APPENDIX B

Quality Management System

B. QUALITY MANAGEMENT SYSTEM

B.1 Proton Quality Assurance Plan

B.1.1 KhSC Quality Management Overview

ILS Proton launch vehicle services are implemented by Khrunichev State Research and Production Space Center (KhSC) in Moscow, Russia. KhSC operates an ISO 9001 registered Quality Management System (QMS) and is accredited through the Russian Federation Roscosmos/Ministry of Defense/Gosstandart under registration number FSS KT 134.03.3.1.00000.31.05 dated 27 December 2005. Recertification to ISO 9001-2008 will be completed in 2009.

The scope of compliance applies to design, development, test, manufacture, and assembly of advanced technology systems for space and defense, including space systems, launch systems, and ground systems. Adherence to ISO 9001's quality standard is revalidated at yearly intervals by Roscosmos.

ISO 9001/9002 is fulfilled through implementation of KhSC Policies in the field of quality and performance of work in conformance with procedures and practices that are described in the approved KhSC Corporate Quality Management System Manual (RK 737.340.01). The Manual is structured in a manner similar to that of the EN 9100 standard and includes a documented process-oriented approach to designing (design engineering), refining, testing, manufacturing, and assembling advanced technology systems for space and defense. The KhSC Quality Manual (KQM) is continually updated and revised in order to reflect the continuous improvement of QMS processes.

In accordance with the standards documents, the following are the basic processes of the KhSC corporate quality management system employed in the creation, manufacture, and preparation of rocket-space technology articles for use:

- Management processes
- Resource supply processes
- Product life cycle processes
- Measurement, analysis and improvement processes

B.1.2 KhSC Quality Management Organization

The Russian Space Agency (Roscosmos), Russian Standards Organization (Rostekhregulirovanie), and Russian Federation Ministry of Defense (MoD) provide joint oversight of compliance with technical and quality provisions and standards, and certify conformance to, quality standards and instructions.

Responsibility and authority for the function and the improvement of KhSC QMS results to satisfy quality requirements for manufactured products is under the KhSC Deputy Director General for Quality, who reports directly to the KhSC Director General.

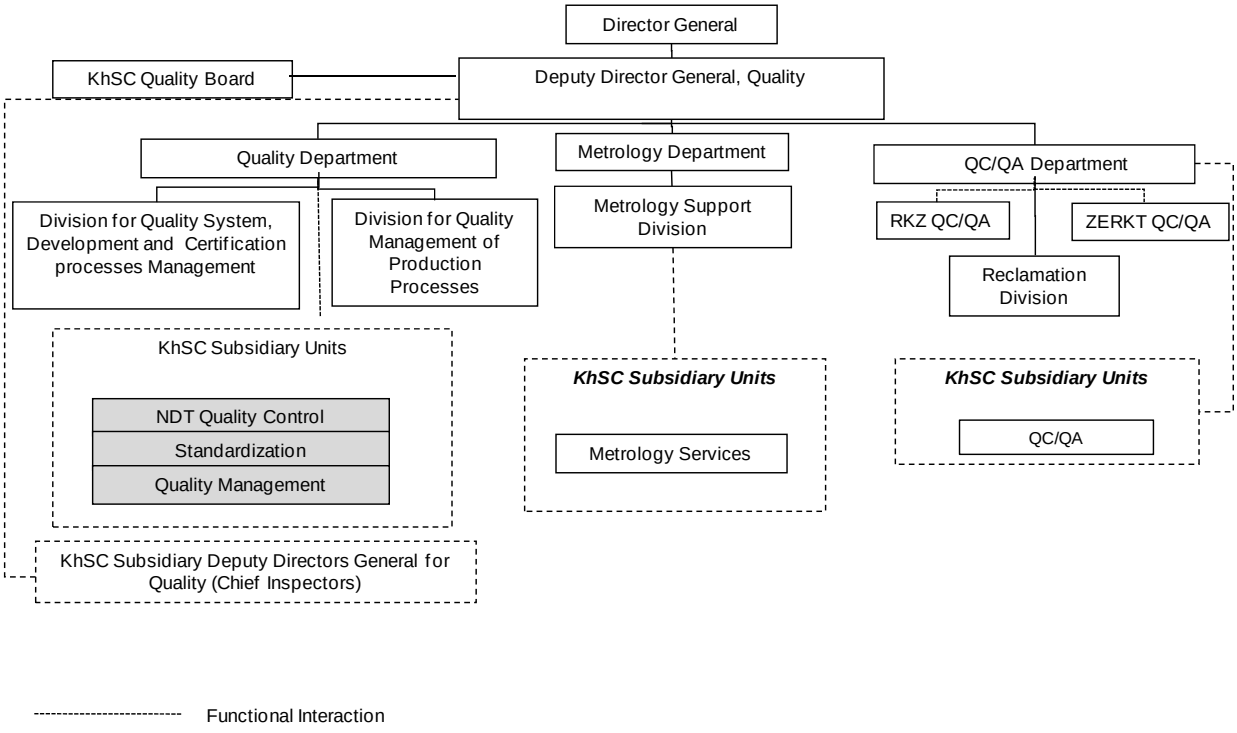
Figure B.1.2-1 shows a management organization chart for the KhSC quality management system, which includes the following:

- **Quality Department and Subdivisions**
  - Management of KhSC corporate QMS documentation
  - Coordination and internal monitoring of product development processes in KhSC organizational subdivisions and subsidiaries.
  - Participates in the conceptual, preliminary, and engineering quality design reviews. Design reviews include:
    - Tracking of requirements
    - Identification of critical parameters
    - Development of strategies for accepting and analyzing implementation methods

- **Metrology Department and Subdivisions**
  - Manages periodic metrological calibration and certification of measurement and monitoring hardware.
  - Maintains commonality of metrological approaches to quality in the creation of products at KhSC organizational subdivisions and subsidiaries.

- **Engineering Verification Department**
  - Assures the timely, complete, and reliable confirmation of product conformance to specified requirements, including deliveries of materials and component articles.

Figure B.1.2-1: Management Organization Chart for the KhSC Quality Management System



B.1.3 KhSC Quality Management Processes/Procedures

To achieve maximum effectiveness and continued customer satisfaction, a required level of quality is ensured through:

- Physical examination (inspection)
- Measurement
- Test
- Process monitoring, and/or employment of other methods required to assure compliance of deliverable products and services with quality requirements.

Independent verification includes:

- Mandatory inspection points for processes
- Documentation (procedures) on work performance
- Manufacturing and testing
- Sample (specimen) collection plans
- Statistical methods
- Data analysis
- Trending, and
- Other engineering methods and tools that are suitable for the articles or processes being verified.

Documented procedures are established and maintained for planning, performing, reporting and follow up internal audits. The KhSC internal audit program coordinates with other audit organizations, including government audit teams, to maximize effectiveness. Quality Assurance has the responsibility for the management and oversight of the internal audit program. Auditors are independent of the party responsible for taking corrective action.

The quality department produces metrics and trend data on a monthly and on an as-needed basis. This data is a summary of trends in the areas of Production, Procurement, and Launch Site nonconformance data. This data is used as an indicator of the performance in those areas. In addition, special trend data such as by Part Number or specific vehicle are produced on an as-needed basis. The level of detail of the data provided is restricted by Russian Security requirements.

Quality is a part of every process at KhSC, and this is reflected in the revisions to the KhSC organizational subdivision and subsidiary quality manuals that reflect the activities specific to ILS commercial Proton launches. Commercial mission analysis and design, and commercial spacecraft ICD verification have been added to the normal vehicle integration work flow, with specific provisions made to provide customer visibility into these processes, as well as into the contracting, launch vehicle fabrication, assembly and test, and launch processing activities.

B.1.4 Functional Area Responsibilities

The functional area responsibilities for the principal KhSC operating divisions under the KhSC quality plan include the following:

DB Salyut

- Design Management
- Documentation Control
- Product Identification

ZERKT

- Launch Vehicle Servicing
- Ground Facilities Maintenance and Operation
- Equipment Storage

NII KS

- Trajectory Measurements
- Ground Monitoring Facilities

Rocket-Space Plant, Voronezh Mechanical Plant, Polyot Production Association, DB Khimmash, DB Armatura

- Identification and Traceability
- Process Control
- Inspection and Testing
- Calibration
- Disposition of Product Nonconformities
- Corrective Actions; Statistical Records
- Quality Records Control
- Internal Quality Audits

B.1.5 Quality Management System Documentation

The KhSC corporate quality management system documentation encompasses all requirements of the ISO-9001 EN9100 standard, and includes the following:

- KhSC Quality Policy
- KhSC standards and provisions:

  RK 737.340.01-2009, "Quality Manual. Corporate Quality Management System. Requirements"

  STP 737.0.2, "Analysis by Senior Management. Work Procedure"

  STP 737.0.3, "Measurement, Analysis, and Improvement. Basic Provisions"

  STP 737.0.4, "Internal Audits. Planning and Conduct"

  STP 737.0.5, "Corrective Actions. Basic Provisions"

  STP 737.0.6, "Preventive Actions. Basic Provisions"

  STP 737.0.7, "Management of Nonconformities. Basic Provisions"

  STP 737.0.8, "Purchasing Quality Management. Basic Provisions"

  STP 737.0.9, "Processes for Controlling Monitoring and Measurement Devices"

  STP 737.0.10, "Verification and Calibration of Measurement Devices. Organization and Procedure"

  STP 737.0.11, "Organizing Performance of Work to Coordinate Documentation with the Metrological Office"

  STP 737.0.12, "Metrological Expert Review of Engineering Documentation. Organization and Procedure"

  STP 737.0.15, "Entry Control. General Provisions"

  STP 737.0.17, "Company Standards. General Provisions"

  STP 737.1.1, "Procedure for Company Standard Development and Revision"

  STP 737.1.2, "Manufacturing Process"

  STP 737.2.11, "Quality Management of the Design Process and the Development of Design Documentation"

  STP 737.3.10, "Maintenance and Preparation for Operation"

  Provision "Selection and Disposition of Personnel at the Company"

  Provision No. 17, "Certification of KhSC Managers, Engineers and Technicians, and Other Specialists"

  Provision "System of Training, Retraining, and Occupational Development of Personnel and KhSC and Its Subsidiaries"

- Planning documents (plans, schedules, programs), intended to maintain quality management system processes in working order and continually improve their effectiveness.
- Documentary certification (entries), maintenance of which is called for in regulatory and engineering documentation**.**

B.1.6 Proton Supplier Network

KhSC uses a network of more than 60 Russian subcontractors, all of whom have demonstrated their ability to function as proven suppliers to the Russian space industry. In addition, six suppliers are based in Ukraine, and one operates from Sweden (RUAG Aerospace Sweden AB). Ninety-seven percent (97%) of KhSC's suppliers have been with the Proton program since its inception in the early 1960's. Long-term, stable subcontractor relationships are emphasized at KhSC, and by the Russian government. This allows the implementation of multi-year contracts and long-term working relationships among key personnel. All Proton subcontractors are certified and monitored by Russian Federal agencies, and are debt free with a stable financial base. All Proton subcontractors are subject to the same quality standards as KhSC itself; all must have ISO 9001/9002 registered quality management systems and be accredited through the Russian Federation Roscosmos/Ministry of Defense/Gosstandart organizations. In addition, KhSC levies and monitors its own specific schedule and quality requirements, and maintains oversight personnel at the facilities of key subcontractors.

Subcontractor auditing is specified in all KhSC procurement contracts, and is implemented according to a Russian government approved plan described in GOST R ISO 10011-1 and STP 104-892 KhSC company standard. Audits focus on the following issues:

- Incoming inspection procedures
- Qualification test results
- Nonconformance disposition procedures
- Production anomaly and Customer complaint histories
- Corrective actions and nonconformance mitigation guidelines

The audits are witnessed by subcontractor representatives, and the final audit report is signed by both the subcontractor and a Russian Ministry of Defense inspector.

B.1.7 Launch Vehicle Production and Integration

The launch vehicle production and integration process has a test and quality inspection plan that covers the areas of design, production preparation, fabrication, assembly, testing, final acceptance, transportation, and launch site operations.

B.1.7.1 Design Configuration Management

KhSC executes configuration management using Russian Federation-standardized benchmark procedures and processes on the Proton program. Senior engineering and production management provide program-wide communication of all proposed configuration changes, and has representation from Engineering, Production, Parts/Materials/Processes, and Launch Operations. Functional, allocated, and product baselines have been established.

The functional baseline consists of documents such as the system and segment specifications, integration interface control documents, and measurements and mission-discrete lists. The allocated baseline consists of the configuration integration specifications, design requirements documents, and design change documents. The product baseline consists of the process and material specifications, program-released drawings, software development files, and software version description.

B.1.7.2 Acceptance Requirements

The Proton M program uses the proven qualification and acceptance processes for Proton development as were used for all prior Proton upgrade programs. The governing requirements for qualification and acceptance environments are documented in the Russian Federation Standard GOST R ISO-9001and KhSC Company Standards.

All new Proton components undergo a full qualification testing cycle. All existing vehicle components are assessed against Proton specifications by qualified responsible engineers to determine which components meet all predicted environments with the required margin.

Component qualification and acceptance test requirements are captured in test requirements documents and used to maintain the qualification and acceptance test procedures with the component vendors. In order to verify the quality characteristics of components, qualification and acceptance tests are performed under flight-like temperature, humidity, vacuum, vibration, and shock conditions. System-level testing is then performed to further validate component functionality and integration.

Each hardware-responsible engineer is responsible for full ownership of their respective components or subsystems that includes the following qualification and acceptance responsibilities: identifying design and performance specifications, defining component or subsystem qualification and acceptance requirements, working with the component vendor to mutually define and maintain the component qualification and acceptance test procedures, and reviewing and buy-off of all qualification and acceptance test reports or analyses. All Proton qualification units are production units that successfully passed acceptance testing.

B.1.8 Quality Assurance Participation

Quality Assurance representatives participate with the responsible engineer in each step of the component buy-off process, from receipt-and-inspection to review of the test reports. Quality Assurance provides a positive control system for identifying the inspection and acceptance status of products.

B.1.9 Personnel Training

Skilled job performers are essential to the achievement of high product quality. In order to maintain the specialized skills KhSC needs, personnel training/re-training programs are conducted annually. These programs include:

- A 550-hour course of training and certification in job related skills upon initial employment
- Annual re-certification of job performers for critical operations
- Annual re-certification of job performers for the supporting activities required by their jobs, including knowledge of safety and environmental regulations
- Re-certification of personnel in the event of primary occupational work interruptions of longer than three months
- 70-hour skill upgrading courses (at KhSC)
- Skill upgrading assignments to Russian scientific centers and Russian State Standards institutions (50 hours)
- Advanced training courses at European training centers (Germany, England).

B.1.10 Quality Parameter Trend Analysis

KhSC QA personnel monitor and control all important technological processes. As part of this effort statistical stability checks are made on all key parameters. The data gathered is used to define corrective actions and improve process capability.

KhSC monitoring of trends provides feedback for continuous quality improvement and internal audit results, including factory build nonconformance trends and supplier trends.

B.1.11 Corrective Action Plans and Continuous Improvement Program

Corrective action plans are created based on data from the following:

- Nonconformance preventive measures at production, testing and operation phases
- Specifications compliance audit results
- Actions based on factory/shop level board reports
- Quality board findings and "quality awareness day" results
- Internal audits for compliance with regulatory procedures
- Quality management recommendations for improvement of technical inspection processes and techniques
- Actions based on vendor audit results

Continuous improvement program is developed annually and consists of the following sections:

- Requirements compliance — designer's oversight of design and operational documentation during production and at the launch complex
- Monitoring of vendors
- Production, test and service equipment upgrades
- Application of new quality control non-destructive testing methods
- Process parameters stability control
- Personnel training

B.1.12 Customer Visibility

ILS ensures customer visibility into all mission integration related activities regarding the Proton launch vehicle and its Upper Stages through customer participation in all Technical Interchange Meetings (TIMs), Preliminary and Critical Design Reviews (PDR and CDR), fitcheck activities, Launch Vehicle Quality Review (LVQR), two Launch Site Intergovernmental Commission Meetings, Countdown and Launch activities, and the Post Launch Meeting and Report. In addition, ILS produces a Quarterly Quality Report that is provided to all Customers to detail the status of Production related Quality Trends and actual hardware quality status.

TIM's occur no later than as needed, throughout the mission integration process, and cover all aspects of the mission integration effort, primarily through the progressive development of the mission Interface Control Document (ICD) and through reporting of supporting analysis activities. Special purpose TIMs, such as the Ground Operations Working Group (GOWG) are also scheduled as needed. The PDR represents a first complete overview of the work documented in the ICD, and typically occurs at approximately L-12 months. The CDR occurs when approximately 90% of mission integration activities are complete, at roughly L-6 months. The fitcheck is a test of the adapter and separation system with the SC, and usually occurs only with a new or substantially modified spacecraft bus. When necessary, it is held at L-4 months. A LVQR of the Proton M, Breeze M, Payload Fairing and Adapter/Separation System takes place at L-2 months.

The first Intergovernmental Commission Meeting takes place at L-6 days, when senior representatives of all parties concerned with the LV, US, SC and launch base meet to approve roll-out of the ILV to the launch pad. The second such meeting occurs at L-7 hours, when the same representatives meet to give final approval to LV fueling and final countdown operations. During the launch itself, customer representatives play an active role in preparing the SC for launch and determining the final GO/NO GO status of the overall launch system. Finally, a Post-Launch Meeting is held, and a Final Report is prepared, two months after lift-off, to review the success of the mission and any applicable lessons learned, with the intent of constantly improving the Proton mission integration and flight experience.

For ongoing insight into LV manufacturing quality, ILS produces a Quarterly Quality report that provides factory quality trends, as well as the actual hardware quality status for each Proton and Breeze M stage.

B.1.13 Hardware Evolution Design Development Processes

KhSC's standard ISO 9001-based design development policy is used as documented in the KQM, to control and verify that the design of all Proton products meet the specified requirements. The KQM, policies, procedures, and practices identify the design activities, assigned responsibilities for implementing them, and defined and controlled organizational interfaces. A standard development cycle is followed: conceptual design and definition of system requirements, system requirements review, preliminary design, preliminary design review, detailed design, tailored critical design review, component qualification and acceptance, and launch site pathfinder.

The evolved Proton vehicle family was developed to satisfy the requirements of both commercial and Russian Federation customers. The Roscosmos, the Russian Ministry of Defense and its various support organizations, including the GOSS Standardization Committee, the Institute for Machine Building and the Test and Certification Institute, provide technical and programmatic oversight. The Proton development program has now successfully completed the development, production and launch of the first flight articles of the Proton M and Breeze M, the Phase I-enhanced Proton M/Breeze M, the Phase II-enhanced Proton M/Breeze M, and most of the upgrades for the Phase III-enhanced Proton M/Breeze M.

B.1.13.1 Proton M/Breeze M Guidance, Navigation and Control System Hardware and Software Development, Qualification and Testing

Testing and qualification of the Proton M Guidance, Navigation and Control (GN&C) system was conducted through a full set of procedures carried out in accordance with the requirements of Russian government standards, including four principal phases:

1. Each major component and subsystem was put through "stand-alone" laboratory tests that exposed it to all anticipated flight loads (temperature, pressure, vibration, etc.).
2. These components and subsystems were subjected to "joint acceptance tests," conducted with the participation of Russian state inspection organizations.

3. The integrated "flight-like" GN&C system was operated through a comprehensive and varied series of simulations of the anticipated flight profile, using a program-controlled "full-size simulation dynamic stand" that verified both the control system itself and the control system's actuators.
4. The first flight article of the Proton M launch vehicle's GN&C system was subjected to comprehensive acceptance testing at the facilities of the company that manufactured the system, and again at the electrical and electronic checkout area of the launch site. These tests will, of course, be repeated for each subsequent flight article.

The Proton M flight control system software has been developed and tested in special simulation test stands at the facilities of the company that developed the system. The software has also been tested many times at the electrical and electronic checkout area at the KhSC factory, and in the equivalent area at the launch site.

Design of the flight software involves the development of a number of standard trajectories and event profiles, which are modified as needed through the generation of mission-specific mission constants.

Testing of the standard flight software occurs in two principal phases:

1. The software elements are put through stand-alone tests and debugging, using standard software test tools and facilities, as well as the On-Board Digital Computer (OBDC), without hooking up the control system related launch vehicle actuators and instrumentation.
2. Integrated tests which exercise all control system operating modes are performed on an "analogue and digital complex" (simulation rig) using the complete set of OBDC flight control programs, as well as on an "integrated system test console" (breadboard), using the complete control system instrumentation package which would be used in flight. These tests are conducted in conjunction with the hardware tests of the GN&C system.

These test conditions envelope the anticipated range of operating environments, with appropriate margin, to ensure system reliability under all expected real world flight conditions.

The mission design process flow involves multiple agencies in the development and validation of the mission design; including KhSC, KhSC's control system subcontractors (MOKB Mars for the Breeze M; NII AP for the Proton M), and the Ballistics Center (a Russian government agency).

B.1.14 Quality Initiatives

As discussed previously, the vertical integration of Proton key suppliers under KhSC had prompted efforts to consolidate the various suppliers' QMS into the KhSC QMS.

The following are currently implemented:

- A series of audits and reviews:
  - Using a launch vehicle as the audit article, Russian independent auditors carried out an extensive examination of the QMS at KhSC and KhimMASH (Federal Certification Center for Space Technology) and of the launch vehicle processing at the launch site (Federal Space Center).
  - Additional internal reviews of the Proton M and Breeze M components, manufacturing processes and key parameters.
  - Procedure for implementing and evaluating launch site readiness.
  - Audit of the Breeze M main engine test facilities.
  - Expanded vendor audit plan.
  - Review of contamination control processes and additional training and certification of the workforce.
  - Comprehensive analysis of critical operations related to the key performance parameters of the Proton and Breeze M and of the Breeze M main engine.
- Documentation of corporate quality management system processes.
- Increase involvement of the KhSC design bureau in production and testing: the Chief Designer actually supervised the qualification testing mentioned below. Organizational changes formalize the Chief Designer involvement in launch vehicle production critical operations.
- Completion of the qualification testing to validate the modified Breeze M engine design and the rework that was carried out on the previously accepted (including test firing) engines.
- A complete reevaluation of the Breeze M engine reliability was conducted. The life time margin of the engine has more than doubled.
- Creation of a single quality database.
- General revision of Quality Control technical processes.

The medium- and long-term initiatives will ensure the current drive towards an improved QMS is sustained over the long term. They include:

- A number of certifications or recertifications:
  - Recertification of the KhSC QMS to the Russian Federal standard and to the ISO 9001-2008 standard.
  - Accreditation of the KhSC metrological services by the Federal Agency for Technical Regulation and Metrology.
  - Certification and/or upgrading of the manufacturing processes of critical elements, including an independent audit.
- Improvements to Quality Control:
  - Development of methodology to make expanded use of statistical data in validating compliance to requirements.
  - Use of state-of-the-art methods and techniques for Quality Control.
  - Verification of key inspection points and associated methods (continuous recurring activity).

ILS and KhSC are committed to carrying through this broad undertaking to its completion and to inform customers along the way as progress is made. To that end, ILS/KhSC will provide the following expanded insight into Proton M/Breeze M Quality:

- Increased scope of PDR and CDR Quality presentations, Standardized: PDR/CDR Quality presentations templates and contents. PDR presentations focus on QMS processes and procedures, while CDR presentations focus on the Quality status of mission specific Proton M Breeze M hardware.
- Quarterly Quality Reports: In conjunction with internal ILS/KhSC monthly production and quality reviews, ILS produces quarterly quality reports that will be submitted to Customers and Insurance underwriters. This will provide insight into hardware status and trends.
- Expanded LVQR: Prior to the start of the launch campaign, ILS, KhSC and the Customer review the entire Quality Package for the mission-specific LV hardware. The resulting LVQR presentation will be a comprehensive package reviewing the KhSC Quality processes and procedures, all first flight items and their qualification program, LV configuration, and all manufacturing anomalies/non-conformances. An example of the contents of the LV Quality Review Briefing is shown in Table B.1.14-1.

Table B.1.14-1: LV Quality Review Briefing — Example Contents

Proton M Stages 1/2/3, Breeze M, PLF and Adapter Quality Reports (Main Components)

- Configuration
- Comparison with Previous Missions
- First Launch Items
- Mission-Specific Units
- Software
- Waivers
- End of Warranty Components
- Spares Plan
- Flight Anomalies

Launch Complex Report

- Maintenance — Ground Systems Test Results
- Mission Specific Configuration
- All Maintenance Processes Certified and Documented
- Scheduled Maintenance:
  - Processing Facility and Launch Pad STE — Monthly
  - Filling Hall — Monthly
  - Gas/water/power Supply and Ventilation Systems — Annual
  - Climate Conditioning Systems of Integration and Testing Facilities — Daily
- Ground Complex Validation for Integrated LV Operations

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