# First Lunar Outpost
# Conceptual Surface Mission

**(by John E. Gruener)**

## PURPOSE

The purpose of this document is to describe the types of activities that are planned for the 42 day surface stay on the First Lunar Outpost (FLO) mission. Descriptions for intravehicular activities (IVA) and extravehicular activities (EVA) are included.

## OVERVIEW

The FLO surface mission consists of four crew members living and working on the lunar surface for 42 days. The crew lives in a habitat that is landed unmanned on the Moon prior to the crew's arrival. The habitat is largely based on Space Station Freedom (SSF) hardware and consists of a habitation module, an airlock, a photovoltaic array/regenerative fuel cell (PVA/RFC) power system, and a thermal control system. All of the systems are integrated on Earth and remain on the lander vehicle when they reach the Moon. Both the power system and the thermal control system are self deployable upon arrival, and the health of the activated habitat is determined before the crew is launched from Earth.

The crew arrives at the Moon in their own piloted lander vehicle. During their stay in the habitat, the piloted lander is powered down and remains in a quiescent state until needed at the end of the surface mission. The Earth return stage is incorporated into the piloted lander, so no rendezvous in lunar orbit is required, and the crew travels directly to Earth.

## DESCRIPTION OF ACTIVITIES

For initial mission planning analyses, Mare Smythii, located near the lunar equator on the eastern limb, was chosen as the site for the initial FLO surface mission. This was based on the recommendations of the Lunar Outpost Site Selection Workshop held at the Johnson Space Center in August of 1990. It should be noted, however, that this is only a strawman site used to illustrate the strategies that are being developed for the FLO surface mission.

The 42 day surface mission spans two lunar days and one lunar night (one lunar day or night is roughly equivalent to 14 Earth days), and is summarized in figure 1. The lighting conditions and the thermal environment on the lunar surface are two important parameters that affect the surface activities at the lunar outpost. The lighting conditions

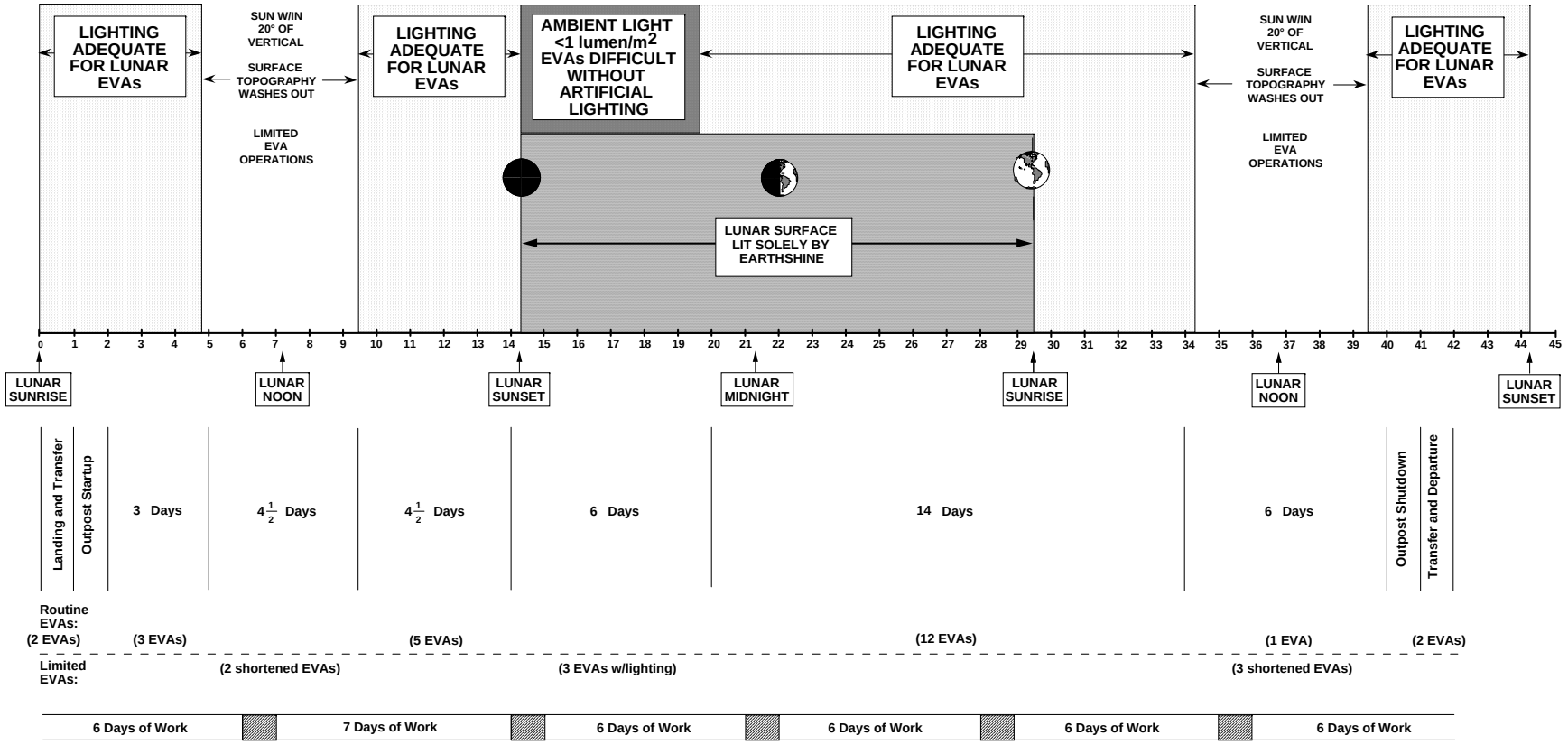



**Figure 1 First Lunar Outpost Conceptual Surface Mission**
**Eastern Limb Site (Equatorial)**

on the Moon are dependent on the lunar latitude and longitude, whereas the thermal environment on the Moon is dependent only on latitude, with the highest temperatures at the equator. While the lighting and thermal conditions are not critical to IVA operations, the light available to a crew member conducting EVA on the surface and the thermal loads that the crew member's EVA suit are subjected to are two important factors in planning EVA operations. The optimum times to conduct EVAs on the lunar surface are shortly after sunrise and shortly before sunset. At these times the temperatures are moderate and the sun angles and shadows are favorable for identifying surface features. All of the Apollo surface missions were carried out during the lunar morning.

The 42 day surface mission is divided into six work weeks (weeks vary in length from 6-8 days), with one day per week dedicated as an off duty day where no scheduled activities are planned for the crew. A 24 hour day, as shown in figure 2, is used for planning purposes with the objective to closely maintain the circadian rhythm that humans on Earth are accustomed to [Though no mission guidelines have been established for lunar missions, crew scheduling constraints from Appendix K of the Space Shuttle Crew Procedures Management Plan were used as a basis to work from].

The crew's work load is divided between intravehicular activity (IVA) and extravehicular activity (EVA). These two categories can be further defined as either laboratory/exploration related work or support related work. The four person crew is divided into two teams of two crew members each. The teams will alternate IVA and EVA duties so that one mission day will separate two scheduled EVAs for any given EVA crew member, and the maximum number of EVAs that any one crew member performs per week is three.

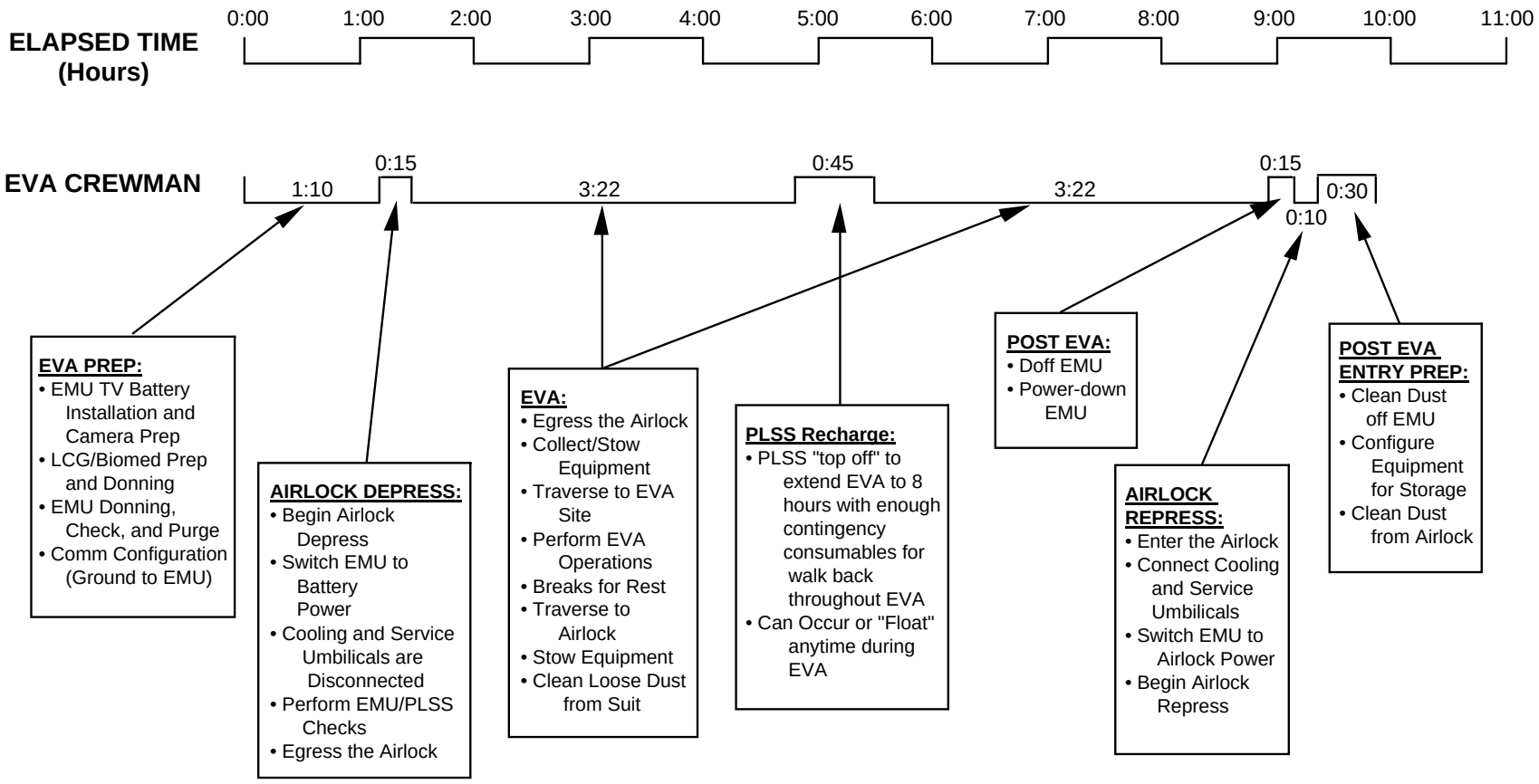
Laboratory IVAs include activities such as basic analysis, sorting, and packaging of samples for return to Earth; gravitational biology experiments and additional physiological experiments; and teleoperation of deployed instruments or scientific rovers. Support IVAs include activities such as outpost maintenance and enhancement, EVA suit maintenance and repair, and training. The primary monitoring of an EVA crew is done from Earth, allowing the IVA crew to devote their time to other tasks.

An EVA is defined as two crew members performing work out on the lunar surface for a maximum of eight hours per EVA. Figure 3 depicts a 10 hour work day for an EVA crew member based on advanced EVA suit technology. Support EVAs include activities

| POST SLEEP (3 hours) | ON DUTY (10 hours) | PRE SLEEP (3 hours) | SLEEP (8 hours) |
|---|---|---|---|

**ASSUMPTIONS:** (1) On duty activities include exploration and support EVAs, laboratory and support IVAs, and one meal
(2) Post/Pre sleep activities include two meals, hygiene, house keeping ,and leisure

**Figure 2 First Lunar Outpost Conceptual Surface Mission Typical One Shift Workday**




**ASSUMPTIONS:** (1) Lunar EVA operations guidelines for the advanced technology suit are similar to existing shuttle suit
(2) 10.2 psi habitat and 5.85 psi suit pressures (no prebreathe required)
(3) Total suit time is 8 hours per EVA
(4) An 8 hour EVA is an acceptable duration for crew efficiency/physiology in 1/6 G (rover assisted)
(5) 8 hour EVAs are technically feasible, but necessitate a 45 minute recharge or rover/PLSS umbilical support
(6) A minimum of two crew members are required for each EVA

**Figure 3 First Lunar Outpost Conceptual Surface Mission Extravehicular Operations Timeline (Advanced Technology Suit)**

such as outpost maintenance and enhancement, rover maintenance and repair, and engineering/operations detailed test objectives. These EVAs are mostly conducted on foot in the immediate vicinity of the outpost and make up about 25 % of the total number of EVAs conducted during the 42 day surface mission. Exploration EVAs include activities such as geologic field work, emplacing astronomical and space physics instruments, and emplacing and operating resource utilization (ISRU) equipment. Exploration EVAs are aided by the use of an unpressurized rover, and the type of exploration performed and the lighting and thermal environment on the lunar surface dictate how much of the EVA is spent driving the rover.

Short distance exploration EVAs are planned when the driving time is less than or equal to 40 % of the total EVA. These types of EVAs occur near the beginning of the 42 day mission as the surface EVA systems are being tested and evaluated, and also during times of restricted operations such as during lunar noon when there are high thermal loads and high sun angles and during lunar night when there is complete darkness. Obviously, as experience and confidence are gained in these extreme conditions, longer EVAs can be expected to occur. Local geologic field work, ISRU experimentation, and emplacement of geophysical monitoring instruments are the activities performed on these types of EVAs.

Long distance exploration EVAs are planned when the driving time exceeds 60 % of the total EVA. These types of EVAs are planned during the lunar morning or lunar afternoon when the temperatures and lighting are optimum for surface exploration and when the outpost power system is able to quickly recharge the rover between consecutive days of long traverses. It is on these long traverses that the astronomical, space physics, and heat flow experiments are emplaced at remote sites, and geophysical traverse experiments are conducted.

A brief week by week description now follows, describing the types of activities planned for the different environments encountered during the 42 day surface mission. As mentioned earlier, the lighting and thermal environments on the lunar surface do not greatly affect the IVA being performed, so only EVA is mentioned in this section.

Week One (Day 1 -Day 7): The first week of the surface mission is characterized by transfer, move in, and start up activities, and is summarized in figure 4. As mentioned previously, the crew arrives at the Moon in their own lander vehicle about one kilometer

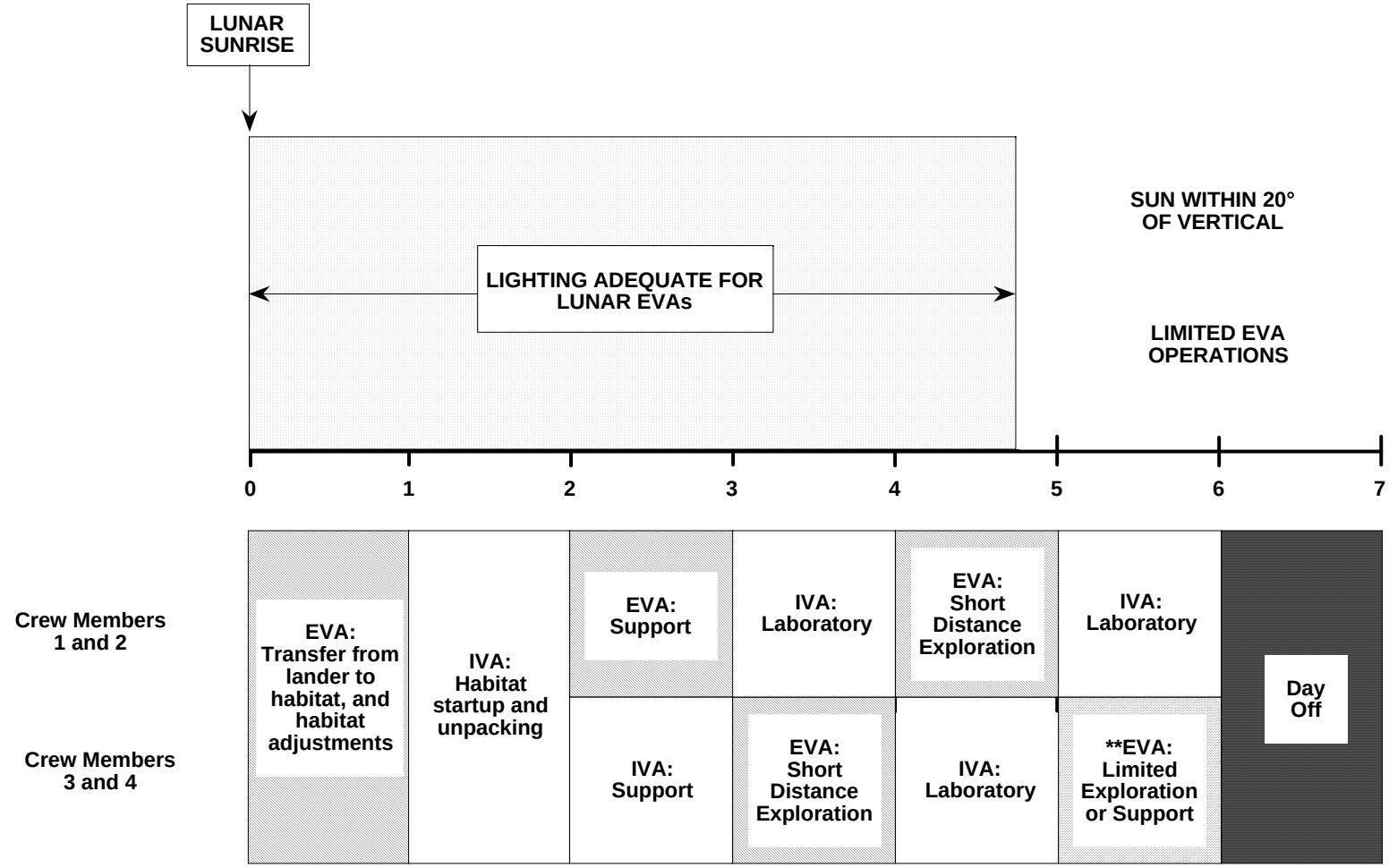



**Figure 4 First Lunar Outpost Conceptual Surface Mission**
**Eastern Limb Site - First Week (Day 1-Day 7)**

from the habitat. If the habitat is operational and ready for occupation, the crew immediately performs EVA and transfers to the habitat with science equipment and logistics. This transfer utilizes an unpressurized rover and will take several traverses between the crew's lander and the habitat. The first day's activities are concluded after all four crew members have established residence in the habitat. If the habitat is not in a liveable state when the crew arrives, the crew can live out of their lander for two days while performing EVAs to rectify the problems with the habitat to make it liveable. If the habitat still cannot be occupied after the two days of EVA repairs, the crew must return to Earth.

Assuming transfer and move in activities are successful, the remainder of the week is spent unpacking, setting up laboratory equipment and conducting preliminary tests, and testing and evaluating the surface EMUs. Support EVAs are conducted to finish up the transfer of any items from the crew lander to the habitat and to inspect the crew lander to make sure it is functioning properly in its dormant state. Short distance exploration EVAs are conducted where initial samples are collected and some of the scientific packages such as the geophysical monitoring package and ISRU test equipment are emplaced locally. The week ends with EVA tests being conducted in the extreme thermal and lighting environment of local noon.

Week Two (Day 8 -Day 15): The second week of the surface mission is characterized as the beginning of routine operations, and is summarized in figure 5. The first few days of the week will be used to further investigate the restrictions that the extreme conditions of lunar noon impose on surface activities. Exploration and support activities will be concentrated in the immediate vicinity of the lunar outpost during this time. As the thermal and lighting environment becomes more conducive to surface exploration, a series of three long distance traverses are conducted. The purpose of these missions is to first geologically survey and sample remote areas (> 10 km from the outpost), and then emplace astronomical and space physics instruments and heat flow experiments in those areas. From that point on, further human activities, except for maintenance, are restricted from those areas,and the instruments are controlled by remote operators.

Week Three (Day 16 -Day 22): The third week of the surface mission is the first full week of manned surface activities conducted during a lunar night, and is summarized in figure 6. Most of the week will be used to investigate the restrictions that the extreme conditions of lunar night impose on surface activities, in much the same way that the

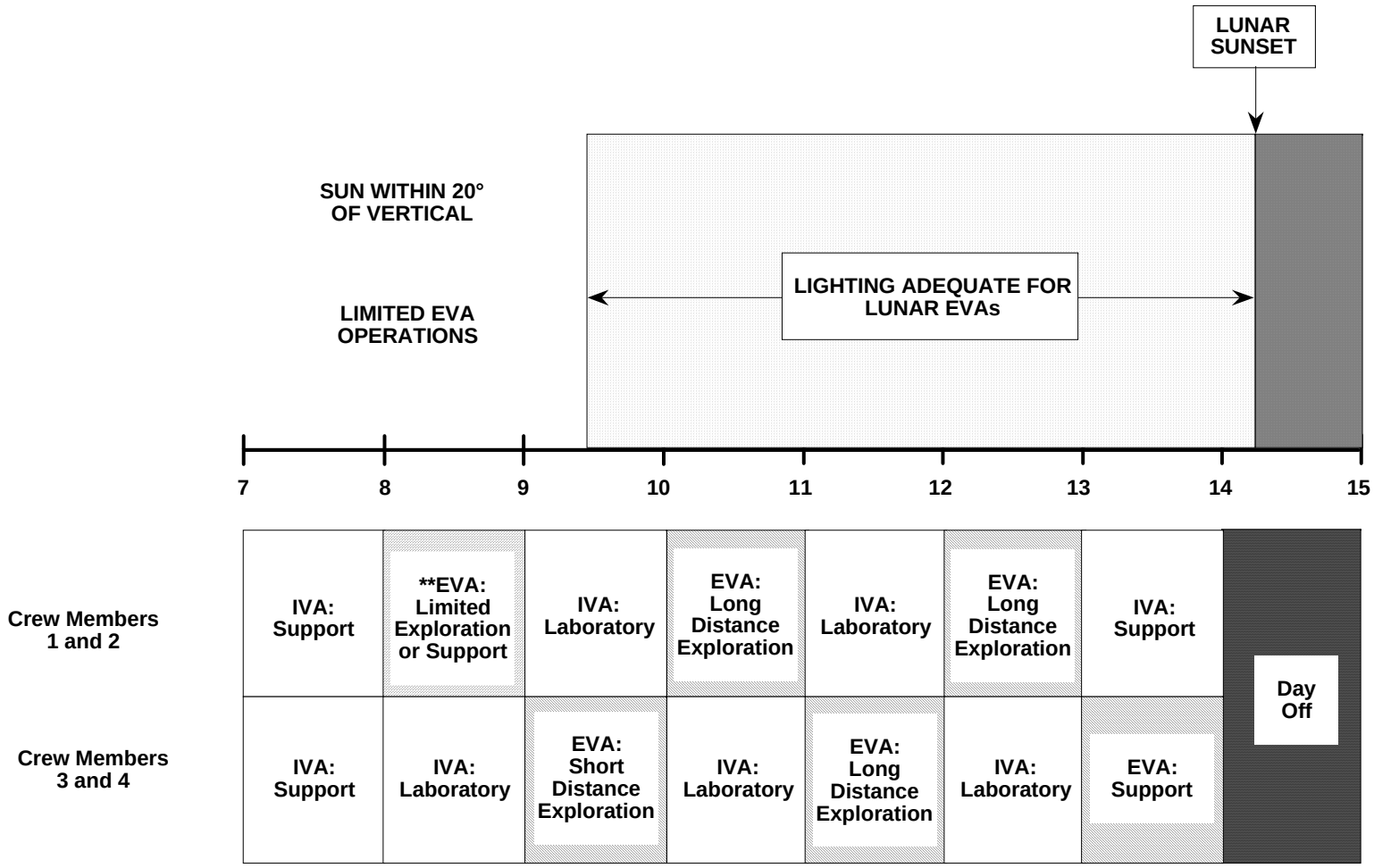
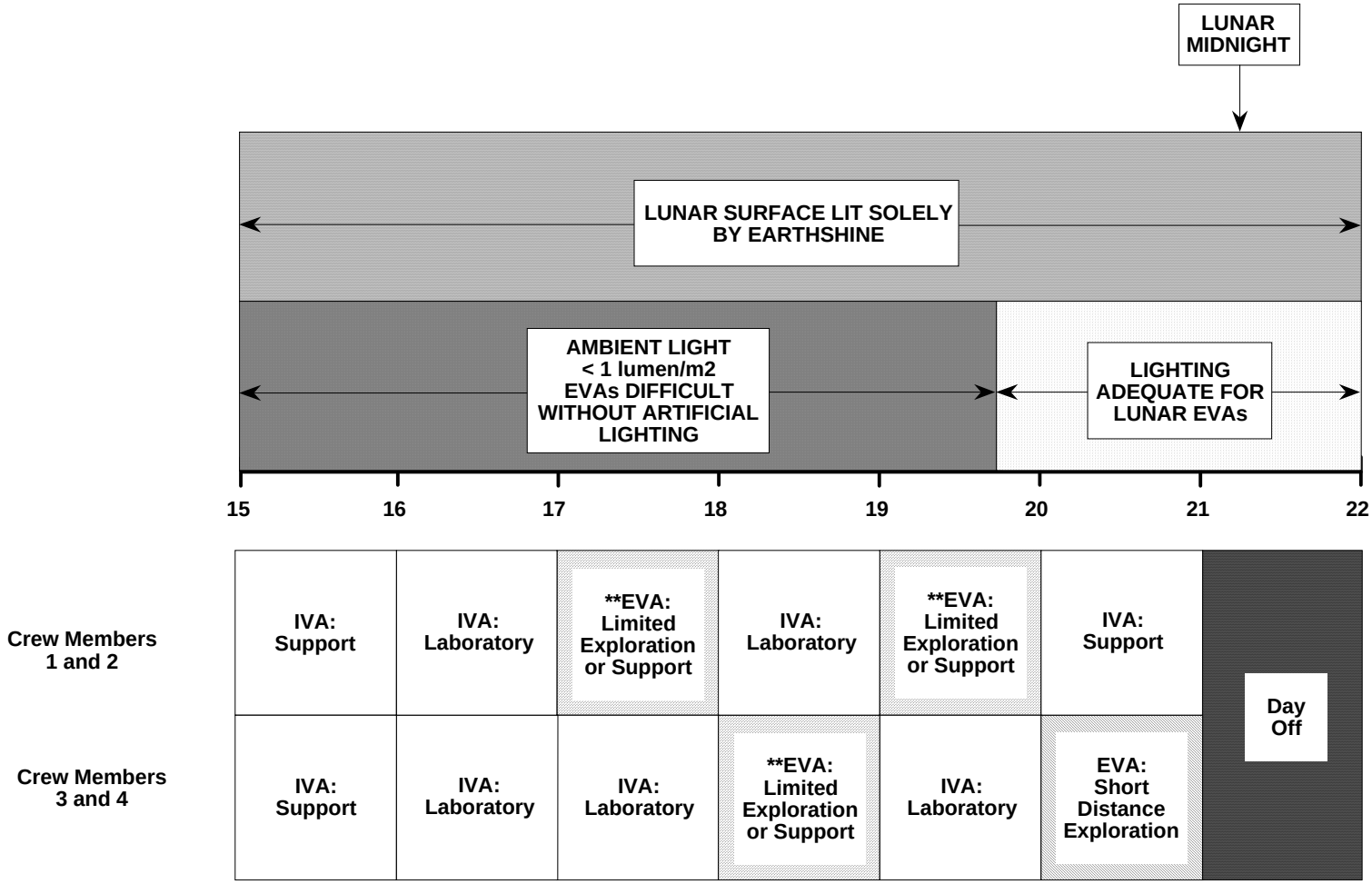



**Figure 5 First Lunar Outpost Conceptual Surface Mission**
**Eastern Limb Site - Second Week (Day 8-Day 15)**




**Note: EVA limited by thermal load, surface lighting, and rover recharge

**Figure 6 First Lunar Outpost Conceptual Surface Mission**
**Eastern Limb Site - Third Week (Day 16-Day 22)**

environment at lunar noon was studied. Again, exploration and support activities will be confined to the local area around the outpost, and as confidence is gained in nighttime operations the range of activities will be increased. Since the Mare Smythii site is located on the eastern limb of the Moon, the area around the outpost will be very dark immediately after sunset, and illumination from earthshine does not become significant until six days into the night. During this period, artificial lighting is required for EVAs.

Another factor that affects nighttime activities is the ability to recharge the unpressurized rover. During the night, the outpost is powered by fuel cells, and not as much power is available as there is during the day. However, there is adequate power to charge the rover at a slower rate than during the day, or activities can be planned so that experiments or instruments requiring large amounts of power are turned off during rover recharging. In any case, the strategy is to conduct short distance traverses, or EVAs not requiring the rover at all during the lunar night so rover recharging is kept at a minimum. These activities include outpost maintenance, geologic field work, and ISRU experiments using samples collected from previously conducted traverses.

Week Four (Day 23 -Day 29): The fourth week of the surface mission is the second full week of manned surface activities conducted during the lunar night, and is summarized in figure 7. Experience gained during the previous week and increased illumination form earthshine allow for nighttime exploration and support activities to be accomplished with greater confidence.

Week Five (Day 30 -Day 36): The fifth week of the surface mission includes sunrise and the beginning of the second lunar day, and is summarized in figure 8. The main objective of this week is to accomplish another series of three long distance traverses to remote sites to conduct geologic field work and geophysical traverse experiments. This is possible now that the photovoltaic array is generating power at levels above that required by the habitat, enabling rapid recharging of the unpressurized rover. The week ends as lunar noon approaches, and exploration and support activities are again restricted to the local area around the outpost.

Week Six (Day 37 -Day 42): The final week of the surface mission, summarized in figure 9, is characterized by transitioning the assets that have been emplaced on the Moon to operate in an unmanned mode and preparing items for return to Earth. Activities are

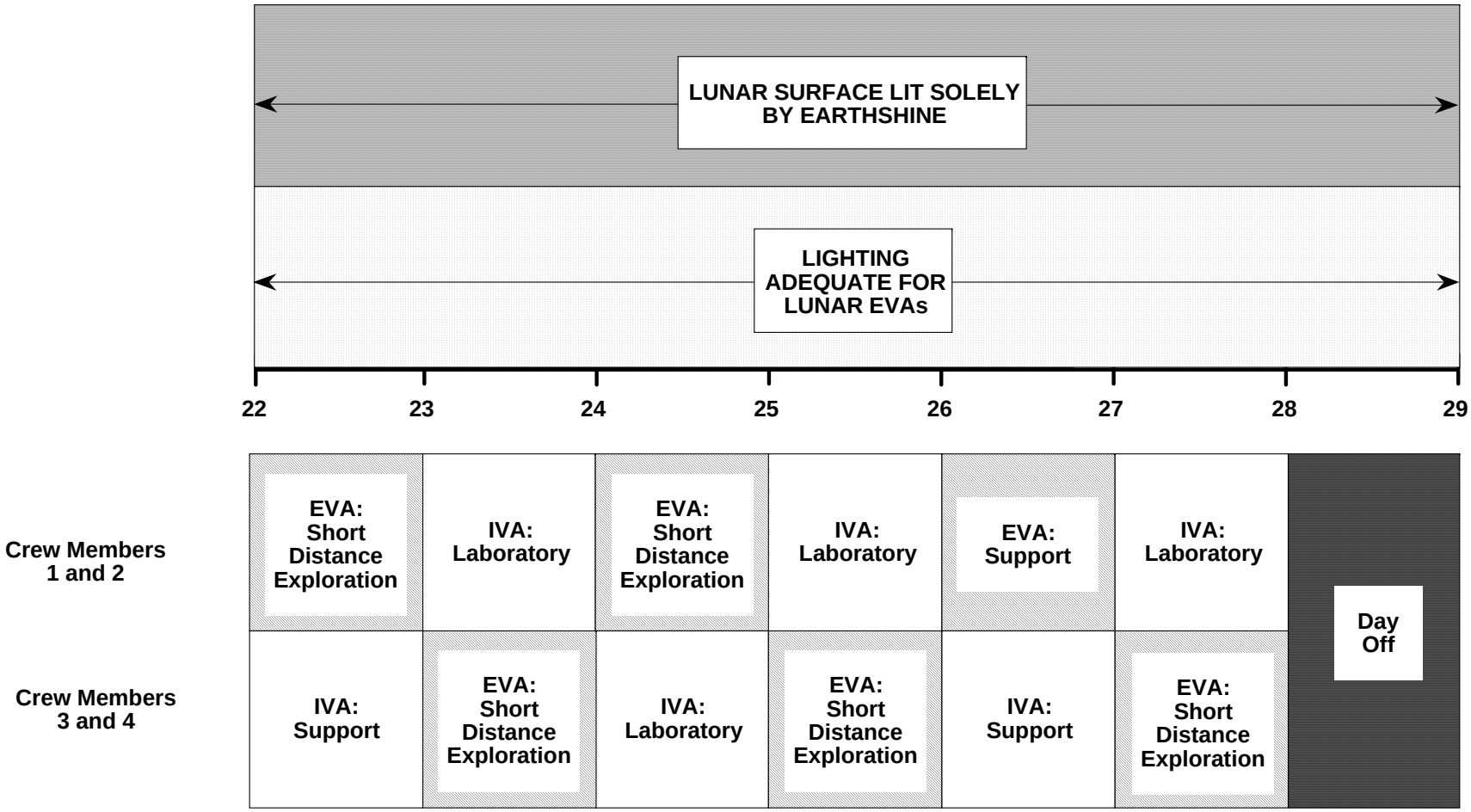
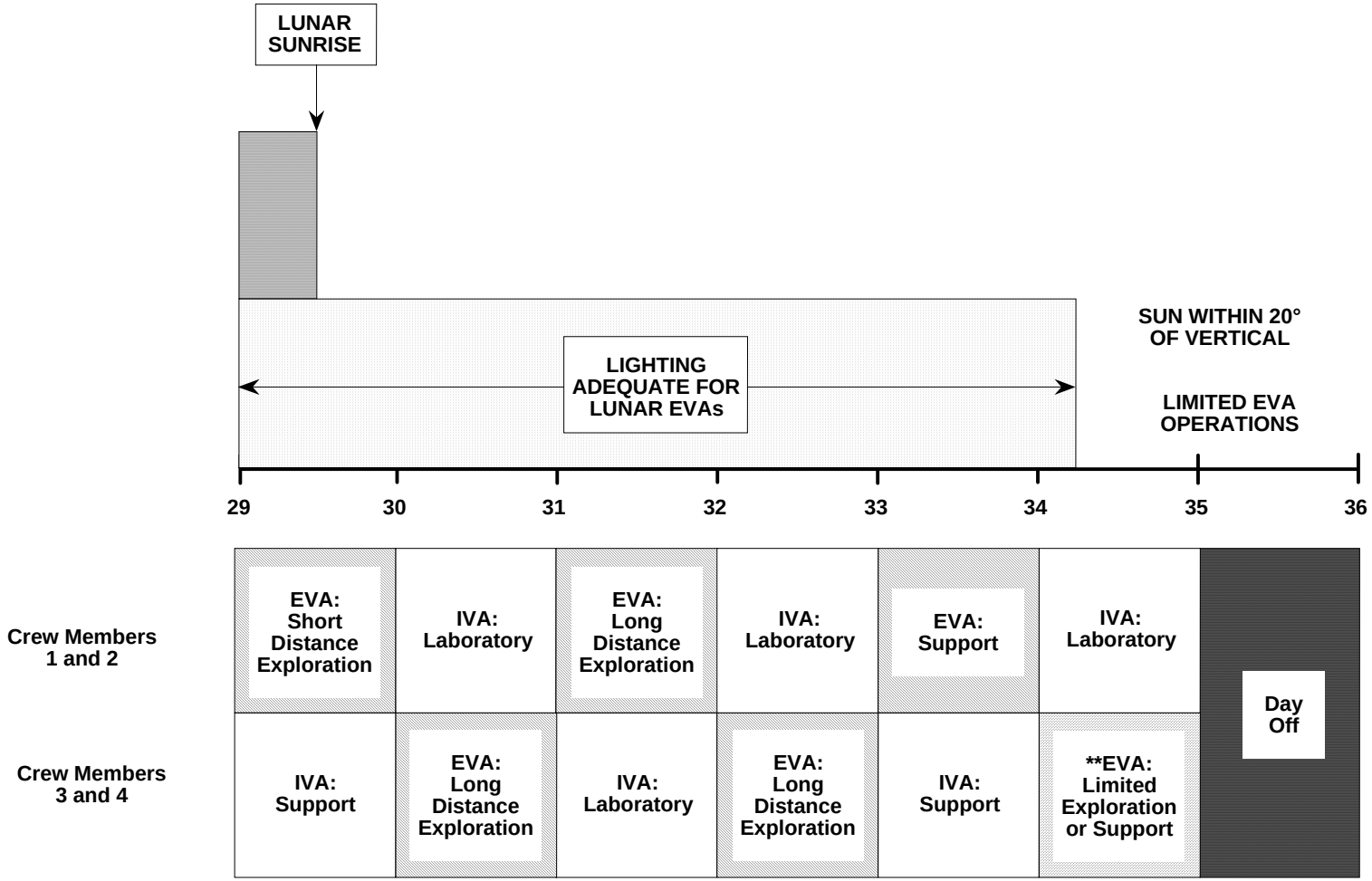



**Figure 7 First Lunar Outpost Conceptual Surface Mission**
**Eastern Limb Site - Fourth Week (Day 23-Day 29)**




**Note: EVA limited by thermal load, surface lighting, and rover recharge

**Figure 8 First Lunar Outpost Conceptual Surface Mission**
**Eastern Limb Site - Fifth Week (Day 30-Day 36)**

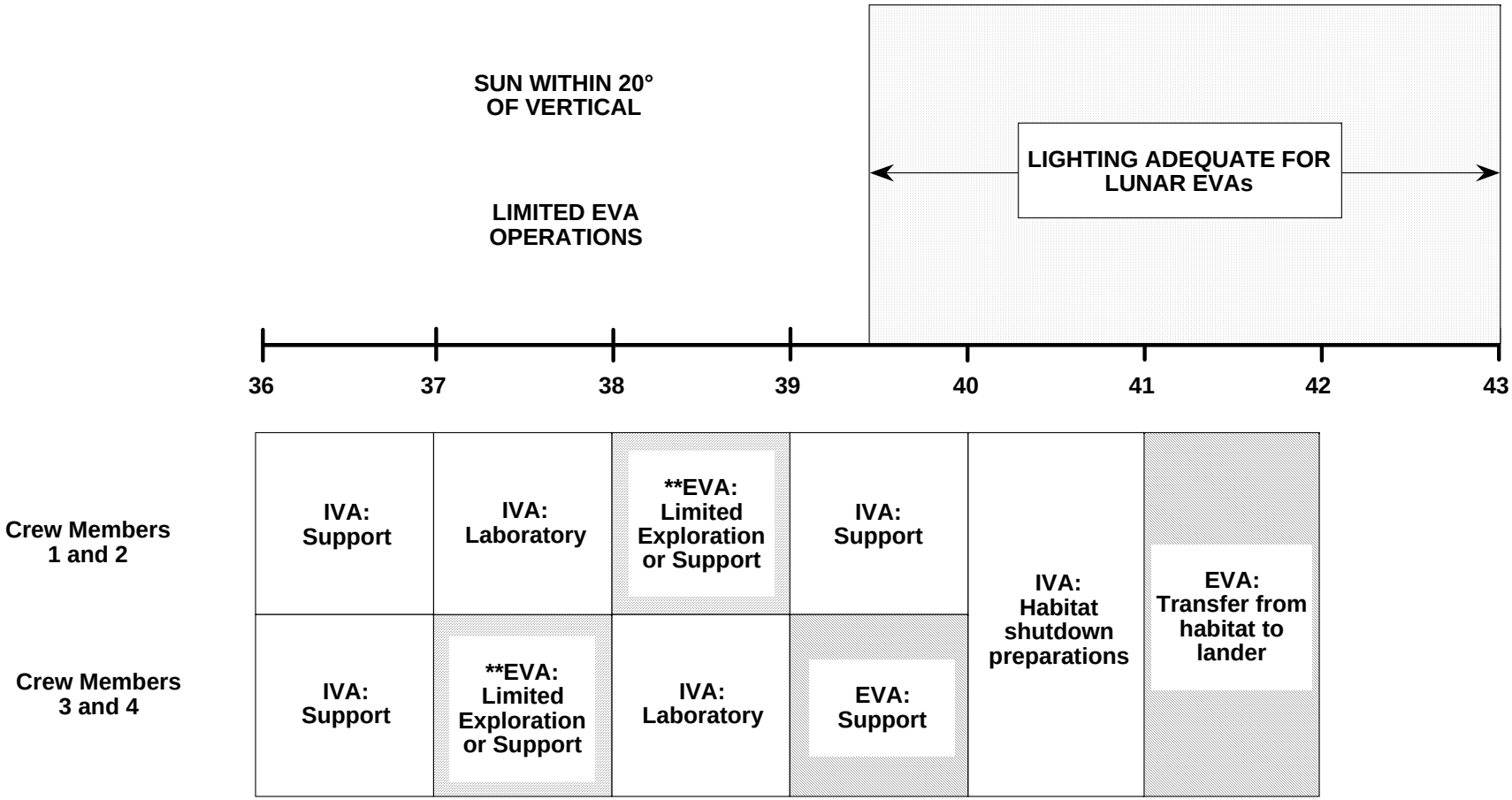



**Figure 9 First Lunar Outpost Conceptual Surface Mission**
**Eastern Limb Site - Sixth Week (Day 37-Day 42)**

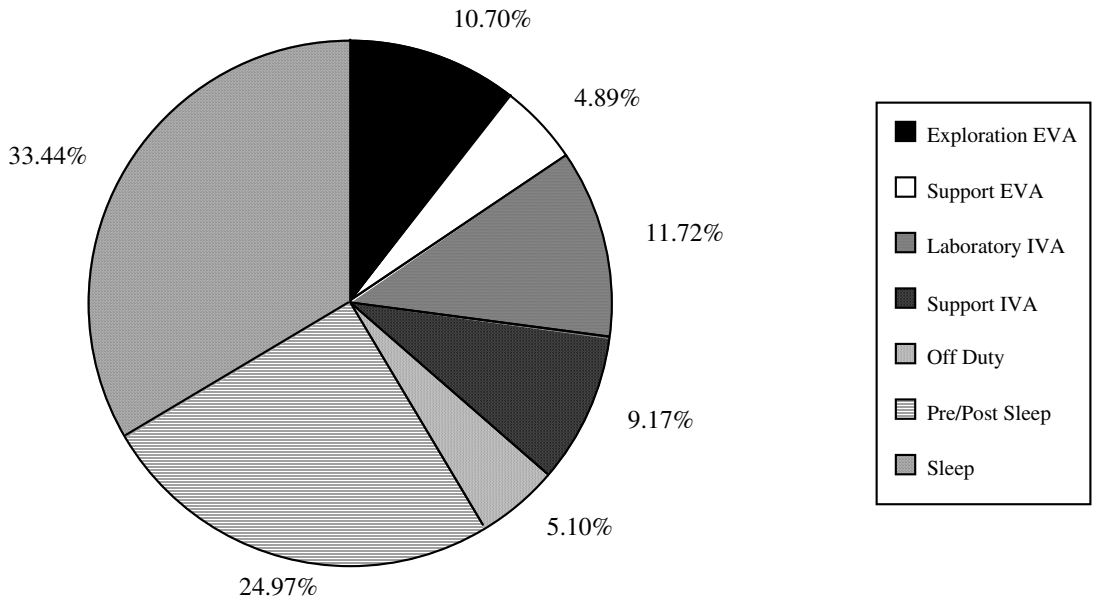
focused on concluding the surface exploration, preparing the outpost for a period of unmanned dormancy, reactivating the crew lander, and departing from the Moon.

## SURFACE MISSION SUMMARY

During the 42 day surface mission, 29 EVAs are planned with roughly 22 EVAs dedicated to exploration and 7 EVAs allotted for support. This translates to each crew member performing 14 or 15 EVAs, not including the transfers between the crew lander and habitat at the beginning and end of the mission, and the airlock at the outpost cycling 33 times (one cycle includes one depressurization and one pressurization of the airlock). Figure 10 shows a breakdown of the activities performed on the Moon during the surface mission. An important point that the figure makes is that less than 25 % of the time that the crew spends on the lunar surface is devoted to exploration and research. This is primarily due to the high overhead associated with keeping humans healthy and productive (approximately 64 % of the surface time) during the mission. Also, support activities such as maintenance consume a fair proportion of the crew's time (approximately 14 %). It should be noted however, that very little work has been done on the maintenance requirements of the First Lunar Outpost during the initial period of analyses, and some estimates suggest that the time associated with support activities will increase.

Figure 11 shows a breakdown of the exploration EVA activities that are planned for the surface mission. There are two different types of science activities that are illustrated in this figure. Emplacement science, such as deploying a telescope, only requires a small amount of crew time during the actual set up of the instruments. Field work, such as geologically surveying an area and collecting samples is crew intensive and requires considerable amounts of crew time.

Figure 12 shows a cumulative record of the crew hours spent on the lunar surface during the 42 day mission and compares those totals to the crew hours accumulated during the Apollo program. By the end of the first week, the total crew hours spent at the outpost surpasses the total crew hours spent on the Moon during the six Apollo missions, and by the end of the second week the Apollo program EVA hours are also surpassed.




**Exploration EVA** includes activities such as geologic field work, emplacing scientific packages, and emplacing and operating resource utilization packages

**Support EVA** includes activities such as outpost maintenance and enhancement, rover maintenance and repair, and engineering/operations testing

**Laboratory IVA** includes activities such as life science experiments in human physiology and gravitational biology, lunar sample analysis, and telerobotic exploration

**Support IVA** includes activities such as outpost maintenance and enhancement, EMU maintenance and repair, and training

**Off Duty** hours include the crew's one day off each week where no scheduled activities are planned

**Pre/Post Sleep** activities include the morning and evening meals, personal hygeine, house keeping, and leisure time

**Sleep** includes eight hours each day for the crew members to rest

Figure 10 First Lunar Outpost Conceptual Surface Mission Surface Activities Summary

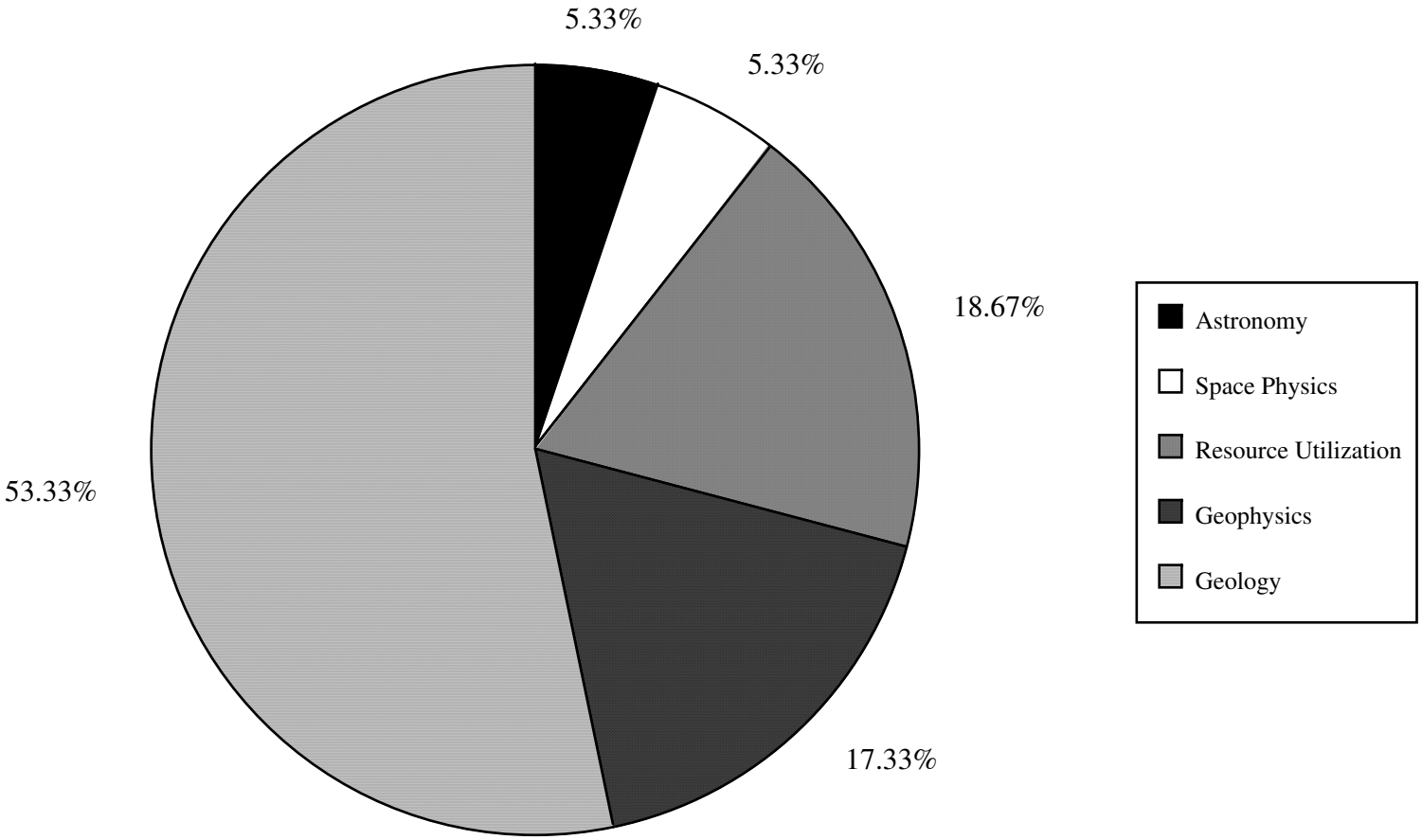



**Figure 11 First Lunar Outpost Conceptual Surface Mission Exploration EVA Summary**

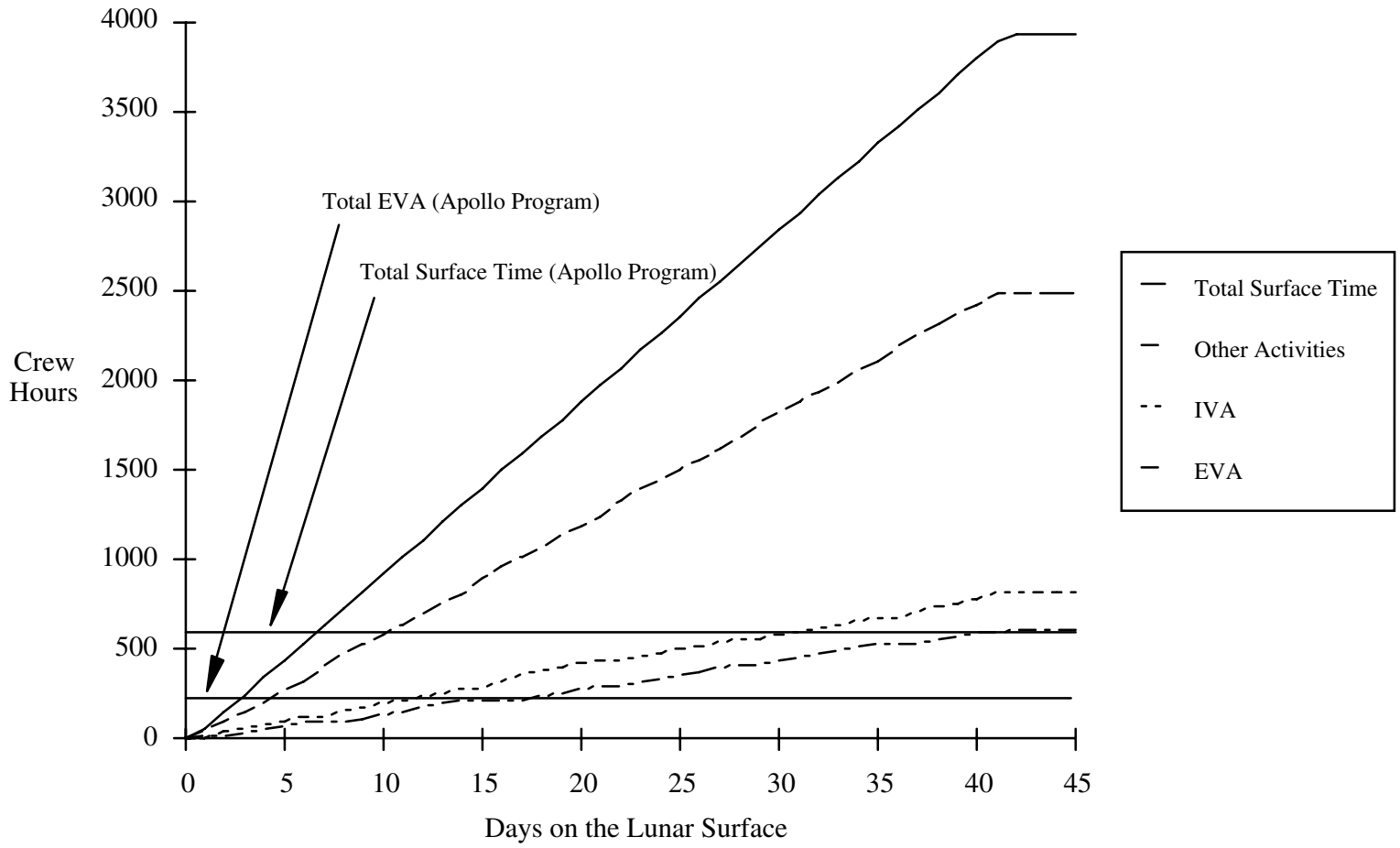



**Figure 12 First Lunar Outpost Conceptual Surface Mission Cumulative Surface Activities**

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