Upgraded Control System for LHC Beam-Based Collimator Alignment

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Abstract

In the Large Hadron Collider (LHC), over 100 movable collimators are connected to a three-tier control system which moves them to the required settings throughout the operational cycle from injection to collision energy. A dedicated control system was developed to align the collimators to the beam during machine commissioning periods and hence determine operational settings for the active run. During Long Shutdown 1, the control system was upgraded to allow beam-based alignments to be performed using embedded beam position monitors in 18 newly installed collimators as well as beam loss monitors. This paper presents the new collimation controls architecture for LHC Run II along with several modifications in the Java-based application layer.

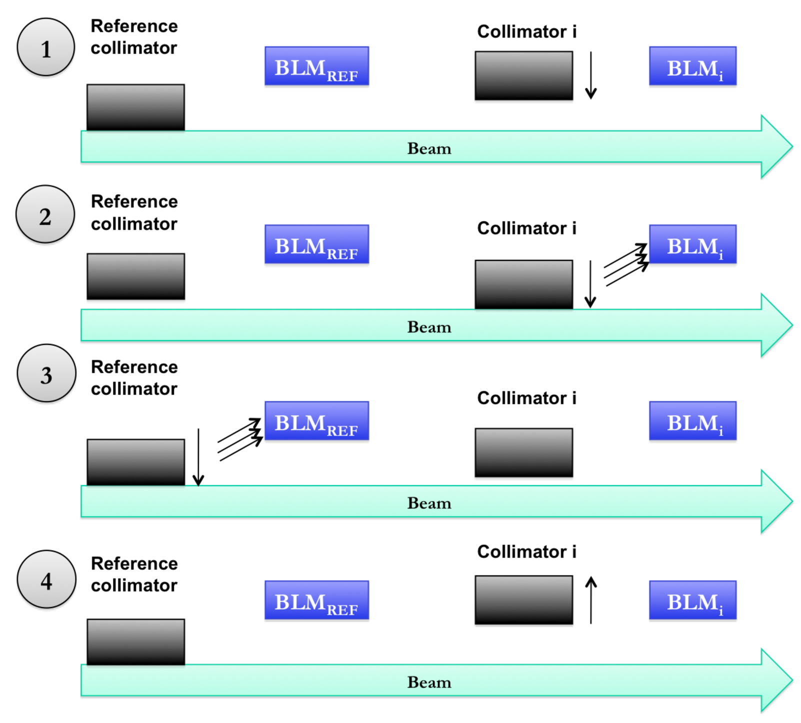
BLM-Based Collimator Alignment

➡ During Run 1, the LHC collimators were aligned using feedback from Beam Loss Monitors (BLMs).

➡ The alignment is performed in four steps (only one jaw shown for simplicity):

1. A reference collimator is used to define the beam halo
2. The collimator *i* is aligned.
3. The reference collimator is re-aligned.
4. Collimator *i* is retracted to the operational positions.

➡ This allows both the beam center and beam size at collimator *i* to be measured.

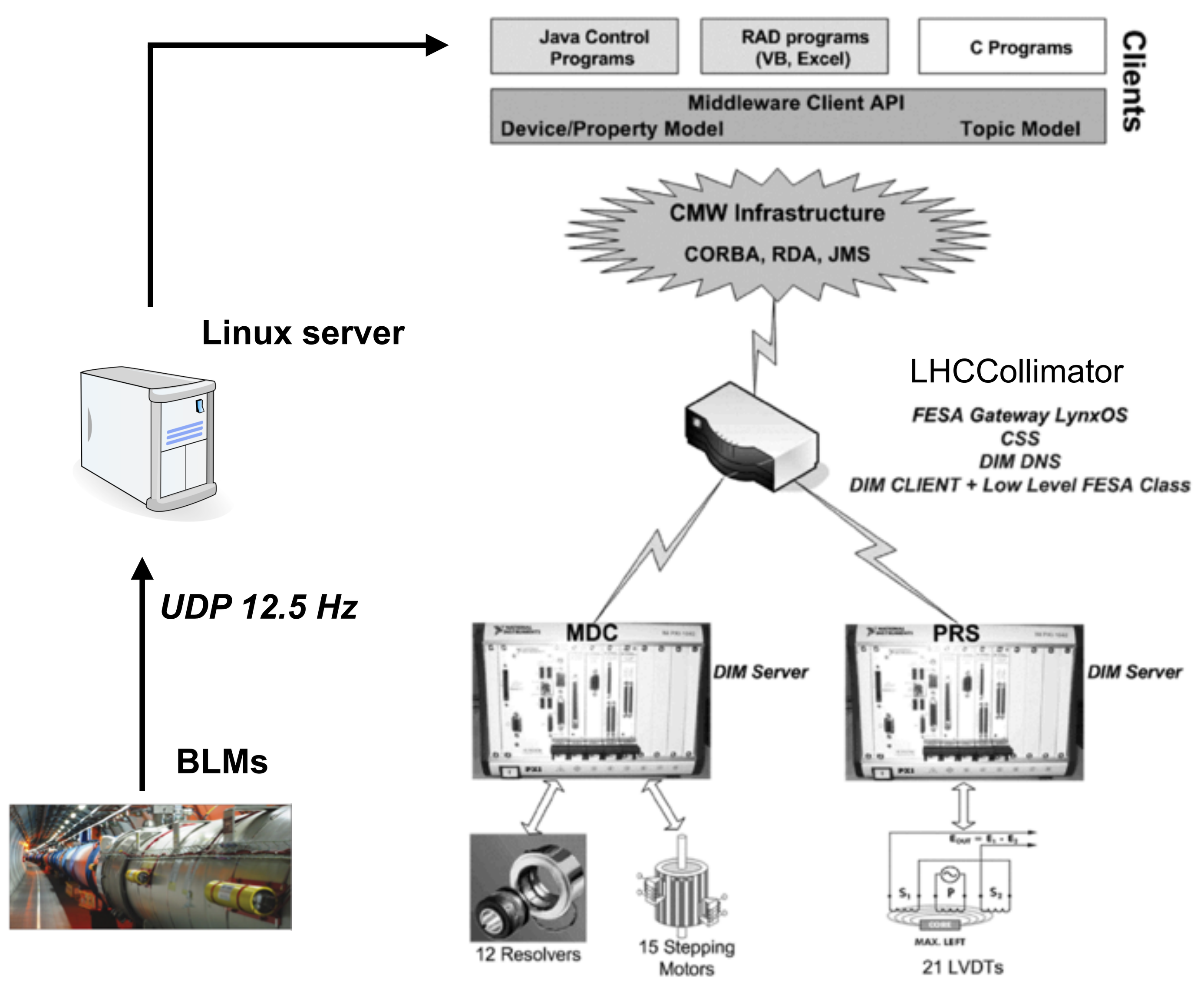


Run 1 Software Architecture

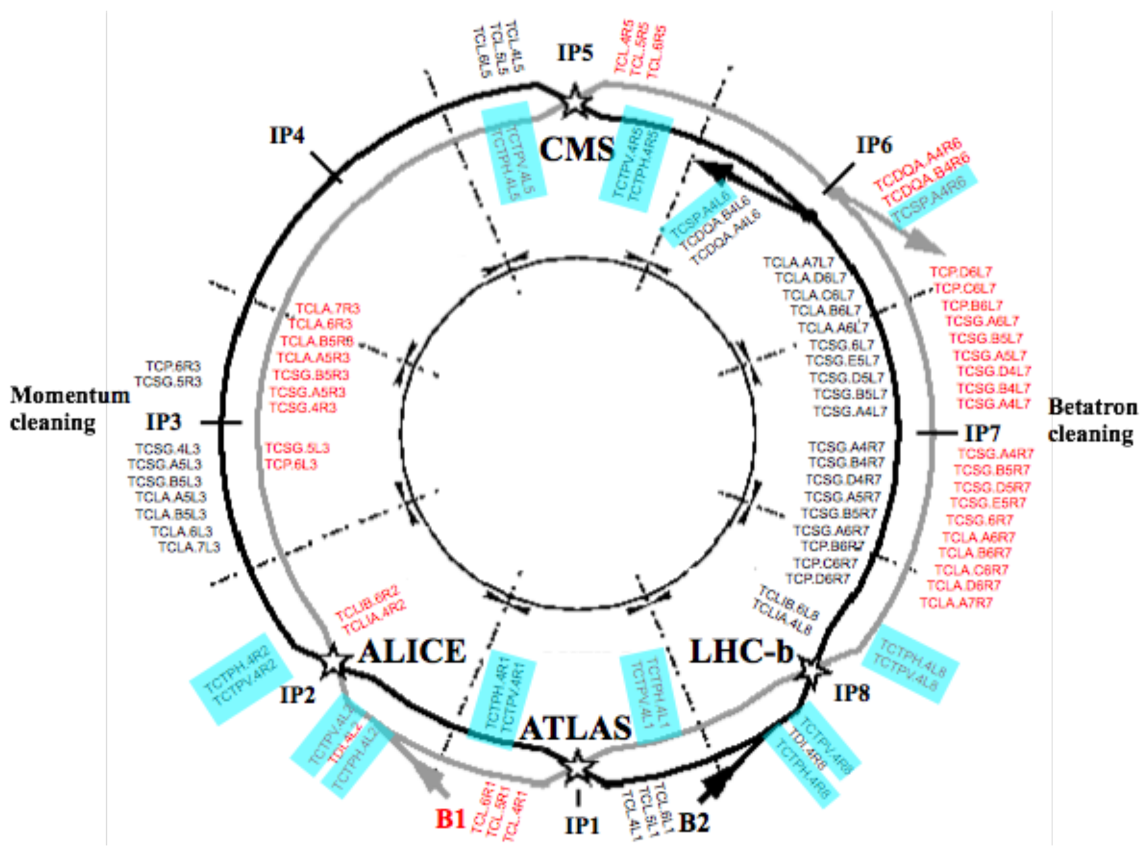
➡ The BLM-based feedback loop was implemented in a Java application.

➡ The jaws were moved via the 3-tier architecture and were automatically stopped when the losses exceeded a pre-defined threshold.

➡ The time required to align a collimator is ~5 minutes.



LHC Collimation System

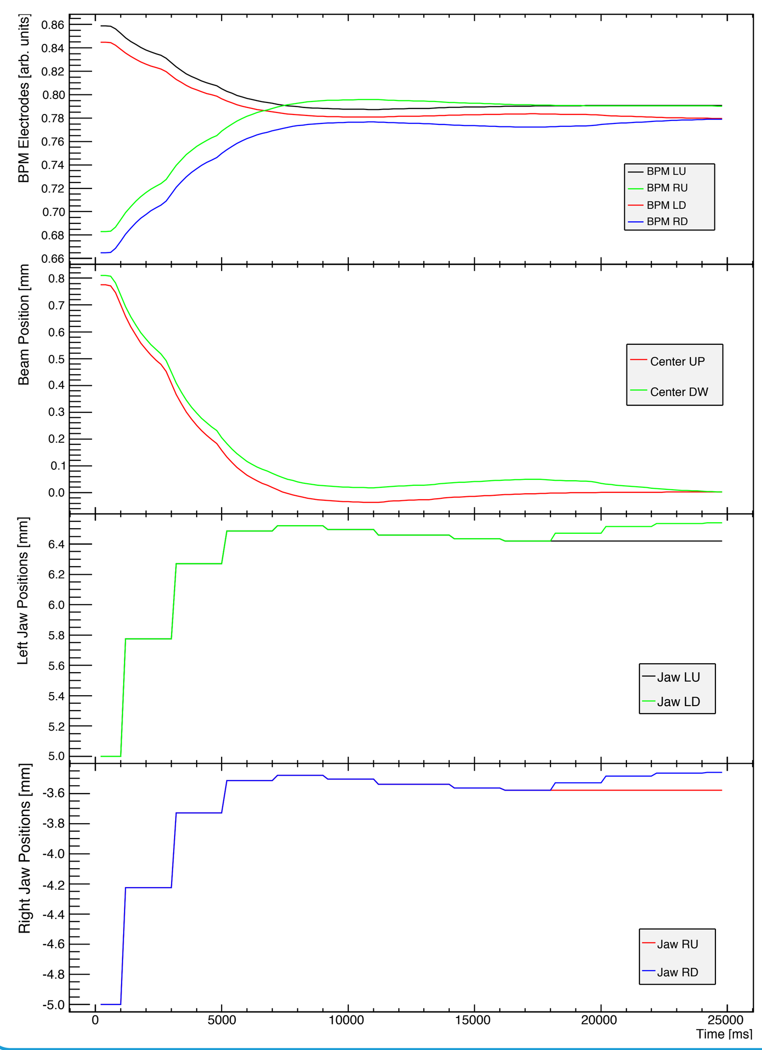


➡ 94 collimators are installed in the 27 km LHC ring. They need to be set up in a 4-stage hierarchy to protect the LHC from beam losses.

➡ A three-tier software architecture is used to control the collimator positions. Java applications running in the CERN Control Center send movement requests via the Common Middleware (CMW), to the Front-End Software Architecture (FESA) middleware layer which controls the PXI-based low-level electronics.

➡ 18 collimators (highlighted in blue) were replaced during Long Shutdown 1 (LS1) with a new design having Beam Position Monitor (BPM) pick-ups embedded in the collimator jaws [1].

BPM-Based Collimator Alignment



➡ The beam position between 2 BPM electrodes can be calculated using a well-known linear technique:

$$X_{bpm} = \frac{B}{4}\frac{V_1 - V_2}{V_1 + V_2}$$

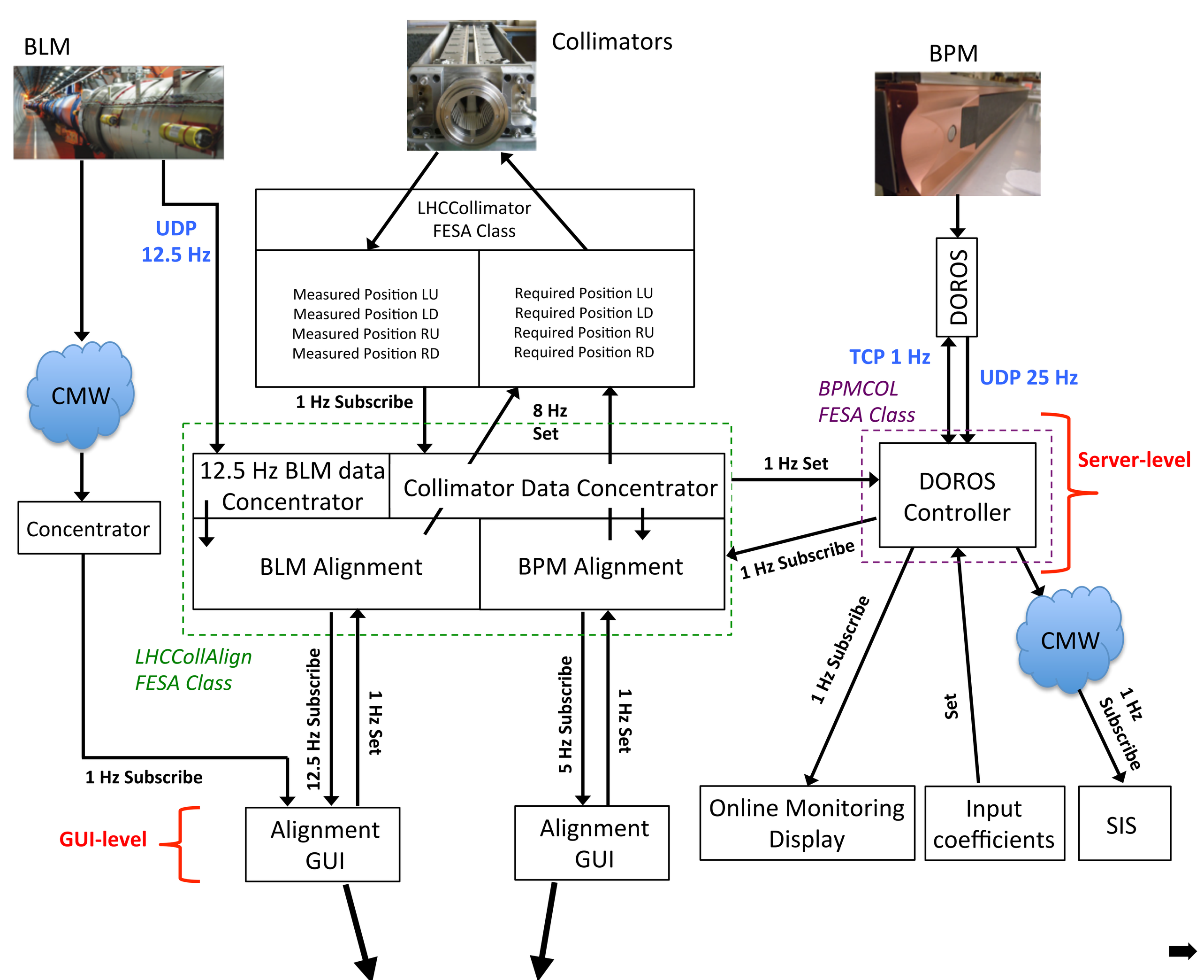
where B is the BPM aperture and V1 and V2 are the signals from the opposite electrodes.

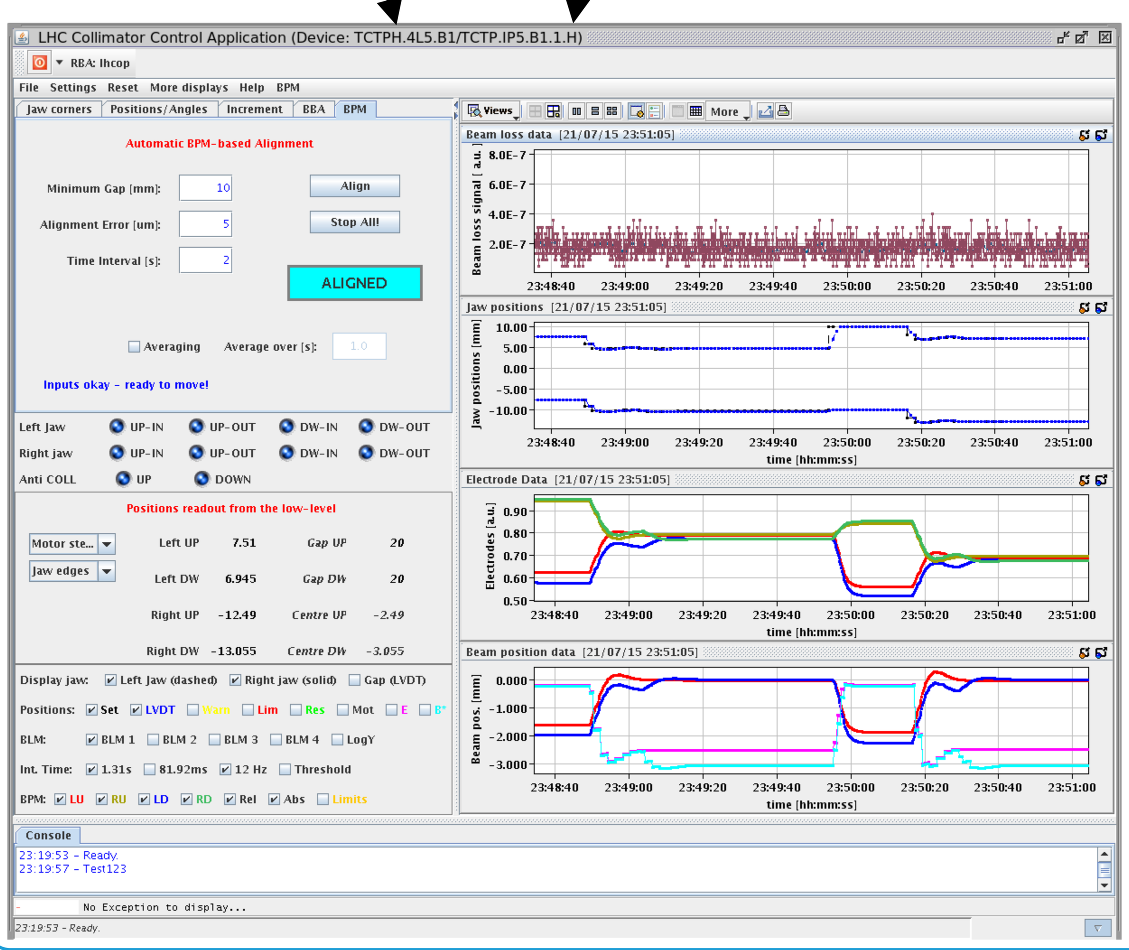
➡ The objective of the alignment procedure is to minimize Xbpm. A successive approximation algorithm was developed to perform this [2].

➡ The left and right jaws are moved towards and away from the beam respectively (or vice-versa depending on the sign of the offset).

➡ The alignment is typically completed in 15-25 seconds. Several iterations are needed due to non-linearities inherent in the BPM geometry.

Upgraded Software Architecture for Run 2





➡ The functionality previously present in two separate Java applications was moved to a new FESA class (*LHCCollAlign*) running on a Front-End Computer (FEC).

➡ The Run 1 UDP packet format was re-used to allow the BLM crates to send the 12.5 Hz data to to *LHCCollAlign,* as 75% of the system still aligned using BLMs.

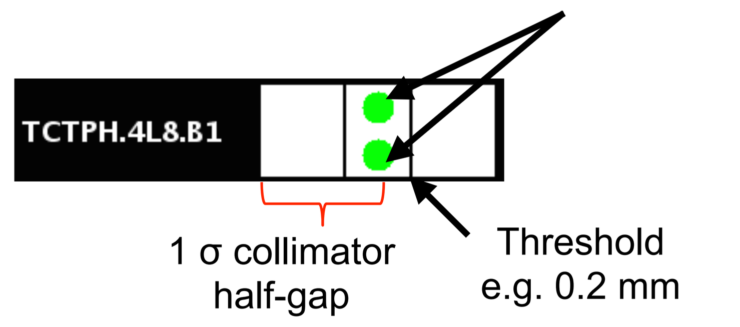
➡ The BPM data is provided by the Diode ORbit and OScillation (DOROS) system, and is acquired by another FESA class (*BPMCOL*).

➡ The beam position Xbpm is calculated via the BPM signals and the collimator BPM aperture provided by *LHCCollAlign.*

➡ Once sufficient experience is gained, the existing collimation hierarchy margins in the TCTPs and TCSPs which account for beam orbit drifts can be reduced, to improve the LHC β* and therefore luminosity reach.

➡ The beam positions will then be sent to the LHC Software Interlock System to dump the beam in case of orbit drifts above a certain threshold.

Orbit monitoring display (1 out of 18 collimators shown)



References

[1] B. Salvachua, G. Valentino et al., "Collimation system post-LS1: status and commissioning". In Proceedings of the 5th LHC Beam Workshop, Evian, France, 2014.

[2] G. Valentino et al., "Successive approximation algorithm for beam-position-monitor-based LHC collimator alignment", *Phys. Rev. ST Accel. Beams*, **17** 021004 (2014).

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