-temporal changes on short timescales (days)
- Astereoseismology operations
  - month-long, high-cadence observations to observe intensity variations over resolved stellar disks to probe interior structure

Servicing

- One of the great advantages of locating AeSI on the Moon is that servicing will be much easier than at L2.
  - Utilize the resources of Artemis to transport new hardware from Earth to the Lunar surface and then to the observatory site,
  - Use a mixture of human and/or robotic services to perform both maintenance and upgrades to the facility. The ideal mix will depend on the evolution of Artemis plans and the availability of astronauts and robots on-site.
  - Regular maintenance requirements should be modest with perhaps an occasional need to remove dust from station surfaces and to repair or replace failed components.
  - Possible upgrades are listed below.

Servicing Details: Maintenance

- The interferometer is modular and most servicing would likely be done by replacing one of the carts (primary mirror stations/"array elements") with a spare
  - The cart with the failed component could be brought back to an Artemis site and repaired, if possible, to serve as a spare to be used to accommodate future failures.
  - The observatory is tolerant to the temporary loss of one or more array elements, so scheduling of such replacements can be done in a way that fits Artemis requirements.

- The hub is a more complex and stationary element, but it could be designed to have modular components that would permit servicing in-situ by robots or astronauts.
  - In the case of a failure that could not be handled in such a manner, we would need to transport it back to an Artemis site and either repair it there or deploy a new unit.
  - Building a spare hub and one or more spare carts/mirror stations is highly desirable but this and alternative options will continue to be studied further.

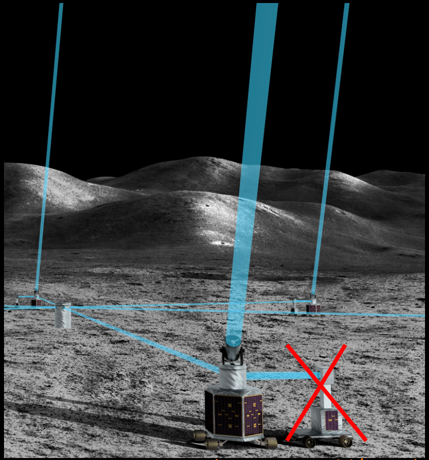
Servicing Details: Upgrades

- The primary upgrade foreseen for AeSI is an increase in the number of array elements from the original 15 to the desired 30, in one or more stages.
  - Mostly just requires deploying additional mobile carts carrying the new array elements.
  - However, we either need to design the central hub to handle 30 incoming beams originally, make it easy (via modular design) to enhance it to accommodate more beams on-site, or plan to replace the hub when adding array elements.
  - The current baseline plan is to deploy a hub that is capable of handling up to 30 elements from the start, though we will continue to examine this trade going forward.

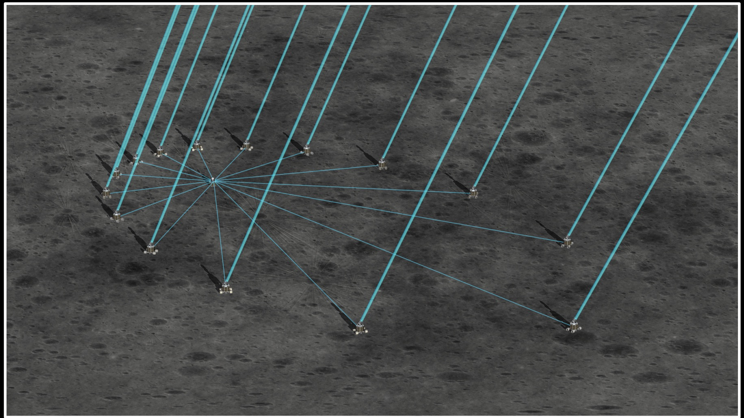
- Other upgrades that may be of interest would be to install new, more efficient detectors and/or mirrors with higher reflectivity if dramatic improvements are made over the years in either or both.
  - These would likely be done by replacement of carts & hub, but the option of replacing just those components within the units on-site will be considered in future trades.

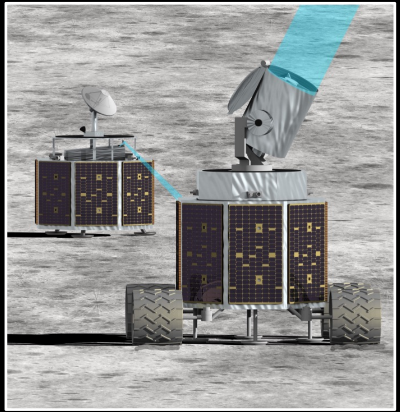
Biggest Improvements to-date

- Eliminated 2nd set of rovers for delay-line optics by using asymmetric primary array configurations to remove large path-length differences (target-to-primary-to-hub) for off-zenith targets; remaining delay line can be fit inside rovers



(Britt Griswold/GSFC)





(Britt Griswold/GSFC)

- Primary mirrors sizes increased to improve sensitivity, array baseline increased to maintain resolution while going deeper into sky for more targets

Challenges and Future Work

- Low UV-Sensitivity due to # of reflections in delay-lines require:
  - Better-reflectivity UV mirror coatings
  - More sensitive detectors, esp. for 1200-1600 A
- Refine dust & scattered light control
- Demonstrate control system to align carts/hubs/optics after moves (NPOI!)
- Pursue Remote Power Station Options to enable more continuous operations, even in array night
  - Solar arrays on higher illumination, nearby peaks
  - Nuclear source over nearby hill
  - Supplied by Artemis infrastructure
- Investigate possibility of putting primary mirror carts on rails
- Refine support needed from human/robotic infrastructure
  - Deployment and/or servicing

Artemis-enabled Stellar Imager (AeSI)

is a UV-Optical, space-based interferometer for 0.1 milli-arcsecond spectral imaging of stellar surfaces and interiors and of the Universe in general.

https://hires.gsfc.nasa.gov/si/aesi.html

It will resolve for the first time the surfaces and interiors of sun-like stars and the details of many other astrophysical objects & processes, e.g.:

Magnetic Processes in Stars
activity and its impact on planetary climates and on the origin and maintenance of life; stellar structure and evolution

Stellar interiors
in solar and non-solar type stars

Infant Stars/Disk systems
accretion foot-points, magnetic field structure & star/disk interaction

Hot Stars
hot polar winds, non-radial pulsations, envelopes and shells of Be-stars

Supernovae & Planetary Nebulae
close-in spatial structure

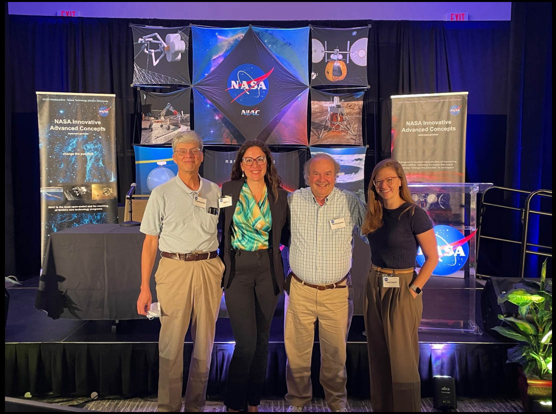
Cool, Evolved Giant & Supergiant Stars
spatiotemporal structure of extended atmospheres, pulsation, winds, shocks

Interacting Binary Systems
resolve mass-exchange, dynamical evolution/accretion, study dynamos

Active Galactic Nuclei
transition zone between Broad and Narrow Line Regions;
origin & orientation of jets; distances

Exoplanet Host Stars
escaping atmospheres from gas giants; H II fluorescence in hot Jupiter atmospheres;
transit light source effect

2024 NIAC Symposium: AeSI

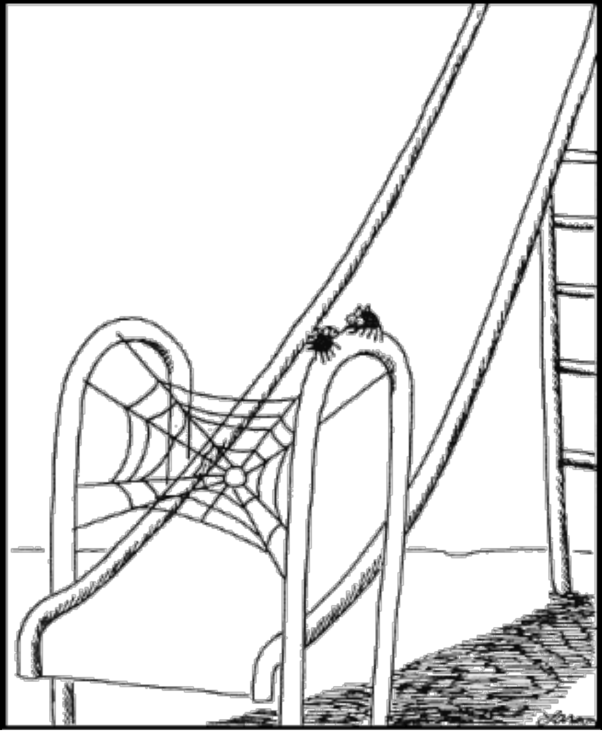


2024 NIAC Symposium: Some Fun Moments

The Current State of Space Interferometry

- "Yeah, that can't be good."
  - Sheriff Jack Carter/Eureka
- "It was the best of times,
  it was the worst of times, ...
  the spring of hope,...
  the winter of despair...
  we had everything before us, we had nothing before us..."
  - from a "Tale of Two Cities"/Dickens
- "Risk. Risk is why we're here. It is what this (starship) interferometer is all about."
  - James T. Kirk/ST:TOS

However...



"If we pull this off, we'll eat like kings."

The Farside/Gary Larson, courtesy of Gerard van Belle

For Additional Information

- Mission Concept Homepages
  - AeSI: https://hires.gsfc.nasa.gov/si/aesi.html
  - SI: https://hires.gsfc.nasa.gov/si/
- Follow me on my personal Social Media accounts:
  - @kenastro (bsky.social)
  - @KenAstro1804 (IG)
  - @kencarpenter2504 (YouTube)
  - (though be warned you'll get a lot of Star Trek, Disney, and Renaissance Festival info & photos as well as NASA & Hubble!)