
The CenterTX

Software Requirements Specification

Version 2.0

<MPC+>	Version: 2.0
Software Requirements Specification	Date: 03/04/2026
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Revision History

Date	Version	Description	Author
03/04/26	2.0	Updated to reflect latest changes	Madhavam

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Software Requirements Specification

1. Introduction

The purpose of this Software Requirements Specification (SRS) is to clearly define the functional and nonfunctional requirements for the CenterTX MPC Plus System- a web-based platform designed to ingest, process, analyze, visualize, and manage Machine Performance Check (MPC) data originating from Varian TrueBeam linear accelerators. The document provides a structured description of the system to ensure common understanding among stakeholders, support development planning, guide implementation, enable QA and testing, and serve as the foundation for maintenance and future system enhancement.

This SRS identifies the system’s goals, constraints, user groups, and required behaviors derived from clinical workflows, data processing needs, QA review practices, and the limitations of the current MPC and QA tool ecosystem as described in project presentations.

1.1 The Purpose of the MPC Plus Project

The MPC Plus Project aims to improve the workflow used in radiation oncology clinics for daily Machine Performance Check quality assurance on Varian TrueBeam linear accelerators. MPC produces large amounts of beam, geometry, and image data that must be reviewed to ensure that each machine is functioning safely, but current tools make this difficult because they do not offer approval or auditing features, provide limited analytics, lack options for setting custom tolerances or creating useful reports, and make it challenging to review large and detailed data sets. The MPC Plus system resolves these issues by creating a single platform that collects and processes both past and current MPC data, organizes results from many machines and clinic locations, and presents beam, leaf, and geometry information in clear dashboards. It supports better decision making with adjustable thresholds, updated baselines, and statistical analysis, and it includes features for clinical workflows such as user roles, sign off, and reporting. The overall goal is to give clinical physicists and other radiation oncology staff a more efficient and reliable way to access and analyze MPC information, reduce the time spent on daily quality assurance tasks, ensure compliance with clinical standards, and make full use of the valuable data produced by MPC across all Center for Cancer and Blood Disorders locations and possibly many more clinics that use TrueBeam systems.

1.2 The Purpose of this Document

The purpose of this Software Requirements Specification is to clearly describe all functional and nonfunctional requirements for Version 1.0 of the CenterTX MPC Plus System. This document explains how the system is expected to behave externally, including how it ingests, processes, visualizes, and reports Machine Performance Check data as well as how users interact with it. It outlines the constraints and dependencies that come from clinical quality assurance workflows, required data formats, chosen technologies, and the need for support across multiple clinic locations. It also defines expectations for performance, security, usability, and reliability within radiation oncology environments. The document identifies all system interfaces, such as those that connect to MPC output files including XIM images and metadata. In addition, it describes requirements for user management, alerting, baseline updates, and the extraction, transformation, and loading of data as defined in the project timeline. Overall, this SRS serves as a shared reference for stakeholders, developers, testers, and support teams. It aligns everyone on the system scope and expected behavior, and it provides the baseline used for design decisions, implementation work, validation, and future maintenance.

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1.3 Document Conventions

This SRS uses clear and consistent formatting to help readers understand the requirements. Each requirement is labeled with an identifier such as USE, PER, SEC, SAF, AVL, or ROB, followed by a number that shows its order in that category. All requirement statements use the phrase “The system shall” to describe required behavior. File names and data formats, such as XIM images or CSV files, are written in a monospace style to distinguish them from regular text. References to diagrams, models, and external documents match the links and materials included in the SRS. Numbered lists are used when steps or groups of related requirements need to be shown clearly, while paragraphs are used for general descriptions. These conventions make the document easy to read and ensure that requirements are interpreted consistently.

1.4 References

- Project Glossary: [Glossary Box](#)
- Vision and Scope: [CenterTX Vision and Scope](#)
- Software Architecture: [URL](#)
- Use Cases: [Use Cases Box](#)
- Business Rules: Located below in part 6
- User Interface Wireframe/Prototypes: [Link to Figma](#)
- Business Domain Model: [URL](#)
- API Document: [URL](#)

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2. Project Glossary

The project glossary is available here: [URL](#).

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3. Vision and Scope

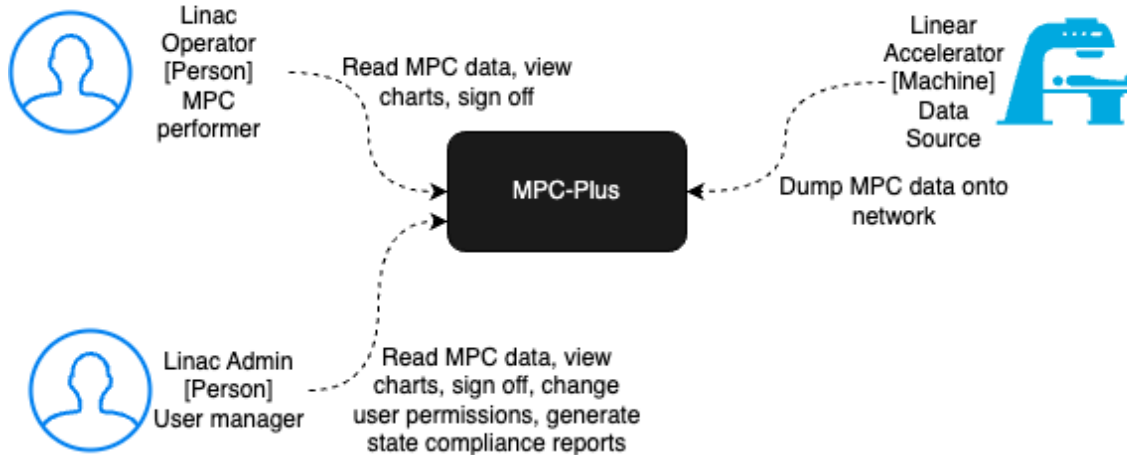
The Vision and Scope document is available here: [CenterTX Vision and Scope](#).

Summary: MPC Plus is a web-based application for radiation oncology clinics that automates the collection, processing, and visualization of Machine Performance Check (MPC) data from Varian TrueBeam linear accelerators. The system addresses the inefficiency of the current Varian MPC workflow, which provides weak reporting, relative-only data metrics, no digital sign-off capability, and limited trend analysis. MPC Plus ingests raw .xim, .xml, and .csv files from the Varian-managed iDrive, standardizes them into a structured database, and presents results through an interactive web dashboard supporting baseline comparison, threshold alerting, historical trending, and compliance sign-off. Post-delivery, all maintenance and support becomes the responsibility of The CenterTX.

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4. Software Architecture

4.1 System Context Diagram

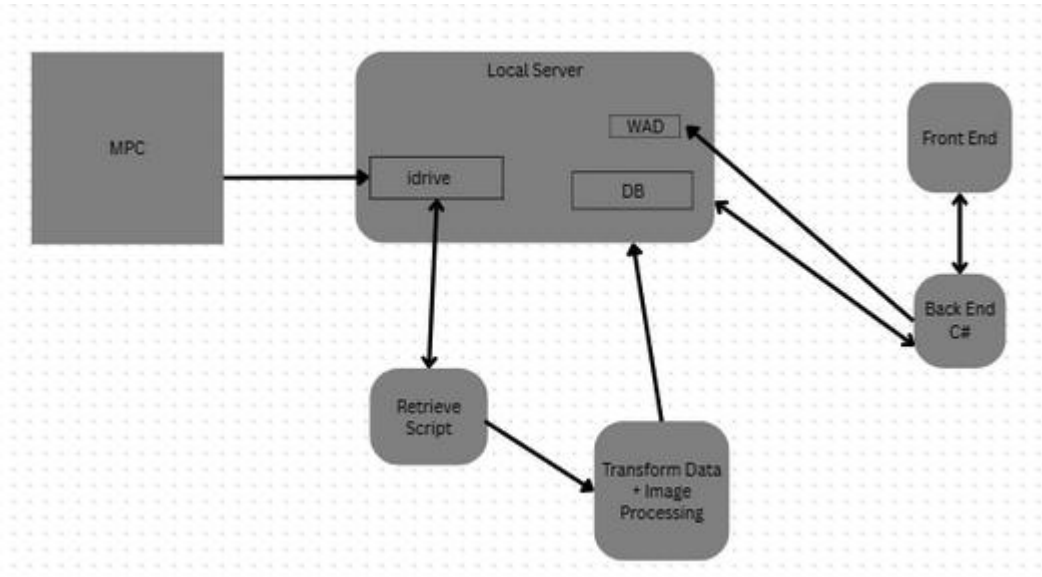


MPC-Plus is a centralized quality assurance platform designed to automate the collection, processing, and visualization of Machine Performance Check (MPC) data from Linear Accelerators used in radiation therapy. The system serves two primary user groups: Linac Operators, who are front-line clinical staff such as radiation therapists and medical physicists responsible for performing daily quality assurance checks, and Linac Admins, who are senior medical physicists or IT administrators with elevated system privileges. Linac Operators interact with MPC-Plus to read MPC data, view performance charts showing quality metrics over time, and digitally sign off on QA results to document compliance with regulatory standards before patient treatments begin. Linac Admins have broader system access, allowing them to manage user permissions, generate comprehensive compliance reports for regulatory bodies like the AAPM and ACR, configure system thresholds, and oversee facility-wide performance across multiple machines. The data source for the system is the Linear Accelerators themselves, which automatically dump MPC data onto the network including XIM imaging files from tests like Winston-Lutz and Picket Fence, machine parameters such as dose output and beam characteristics, and mechanical positioning data for critical components like the gantry and collimator. MPC-Plus sits at the intersection of these actors, providing automated Pylinac-based image analysis, centralized historical data storage, role-based access control, interactive dashboards for trend analysis, and a digital sign-off workflow that creates an audit trail for regulatory compliance while significantly reducing the time physicists spend on routine QA analysis. The iDrive referenced in this diagram is the Varian-managed iDrive shared environment; MPC Plus accesses it directly over the clinic network and does not maintain a local iDrive instance.

4.2 Container Diagram

Container Breakdown

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1. MPC (Machine Performance Check)

- External system component representing the Linear Accelerators
- Source of machine performance data and XIM imaging files
- Sends data to your local server for processing

2. Local Server This contains several key components:

- **Idrive:** Likely file storage/staging area where raw MPC data and XIM files are initially stored
- **DB (Database):** Your Supabase instance providing both SQL and NoSQL capabilities for storing processed data, analysis results, and application state
- **WAD (appears to be a service component):** Could be related to data routing or service coordination

3. Retrieve Script (Python ETL)

- Monitors and retrieves data from the Idrive storage
- Part of your Python ETL pipeline
- Triggers the data processing workflow

4. Transform Data + Image Processing

- Core Python ETL component using Pylinac
- Processes XIM files to extract quality assurance metrics
- Transforms raw machine data into structured format
- Loads processed data into the Supabase database

5. Back End (C# API)

- RESTful API layer that interfaces with the database
- Provides endpoints for the frontend to query processed data
- Handles business logic and data validation

6. Front End (Next.js React)

- User interface for clinicians/physicists
- Displays MPC results, trends, and alerts
- Consumes data from the C# API

Data Flow

1. Linacs generate MPC data → stored in Idrive
2. Python ETL retrieves files → processes with Pylinac → stores in Supabase
3. Frontend queries C# API → API fetches from database → displays results to users

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4.3 Operating Environment

- **OE-1:** The system shall operate on a locally hosted server within the clinic’s internal network, accessible on-site or through a secure VPN connection, consistent with the deployment model.
- **OE-2:** The system shall run on standard clinic workstations using modern web browsers, such as Google Chrome, Microsoft Edge, or Firefox.
- **OE-3:** The system shall retrieve MPC files from the Varian-managed iDrive shared directory, accessed over the clinic's internal network. The system does not require or maintain a local copy of the iDrive; all file retrieval occurs through a read-only network connection to the Varian-managed storage path.
- **OE-4:** The system shall coexist with existing clinical systems and file-sharing infrastructure without requiring changes to the Varian MPC output process.

4.4 Design and Implementation Constraints

- **CO-1:** The system shall use the technology stack identified by the project sponsor, including a NextJS frontend, a C# backend API, and a Python ETL pipeline.
 - The system shall use the pylinac library for processing and analyzing MPC XIM images, which could constrain the ETL pipeline to pylinac-compatible data formats and workflows.
- **CO-2:** The system shall use Supabase as the database platform for storing MPC results, baselines, and configuration data.
- **CO-3:** The system shall comply with clinical IT security policies, including local hosting, encrypted communication, and access control.
- **CO-4:** The system shall process MPC files exactly as produced by the Varian TrueBeam MPC software and cannot modify their format or generation process.
- **CO-5:** The system shall run within the hardware limitations of standard clinic workstations and local servers, as no specialized hardware is allocated for deployment.

4.5 Assumptions and Dependencies

- **AS-1:** It is assumed that all TrueBeam LINAC machines will continue to export MPC data to the shared iDrive directory in a consistent format, including XIM images, metadata, and more.
- **AS-2:** It is assumed that the clinical network environment will provide stable access to the local server, database, and iDrive directory needed for ETL operations.
- **AS-3:** It is assumed that the C#.NET framework will remain supported and compatible with The CenterTX's IT environment for the operational lifetime of the system.
- **DE-1:** The correct operation of the ETL pipeline depends on the availability and accessibility of the iDrive network location where MPC files are stored.
- **DE-2:** The system depends on consistent and stable network access between the MPC machines, the Varian-managed iDrive, the local server, and the web interface. Any network interruption that prevents file retrieval will cause MPC data to be absent from the dashboard for the affected period.
- **DE-3:** The user interface depends on the backend API to return valid processed MPC data for display in charts, tables, and dashboards.

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5. Functional Requirements

*[This section of the **Software Requirements Specification** contains all functional requirements to a level of detail sufficient to enable designers to design a system to satisfy those requirements and testers to test that the system satisfies those requirements.]*

5.1 Use Cases

The full use case specifications are available here: [Use Cases Document](#).

The table below summarizes all use cases by actor. Items marked * are not part of the MVP and are targeted for Spring semester delivery.

Primary Actor	Use Cases
Admin	UC-1: Create standardized data from historical data
Admin	UC-2: Create standardized data from live data
Admin	UC-3: Modify baseline for a machine check
Admin	UC-4: Modify threshold for a machine check
Admin	UC-5: Modify threshold for warning and alert system *
Admin	UC-6: Change user configurations *
Admin	UC-7: Change user role *
User	UC-8: View all MPC Results
User	UC-9: View a specific MPC Result
User	UC-10: View Beam MPC Results (16e, 6x, 12e, 6e, 9e, 15x, 2.5x, 6xFFF, 10x)
User	UC-11: View Leaf MPC Results
User	UC-12: View Geometry Checks Results
User	UC-13: View Beam MPC Charts
User	UC-14: View Leaf MPC Charts
User	UC-15: View Geometry Check Charts
User	UC-16: Sign off on MPC Data
User	UC-17: Generate a report of MPC Checks *

Development phasing:

- Fall semester: UC-1, UC-8, UC-9, UC-10, UC-11, UC-12
- Spring semester: UC-2, UC-3, UC-4, UC-5, UC-6, UC-7, UC-13, UC-14, UC-15, UC-16, UC-17

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5.2 Non-Use Case Functional Requirements

- **NUC-1:** When new MPC files (.XIM images and results.csv) appear on the shared iDrive, the system shall automatically retrieve and process them, as described in the ETL pipeline workflow.
- **NUC-2:** When MPC data is processed, the system shall standardize the values and store them in the database so they can be used for real-time and historical analysis.
- **NUC-3:** When measurements are compared to their baselines and tolerances, the system shall automatically determine whether each check passes or fails, reflecting the thresholds used in clinical QA.
- **NUC-4:** When MPC data is received from multiple machines or multiple clinic sites, the system shall identify the machine and site and store the data separately, as shown in the multi-site pipeline diagram.
- **NUC-5:** When MPC results fall outside their configured thresholds, the system shall automatically flag them so they appear clearly in the dashboard for clinical review.
- **NUC-6:** When corrupted or incomplete MPC files are detected, the system shall skip them, record the issue, and continue processing remaining valid files.
- **NUC-7:** The system shall allow an Admin to view and modify baseline reference values for a specific machine and check type. All baseline changes shall be saved with a timestamp and the Admin's user ID, and all future MPC result comparisons for that machine and check type shall use the updated baseline.
- **NUC-8:** The system shall enforce that a warning threshold value is always less than the corresponding alert threshold value, and that both values are greater than or equal to zero. The system shall reject any threshold configuration that violates these rules and display a specific error message.
- **NUC-9:** When a user digitally signs off on an MPC result, the system shall record the user's name, role, and a system-generated ISO 8601 timestamp, and shall mark that MPC result as read-only. No user, including Admins, shall be able to modify or delete a signed-off record.
- **NUC-10:** The system shall compile daily beam check and geometry check statuses (pass, warning, or fail) for each machine into a monthly results summary. Each day's status shall be stored as a DayCheckStatus record containing the date, a beam check status enum, and a geometry check status enum, which are aggregated into the MonthlyResults for that machine.
- **NUC-11:** Interactive charts (beam, leaf, and geometry) shall support zooming, panning, date range selection, and multi-machine overlay comparison. When a user adjusts a filter or date range, the chart shall update within 2 seconds.
- **NUC-12:** The system shall store image files selectively. Critical QA images shall be saved locally in the database for redundancy and reporting. Non-critical bulk images shall be referenced by their iDrive path rather than duplicated in local storage. This behavior shall be configurable by an Admin.

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6. Business Rules

BR-1: Daily MPC Data Ingestion Rule

The system must automatically ingest all new MPC output files (.xml, .xim, .csv) from the iDrive once per MPC run, without requiring manual user actions.

BR-2: Data Integrity Rule

All calibration data ingested into the database must remain unaltered from the original Varian-generated values unless the user explicitly enables Chamber Output Correction.

Any corrections applied must be logged, reversible, and auditable.

BR-3: Threshold Enforcement Rule

The system must compare all measured values against the machine's configured threshold tolerances and clearly flag any results that fall outside acceptable ranges.

BR-4: User Sign-Off Rule

A machine's daily MPC results cannot be marked complete until a credentialed physicist or authorized technician performs a digital sign-off using their authenticated account.

BR-5: Role-Based Access Rule

System configuration operations—including modifying baselines, thresholds, machine profiles, or correction factors—may only be performed by users in supervisory or admin roles.

BR-6: Compliance Traceability Rule

All sign-offs, configuration changes, and threshold adjustments must be timestamped and associated with a unique user account to maintain auditability for state compliance.

BR-7: Data Retention Rule

The system must retain all MPC numerical results and sign-off records indefinitely (or until clinic policy dictates), while storing large image files selectively to avoid excessive storage consumption.

BR-8: Alert Generation Rule

- The system must automatically generate alerts when:
- A measured value exceeds its configured tolerance threshold,
- A machine's daily MPC results have not been signed off by the required deadline, or
- The ETL pipeline detects missing or corrupted input files.

BR-9: Multi-Machine Consistency Rule

All machines across all sites must be processed using the same standardized data model to ensure consistency in analytics, visualization, and reporting.

BR-10: System Access Rule

Only authenticated users on The CenterTX network or connected through VPN may access the web interface. External access is prohibited.

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7. Data Requirements

[This section describes various aspects of the data that the system will consume as inputs, process in some fashion, or create as outputs.]

7.1 Business Domain Model

*[The **Business Domain Model** represents the key concepts and relationships within the domain, focusing on the core logic and shared understanding of the problem being solved. It should capture the main entities and their interactions in a way that reflects the business processes and goals. Domain models are most commonly created as an UML class diagram.]*

The domain model diagram is available here: [Model](#).

The following entities form the core data model of the MPC Plus system. All entities with a machineId field reference the central Machine entity.

Machine - Represents a single Varian TrueBeam linear accelerator. Fields: id (string), location (string), name (string), type (string).

Beam - Stores the results of a single beam performance check run on a machine. Fields: id (string), type (string), date (date), machineId (string), relUniformity (double), relOutput (double), centerShift (double).

GeoCheck - Stores the results of a single geometry check run on a machine. Fields: id (string), type (string), date (date), machineId (string), relativeOutput (double), relativeUniformity (double), centerShift (double).

Baseline - Stores the reference value for a specific check type and beam variant on a given machine, used to evaluate whether current results are within acceptable range. Fields: machineId (string), checkType (string), beamVariant (string), metricType (string), date (date), value (double).

Threshold - Stores the warning and alert tolerance limits for a specific check type and beam variant on a given machine. Fields: machineId (string), checkType (string), beamVariant (string), metricType (string), lastUpdated (datetime), value (double).

Update - Records a configuration or system event associated with a machine. Fields: id (string), machine (string), info (string), type (string).

MonthlyResults - Aggregates daily check statuses for a machine for a given month. Fields: month (integer), year (integer), machineId (string), checks (array of DayCheckStatus).

DayCheckStatus - Represents the pass/warning/fail outcome for a single day's beam and geometry checks. Fields: date (date), beamCheckStatus (enum), geometryCheckStatus (enum). This entity is contained within MonthlyResults

7.2 Data Acquisition, Integrity, Retention, and Disposal

[If relevant, describe how data is acquired and maintained. State any requirements regarding the need to protect the integrity of the system's data. Identify any specific techniques that are necessary, such as backups, checkpointing, mirroring, or data accuracy verification. State policies the system must enforce for either retaining or disposing of data, including temporary data, metadata, residual data (such as deleted records), cached data, local copies, archives, and interim backups.]

Example:

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- **DI-1:** The system shall acquire MPC data automatically from the shared iDrive directory, including XIM images, metadata, and the results.csv file generated by the Varian TrueBeam machine.
- **DI-2:** The system shall store all processed MPC results in the local database to support historical trending, as described in the data pipeline overview.
- **DI-3:** The system shall verify that each MPC dataset is complete and valid before storing it; incomplete or corrupted datasets shall be rejected and logged.
- **DI-4:** The system shall retain all MPC numerical results and sign-off records indefinitely, or until The CenterTX's internal data policy requires disposal. At a minimum, data must be retained for three years to support trend evaluation and regulatory audits.
- **DI-5:** The system shall retain audit logs, including sign-off actions and configuration changes, for at least three years to ensure traceability.
- **DI-6:** The system shall not modify or delete historical MPC data after it has been signed off, preserving data integrity for long-term machine performance records.
- **DI-7:** Temporary files generated during data ingestion shall be removed after processing so that only validated MPC data remains stored in the system.
- **DI-8:** The system shall ensure that cached or interim processing data does not persist beyond its required use and shall remove such data after processing is complete.
- **DI-9:** The system shall maintain archived datasets in the same protected storage environment or iDrive as active data to preserve long term accuracy and traceability.

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8. External Interface Requirements

[This section provides information to ensure that the system will communicate properly with users and with external hardware or software elements.]

8.1 User Interfaces

[Describe the logical characteristics of each interface between the software product and the users. This may include prototypes, any GUI standards or product family style guides that are to be followed, screen layout constraints, standard buttons and functions (e.g., help) that will appear on every screen, keyboard shortcuts, error message display standards, and so on. Define the software components for which a user interface is needed. Details of the user interface design should be documented in a separate user interface specification.]

- **UI-1:** The system shall provide a web-based dashboard that allows users to view MPC results, thresholds, baselines, and machine performance charts, consistent with the interface shown in the project presentations.
- **UI-2:** The system shall display MPC results in both table and chart formats, including beam checks, geometry checks, and leaf position results, as described in the website demo.
- **UI-3:** The system shall present visual indicators for pass, warning, and fail conditions based on configured thresholds to support clinical review.
- **UI-4:** The system shall use consistent navigation and layout across all screens, including access to machine selection, date filters, and result details.
- **UI-5:** Error messages shall be displayed in clear, non-technical language and shall describe the corrective action when applicable.
- **UI-6:** The system shall support access through standard modern web browsers used in clinical environments.

8.2 Software Interfaces

[Describe the connections between this product and other software components (identified by name and version), including other applications, databases, operating systems, tools, libraries, websites, and integrated commercial components. State the purpose, formats, and contents of the messages, data, and control values exchanged between the software components. Specify the mappings of input and output data between the systems and any translations that need to be made for the data to get from one system to the other. Describe the services needed by or from external software components and the nature of the intercomponent communications. Identify data that will be exchanged between or shared across software components. Specify nonfunctional requirements affecting the interface, such as service levels for responses times and frequencies, or security controls and restrictions.]

Example:

SI-1: Cafeteria Inventory System

SI-1.1: The COS shall transmit the quantities of food items ordered to the Cafeteria Inventory System through a programmatic interface.

SI-1.2: The COS shall poll the Cafeteria Inventory System to determine whether a requested food item is available.

SI-1.3: When the Cafeteria Inventory System notifies the COS that a specific food item is no longer available, the COS shall remove that food item from the menu for the current date.

SI-2: Payroll System

The COS shall communicate with the Payroll System through a programmatic interface for the following operations:

SI-2.1: To allow a Patron to register and unregister for payroll deduction.

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SI-2.2: To inquire whether a Patron is registered for payroll deduction.

SI-2.3: To inquire whether a Patron is eligible to register for payroll deduction.

SI-2.4: To submit a payment request for a purchased meal.

SI-2.5: To reverse a previous charge because a patron rejected a meal or wasn't satisfied with it, or because the meal was not delivered per the delivery instructions.

SI-1: Varian TrueBeam MPC File Output Interface

- **Purpose:** Receives raw MPC data for ingestion and analysis.
- **Format:**
 - *.XIM image files (beam and geometry frames)
 - results.csv (summarized MPC measurement data)
 - Metadata files (*.xml or embedded JSON fields)
- **Exchange Method:**
 - The ETL pipeline retrieves files from the shared iDrive path used by all clinic TrueBeam LINACs.
- **Constraints:**
 - File format is defined exclusively by Varian; the system must not modify it.
 - ETL must validate dataset completeness before ingestion.

SI-2: Python ETL Pipeline ↔ C# Backend API

- **Purpose:** Transfer processed MPC results, baselines, statistical outputs, and alerts into the backend.
- **Data Format:** JSON payloads containing:
 - Machine metadata
 - Measurement values
 - Calculated deviations
 - Baseline comparison outcomes (pass/warning/fail)
 - Exceptions or ingestion errors
- **Communication Method:**
 - Local API endpoints (RESTful, authenticated, HTTPS-only).
- **Frequency:**
 - Triggered automatically when new MPC data appears on iDrive.

SI-3: Backend API (C#) ↔ Supabase Database Interface

- **Purpose:** Persistent storage of MPC results, baselines, thresholds, sign-off records, alerts, and audit logs.
- **Format:**
 - SQL queries executed through Supabase/PostgreSQL.
 - JSON for structured configuration values.
- **Constraints:**
 - All sensitive data must be encrypted at rest.
 - Transactional integrity required for ingestion and sign-off operations.

SI-4: Next.js Frontend ↔ Backend API

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- **Purpose:** Retrieve MPC data for dashboards, charts, thresholds, baselines, user roles, and sign-off workflows.
- **Communication:**
 - REST API calls using HTTPS/TLS 1.2+.
 - JSON request/response format.
- **Key Endpoints Include:**
 - /machines — Retrieve list of clinic LINACs
 - /mpc/results — Daily MPC values + pass/fail status
 - /mpc/history — Historical trend data
 - /config/baselines — Baseline + tolerance configuration
 - /signoff — Submit sign-off action
- **Constraints:**
 - Endpoint access must enforce RBAC rules defined in Section 9.3.

SI-5: In-Application Authentication Interface

- **Purpose:** Provides user login, session management, and role enforcement within MPC Plus.
- **Communication Method:** Credentials (username and password) are submitted via the web interface over HTTPS and validated against user accounts stored in the local Supabase database.
- **Requirements:**
 - User accounts, usernames, passwords, and role assignments are created and managed directly within the MPC Plus application by an Admin.
 - Passwords shall be stored as salted hashes; plaintext passwords shall never be stored.
 - The system does not integrate with Windows Active Directory or any external identity provider.
 - Role assignments (Admin or User) are set per account and enforced by the backend API on every request.

8.3 API Document

[This section is used to provide details about APIs exposed or consumed by the system, including endpoints, inputs, outputs, and error handling. Link to the API document.]

The API document is available here: [URL](#).

8.4 Hardware Interfaces

[Describe the characteristics of each interface between the software and hardware (if any) components of the system. This description might include the supported device types, the data and control interactions between the software and the hardware, and the communication protocols to be used. List the inputs and outputs, their formats, their valid values or ranges, and any timing issues developers need to be aware of. If this information is extensive, consider creating a separate interface specification document.]

- **HI-1:** The system shall interface with Varian TrueBeam MPC output only through the generated MPC files located on the iDrive directory; no direct hardware communication with the LINAC is performed.
- **HI-2:** No additional hardware interfaces have been identified.

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8.5 Communications Interfaces

[State the requirements for any communication functions the product will use, including e-mail, Web browser, network protocols, and electronic forms. Define any pertinent message formatting. Specify communication security or encryption issues, data transfer rates, handshaking, and synchronization mechanisms. State any constraints around these interfaces, such as whether e-mail attachments are acceptable or not.]

Example:

CI-1: The COS shall send an email or text message (based on user account settings) to the Patron to confirm acceptance of an order, price, and delivery instructions.

CI-2: The COS shall send an email or text message (based on user account settings) to the Patron to report any problems with a meal order or delivery.

CI-1: Web Communication Protocols

- The system shall use **HTTPS/TLS 1.2 or higher** for all communication between the web application, backend API, and database.
- All browsers must support modern TLS cipher suites.
- Internal HTTP is prohibited except for secured localhost calls within the server.

CI-2: Internal Network Communication (Clinic LAN / VPN)

- The system shall operate entirely within the clinical network or via secure VPN.
- No external internet communication is permitted except:
 - Windows Active Directory authentication
 - (Optional) GitHub updates and version checks by admins
- All inter-component communication must be IP-restricted to authorized devices.

CI-3: File Transfer Communication (iDrive Access)

- The ETL pipeline communicates with the iDrive shared file directory using SMB/CIFS file sharing.
- Requirements:
 - Read-only access to MPC directories
 - Automatic polling or directory event monitoring
 - Integrity checks on file transfer
- No direct communication with TrueBeam hardware occurs.

CI-4: Email Alerting Interface (Optional Future Enhancement)

For MVP, email alerts may not be implemented; below is the planned interface.

- The system may send automated alerts (out-of-tolerance, missing files, unsigned MPC results) via SMTP.
- SMTP Server: Clinic-managed secure email server
- Protocol Requirements:
 - TLS-encrypted SMTP
 - No PHI permitted in email content
- Notification Types:
 - Threshold failure alerts
 - ETL ingestion failure notifications
 - Daily sign-off reminders

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CI-5: Data Export Interfaces (PDF, CSV)

- The system exports reports via download through HTTPS.
- Formats:
 - CSV with standardized column format
 - PDF with structured headers + machine/date metadata
- Reports must not include patient identifiers (MPC contains none by design).

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9. Quality Attributes

9.1 Usability

USE-1: The system shall provide an intuitive dashboard that allows users to access daily MPC results, baseline values, threshold settings, and compliance reports within three clicks from the main menu.

USE-2: The system shall display data in both tabular and graphical formats to accommodate different user preferences for data interpretation, with a toggle option between views.

USE-3: All error messages shall be presented in plain language (avoiding technical jargon) and shall include actionable guidance for resolving the issue (e.g., "Baseline value must be a positive number. Please re-enter.").

USE-4: New clinical users (without prior web application experience) shall be able to complete a sign-off workflow within 5 minutes on their first attempt after a 30-minute orientation session.

USE-5: The system shall display baseline and tolerance values alongside raw MPC data to provide immediate context for performance evaluation without requiring users to navigate to separate configuration panels.

USE-6: Navigation elements shall remain consistent in location and style across all pages to minimize user learning time and reduce errors.

USE-7: The system shall provide keyboard shortcuts for frequently used actions (e.g., "S" to sign off, "R" to refresh data) to improve efficiency for power users.

9.2 Performance

PER-1: The system shall process and display calibration data from a single MPC result within 5 seconds of user request, measured from click to complete page render on standard clinic workstations (Intel i5 or equivalent, 8GB RAM, modern browser).

PER-2: Interactive charts and visualizations shall update in near real-time (within 2 seconds) when users interact with filters, zoom controls, or date range selectors.

PER-3: The system shall support at least 3 years of historical data (approximately 1,000+ daily MPC records per machine × 4 machines) without performance degradation when generating trend reports.

PER-4: The system shall accommodate simultaneous access by at least 10 concurrent users during peak usage periods (morning shift calibration reviews) with response times not exceeding 5 seconds per request.

PER-5: Data ingestion from iDrive (retrieval, standardization, and database upload) shall complete within 10 minutes for a full daily MPC dataset from all 4 machines.

PER-6: Report generation (PDF or CSV export) shall complete within 15 seconds for single-machine reports and within 30 seconds for multi-machine or multi-year trend reports.

PER-7: System memory usage shall not exceed 2GB during normal operations with 10 concurrent users viewing historical data and generating charts.

9.3 Security

SEC-1: All user access shall be controlled through the MPC Plus in-application authentication system. User accounts, roles, and credentials are created and managed by an Admin directly within the application. No external identity provider or directory service is required.

SEC-2: Users shall be required to authenticate with their MPC Plus username and password before accessing any MPC data, dashboards, or reports. Sessions shall be invalidated after 30 minutes of inactivity.

SEC-3: Role-based access control (RBAC) shall enforce the following permission model:

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- Admin/Supervisor: Full access to all data, configuration panels (baselines, tolerances, thresholds, user roles), and system settings.
- Traditional Users (Physicists/Oncologists): View-only access to MPC results and charts; ability to sign off on data; no access to configuration or system settings.
- IT/Admin Staff (non-clinical): Access limited to system monitoring, server logs, and backup management; no access to clinical MPC data.

SEC-4: All MPC data shall be stored in encrypted form at rest using industry-standard encryption (AES-256 or equivalent).

SEC-5: All network communications between the web interface and the local server shall be encrypted using HTTPS/TLS 1.2 or higher.

SEC-6: The system shall log all access to MPC data, configuration changes, and sign-offs, including user ID, timestamp (ISO 8601 format), and action performed, for audit trail purposes.

SEC-7: Signed-off MPC data shall be marked as read-only and immutable; no user (including Admins) shall be able to modify, delete, or tamper with historical signed-off records.

SEC-8: The system shall enforce password policies consistent with hospital IT standards (e.g., complexity requirements, expiration periods) through Active Directory group policy.

SEC-9: Session timeouts shall occur after 30 minutes of inactivity to prevent unauthorized access to unattended workstations.

SEC-10: Audit logs shall be retained for a minimum of 3 years to support regulatory inspections and compliance audits.

9.4 Safety

SAF-1: The system shall prevent accidental data loss by requiring explicit confirmation (two-step confirmation) before executing irreversible actions such as baseline modification or deletion of historical records.

SAF-2: When a user initiates a baseline or tolerance change, the system shall display the previous value, the new value, and a summary of how this change will affect future MPC result evaluations before confirming the change.

SAF-3: The system shall alert users (via on-screen warning) if MPC results fall outside configured tolerance thresholds, with visual indicators (e.g., red highlighting) to draw immediate attention to potentially unsafe machine states.

SAF-4 (Post-MVP): After MVP, the system should not permit sign-off on MPC data that contains unacknowledged warnings or alerts indicating out-of-tolerance performance. Users must explicitly acknowledge and document any overrides before sign-off is permitted. This requirement is deferred to a post-MVP release and is documented in Appendix A.

SAF-5: All calculations, conversions, and comparisons of MPC values shall be validated for mathematical correctness; the system shall not apply chamber output corrections or baseline adjustments unless explicitly enabled and configured by an Admin.

SAF-6: The system shall prevent concurrent modifications to the same baseline or threshold configuration; if two Admins attempt to modify the same value simultaneously, the system shall reject the second request and notify the user.

9.5 Availability

AVL-1: The system shall maintain at least 99% uptime during operating hours (6:00 A.M. to 8:00 P.M., Monday through Friday) and at least 95% uptime during off-hours, excluding scheduled maintenance windows (which shall be announced at least 1 week in advance).

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AVL-2: Scheduled maintenance windows shall occur outside of peak clinical hours (before 6:00 A.M. or after 8:00 P.M.) and shall not exceed 2 hours per week on average.

AVL-3: The system shall automatically recover from transient network interruptions (connection timeouts, temporary server unavailability) and resume operations within 30 seconds without requiring user intervention.

AVL-4: Critical system services (database, web server, file retrieval service) shall have redundancy or failover mechanisms to minimize single points of failure (detailed architecture to be defined during design phase).

9.6 Robustness

ROB-1: If a user's network connection is lost during a sign-off operation (after clicking confirm but before the system records the sign-off), the system shall detect the incomplete operation upon reconnection and allow the user to retry the sign-off without re-entering data.

ROB-2: If data retrieval from iDrive fails midway through ingestion, the system shall roll back any partial database entries and alert the system administrator; the next scheduled retrieval shall re-attempt the failed data set.

ROB-3: The system shall gracefully handle malformed or corrupt input files (.xim, .xml, .csv) from the Varian machine by logging the error, notifying the administrator, and continuing to process valid files without crashing.

ROB-4: If a database query times out (e.g., when generating a multi-year trend report), the system shall display a user-friendly message ("Report generation is taking longer than expected. Please try again in a few moments.") instead of a technical error.

ROB-5: The system shall validate all baseline and tolerance values before saving them to the database; if validation fails, the system shall reject the change and provide specific feedback (e.g., "Warning threshold cannot be greater than Alert threshold.").

ROB-6: If the iDrive network path becomes inaccessible (e.g., due to network misconfiguration), the system shall notify administrators and prevent incomplete or misleading data from being displayed to clinical users.

9.7 Reliability and Scalability

Reliability

REL-1: The system shall correctly calculate and display all baseline comparisons, tolerance deviations, and chamber output corrections with a mathematical accuracy of $\pm 0.01\%$ (verifiable through unit testing and validation against known datasets).

REL-2: Data retrieved from iDrive and stored in the database shall be verified for integrity; the system shall perform checksum validation on critical fields (e.g., beam output, MLC position) to detect corruption.

REL-3: All sign-off records shall be immutable and timestamped; the system shall prevent modification or deletion of signed-off records even by Admins, ensuring audit trail integrity.

REL-4: The system shall maintain a complete and accurate audit log of all user actions; audit logs shall be backed up daily and retained for a minimum of 3 years.

Scalability

SCA-1: The system architecture shall be designed to accommodate expansion to additional machines (beyond the initial 4 TrueBeam systems) without requiring database restructuring; adding a 5th machine should require only configuration updates, not code changes.

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SCA-2: The database schema shall be optimized for efficient querying of historical data; adding 1 year of additional historical data should not increase query response time by more than 10%.

SCA-3: The system shall support user growth to at least 50 concurrent users without performance degradation; performance testing shall be conducted at this scale during development.

SCA-4: The web interface shall be designed using responsive design principles to accommodate future deployment across multiple clinic locations (out of scope for MVP but considered in architecture).

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10. Deployment

The ETL pipeline will be deployed on both the local workstation and the on-site Varian Linear Accelerator (LINAC) machine environment. Its primary role in deployment is to continuously monitor the shared iDrive directory for newly generated Machine Performance Check (MPC) data.

At each site, the on-site machine will automatically upload extracted and transformed data to a locally hosted database. This database will be deployed on-premises and managed using Supabase as the chosen DBMS. Because all LINAC machines operated by a given organization share a common network-accessible iDrive, the ETL workflow is inherently scalable across multiple machines and sites. Additionally, the workstation responsible for monitoring the iDrive can be configured to invoke ETL tasks in parallel, enabling efficient processing even when multiple MPC files are produced simultaneously.

Website Deployment

Processed data stored in the database will be displayed through a web application hosted on a local server. This site will be accessible to radiation physicists on-site or remotely through a secure VPN connection. This ensures rapid access to machine performance metrics without exposing the system to external networks.

Updates and Maintenance

The software will be published on GitHub as an open-source project, allowing both internal developers and external collaborators to contribute to its ongoing maintenance. Open-source development is a standard practice within the radiation therapy industry, promoting transparency, reliability, and long-term software sustainability.

Performance and Security

Although MPC data contains no patient-identifying information, the system is deployed within a clinical network environment and must meet the security requirements defined in §9.3. All inter-component communication shall use HTTPS/TLS 1.2 or higher, data at rest shall be encrypted using AES-256 or equivalent, and access shall be restricted to authenticated users on the clinic network or VPN. Performance requirements are modest; the ETL pipeline handles lightweight database uploads and stores a selective subset of QA images per MPC run. Standard clinic server hardware is sufficient to meet the performance targets defined in §9.2.

Following delivery of the software, all maintenance, updates, server upkeep, and user support become the sole responsibility of The CenterTX. The development team will provide deployment documentation, configuration guides, and training materials at the time of handover to support a smooth transition.

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11. Internationalization and Localization Requirements

The system is intended for use primarily by English-speaking clients. As such, full internationalization and localization support (e.g., multiple languages, region-specific formatting) is not required. However, the following minimal considerations apply to ensure clarity and usability across English-speaking regions:

- **Language:**
 - The interface, documentation, and help resources will be provided in English only.
 - American English spelling and wording conventions will be used consistently throughout the product.
- **Date, Time, and Number Formatting:**
 - The system will standardize on a single formatting style (e.g., MM/DD/YYYY for dates, 12-hour time format with AM/PM) and apply it consistently.
 - Time calculations may need to account for U.S. time zones if applicable, but no international timezone support is required.
- **Names and Addresses:**
 - Inputs and displays for names and addresses will follow U.S. conventions.
- **Character Set:**
 - Standard ASCII/UTF-8 English characters will be supported.
- **Regulatory Considerations:**
 - Only U.S.-based regulations, business rules, and compliance requirements will be considered.

Since the intended user base is restricted to English-speaking environments, the product will not support localization for additional languages, date formats, or cultural adaptations unless future requirements arise.

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12. Other Requirements

12.1. Legal and Regulatory Compliance

MPC Plus processes machine calibration and quality assurance data generated by Varian TrueBeam linear accelerators. This data does not contain any patient-identifying information and is therefore not subject to HIPAA, HITECH, or the Texas Medical Privacy Act.

The system must comply with the following applicable standards and regulatory requirements:

- **State Radiation Equipment Compliance:** The system must support the daily, weekly, and monthly machine performance check documentation and sign-off requirements mandated by Texas state regulations governing radiation therapy equipment.
- **Audit Traceability:** All sign-off records, configuration changes, and threshold adjustments must be traceable to a specific authenticated user with a timestamp, enabling regulatory inspectors to verify that calibration checks were performed and reviewed by credentialed personnel.
- **Data Integrity for Regulatory Purposes:** Signed-off MPC records must be immutable. No modification or deletion of a signed record is permitted, consistent with audit trail requirements for radiation therapy QA documentation.
- **Reporting:** The system must be capable of generating compliance-ready reports that can be presented to state regulatory bodies as evidence of machine quality control, as described in FE-7 and UC-17.

12.2. Security, Auditing, and Monitoring

To support regulatory compliance and ensure data integrity and patient privacy:

- System access will require authentication and authorization controls based on user roles.
- All access to patient data, system configuration, and administrative functions will be logged.
- Audit logs must be tamper-resistant and retained in accordance with Texas medical data retention requirements.
- The system will include monitoring capabilities for unauthorized access attempts or suspicious activities.

12.3. Installation, Configuration, and Deployment

- Product installation and configuration must support secure deployment in clinical and/or research environments that handle cancer oncology patient information.

12.4. Shutdown and Backup Procedures

- System shutdown processes must prevent data corruption and preserve the integrity of audit logs.

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13. Appendix A

A.1 MVP vs. Post-MVP Use Case Classification

The following use cases are not part of the MVP and are targeted for post-MVP or Spring semester delivery:

Use Case	Description	Status
UC-5	Modify threshold for warning and alert system	Post-MVP
UC-6	Change user configurations	Post-MVP
UC-7	Change user role	Post-MVP
UC-17	Generate a report of MPC Checks	Post-MVP
SAF-4	Block sign-off on unacknowledged out-of-tolerance data	Post-MVP

A.2 DayCheckStatus Enum Values

The beamCheckStatus and geometryCheckStatus fields in the DayCheckStatus entity use the following enumerated values:

Enum Value	Meaning
PASS	All checks for that day fell within the configured tolerance thresholds
WARNING	One or more checks fell outside the warning threshold but within the alert threshold
FAIL	One or more checks exceeded the alert threshold
MISSING	No MPC data was received or processed for that day

A.3 Supported Beam Energy Types

UC-10 and the Beam data entity support the following beam energy type identifiers as generated by the Varian TrueBeam MPC system:

16e, 6x, 12e, 6e, 9e, 15x, 2.5x, 6xFFFF, 10x