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Speaker on What's Up, Hubble? Astronomy Enabled by the Return to the Moon

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NASA-Goddard

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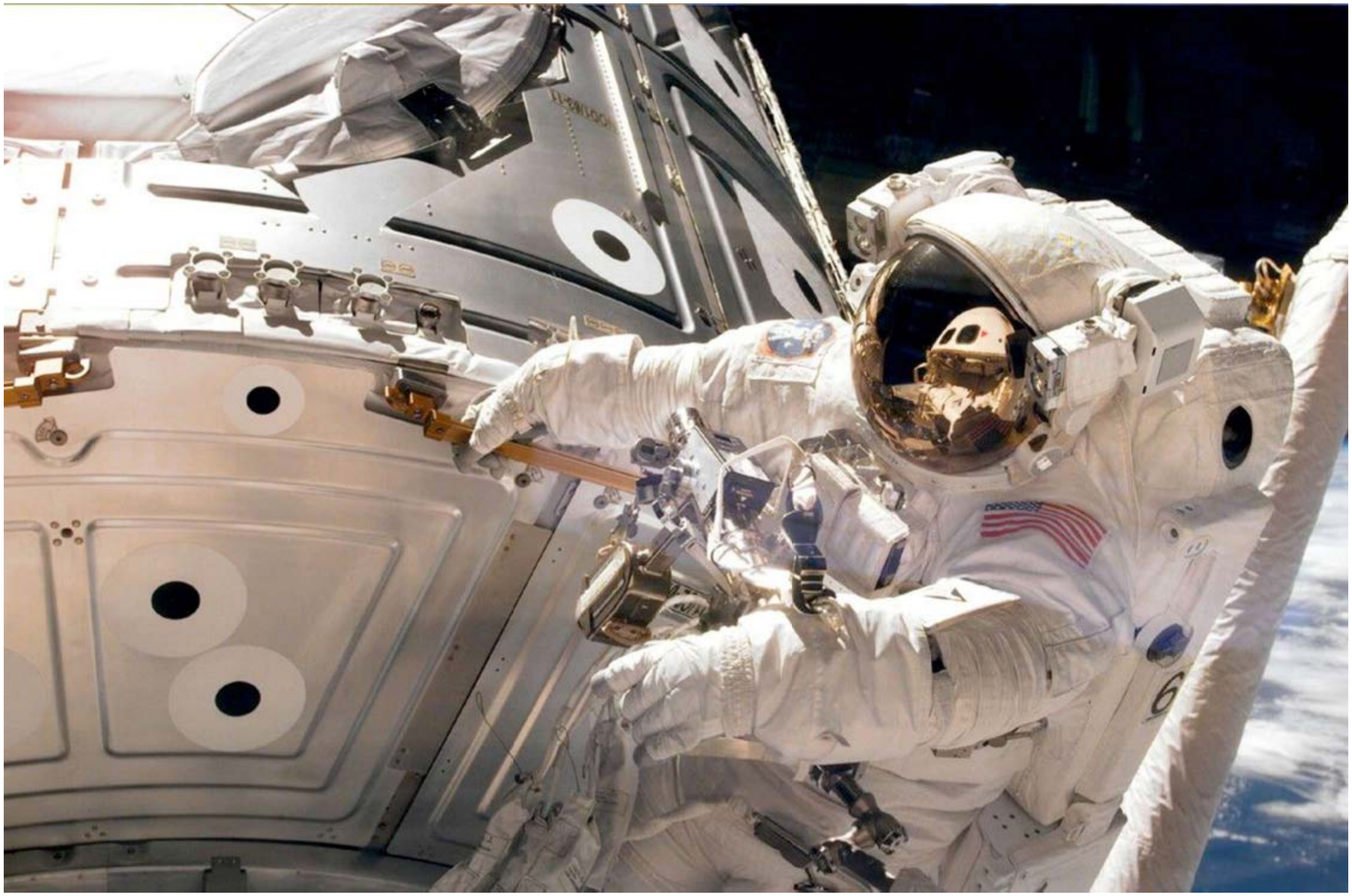
SPACE VISIONS CONGRESS 2007

FRIDAY EVENING SPEAKER THREE

HARLEY A. THRONSON

What's Up, Hubble?
Astronomy Enabled by the Return to the Moon



Harley A. Thronson
Exploration Concepts & Applications,
Flight Projects Division
NASA GSFC

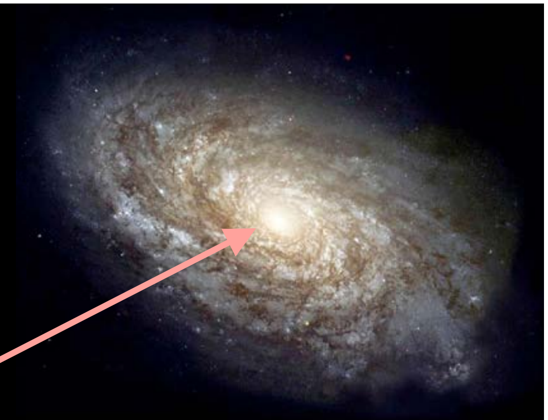
with material adapted from Dr. Mario Livio's report on the STScI workshop "Astronomy Enabled by the Return to the Moon," Dr. Dan Lester's assessments of the lunar surface for astronomy, and Dr. Phil Stahl's concept for very large telescopes within Ares V.

The Space Visions Congress

Cocoa Beach, Florida -- 27 April 2007

Dirt, Gravity, and Lunar-Based Telescopes:

The Value Proposition for Astronomy



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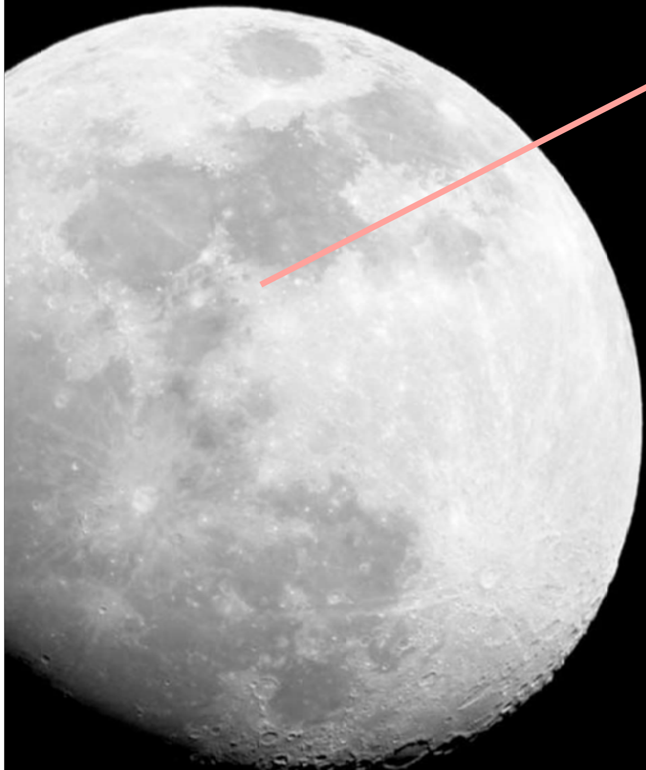


Dan Lester
University of Texas

Astrophysics Enabled by The Return to the Moon

Space Telescope Science Center
29 November 2006

Genesis of the lunar astronomy vision

"So many factors favor the Moon as a site for future large-scale space astronomy that planning an observatory there deserves the closest attention in the years ahead."

William Tifft, Steward Observatory
***Aeronautics and Astronautics* December 1966**

The world in 1966: Earth-based sites (1" seeing)
emulsions , photomultipliers
post-Gemini, pre-Apollo
OAO-2 (point/track 1'/1")

and also …

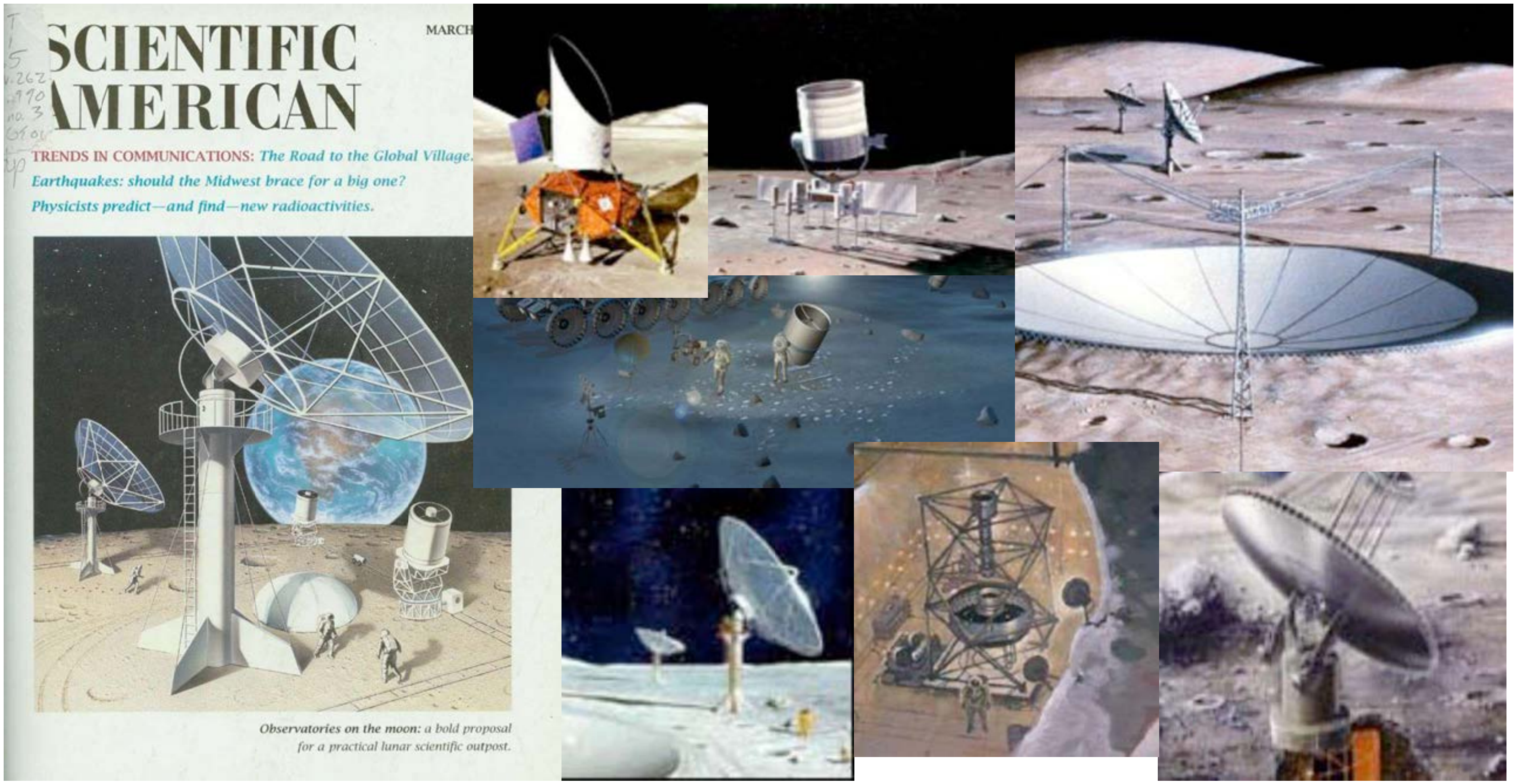
we were <u>actively</u> headed to the Moon

Advantages of the Moon for astronomy c.1966

- **Vacuum (compared to Earth)**
  - multiwavelength
  - not seeing-limited
- **Radiation isolation (compared to Earth orbit)**
  - no damage to sensitive emulsions
- **Stable surface (compared to free space)**
  - proven tracking technologies
  - no human perturbations
- **Thermal control (compared to low Earth orbit)**
  - long diurnal cycle & lunar polar craters
- **Accessibility (if near an outpost)**
  - service, maintenance

This vision was smart, both scientifically and technologically!

Lunar telescopes were a bold answer to our needs!



Innovative optical, mechanical, thermal, and civil engineering.

But then something changed …

… we came to understand that telescopes in free-space could meet our needs, offering advantages previously seen only for the lunar surface.

HST gave technology leap - free-space potential

- **demonstrated precise pointing and tracking (0.003”)**
- **demonstrated widefield diffraction-limited performance**
- **demonstrated precise thermal control in tough environment**
- **demonstrated high observational efficiency**
- **demonstrated long timescale survivability in space**

and, in particular

- **demonstrated accessibility for servicing and maintenance**

Space performance with ground-based reconfigurability

All this with what is now 25 year old technology …

Potential problems for lunar surface siting - 1

- <u>**Precise alignment: thermal stability, low flexure**</u>

1/6 Earth gravity - bending modes.

Changing illumination - temperature changes.
TPF-C needs 10mK temperature stability!

- <u>**Precision acquisition and tracking**</u>

Slow-moving moving coordinate system,
but need <u>very</u> high precision.

Natural seismic activity low, but induced activity may be a risk.

- <u>**Large field of regard**</u>

One hemisphere FOR, significantly less if in crater.
Supernovae and NEOs monitoring?

Potential problems for lunar surface siting - 2

- **Large baselines and collecting areas**

Gravity disadvantageous for assembly. Delivery to surface adds risk.

Non-uniform surface complicates optical linkage and UV plane-filling.

- **Low natural background emission**

“Horizon glow” may add to background emission.

IR shielding challenging. Sun & Earth not blockable simultaneously.

- **Low temperatures**

Cosmic background-limited IR telescopes will need T <10K. Probably unachievable passively in sunlit parts of the Moon.

Potential problems for lunar surface siting - 3

- **<u>Low scatter, high reflectivity optical surfaces</u>**

Dust: natural – electrostatically levitated and meteoritic, and activity-driven – surface ops, etc., can compromise performance.

- **<u>Assured communications and power</u>**

Solar power assured only 1/2 time except in <u>very</u> limited areas (Malapert, etc.). Direct comm convenient only on nearside.

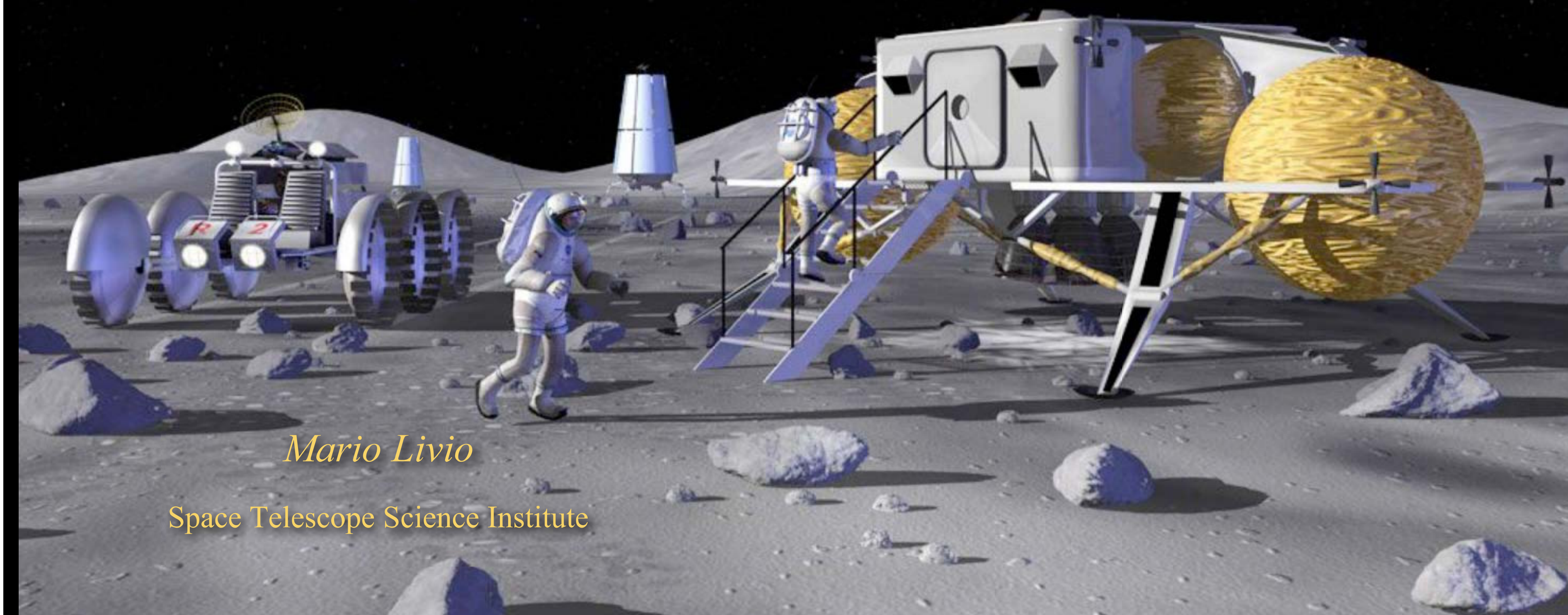
- **<u>Upgrade/repair opportunities by humans</u>**

Risk and propulsion requirements to both agents and their tools.

Mitigation of problems like these translates to COST.

Astrophysics Enabled by the Return to the Moon

"One's Destination is never a place but rather a new way of looking at things."
– *Henry Miller*

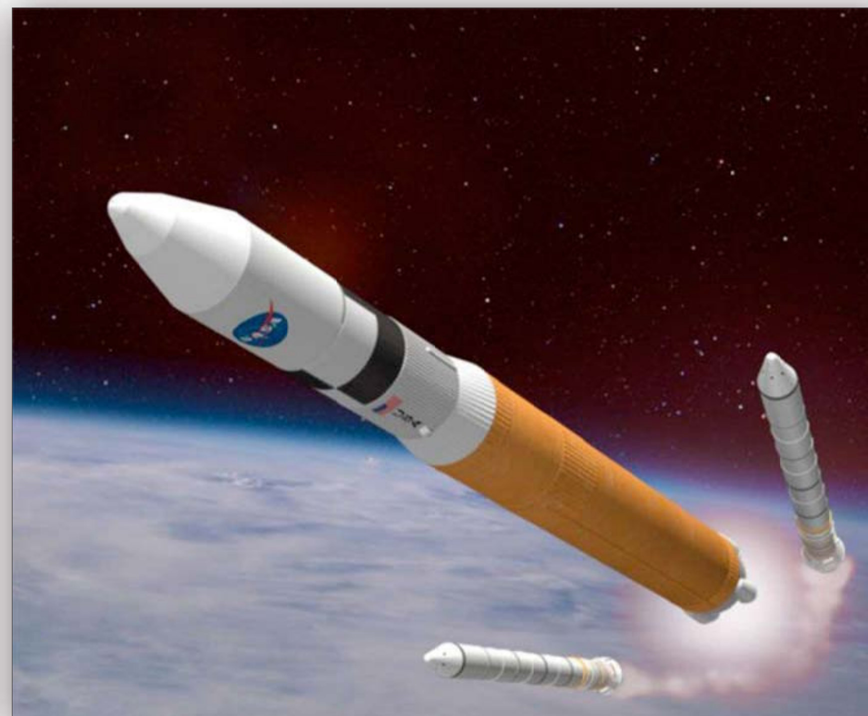


Mario Livio

Space Telescope Science Institute

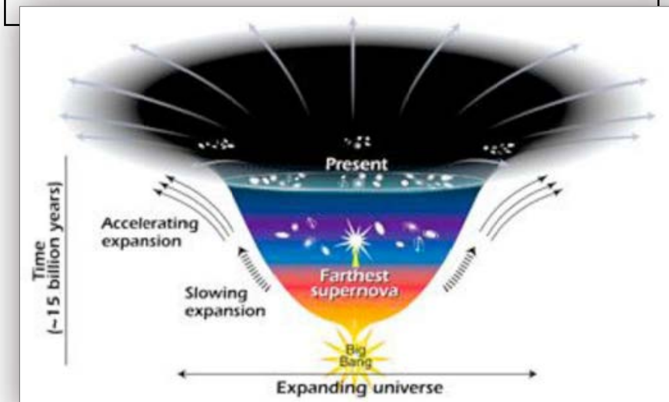
Goals of the Workshop Were:

- To identify what are intriguing astrophysical questions for the next two decades and beyond.
- To explore how the VSE and the return to the Moon can provide opportunities for significant progress toward answering those questions.

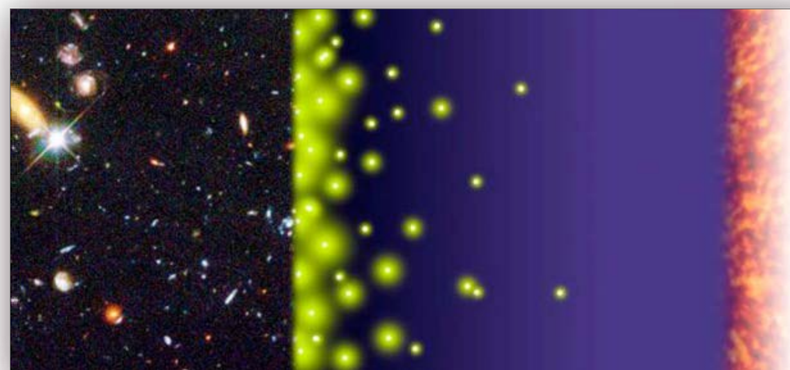


Big Questions in Astrophysics

- Why is the universe accelerating?



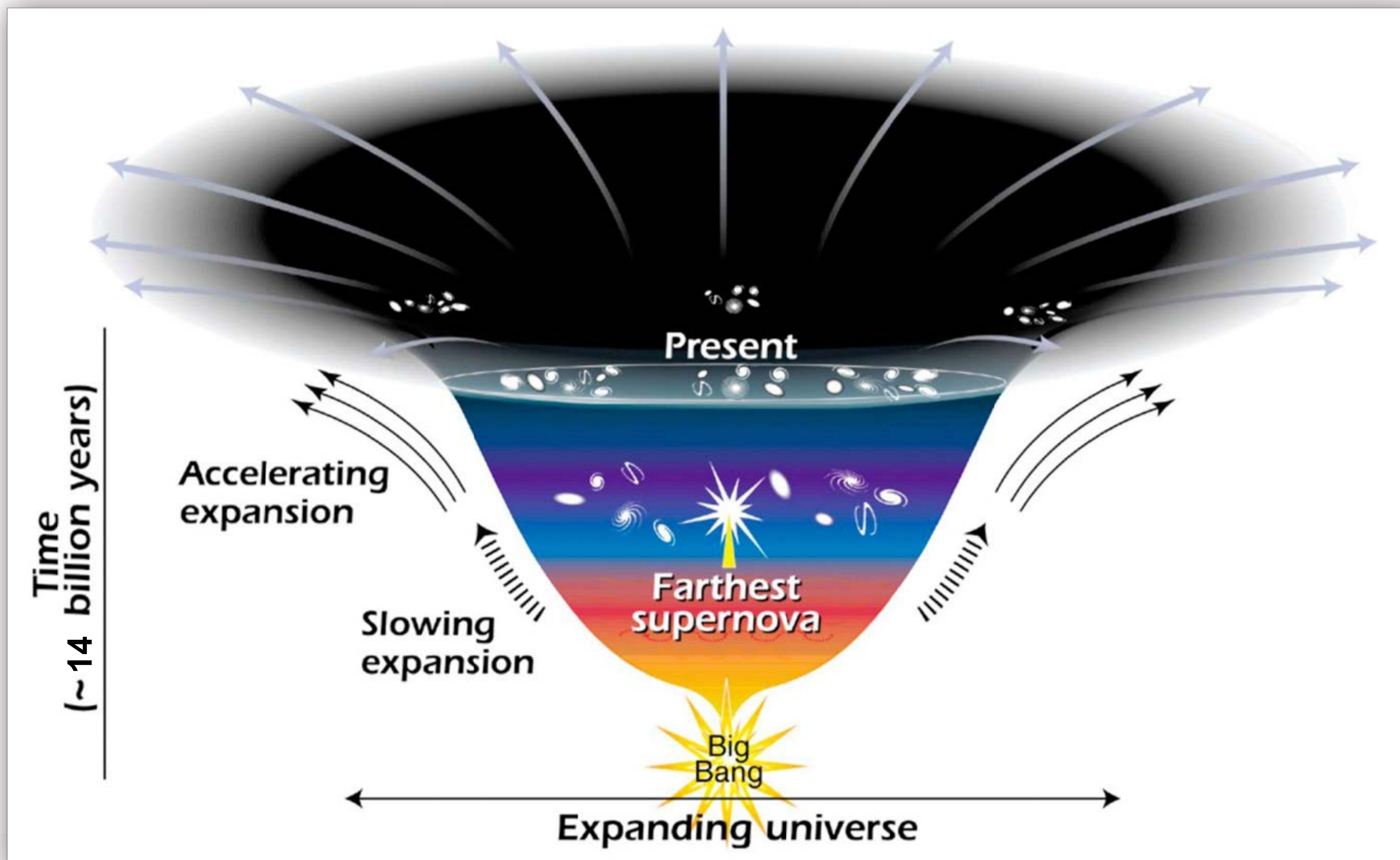
- Which astronomical objects were involved in the "first light"?



- Are there habitable extrasolar planets?

- How did galaxies and the large-scale structure form?

1. The Accelerating Universe

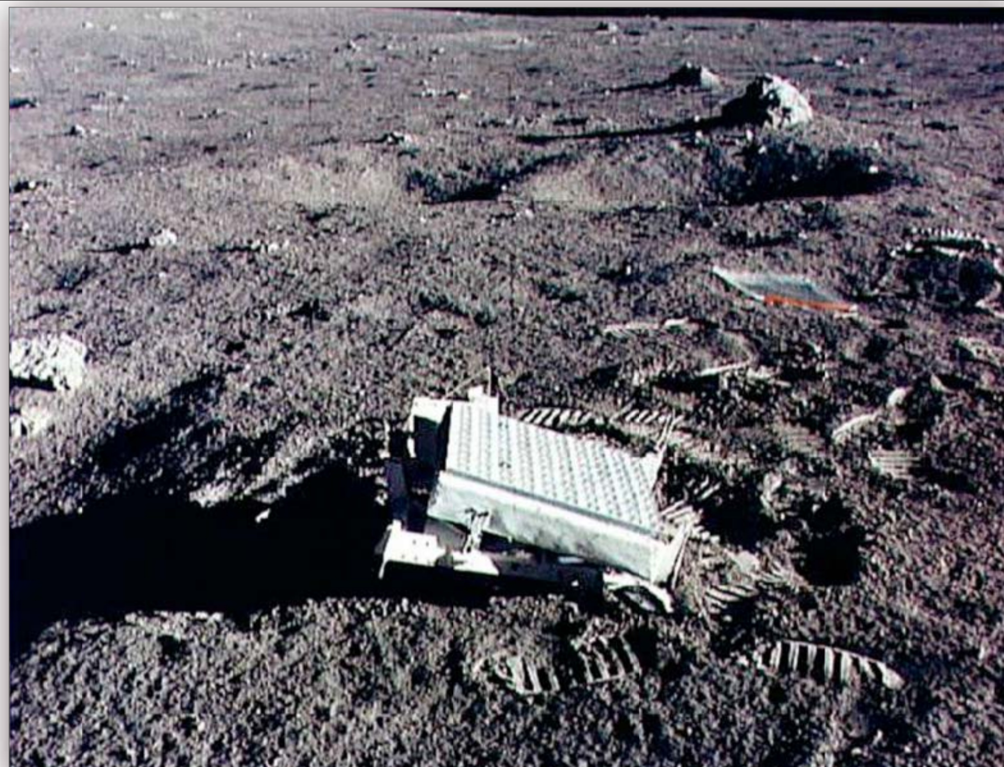


Lunar Ranging Experiments and Theories of Gravity

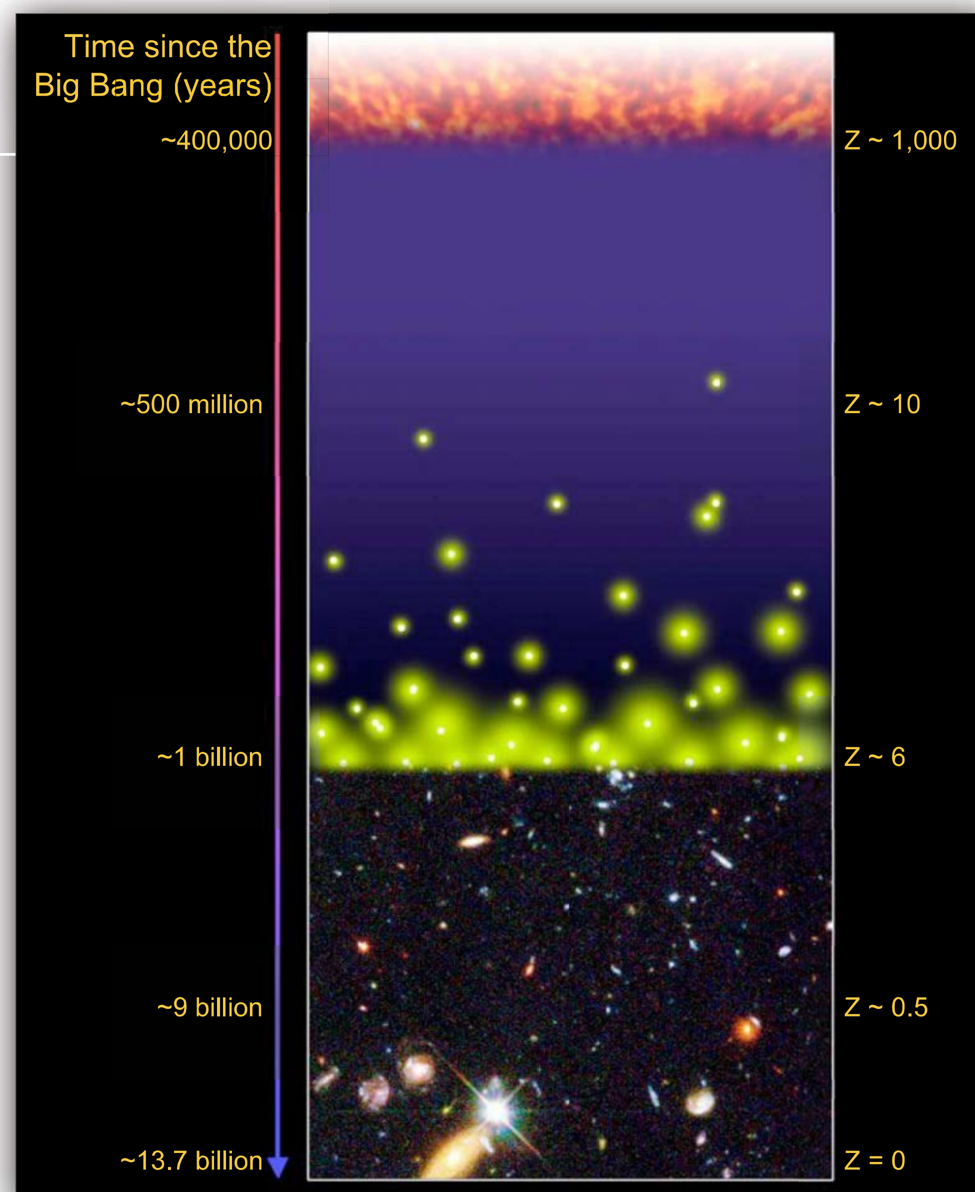
- Measurements of lunar perihelion precession with an accuracy of $\delta\Phi = 1.4 \times 10^{-12}$ to test alternatives to general relativity.

- Currently accuracy is 2.4×10^{-11}.

- Placing a carefully designed array of small transponders expected to achieve desired accuracy: may be placed by robotic systems and/or astronauts.



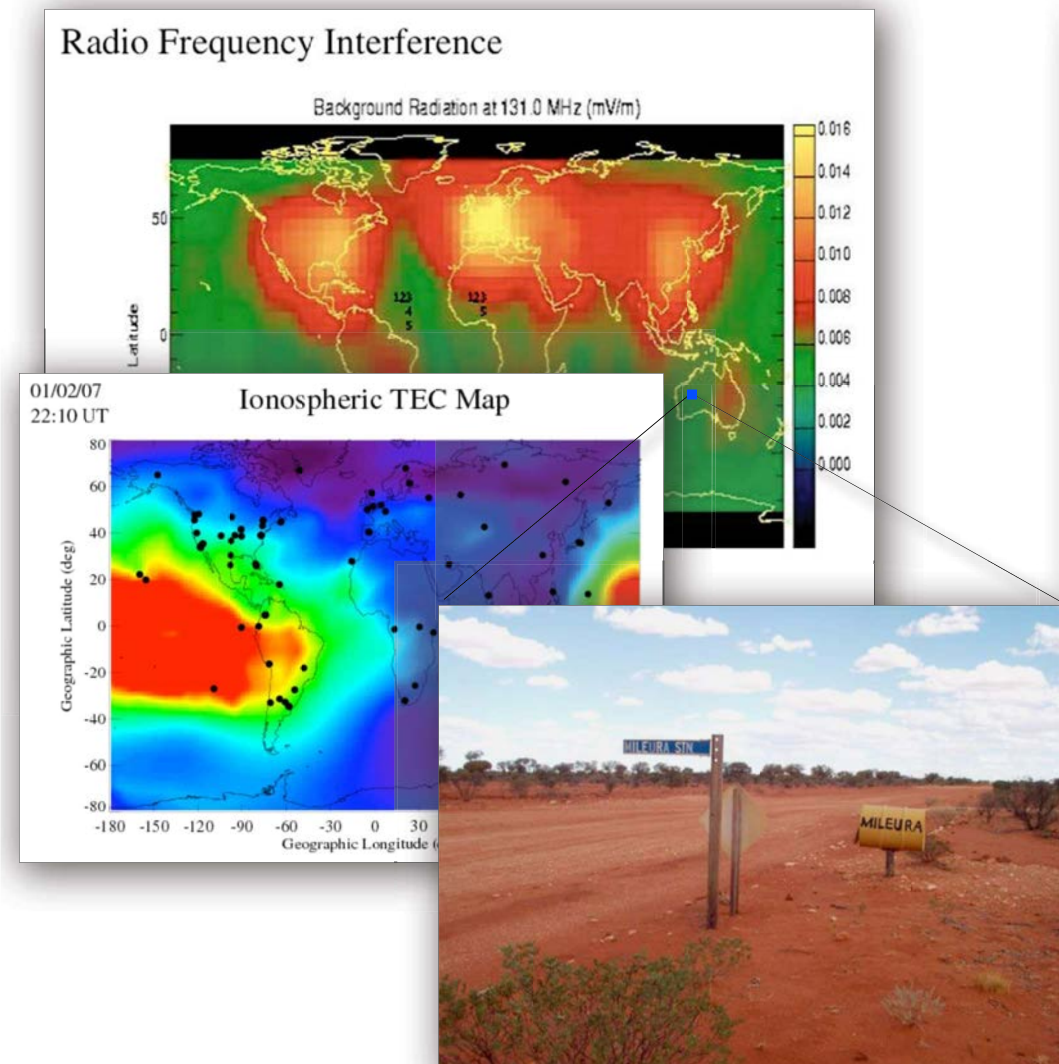
2. The Epoch of Reionization *and Before*



Approximate limit to HST observations

Observations of redshifted 21 cm (in the frequency range 10-200 MHz) neutral hydrogen emission could probe $7 \lesssim z \lesssim 100$ (i.e., 100 million - 1 billion years after the Big Bang)

On Earth

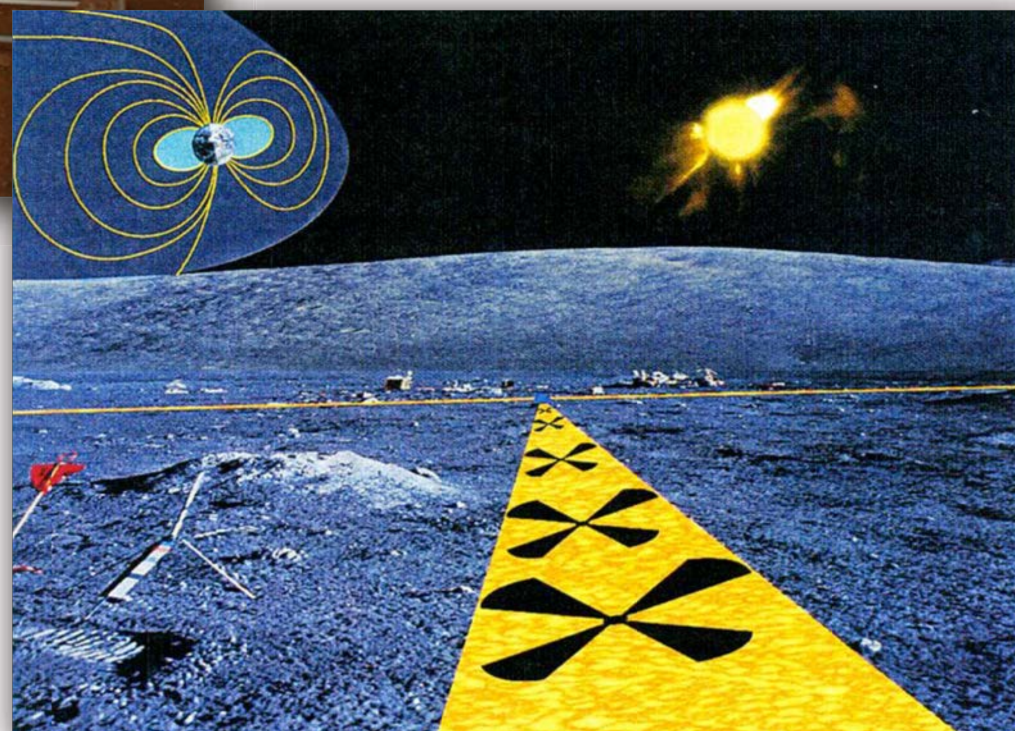


On the Moon

•"Everyone is a Moon,
and has a dark side."
– *Mark Twain*

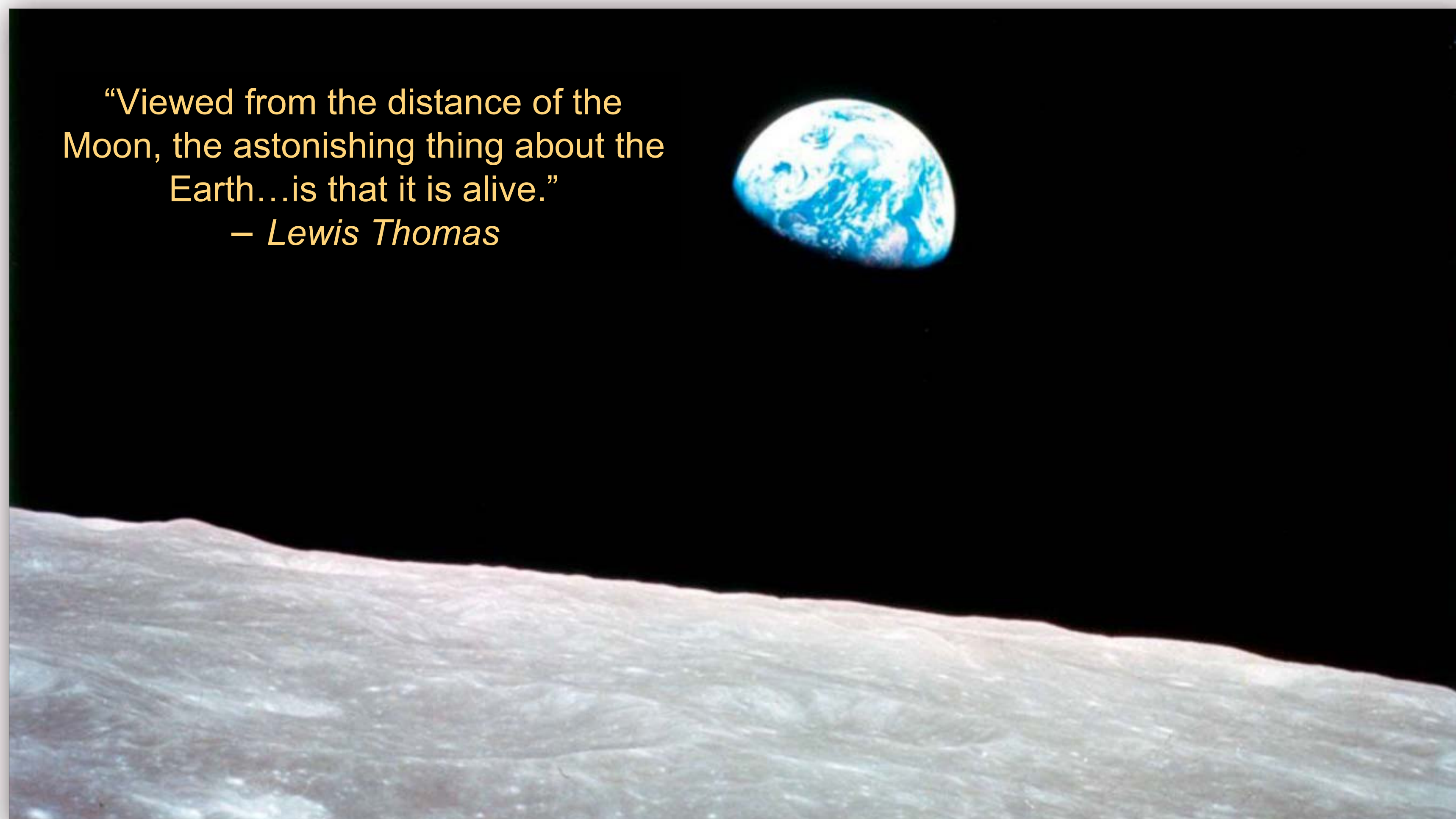
Low frequency radio observations require only lightweight dipoles

Currently: demonstration facilities in the Australian outback



Proposed: extended array on the lunar far side

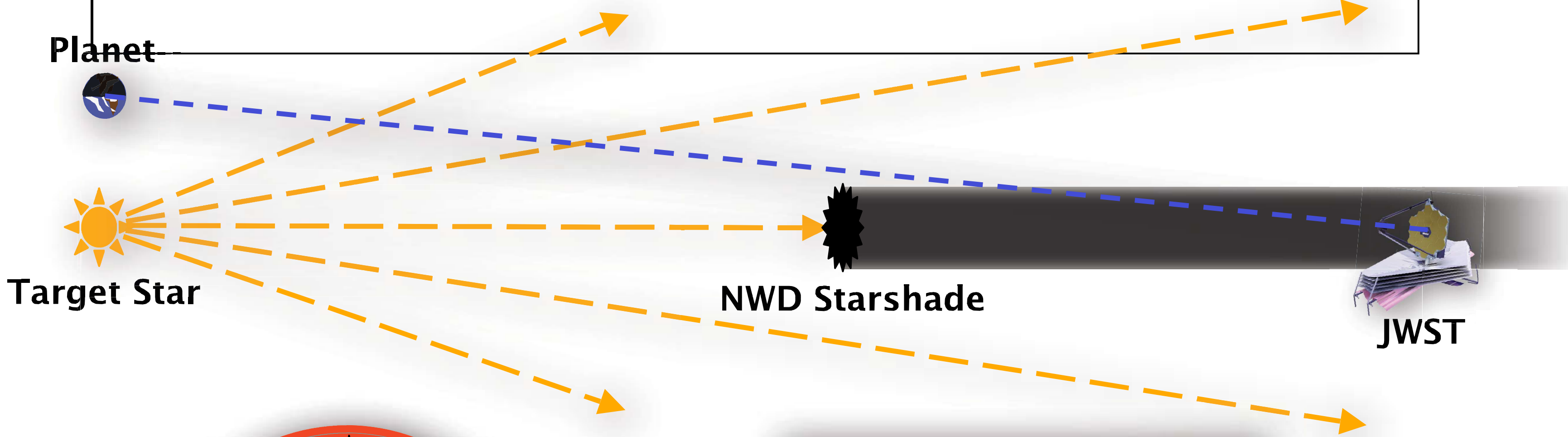
The Search for Earth-like Worlds?

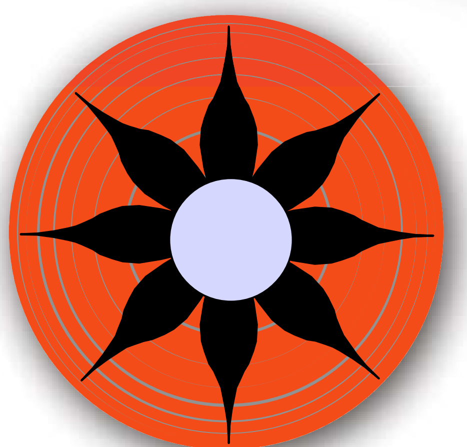


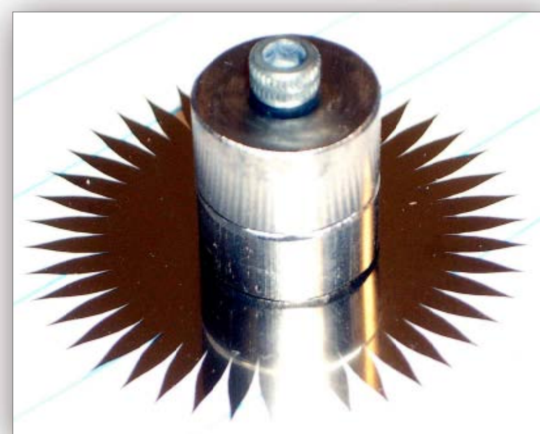
3. Are There Extrasolar Habitable Planets?

Potential observations from free space using very large optical systems:

External occulter throws deep shadow over the James Webb Space Telescope, but allows planet light to pass.

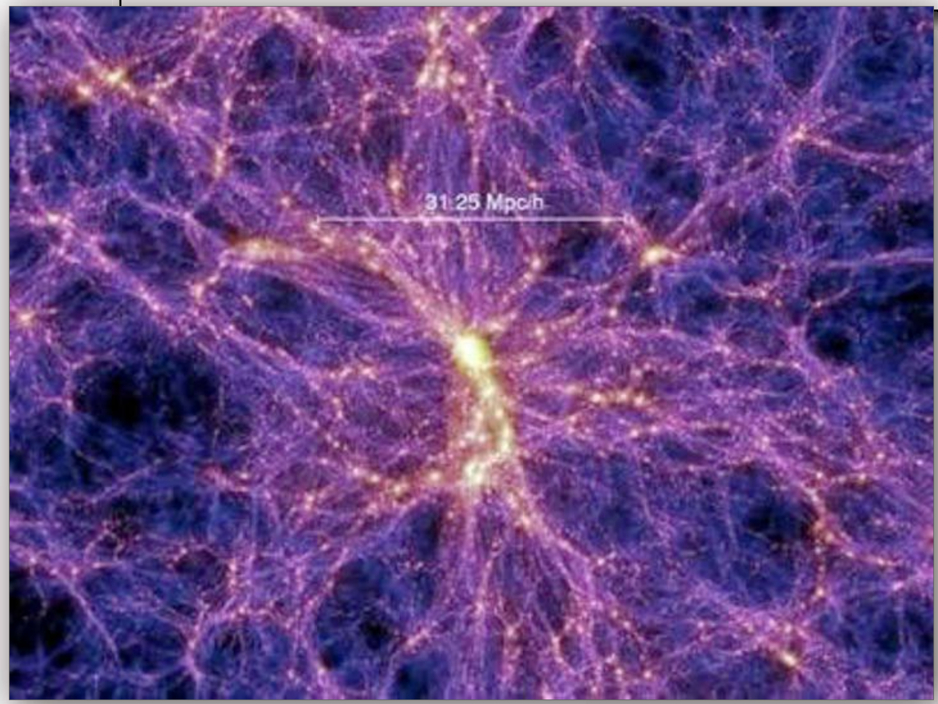






4. The Assembly of Structure

Potential observations from free space



Structure of the cosmic web and the intergalactic medium can be best studied by ultraviolet spectroscopy from L2.

CONCLUSIONS

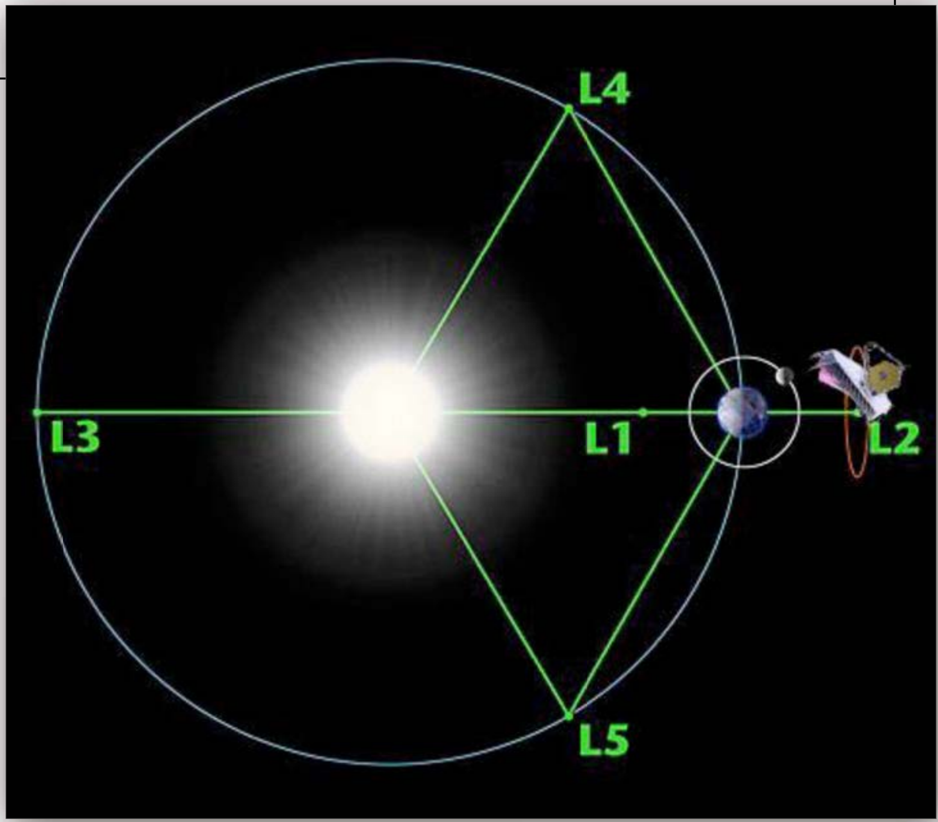
1. The return to the Moon will enable significant progress in astrophysics.

2. The workshop identified some important astrophysical observations, as well as a few smaller experiments that can be uniquely carried out from the lunar surface.

CONCLUSIONS

3. Observations from free space (in particular Lagrange points) offer the most promise for broad areas of astrophysics.

- Capabilities in free space include:
- All-sky access
- Diffraction-limited performance
- Very precise pointing and attitude control
- Thermal equilibration and temperature stabilization
- Efficient operations

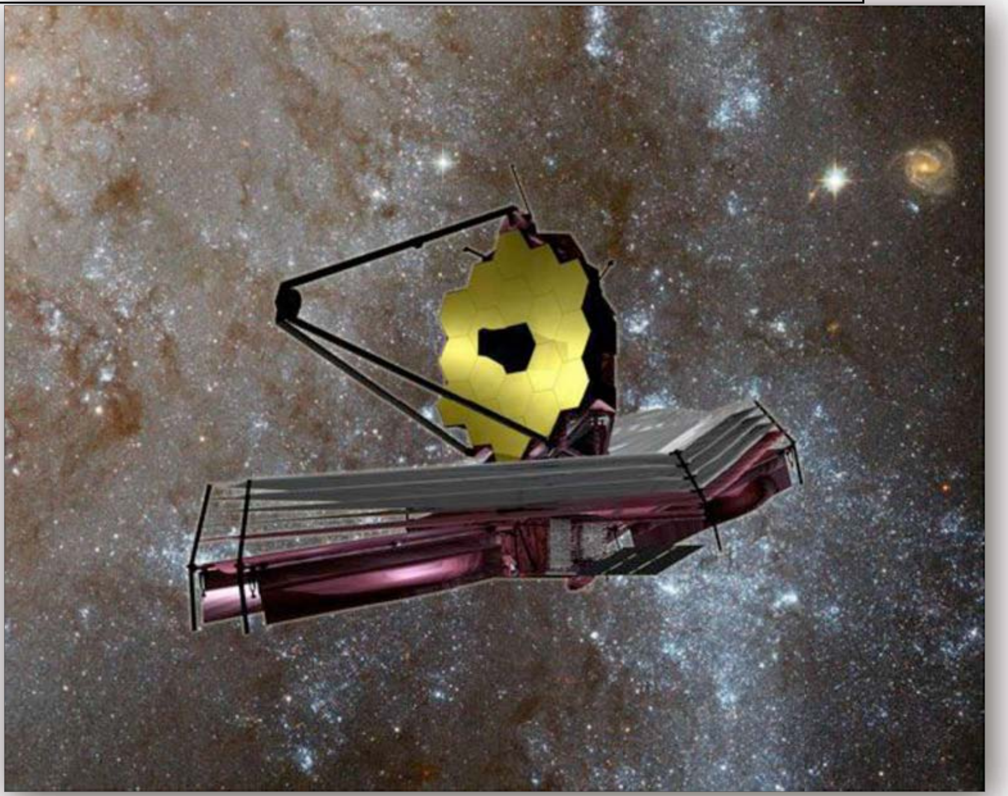


Sun-Earth Lagrange points (not to scale)

CONCLUSIONS

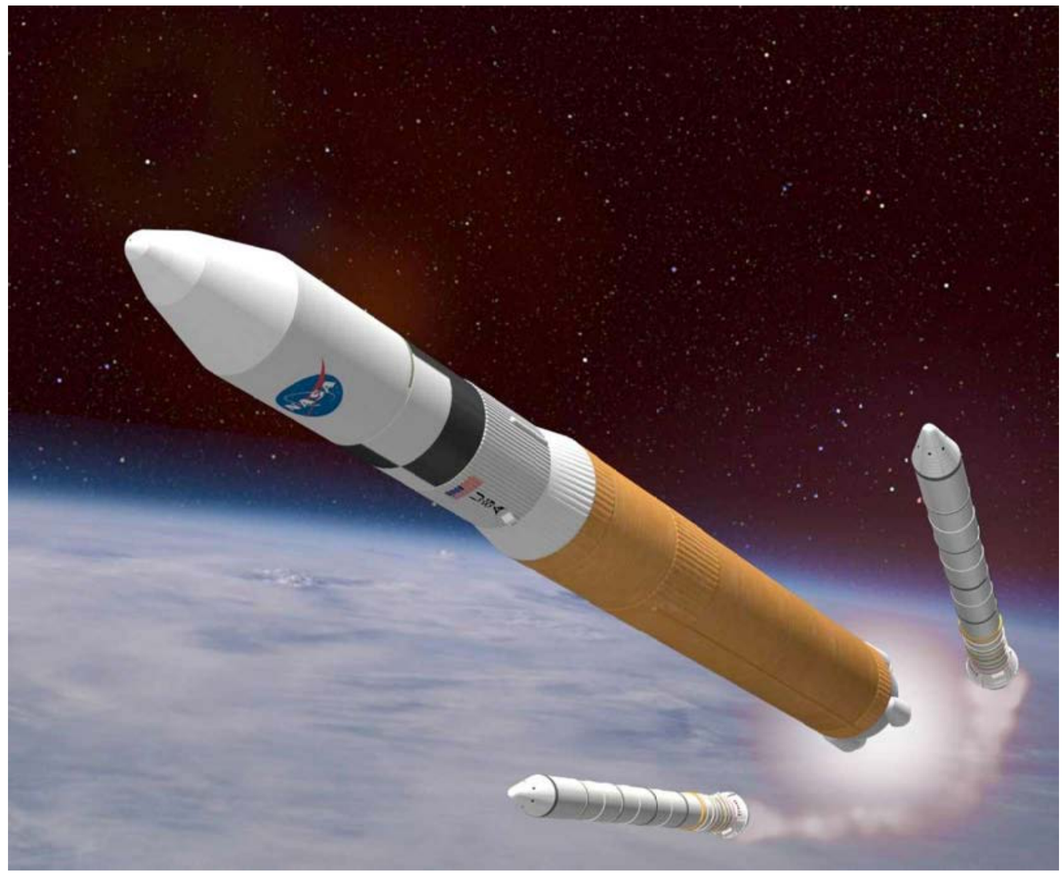
- 4. The VSE should be planned so as not to preclude — and to the extent possible to include — capabilities that will enable astrophysics from free space.

- Capabilities of great interest include:
- Large fairings
- Advanced telerobotics
- EVA capabilities
- High-bandwidth communication
- A low-cost transportation system (e.g. between Lagrange points)



Ares V: an Enabling Capability for Future Space Astrophysics Missions

Courtesy: H. Philip Stahl



Executive Summary

Current Launch Vehicle Mass & Volume limits drive Mission Architecture & Performance:

Volume limits Aperture

Mass limits Areal Density

And, drive Mission Implementation Cost & Risk

Ares V eliminates these constraints and enables an entirely new class of mission architectures.

Ares V delivers 5X more Mass to Orbit

Delta IV can Deliver

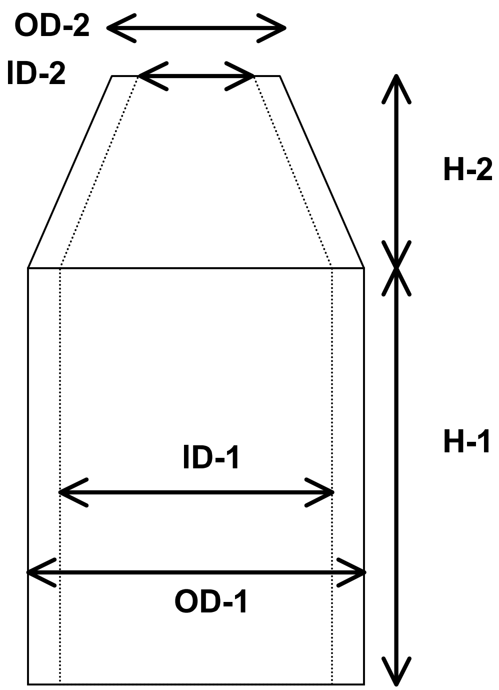
- 23,000 kg to Low Earth Orbit
- 13,000 kg to GTO or L2 Orbit w/ phasing
- 5 meter Shroud

Ares V can Deliver

- 130,000 kg to Low Earth Orbit
- 60,000 kg to GTO or L2 Orbit w/ phasing
- 8.4 meter Shroud
- (slightly less with 12 meter Shroud)

Ares V Preliminary Shroud Dimensions

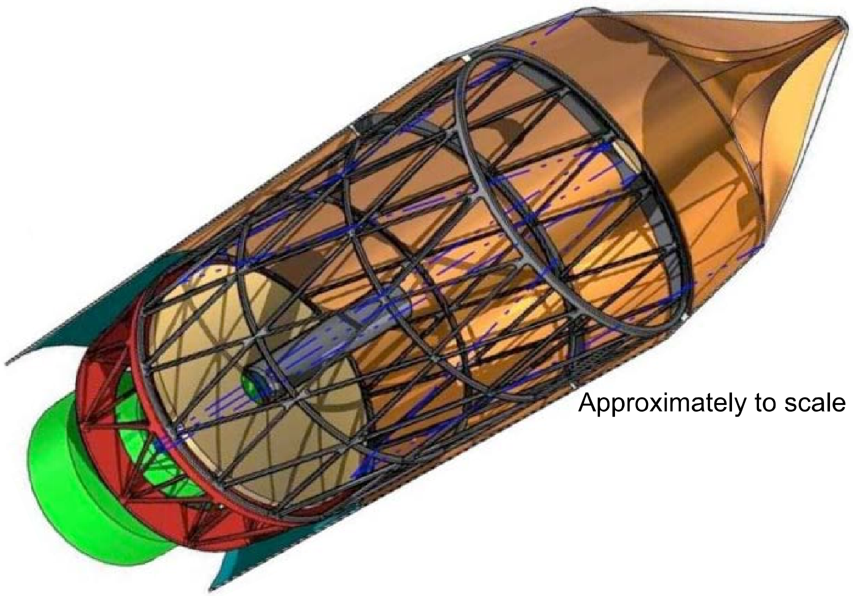
ID is the payload dynamic envelope, not the wall thickness.



	Shroud Outer Diameter			
	8.4-m	10-m	12-m	
Shroud Mass	5.9	8.4	12.5	mT
OD-1	8.4	10	12	m
ID-1	7.5	8.77	10.3	m
H-1	12	12	12	m
OD-2	4.8	5.75	6.9	m
ID-2	3.9	4.52	5.2	m
H-2	6.3	7.5	9	m
Total Height	18.3	19.5	21	m
Payload to SEL2	62	61	60	mT

NOTE: these shroud dimensions are preliminary, are subject to change, and have not been approved by the Ares project office.

Case Study:
6 to 8 meter Class Monolithic Space Telescope



Approximately to scale

Hubble

As for the future, your task is not to foresee it, but to <u>enable</u> it. -- Antoine de Saint-Exupery

The space and Earth science communities have identified priority goals that are major design, technology, and operational challenges for NASA.

While a number of these goals may be met by operation on the lunar surface with robots and/or humans, many others will be enabled only by very large, complex facilities in free space: UV/vis/IR filled-apertures, spatial arrays for x-ray and radio observations, and millimeter and sub-millimeter antennae observing the Earth from geo-synch or libration points.

Successful operations at these locations can build upon almost two decades of successful human-robotic experience in LEO to assemble, repair, upgrade, and rescue complex facilities of many kinds.

In response to opportunities offered to the science communities by NASA leadership over the past three years

As a consequence, NASA's evolving Exploration Architecture is being evaluated as to how modest augmentations may enable "sortie" operations in free space, just as NASA welcomes options for "sortie" missions on the lunar surface.

> Preliminary marginal cost estimates for alternative "sorties": ~ $2 B per surface "sortie" (ref: NASA Administrator), whereas a major cis-lunar "sortie" that does not require soft lunar landing costs ~0.7 of surface "sortie" (ref: Boeing, LM).

The FISO working group has taken national science priorities in space as given by NAS/NRC "decadal reviews" and incorporated in NAC advice. We have concentrated on evaluating broadly enabling capabilities, rather than designs for science missions or new science goals.

For the past two years, our group has been assessing options for in-space capabilities, including the most cost-effective use of astronauts and/or robots, the *Orion/Ares* systems, as well as how these capabilities may support lunar surface operations. Such a multi-use capability has an historical precedent . . .

The FISO Working Group consists of about two dozen US scientists and engineers working in NASA, academia, and industry. See reference list at the close of this presentation.

History's lesson: when science goals and human exploration combined to achieve multiple goals with a single system

GSFC, a science Center, partnered with JSC, the human spaceflight Center, in 1972 at the start of Space Shuttle development. From this partnership arose breakthrough capabilities …

A design that made possible on-orbit servicing:
- More effective cargo bay
- Large robotic arm for capturing and repairing satellites.

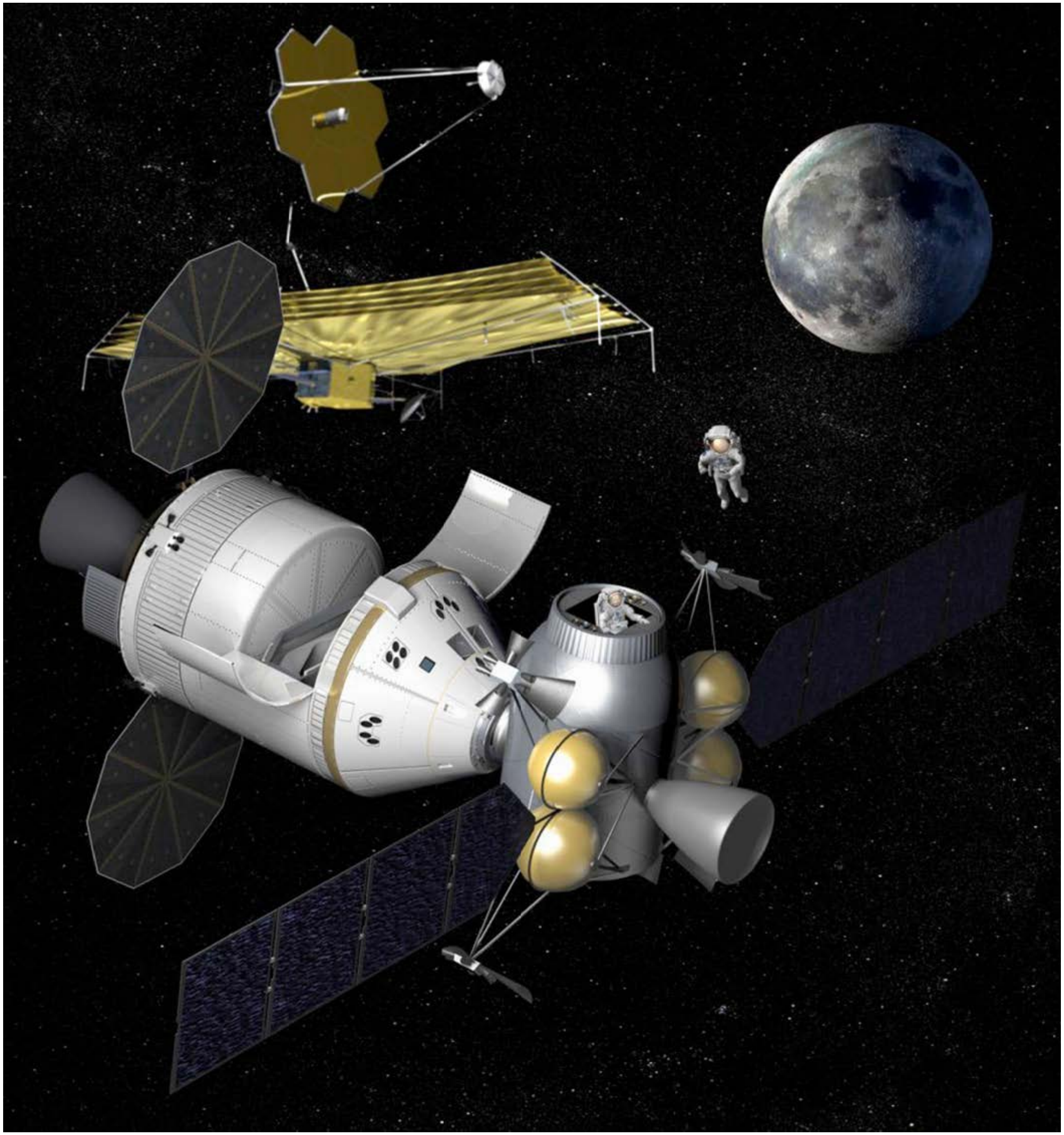
Modular spacecraft designed to be approachable, retrievable, and repairable

Generic Shuttle-based carriers to berth and service on-orbit spacecraft, not exclusive to one particular vehicle.

On-Orbit Satellite Servicing Concept, 1975

With the same philosophy, what might Orion make possible?

Future major science facilities in space will be extremely challenging. Humans and robots on site are likely to be necessary if these missions are to be successful.



A cis-lunar "sortie:" one FISO concept for servicing the ~ 10 m SAFIR observatory at the Earth-Moon libration point using an augmented *Orion* and LSAM crew module.

Current/Near-Future Assessment and Trade Studies

<u>Space robotics:</u>

Surface or in-space ops, human-robot interaction

=> AR&D and inspection of ISS, Shuttle, *Orion*; space tugs and remote cargo transfer; refueling;

<u>*Orion* + robots + astronaut EVA</u>:

manipulation, upgrade, construction with astronauts on-site

=> complex assembly, rescue, servicing etc. possible only with astronauts and advanced robotics; cost trades

<u>In-space support for lunar surface ops</u>:

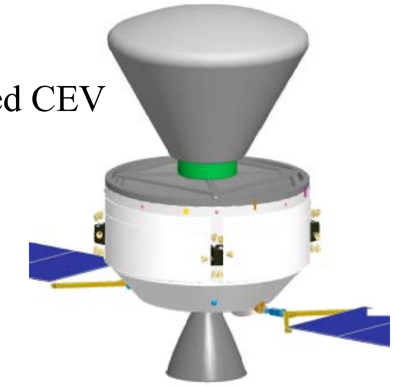
Application of in-space capabilities to lunar surface ops and vice versa

=> Depoting, refueling in space; contingency and medical support for surface humans operations; preparations for long human space voyages

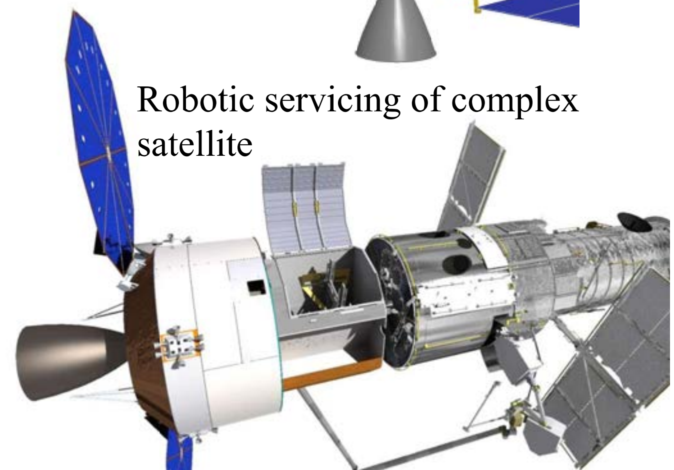
<u>*Ares 5*: heavy lift and very large optical systems:</u>

Invited proposal via Pete Worden (@STScI workshop)

=> very large apertures, multiple payloads, etc. Design study coordinated among GSFC, ARC, MSFC, JSC, NRO, academia, industry; costs



Tug rescue of stranded CEV



Robotic servicing of complex satellite

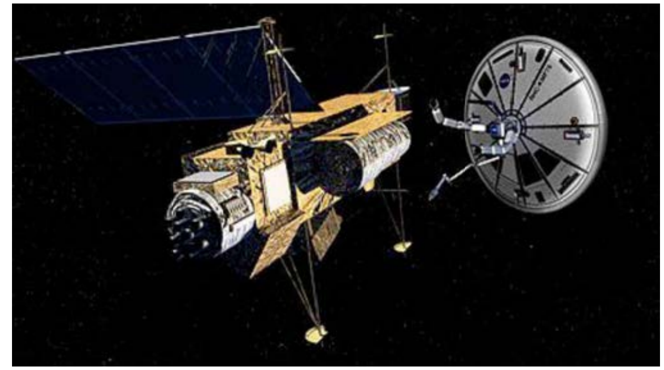
Science enabled by *Ares 5*

Augmenting the Exploration Architecture: A Notional Top-Level In-Space "Roadmap"

1. Space robotics (LEO):

remote manipulation, simple examination, recon, & rescue

=> External examination of ISS, Shuttle, *Orion*; space tugs, cargo transfer, refueling, commercial interest



2. *Orion* + robotic systems (LEO):

manipulation, upgrade, construction with humans nearby

=> external inspection/repair of ISS, *Orion*

3. *Orion* + robotics + LCM (LEO, HEO):

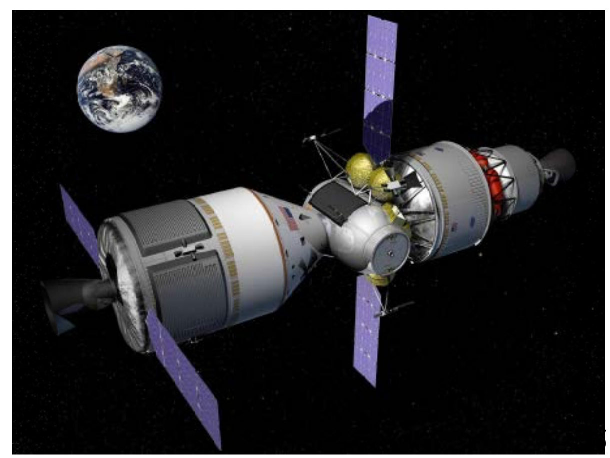
advanced capabilities using human EVA & robots

=> Construction/servicing of complex in-space facilities; research in LCM

4. *Orion* + robotics + LCM + EDS + *Ares 5* (Lunar, EM L1):

in-space support for lunar surface ops, in-space demos

=> Contingency supply, on-orbit depoting,
line-of-sight control of surface robots;
very large optics for multiple users



Conclusions

Augmenting the NASA Exploration Architecture potentially offers a large community of science users the capability to achieve major goals in Earth science, solar science, and astronomy at the libration points, geosync, and other locations in the Earth-Moon system.

Successful operation in free space with astronaut EVA, advanced tool systems, and robots is now almost two decades old.

Using NASA's Exploration Architecture to achieve several major science goals is extremely attractive without the complexity and expense of landing on the lunar surface.

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