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To: Members, House of Representatives Committee on Financial Services
Subcommittee on Capital Markets and Government-Sponsored Enterprises

Re: Using Regulation to Create a Reliable National Market System

Dear Chairman Garrett, Ranking Member Maloney, and Members of the Subcommittee:

Thank you for the opportunity for us to submit this exhibit to the House of Representatives Committee on Financial Services Subcommittee on Capital Markets and Government Sponsored Enterprises. We applaud the Committee for holding this hearing called "Equity Market Structure: A Review of SEC Regulation NMS" and are honored that Steven Lofchie, Partner and Co-Chair of the Financial Regulatory Group at the international law firm Cadwalader, Wickersham & Taft LLP, thought that the views of System Logic would be a valuable addendum to his testimony. We hope that this memorandum will aid the work of this Committee in considering how to create the right regulatory environment for a reliable and fair national securities market.

About System Logic

System Logic is an independent research and consulting firm that helps organizations manage complexity. System Logic works with both private- and public-sector clients and specializes in combining academic research with practical practices to help firms improve risk management and reduce their exposure to catastrophic failures, even as operations become more complex. More information about System Logic can be found at www.system-logic.com.

By drawing on experience in diverse industries and leading academic research, System Logic uses a sophisticated systems-level paradigm to help uncover and understand the risks that arise from the unexpected interactions present in complex systems, of which the current national market system is an example. It is through this lens that we turn our attention to the role of regulation in creating a reliable equities market.

Executive Summary

Mr. Lofchie requested that we address how complex systems, such as high-speed electronic trading, cause errors and why the tools of regulatory examinations and enforcement actions fail to prevent such errors. Additionally, he asked that we discuss how different regulatory approaches—for example, those used in the regulation of commercial aviation—might help inform the structure of securities regulation

and reduce the vulnerability of the equity market to catastrophic failure.

Complex systems can cause and magnify errors due to unexpected interactions that are difficult to understand and stop in real time. For electronic trading, these errors can be extremely costly and detrimental to the smooth and orderly functioning of the market. Unfortunately, the tools of regulatory examination and enforcement actions on which securities regulators rely do not reliably mitigate errors that arise from complexity. Rather, enforcement and examinations inadvertently create an environment that exacerbates the likelihood and severity of such errors, leading to a less robust and stable national market system. Instead, securities regulators should consider the tools that increase systemic reliability in commercial aviation, such as anonymous self-reporting, industry-led reliability monitoring, and no-fault investigatory practices, especially for severe errors. This memorandum discusses each of these issues in turn.

How the National Market System Causes and Magnifies Errors

The U.S. stock trading industry today is fundamentally different than it was at the turn of the millennium. One reason for the change is the increasing role of technology in securities trading. As it has with almost every aspect of modern life, technology fundamentally changed the way that market participants created models, processed data, and sent trades to the markets. The growth of the internet and rapidly increasing computing power yielded faster and cheaper communications and computation infrastructure, lowering barriers to entry and facilitating innovation in electronic trading.

A second, more direct reason for this change was the development of a modernized National Market System through the enactment of SEC Regulation NMS ("Reg NMS"). By implementing a rule requiring that quotes had to be honored on a national level, thus breaking the long-held monopoly of New York Stock Exchange ("NYSE") specialists, Reg NMS led to the interconnection of exchanges and shifted the vast majority of securities trades to anonymous, electronic interactions, facilitating a technology-driven approach to trading. While some effects of Reg NMS were immediately visible, the increased complexity of the resulting market system and its propensity for errors have been more difficult to recognize, even as the structure of the national market system itself creates profound challenges.

First, the changes due to the implementation of Reg NMS were overlaid on a legacy system which caused existing components to take on new roles for which they were not originally designed. For example, rather than christen new exchanges or redesign the trade matching process, Reg NMS required existing exchanges to connect in new and different ways. Although new technology was developed to implement Reg NMS on the exchange and market participant level, and there are quasi-standards like the Financial Information Exchange ("FIX") protocol,[1] the connected national market system relies on a

[1] Though FIX allows for a standard communications protocol between market participants, it often is implemented in idiosyncratic ways.

variety of distinct technology choices and rule implementations that vary between exchanges. These result in exchanges that are similar enough to provide little diversification from market-wide failures yet are different enough that their idiosyncratic features can create substantial problems.

Second, Reg NMS increased complexity and reduced tolerance to errors by significantly increasing the coupling (i.e., connectedness) among different participants of the national market system. Embedded in the operation of the individual exchanges of the national market system is a vast array of distinct functions that all need to be working properly. These include connectivity to broker-dealer participants and other exchanges; the conduct of automated opening auctions; the continuous matching of securities trades; and the real-time reporting of quotes, trade, and volume data both to subscribers of data from individual exchanges and the consolidated national reporting "tape." Many of these functions are *tightly coupled*, meaning that the failure of one quickly exerts a significant effect on the operation of the market system as a whole. As a result, broad swaths of the national market system may be crippled by a bug in a single ancillary component.

Third, given the raw number of software components and organizations involved, and the fact that the national market system was not primarily designed to maximize error-tolerance and robustness, it is now difficult to build effective redundancies into this system. Even when backup systems do exist, they are often vulnerable to the same failure against which they were designed to protect. Thus, what appear to be redundant features of the system might provide little redundancy in practice.

The failure of NASDAQ's Securities Information Processor ("SIP")[2] in August 2013 illustrates many of these points. The SIP consolidates and disseminates trade data nationally for NASDAQ-listed securities. A connectivity problem from another exchange overwhelmed the SIP's software which ran on the out-of-date Windows 2003 operating system.[3] Ultimately, the SIP's backup instance failed as well. As a result, the trading of all NASDAQ-listed securities which include Microsoft, Google, Facebook, and other tech giants, was halted nationwide for over three hours. Given the complexity of the national market system, such failures often are exceedingly difficult to identify, diagnose, and fix in real time.[4] But rather than rely on sharp troubleshooting skills and heroic real-time efforts to bring critical software components back online, the national market system should systematically be designed to reduce vulnerabilities and the impact of errors.

Indeed, similar problems affect the professional market participants (i.e., broker-dealers) as well. The competition that drives markets creates correlated risks that can lead to failures of the national market system as firms pursue similar strategies which rely on similar or identical sources of information. Again,

[2] The SIP, operated by NASDAQ, is for the reporting of trades in NASDAQ-listed securities.

[3] See Hope, Bradley. U.S. Exchanges Near Deal for Infrastructure Upgrade. *The Wall Street Journal*. Dec. 15, 2013.

[4] Indeed, attempting a fix in real time can cause additional problems, as seen in NASDAQ's handling of the Facebook IPO.

this leads to implementations that are similar enough to be vulnerable to the same sources of errors yet different enough to create a diversity of exposure to bugs and even potentially catastrophic failures. For example, market participants depend on the reliable and timely delivery of market data, yet bugs can occur in the firm-specific software implementations that integrate market data into trading systems, as occurred recently at a Merrill Lynch trading unit.[5] Moreover, technological features that are added onto legacy systems create complex vulnerabilities for market participants and have potentially powerful systemic consequences. For example, the SEC's recent detailed release on the failure of Knight Capital reveals[6] multiple layers of legacy software components that interacted in unexpected ways to nearly bankrupt the firm. In particular, code from a software component that had been discontinued nine years earlier accidently was reused. Because of the fast and tightly-coupled nature of electronic trading, this error was hard to identify, diagnose, and fix in real time. As a result, Knight suffered a loss of over $460 million in a span of 45 minutes—more than $10 million dollars per minute. During this time, Knight's automated order router inadvertently sent millions of orders into the market, causing market-wide disruptions and movements in the prices of 140 NYSE-listed stocks.

Finally, it should not escape notice that the current structure of the national market system and its potential intolerance to the failure of even relatively minor components leads to unnecessary geographic vulnerabilities. Finance is a key part of the national infrastructure. As a result of the events of September 11, 2001, organizations like the Depository Trust & Clearing Corporation which clears and settles the majority of U.S. equity trades, have developed geographically diverse backup and business continuity capabilities to maintain their ability to clear and process trades even if a protracted disruption were to affect the broader New York City region. And though financial services are concentrated in the New York City region, there are exchanges in locations such as Chicago, Philadelphia, and Kansas City. However, it is likely that the expected backup capability provided by this diversity is, to a large degree, *illusory*. In the event of a protracted disruption to New York City's power or telecommunications infrastructure, it is likely than an unexpectedly critical software component (such as a SIP system) will fail, preventing trading and thus grinding the national markets to a halt. This will persist until exchanges and market participants make *ad hoc* compromises, implement technical fixes, and obtain regulatory approvals to operate without an entirely functioning marketplace.

The Current Role of Regulators

Regulators have been struggling to deal with the tremendous shifts in the securities industry even as they have facilitated those shifts through the enactment of Reg NMS. By removing the barriers that limited competition, Reg NMS fostered the development of a complex national market with tightly coupled components and unexpected interactions between them. While there are tremendous benefits to the development of this competition-driven system, regulators have been slow to realize the limitations of their traditional tools in regulating such a market.

[5] See FINRA's Letter of Acceptance, Waiver and Consent No. 20080145847-01 against Merrill Lynch.
[6] See SEC Release No. 70694, Knight Capital Americas LLC.

Bad Actors

Securities regulators are used to dealing with bad actors, not with complex systems. Regulators discover bad actors, like fraudsters, those with prior criminal convictions, or those misrepresenting information or misleading customers, through a variety of mechanisms, including an examination of books and records, requirements for background checks, or by collecting and acting on customer complaints. These are linear processes that lend themselves to investigation by teams of people armed with rulebooks (such as rules about how firms must store their books and records, for example). When violations are found, remedial actions are negotiated, mitigations are implemented, and firms are punished. Some cases are deemed worthy of enforcement and larger, usually civil, actions are brought against the offending parties.

This process does not mitigate or prevent errors that arise from complexity. While advances in real-time trading data collection and analysis will provide a more detailed and comprehensive picture of trading and might allow regulators to identify bad actors more effectively, it will not increase the stability of the markets. Even if regulators have access to copious amounts of data, the nature of systemwide failures in the national market system generally will be indirect and elude real-time analysis.

Examination and Enforcement

Examination and enforcement inadvertently create an environment that exacerbates the likelihood and severity of errors caused by complexity. When it comes to the complexity of electronic trading systems, examinations can only scratch the surface. Because software development is complex, and because most firms have unique trading systems, examiners scarcely are able to understand the detailed workings that might stem from the unexpected interactions of complex systems (consider, as examples, the failure of Knight Capital and NASDAQ's handling of the Facebook IPO). Furthermore, although regulations such as Rule 15c3-5 require broker-dealers to implement "reasonable" risk controls, reasonableness is not well-defined and there is not a universally accepted software development and testing process that implies reasonableness. As a result, examinations are most likely to discover errors that are self-reported (e.g., short-sale mismarkings[7]) and necessarily minor (otherwise, they likely would have been discovered due to their consequences, not during an examination). Thus, the regulatory examination of electronic trading systems likely is to be ineffective: It serves to highlight issues that already are understood and might discourage deeper self-examinations by broker-dealers for fear that regulators will harp on issues that are being self-corrected.

Enforcement actions (and the fear of enforcement actions) have a similar chilling effect on the systemic stability of the national market system. While it is important that errors are understood, and such understanding is widely disseminated to encourage learning across the industry, enforcement is a poor mechanism to pursue this, and SEC Orders are not the ideal means of dissemination. First, an

[7] While these may be important, the fact that they are self-reported is *prima facie* evidence that a firm is surveilling for, documenting, and, most likely, handling these errors in a thoughtful way.

enforcement action likely is to reduce the level of cooperation to the minimum required to be regarded as not obstructing an investigation. Second, enforcement increases the likelihood of certain types of errors. For example, market maker rules, enacted after the 2010 Flash Crash, require broker-dealers to continuously quote two-sided markets in securities in which they make markets; this restricts market makers' ability to stop trading in the face of a known or suspected systems malfunction. This increases the risk of a catastrophic failure, but firms are loathe to stop trading in the absence of a change in the rules or a no-action letter by regulators. Finally, through enforcement actions, regulators make inadvertent, and sometimes conflicting, *ad hoc* policies that usurp more carefully considered rulemaking and interpretation processes. For example, while the SEC's enforcement action against Knight Capital[8] admonished Knight for not identifying and fixing its coding issue before the start of the trading day through a quick *ad hoc* solution, the Order disciplining NASDAQ for its mishandling of the Facebook IPO criticized NASDAQ for implementing such a real-time *ad hoc* fix to try to salvage their ongoing technical problems.[9]

Furthermore, it is not lost on the industry that these Orders are in the form of enforcement actions, sending the message that, if you make a mistake, a disciplinary action will follow. This incentivizes broker-dealers to focus on the minutiae of a particular order and take corresponding corrective actions, rather than take a step back and assess what steps could increase the safety and reliability of their systems. This, in turn, reduces the resilience of the industry and makes failures such as those that occurred with Knight and NASDAQ more probable and potentially more severe.

Reducing Systemic Errors through Regulation

Managing and Preventing Crises

To reduce the potential for errors that arise from complex systems, regulators should temper their use of examinations and enforcement. Instead, they should increase the development of rules—such as limits and circuit breakers that pause trading—that can slow down the market during times of crisis and give participants time to identify, diagnose, and fix problems (including "fixing" a problem by stopping trading).

In addition to slowing the market down during times of crisis, regulators should foster an industrywide cultural emphasis on safety. Cultural change must start with the regulators themselves. If a firm needs to stop trading because they fear a technical glitch, regulators need to defer such decisions to firms themselves and encourage that they make such safety-oriented decisions without fear of regulatory consequences. Regulators either should amend marketing rules or adopt a no-action letter that enshrines a no-fault policy to the cessation of firms' market-making requirement when a technical problem is suspected and trading is halted.

[8] SEC Release No. 70694, Knight Capital Americas LLC, p. 7.
[9] SEC Release No. 69655, The NASDAQ Stock Market, LLC, p. 6.

Moreover, regulators need to establish a clear public commitment to the integrity of the markets, even during times of crisis. Market-wide movements such as the Flash Crash were exacerbated as liquidity providers that may have been willing to purchase securities at low prices stopped trading because of uncertainty as to whether or not trades would stand or be busted. Notably, during Knight's crisis, Chairman Mary Shapiro was very clear that the trades that occurred because the trading glitch would stand as appropriate. This dampened the price swings caused by Knight's glitch. Regulators firmly should commit to and enshrine such a practice, even at the expense of helping potentially significant and politically important firms "do over" an electronic trading error that might cost billions of dollars.

Looking for Trouble

In the world of complex, tightly coupled systems that are the new normal in electronic trading, regulators proactively should "look for trouble," seeking out problem areas, such as bugs and potential adverse interactions among systems. This is in contrast to the standard approach of waiting for problems to occur and using infrequent examination—and enforcement-based regulatory activities to uncover them.

To look for trouble proactively, regulators should consider leveraging the experience and expertise of those already involved in electronic trading by partnering with broker-dealers to improve the stability of the marketplace. By creating a regulatory framework that focused on a partnership and maximized the reduction of systemic risk, regulators could leverage the direct operational experiences of broker-dealers in a structured way. Such a framework could create a reliable and effective paradigm to identify, mitigate, and even predict risks, communicate findings across the industry, and simultaneously retain the power of regulators to enforce as a last resort.

While this proposal may sound radical in the securities context, such a partnership characterizes the effective and safety-driven regulatory scheme present in modern commercial aviation.

Preventing Crashes: Lessons from Commercial Aviation

The complex system of commercial aviation provides an example of the successful regulation of another national asset whose safety and reliable operation is critical to national interest. Although an in-depth comparison between the system of commercial aviation and the national market system is outside the scope of this memorandum, sufficient similarities exist, and securities regulators might consider the tools used within aviation to increase systemic reliability.

Anonymous Self-Reporting

Aviation uses anonymous reporting to collect and share data on near misses and regulatory violations across the industry. Individuals, from maintenance technicians and dispatchers to flight crews and air traffic controllers, can self-report errors. As an incentive for such reports, proof of a report submitted will result in waived sanctions from a regulatory violation, assuming it is in the absence of intent or gross negligence. Note that these are not "whistleblower" reports but, rather, individuals incentivized, through a waiver of sanctions, to contribute to the overall safety of the industry. This system leads to

industrywide benefits because operating entities (such as commercial airlines) can obtain information relevant to the safety of their operations that they would never have otherwise obtained and are able to act on that information to mitigate vulnerabilities due to similar circumstances. Additionally, airlines and aircraft manufacturers themselves can self-report issues to regulators. These reports include corrective actions taken, if any, and are not used as the basis for regulatory enforcement; further, the timely provision of a self-report (before the FAA begins an enforcement action) revealing the company's violation and its corrective action will avert the enforcement, under this program.

By analogy, securities regulators, traders, and a firm's compliance might work together to review self-reports of incidents, and agree on corrective actions, outside of the context of enforcement actions. This would help firms identify whether, for example, errors have occurred in the deployment of critical software (even if those errors did not have direct consequences), understand the root causes of the incorrect deployments through an analysis of self-reports, and subsequently develop software to surveil for incorrectly deployed software or create new procedures to mitigate the issue.

Industry-Led Reliability Monitoring

Following the crash of ValuJet 592 in 1996,[10] the FAA began to recognize that the systemic complexity of modern airline operations exceeded their ability to directly regulate. While the FAA still has responsibility as a regulator, it began to facilitate industry-lead safety and reliability monitoring, ultimately through an operator-implemented Safety Management System ("SMS") framework.

The FAA recognized that commercial operators, through their day-to-day "on the ground" (and in the air) experiences, have insights into safe operations that regulators do not. To take advantage of these insights, an SMS typically involves four major steps: obtaining information, analyzing the resulting data to identify and classify risks, changing operational procedures to mitigate the identified risks, and auditing to ensure the changes were effective. With information about routine and non-routine events as the bedrock of the SMS process, typical data sources comprise voluntary reporting systems, large volumes of recorded information about routine operations, directed investigations of non-routine events, and proactive auditing and probing of daily operations. The goals of an SMS are to encourage the development of safety management capability, increase confidence in risk controls, and increase the reliability and effectiveness of risk mitigations. To facilitate regulatory participation, the SMS process depends on an interface to promote knowledge sharing between regulator and commercial operators. Ideally, such a system also would support safety and systemic reliability between operators by allowing the sharing of data and safety insights.

[10] Mislabeled and mispacked hazardous cargo, packed by a maintenance contractor, was improperly loaded onto the flight. The resulting fire brought down the aircraft and killed all 110 souls on board. Post-accident, the regulator identified that the airline's oversight of its subcontractor was inadequate and that its own regulatory surveillance of airlines was not capable of reliably identifying and correcting systemic flaws such as these.

While the success of an SMS depends on industry and regulator working hand-in-hand, the FAA still has enforcement tools to identify bad actors and maintain oversight. The FAA, however, recognizes that some of the key incentives of commercial airlines (analogous to broker-dealers) and regulators are aligned: to avoid catastrophic failures that result in loss of life (for broker-dealers, massive loss of profits) and the consequences that follow.

In the context of finance, an analogous system would specify rules that broker-dealers were required to follow to collect data on systems problems and analyze the resulting data to identify and classify risks (e.g., coding errors, connectivity problems, incorrectly set limits, etc). The data and analysis would be for the broker-dealer itself. Each broker-dealer would be responsible for specifying an appropriate form for the data, methods of collection, and techniques for analysis, rather than being required to shoehorn results into a one-size-fits-all data model specified by the regulator. Any changes in operations or procedures to mitigate identified risks would be followed up with internal spot-checks and audits to ensure that the changes were effective. A well-structured system of this kind would be more effective than the current trend toward unspecified compliance involvement in the highly technical process of controlling electronic trading risk. Finally, such a system would allow regulators to examine the results of each firm's risk management process which would give regulators insight into important operational concerns, rather than the more distant view generally afforded by regulatory exams.

No-Fault Investigations

In addition to anonymous self-reporting and industry self-monitoring, commercial aviation benefits from the independent contribution and expertise of the National Transportation Safety Board ("NTSB") which has the primary authority to identify the causes of aircraft accidents in the United States. The NTSB's chief mission is to promote safety.

Through its role as a non-regulatory investigator that does not bring enforcement actions, the NTSB investigates accidents and serious incidents. The products of its investigations are recommendations to prevent the recurrence of similar events. While these recommendations are not binding on the regulator, the NTSB achieves substantial compliance with its recommendations from both the regulator and operators. By being sensitive to failures that underlie rare, major events with highly negative outcomes (e.g., fatal airline accidents), the NTSB can detect issues that affect systemic safety and mitigate risks that apply broadly to worldwide aviation operations. Indeed, the NTSB's explicit focus on safety, rather than enforcement, even allows it to consider and reveal the role that regulatory failures might play in causing errors. Overall, the agency's focus on highly consequential events complements the above-described safety management systems which focus primarily on safety issues arising from routine events and minor incidents. In sum, the NTSB acts as a *blocker*, a technically oriented and informed third party that is not held captive to the compromises of the rulemaking process.

We suggest that a similar approach would greatly enhance the stability and robustness of electronic trading. For example, the SEC's Orders following the Knight failure and NASDAQ's mishandling of the Facebook IPO were valuable to the entire electronic trading industry precisely because they provided details about the errors in Knight's and NASDAQ's electronic-trading systems that other participants

could learn from and avoid. Moreover, these Orders illuminated how human judgment might interact with highly technical systems during such crisis events, potentially allowing others to make more effective decisions in the face of unfolding failures. However, because these Orders were enforcement actions, they shifted the focus of firms from increasing reliability to implementing *ad hoc* suggestions to avoid punitive action. Furthermore, because such investigations are conducted by the regulator itself, their results typically shed little light on the role of rules, regulations, and regulators in shaping the environment that contributed to failure. Creating an independent and non-regulatory party with the power to investigate major incidents would strengthen the resilience of the finance industry and improve the reliability of the national market system.

Conclusion

Securities regulators have a daunting task in increasing the reliability of the national market system. As technology has evolved, and as Reg NMS has facilitated competition and interconnectedness, the complexity of the national market system has increased significantly. To date, regulatory tools have reflected traditional priorities in catching bad actors. But unlike with other regulatory concerns, such as insider trading, the management of electronic trading systems should have few bad actors—as firms already are incentivized to prevent the catastrophic failure of their trading systems—and so regulatory examinations and enforcement actions actually decrease the reliability of the national securities market.

Instead, securities regulators should consider adopting lessons from commercial aviation which, analogous to the securities industry, operates in a high-risk environment demanding high reliability: anonymous self-reporting, industry-led monitoring, and no-fault investigations. By defining risk management and mitigation as corporate responsibilities for the airlines, and by changing the focus of its surveillance and oversight to ensure the reliable and effective function of these corporate activities, the regulatory functions of the FAA have the opportunity to be much more effective. Also, by explicitly separating FAA enforcement and the NTSB's accident investigation practice, and by endowing the NTSB with an independent mission of promoting safety, commercial aviation regulations have successfully empowered a technically sophisticated group with the tools to increase aviation safety.

Securities regulators might consider adopting such methods, lest our national market infrastructure becomes overwhelmed by a series of increasingly frequent and violent errors that shake the confidence of the investing public and the world. Too much of the nation's economic well-being and competitiveness is at stake to be bound by an ineffective *status quo*.

Respectfully submitted,

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