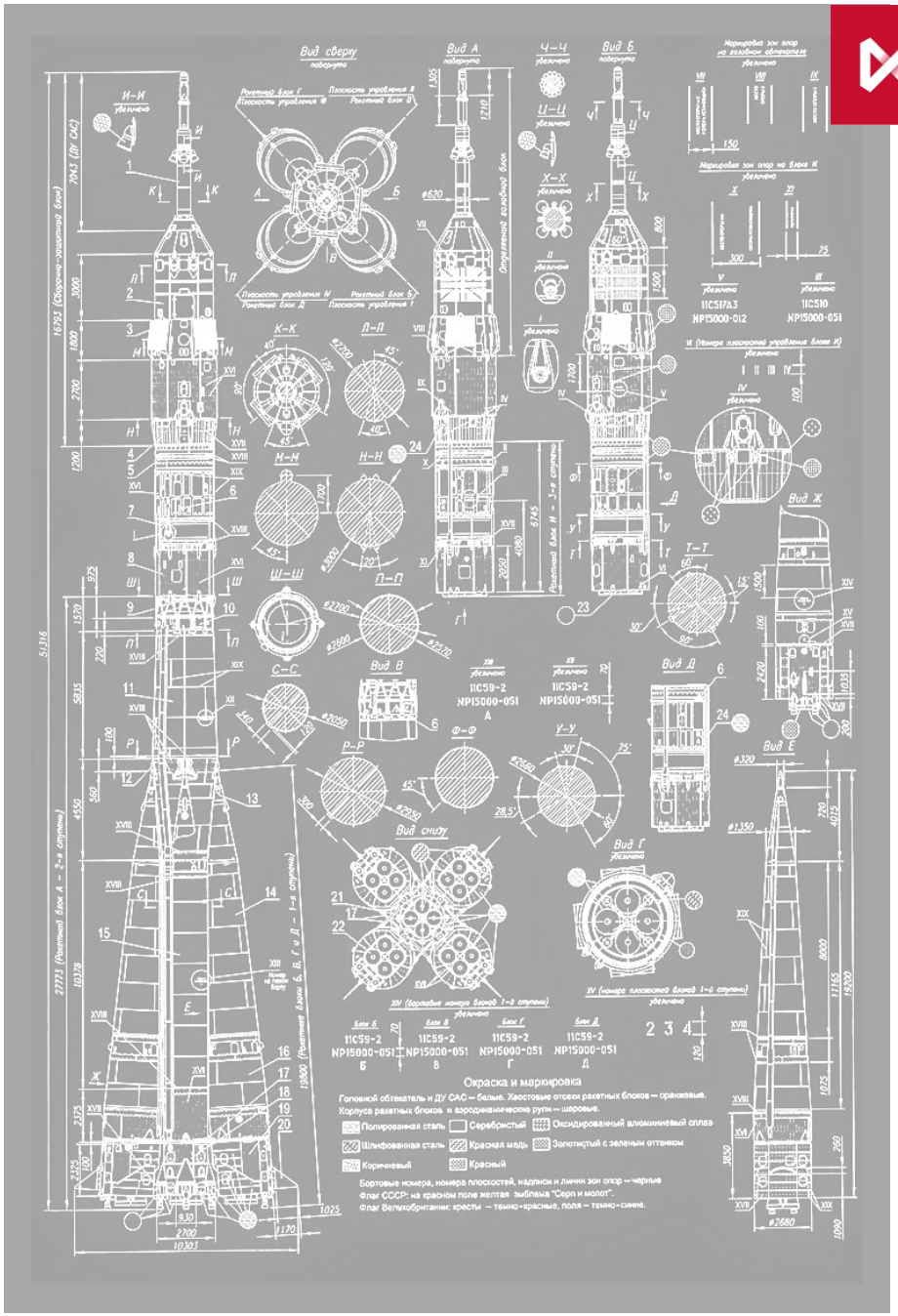
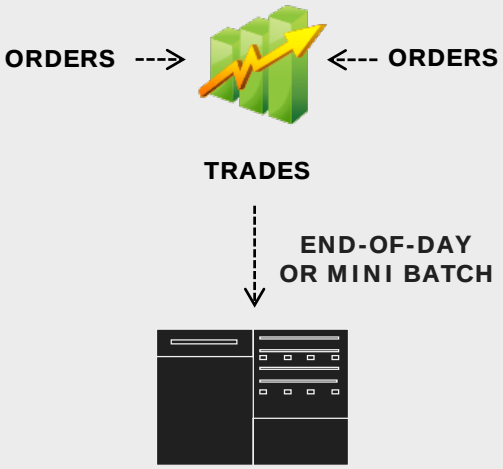


MOSCOW EXCHANGE

CLIMBING OUT OF THE STABILITY SINKHOLE

UNIQUE REAL-TIME RISK MANAGEMENT = STABILITY CHALLENGE

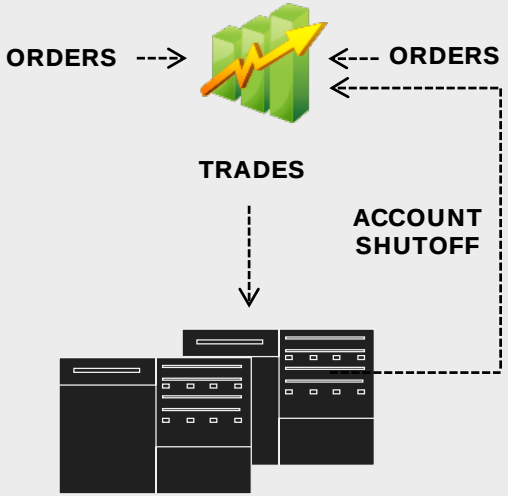
BASIC



END-OF-DAY, INTRA-DAY
MARGIN CALL

RISK AND MARGIN
CALCULATED
IN BATCHES

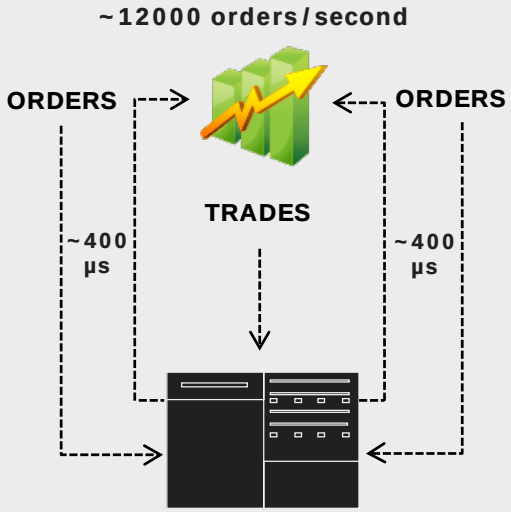
REAL-TIME POST-TRADE



REAL-TIME POST-TRADE
RISK CHECK
AND
MARGIN CALL

RISK AND MARGIN
CALCULATED
POST-TRADE IN REAL-TIME

REAL-TIME ORDER PRE-CLEARING



HYPOTHETICAL TRADE
RISK CALCULATION

PROJECTED RISK
CALCULATED
BEFORE ACCEPTING THE ORDER

IF PROJECTED MARGIN
REQUIREMENT BREACHES
AVAILABLE MARGIN,
ORDER IS NOT ADMITTED TO
MATCHBOOK

MOSCOW
EXCHANGE

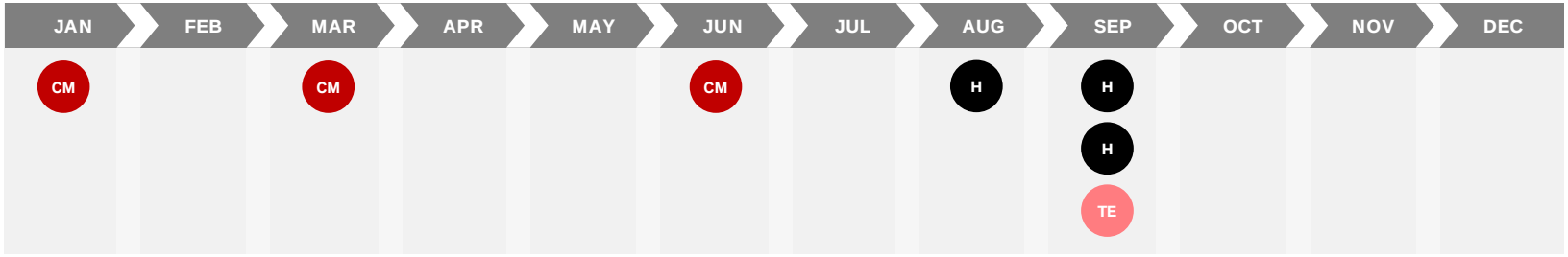
THE INGLORIOUS 2015

INCIDENT	DATE	SOLUTION
HARDWARE FAULT DISRUPTING THE BACKUP SCHEME	**August, 12** **September, 1** **September, 8**	▪ Hardware replacement and upgrade (< 3 years) ▪ Migration to «flat» network topology ▪ Network segregation ▪ Human resource development in operation and maintenance department ▪ New Tier III data center

CLEARING MODULE FAULTS	**January, 12**
	March, 5
	June, 15
		▪ Segregation of Trading and Clearing modules
		▪ Emergency limit check scheme
		▪ Orders risk check model update
		▪ Development process improvement
		  ▪ Software Development Life Cycle practices implementation
		  ▪ Introduction of “destructive testing”
		  ▪ Testing cycle extension

TRADE ENGINE FAULTS	**September, 21**	▪ Trade engine cloning (as a part of trading and clearing modules segregation programme) ▪ Common development process improvement

CRITICAL FAULTS IN 2015 TIMESCALE



MOSCOW EXCHANGE

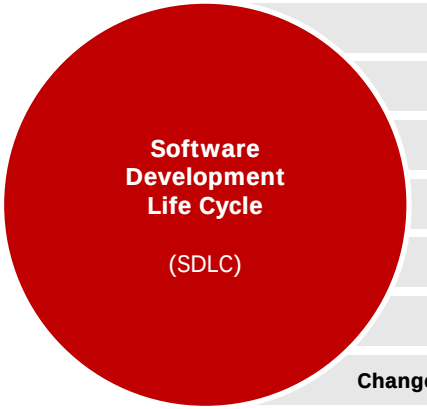
H HARDWARE FAULTS

CM CLEARING MODULE FAULTS

TE TRADE ENGINE FAULTS

OLD SOFTWARE DEV PRACTICES COULDN'T COPE WITH COMPLEXITY => NEW DEV PROCESS

SOFTWARE DEVELOPMENT LIFE CYCLE



- Regular Code Review Practices
- Static and Dynamic Code Analysis
- Continuous Integration (CI)
- Auto deployment
- Unit-like Testing Practice
- Auto tests Coverage Extending
- Changes reference to projects, tasks and issues

TOOLS	FUNCTIONS
Clarive + Ansible	Auto deployment
Coverity	Static code analysis
GitLab, Crucible	Code review
Jenkins	Continuous integration
Address Sanitizer	Dynamic code analysis (ASTS)
Undefined Sanitizer	
Valgrind	Dynamic code analysis (Spectra)
PyTests	Regression testing
HP ALM	Testing lifecycle management
Serena, Jira	Bug Tracking, Task Tracking
Doxygen	Auto documentation

QUALITY ASSURANCE PRACTICES

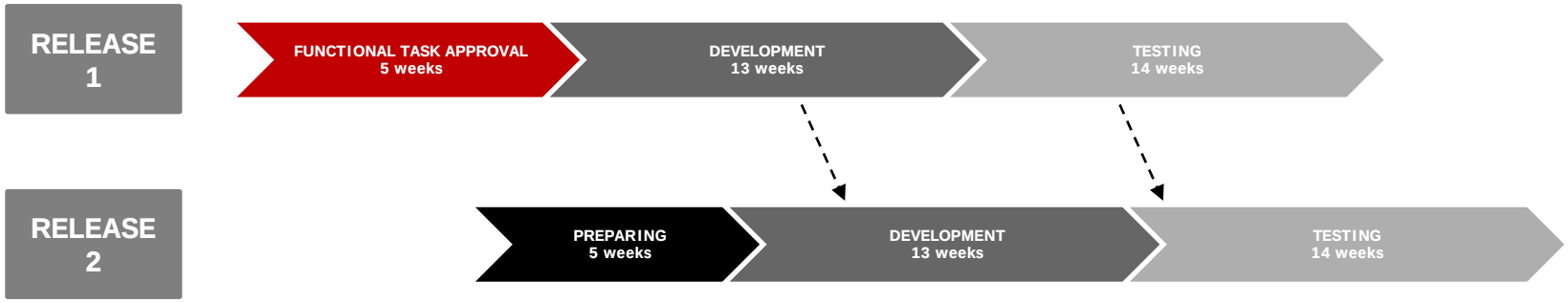
	2014		2017 – NEW & IMPROVED PRACTICES	
DEVELOPMENT			Unit Tests	Static code review
TESTING	Manual functional testing Manual regression testing	Testing metrics	Automatic functional testing	Automatic regression testing
IMPLEMENTATION	UAT (external) Acceptance testing	Testing metrics	Integrational testing (cross-system)	Simulation testing Destructive testing

AUTODEPLOYMENT COVERAGE:	100% for real-time systems
OTHER TOOLS COVERAGE:	~80% of current releases

PREVIOUS | IMPROVED | NEW

MOSCOW EXCHANGE

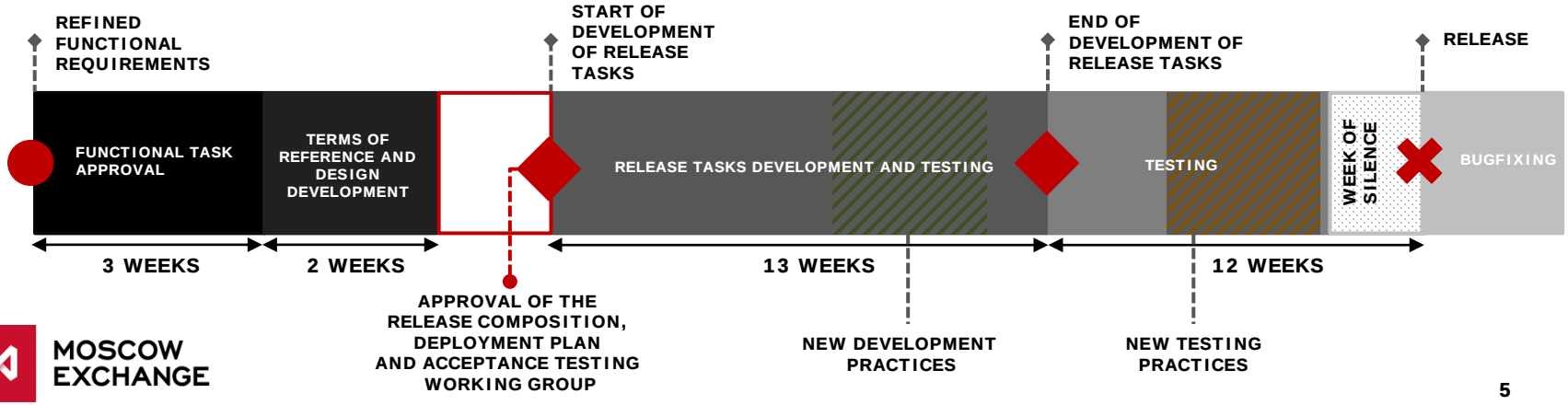
CAN'T SPEND 100% TIME TESTING, NEED TO DELIVER!



AFTER THE ACTIVE PHASE OF DEVELOPMENT, DEVELOPERS

- ✓ PARTICIPATE IN BUG CORRECTION
- ✓ START WORKING ON THE TASK OF THE NEXT RELEASE
- ✓ IMPROVE METHODS AND TOOLS FOR TESTING
- ✓ WORK ON APPROVED NON-RELEASE TASKS
- ✓ WORK ON OPTIMIZATION AND TECHNOLOGICAL DEVELOPMENT

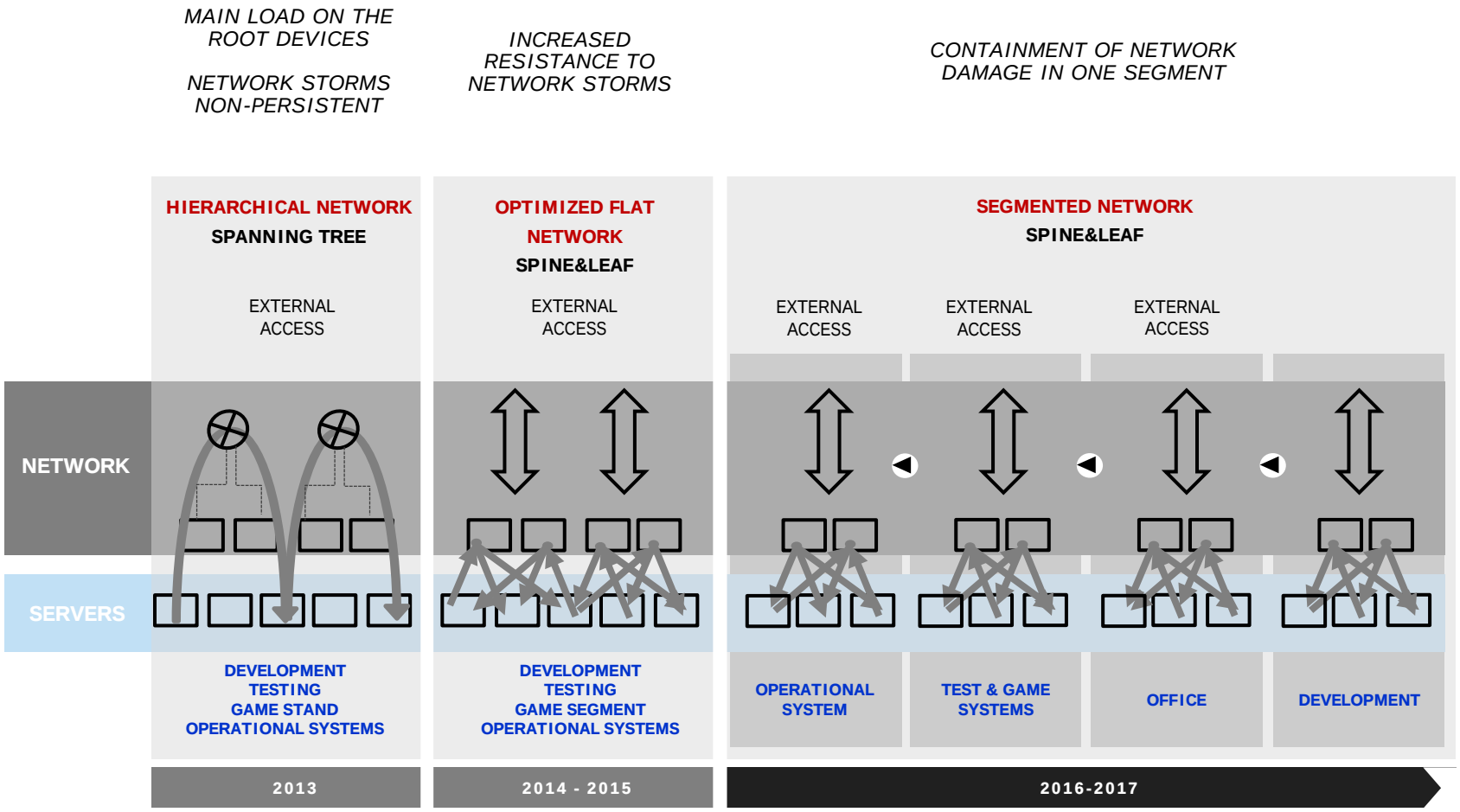
RELEASE CYCLE



MOSCOW EXCHANGE

THE GREAT NETWORK MELTDOWN OF AUGUST, AND WHAT WE DID ABOUT IT

Spine & Leaf «flat» network topology implementation significantly decrease expectation of repeating serious consequences in case of network storm



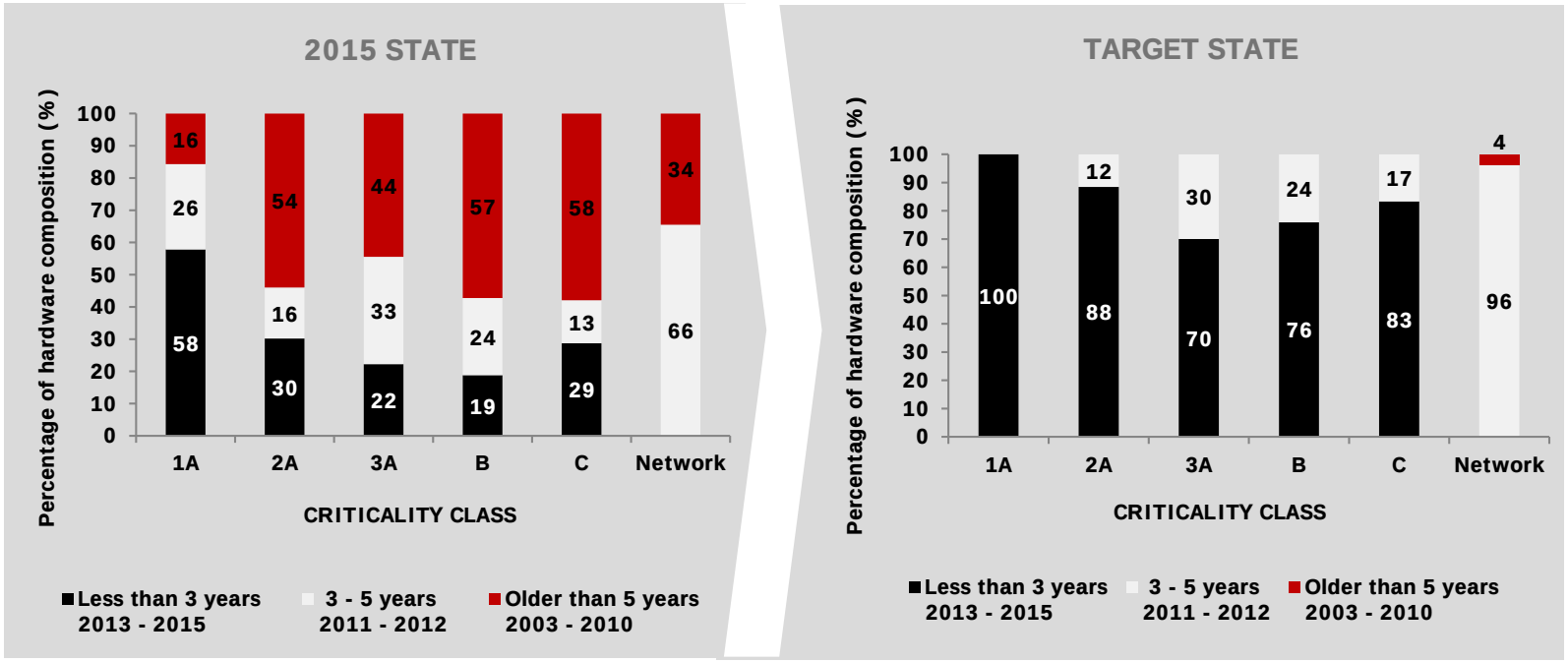
MOSCOW EXCHANGE

HARDWARE: NEWER IS BETTER

TECHNICAL POLICY REQUIREMENTS (INTRODUCED IN 2014)

SYSTEM	CRITICALITY CLASS	EQUIPMENT UPDATE PERIOD
TRADING SYSTEM ENGINE (REAL-TIME)	1A	3 YEARS
MAIN PRODUCTION SYSTEMS	2A, 3A	4 YEARS
RESPONSIBLE SYSTEMS	B	4 YEARS
NON-CRITICAL SYSTEMS	C	5 YEARS
NETWORK	---	5 YEARS

HARDWARE PARK BY AGE



MOSCOW EXCHANGE

NEW DATA CENTER

RELIABILITY

- ✓ **Tier-3 certified data center delivers 99,98% availability**
- ✓ **Compliance with safety requirements of Payment Card Industry Data Security Standard (PCI DSS) v.3 to ensure the security of customer information**
- ✓ **High level of safety and resistance to adverse external influences**

SECURITY

- ✓ **Stand-alone building**
- ✓ **Security service**
- ✓ **Administered surrounding territory, guarded area**
- ✓ **Access control system**
- ✓ **CCTV monitoring**

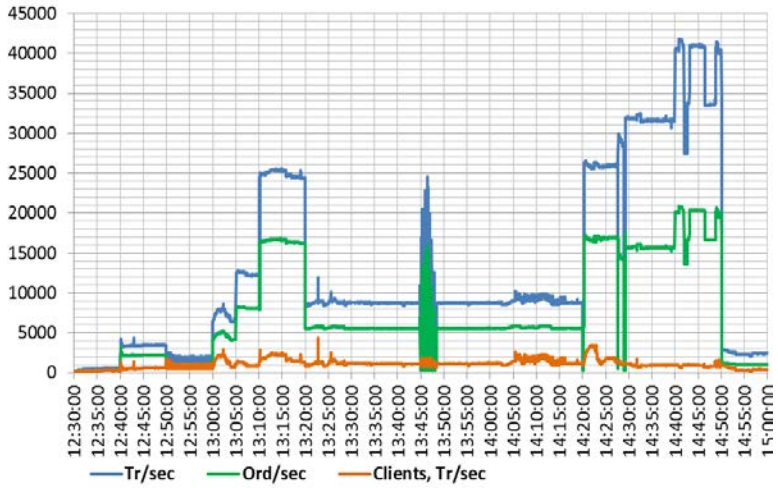
FURTHER DEVELOPMENT CAPACITY

ICING ON A RELIABILITY CAKE: BETTER PERFORMANCE

Results below from annual joint Exchange / brokers stress tests of core infrastructure , fall 2016

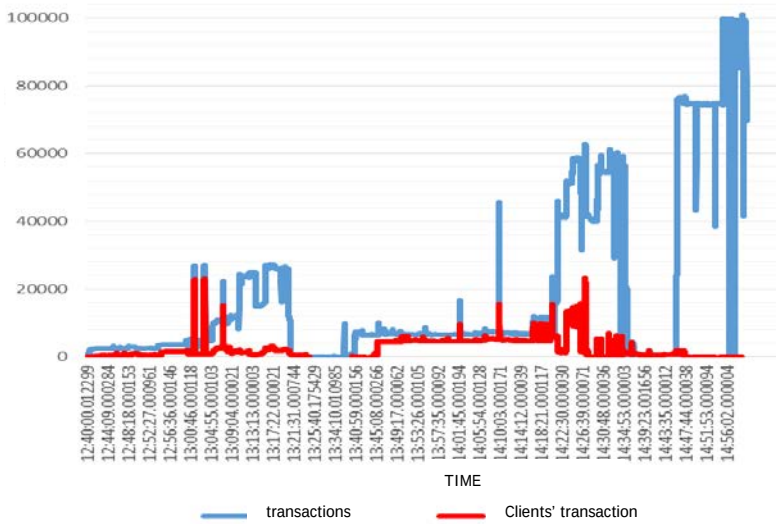
LOAD TESTING RESULTS

ASTS+



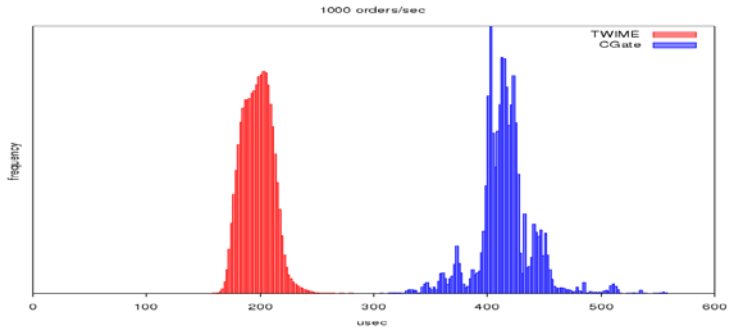
Average response time:	**230 µs**
90% responses	**< 270 µs**
99% responses (transaction frequency less than 50 per second)	**< 400 µs**
99% responses (transaction frequency higher than 500 per second)	**1500 µs**
99.9% responses (typical real market frequency of transactions)	**< 600 µs**

SPECTRA



Average response time:[1]	**250 µs**
Under load up to 50 000 Tr/sec	**< 250 µs**
99% responses	**< 1000 µs**

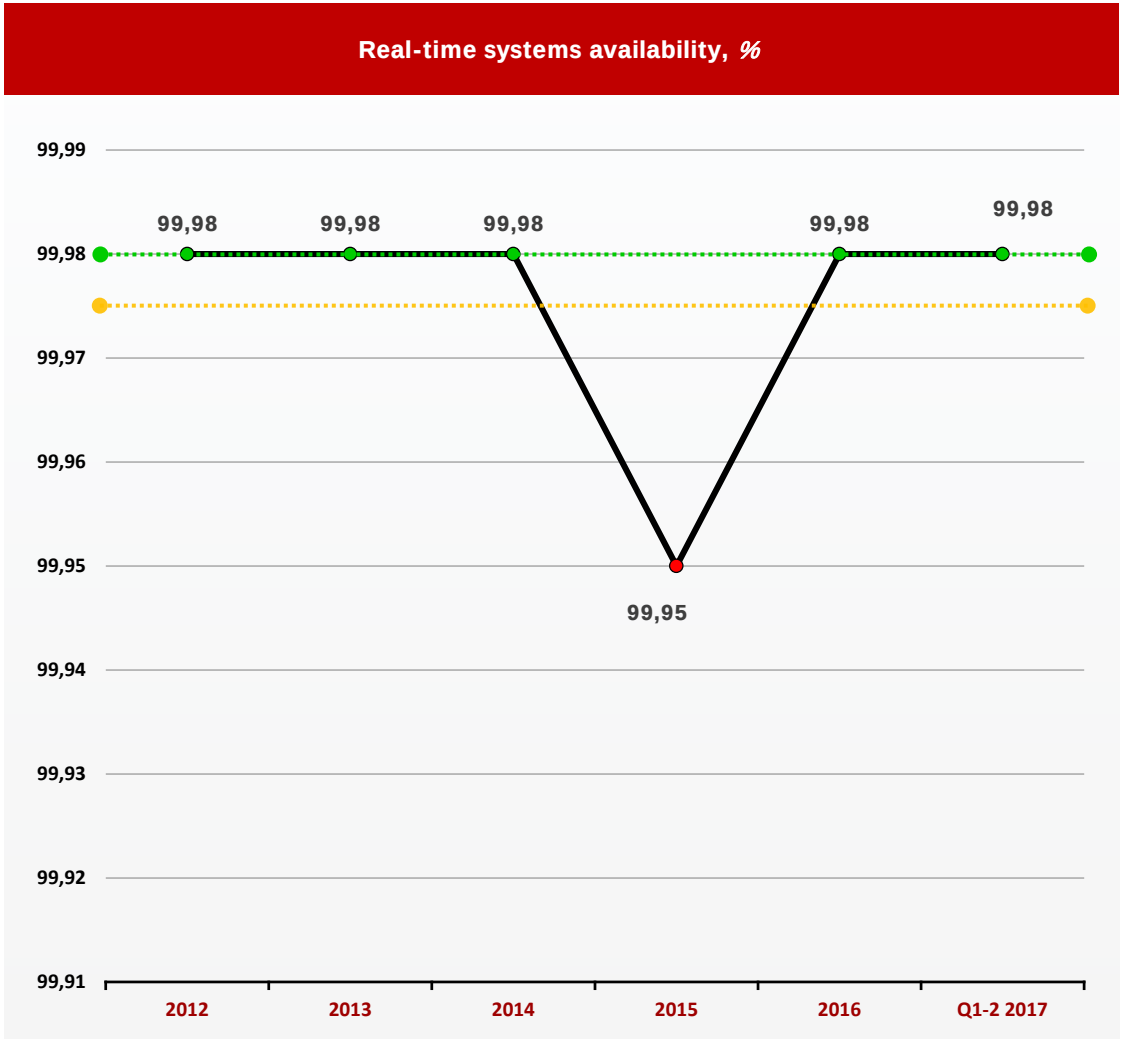
TWIME AND CGATE COMPARISON



MOSCOW EXCHANGE

[1] For forecasted within the next year peak frequencies of 20 000 - 30 000 transactions per second

2016 – RETURN TO STABILITY, HOPEFULLY LASTING



MOSCOW EXCHANGE