Keck LGSAO and Laser Clearinghouse Blanket Closures

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11 Nov 2011

Executive Summary

The frequency and duration of space event blanket closures issued by the Laser Clearinghouse, LCH, has increased significantly over the past two years. These blanket closures have severely impacted scientific productivity at the W. M. Keck Observatory, WMKO, particularly during the period July – September, 2011. Blanket closures are now the most significant source of lost science time other than weather thus far in the year 2011. It is estimated that the space events triggered by a launch or maneuver of a particular satellite has a 1.7×10^{-6} probability of being illuminated by the Keck laser over a period of an average blanket closure. Furthermore, even if a satellite were illuminated by a Keck laser the probability of being damaged of 1×10^{-4} . The product of these two probabilities is 1.7×10^{-10}. Keck understands the need to protect satellites and intent of the DoD policy that states "laser activities shall be conducted in a safe and responsible manner that protects space systems" (ref 3). However, Keck asserts that the chance of damage to a space event satellite is at a negligible level of risk and thus blanket closures are not necessary. Further more, Keck suggests that allowing laser propagation during a space event could be considered consistent with the DoD policy of "Safe and Responsible" laser operations. The significant loss of science time is unacceptable to WMKO and the recent events compel WMKO to pursue whatever remedies may be available to us, such that these types of closures can be eliminated or minimized.

1. Background

The W. M. Keck Observatory operates laser guide star adaptive optics (LGSAO) systems for the purpose of improving the quality of data acquired through the earth's turbulent atmosphere. The observatory has a history of safe laser operation and has not only complied with existing regulations and guidelines, but has pioneered new techniques and procedures to ensure that the active propagation of laser light has no detrimental effects, whatsoever. This includes the process of avoiding laser illumination of satellites through cooperation with US StratCom's Predictive Avoidance process [1]. There is no legal requirement for Keck to participate in the PA process and it does so voluntarily. Over the course of 7 years of Keck has been able to accomplish it's scientific mission with only minor downtime due to PA and with an occasional blanket closure; a blanket closure is a directive to the observatory to cease all laser propagation either for a

prescribed period of time or until further notice. However, in the period of 8 weeks from late July to mid Sept of 2011, the US StratCom Space Situational Awareness Operators (SSA Ops) issued blanket closures for 7 of the 20 nights scheduled resulting in a 35% loss of operation. By comparison, lost time previous to this period had only a 0.012% average lost time to blanket closures.

W.M. Keck is the world's leading ground based astronomical research facility. In particular, Keck excels in high angular resolution research enabled by LGSAO. Keck's primary competition for LGSAO scientific productivity are the Gemini Observatory and the European Southern Observatory (ESO). Gemini complies with PA procedures but ESO does not participate in the PA process.

The NSF commissioned a study on the impact of PA restrictions to science in 2010. The study was conducted by Dr. Steven Kramer and led to a report published in Nov. 2010 (ref 2). The "Kramer Report "concluded at the time that PA impact was minimal to the Keck science mission but noted that blanket closures were a concern. Keck does not disagree with the conclusion of the Kramer report based on the situation at that time. However, blanket closures have become much worse since the Kramer report and can no longer be considered insignificant by Keck.

Blanket closures are termed "Space Events" by US StratCom and are caused by either new launches or maneuvers. Following an inquiry to US StratCom when Keck began to notice an increase in blanket closures, MAJ Tom Bloomfield, US Army, Chief of the Directed Energy Branch, responded in a email on August 19, 2011:

> Sometimes we don't know with certainty where an object is located if it is newly launched or it maneuvers. In short, when we can't get an accurate location for a particular space object, we have no way of knowing if it's in danger of being illuminated by a particular laser.
> Sometimes we're able to mitigate the impact of space events on laser programs with workarounds. For example, if we don't have a satellite's exact location, but know that it's on the other side of the Earth from the laser during operations, obviously the satellite is in no danger of being illuminated and operations can proceed. That's a simple example, and we've used more complex techniques in the past. One issue with workarounds is that they take time, and LCH and the SSA Ops cell support many laser programs. Additionally, space events cause problems not just for astronomy lasers, but other operations as well, including combat ops. Operators have to prioritize, and that may mean putting astronomy sites last.

Keck inquired if a reduction in blanket closures might be possible but Maj. Bloomfield indicated in his 19 August 2011 correspondence that any changes in policy or technical processing would be unlikely.

The Kramer report concluded that he could find no examples of a particular science project or PhD thesis that was not accomplished due to closures in the PA process. However, the recent increase in blanket closures has generated at least one such example, a PhD thesis project of Tiantian Yuan of Institute for Astronomy at the University of Hawaii, who lost several nights worth of LGSAO time in 2011. Ms. Yuan writes:

> From Jan to Sep 2011, I have lost 4 clear-weather KECK nights due to space command closures. The 4 KECK nights composed of ***90%*** of the total telescope time that I obtained for two semesters. They were proposed to test two of the very exciting results that I have found in my thesis so far. I have painstakingly selected the best targets and designed the observational projects such that no matter what we would have observed in these targets, it would make a big impact in the field of disk galaxy formation and evolutions. If it were not for the space command closure, I would have obtained crucial data to 1) constrain the disk formation scenario of galaxies, and 2) be the first ever observation on the metallicity gradient of a high-redshift merger system.*The loss of these nights have made it impossible to proceed with the second half of my thesis. This has put me in a very negative position of the post-doc job application this year.*

2. **Keck lost time statistic**s.

Figure 1. shows the rate of LGSAO operational lost time to blanket closures over the 7 years that Keck has been using lasers for science. Blanket closures were rare in the period from 2006-2009, lost time rates being only about 10min per night on average. There was a slight increase starting in 2010 to about 20min per night on average. 2011 has experienced a sharp increase in blanket closures averaging nearly an hour a night over the past 117 nights. In particular, an 8 week period from late July to mid September, the losses averaged 3.6 hours of lost time per night for the 20 nights scheduled in this period.

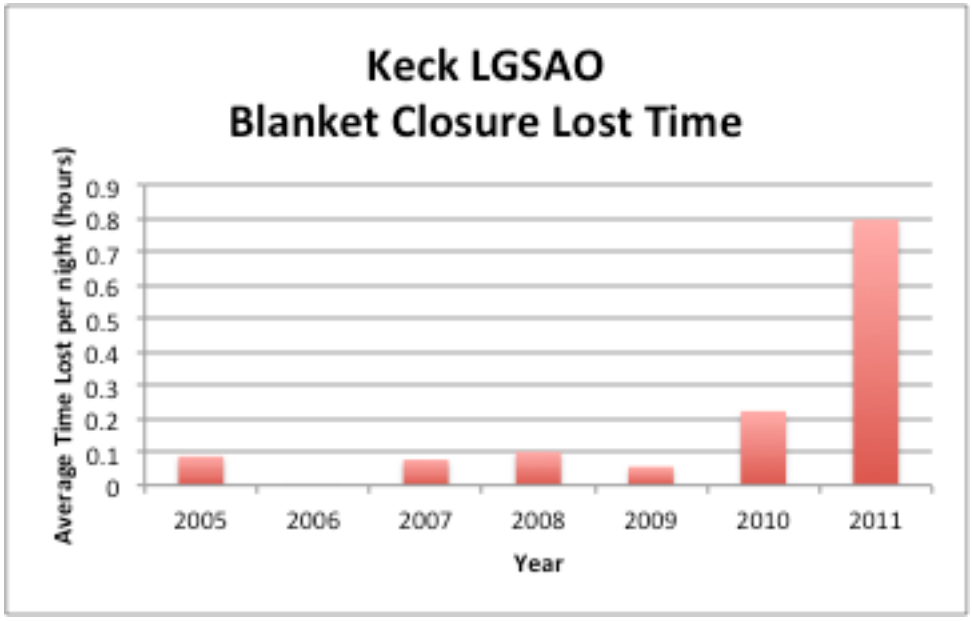

Figure 1. Total time lost to Laser Clearinghouse blanket closures per year of operation.

Keck operates in classically scheduled mode where observing time is scheduled months ahead of time and a principle investigator is in charge of the night's observing program. . Keck's LGSAO system provides unique capabilities to the scientific community in terms of resolution, sky coverage, sensitivity, and spectral coverage. Investigators attempt programs that can only be done at Keck with LGSAO. When laser propagation is inhibited, which can occur for a number reasons in addition to satellite closures, the observer conducts a backup program, one that does not utilize the laser. The backup programs are typically not in this unique class of projects and tend to be an under-utilization of the world's premier astronomical telescope. LGSAO observations are more expensive than other modes of operation at the observatory and those expenses are realized during closures. Thus there is a significant cost, both in terms of science production and to observatory operations to closures.

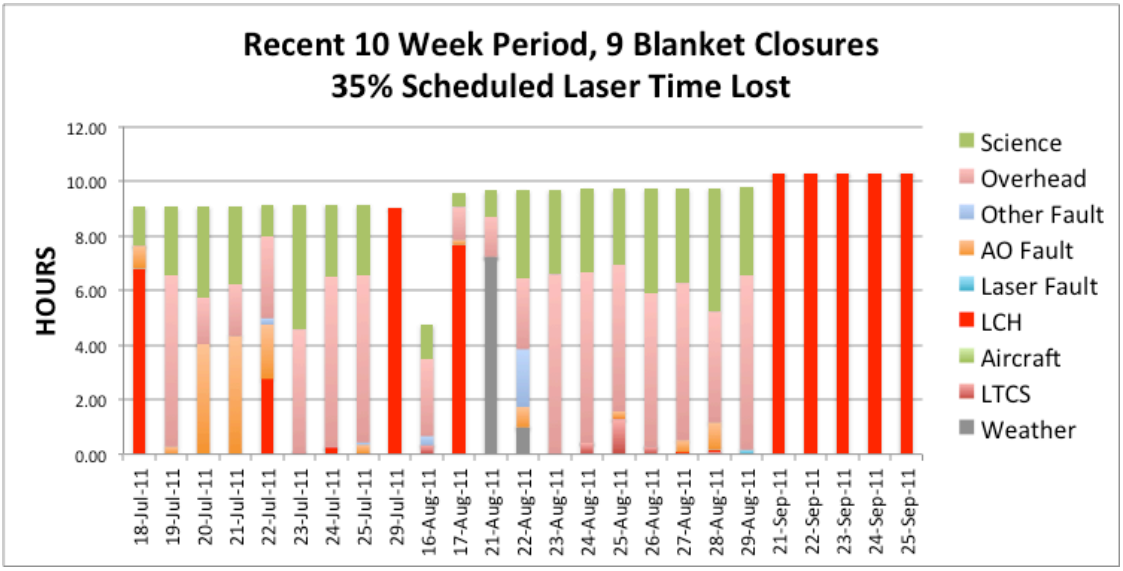

Figure 2 LGS time accounting from mid-July 2011 to late September 2011. LCH blanket closures are shown in red. 9 of 25 nights were impacted, including 5 consecutive nights of complete closure. For 16 Aug 2011, the laser was only scheduled for half of the night.

3. **Probability of damaging a satellite during a space event**.
   The Kramer report [2] includes a detailed analysis of the probabilities associated with illuminating and damaging a satellite. Based on a geometric argument, Dr. Kramer estimates the odds of illuminating a single satellite over a period of 1 sec is 1×10^{-10}. Extending this over the period an average blanket closure (4.6 hours) is about 1.7×10^{-6}. Dr. Kramer also estimates the upper limit on the odds of damaging an operational satellite at 1×10^{-4}. Of course a space event is likely not operational and wouldn't be in a mode where the laser light is amplified onto a detector through a high gain 1 m telescope, as Dr. Kramer uses in his upper limit estimate. Nevertheless, we assume the worst case probability of 1×10^{-4} of damage occurring to a satellite when illuminated by a Keck laser. Thus, we conclude the lower limit probability of damaging a satellite that is undergoing a space event is 1.7×10^{-10}. For comparison, the nuclear regulatory commission safety goal is 5×10^{-7} average probability of an individual early fatality per reactor per year [4]. The odds of winning the California Super-lotto [5] with a single ticket are 4.1×10^{-7}.

4. **Safe and Responsible Operation of Lasers**
   The deconfliction process that protects satellites does not consider the value of lost LGSAO science or the cost of operating an astronomy laser facility. This has resulted in an extremely conservative satellite protection policy that has led to a negative impact on LGSAO science productivity at the W. M. Keck Observatory. Keck understands the need to protect satellites and agrees with the intent of the DoD policy[3] that states "laser activities shall be conducted in a safe and responsible manner that protects space systems" . However, Keck suggests that

the policy could be interpreted such that the extremely low odds are an acceptable level of risk to the satellite and thus blanket closures are not necessary. Keck asserts that a more reasonable value comparison combined with the miniscule risk of damage during a space event should be considered. An estimate based on the analysis in the Kramer Report concludes that there is only 1.7×10^{-10} risk of damage to a single satellite over the period of an average space event blanket closure. WMKO contends that the risk of damage is negligible. If blanket closures can be eliminated then Keck can continue to accomplish its scientific mission with the use of laser guide stars while continuing to comply with the predictive avoidance method of protecting satellites. The blanket closure issue has become very significant in the latter part of 2011 and is the most significant source of lost LGSAO science time other than weather. Thus, the W. M. Keck Observatory is compelled to pursue whatever remedies to the blanket closure issue may be available to us.

5. References

1. US Strategic Command Standard Centralized Predictive Avoidance Plan, Appendix A, KAON-781

2. Kramer, Steven D. 2010 "*The Impact of Predictive Avoidance Restrictions on Astronomical Observatories*", Institute for Defense Analysis D-4202(KAON-851)

3. "Illumination of Objects in Space by Lasers", DoD directive 3100.11 "

4. Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants (NUREG-1150)

5. http://www.calottery.com/default.htm