Enhanced Laser Traffic Control System Operation Mode

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Abstract

The proportion of telescopes using Laser Guide Star (LGS) systems is increasing worldwide. LGS systems generally use either "pulsed lasers" (at 532 nm), creating an LGS in the upper troposphere by means of molecular scattering of light, or "sodium lasers" (at 589 nm), creating an LGS by means of excitation and spontaneous emission of sodium atoms in the mesosphere.

Adequate coordination of observations involving non-laser and laser-assisted telescopes is necessary to prevent the laser beams from contaminating the field of view of telescopes operating in the visible.

This coordination is done using a Laser Traffic Control System (LTCS), originally implemented for Mauna Kea.

A key aspect of the LTCS is the implementation of a set of policies defining the pointing priorities of all telescopes during LGS assisted observations.

A simple policy, **"lasers always yield", was to assign the lowest operational priority to the lasing telescope**. This basic scheme evolved into the **"first-on-target" policy, giving priority to the first telescope pointing in a given direction**.

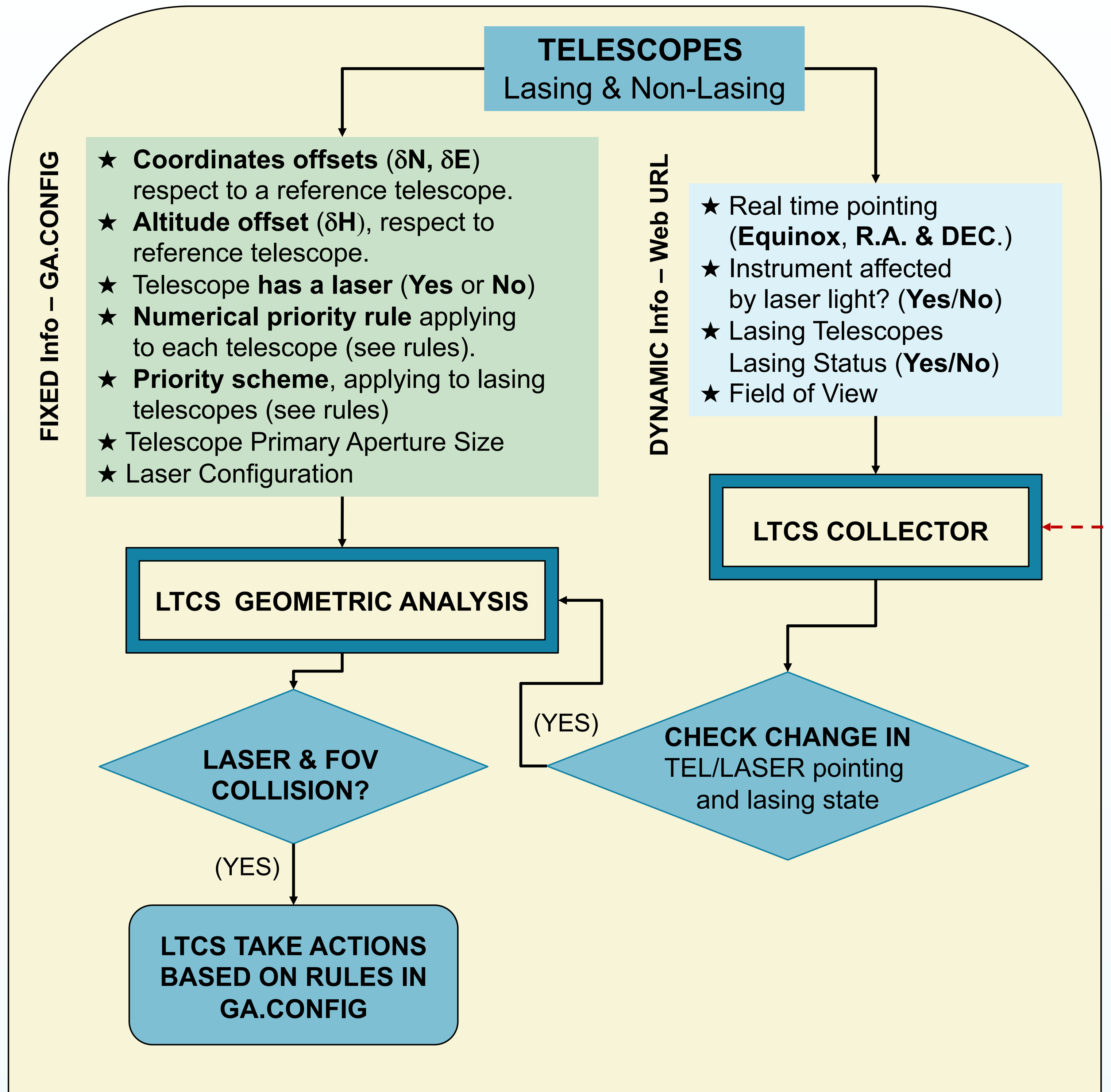
In this study we propose an evolution of these policies, the "enhanced LTCS", which defines pointing privileges according to the scientific priority of the telescopes involved in a collision.

This study was made in the context of the Observatorio Roque de Los Muchachos (ORM), the future location of the Cherenkov Telescope Array North (CTA-N). The Thirty-Meter-Telescope (TMT) project has selected ORM as its alternate site, and it is the location of the Gran Telescopio de Canarias (GTC).

This study was conducted to assess the operational impact of LGS-equipped telescopes on all existing and future ORM telescopes.

Our results show that implementing an enhanced LTCS Mode, based on the scientific priorities of the executed programs, minimizes the disruption imposed on high-priority science programs, maximizing the science impact of all telescopes operating at a given site.

LTCS Methodology



RULES

1 : A Laser has no priority

2 : Telescopes have priority over lasers.

In a collision between two lasers, LTCS applies "**first on target**" rule.

3 : LTCS operates in a mode of "**first-on-target**" for both telescopes and lasers.

4 : Priority is calculated using a specified priority level (numeric) for each telescope and laser. Telescopes have one priority designator; lasers have two (one for use when acting as a telescope, and the other for when they acting as a laser). They include: a. "**lasers-yield**", b. "**first-on-target**", c. "**lasers lase-through**".

5 : Laser has priority

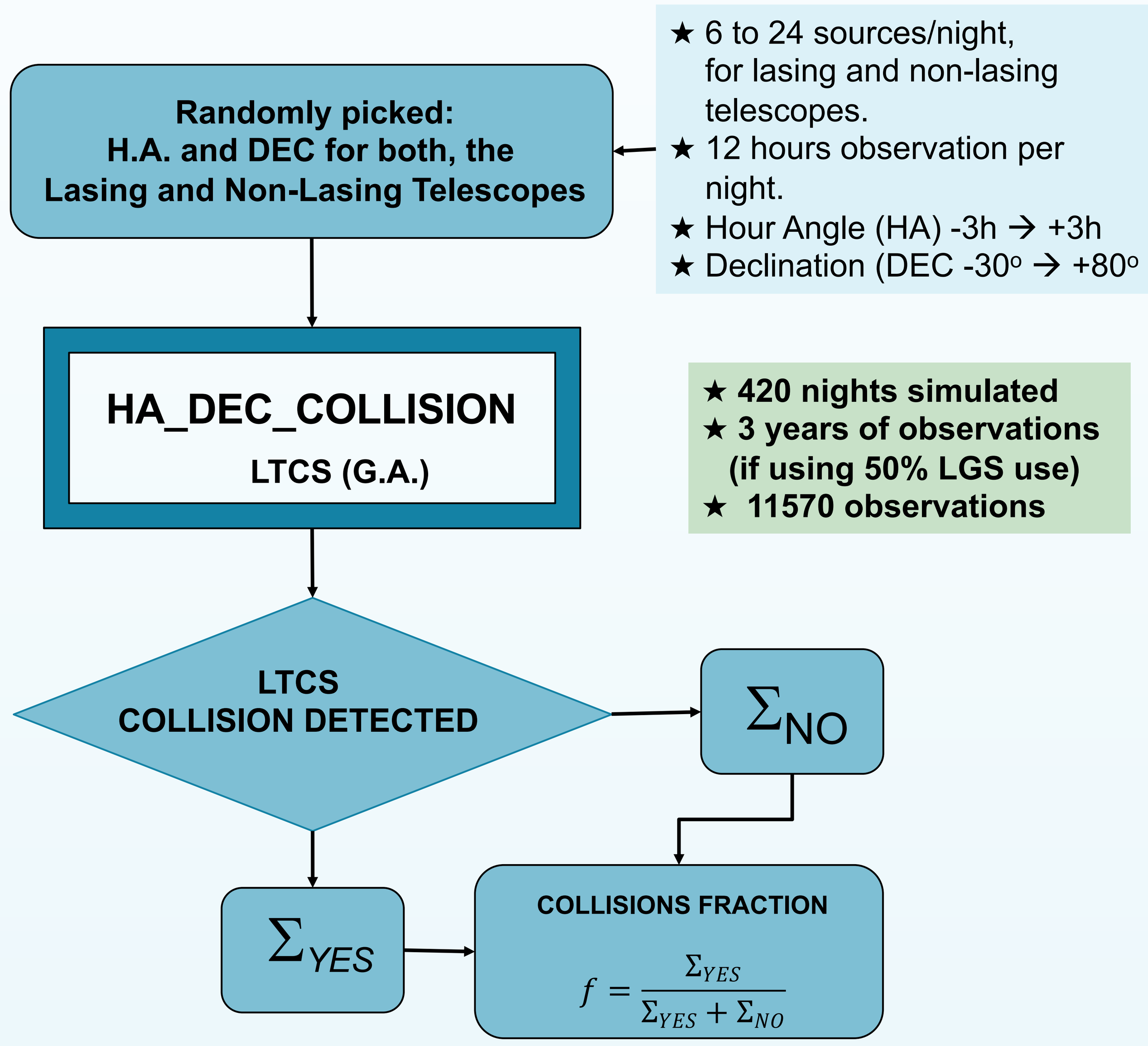
The Enhanced LTCS Mode

In the **ENHANCED LTCS mode the idea is to provide additional information to the LTCS so that it will make a decision based on the PRIORITY of the science programs under observation** by the TELESCOPES (Lasing and non-lasing). **LTCS will allow the program of highest reported priority to continue uninterrupted. For the lowest priority telescope, LTCS will issue a collision warning (if using an instrument in a spectral band that could be affected by laser light). Alternatively, it will shutdown the laser of the lasing telescope.**

SCHEME 1: The PRIORITY of an observing program are pre-assigned by each telescope team based on categorization of the programs. For instance**: 15% are priority 1 (Top priority), 20% (priority 2), 30% (priority 3) and 35% (priority 4)**.

SCHEME 2: The **PRIORITY** of an observing programs **gets calculated [**by a piece of software prior to the LTCS**] based on information associated to each program**, such as: Time Critical Observation (**YES**/NO), Observing Mode (**Visitor**/Service), Program Completion (near completion, **YES**/NO), Flexible Adaptive Queue Status (**Best atmospheric conditions** / Standard Atmospheric Conditions).

Simulations of the LTCS Enhanced Operation Mode, a Montecarlo Approach



★ **For every simulated night**: the hour angle (HA) and Declination (DEC) of a random number of sources (minimum: 6, maximum : 24, sources per night,) where prepared for each telescope (a lasing, and a non-lasing telescope).

★ For each simulated astronomical source, the HA was picked randomly in the range -3h – 3h. The DEC angle was picked randomly in the range -30º – +80º. (i.e. **limiting the zenith angle to 60 degrees maximum**).

★ The observing time was split evenly among all the sources to be scheduled in a given night at each telescope.

★ **Priorities were randomly assigned (to each obs.) based on SCHEMES 1 and 2**

Results of simulations at the Observatorio Del Roque de los Muchachos (La Palma, Canary Islands)

Lasing Telescope TMT / GTC	CTA	GTC	WHT	INT	NOT
Total simulations	11570	11570	11570	11570	11570
Field of View	8 degrees	10 arcmin	2 degrees	20 arcmin	10 arcmin
Number of collisions predicted (annual)	**720** / **900**	103	154	57	55
Collision probability **50% / 15% of annual obs. Make use of LGS**	**3.1% / 1.2%**	**0.5%**	**0.7%**	**0.25%**	**0.2%**
Mean collisions duration (seconds)	760±972 622±979	511±584	700±912	401±476	310±433

This Montecarlo study results agrees with Gaug & Doro (MNRAS, 2018) analytical study: *"We find no conflict expected for the [use of] lasers, However, **1%** (**3%**) of extra-galactic and **1%** (**5%**) of galactic observations with the CTA may be affected by the GTC (**TMT**) LGS lasers, unless an enhanced version of a laser tracking control system gets implemented. " –from GTC/MAGIC historical pointing analysis.*

LTCS: Results from FIRST ON TARGET POLICY: For the case of collisions between the TMT / GTC and the field of view of the Cherenkov Telescope Array (CTA-North):

★ Out of the 100 of collisions detected, it is expected (and so it is confirmed by the Montecarlo Simulations) that 50% of the time the LTCS will rule in favor of the non-lasing telescope (i.e. CTA) and 50% of the time in favor of the lasing telescope (i.e. GTC or TMT).

★ Out of all the times that either telescope (non-lasing or lasing) was asked to yield by the LTCS, **25% of those occasions the telescopes were engaged in high-priority observations**.

★ In the case of collisions with the large field of view of the CTA telescope elements, this potentially imply a long disruption in these high priority observations.

LTCS: Results from ENHANCED LTCS POLICY (USING THE PRIORITY FLAG AS AN INPUT): For the case of collisions between the TMT / GTC and the field of view of the Cherenkov Telescope Array (CTA-North):

★ 73% of the time, LTCS was able to rule in favor of the telescope that was engaged in a science observation that was previously classified as of high priority. The rule split the decision in half between the two telescopes (i.e. there is no bias in favor of either, lasing / non-lasing).

★ 27% of the time, **LTCS was not able to make a decision** because both telescopes (lasing and non-lasing) were engaged in an observation of equal priority. In those cases LTCS can default to the FIRST ON TARGET policy. However, only 4% of those cases (**equivalent to 1% of the total collisions**) were cases when the programs were engaged in the upmost high priority (an alternate share of the risk / night observing coordination) can help make a fair decision in those few cases.

Relevant Bibliography & Acknowledgments

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The authors are thankful to Douglas Summers for providing us with an executable version of the **HA_DEC_COLLISION** tool**.** This tool does calculations for the determination of a collision between a laser beam and the field of view of a given telescope. This program uses as inputs the hour angle and declination, on the sky, of the sources being observed by a lasing and a non-lasing telescope of given field of view.