

**Limit Up – Limit Down:
National Market System Plan Assessment
To Address Extraordinary Market Volatility**

Specially prepared for
Limit Up – Limit Down Operating Committee

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I. Executive Summary

The LULD Plan requires that, at least two months prior to the end of the Pilot Period, the Participants shall provide the SEC assessments of the impact of the Plan. This assessment is submitted in satisfaction of that requirement.

Following the Flash Crash of 2010, the U.S. equity market rolled out a series of changes designed to deal with excessive volatility, culminating in the rollout of the Limit-Up Limit-Down (LULD) plan on a pilot basis. The LULD Plan moderates excessive volatility by preventing trades from occurring outside trading bands that are set around a reference price. During regular trading hours from 9:30 am until 4:00 pm EST, a reference price is determined that is generally the average transaction price over the last five minutes. This reference price determines upper and lower price bands. The width varies with the nature of the stock and the time of day. If the best bid hits the upper price band or the best offer hits the lower price band, the market enters a limit state. If the limit state is not exited based on trades or quote updates within 15 seconds, then there is a five minute trading pause. The market then reopens with an auction on the primary listing market.

On an average trading day, there are nearly five thousand limit state events per day, which result in an average of 33.8 trading pauses per day. The vast majority of limit state events resolve themselves without triggering a trading pause, indicating the advantage of the limit state approach versus the straight-to-trading halt approach used by some European markets. However, some stocks oscillate in and out of limit states.

For the most part, LULD has succeeded in preventing erroneous trades in large cap stocks during regular trading hours. Cancellation events in which multiple executions have been cancelled have fallen from an average of 90.48 per month in the pre-circuit breaker period to 13.45 in the LULD era.

Furthermore, most of the LULD limit states and pauses have been occurring in small, low volume stocks, most of them unnecessary due to problems with determining the opening reference price for stocks that have not traded in the opening auction. Over half the LULD pauses occurred in just 50 of the over 5,000 symbols in the data. Many of these pauses result from situations in which no trade occurs in the opening auction. In such cases, the first reference price is based on the midpoint of the opening bid-ask quotes, which may be extremely unrepresentative of the fair value of the stock. These pauses, most of which occur in the first half hour of trading, provide unnecessary distractions to traders and regulatory personnel during a time of heavy trading activity. These unnecessary pauses can be prevented by redefining the first reference price of the day in such cases as the previous primary market closing price instead of the midpoint of the opening bid-ask quotes.

Although LULD has been largely successful in achieving its purpose for single-stock events, it has not yet been tested in large, systemic, market-wide events. It is unclear how

the interaction of LULD with market-wide circuit breakers will perform in the next market-wide event.

Recommendations:

1. LULD should be continued and made permanent with the following modification: Starting reference prices in cases where there is no trade in the opening auction should be based on the previous close. The previous close is generally a better indication of the appropriate price for a thinly traded stock than the opening bid-ask midpoints. This would eliminate the inappropriate and unnecessary LULD halts near the open.
2. Future consideration should be given towards harmonizing tiers with other existing and future rules, such as the numerical guidelines for breaking clearly erroneous executions (“CEEs”), the tick size pilot, and any changes in access fee caps. Different tier specifications for different rules create unnecessary complexity and confusion in the market. Basing tier sizes primarily on index membership may result in securities whose tier does not fit their economic characteristics. Consideration should be given to factors such as average trading volume, volatility, market capitalization, and average bid-ask spread. Primary listing exchanges should have the flexibility to determine tier membership. Preliminary evidence indicates that some LULD bands can safely be narrowed without causing major disruptions to trading.
3. In a market-wide event resulting in numerous LULD pauses of index constituents, the market-wide circuit breakers may not be triggered in the appropriate manner. Market-wide circuit breakers need to be re-thought and integrated with LULD and the circuit breakers on derivative exchanges. Careful thought should be given to the re-opening process after a market-wide halt.

II. Introduction

From time to time, financial markets experience abnormal events that challenge their ability to operate in a fair and orderly manner. These abnormal events may result from any number of possible causes, including macro-economic shocks, “fat-finger” trading mistakes, and machine malfunctions. In such situations, a market mechanism that operates properly, under normal conditions, may produce aberrant prices that call into question the integrity of the overall market mechanism and may impose serious losses on market participants that jeopardize the solvency of the financial system.

In the old days of human intermediated trading, common sense human judgment would prevent trades from occurring at truly ridiculous prices. The occurrence of “out-trades,” trades in which the buyer and seller did not agree on all the details of a trade, led to a system for a rapid correction of errors and resolution of disputes.

In previous market-wide events, limitations in system capacity led to serious problems. The ticker tape ran seriously late many times, leading to confusion regarding the actual price at the moment.¹ In the crash of 1987, known as “Black Monday,” the high level of trading volume overwhelmed the printers that printed out order tickets at the NYSE. This led to delays in delivering orders that exacerbated the confusion in the market.²

Subsequent to the crash of 1987, market-wide circuit breakers were imposed for the first time. Market-wide halts would occur of varying lengths if the Dow Jones Industrial Average fell by a specific amount. For example, if the Dow Jones Industrial average dropped by 10% before 2:30 pm, the market would close for one hour. The logic behind such a close is that it would allow market systems and participants to catch up while assessing the information that led to and was generated by the market downturn. This circuit-breaker was activated only once, on October 27, 1997, when the market fell amidst concerns over an economic crisis in Asia. After a 30-minute halt at 2:35 pm, the market fell further upon re-opening and was closed for the day at 3:30 pm.³

The exchanges engaged in a continuum of efforts over the years to deal with single stock volatility on an exchange-by-exchange basis. On May 6, 2010, the events known as the “Flash Crash” occurred in three waves.⁴ There had been general price declines amidst

¹ Some of the more newsworthy events with disruptions to the market mechanism occurred on May 2, 1906, August 7, 1919, September 26, 1955, October 29, 1929, May 29, 1962, and October 19, 1987.

² For more information about the events of October 19, 1987, see Carlson, Mark, A Brief History of the 1987 Stock Market Crash with a Discussion of the Federal Reserve Response, <http://www.federalreserve.gov/pubs/feds/2007/200713/200713pap.pdf>

³ For more details see Goldstein, Michael, and Kavajecz, Ken, Trading Strategies during Circuit Breakers and Extreme Market Movements, *Journal of Financial Markets*, June 2004, Vol. 7, No. 3, pp. 301-333.

⁴ For more information about the Flash Crash, see Preliminary Findings Regarding

heavy volume and high volatility in the morning and early afternoon, upon news of economic turmoil in Greece. The NYSE's Liquidity Replenishment Points or LRPs were applied to a number of stocks. Starting at around 2:40 pm, large sell orders in the Chicago Mercantile Exchange's ("CME") E-Mini S&P 500 futures contract ("E-Mini") arrived at a time of low liquidity, leading to a rapid fall in the price of the E-Mini.⁵ Between 2:41:00 and 2:45:27 pm, the price of the E-Mini declined by 5%. At 2:45:28 pm the CME applied a five second "Stop Logic Functionality" trading pause, after which the price of the E-Mini rebounded.

The second wave of the Flash Crash affected the cash equities directly tied to the S&P 500. The prices of major large capitalization stocks in the S&P 500 dropped and rebounded with a lag. The worst hit of the Dow Stocks, Procter and Gamble, hit its low price of \$39.37 (relative to its earlier price of \$55.00) at 2:47:19 pm and then rebounded, nearly two minutes after the E-Mini rebound started.

The third wave affected other stocks and most notably, ETFs, and lasted for many minutes longer. The Vanguard Total Stock Market Index Fund (VTI) traded at its low of \$0.15 at 2:55:32 pm, 10 minutes after the E-Mini had begun its rebound. Concerns about data integrity led some important liquidity providers to withdraw from the market.⁶ Without these liquidity providers, trades occurred at extremely low or high prices.

ETFs were the hardest hit. Of the 326 securities with cancelled trades, over two-thirds (227, 69.6%) were ETFs.⁷ In all, 20,761 trades were cancelled, using the criterion that they were more than 60% way from the last trade price as of 2:40 pm.

The market-wide circuit breakers were not activated on May 6, 2010, as the drop was not large enough to trigger the market-wide circuit breakers. If the market had been halted for a lengthy period at Flash Crash lows, it is easy to speculate that the market reaction may have been very different upon re-opening. Media reports of the crash could have set off a general panic among investors, prolonging and deepening the crash. Automated margin liquidations may have occurred upon the reopening, increasing selling pressure.

the Market Events of May 6, 2010: Report of the Staffs Of The CFTC and SEC to the Joint Advisory Committee on Emerging Regulatory Issues ("SEC/CFTC Preliminary Report"), available at <http://www.cftc.gov/ucm/groups/public/@otherif/documents/ifdocs/opa-jointreport-sec-051810.pdf> and The Findings Regarding the Market Events of May 6, 2010: Report of the Staffs Of The CFTC and SEC to the Joint Advisory Committee on Emerging Regulatory Issues, available at <https://www.sec.gov/news/studies/2010/marketevents-report.pdf>.

⁵ The E-Mini is a futures contract whose payoff is based on changes in the S&P 500 index.

⁶ Liquidity providers include those market participants who provide liquidity to the markets by submitting limit orders into the electronic order books. Their business model is to purchase at the lower bid price and sell at the higher offer price.

⁷ SEC/CFTC Preliminary Report, page 30.

The events of May 6 led to a realization of the market's vulnerability to such events and led to the rapid introduction of circuit breakers and revamped rules on breaking trades. The industry rapidly adopted single-stock circuit breakers that paused trading for five minutes if a stock moved 10% or more during a 5 minute period. These single-stock circuit breakers were implemented on a rolling basis, starting with major index constituents and major ETFs.

However, it soon became clear that these single-stock circuit breakers could be improved upon. A reporting error on a single trade could (and did) trigger a needless trading halt.⁸

⁸ On June 29, 2010, a reporting error triggered a trading halt in Citigroup. See "Reporting Error Triggers Citi Circuit Breaker" <http://www.wsj.com/articles/SB20001424052748704103904575336834002120488>. The circuit breakers were then modified to require at least three prints outside the range before triggering the pause.

III. Other jurisdictions and approaches

The problem of how to stabilize electronic markets is not unique to the U.S. equity market. A variety of techniques are in use in other asset classes and jurisdictions.⁹

However, the competitive open-architecture nature of the U.S. equity market makes direct application of results from more centralized markets problematic. Indeed, as other jurisdictions move to adopt more open-architectures, they are still grappling with these issues. For example, the regulated exchanges in Europe generally have circuit breakers of various types, while they compete with multi-lateral trading facilities (“MTFs”) that often do not.¹⁰

Daily Price Limits

One of the simplest approaches is to set a daily price limit on price movements. No trades are permitted outside the range, and there is no mechanism for adjusting the permissible range within the day. For example, the Tokyo stock exchange sets daily price limits based on the previous day’s closing price. An ¥800 stock is allowed to move no more than ¥150 up or down from the previous day’s close.¹¹ Daily price limits are also common in U.S. agricultural futures contracts.¹²

The simplest form of daily price limits suffers from two major problems. First, there are times when the appropriate price should move beyond the limit, such as when important news arrives. By preventing trades outside the range for the rest of the trading day, the market is not permitted to find the correct price. The closing price does not reflect the fair market value, leading to dislocations caused by inaccurate closing prices, such as in mutual fund pricing and margin calculations.¹³ Furthermore, investors are denied the

⁹ There has also been a body of academic research into circuit breakers in various countries. For two excellent summaries, see the work that the U.K. Foresight Project has done in this area. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/289039/12-1070-eia9-impact-circuit-breakers-on-market-outcomes.pdf and https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/289043/12-1066-eia4-stock-market-circuit-breakers.pdf

¹⁰ See Gomber, et al. http://www2.warwick.ac.uk/fac/soc/wbs/subjects/finance/fof2012/programme/single_stock_circuit_breaker_s_-_issues_in_fragmented_markets.pdf

¹¹ In addition, the TSE has a special quote procedure that is used to attract liquidity in situations where there is inadequate liquidity. It is basically a non-executable quote at the limit price. See <http://www.jpx.co.jp/english/equities/trading/domestic/index.html> for more details.

¹² See <http://www.cmegroup.com/trading/Price-Limit-Update.html>

¹³ Mutual funds are generally required to value their assets at “fair value as determined in good faith by the board of directors,” not necessarily the last price. 17CFR270.2a-4. See <https://www.sec.gov/divisions/investment/icvaluation.htm>. If the market price is frozen at some level that does not reflect fair value, a fund is required to go through a valuation process. However, without a

ability to modify their holdings based at any price. This can cause liquidity problems for investors who need to sell or otherwise modify their holdings. Halting trading also prevents hedgers such as option market makers from appropriately adjusting their hedges.

Second, a daily price limit alone does not address the problem of excessive or erroneous price movements that are not severe enough to trigger the limit.

Trading Halt Circuit Breakers

When a market is no longer fair and orderly, in the sense that it matches buyers and sellers at prices that properly reflect supply and demand given information in the market, then it makes sense to halt the market. A trading halt serves two major purposes. First, it gives market participants time to assess the situation and update their trading decisions. This provides the time to gather additional liquidity to achieve a fair and orderly price. Second, it allows for a change in the market mechanism. The market can move from the usual continuous auction to a call auction, thus concentrating liquidity to a single point in time.

However, the design of trading halts requires much fine tuning of the circumstances that trigger a halt and the process for re-opening the stock after the halt.

For example, in the Deutsche Boerse Xetra system, there are two limiting bands, a static band, based on the last auction price, and a dynamic band, based on the most recent price.¹⁴ If a trade execution would occur outside the band, the stock is immediately halted and an auction process occurs. Unlike LULD, there is no waiting period to see if the market will naturally supply liquidity without resorting to a trading halt. The length of the halt (also called the call phase of the auction) is determined randomly to prevent gaming of the auction price.

The London Stock Exchange's Millennium trading system's safeguards are similar to Xetra's.¹⁵ There is both a static band based on the last auction price, and a dynamic band based on the most recent price. A trade that would breach the band is not executed, and the market then goes into an auction mode without a waiting state, to see if natural liquidity will occur and remove the need for a longer trading halt.

functional market in the asset, it is very difficult to determine fair value, especially in a time of market turmoil or if the asset is highly illiquid.

¹⁴ See <http://www.deutsche-boerse-cash-market.com/blob/1193332/8b79d504d5aaf80be8853817a6152ecd/data/Xetra-Market-Model-Equities-Release-15.0.pdf>

¹⁵ See <http://www.lseg.com/documents/guide-new-trading-system-doc>.

IV. Limit Up Limit Down

LULD, more formally known as the National Market System (NMS) Plan to Address Extraordinary Market Volatility, was approved by the SEC on May 31, 2012.¹⁶ This section describes in more detail the operation of the plan.

Reference Price: Under LULD, for each stock there is a reference price that is determined as the simple average or the arithmetic mean price of all eligible transactions over the immediately preceding five minute period. Only trades eligible for last-sale reporting are included. Thus, average price trades, late-reported trades, and trades calling for settlement outside the regular way settlement are not included.

If there is no trade within the last five minutes, then the previous reference price is retained. The reference price is updated only if the rolling five-minute average price has changed by more than 1%. Thus, if the reference price is \$10.00 and the rolling average is \$10.02, the reference price would not change. The reference price would have had to have changed by 1%, or \$.10 in this example, in order for there to be an update in the reference price. Note that the reference price is not volume weighted. This prevents a single large block trade from distorting the calculation.

Each new reference price remains in effect for at least 30 seconds. For example, suppose that at 10:00:00 am the new reference price became \$20, based on a single trade in the last five minute period at 9:59:59 am. If at 10:00:01 am the stock then traded at \$25, pushing up the average price to \$22.50, the new reference price would not go into effect for another 29 seconds at 10:00:30 am.

The first reference price of the day is the opening print on the primary market or the midpoint of the primary market's first quote, whichever occurs first. (If the primary market does not trade or quote by 9:35 am, the first reference price is the arithmetic mean price of eligible reported transactions from all NMS markets over the preceding five minutes.) Stocks with little trading activity or ETFs for which the underlying issues are in the process of opening may open on a quote that is either extremely wide (e.g., stub quotes) or skewed to the bid or the offer, leading to an unrealistic reference price that may unnecessarily trigger a limit state or a trading pause.¹⁷

The Bands: Once the reference price is determined, the SIP then calculates a lower and an upper price band based on the reference price and the appropriate percentage. For example, if the reference price is \$10.00 and the band size is +/-5%, then the lower limit band would be \$9.50 and the upper limit band would be \$10.50.

¹⁶ See <http://www.sec.gov/rules/sro/nms/2012/34-67091.pdf>.

¹⁷ A stub quote is a quote that is so far away from the fair value of a security that it is unlikely to be executed, such as a bid of \$0.01 and an offer of \$99,999.99. Although market makers are required to submit quotes within a certain range of the NBBO, that NBBO may still be extremely wide in an illiquid stock. See <https://www.sec.gov/rules/sro/bats/2010/34-63255.pdf> for more details about stub quotes.

The exact percentage used for the band is a function of the tier size, the previous day's close, and time of day.

The price bands are disseminated over the standard SIP trade and quote feeds, CTA/CQS for NYSE, NYSEMKT, NYSEARCA, and BATS-listed stocks, and UTDF/UQDF for NASDAQ-listed securities.

All trading centers are expected to have procedures in place to prevent trades outside the LULD bands and to prevent the display of executable quotes outside the LULD bands. The SIPs, however, do not reject trades or quotes that are outside the bands. Anything that is reported to the SIP is disseminated.

As a result, exchanges can post bids below the lower price band, but such bids would be marked as non-executable. However, they could become executable later if the band changes. Likewise, an exchange can post an offer above the upper price band, but it would also be non-executable. For example, if the lower and upper bands were set at \$9.50 and \$10.50, an exchange could post a bid at \$6.00, but it would be non-executable. However, exchanges cannot post bids higher than the upper band or offers lower than the lower band. In practice, they may accept such orders from customers but reprice the displayed part of the order to the relevant limit band price. For example, suppose that the best bid is \$6.00 and the lower band is \$9.50 and the upper band is \$10.50. If the exchange then received an order to sell at \$7.00, which is below the lower band, it could not post the offer to sell at \$7.00. It may instead post an offer to sell at the lower band of \$9.50, which would trigger a limit state. The exact handling of such orders will vary based on the order instructions from the customer and the policies of a particular exchange. Other possible treatments include rejecting orders outside the band outright or treating them as undisplayed orders.

Time of Day: LULD is in effect throughout regular trading hours from 9:30 am to 4:00 pm. The band sizes double during the first 15 and last 25 minutes of trading to allow more room for price discovery around the open and the close. During the early phases of the rollout, LULD did not apply during the first 15 or last 30 minutes of trading.

LULD does not apply during the pre-open and after-market trading sessions operated by some market participants.¹⁸

Tier Definitions: There are two tiers for LULD that are used for determining the band size.

Tier 1 consists of NMS securities in the S&P500 and the Russell 1000, along with a number of high-volume ETFs.¹⁹

¹⁸ Some exchanges are available for trading as early as 4:00 am and as late as 8:00 pm. During these periods outside regular trading hours there is no official NBBO.

Tier 2 consists of all other NMS securities except for rights and warrants. Note that there is no exception for ultra-low priced stocks.

Band Sizes: In general, for Tier 1 stocks greater than \$3.00, the lower band price is 5% below the reference price and the upper band price is 5% above the reference price between 9:45 am and 3:35 pm. For a stock with a \$10 reference price, the lower and upper band prices would be \$9.50 and \$10.50 respectively. These bands are doubled to 10% from 9:30 am to 9:45 am and from 3:35 pm to 4:00 pm.

For Tier 2 stocks greater than \$3.00, the band width is basically double that of Tier 1: 10% intraday and 20% near the open and close. Approximately 89% of US exchange traded stocks have prices above \$3.00.²⁰

For Tier 1 and Tier 2 stocks priced from \$0.75 through \$3.00, the band width is +/- 20% of the reference price between 9:45 am and 3:35 pm. Thus, a stock with a \$2.00 reference price would have lower band price of \$1.60 and an upper band price of \$2.40. These bands are doubled to 40% from 9:30 am to 9:45 am and from 3:35 pm to 4:00 pm.

For both Tier 1 and Tier 2 stocks priced less than \$0.75, the width of the band is the lesser of \$.15 or 75% of the reference price between 9:45 am and 3:35 pm. Thus, a stock selling for \$0.50 would be subject to the +/- \$0.15 band width because \$.15 is less than 75% of \$0.50, or \$0.375. Thus, this stock would have lower and upper bound prices of \$0.35 and \$0.65. A stock selling for \$0.10 would be subject to a width of 75% of the reference price, or \$0.075, and would thus have a lower band of \$0.025 and an upper band price of \$0.175.

For leveraged ETFs, the band width is multiplied by the leverage factor.²¹ Thus if the usual band width would be +/-10%, a 2X leveraged ETF would have a band width of +/- 20%.

The following table summarizes the sizes of the bands at various times:²²

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¹⁹ The list of Tier 1 ETPs as of January 2, 2015 can be found at https://www.nyse.com/publicdocs/nyse/products/etp-funds/ETP_Tier_1_List_Effective_Jan_2_2015.pdf

²⁰ As of December 31, 2014, 88.9% of the 5,701 US exchange-traded symbols for which I have data were at \$3.00 or above. Another 8.7% were between \$0.75 and \$3.00, and the remaining 2.4% below \$0.75.

²¹ Some ETFs are leveraged in that their investment objective is to deliver a certain multiple of an index. For example, the Ultra S&P500 seeks to deliver a return that is 200% of the daily return on the S&P 500. Its leverage factor is thus 2.0 and would have band sizes twice the normal size for its tier.

²² As explained below, LULD was rolled out in stages. For a complete table with the LULD bands for various tiers during different phases of the rollout, see the appendix.

Table 1: LULD Reference Band Sizes				
	Tier 1 Russell 1000 stocks and selected ETFs ²³		Tier 2 All other NMS securities except rights and warrants	
Previous Closing Price	9:30 am – 9:45 am and 3:35 pm - 4:00 pm (bands doubled)	9:45 am – 3:35 pm	9:30 am – 9:45 am and 3:35pm -4:00 pm (bands doubled)	9:45 am – 3:35 pm
> \$3.00	10%	5%	20%	10%
\$0.75 through \$3.00	40%	20%	40%	20%
< \$0.75	Lesser of \$.30 or 150%	Lesser of \$.15 or 75%	Lesser of \$.30 or 150%	Lesser of \$.15 or 75%

Limit State: If the national best bid hits the upper price band, or the national best offer hits the lower price band, then the market enters a limit state. For example, if the lower band is \$8.00 and the upper band is \$12.00, a limit state would occur if the national best offer fell to \$8.00. The limit state status is disseminated via the SIP quote feed. There are no updates to the reference price or the bands during a limit state.

Trades may not take place outside the bands, but they may take place at or within the bands. During this time, a limit state may resolve itself. For example, the offer to sell at the lower band that triggered the limit state may be cancelled. Or, a buy order may fill the sell order. If there are no more sell orders at the lower band (or buy orders at the upper band) then the limit state is exited.

Straddle States: A straddle state occurs when the best bid is below the lower band, when the best offer is above the upper band, or both. For example, suppose that the lower band is \$9.50 and the upper band is \$10.50. If the best bid is \$6.00 and the best offer is \$10.00, the market would be in a straddle state. A straddle state does not trigger a limit state or a trading pause, but the primary listing exchange has the ability to declare a trading pause if it believes that one is warranted. To date, the exchanges have not declared pauses during straddle states.

Trading Pause: If there is no exit from the limit state by the end of 15 seconds, then the primary listing exchange for the security declares a five minute trading pause and notifies the SIP, which then disseminates the trading pause information to the public. Trading must also stop on all other venues trading the security.

²³ For leveraged ETFs, the band sizes are increased by the leverage factor. For example, if the ETF was a 2X ETF, the band sizes would be doubled.

When a pause occurs, email notifications are automatically sent out over the various mailing lists operated by the exchanges. The exchanges have also implemented internal system alerts to notify the appropriate exchange personnel.

Reopening: After the five minute pause, stock trading will resume. However, the primary listing market may pause for an additional five minutes. The primary listing market will reopen the stock with its customary re-opening procedure. If the auction produces a trade, then the auction price becomes the new reference price. However, if there are no trades in the auction, then the midpoint of the primary listing exchange’s bid-ask spread is used. This can be problematic if the bid and offer quotes are far from a realistic price. Such instances can lead to multiple trading pauses in an illiquid stock.

When LULD does Not Apply: LULD does not apply in several situations:

- Before the open and after the close
- Rights and warrants; and
- Non NMS securities such as OTC stocks and fixed income products.

Rollout Schedule: LULD was rolled out in phases. In Phase 1, LULD applied only to the Tier 1 stocks from 9:45 am to 3:30 pm. LULD did not operate during the open and close. Phase 2 brought in Tier 2 stocks. In the first part of Phase 2, LULD did not operate from 3:35 pm to the close. These last 25 minutes of trading were added during the second part of Phase 2.

Symbols were added gradually during the rollout of each phase. Stocks that were not yet covered by LULD were still subject to the previous single-stock circuit breakers.

Table 2: LULD Rollout Schedule	
Date	Description
May 31, 2012	Initial SEC approval
April 8, 2013	LULD Phase 1 rollout began ²⁴ Tier 1 only (S&P 500, Russell 1000, and some ETPs)
May 6, 2013	LULD Phase 1 rollout complete
August 5, 2013	LULD Phase 2 Phase 1 rollout began ²⁵

²⁴ The rollout list for NASDAQ-listed stocks can be found at http://www.nasdaqtrader.com/content/marketregulation/luld_nasdaq_phase1_symbol_rolloutlist.xlsb

²⁵ The rollout list for NASDAQ-listed stocks can be found at http://www.nasdaqtrader.com/content/marketregulation/luld_nasdaq_phase2_symbol_rolloutlist.xls. The rollout list for NYSE-listed stocks can be found at https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=5&ved=0CEAQFjAE&url=https%3A%2F%2Fwww.nyse.com%2Fattachment%2FNYSE_NYSEMKT_Phase2_LULD_Rollout.xls&ei=amYtVeG1JozGsAWJ6oDwDA&usg=AFQjCNEMTBefK0n42ro-ht_IKFcDZtX8SQ&sig2=Ulgde16hfri7BaZWNHTf7w

	All Tier 1 and Tier 2 stocks 9:30 am to 3:45 pm
September 3, 2013	LULD Phase 2 Part 1 complete
February 24, 2014	LULD Phase 2 Part 2 rollout began All Tier 1 and Tier 2 stocks Effective 9:30 am to 4:00 pm
May 12, 2014	LULD Phase 2 Part 2 complete
<i>Note: Various securities changed their tier status at different times as a result of changes in the constituents of the Russell 1000 indices and the re-categorization of some ETPs.</i>	

V. The Opening Reference Price Problem

Several commenters expressed concerns that the application of LULD during the opening and closing could be disruptive to price discovery.²⁶ Under normal trading conditions, the opening print from the opening auction of the primary listing exchange sets the first reference price. However, trading interest in some stocks is so thin that sometimes there are no trades in the opening auction. In such cases, the first reference price is set as the midpoint of the primary listing exchange's best bid and offer prices. However, there are occasions in which the bid and offer quotes are so wide that the midpoint is not reflective of the fair market value of the security.

For example, suppose that a thinly traded stock normally trades around \$10. Yet at the start of the trading day, the only quotes are a bid of \$0.01 and an offer of \$100,000.00. Such situations do occur. This leads to a quote midpoint and thus reference price of \$50,000.00. If the stock is in a 20% band, the lower band price would be \$40,000 and the upper band \$60,000.00. An offer to sell the stock at its fair value of \$10 would immediately put the stock into a limit state and likely result in a trading halt.

One of the benefits of a trading halt is the opportunity to concentrate liquidity in an auction process. However, there is little benefit in holding another auction a few seconds after the opening auction when no news has arrived.

This is not just a theoretical problem; it is a real one. Out of the 3.8 million observations of stock-days in the sample, there were 1,527 cases of opening reference prices (for stocks other than Berkshire Hathaway Class A) greater than \$5,000 per share. These stocks had an average closing price of \$14.23 and none of them were over \$150. Yet the median reference price was \$100,002.80.

These stocks with bad reference prices, even though they represent less than 0.05% of stock days, severely skew the results. These particular days of bad reference prices in a tiny minority of symbols were responsible for the bulk of the limit and straddle states. The following table displays the number of observations with and without these problematic stocks. In order to avoid having these observations skew the results, these bad opening price days are eliminated from the study unless otherwise noted.²⁷

²⁶ See the Approval Order (SEC Release 34-67091), pages 22-24.

²⁷ This filter does not necessarily remove all opening reference prices with no relation to the fair market value of the stock. Any filtering technique involves a tradeoff between not filtering out bad reference prices and filtering out good ones.

Table 3: Impact of Bad Reference Prices on Numbers of Observations From Inception of LULD (May 2013) through December 31,2014				
	Total observations	Without bad reference price observations	% without bad reference price	% with bad reference price
Number of limit states	1,991,968	182,218	9.1%	90.9%
Number of trading pauses	8,515	5,973	70.1%	29.9%
Number of straddle states	4,848,578	917,042	18.9%	81.1%
<i>Note: Bad reference prices are defined as price in which the reference price is greater than \$5,000 (other than Berkshire Hathaway Class A)</i>				

Inaccurate reference prices inhibit normal trading and lead to unnecessary limit states and trading halts. Here is a specific example in a thinly traded issue name XYZ Corporation that illustrates the problem.²⁸

On December 9, 2014, XYZ Corporation previously closed at \$10.21. When the market opened, there was no trading in the opening auction. Indeed, the stock did not trade at all that day. The opening bid and ask quotes at 9:30:00.058 were \$.01 and \$99,999.00. At 9:30:00.529 the lower and upper price bands were broadcast at \$51,203.58 and \$76,805.37, indicating a reference price of \$64,004.48.

Such an inaccurate reference price created a pathological situation. Any orders to sell the stock near the previous market value would have immediately triggered a limit state, which is what happened. Any attempts to trade the stock anywhere near the fair value of the stock would have been rejected by the exchanges as outside the LULD bounds.

At 9:30:01, the stock hit its first limit state. The limit state lasted the full 15 seconds, and ended in a trading halt. No trades resulted from the trading halt, but the bands were adjusted slightly. Still, the bands of \$25,605.88 / \$38,408.82 bore no resemblance to economic reality. There were no trades at all during the day.

²⁸ Issuer name is withheld to preserve anonymity.

Here are the bands for the day:

Table 4: Upper and Lower Price Bands for an Example of a Bad Reference Price December 9, 2014		
Time	Lower	Upper
9:30:00.529	51,203.58	76,805.37
9:30:15.902	0.00	0.00
9:35:15.902	25,605.88	38,408.82
9:45:00.015	28,806.61	35,208.09
15:35:00.014	25,605.88	38,408.82
16:00:00	0.00	0.00

This pattern continued for the rest of the month. For the rest of December, the stock started the day with an immediate trading halt almost every trading day in December. One of the advantages of a trading pause is to switch the market mechanism from a continuous auction to a call auction in order concentrate liquidity in the reopening auction. However, it does little good to call another auction immediately after the opening auction when there has been no news and no trading interest in the stock. Limit states associated with this particular company alone generated over one fourth of the limit state records in the study.

The experience of XYZ Corporation and that of other very thinly traded securities demonstrates the need to adjust the procedure for determining a reference price when there is no trading in the opening auction. In such cases, the previous closing price is a far better estimate of the value than the midpoint of very wide bid and offer quotations. The limit states are concentrated in a small number of securities that have multiple limit states. Approximately 95% of the two million limit states are accounted for by these 50 securities.

VI. Impact Assessment of LULD

The data used in this study were provided by the exchanges and FINRA for the time period from the initiation of LULD in April 2012 through December 2014. The data include the dates and times of limit states, straddle states, LULD trading pauses, and upper and lower price bands, in addition to trade and quote (TAQ) data.

The following sections examine various aspect of the economic impact of LULD:

A. Impact of approaching price bands on limit order book

Any change in the market mechanism has an impact on how market participants engage with the market. One concern about the price bands is whether they exert an impact on liquidity such as a “gravitational” pull that will trigger the trading pauses. Fortunately, this is not the case with LULD. Rather than exerting a gravitational pull, the price bands exhibit a magnetic repulsion. When a limit state is reached, it is almost immediately exited. As shown below in Table 5, most of the limit states (63.3%) naturally resolve themselves within one second without triggering trading pauses. Only 4.08% of the limit states resulted in trading pauses. It appears that many market participants react to a limit state by cancelling orders. They may be reluctant to trigger a trading pause, or may view the arrival of a limit state as news requiring the reevaluation of their trading strategy.

Table 5: Limit State Duration From Inception of LULD through December 31,2014				
Limit State Duration	Frequency	Percent	Cumulative Frequency	Cumulative Percent
< .1 second	52364	28.74	52364	28.74
.1 to 1 second	63020	34.58	115384	63.32
1 to 5 seconds	56080	30.78	171464	94.10
5 to 10 seconds	2373	1.30	173837	95.40
10-14.999 seconds	948	0.52	174785	95.92
15 seconds	7433	4.08	182218	100.00

These limit states are highly concentrated in the first half hour of trading. Nearly a third (31.8%) of the limit states occur in the first half hour of trading, as shown in the following table.

Table 6: Limit States by Time of Day
From Inception of LULD through December 31,2014

Time of day	Frequency	Percent	Cumulative Frequency	Cumulative Percent
9:30-9:45	35324	19.39	35324	19.39
9:45 - 10:00	22624	12.42	57948	31.80
10:00 - 10:30	17102	9.39	75050	41.19
10:30 - 11:00	13223	7.26	88273	48.44
11:00 - 11:30	26826	14.72	115099	63.17
11:30 - 12:00	15535	8.53	130634	71.69
12:00 - 12:30	11949	6.56	142583	78.25
12:30 - 13:00	11196	6.14	153779	84.39
13:00 - 13:30	6890	3.78	160669	88.17
13:30 - 14:00	4557	2.50	165226	90.67
14:00 - 14:30	4482	2.46	169708	93.13
14:30 - 15:00	3953	2.17	173661	95.30
15:00 - 15:30	5112	2.81	178773	98.11
15:30 - 16:00	3445	1.89	182218	100.00

However, limit states are often followed almost instantly by another limit state, as shown in the following table. Over 90% of limit states are followed by a limit state within one second. These oscillations appear to result from situations in which a limit state leads to the cancellation of the order that created the limit state, and the end of the limit state prompts the resubmission of the order, leading to a repetitive loop.

Table 7: Time Between Limit States
From Inception of LULD through December 31,2014

Time between limit states	Frequency	Percent	Cumulative Frequency	Cumulative Percent
< .1 second	143506	78.76	143506	78.76
.1 to 1 second	21029	11.54	164535	90.30
1 to 5 seconds	2959	1.62	167494	91.92
5 to 10 seconds	564	0.31	168058	92.23
10-15 seconds	449	0.25	168507	92.48
> 15 seconds	4633	2.54	173140	95.02
No following limit	9078	4.98	182218	100.00

Another method of assessing the impact of approaching price bands on the limit order book is to see what happens to the top of the limit order book, the national best bid or offer. When the quote is close to a band limit, is it more likely to move toward the band or away from the band? To examine this, quotes were classified based on their location relative to the lower and upper price bands. A quote at the lower band was given a

location value of zero and a quote at the upper price band a location value of one. Quote changes in the national best bid and offer from one quote to the next were then examined to count the number of times the quote moved up or down.

A sample of stock-days were selected as follows: As the typical stock price trading range on most days does not come close to the bands, a sample of stocks were chosen with a trading range in which the high price for the day was more than 10% higher than the low price and in which there was at least one limit state. Then a random sample of 75 such Tier 1 events and 75 Tier 2 events were chosen. These sample stocks were matched with 75 Tier 1 and Tier 2 controls based on the size of the high-low trading range and market capitalization.

The locations of the quotes were then assigned to categories, and the number and percent of up and down moves was calculated for each category. The following table displays the results for the Tier 1 sample for ask quotations. Each cell contains the number of observations in that category and the percentage of the row. When the ask quote was closest to the lower price band (location 0 to 0.05), the next quote was almost equally likely to move down (32.51%) as up (32.02%). Despite proximity to the band, the price was as likely to move away from the band as toward it.

Table 8: Impact of Approaching Price Bands on Top of Book From Inception of LULD through December 31,2014				
<i>Tier 1 Ask quote</i>				
Ask location relative to lower band price	Change in ask quote from previous quote			
	Down Move	No Change	Up Move	Total
0 - .05 (near lower band)	66	72	65	203
Number	32.51	35.47	32.02	
Percent of row				
.05 - .10	75	78	74	227
	33.04	34.36	32.60	
.10 - .10	83	87	79	249
	33.33	34.94	31.73	
.15 - .20	92	98	88	278
	33.09	35.25	31.65	
.20 - .25	103	104	102	309
	33.33	33.66	33.01	
.25 - .30	109	115	109	333

	32.73	34.53	32.73	
.30 - .35	119	132	117	368
	32.34	35.87	31.79	
.35 - .40	136	162	132	430
	31.63	37.67	30.70	
.40 - .45	151	188	147	486
	31.07	38.68	30.25	
.45 - .50	160	219	161	540
	29.63	40.56	29.81	
.50 - .55	173	233	164	570
	30.35	40.88	28.77	
.55 - .60	145	198	152	495
	29.29	40.00	30.71	
.60 - .65	133	168	142	443
	30.02	37.92	32.05	
.65 - .70	116	134	116	366
	31.69	36.61	31.69	
.70 - .75	112	121	111	344
	32.56	35.17	32.27	
.75 - .80	106	113	110	329
	32.22	34.35	33.43	
.80 - .85	99	108	102	309
	32.04	34.95	33.01	
.85 - .90	88	94	92	274
	32.12	34.31	33.58	
.90 - .95	81	88	87	256
	31.64	34.38	33.98	
.95 - 1 (near upper band)	76	79	78	233
	32.62	33.91	33.48	
Total	2223	2591	2228	7042

Results for Tier 2 are shown in the next table. The results are similar. In the category closest to the lower price band on the top row, the ask price does show a higher chance of going down toward the band at the next quote change, 35.42% to 25.00%. However, this difference is suggestive and not significant at conventional significance levels.

Table 9: Impact of Approaching Price Bands on Top of Book From Inception of LULD through December 31,2014				
<i>Tier 2 - Ask quote</i>				
Ask location relative to lower price band	Change in ask quote from previous quote			
	Down Move	No Change	Up Move	Total
0 - .05 (near lower band)	17	19	12	48
Number	35.42	39.58	25.00	
Percent of row				
.05 - .10	13	16	14	43
	30.23	37.21	32.56	
.10 - .10	26	24	16	66
	39.39	36.36	24.24	
.15 - .20	30	31	21	82
	36.59	37.80	25.61	
.20 - .25	44	44	36	124
	35.48	35.48	29.03	
.25 - .30	52	49	46	147
	35.37	33.33	31.29	
.30 - .35	58	61	52	171
	33.92	35.67	30.41	
.35 - .40	78	76	66	220
	35.45	34.55	30.00	
.40 - .45	84	91	78	253
	33.20	35.97	30.83	
.45 - .50	108	145	106	359
	30.08	40.39	29.53	
.50 - .55	110	148	125	383

	28.72	38.64	32.64	
.55 - .60	86	142	113	341
	25.22	41.64	33.14	
.60 - .65	78	106	99	283
	27.56	37.46	34.98	
.65 - .70	74	94	85	253
	29.25	37.15	33.60	
.70 - .75	60	73	71	204
	29.41	35.78	34.80	
.75 - .80	57	67	65	189
	30.16	35.45	34.39	
.80 - .85	49	58	61	168
	29.17	34.52	36.31	
.85 - .90	43	54	53	150
	28.67	36.00	35.33	
.90 - .95	36	47	46	129
	27.91	36.43	35.66	
.95 - 1	37	41	38	116
	31.90	35.34	32.76	
Total	1140	1386	1203	3729

The next table examines the results for the bid quote for Tier 1. Here, the row at the bottom is the one in which the bid is closest to the upper band price. The frequency with which the bid quote went up closer to the band on the next quote update was 33.06%, slightly but not statistically higher than the 30.99% chance that the quote would move away from the band.

Table 10: Impact of Approaching Price Bands on Top of Book From Inception of LULD through December 31,2014				
<i>Tier 1 - Bid quote</i>				
Bid price relative to lower band price	Change in bid price from previous quote update			
	Down Move	No Change	Up Move	Total
0 - .05	69	70	67	206
	33.50	33.98	32.52	
.05 - .10	77	79	77	233
	33.05	33.91	33.05	
.10 - .10	83	88	82	253
	32.81	34.78	32.41	
.15 - .20	93	96	92	281
	33.10	34.16	32.74	
.20 - .25	103	112	101	316
	32.59	35.44	31.96	
.25 - .30	112	119	110	341
	32.84	34.90	32.26	
.30 - .35	119	136	117	372
	31.99	36.56	31.45	
.35 - .40	141	165	133	439
	32.12	37.59	30.30	
.40 - .45	152	192	147	491
	30.96	39.10	29.94	
.45 - .50	169	230	173	572
	29.55	40.21	30.24	

.50 - .55	157 29.57	215 40.49	159 29.94	531
.55 - .60	141 29.50	189 39.54	148 30.96	478
.60 - .65	126 29.37	162 37.76	141 32.87	429
.65 - .70	114 31.49	129 35.64	119 32.87	362
.70 - .75	110 31.88	121 35.07	114 33.04	345
.75 - .80	104 32.91	107 33.86	105 33.23	316
.80 - .85	93 31.74	101 34.47	99 33.79	293
.85 - .90	88 32.71	91 33.83	90 33.46	269
.90 - .95	78 31.58	84 34.01	85 34.41	247
.95 - 1	75 30.99	87 35.95	80 33.06	242
Total	2204	2573	2239	7016

The results for the bid quotes for Tier 2 are displayed below. The bottom row displays the relative frequency of up versus down moves when the bid quote is closer to the upper price band. Again, the results suggest that there is more of a chance of an upward move (36.14%) toward the upper band versus a downward move (25.30%) away from it. Once again, the difference is not significant at normal confidence levels.

Table 11: Impact of Approaching Price Bands on Top of Book
From Inception of LULD through December 31,2014

<i>Tier 2 - Bid quote</i>				
Bid price relative to the lower and upper price bands	Change in bid price from previous quote update			
	Down Move	No Change	Up Move	Total
0 - .05	27 31.76	32 37.65	26 30.59	85
.05 - .10	36 34.95	38 36.89	29 28.16	103
.10 - .10	44 35.48	43 34.68	37 29.84	124
.15 - .20	51 34.69	53 36.05	43 29.25	147
.20 - .25	62 35.43	62 35.43	51 29.14	175
.25 - .30	64 32.00	78 39.00	58 29.00	200
.30 - .35	83 34.30	89 36.78	70 28.93	242
.35 - .40	108 34.39	119 37.90	87 27.71	314
.40 - .45	125 34.63	137 37.95	99 27.42	361
.45 - .50	118 28.37	180 43.27	118 28.37	416
.50 - .55	99 28.78	134 38.95	111 32.27	344
.55 - .60	73	97	82	252

	28.97	38.49	32.54	
.60 - .65	65	76	72	213
	30.52	35.68	33.80	
.65 - .70	52	63	56	171
	30.41	36.84	32.75	
.70 - .75	42	53	54	149
	28.19	35.57	36.24	
.75 - .80	41	52	45	138
	29.71	37.68	32.61	
.80 - .85	33	38	41	112
	29.46	33.93	36.61	
.85 - .90	35	34	37	106
	33.02	32.08	34.91	
.90 - .95	27	29	31	87
	31.03	33.33	35.63	
95 - 1	21	32	30	83
	25.30	38.55	36.14	
Total	1206	1439	1177	3822

B. Impact on erroneous trades

One of the important functions of a securities market is to discover the price of a security. However, there are clearly times when a trade occurs at a price that does not reflect a fair and orderly market. These can occur due to a variety of causes, including false information hitting the market, “fat finger” trading mistakes, liquidity gaps, and machine malfunctions. It is important that there be a mechanism in place for a swift and fair adjustment when such situations occur.

Breaking trades is a process fraught with difficulties. Investors normally rely upon execution reports in making follow-on trading decisions. After receiving an execution, an investor may or may not make other trades as a result. For example, an investor may step in and provide liquidity by purchasing a stock after its price has suddenly fallen, thus reducing the descent of the stock price. This investor may later sell the stock after the price has recovered. Such activity benefits the market by producing more stable prices. However, if the purchase transaction is later cancelled, this investor has an unintended naked short position with all of its attendant risks.

Investors may be reluctant to step in and provide needed liquidity during times of market turmoil if they suspect that their trades may be broken later. It is thus important to provide mechanisms to reduce the possibility that trades will be broken, as well as provide predictability as to what types of trades will be broken.

Subsequent to the Flash Crash, the exchanges and FINRA worked together to develop new rules for the cancellation of Clearly Erroneous Executions (CEEs).²⁹ A request for a trade cancellation as clearly erroneous has to be made within 30 minutes of the trade. If the challenged trades occurred on multiple exchanges, the primary listing exchange generally takes the lead and organizes a conference call to discuss the issue. Although the rules do provide some limited flexibility for human judgment, the practice is to determine a reference price that reflects the price of the security just before the suspect event started. If the price of the suspect trades deviates by more than a specific amount, it is likely that the trades will be cancelled as clearly erroneous. The exchanges do not have the ability to cancel trades that deviate less than the numerical guidelines from the reference price. The guidelines for cancelling trades are as follows:

Table 12: Numerical Guidelines for Cancelling Clearly Erroneous Executions (CEEs)		
Reference Price	Regular Trading Hours	Pre-Opening and After Hours
≤ \$25.00	10%	20%
\$25 to \$50	5%	10%
> \$50.00	3%	6%
Multi- Stock Events 5-20 stocks	10%	10%
Multi-Stock Events 20+ stocks	30%	30%
Leveraged ETF/ETN securities	Regular Trading Hours Numerical Guidelines multiplied by the leverage multiplier (e.g.. 2x)	Regular Trading Hours Numerical Guidelines multiplied by the leverage multiplier (e.g. 2x)

A comparison of the CEE numerical guidelines with the LULD parameters makes it clear that the current design of LULD can still permit CEEs to occur. Note that there are major

²⁹ The exchanges have long had rules to cancel CEEs, but the Flash Crash indicated a need to amend the rules, in particular to deal with multi-stock events. See <http://www.sec.gov/rules/sro/bats/2010/34-62886.pdf>

differences in the design of the CEE numerical guidelines compared with the LULD parameters. These include:

Reference price: The LULD reference price is based on a five minute average of prices. The CEE reference price is generally the last consolidated trade before the suspect event. However, one very important difference is that there is human discretion in determining the CEE reference price. The exchange (or committee, if it affects more than one exchange) can examine the facts and circumstances of the particular situation to determine the appropriate response.

Percentage guidelines: The LULD bands are typically much wider than the numerical guidelines.

Price breakpoints: The LULD parameters have three price categories, with breakpoints at \$0.75 and \$3.00. The CEE numerical guidelines also have three price categories, but with breakpoints at \$25.00 and \$50.00 dollars.

Time of day: The LULD parameters are different at different times during regular trading hours, but do not apply outside regular trading hours. The CEE numerical guidelines do not change during regular trading hours but do apply outside regular trading hours.

Tiers: The LULD parameters specify two different tiers, while there is no tiering in the CEE numerical guidelines.

Thus, it is clear that CEEs can still occur under the current LULD rules. Here are some possible scenarios:

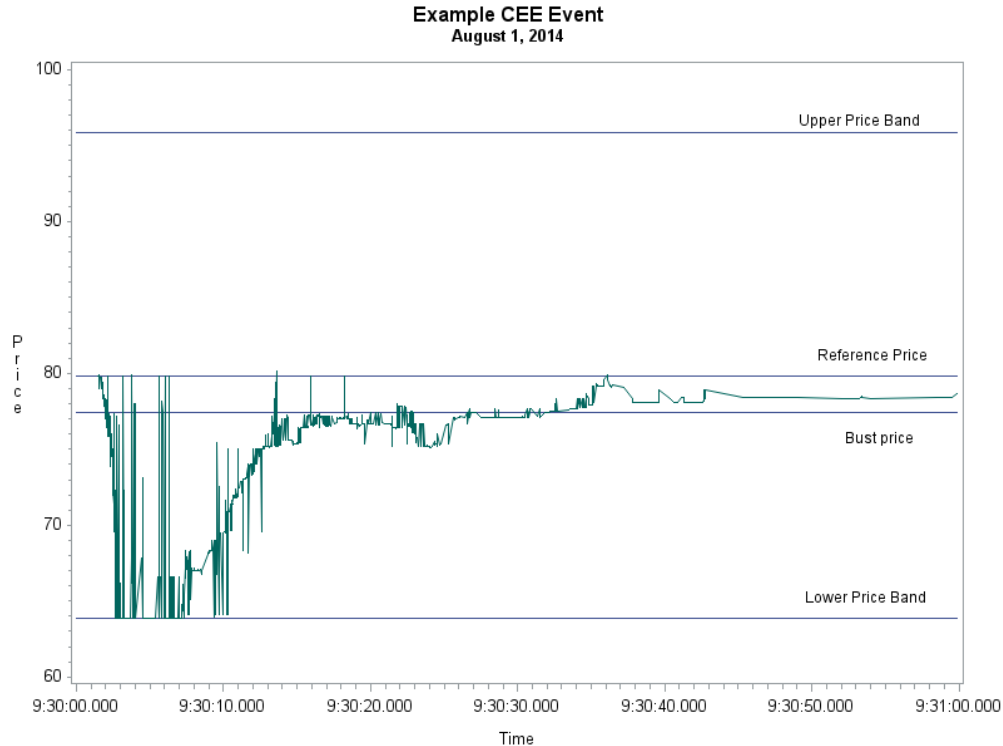
Outside regular trading hours: As LULD does not apply outside regular trading hours, a CEE can occur at those times.

LULD parameters larger than CEE guidelines: Suppose that both the LULD reference price and the last consolidated sale price for a Tier 1 stock at 10:00 am is \$100, leading to lower and upper bounds of \$95 and \$105. A trader mistakenly enters a large market sell order and the price instantly collapses in a mini flash crash as low as \$95.01 before quickly rebounding back to around \$100. As the CEE numerical guidelines are 3% for a stock in that price category, the trades that occurred below \$97 are likely to be broken. While the LULD guidelines would prevent a fall below \$95 in this situation, they would not have prevented the breakable trades between \$95 and \$97.

Here is an example of just such an event. On August 1, 2014, a stock³⁰ opened at 9:30:01.467. The opening print and first reference price was \$79.86. The band size was 20%, and thus the lower and upper band prices were \$63.89 and \$95.83 respectively. However, the numerical CEE guideline for a stock in this price range is only 3%. Almost

³⁰ Once again, the names of specific issuers are withheld to preserve anonymity. This example company is, however, different from the example company in the previous example of bad opening reference prices.

immediately after the open, the stock price plunged. The offer hit the lower band of \$63.89, triggering a limit state that lasted 4.132 seconds. During that state, 340 trades took place at the lower band of \$63.89. Within seconds, the price rebounded to near the opening price.



All trades at \$77.46 or below were busted, resulting in 3,080 cancellations across 11 SROs.

Note that in this CEE event, the LULD bands created an effective boundary that prevented even more trades from printing at even lower prices. This prevented the possibility of executing trades at prices such as \$.01 as occurred during the Flash Crash.

However, LULD did not prevent the trades that were later cancelled. This indicates that in this situation, at least, a narrower band would have prevented more cancelled trades.

Slow reference price update: As reference prices are updated no more frequently than every 30 seconds, a CEE could occur as follows. At 10:00:00 a new reference price of \$100 is determined for a Tier 1 stock, with lower and upper LULD bounds at \$95 and \$105. The stock rises to \$104 on the positive news, when a fat finger trade momentarily pushes the price back down to \$100 before it rebounds back to \$104. The trades at \$100, being more than 3% below the last consolidated trade, could be broken even though they are exactly the same as the LULD reference price.

One of the goals of LULD is to prevent erroneous executions that must be cancelled. To assess the impact of LULD on erroneous executions, trade cancellation events were identified by examining the trade data for cancellation records on one or more of the

exchanges in which there were at least six cancelled trade reports.³¹ A Multiple Cancellation Event (MCE) is defined as an event in which multiple trades were cancelled for a single stock during the day. For example, an event in which 10 trades were cancelled for one stock is counted as one MCE. If 10 trades are cancelled for one stock and 15 for another at the same time, that is counted as two MCEs. Cancellation data were available from October 2006 through March 2015. Records of breaking of Clearly Erroneous Executions were not available back that far, so MCEs are used in order to give a longer sample history.

Table 13: Multiple Cancellation Events by Time of Day
October 2006 through March 2015

Time	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Pre-open	881	14.47	881	14.47
9:30-9:45	2112	34.70	2993	49.17
9:45 - 15:35	2468	40.55	5461	89.72
15:35 - 16:00	196	3.22	5657	92.94
After close	430	7.06	6087	100.00

The bulk of these MCEs, 78.5%, occurred during regular trading hours, while 14.5% occurred before the open and 7.0% after the close. This indicates that the thin trading that occurs outside of regular trading hours makes it more likely that a trading mistake will result in price dislocations severe enough to warrant a cancellation. For example, a large order that is intended for the opening auction but that is mistakenly executed before the open can have a much larger effect on prices than a similar order during regular market hours.

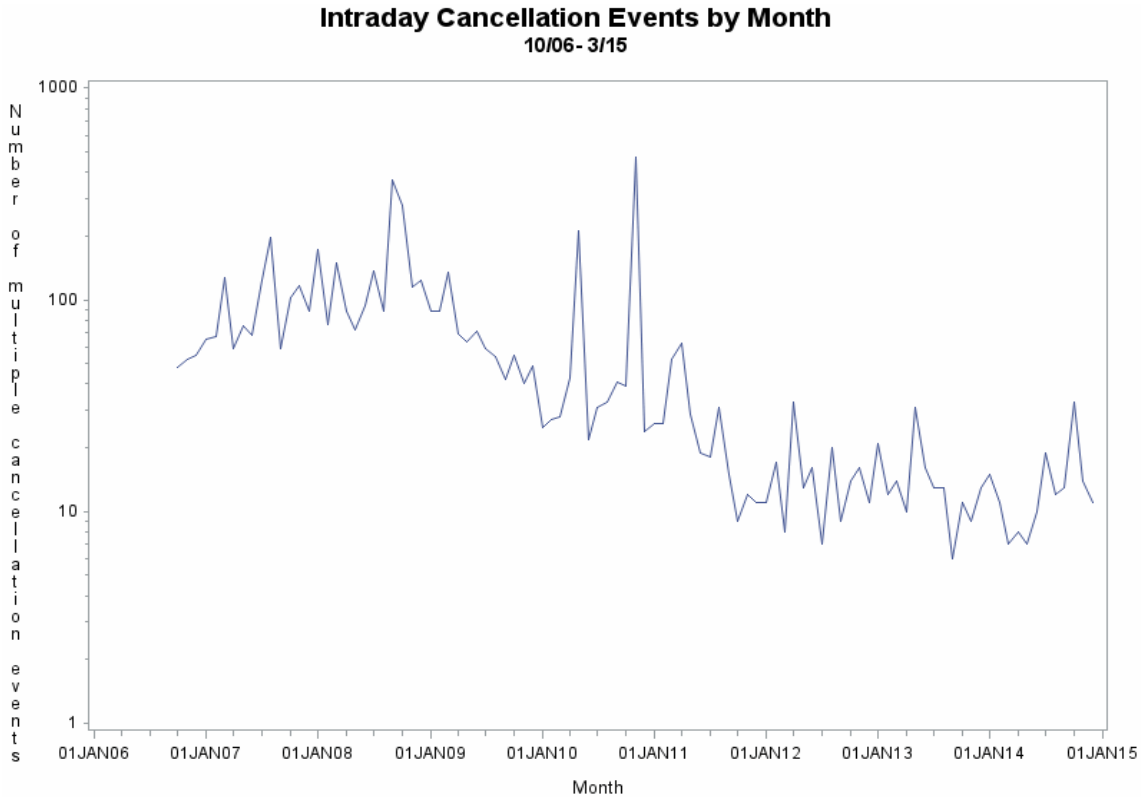
Of the MCEs that occurred during regular trading hours, 44.2% of them occurred during the first 15 minutes of trading. The high trading volume and volatility near the open make it much more likely for mistakes to occur that result in clearly erroneous executions.

In terms of market capitalization, small cap stocks with a market capitalization of less than \$100 million accounted for 22.5% of the MCEs, while stock greater than \$1 billion accounted for 51.6%, as shown in the following table.

³¹ Cancellations of trades reported off-exchange (Exchange code = "D" in the TAQ data) were not included in defining Multiple Cancellation Events for this study as such cancellations typically involved a small number of trades.

Table 14: MCEs by Market Capitalization				
October 2006 through March 2015				
	Frequency	Percent	Cumulative Frequency	Cumulative Percent
< \$100 million	1366	22.49	1366	22.49
\$100m to \$1 billion	1574	25.91	2940	48.40
> \$1 billion	3134	51.60	6074	100.00

Since LULD is only in effect during regular trading hours, the remainder of this section will concentrate on intraday MCEs. The first task is to examine the impact of LULD on the total number of MCEs. The following chart displays the number of intraday MCEs each month during the sample period:



The graph demonstrates the drop in cancellation events from the levels of earlier years.

It is quite clear that the number of MCEs has declined substantially from the rate experienced prior to the Flash Crash. This is likely due to the circuit breakers and LULD.

In order to see whether there are statistically significant differences, this period is divided into four time periods. Period 1 is the time period from October 2006 through September 2010. This generally corresponds to the post-NMS pre-circuit breaker era. September 2010 was chosen as the end of the first period as that was the month during which the single stock circuit breakers were rolled out to the entire Russell 1000 index in addition

to various ETFs. Period 2 is the period from October 2010 through March 2013. This was the period during which single stock circuit breakers were rolled out and in operation. Period 3 is the rollout period for LULD, and Period 4 is the time after the complete rollout of LULD. The following table displays the results:

Table 15: Intraday Multiple Cancellation Events Before and After LULD				
Period	Dates	Number of months	Mean number of Intraday Multiple Cancellation Events per month	Standard error
1: Pre-single stock circuit breakers	10/06 – 9/10	48	90.48	9.60
2: Single-stock circuit breakers	10/10-3/13	30	35.63	15.29
3: Rollout of LULD	4/13 – 4/14	13	12.54	1.75
4: Full LULD Operation	5/14 – 3/15	11	13.45	2.44

The raw statistics indicate a drop of $90.48 - 13.45 = 77.03$ intraday cancellation events per month, which is highly significant ($t=7.77$, $p < .001$). This shows that there has been a significant drop in the number of cancellation events from the pre-circuit breaker era to the LULD era.³²

Clearly, one would expect more cancellation events to occur during periods of high volatility, as occurred during the financial crisis. To control for volatility, a Poisson regression model was estimated to control for volatility using the VIX index as a proxy for market volatility.³³ Dummy variables were used to indicate the periods of the circuit-breaker era along with the rollout and full implementation of LULD. The following equation was estimated with standard errors in parentheses:

³² Eliminating May 2010, the month of the Flash Crash, reduces the average number of MCEs per month in the pre-single stock circuit breaker era to 87.89 with a standard error of 9.44.

³³ VIX is an index of volatility that is derived from the market prices of S&P500 index options.

$$\begin{aligned}
&\text{Number of cancellation events per month} \\
&= 3.97 + .02 * \text{VIX} - .81(\text{single stock circuit breakers}) - 1.74*(\text{LULD Rollout}) \\
&\quad (0.04) \quad (0.001) \quad (-.04) \quad (0.08) \\
&\quad -1.67*(\text{LULD_Full}) \\
&\quad (0.09)
\end{aligned}$$

The coefficients are all highly statistically significant with p-values less than 0.001. The negative signs on the coefficients indicate that cancellation events became significantly less frequent after the introduction of single stock circuit breakers and LULD. The coefficient for the impact of the LULD era is approximately twice as great as that of single stock circuit breakers alone.³⁴

It is clear that there has been a dramatic reduction, although not a total elimination, of cancellation events. This is undoubtedly a combination of several factors, including most notably circuit breakers and LULD. In addition, there has been a generally higher degree of diligence in the industry to prevent costly trading mistakes, as well as new rules such as the Market Access Rule (SEC Rule 15c3-5).

C. Appropriateness of the percentage parameters

The appropriate percentage parameters for the width of the band around the reference price represent a tradeoff between two opposing concerns. In the language of statistics, it is a tradeoff between Type I and Type II errors. Bands that are too wide will permit trades to occur at prices that don't properly reflect supply and demand in the market. Bands that are too narrow will result in excessive disruptions to the price discovery, liquidity provision, and hedging functions of the market.

If an institutional trader executes an order in a sloppy manner with a very large short-term price impact, other market participants usually respond quite quickly and push the price back to its appropriate level, making a profit in the process. How paternalistic should the market mechanism be in order to protect investors from their own trading mistakes? This is a judgment call. Making investors experience the consequences of their mistakes imposes a powerful discipline that should make investors more careful about entering orders. However, the risk is that a retail market order may get executed during such an event, or that stop orders or the short sale restriction may be erroneously triggered. Especially large trading mistakes could lead to the insolvency of important market participants and undeserved windfalls for others.

³⁴ These results are robust to the exclusion of May 2010, the month of the Flash Crash. There has still been a significant reduction in the number of multiple cancellation events subsequent to the introduction of LULD.

A market structure that provides some protection even from one's own mistakes reduces not only the risk to a single entity but also systemic risk as well. As risk is priced into all services provided, a lower risk market structure is also a lower cost market structure.

The appropriate band size should prevent truly erroneous trades from occurring while allowing for normal price discovery. The historical distribution of stock returns can be used to help inform the discernment of when abnormal price movements should trigger a pause.

One approach to assessing the size of the percentage parameters is to look at the frequency distribution of intraday stock returns. This can provide some insight as to reasonable price moves that could take place within day. A sudden price movement that is far larger than the normal daily return could very well reflect a clearly erroneous transaction.

The following table displays the range of U.S. daily stock prices (expressed as a percentage of the low price for the day) from 2010 to 2014:

Table 16: Intraday Range for U.S. Stock Prices 2010-2014 By Price Category					
Price category	Number of observations	50 th Percentile	95 th Percentile	99 th Percentile	99.5 th Percentile
< \$.75	134,416	7.86	26.19	49.81	65.45
\$.75 - \$3	707,636	5.11	15.86	28.38	35.83
> \$3	7,372,538	2.00	7.09	12.26	15.28

This table shows that for stocks over \$3.00, which is majority of stocks, prices on a typical day move in a range of about 2% during the entire day. At the 95th percentile, which is approximately one trading day per month, prices generally move in a range about 7%. At the 99.5th percentile, which is approximately one trading day per year, prices generally move in a range around 15% for the entire day.

Lower-priced stocks are more volatile. Stocks in the \$.75 to \$3.00 category move within a range of approximately 36% at the one-day-per year 99.5% level, and stocks less than \$.75 move approximately 65% at the 99.5% level.

Another method for informing the band size discussion is to look at changes in reference prices to get a sense of what the distribution of price changes look like. This provides more granularity than daily open to close price ranges. Although the bands can update as often as every 30 seconds, in practice they change much less frequently because they are only changed when stocks have moved by 1% or more. The following table displays the frequency of band updates.

Table 17: Descriptive Statistics on Number of Band Updates
per Day
From Inception of LULD through December 31,2014

Mean	6.28
Standard Deviation	4.73
Min	1 ³⁵
Median	5
75 th percentile	7
95 th percentile	14
99 th percentile	24
Max	336

The absolute sizes of these updates can also help to inform the selection of the optimal band size. The following table displays the percentiles of the distribution by price level.³⁶ For stocks priced above \$3, one out of 100 changes is at approximately 5%. As the median update is five times per day, this implies that about one day out of 20 a stock may move 5% from one update to the next.

Table 18: Absolute Percentage Changes in LULD Reference
Prices
LULD Inception through December 2014

Price	Number of reference price changes	Percentile				
		50 Median	95	99	99.5	99.9
< \$.75	23,883	1.82	25.00	27.27	28.57	33.33
\$.75 - \$3	1,029,940	1.28	3.45	6.01	7.41	11.56
> \$3	3,896,924	1.07	2.37	4.76	6.67	17.16

³⁶ These updates include those following a trading halt. Although they do not represent normal trading, the new price following a halt presumably reflects the true change in the fair market value of the stock.

Here is the breakdown using the price breakpoints from the CEE guidelines:

Table 19: Absolute Percentage Changes in LULD Reference Prices <i>LULD Inception through December 2014</i>						
Price	Number of observations	Percentile				
		Median	95	99	99.5	99.9
< \$1	147,270	1.33	4.76	24.00	25.81	28.57
\$1-\$25	3,565,729	1.13	2.86	5.38	7.01	13.58
\$25-\$50	779,409	1.03	1.84	3.98	7.05	18.95
> \$ 50	458,339	1.01	1.58	3.00	4.47	20.43

Here is the breakdown by time of day. There is significantly more volatility during the first and last 15 minutes of the trading day:

Table 20: Absolute Percentage Changes in LULD Reference Prices <i>LULD Inception through December 2014</i>						
Time	Number of observations	Percentile				
		Median	95	99 th	99.5	99.9
9:30-9:45	622,584	1.17	3.46	7.14	10.43	26.88
9:45 - 10:00	376,483	1.10	3.00	9.67	14.93	20.91
10:00 - 10:30	611,070	1.09	2.63	5.16	6.86	13.64
10:30 - 11:00	469,432	1.08	2.47	4.76	6.17	11.40
11:00 - 11:30	397,968	1.09	2.49	4.72	6.08	10.05
11:30 - 12:00	348,063	1.09	2.42	4.51	5.79	9.87
12:00 - 12:30	297,029	1.09	2.46	4.58	5.84	9.60
12:30 - 13:00	263,028	1.10	2.50	4.61	5.88	10.05
13:00 - 13:30	255,832	1.09	2.40	4.40	5.58	9.32
13:30 - 14:00	251,778	1.09	2.44	4.54	5.72	9.46
14:00 - 14:30	273,199	1.09	2.39	4.34	5.50	8.89
14:30 - 15:00	261,643	1.09	2.45	4.50	5.68	9.36
15:00 - 15:30	275,618	1.09	2.46	4.49	5.63	9.20
15:30 - 16:00	246,917	1.12	3.23	15.22	24.32	27.27

The following table shows the 99th percentile of reference price updates for various band sizes, times, and prices:

Table 21: 99 th Percentile of Reference Price Updates From Inception of LULD through December 31,2014				
Band Size %	Time	Price	Number of observations	99 th percentile
5	9:45 - 15:35	> \$3	387,183	1.26
10	9:30-9:45	> \$3	42,964	2.45
10	9:45 - 15:35	\$.75 - \$3	16,890	6.43
10	9:45 - 15:35	> \$3	2,808,238	4.63
10	15:35 - 16:00	> \$3	9,944	1.27
20	9:30-9:45	\$.75 - \$3	1,821	10.69
20	9:30-9:45	> \$3	449,657	7.11
20	9:45 - 15:35	< \$.75	13,212	7.14
20	9:45 - 15:35	\$.75 - \$3	839,568	5.77
20	9:45 - 15:35	> \$3	61,834	5.83
20	15:35 - 16:00	\$.75 - \$3	1,149	6.56
20	15:35 - 16:00	> \$3	126,548	4.93
40	9:30-9:45	< \$.75	1,024	10.29
40	9:30-9:45	\$.75 - \$3	117,119	7.46
40	9:30-9:45	> \$3	7,234	19.01
40	9:45 - 15:35	\$.75 - \$3	1,504	6.01
40	9:45 - 15:35	> \$3	104	2.29
40	15:35 - 16:00	< \$.75	804	6.85
40	15:35 - 16:00	\$.75 - \$3	51,720	5.75
40	15:35 - 16:00	> \$3	3,094	6.79
100	9:30-9:45	< \$.75	2,735	13.64
100	9:45 - 15:35	< \$.75	132	60.00
100	15:35 - 16:00	< \$.75	5,942	29.63

The relative rarity of large price updates of comparable magnitude to the wider price bands indicate that the bands could be narrowed substantially without causing undue restrictions on trading.

However, the reference prices are based on a five minute average. As such, they give a good measure of the average trend in fair prices. However, such an average price may not be greatly affected by a “mini” flash crash, even one that produces a few erroneous prices.

Another way to get a sense of the distribution is to examine minute by minute changes in stock prices and especially to examine short-term reversals. A large price swing that is quickly reversed could reflect poor price formation, while a large price swing that continues reflects a true change in the fair market value of the assets. Reversals, however, do not necessarily indicate poor price discovery, but can be the natural artifact of a wide bid-ask spread.

To examine this, the minute by minute returns were estimated for all U.S. stock trades in October 2014, the month with the highest volatility in the sample period. The return in one minute was deemed to be reversed if the next minute's return changed sign and was at least half as large as the original return in the previous minute. If the return was not reversed, the next minute was deemed a continuation. The following table shows the results for those minutes in which the absolute return was at least 3%. The table shows that even for very large absolute returns, the majority of them are not reversed from one minute to the next. The large number of continuations, even for rather large price movements highlights the tradeoff in setting the bands.

Table 22: Price Reversals and Continuations October 2014			
Absolute return	Number of events	% Reversals	% Continuations
Tier 1 stocks above \$3			
3 - 4%	865	21.50	78.50
4 - 5%	331	23.26	76.74
5 - 10%	276	18.84	81.16
10 - 20%	41	31.71	68.29
> 20 %	6	33.33	66.67
Tier 2 stocks above \$3			
-3 - +3%	15452	20.30	79.70
3 - 4%	16177	18.94	81.06
4 - 5%	6277	19.10	80.90
5 - 10%	6135	20.07	79.93
10 - 20%	626	18.69	81.31
> 20 %	131	17.56	82.44
Tier 2 stocks below \$3			
3 - 4%	20718	18.51	81.49
4 - 5%	8947	18.16	81.84
5 - 10%	10054	18.53	81.47
10 - 20%	1145	17.29	82.71
> 20 %	136	21.32	78.68

While narrower bands might prevent more trades at inferior prices, they would also inhibit legitimate price movements. Some securities naturally have bid-ask spreads wide enough that bid-ask bounce could trigger trading halts in a market with narrower bands. It is a judgment call to determine the best band sizes. If bands are narrowed for some

stocks in order to prevent more erroneous trades, then consideration should be given to creating a Tier 3 for especially illiquid symbols.

D. Length of limit state

Is the length of the limit state appropriate to allow for liquidity replenishment when the limit state is reached? A longer limit state may permit more time for needed liquidity to be replenished. On the other hand, there are risks to a limit state that is too lengthy. For example, if the ask is pegged at the lower price band as bad news has just arrived, a lengthy limit state before a trading pause just delays the market's move to the new lower price. Even worse, uninformed retail investors may have their orders filled at the ask price during the limit state, even though their orders would likely have been filled at better prices in the reopening auction.

In the vast majority of cases, limit states resolve themselves naturally in a short period of time. The majority of limit states end within less than one second, as displayed above in Table 5. For limit states that resolve themselves without a trading halt, the length of time was clearly adequate for the market to revert.

Likewise, over 99% of limit states resolve themselves naturally without ending in a trading pause. The same general pattern holds for large as well as small capitalization stocks. Over 99% of the limit states in stocks with a market capitalization of over \$1 billion resolve themselves without a trading pause, and the vast majority of these are resolved in one second. This is strong evidence that market participants respond to hitting limits, either by cancelling potentially erroneous orders, or by providing additional liquidity.

The following tables demonstrate the duration of limit states by categories of market capitalization and tier status.

Table 23: Duration of Limit States by Market Capitalization From Inception of LULD through December 31,2014				
Tier 1				
Limit state duration seconds	Market Capitalization (\$million)			
	< \$100 million	\$100m to \$1 billion	> \$1 billion	Total
< .1 second	4	112	1664	1780
Row percent	0.01	0.18	2.61	2.79
Column percent	13.33	56.00	2.62	
.1 to 1 second	2	37	39940	39979
	0.00	0.06	62.61	62.67
	6.67	18.50	62.84	
1 to 5 seconds	0	17	21722	21739
	0.00	0.03	34.05	34.08
	0.00	8.50	34.18	
5 to 10 seconds	0	3	88	91
	0.00	0.00	0.14	0.14
	0.00	1.50	0.14	
10-15 seconds	0	6	40	46
	0.00	0.01	0.06	0.07
	0.00	3.00	0.06	
15 seconds	24	25	104	153
	0.04	0.04	0.16	0.24
	80.00	12.50	0.16	
Total	30	200	63558	63788
	0.05	0.31	99.64	100.00

Table 24: Duration of Limit States by Market Capitalization-
From Inception of LULD through December 31,2014

Tier 2

Limit state duration seconds	Market Capitalization \$million			
	< \$100 million	\$100m to \$1 billion	> \$1 billion	Total
< .1 second	32642	9240	5887	47769
Row percent	40.20	11.38	7.25	58.83
Column percent	66.29	45.85	49.88	
.1 to 1 second	6634	5043	3785	15462
	8.17	6.21	4.66	19.04
	13.47	25.02	32.07	
1 to 5 seconds	7179	4448	1867	13494
	8.84	5.48	2.30	16.62
	14.58	22.07	15.82	
5 to 10 seconds	435	278	61	774
	0.54	0.34	0.08	0.95
	0.88	1.38	0.52	
10-15 seconds	602	350	49	1001
	0.74	0.43	0.06	1.23
	1.22	1.74	0.42	
15 seconds	1747	793	154	2694
	2.15	0.98	0.19	3.32
	3.55	3.94	1.30	
Total	49239	20152	11803	81194
	60.64	24.82	14.54	100.00

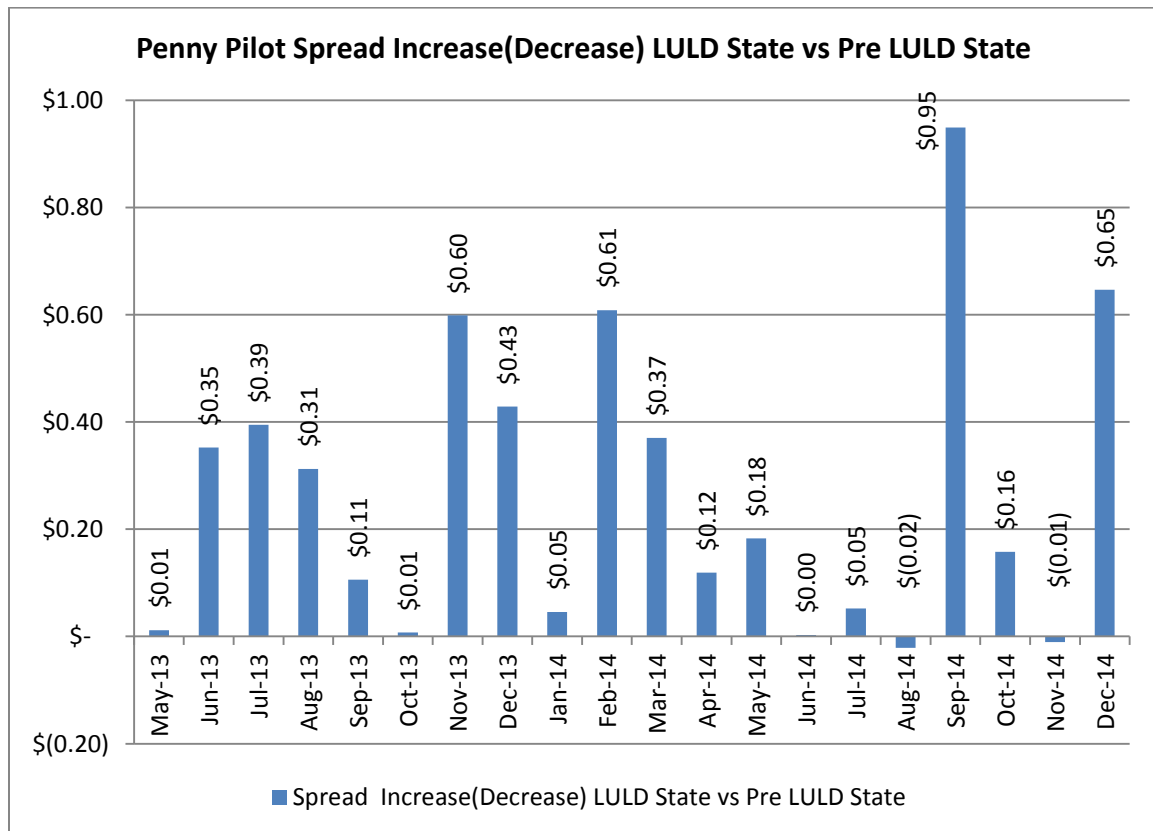
Would allowing limit states even longer than 15 seconds permit more liquidity to arrive without triggering a trading pause? Given the relatively few limit states that are resolved between 10 and 15 seconds, it is doubtful that much additional liquidity would arrive between 15 and 20 seconds or in some longer interval.

E. Options market concerns regarding limit states

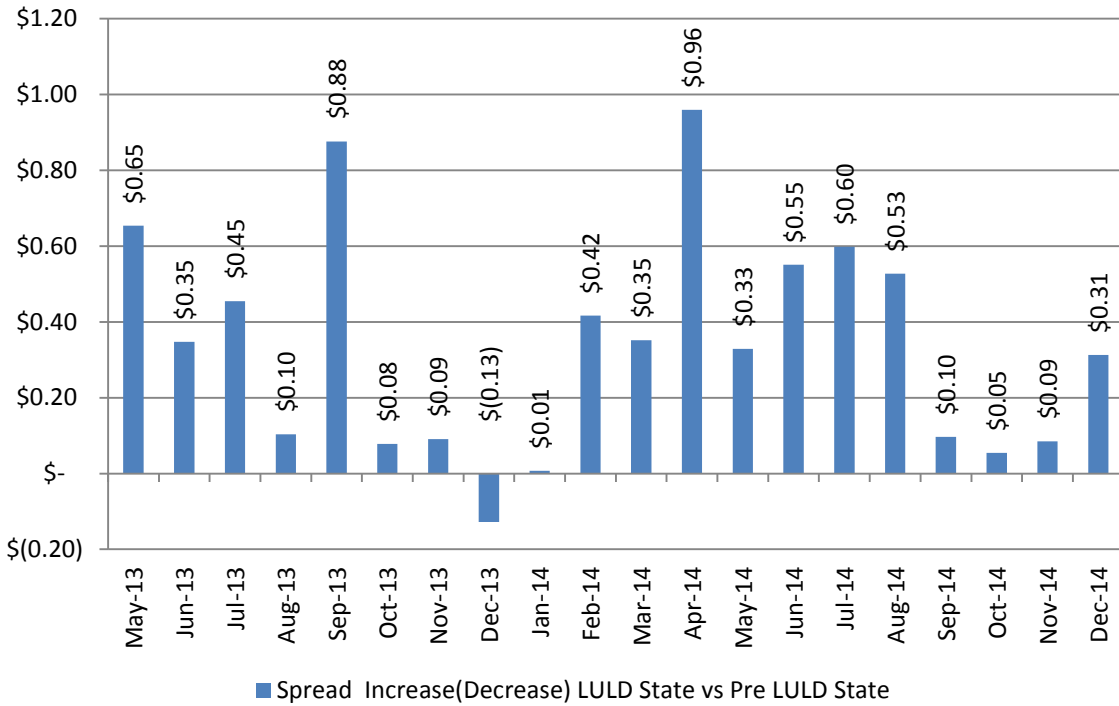
Concern was expressed during the comment period that limit states may impact market quality and liquidity in the options markets. In general, the options exchanges halt trading in listed options during trading pauses. During limit states, the options exchanges reject market orders but permit limit orders. In particular, the trading restrictions imposed under LULD may impair the ability of options market participants to hedge exposures. One would expect such an impairment to result in wider bid-ask spreads and reduced depth. However, any impact is confounded by the fact that limit states result from jumps in stock prices. Such discontinuous moves are a sign of high volatility that would lead to wider spreads and lower depth.

The exchanges examined the impact of limit states on options market bid-ask spreads and depth for stocks that entered limit states. The equally weighted average bid-ask spreads and depths for all traded options on each stock were calculated for a period 15 seconds before, during, and 15 seconds after each limit state. Inactive options were weighted the same as the most heavily traded. In general, as would be expected in a time of increased volatility, spreads widened and depths decreased.

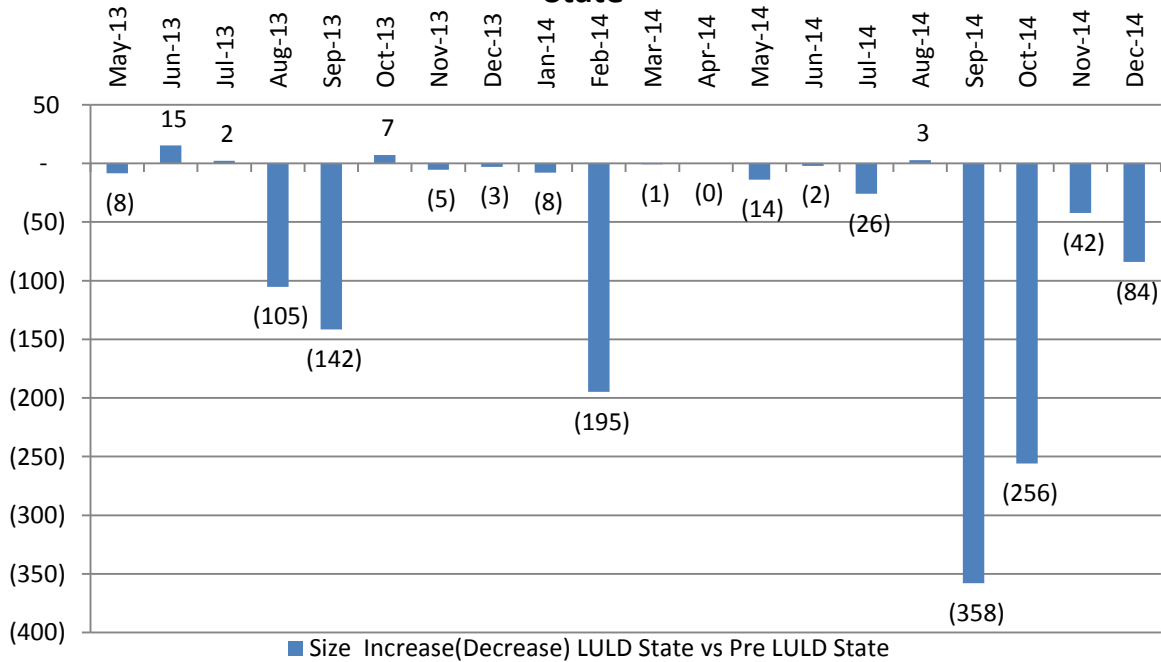
The following charts provided by the exchanges display the results on a month-by-month average basis for both penny-pilot and non-penny-pilot stocks.



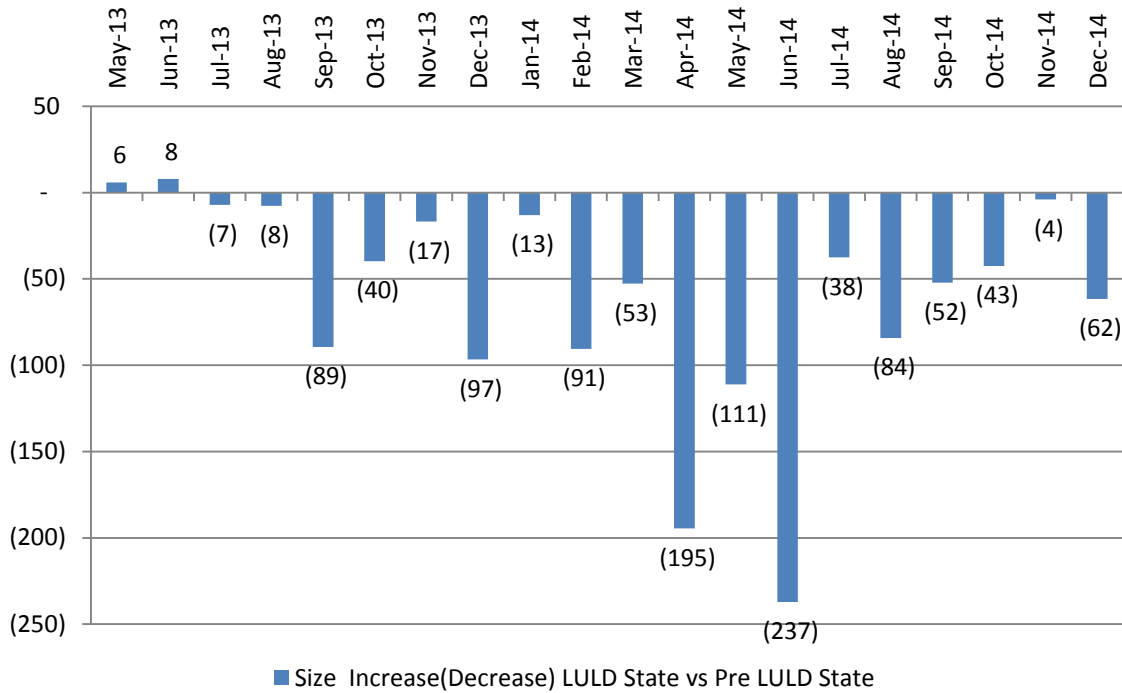
Non-Penny Pilot Spread Increase(Decrease) LULD State vs Pre LULD State



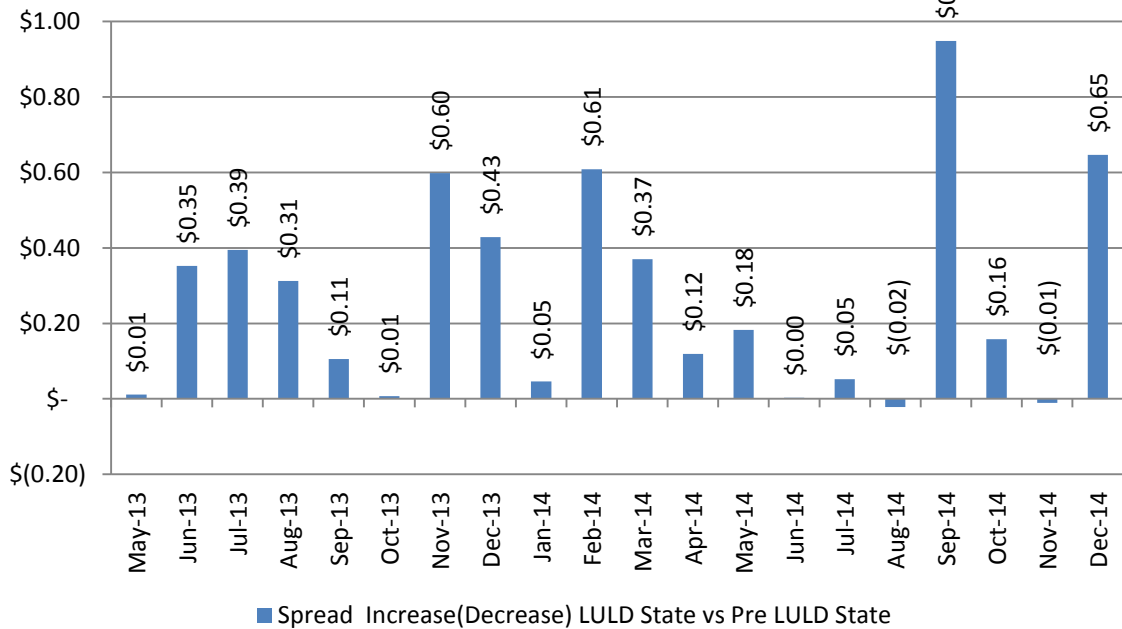
Penny Pilot Size Increase(Decrease) LULD State vs Pre LULD State



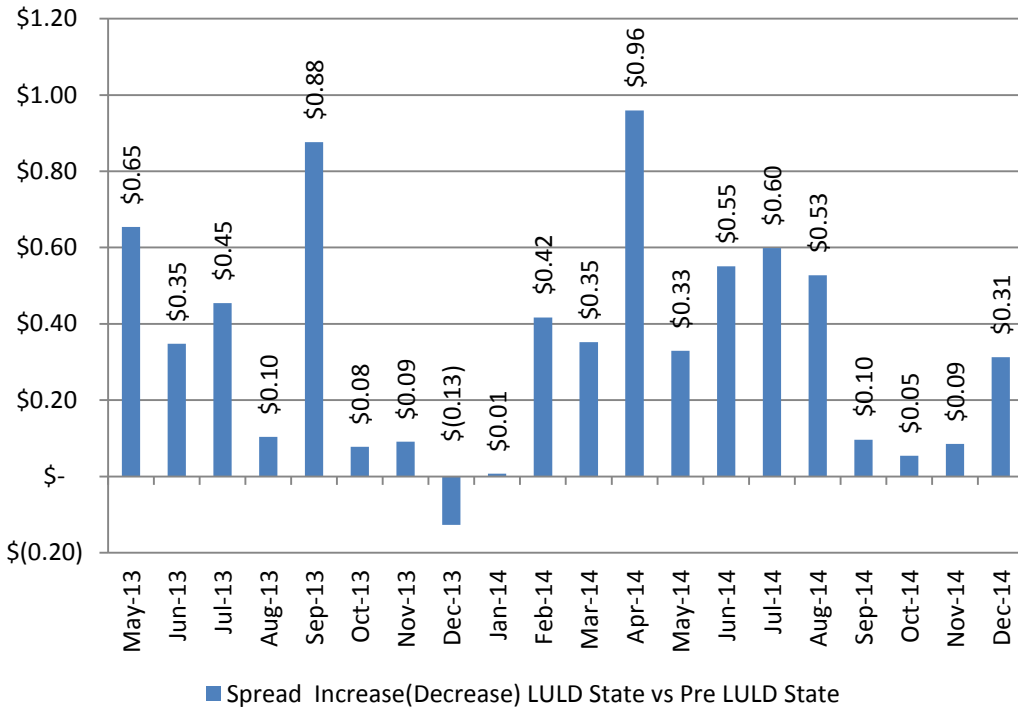
Non-Penny Pilot Size Increase(Decrease) LULD State vs Pre LULD State



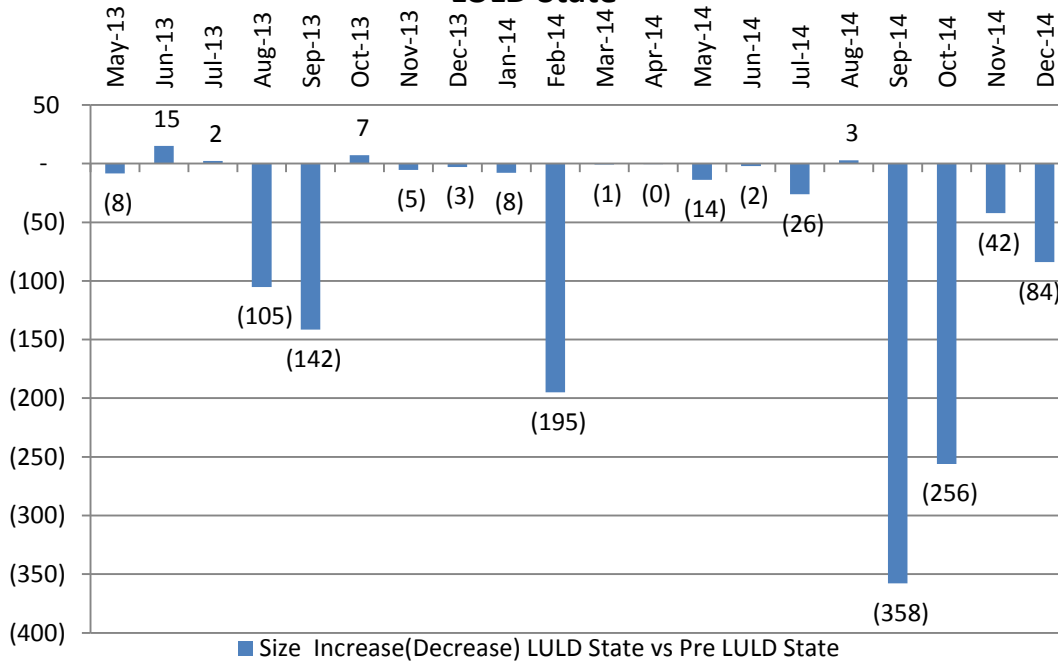
Penny Pilot Spread Increase(Decrease) LULD State vs Pre LULD State

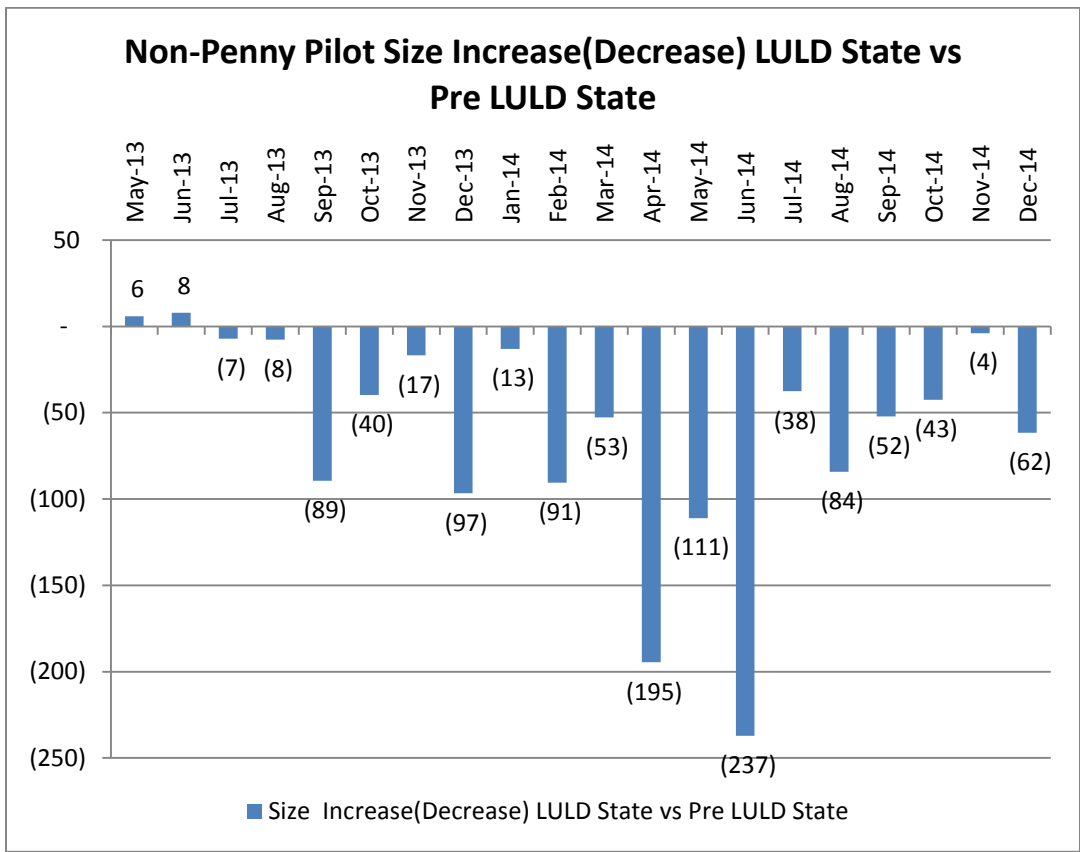


Non-Penny Pilot Spread Increase(Decrease) LULD State vs Pre LULD State



Penny Pilot Size Increase(Decrease) LULD State vs Pre LULD State





The widening of bid-ask spreads in options during a limit state is not necessarily a problem, and is actually a good response that helps to stabilize the market. During a limit state, one half of the equity market in a stock is effectively closed. For example, if the ask is pegged at the lower band price, a liquidity-seeking investor can only buy the equity and not sell it. The ability to sell the stock is effectively shut off during the limit state in this example for option market makers as well as other investors. One would naturally expect bid-ask spreads to widen to reflect the increased risk to the market maker. Indeed, since selling a call or purchasing a put is economically similar to selling a stock, such activity would add further pressure on the stock price due to hedging activity by market makers. Wider spreads in the option market during limit states deter investors from getting around the limit state by trading with options rather than cash equities.

F. Process for entering limit states and impact of straddle states

The major defect observed in entering the limit state is the bad opening reference price problem described above. When the reference price is far away from the fair market value of the stock, the lower and upper price bands will not encompass the fair market value of the stock. Attempts to provide liquidity at the fair market value will trigger limit states and unnecessary trading pauses. This problem can be fixed rather easily by using the previous closing price as the reference price when there is no trade in the opening auction.

Commenters were concerned that the process for entering limit states would not work because order prices would not exactly equal the band price, but would instead be outside the bands. In practice this does not happen because exchanges must re-price or reject orders that are priced more aggressively than the bands. Once a more aggressive order is re-priced to the band price level, the resulting limit state begins.

Commenters were also concerned about straddle states resulting in markets that are essentially halted without a formal halt and re-open. This is particularly a problem when both best quotes are in straddle states. While these situations do occur, those that occur when trading interest is available are quickly resolved.

A straddle state in and of itself is not necessarily problematic, but can be a sign of a lack of trading interest in the stock. There are many thinly traded stocks for which a bid below the lower band or an offer above the upper band merely reflects a lack of trading activity and not a forthcoming erroneous execution.

There were approximately 4.8 million straddle states (including stocks with bad opening reference prices) during the sample period, in which either the best bid was below the lower price band or the best offer was above the upper price band. These far outnumber limit states and trading pauses. As mentioned above, most of these straddle states occurred in a small number of illiquid securities

Straddle states disappear even faster than limit states. Over half of the reported straddle states disappeared within one tenth of a second, and over three quarters within one second. The following table displays the lifetimes of straddle states:

Table 25: Straddle State Duration From Inception of LULD through December 31,2014				
Duration	Frequency	Percent	Cumulative Frequency	Cumulative Percent
< .1 second	2549585	52.58	2549585	52.58
.1 to 1 second	1305761	26.93	3855346	79.51
1 to 5 seconds	843502	17.40	4698848	96.91
5 to 10 seconds	25901	0.53	4724749	97.45
10 to 15 seconds	13277	0.27	4738026	97.72
15 to 30 seconds	23088	0.48	4761114	98.20
> 30 seconds	87464	1.80	4848578	100.00

There is a slight concentration of straddle states in the first half hour of trading (17.24% of the total), which is more than during other half hour periods during the day. However, straddle states are not nearly as bunched in the first half hour as LULD halts.

Table 26: Straddle States by Time of Day
From Inception of LULD through December 31,2014

	Frequency	Percent	Cumulative Frequency	Cumulative Percent
9:30-9:45	513250	10.59	513250	10.59
9:45 - 10:00	322485	6.65	835735	17.24
10:00 - 10:30	503256	10.38	1338991	27.62
10:30 - 11:00	433486	8.94	1772477	36.56
11:00 - 11:30	417630	8.61	2190107	45.17
11:30 - 12:00	356078	7.34	2546185	52.51
12:00 - 12:30	335322	6.92	2881507	59.43
12:30 - 13:00	330637	6.82	3212144	66.25
13:00 - 13:30	304683	6.28	3516827	72.53
13:30 - 14:00	286762	5.91	3803589	78.45
14:00 - 14:30	278248	5.74	4081837	84.19
14:30 - 15:00	266544	5.50	4348381	89.68
15:00 - 15:30	269844	5.57	4618225	95.25
15:30 - 16:00	230353	4.75	4848578	100.00

Most of the straddle states occurred in illiquid stocks. Approximately half of the straddle states occurred in just 50 symbols. Eliminating the 1,527 stock-days with bad opening reference prices reduces the number of straddle states to 917,042. The results with respect to duration of straddle states are still the same; the overwhelming majority end within one second.

Table 27: Straddle States Duration
Without Bad Reference Prices
From Inception of LULD through December 31,2014

Duration	Frequency	Percent	Cumulative Frequency	Cumulative Percent
< .1 second	589043	64.23	589043	64.23
.1 to 1 second	162358	17.70	751401	81.94
1 to 5 seconds	43471	4.74	794872	86.68
5 to 10 seconds	15534	1.69	810406	88.37
10 to 15 seconds	10771	1.17	821177	89.55
15 to 30 seconds	19348	2.11	840525	91.66
> 30 seconds	76517	8.34	917042	100.00

Note: Straddle states occurring on days then the stock's opening reference price is > \$5,000 (except for Berkshire Hathaway Class A) are excluded.

With respect to the time of day, the results are again similar: Approximately 20% of the straddle states occur within the first half hour of trading.

Table 28: Straddle States by Time of Day Without bad reference prices From Inception of LULD through December 31,2014				
Time	Frequency	Percent	Cumulative Frequency	Cumulative Percent
9:30-9:45	97331	10.61	97331	10.61
9:45 - 10:00	81632	8.90	178963	19.52
10:00 - 10:30	97351	10.62	276314	30.13
10:30 - 11:00	76467	8.34	352781	38.47
11:00 - 11:30	103404	11.28	456185	49.75
11:30 - 12:00	69062	7.53	525247	57.28
12:00 - 12:30	58313	6.36	583560	63.64
12:30 - 13:00	54267	5.92	637827	69.55
13:00 - 13:30	47789	5.21	685616	74.76
13:30 - 14:00	46451	5.07	732067	79.83
14:00 - 14:30	50614	5.52	782681	85.35
14:30 - 15:00	48060	5.24	830741	90.59
15:00 - 15:30	54783	5.97	885524	96.56
15:30 - 16:00	31518	3.44	917042	100.00
Note: Straddle states occurring on days then the stock's opening reference price is > \$5,000 (except for Berkshire Hathaway Class A) are excluded.				

As can be expected, the overwhelming majority (97.85%) of straddle states occur in Tier 2 stocks.

One question is whether straddle states lead to limit states. In a low liquidity situation, the straddle may just indicate a lack of trading interest, leading to quotes wider than the price bands. Such a lack of liquidity is often the case in pre-open trading and often resolves itself naturally as more investors wake up and submit orders. A trading pause in such situations would be unlikely to prevent any extreme trades or to be followed by a re-opening cross.

Alternatively, the straddle state may be caused by disappearing liquidity. If the bid falls rapidly, due to either sales or cancellations of orders, causing a straddle state, the offer may likewise drop to the point of causing a limit state.

Most (63.25%) straddle states are not followed by limit states. However, for those straddles that are followed by limit states, the limit state usually follows immediately. These are mostly an artifact of a number of oscillation events in which a straddle state exists, and then an order leads to a limit state. It is the practice of some market participants to cancel orders when a limit state exists. When there is no longer a limit

state, the orders are resubmitted. However, if that particular order triggers a limit state, this particular order routing behavior may lead to an oscillation of flickering quotes. The most extreme example during the sample period was that of a stock on February 21, 2014. On that day a single security experienced 35,452 straddle states and 22,705 limit states. That is an average of approximately 1.5 straddle states and 1.0 limit states every second.

The majority of straddle states, as with limit states, occur in a limited number of securities. Even after excluding those stock-days with bad opening reference prices, approximately one fourth (28.3%) of the total combined limit and straddle state events are accounted for on 50 stock days.

G. Exiting the limit state

Commenters were concerned about the inability to predict when a limit state will end and the impact that would have on trading decisions. While transparency is always best, it is impossible to predict when an order may arrive or be cancelled, even during regular trading.

There are a number of ways in which a stock can exit a limit state. The order/quote that triggered the state may be cancelled, causing a quote update that exits the limit state. Alternatively, the order/quote could be executed, also leading to a quote update that exits the limit state. The stock could enter a trading pause during which trading is halted. When trading resumes, the reference price is updated based on the auction results. A limit state can also end naturally at 3:35 pm when the reference bands widen before the close.

One commenter suggested not ending a limit state when the offer moves away from the lower band (or the bid moves away from the upper band), but instead to maintain the limit state until a new bid (offer) appears within the bands (i.e. until the quote in a straddle state ends as well). This would maintain the limit state until passive liquidity is available on both sides of the market. If the rule were modified, many more limit states would end in halts.

As mentioned above in Table 7, most limit states end naturally without a trading halt, but many are followed almost immediately by another limit state. Oscillation cycles occur in which an order triggers a limit state, the order is cancelled because of the limit state, and then the order originator observes that the limit state has been exited and then resubmits the order. Maintaining the limit state until liquidity appears on the other side of the market would cause these cases to end in a halt even while the order that caused the limit state was cancelled periodically to avoid extending the limit states.

While it is desirable to encourage a two-sided market and discourage cycles of order entry and cancellation, there is no evidence that either of these goals will be achieved by changing the way limit states end. The vast majority of limit states achieve the primary goal of preventing extreme price changes without resulting in a halt. Many of these are

accompanied by straddle states that last longer than the limit state when there is no trading interest on the other side of the market. The frequency of halts that do not result in a re-opening trade demonstrates that halting does not necessarily attract trading interest.

Changing the way limit states are exited, particularly requiring the arrival of trading interest within the bands on both sides of the market would make exiting limit states less likely and less predictable.

H. Trading pause length and reopening process

In general, a trading pause should be as short as possible in order to minimize lost trading opportunities for other market participants. On the other hand, the pause needs to be long enough to allow market participants to interpret the situation and for additional liquidity to arrive or to cancel erroneous orders. Would a short pause similar to the CME's five second "stop logic" be appropriate for less liquid cash equities or would it be too short? As many trading systems are fully automated, a very short pause may be all that is needed.

The LULD pause length has been set at five minutes, although the exchanges do have the flexibility to extend the pause for five more minutes. However, this flexibility has rarely been used. As most of the pauses have been almost exactly five minutes, there is little data to empirically investigate different pause lengths.

The appropriate pause length is a function of the circumstances leading to the pause in the first place. If the market is volatile and new information has arrived concerning the stock, then a longer pause may be appropriate in order for humans (both regulators and traders) to assess the situation and determine the best actions to take. On the other hand, if a pause is triggered by a single order in a less active stock, then five minutes is more than enough time for the few interested participants to adjust their orders. Current rules provide appropriate flexibility to the primary exchange to extend a pause when warranted by market conditions.

A repeat pause could be a sign that the pause length was too short. Market participants may not have had enough time to assess recently arrived information and to adjust their trading strategies. On the other hand, repeat pauses could be a sign of a flaw in the LULD mechanism such as a defective reference price.

The majority (50.4%) of the LULD pauses are accounted for by 50 stocks that have been and are the subject of repeated LULD pauses. These 50 "frequent halters" are low volume stocks. Collectively, the group has a median trading volume of 1,449 shares per day with an average of 93,903 shares per day.

VII. Recommendations

1. LULD should be continued and made permanent with a minor modification to the reference price for less active stocks.

Cancellation events have fallen significantly subsequent to the introduction of LULD. The system effectively prohibits trades outside of the LULD bands. This goes a long way to preventing the types of extremely mispriced trades that occurred during the Flash Crash. LULD should clearly be made permanent.

We note, however, that commenters expressed concern about the possibilities of disruptions to the price discovery process around the opening and agree that some improvements can be made in this regard.

Currently, the reference price is set as the price of the opening transaction or midpoint of the first quote on the primary listing market. Sometimes this opening quote is extremely wide or skewed as market makers “leg into the market”, leading to a reference price that bears no resemblance to the fair value of the security. Such an inaccurate reference price can cause a reasonably priced legitimate order to trigger unnecessary trading halts.

An inaccurate reference price can create a pathological situation in which reasonable orders trigger limit states or worse yet, trading halts for no discernible reason. This makes it even harder for market participants to trade less liquid stocks, further hurting their liquidity.

Unnecessary trading halts create numerous problems, especially ones that occur during the first half hour of trading. This is the busiest time of the trading day. Unnecessary halts require the attention of the regulatory personnel who monitor the market. They may be distracted from more important duties at that busy time. When a halt occurs, trader alerts go out to the subscribers via email. Unnecessary halts are basically false alarms that train market participants to ignore market halt messages. Thus, legitimate market halts that do require attention may be ignored.

In such a situation, the previous closing price of the regular trading session on the primary market is generally a better indication of the appropriate price for a thinly traded stock than the midpoint of stub quotes. The previous close should be used as the first reference price in situations where there are no trades in the opening auction. This will help to prevent inappropriate trading halts at the beginning of trading.³⁷

³⁷ For some very thinly traded symbols, the reference price could be a last sale several days old. This would not be a common event but note that this situation also arises with respect to the reference price under SEC Rule 201, the Short Sale Rule.

2. Harmonize tiers across with future rules and CEEs.

A tier structure that appropriately treats different stocks differently makes good sense. However, having different tier specifications for different rules leads to unnecessary complexity and confusion in the market. Tiers should be harmonized with other existing and future rules such as the numerical guidelines for breaking clearly erroneous trades, the tick size pilot, and any changes in access fee caps. Tiers should not be based purely on index membership. Basing tiers primarily on index membership can result in securities whose tier does not fit their economic characteristics.

Consideration should be given to factors including average trading volume, volatility, market capitalization, and average bid-ask spread. Primary listing exchanges should have the flexibility to determine tier membership.

3. Market-wide circuit breakers need to be re-considered to take into effect LULD.

LULD has worked well so far. However, market conditions have been fairly normal since its inception. LULD has not yet been completely tested in conditions of extreme market volatility such as was experienced during the Flash Crash or October 1987. It remains to be seen what will happen under those conditions.

In a market-wide event resulting in numerous LULD pauses of index constituents, the market-wide circuit breakers may not be triggered at the appropriate time. The S&P 500 generally uses the last trade to value a stock, and if a stock is halted, the value of the stock in the index does not update. This means that if a large number of securities are halted at once during a crash, the index will not reflect the decline. Market-wide circuit breakers need to be re-thought and integrated with LULD and the circuit breakers on derivative exchanges. Careful thought should be given to the re-opening process after a market-wide halt.

VIII. Appendix

Table A-1: LULD Reference Band Sizes during rollout phases				
Phase 1: Rolled out April 8, 2013 through May 6, 2013				
	Tier 1 Stocks S&P 500, Russell 1000, and select ETPs		Tier 2 All other NMS stocks except rights and warrants	
Previous Closing Price	9:30 am – 9:45 am and 3:30 pm - 4:00 pm	9:45 am – 3:30 pm	No LULD	
> \$3.00	No LULD	5%		
\$0.75 through \$3.00		20%		
< \$0.75		Lesser of \$.15 or 75%		
Phase 2 Part 1: Rolled out August 5, 2013 through September 3, 2013				
Previous Closing Price	9:30 am – 9:45 am and 3:35 pm - 3:45 pm (bands doubled)	9:45 am – 3:35 pm	9:30 am – 9:45 am and 3:35-3:45 pm (bands doubled)	9:45 am – 3:35 pm
> \$3.00	10%	5%	20%	10%
\$0.75 through \$3.00	40%	20%	40%	20%
< \$0.75	Lesser of \$.30 or 150%	Lesser of \$.15 or 75%	Lesser of \$.30 or 150%	Lesser of \$.15 or 75%
Phase 2 Part 2 Rolled out February 24, 2014				
Previous Closing Price	9:30 am – 9:45 am and 3:35 pm - 4:00 pm (bands doubled)	9:45 am – 3:35 pm	9:30 am – 9:45 am and 3:35pm -4:00 pm (bands doubled)	9:45 am – 3:35 pm
> \$3.00	10%	5%	20%	10%
\$0.75 through \$3.00	40%	20%	40%	20%
< \$0.75	Lesser of \$.30 or 150%	Lesser of \$.15 or 75%	Lesser of \$.30 or 150%	Lesser of \$.15 or 75%