

Assessing Tracking Performance of High Satellites at Mt Stromlo SLR Station

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Abstract

An analysis of changes to tracking productivity of high satellites following the 2007 laser power upgrade at Mt Stromlo SLR Station is presented. This analysis uses data obtained from tracking Giove A and other satellites during June-August 2008 and contrasts the results with similar data obtained during May-August 2006. The results show that the increase in power level has subsequently allowed the station to operate unmanned in all weather conditions and still maintain productivity levels.

Introduction

In mid 2006, Mt Stromlo SLR station undertook an analysis of tracking productivity primarily based on the recently launched Giove A satellite (Moore, 2006). Since that time, the station has been subject of some significant changes in equipment and procedures. These include;

- June/July 2007 – Laser power upgraded from approximately 400 to 1200 mW. Pulse energy increased from 13 to 20 mJ and the fire rate from 30 to 60Hz.
- December 2007 – facility cooling systems upgrade.
- April 2008 – 1m telescope coude mirrors replaced.
- From July 2007 – automated (all weather) tracking.

This paper describes a re-assessment of the productivity performance of Mt Stromlo SLR station in light of these changes based on a comparison of recent Giove A tracking performance with the earlier study, and analysis of other productivity statistics using a number of high earth orbit (HEO) satellites, such as the Etalon and Glonass satellites, and the geostationary ETS8 satellite. An analysis of productivity for all routinely tracked satellites is also presented.

Performance Factors

Of primary interest is the change in productivity performance of the station resulting from the

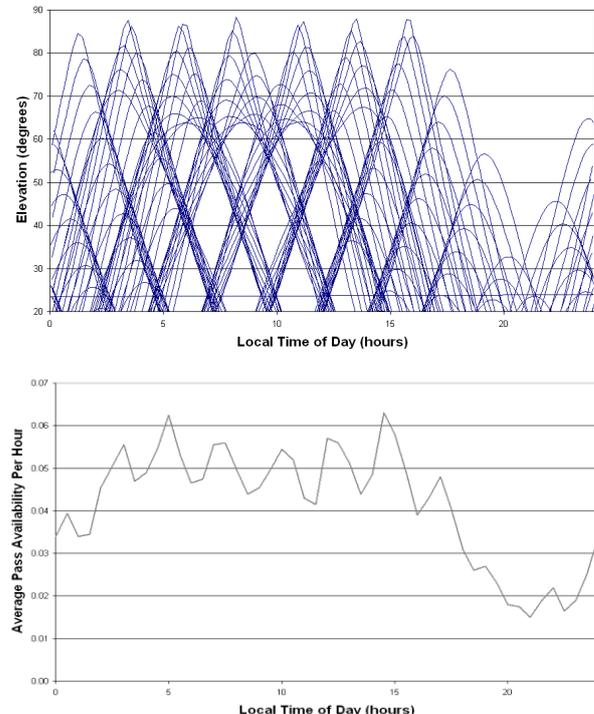


Figure 1. Giove A pass availability, May-August 2008.

increase in laser power, but such assessment is compounded by other factors including;

1. Changed operational mode – before the upgrade tracking was operator (manual) control, generally with no dome window in place. After the upgrade, tracking has been automatic through the glass dome window.
2. Effects of weather – A very significant period of overcast weather experienced in the months soon after the upgrade.
3. Coude mirror replacement – Most mirrors in

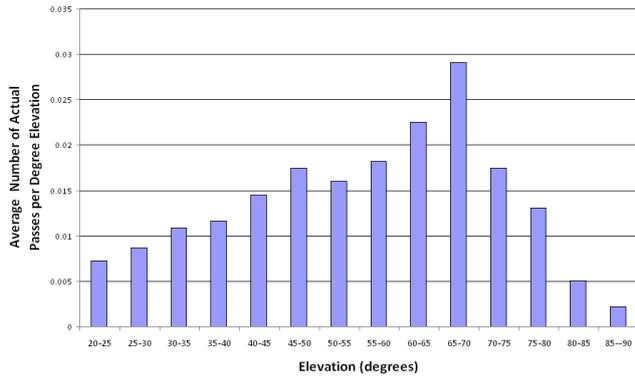


Figure 3a. Available Giove A passes versus elevation.

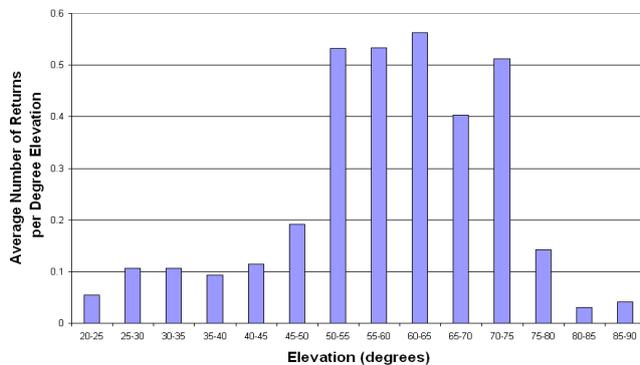


Figure 3b. Giove A productivity versus elevation.

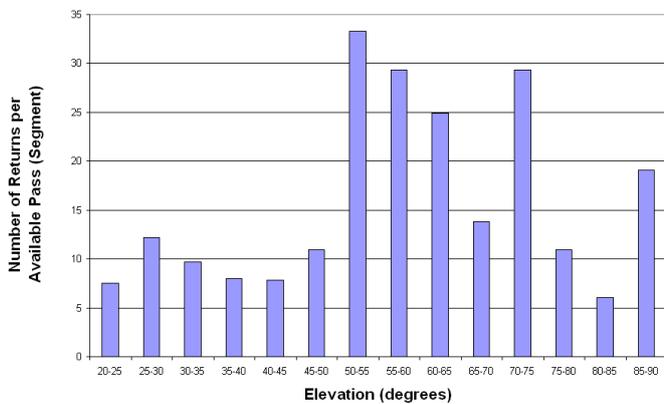


Figure 3c. Giove A normalized productivity versus elevation.

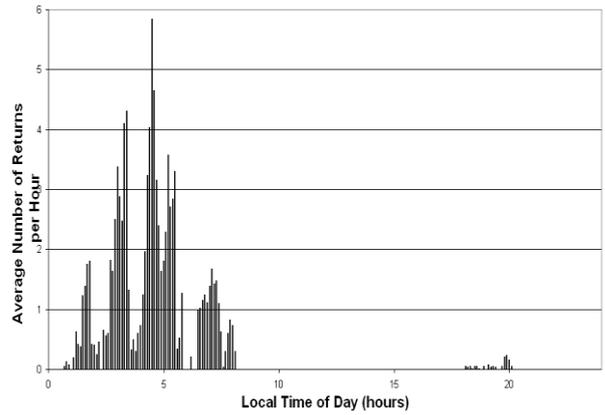


Figure 2. Giove A passes tracked, May-August 2008.

the coude path were replaced after the upgrade due to significant degradation of the coatings.

4. Changed tracking priorities – fewer Giove A tracking periods to accommodate more Giove B, Etalon, Glonass, and ETS8 passes.

Giove A Analysis

Giove A tracking data obtained during May – August 2008 were analysed in the same manner as the May-August 2006 data (Moore, 2006). As illustrated in Figures 1 and 2 the distribution of Giove A passes were quite different between the two periods, with successful tracking confined to the early hours in the day in the latter period. Few passes are tracked during daylight periods and there was a lack of evening passes. A distribution of actual passes tracked in the latter period is shown in Figure 2.

To allow comparisons to be drawn with the results of Giove A tracking in 2006, factors such as pass availability and elevation were normalized as shown in Figures 3a, 3b and 3c.

The results indicate that low elevation productivity was a little higher in 2008, mid-elevation values were similar for the two periods and high elevation productivity in 2008 were perhaps a little less than 2006. Given the relatively few

data and variability in atmospheric conditions, these results imply that there was a very similar level of performance between the two periods, noting that Giove A was generally tracked through the dome window in 2008, but not in 2006.

Table 1. Productivity Statistics for the Glonass and Etalon satellites.

Statistic	Satellite	May-Aug 2006	May-Aug 2008
<i>Normal Points per Pass</i>	<i>Glonass</i>	10-12	12-13
	<i>Etalon</i>	9-12	10-15
<i>Returns per Normal Point</i>	<i>Glonass</i>	20-40	50-80
	<i>Etalon</i>	20-30	20-60
<i>Returns per Pass</i>	<i>Glonass</i>	300-600	500-1000
	<i>Etalon</i>	100-300	300-600

HEO Productivity

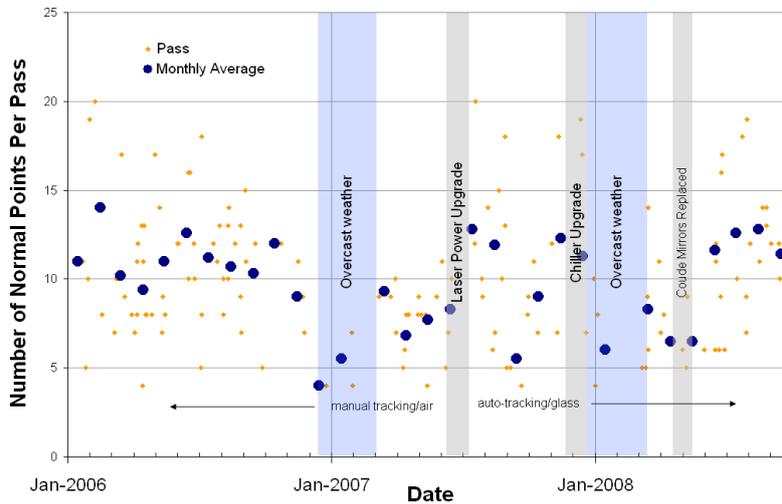


Figure 4a. Number of normal points per pass from January 2006 to September 2008 for the Glonass satellites.

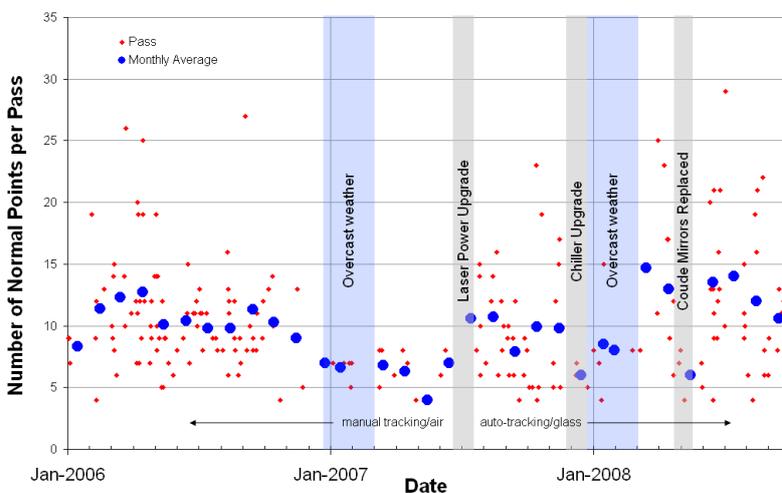


Figure 4b. Number of normal points per pass from January 2006 to September 2008 for the Etalon satellites.

Table 1 shows a summary of the productivity statistics for the Glonass and Etalon satellite passes during the May-August periods in 2006 before changes were made and 2008 after such changes, and corresponding to the Giove A analysis periods. For these satellites and periods, the productivity in the latter period was at least as good as the earlier period and by some measures, significantly better. Improvements of up to 100% in maximum returns per normal point and returns per pass are evident.

To determine the impact of the various factors described in the introduction that might affect the station performance, data from all Glonass and Etalon satellite passes throughout the whole

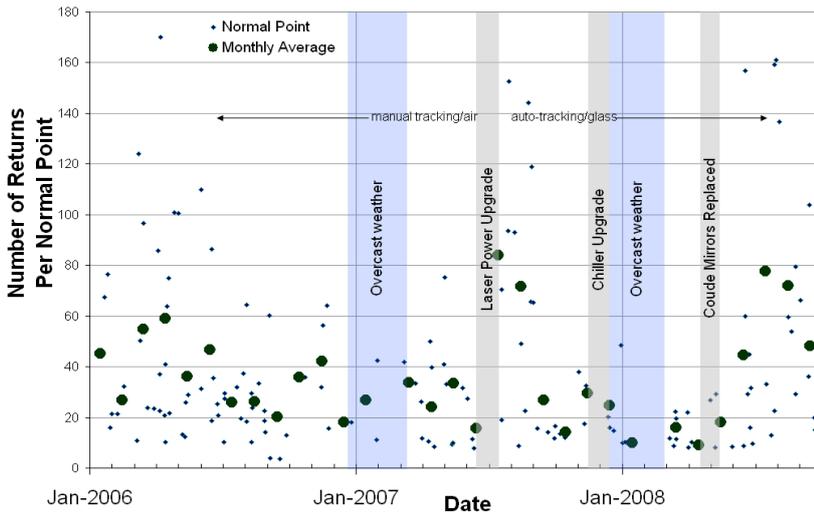


Figure 5a. Number of returns per normal point for the Glonass satellites.

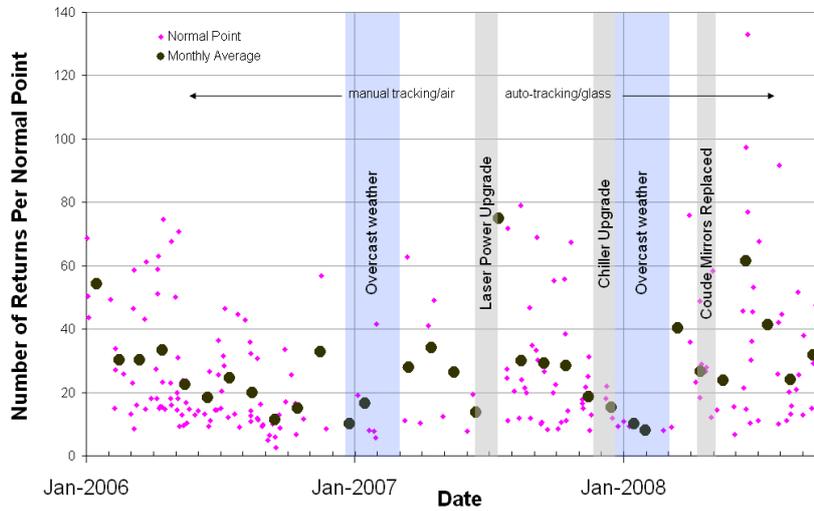


Figure 5b. Number of returns per normal point for the Etalon satellites.

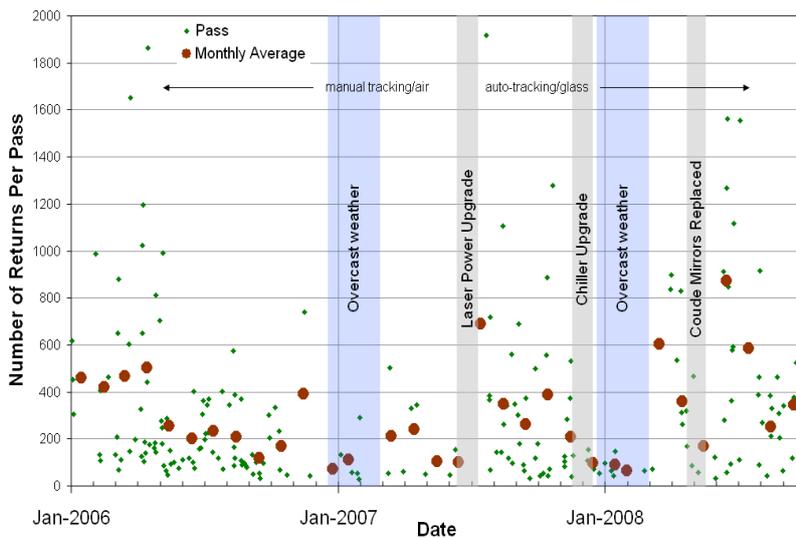


Figure 6a. Number of returns per pass for the Glonass satellites.

period January 2006 to September 2008 were analysed. Figures 4, 5 and 6 show the results of these analyses together with identification of the various events and milestones where conditions changed significantly.

These figures show both monthly averages (large symbol) and daily passes or normal points (small symbol).

The number of normal points per pass, shown in Figure 4, the number of returns per normal point, shown in Figure 5, and the number of returns per pass, shown in Figure 6 for Glonass and Etalon satellites increased in all cases immediately in the 1-2 months immediately after the power upgrade.

However this trend was interrupted by station maintenance activities and a period of particularly overcast skies. From May 2008 the increase in productivity (in comparison to 2006) is quite evident, but by this time the coude mirrors had also been replaced. It is not clear to what impact the deterioration of the coatings on these mirrors had on the longer term productivity, but they may have contributed to the apparent long term downward trend evident during 2006 and 2007.

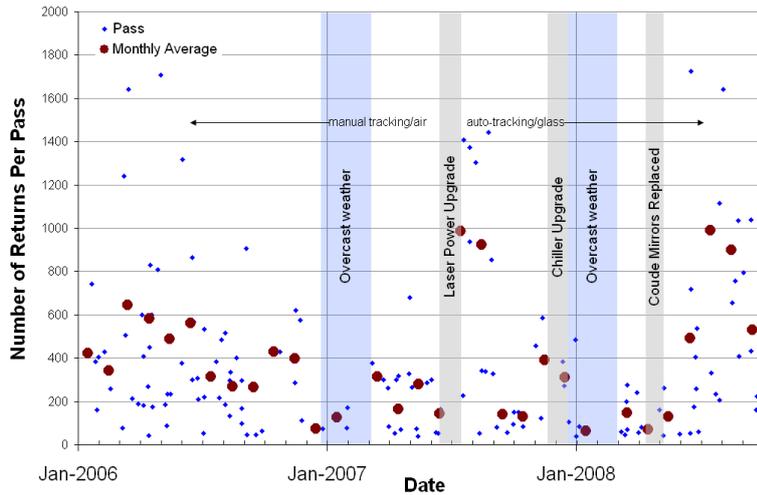


Figure 6b. Number of returns per pass for the Etalon satellites.

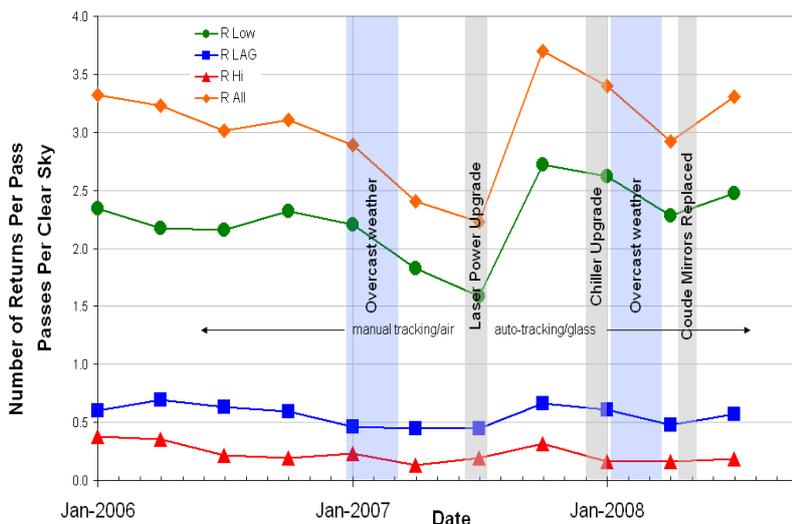
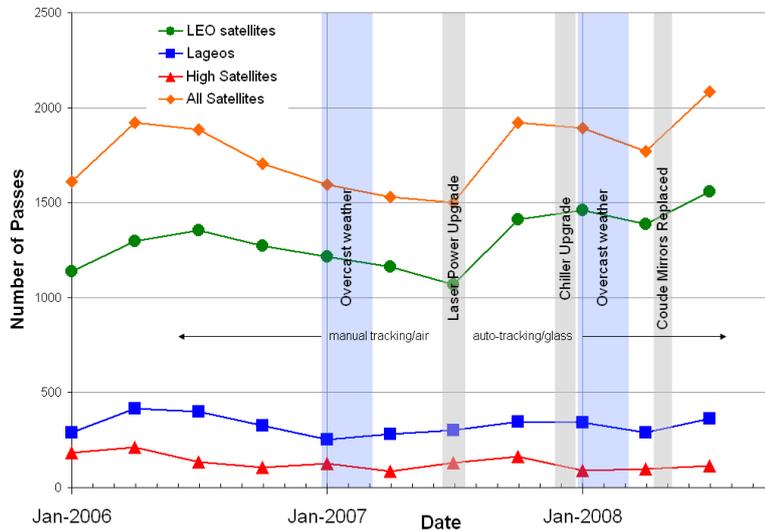


Figure 7. Mt Stromlo productivity for low earth orbit, high earth orbit, Lageos and all satellites. *Top*; quarterly averages of the number of passes per day and *bottom*; quarterly averages of the number of passes per clear sky

General Productivity

Figure 7 summarizes some continuous combined productivity statistics for the period January 2006 to September 2008. It is clear from this figure that there was an improvement in the average number of LEO satellite passes per day resulting from the laser power upgrade, and correspondingly an improvement in overall results. Immediately following the upgrade, a slight improvement in Lageos productivity in clear sky conditions is also apparent. More significantly, it is clear that the overall productivity of both Lageos and high earth satellites after the power upgrade was at least maintained despite the change to auto-tracking which requires that ranging is performed with the enclosure window in place.

Geostationary Satellite Productivity

In early 2007, the Japanese Aerospace Exploration Agency (JAXA) requested a number of Western Pacific Laser Tracking Network (WPLTN) stations, including Mt Stromlo, to undertake routine tracking of their recently launched geostationary satellite, ETS-8. At a range of approximately 37,000 km from the station, only manual tracking with the enclosure window removed

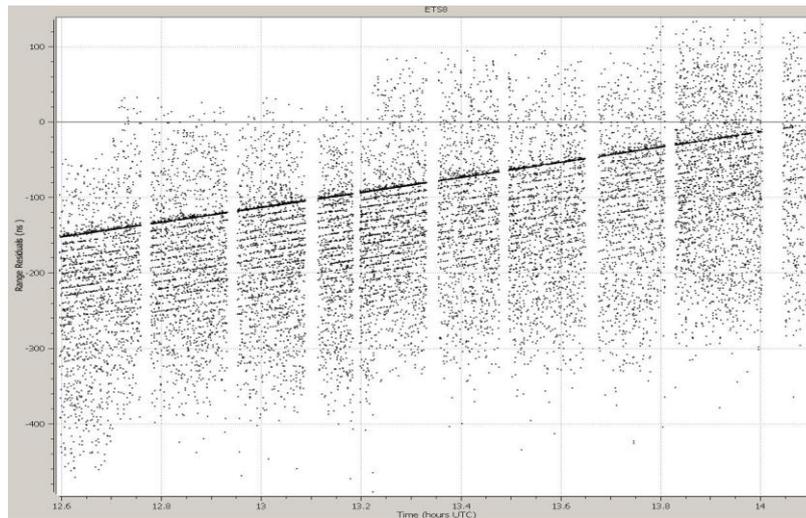


Figure 8. Residual plot of returns from tracking ETS-8 at 37000 km over a number of hours on the 11th September 2008. Even returns from pre-pulses ('tramtracks') can be observed.

was feasible. Even though the satellite was successfully tracked prior to the laser power upgrade (in very good seeing conditions), the signal was very marginal. After the upgrade, there was at least a three-fold increase in the signal return rate, which subsequently allowed routine clear sky tracking to be carried out. Figure 8 shows the residuals from such a tracking period in September 2008, where return rates exceeded 0.6% (primary signal only) or 3% including all pre-pulses and the signal-to-noise exceeded 10%. It was observed that during ranging with the enclosure window in the optical path, a signal was observable but again was quite marginal. In this configuration, a successful search for such a signal would have been very difficult to achieve.

Conclusion

Moore (2006) estimated that an increase in the link budget by a factor of at least 2, and more probably 4, was necessary to maintain productivity levels if the station was to operate in its "all weather" configuration appropriate for automated and unmanned operations. This is due to the requirement that ranging be performed through an 18mm glass enclosure window.

Subsequent to a laser power upgrade in mid 2007 which increased the link budget by roughly a factor of 3, operations have been largely performed in this all-weather configuration and auto-tracking mode. The evidence has shown that although confounded by some periods of overcast weather and other changes to the station, that productivity levels for high satellites such as Giove A, etc. has been maintained as predicted, and even improved for lower orbit satellites.

Also without the upgrade, it is doubtful that the station could have made a significant contribution to the tracking of the geostationary satellite, ETS-8.

Acknowledgement

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References

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