

Spacecraft Lighting Systems Perspectives for Lunar Missions



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Scale: 1 Pixel = 10 Km / 6.2 mi

2000 Km / 1243.7 mi

Low Earth Orbit is NOT Faraway

Earth Radius 6378 Km / 3963 mi

0 km / mi - Sea Level.

37.6 km / 23.4 mi - Self Propelled Jet Aircraft Flight Ceiling (Record Set in 1977).

215 km / 133.6 mi - Sputnik-1 The first artificial satellite of earth.

340 km / 211.3 mi - International Space Station.

390 km / 242.3 mi - Former Russian Space Station MIR.

595 km / 369.7 mi - Hubble Space Telescope.

[700 - 1700 km] - Polar Orbiting Satellites.

[435 - 1056 mi]

LEO Zone
(Low Earth Orbit)

MEO Zone
(Medium Earth Orbit)

2000 Km / 1243.7 mi

600 - 800 km / 372.8 - 497.1 mi - Sun-synchronous Satellites

These satellites orbit the Earth in near exact polar orbits north to south. They cross the equator multiple times per day and each time they are at the same angle with respect to the sun. Satellites on these types of orbits are particularly useful for capturing images of the Earth's surface or images of the sun.



LEO Zone
(Low Earth Orbit)

Scale: 1 Pixel = 100 Km / 62.1 mi

20000 Km / 12437.4 mi

MEO Zone
(Medium Earth Orbit)

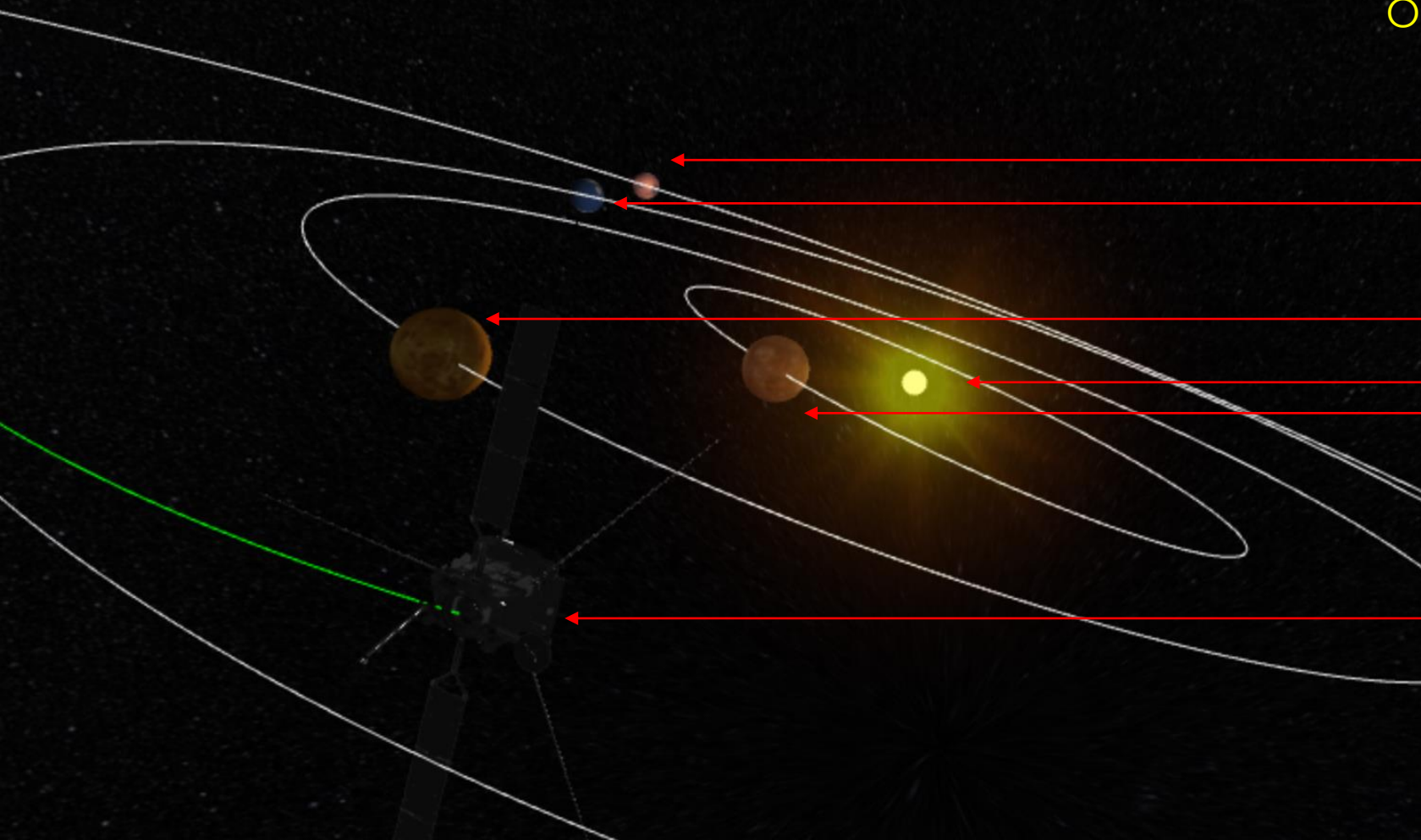
HEO Zone
(High Earth Orbit)

384,000 km
The Moon

The Earth and Moon have the same Solar Illumination

Light that reaches the Earth-Moon system is nearly collimated.

Orbital light level is 130kLux @ Earth



Mars
Earth

Venus

Sun
Mercury

Solar Orbiter Spacecraft

The Lunar Environment Is Very Different



[Image: Apollo 17, Valley of Taurus-Littrow](#)

IT IS DIFFICULT TO VISUALIZE WHAT YOU CAN'T SEE OR EXPERIENCE!

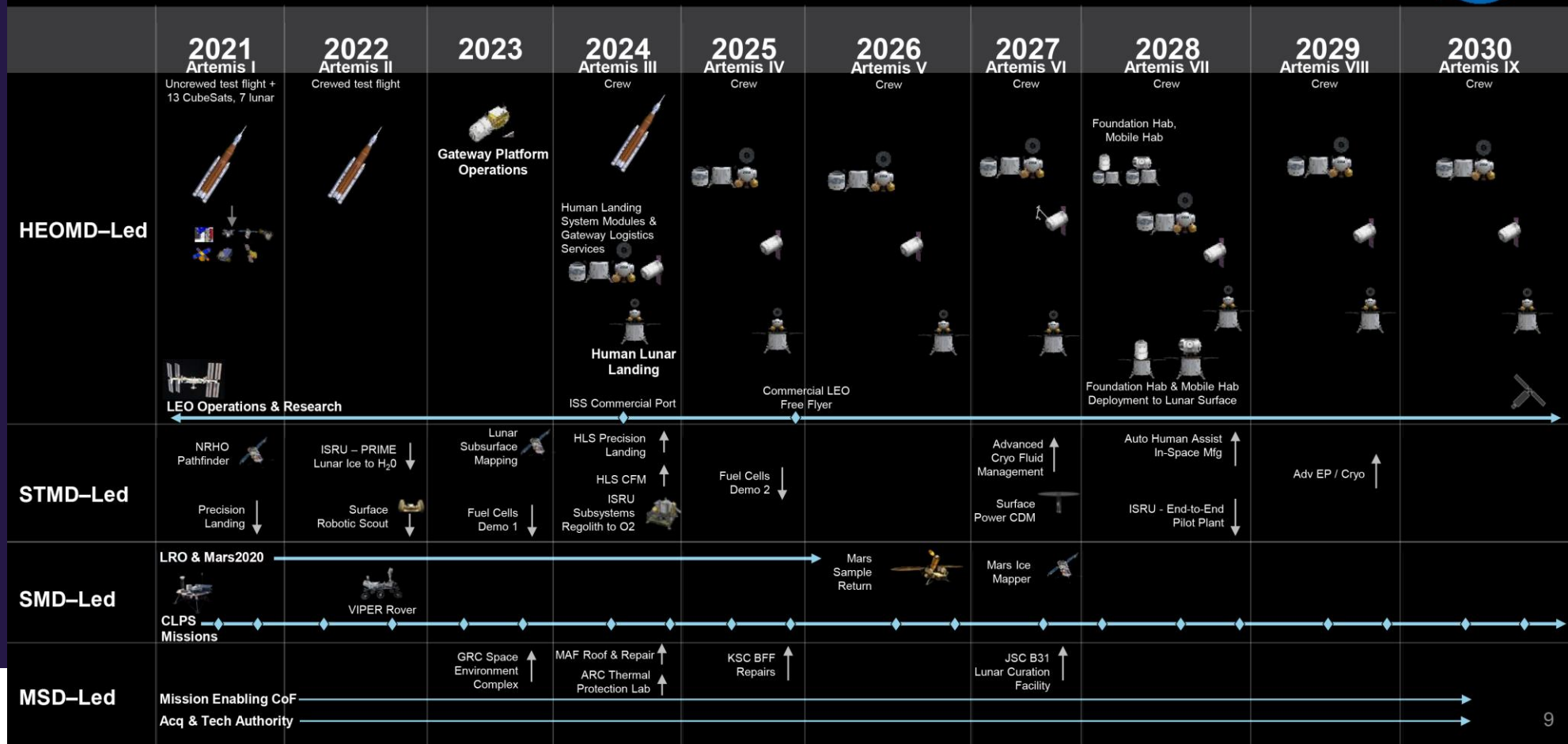
Earth has no physical analog, nor supporting engineering standards, for a surface lighting environment where the sky is black, the Sun's rays are parallel with the ground, and where the condition (day or night) persists for two weeks.

- Activities performed in the span of 8 hours will have persistent hazardous lighting conditions.
- Traditional “night-time” design paradigms for lighting architectures do not address countermeasures to see in the dark, simultaneous to observing objects lit by the Sun.
- Human adaptation to light (or lack of) could create real hazards to crew and impact, assembly, translation, visual monitoring, and inspection tasks.

THE MISSION

EVERY ACTIVITY THAT REQUIRES A CAMERA OR HUMAN OBSERVER WILL REQUIRE A LIGHTING SYSTEM!

NASA Exploration: CY 2021- CY 2030



EVERY MISSION REQUIRES LIGHTS ?

It is a tall order to think about the potentially massive scale lighting systems architecture will play in mission success.

Before diving into this elephant of a problem, we need to understand the basics on why and what goes into a lighting architecture.

The basic understanding can help us:

- Be smarter about hardware and infrastructure development
- Author end item source control documents for lamps and supporting lighting infrastructure that help us build support systems that are scalable with the missions
- Manage technology development risks
- Ensure a proper test and verification program is provided
- Long term budgeting for equipment sparing
- Reduce integration risks for vehicle providers
- Manage safety and emergency planning risks

WHAT IS NOT UNDERSTOOD IS OFTEN TRIVIALIZED

The phrase “out of site – out of mind” often applies to how typical spacecraft system developers tackle lighting related problems. Lighting is a topic they are not used to planning for.

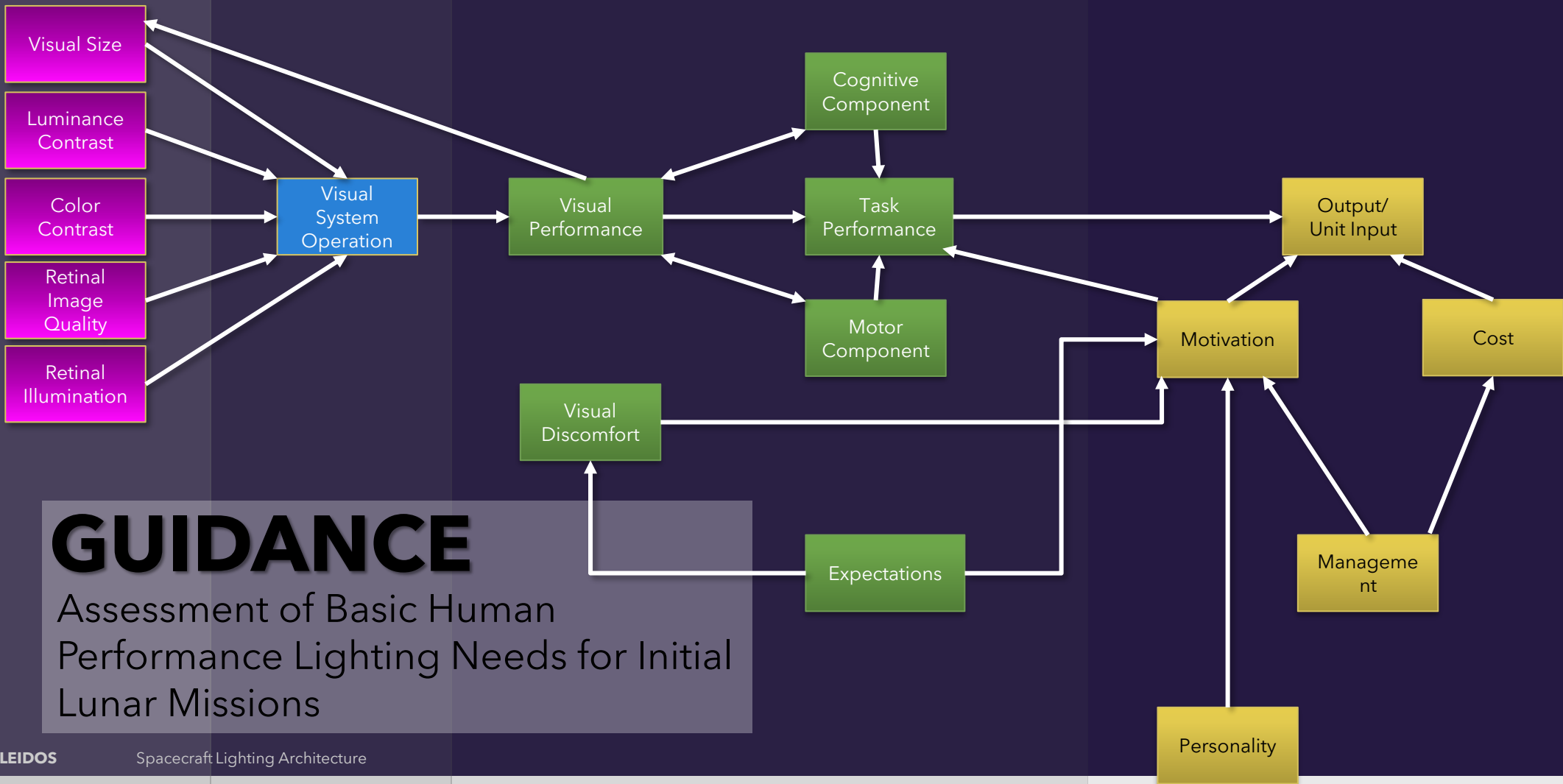
Part of the problem is not understanding some of the basic lighting terminology that is necessary for development of solution to an application.

The application and proper definition of lighting terminology can affect many operational areas.

Interior & Exterior Systems Lighting Architecture	Camera & Sensor System Design
Thermal Systems Design	Power Systems Design
Display Design	Autonomous Systems Design
Exterior Proximity Operations	Simulation of Optical Systems
Test & Verification Systems	Training
Mission Timelines	Hazard Assessments

BASIC LIGHTING SYSTEMS ARCHITECTURE

Adapted from Illuminating Engineering Society Handbook Figure 4.18



CHALLENGING ENVIRONMENT = TECHNOLOGY INNOVATION

In addition to the architectural planning needs, artificial lighting is typically solid state. Design challenges include:

- Thermal
- Radiation
- Power
- Human Adaptation & Camera Exposure Response
- Geometry

WAIT! WHAT ABOUT ALL THOSE YEARS IN LOW EARTH ORBIT? DO THEY MATTER?

Low Earth Orbit (LEO) experience does not provide a good design analog for our Lunar Surface Challenges.

- LEO has a 90-minute day night cycle. Moon has a month long day night cycle.
- Bad exterior lighting for LEO is on the order of minutes. Bad exterior lighting on the Moon is on the order of days and weeks.
- LEO has the benefit of a huge reflector, the Earth, that bounces light onto activities. Lunar surface activities do not have this option.

SUMMARY

There is a lot of opportunity for establishing a new design methodology and paradigm for architectures that produce and manage light for exploration missions.

- Many of the innovations are in the supporting hardware technologies
- Vast improvements can be made on the planning side on how we baseline the utilization of computer modeling, digital twins, and testing of technologies ahead of the Critical Design phase of a project to avoid costly hardware and mission impacts.
- Designing for Lunar surface operations will require us to plan, design, simulate, and test differently and to a different schedule than our standard aerospace process.

We have the opportunity to be leaders instead of followers.