System Requirements Specification

for

Ingenion Telemetry Web Server

Version 1.2 approved

Prepared by Ryan Flinchum
Morgan Smith
Thomas Swenson
Ricky Nelson
Jack Capuano
Conrad Prisby
Hamilton Henneberg

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Revision History

Revision Author	Date	Reason For Changes	Version
Hamilton Henneberg	9-22-23	Creation & Initialization of Document	1.0
Jack Capuano	9-29-23	Initial Draft of Functional & Non Functional Requirements	1.1
Ricky Nelson & Ryan Flinchum	9-29-23	Finalization of draft	1.2

1. Introduction

1.1 Purpose

i. This software requirements specification document pertains to the software specifications governing the Ingenion Telemetry Web Server, a critical component of the enhanced Total Verification System (TVS) project. The purpose of this project is to develop a web server interface between the Digilent Nexys A7 board and an end user to allow the user to collect telemetry. This SRS outlines the interaction between the Xilinx Artix 7 FPGA and MicroBlaze soft-core CPU running FreeRTOS on the Nexys A7 and the client device connected via Ethernet. The scope of this document is dedicated to the internal communication framework and web server user interface.

1.2 Document Conventions

i.The software requirements document (SRS) adheres to industry-standard conventions for clarity and consistency. No specific fonts or highlighting conventions have been employed. We chose not to assign priorities to requirements as requirements must be completed for us to achieve our end goal for this project. The SRS aims to provide a clear and unambiguous representation of the software requirements without relying on formatting nuances for conveying significance.

1.3 Intended Audience and Reading Suggestions

i. **Developers:** Start with the "Product Scope" and "Overall Description" sections for a high-level understanding. Dive into "Design and Implementation Constraints" for technical considerations. Explore "External Interface Requirements" for integration details.
ii. **Scrum Master:** Begin with the "Introduction" and "Product Scope" for project context. Focus on "Assumptions and Dependencies" for potential risks. Review "Other Nonfunctional Requirements" and "Business Rules" for project constraints and standards.
iii. **External Users:** Begin with the "Introduction" and "Product Scope" to grasp the project's purpose. Explore "User Interfaces" for interactions with the system.

1.4 Product Scope

i. The software outlined in this detailed design section forms a crucial part of the enhanced Total Verification System (TVS) project, specifically focusing on the Ingenion Telemetry Web Server. The primary purpose of this software is to facilitate seamless communication and interaction between the Digilent Nexys A7 development board, with the MicroBlaze soft-core CPU and FreeRTOS, and external client devices. The software shall enable the implementation of a real-time web server, the hosting of an interactive user interface for users to initiate commands, configure system settings, and monitor live telemetry data during satellite hardware testing. By leveraging communication

protocols such as Ethernet and TCP/IP, the software ensures reliable and high-speed data exchange within the system. The goals of the software include enhancing the existing Total Verification System by integrating advanced features like the Xilinx MicroBlaze CPU, FreeRTOS, and a user-friendly web interface for efficient telemetry data management. This aligns with the project's objectives of augmenting TVS capabilities for NASA's Goddard Space Flight Center, ultimately contributing to the successful testing and verification of satellite hardware components.

1.5 References

i. Xilinx Wiki. (n.d.). ARTY FreeRTOS Web Server. Retrieved from https://xilinx-wiki.atlassian.net/wiki/spaces/A/pages/18841844/ARTY+FreeRTOS+Web+Server

ii. Digilent. (n.d.). Nexys 4 DDR - Getting Started with Microblaze Servers. Retrieved from https://digilent.com/reference/learn/programmable-logic/tutorials/nexys-4-ddr-getting-started-with-microblaze-servers/start

2. Overall Description

2.1 Product Perspective

i. The Ingenion Telemetry Web Server project serves as an augmentation to the existing Total Verification System (TVS). It enhances the TVS by integrating a Xilinx MicroBlaze soft-core CPU on the Artix 7 FPGA and implementing FreeRTOS as an open-source real-time operating system. These enhancements enable the system to host an interactive web server, establish TCP over Ethernet connections with external computers, and manage telemetry data from external, user-friendly connections. This integration will provide a vital bridge between existing satellite hardware components and the ability to monitor and interact with them remotely.

2.2 Product Functions

i. The system will host an interactive web server, establish TCP over Ethernet connections, and manage telemetry data. The primary functions of the Ingenion Telemetry Web Server project are as follows:

- Hosting an interactive web server to enable remote monitoring and control of satellite hardware components.
- Establishing TCP over Ethernet connections with external computers to facilitate data exchange and remote management.
- Managing telemetry data from external sources, making it accessible through user-friendly interfaces.

2.3 User Classes and Characteristics

i. Potential users of the system may include:
- Developers involved in system design and implementation.
- Engineers responsible for hardware and software integration.
- Project managers overseeing the project's progress.
- External users who access the web server for telemetry data and control.

2.4 Operating Environment

i.The operating environment for the Ingenion Telemetry Web Server project includes:
- Hardware components, such as the Artix 7 FPGA and Digilent Nexys A7 development board. Software components, including FreeRTOS as the real-time operating system.
- Network infrastructure to support TCP over Ethernet connections.
- Integration with the existing Total Verification System (TVS) at NASA's Goddard Space Flight Center.

2.5 Design and Implementation Constraints

i. Constraints for the Ingenion Telemetry Web Server project include:
- Resource Allocation: The project must operate within predefined resource constraints, including FPGA resources, memory, and processing power. Trade-offs have been considered to optimize resource utilization without compromising functionality.
- Compatibility: Compatibility with existing systems, including the TVS and external computer systems, imposes constraints on the design to ensure seamless integration.
- Time and Labor: The project operates within specific time, budget, and labor constraints, in order to complete this project within the given time period (1 semester), and labor (7 team members).

2.6 User Documentation

i. Helpful links/ User Manuals
https://www.xilinx.com/video/fpga/microblaze-webserver-demo.html
https://www.youtube.com/watch?v=Pg7BHJoUPDg

2.7 Assumptions and Dependencies

i. Assumptions and dependencies for the Ingenion Telemetry Web Server project include:
   - Interface Agreements: If interface agreements are difficult to establish, contingency plans will involve identifying alternative communication protocols or temporary solutions.
   - Architectural Stability: In the event that architectural stability issues arise with the chosen FPGA or CPU platform, the project team will explore alternative hardware options or adapt the design to mitigate instability.
   - Project Scale: If, during the course of the project, it is determined that the scope is either too large or too small to align with project objectives, contingency plans will be activated to scale the project accordingly. This may involve expanding or reducing features, adjusting resource allocation, or revisiting project goals to ensure alignment with project size and complexity

3. External Interface Requirements

3.1 User Interfaces

i. The system shall be connected to users via an interactive web server that will have reading and display capabilities of telemetry from peripherals.
ii. The system shall be able to send commands to the CPU over ethernet, sent by the user.

3.2 Hardware Interfaces

i. The system shall have ethernet capabilities in order to connect with the user's computer through an ethernet interface at 10/100 Mbps
ii. The software product shall interface with the DDR3 memory in the Artix 7 FPGA, supporting read and write operations for data storage.
iii. The software product shall interface with the GPIO soft cores within the Artix 7 FPGA, enabling configuration and monitoring of general-purpose input and output signals for enhanced system flexibility.

3.3 Software Interfaces

i. The system shall rely on FreeRTOS as the operating system running on the MicroBlaze CPU.
ii. The system shall use FreeRTOS to manage task scheduling and to provide a software module foundation.
iii. The system shall use a web server software component to host the interactive web server.
iv. The system's web server software component shall interact with FreeRTOS to retrieve real-time telemetry data.

v. The system shall handle TCP/IP communication over Ethernet for external computer connectivity.
vi. The system shall read, process, and display telemetry data from the AXI bus and peripheral devices.
vii. The system shall process telemetry data in real-time to support live data display.

3.4 Communications Interfaces

i. The system shall utilize HTTP protocol standards for interaction with external web browsers.
ii. The system shall implement WebSockets to enable real-time, bidirectional communication between the server and connected clients.
iii. The system shall adhere to IEEE 802.3 standards for Ethernet communication.
iv. The system shall transmit user commands and configurations through HTTP POST requests.
v. The system shall communicate at the 10/100 MBit ethernet rates.
vi. The system shall maintain comprehensive logs of communication events, errors, and warnings for debugging and system analysis.

4. System Features

4.1 System Feature Example

i. Communication Link Establishment

4.1.1 Description and Priority: This feature involves establishing and maintaining a reliable communication link over Ethernet using the TCP/IP protocol suite.

4.1.2 Stimulus/Response Sequences:

- *Stimulus:* User initiates telemetry data capture or configures system settings via the web interface. *Response:* The system establishes and maintains a communication link for real-time telemetry data display.

4.1.3 Functional Requirements:

REQ-1: The system shall establish a communication link over Ethernet using the TCP/IP protocol suite.

REQ-2: The system shall maintain the established link for seamless interaction with external computers.

REQ-3: The communication link setup process should include robust error handling mechanisms to address potential disruptions and ensure a reliable connection.

ii. User Web Interface

4.1.1 Description and Priority: This feature focuses on providing a user web interface, allowing users to initiate telemetry data capture, request specific data, and configure system settings.

4.1.2 Stimulus/Response Sequences:

- *Stimulus:* User interacts with the web interface to initiate telemetry data capture, request data, or configure settings. *Response:* The web interface provides options for these actions.

4.1.3 Functional Requirements:

REQ-4: The web interface must allow users to initiate telemetry data capture.

REQ-5: Users should be able to request specific data through the web interface.

REQ-6: The web interface must provide options for configuring system settings.

iii. Telemetry Data Parsing and Display

4.1.1 Description and Priority: This feature involves parsing of telemetry data upon request and presenting it in a structured format for clarity.

4.1.2 Stimulus/Response Sequences:

- *Stimulus:* System receives a request for telemetry data. *Response:* Telemetry data is parsed and displayed in a structured format on the web interface.

4.1.3 Functional Requirements:

REQ-7: The web server must support the parsing of telemetry data.

REQ-8: Telemetry data should be structured for clarity and ease of interpretation by operators.

5. Other Nonfunctional Requirements

5.1 Performance Requirements

i. The system shall reliably verify the functionality of the implemented Xilinx MicroBlaze soft-core CPU on the Artix 7 FPGA.

ii. The system shall provide real-time data processing and response capabilities through the integration of FreeRTOS as the operating system.
iii. The system shall host an interactive web server accessible via TCP over Ethernet for monitoring and control purposes.
iv. The system shall read telemetry data from the onboard AXI bus and other peripherals, ensuring accurate and timely data acquisition.
v. The system shall allow for the transmission of various commands to the CPU, following a defined protocol.

5.2 Safety Requirements

i. The system shall continuously monitor for abnormal operating conditions, such as voltage fluctuations, excessive temperatures, or hardware malfunctions.
ii. The system shall effectively manage power consumption to prevent overheating and ensure stable performance under various operating conditions.
iii. The system shall implement self-diagnostic routines to detect internal faults and report and log those faults.

5.3 Security Requirements

i.The system shall incorporate measures to maintain data integrity during telemetry data acquisition and transmission to external computers.
ii.The system shall implement redundant storage and backup mechanisms to prevent data loss in the event of system failure or power interruptions.
iii.The system shall implement safeguards to prevent unauthorized access or control, ensuring data integrity and operational safety.
iv.The system shall utilize secure communication protocols, such as TLS (Transport Layer Security), for all interactions with external computers and devices.

5.4 Software Quality Attributes

i.The mean time between failures (MTBF) of the system shall meet the customer's reliability expectations.
ii.The system shall have a low mean time to repair (MTTR) by providing effective error logging, monitoring, and debugging tools for swift identification and resolution of issues.
iii.The system shall implement mechanisms to recover from unexpected failures or errors gracefully, minimizing downtime.
iv.The system shall provide optimal performance to process telemetry data, respond to user interactions, and serve web content in a timely and efficient manner.
v.The response time for critical operations, including data acquisition and command execution, shall be within the customer's to meet performance requirements.

vi. The system shall be designed with modular and well-structured code to facilitate ease of maintenance, updates, and future enhancements.
vii. The system shall feature an intuitive and user-friendly interface that allows users to easily navigate and interact with the functionalities provided.

5.5 Business Rules

i. The system shall adhere to relevant industry standards, guidelines, and applicable regulations governing safety, interoperability, and performance.
ii. Data encryption and anonymization shall be implemented to protect sensitive information in accordance with confidentiality laws and proprietary information regulations.
iii. Adherence to strict resource constraints, including FPGA resources, memory, and processing power.
iv. Optimization strategies, such as trade-off analyses, to ensure efficient resource utilization without compromising functionality.
v. Compatibility with existing systems, particularly the Total Verification System (TVS) and external computer systems.
vi. Time constraint: Project completion within two semesters.
vii. Budget constraint: Project budget set at $0.
viii. Labor constraint: Project execution by a team of seven members.

6. Other Requirements

6.1 The system shall adhere to licensing terms that permit modification, distribution, and use by NASA and Ingenion in current and future projects without restrictions.
6.2 The system shall be accompanied by clear and comprehensive documentation outlining intellectual property rights, licensing terms, and usage permissions.

Appendix A: Glossary

- Ingenion Telemetry Web Server: The software component responsible for facilitating communication and interaction between the Digilent Nexys A7 development board, Xilinx Artix 7 FPGA, MicroBlaze soft-core CPU running FreeRTOS, and external client devices via Ethernet. It is a critical part of the Total Verification System (TVS) project.
- Total Verification System (TVS) Project: A project aimed at enhancing satellite hardware testing by integrating advanced features and improving telemetry data management.
- Digilent Nexys A7: A development board used in the project for interfacing with satellite hardware components.
- Xilinx Artix 7 FPGA: A Field-Programmable Gate Array (FPGA) from Xilinx used to host the MicroBlaze soft-core CPU and execute the software.
- MicroBlaze: A soft-core microprocessor designed by Xilinx for implementation on FPGAs.

- FreeRTOS: An open-source real-time operating system used for running tasks on the MicroBlaze CPU.
- Ethernet: A network communication protocol used for connecting the Nexys A7 board to external client devices.
- TCP/IP: Transmission Control Protocol/Internet Protocol, the suite of communication protocols used for transmitting data over networks, including the internet.
- User Interface (UI): The graphical interface that allows end-users to interact with and control the telemetry system.
- Telemetry Data: Data collected from satellite hardware components, used for monitoring and control.
- External Computer: A device connected to the telemetry system via Ethernet for data exchange and management.
- Real-Time Web Server: A web server that provides immediate and interactive access to telemetry data and system controls.
- Communication Protocols: Standards like Ethernet and TCP/IP used for reliable data exchange within the system.
- Xilinx MicroBlaze CPU: The soft-core CPU integrated into the Artix 7 FPGA for processing tasks.
- HTTP Protocol: Hypertext Transfer Protocol, used for communication between web browsers and the web server.
- WebSockets: A communication protocol that enables real-time, bidirectional communication between the web server and connected clients.
- IEEE 802.3: A standard for Ethernet communication.
- HTTP POST Requests: A method for sending data from a user to a web server.
- System Features: Key functionalities or capabilities of the telemetry web server, such as communication link establishment, user web interface, and telemetry data parsing and display.

Appendix B: Analysis Models

Figure 1

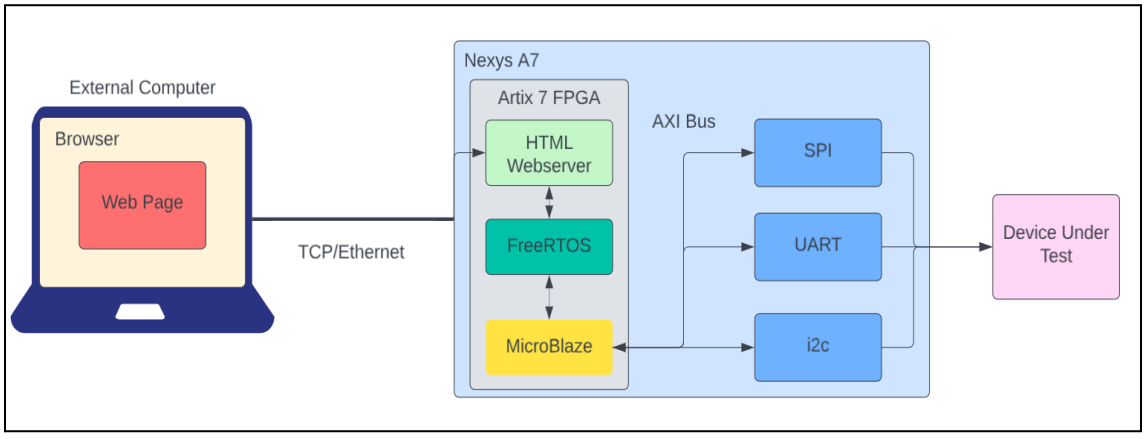

Figure 1 shows a graphical representation of a general component diagram for the system

Appendix C: To Be Determined List