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Concept Design for Teleoperation of a John Deere 909 Feller Buncher

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EXECUTIVE SUMMARY

Teleoperation, or the use of telecommunications to control equipment at a distance, has the potential to improve the safety, productivity and efficiency of harvesting operations on steep terrain. Earlier work within the Future Forests Research Primary Growth Partnership (PGP) "Innovative Harvesting Solutions" programme proposed a concept design for the introduction of teleoperation to steep slope harvesting in New Zealand to achieve these aims.

The concept design was a teleoperated steep slope excavator tree harvester. The design included full teleoperation, visual feedback from cameras on the excavator, and feedback from a range of sensors. This concept design was targeted to result in a commercial implementation by June 2016.

Since remote control was part of the solution for a teleoperated excavator, it was proposed that the development be done in several stages: firstly, to design and build a remote-controlled excavator, and secondly to add video and audio feedback to permit teleoperation. A human factors study of teleoperation in harvesting had underpinned the importance of video and audio feedback for the concept design.

This report documents the concept design for the teleoperation control system for a winch-assisted John Deere 909 feller buncher. This is the fourth and final stage of the PGP Programme Objective 1.2 Task A: Teleoperated Felling Machine. The report describes concept designs for the console for the steep country harvesting machine, the video system and the audio system. The overall system layout is presented with a cost estimate for installation to meet the operational parameters and performance standards defined in the Alpha Prototype Development Plan. The final product will then be peer reviewed and the teleoperation control system commissioned.

INTRODUCTION

Objective

The objective of FFR's teleoperation project is to apply teleoperation to a steep terrain felling machine. Earlier FFR work (Milliken and Parker, 2011) proposed a concept design for the introduction of teleoperation to steep slope harvesting in New Zealand to achieve these aims

The preferred near-term concept for a teleoperated machine for steep terrain harvesting was determined to be a cable-assisted excavator-based harvester of around 30 tonnes machine weight with a felling/bunching head.

A Nelson logging contractor, Wood Contracting Nelson 2014 Limited expressed a desire to control their John Deere 909 feller buncher remotely. The John Deere 909 (Figure 1) was chosen as the target machine for teleoperation because it already has electrically-actuated pilot hydraulics, and therefore the hydraulic systems do not require modification.

Figure 1: The target machine: a John Deere 909 feller buncher

The teleoperation project has been divided into four stages:

- Stage 1 was to implement basic remote-control functionality for a winch-assisted John Deere 909 feller buncher. After installation the basic motion control on the 909, including the emergency stop system was tested. Stage 1 was completed in July 2014 (Milliken *et al*., 2014).

- Stage 2 was to extend the remote control functions to include the functions of the Sealed Switch Module (SSM) and some functions of the Advanced Display Unit (ADU). The SSM and ADU functions were implemented via a touchscreen in the remote control unit (Figure 2).

Figure 2: The remote control unit

- Stage 3 was to implement video-assisted remote control. The earlier FFR human factors study of teleoperation in harvesting (Parker, 2011) underpinned the video and audio feedback requirements for the concept design. Specifically, live video from a camera in the cab was displayed on the touchscreen on the remote-control unit. Stage 3 was completed in June 2015. The video-assisted remote control system that was commissioned for Stage 3 consisted of the following parts:
  - An emergency stop system
  - A motion system to enable control of all axes of motion on the machine and all felling head functions
  - A virtual Sealed Switch Module (SSM) which provides all functions of the SSM in the cab
  - A partial implementation of the functions of the Advanced Display Unit (ADU). Information from the machine such as fuel level, oil temperature, track speed, cab tilt, hydraulics-enable status and the status of the emergency stop system is displayed.
  - A video-feedback system from a camera in the cab (Figure 3) to provide a view on the touchscreen. Pan, tilt and zoom functionality is also provided. The video display was limited to a small screen to avoid having to make the remote-control unit too large.

Figure 3: Pan-Tilt-Zoom camera mounted on the ceiling of the operator cab

- Stage 4 is to implement full teleoperation. It is planned that the operator will sit in an operator seat in a remotely-located console, and high-quality live video will be displayed on multiple screens. The operator controls will replicate the controls in the operator cab of the machine as closely as possible.

  The teleoperation system for Stage 4 will provide the same functions that were provided for Stage 3 but with much better video, a focus on improving productivity and good situational awareness, a comfortable seated console and a number of refinements to many of the components. Stage 4 will also include other improvements to maximise the reliability, productivity, cost and field serviceability of the teleoperated machine.

CONCEPT DESIGN FOR THE OPERATOR CONSOLE

A number of options were considered for the operator console. This section focuses on the preferred design, and discusses its advantages over alternative options.

Cable Price Limited, the New Zealand agents for John Deere products, agreed to supply a seat and pedals identical to those in the target machine. These items will be provided at no cost to FFR. The preferred concept is to fit out a light trailer as an operator console. The seat will be fitted with CAN-attached joysticks with “dead man” switches. A pedal interface board will be designed to convert the analogue signals from the pedals to CAN. The Sealed Switch Module (SSM) and Advanced Display Unit (ADU) functions will be provided by the touchscreen.

The concept of using a remote-control unit that clips into a rack in front of the operator was considered but rejected for two reasons. Firstly, Simon Rayward of Wood Contracting Nelson 2014 Ltd said he preferred the idea of a dedicated operator seat over a detachable remote-control unit. Secondly, a detachable remote-control unit would not be as comfortable as a dedicated seat with integrated joysticks. The concept design for the operator console is shown in Figure 4.

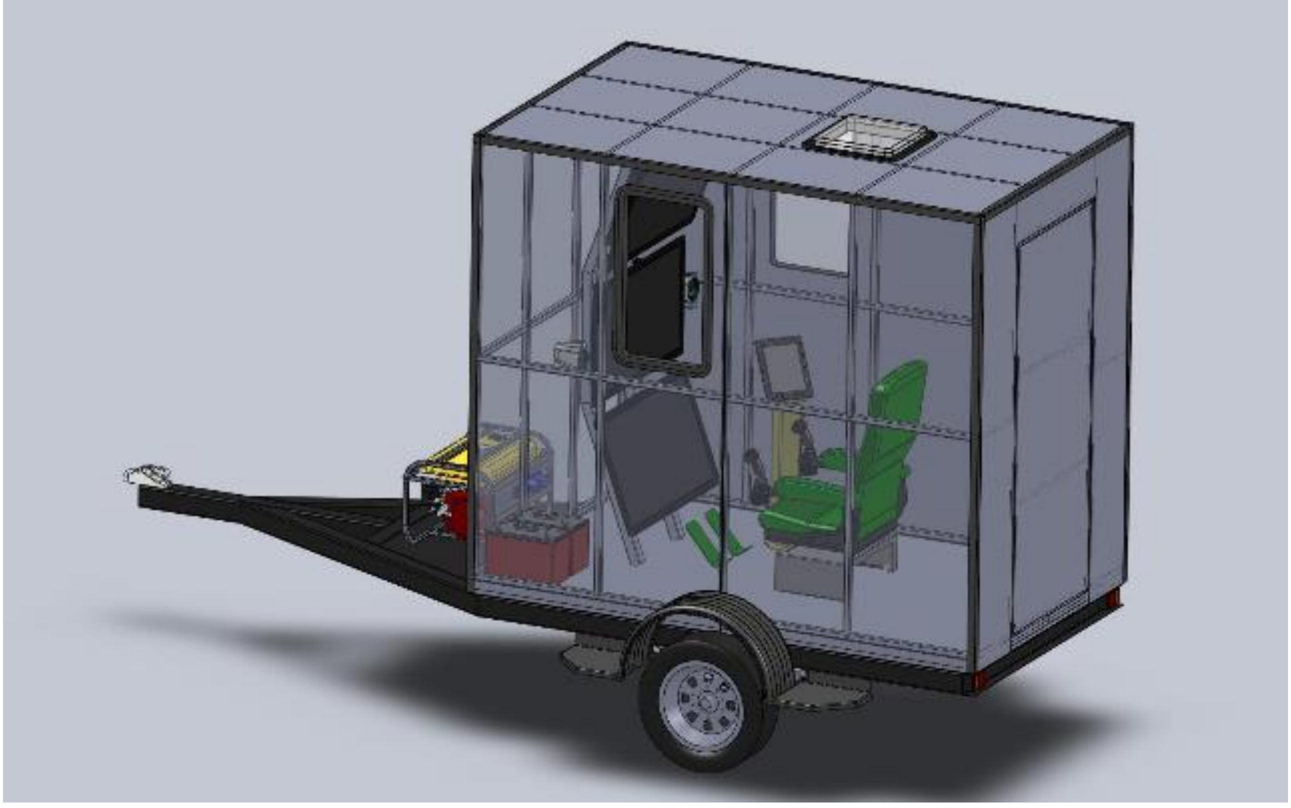

Figure 4: Visual representation of the concept for the operator console

CONCEPT DESIGN FOR VIDEO SYSTEM

Video will be very important for teleoperation because vision is critical for situational awareness and productivity.

The design of the camera system is untested in this application, so it will be refined and developed as testing progresses. At this stage, the favoured camera locations are the four positions shown in Figure 5. These camera locations provide a good view of the tracks, a forward view, a view looking back at the machine and a forward view from the felling head. The view looking back at the machine will give the operator good situational awareness to compensate for loss of peripheral vision and not having a view through the side window.

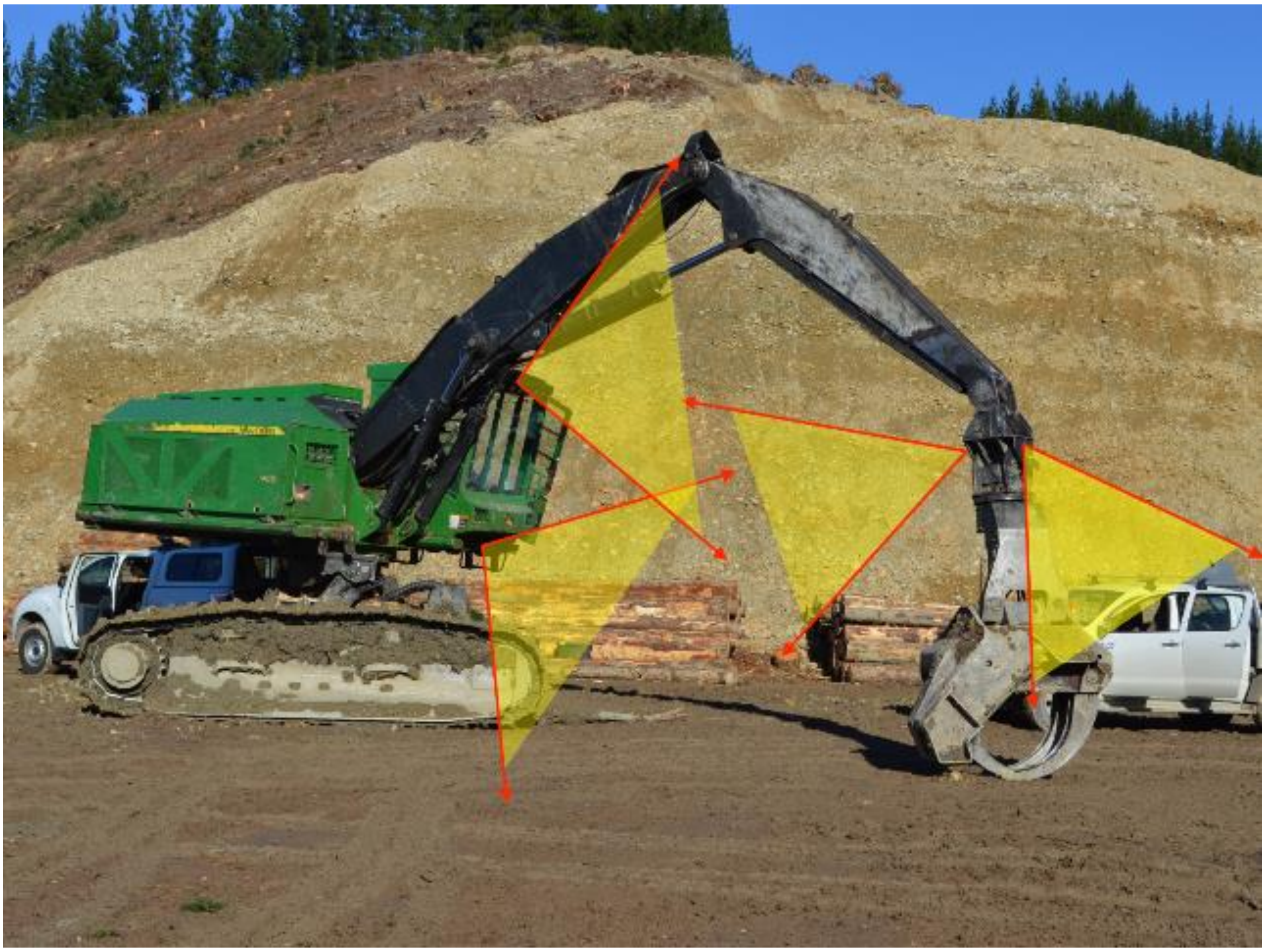

Figure 5: Planned camera locations to maximise remote operator view

Figures 6, 7 and 8 show possible attachment points. The cameras will have to be very well guarded to protect them from damage.

Figure 6: Planned location of camera below windscreen

Figure 7: Planned location of camera above windscreen

Figure 8: Possible location of camera on felling head

An entirely analogue video system was considered, as analogue video has the advantages of simplicity, negligible latency and relatively low cost. However, analogue video was not preferred because:

- Most easily available analogue wireless systems use a 2.4GHz carrier frequency. This frequency requires reasonably good line-of-sight.
- The wireless transmitter may conflict with the existing camera link on the winch or other 2.4GHz systems.
- Only one system of this type can be used in the area unless multiple channels are provided by the hardware.
- A separate link would be required for remote control.
- Analogue video cannot operate over a standard IP link (over the internet) without first digitising the video. This may reduce flexibility for future developments.

Low latency digital video is the preferred option even though the latency will be between 80 and 120 milliseconds and the hardware is more expensive than analogue options.

Advantages of low latency digital are:

- Video and audio can be transmitted over the same wireless link as the remote control system.
- High definition video is available.
- All data on the wireless link will be sent using IP (Internet Protocol). This means the Internet can be used for remote control at a later date if desired.
- Video from multiple cameras can be sent relatively easily over the same wireless link.
- A 900 MHz carrier frequency can be used for the wireless link, giving reasonable tolerance to interrupted line-of-sight between the two transceivers.

A diagram of the configuration for the video system which is preferred at this stage is shown in Figure 9. Video from the existing winch camera will be intercepted as a composite signal, encoded and sent over the IP link. This configuration is only a starting point and may be modified during testing.

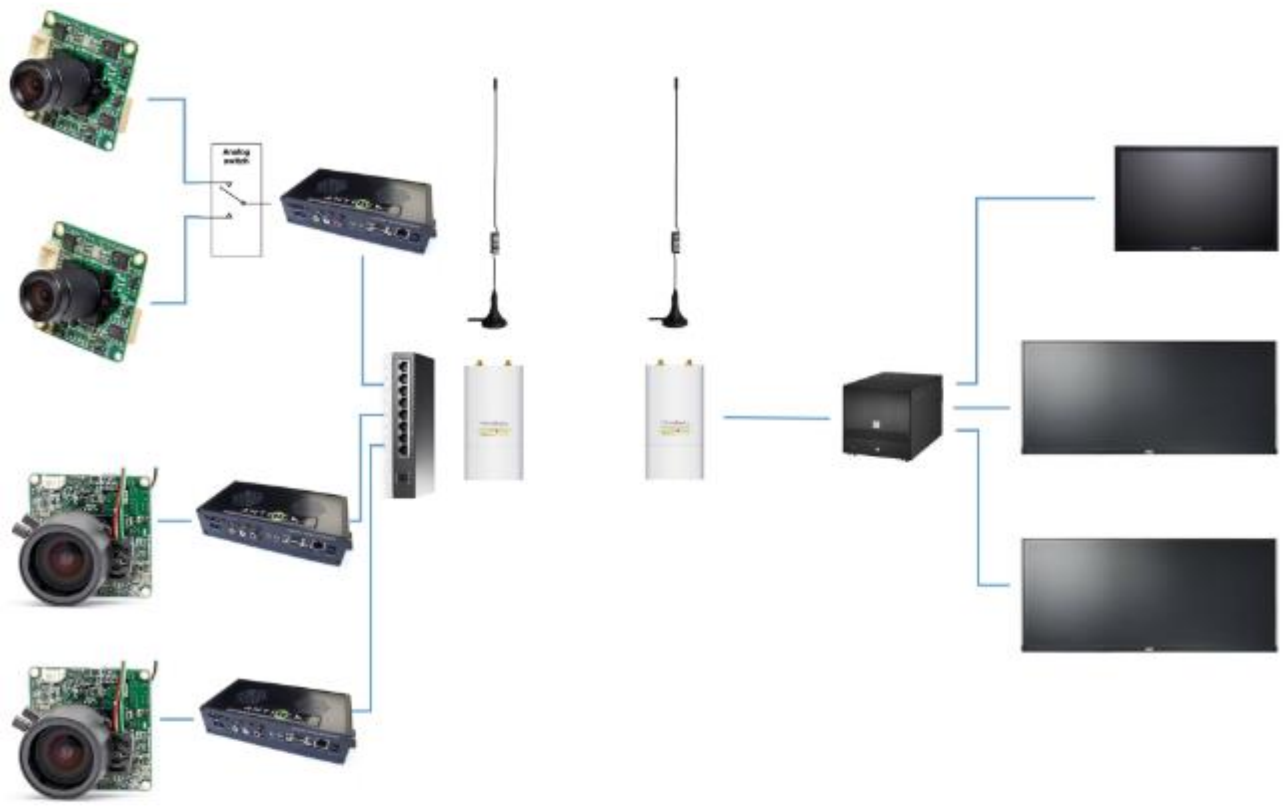

Figure 9: Camera Simultaneous 80ms IP Link Option

CONCEPT DESIGN OPTIONS FOR AUDIO SYSTEM

Audio is believed to be important for situational awareness. Audio will be transmitted from inside the cab. The audio will be mixed with a cheap AM/FM radio and played on speakers in the console as shown in Figure 10.

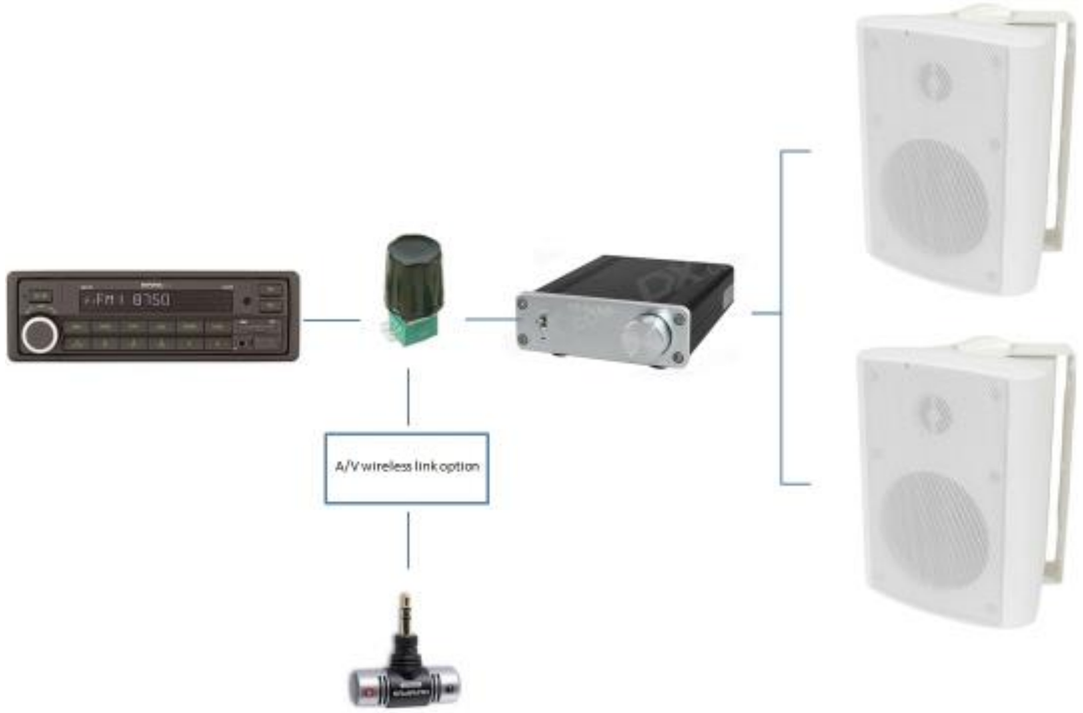

Figure 10: Proposed design for audio system

OVERALL SYSTEM LAYOUT

The overall layout of electronic components on the machine side and the remote side is shown in Figures 11 and 12. The trapped key can be inserted into the machine or the remote console. If the trapped key is inserted into the machine side, power is cut to the machine-side nodes and all motion pins and SSM pins are bypassed. This means the machine will work in manual mode even if one or more of the nodes on the machine side fail. This should result in very good reliability in manual mode.

If the trapped key is removed from the remote side, the nodes in the machine power up and wait for communications from the remote side. The remote side can be powered up only if the trapped key is inserted in the console.

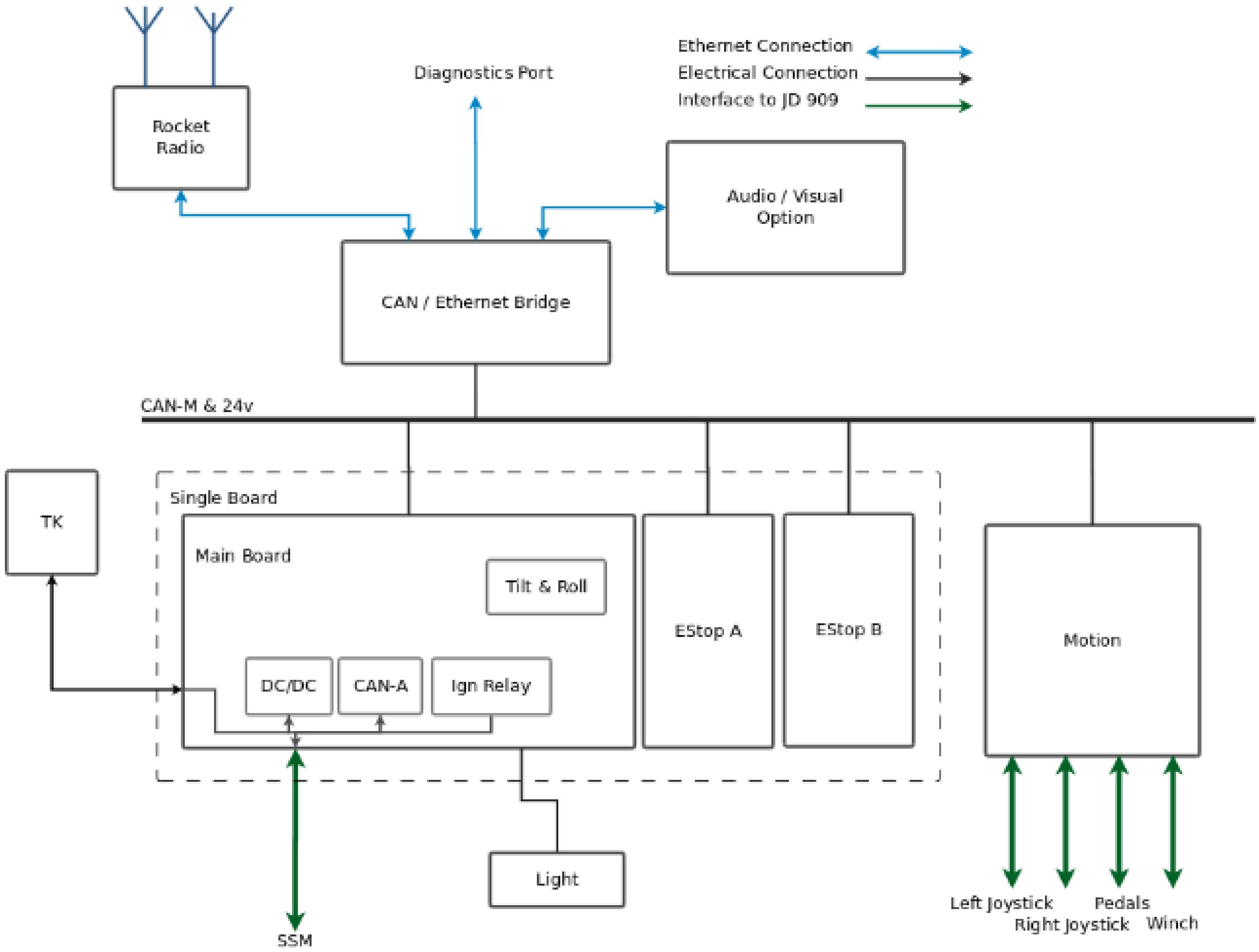

Figure 11: Concept for physical layout of components for the machine side

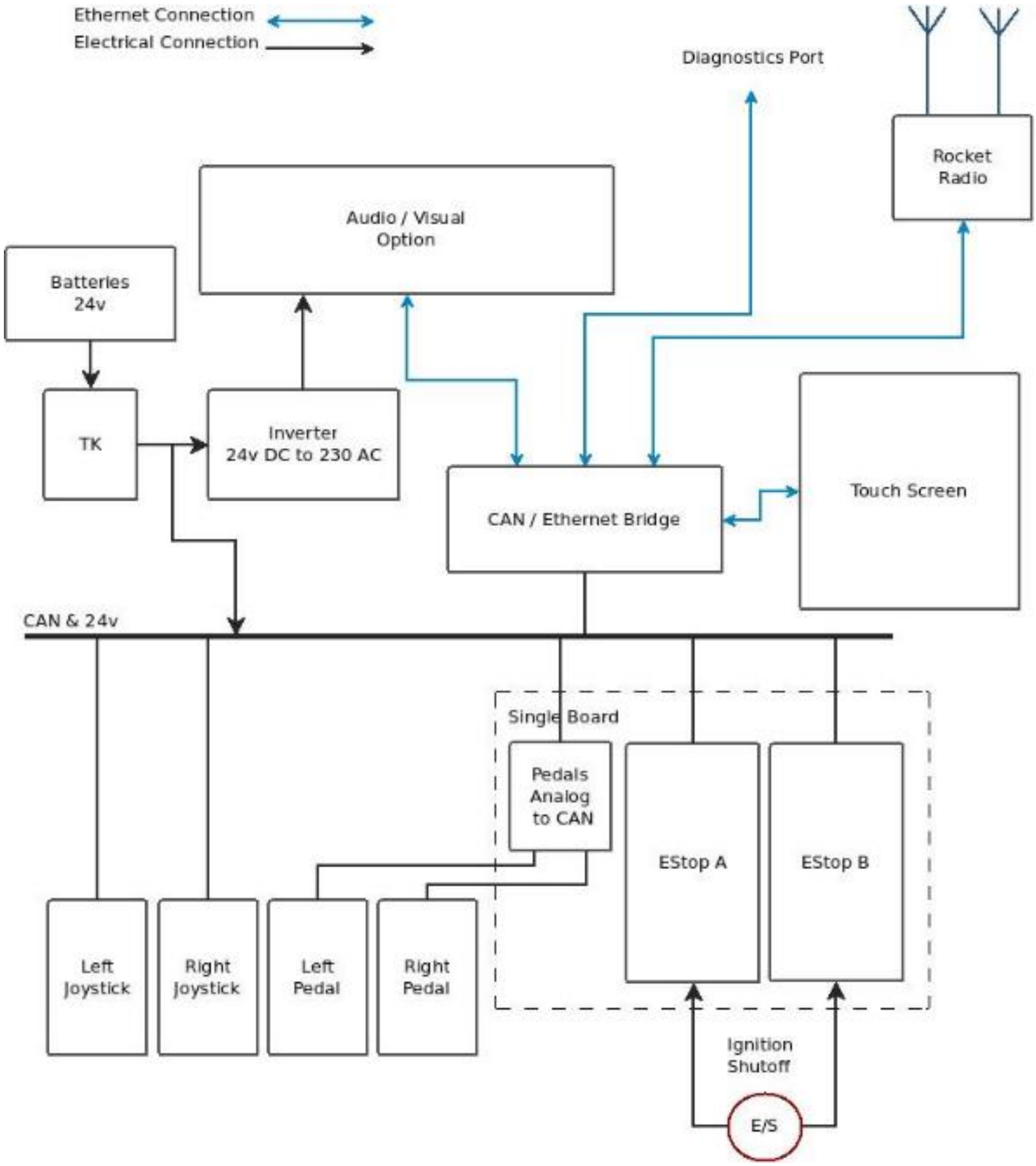

Figure 12: Concept for physical layout of components for the remote side

COST ESTIMATE

The remote control system commissioned in Stage 3 was reviewed. Lessons learned from Stage 3 were applied to the concept design for Stage 4 (teleoperation). The estimated cost for Stage 4 of the project is $305,721 (Table 1).

Table 1: Stage 4 Project Costing

TASK	COST (plus GST)
Complete design of teleoperation system	$3,100
Develop audio and visual feedback	$27,455
Documentation and planning	$27,455
Revise boards	$21,119
Manage buying parts	$3,696
Firmware upgrade	$55,966
Build console	$12,671
Machine side component manufacture	$20,063
System integration and testing	$8,448
Console assembly and wire up	$3,168
Machine assembly and wire up	$3,168
Install and test	$22,175
Field demonstration	$8,448
Commercialisation pitch	$22,175
Purchase items	$56,054
Project Admin (TST meetings)	$10,560
Total	$305,721

PROJECT SCHEDULE

A Gantt chart showing tasks and sub-tasks and their expected completion times has been prepared to schedule the stages and task list for Stage 4 of the project. Some tasks that have been serialised in the project schedule can be completed in parallel. It is estimated that the time saved by paralleling tasks is likely to be offset by additional time for unforeseen delays during development. The Gantt chart was formulated with no contingency for delays or additional costs. Any problems are likely to result in a delay and an increase in the time spent on Stage 4. As a result of this project scheduling, it is estimated that the system will be commissioned at the end of March 2016. Commercialisation will be addressed after commissioning, with the whole project completed by the end of June, 2016.

CONCLUSION

The video-assisted remote control system commissioned in Stage 3 of the project in June 2015 was reviewed. The review was used to provide direction for the concept design for Stage 4 of the project, full teleoperation for the steep country harvesting machine.

This report has described the concept design for the console, the video system and the audio system. The overall system layout has been presented, including a project schedule and cost estimate for the installation. Before installation and commissioning, the system will be peer reviewed. After commissioning, a commercialisation plan for the system will be developed, which will complete the fourth and final stage of the PGP programme Objective 1.2 Task A: Teleoperated Felling Machine.

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