FUTURE FORESTS RESEARCH

Ministry for Primary Industries
Manatū Ahu Matua

Harvesting & Logistics

STEEPLAND HARVESTING PROGRAMME

ANNUAL PLAN 2015 - 2016

Leadership in forest and environment management, innovation and research

Harvesting & Logistics Theme

Research Plan 2015 – 2016

This annual update to the Business Plan is a schedule to and subject to the terms and conditions of the Primary Growth Partnership (PGP) Contract "Innovative Harvesting Solutions" (Contract Ref. CONT-23140-PGP-FFR) between Future Forests Research Limited (FFR) and the Ministry for Primary Industries (MPI).

MINISTRY FOR PRIMARY INDUSTRIES by

Authorised Signature

FUTURE FORESTS RESEARCH LIMITED by

Authorised Signature

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INTRODUCTION

Summary

This Research Plan is an annual update to the “Innovative Harvesting Solutions” Business Plan prepared for the Primary Growth Partnership (PGP) in February 2010. This Research Plan details the annual plan for the sixth and final year of the programme which outlines a pathway for the New Zealand forest industry, through Future Forests Research Ltd (FFR), to realise substantial gains in productivity and cost reduction through improved harvesting technologies. Implementing cheaper and more effective methods for harvesting trees on New Zealand’s steep country is vital if the forest industry is to remain internationally competitive and to grow. There have been no changes in programme direction since the commencement of the programme on 1 July 2010. The expected programme outcomes are unchanged from the “Innovative Harvesting Solutions” Business Plan prepared for the Primary Growth Partnership (PGP) in February 2010.

Contract Details: Innovative Harvesting Solutions

Contract ID:	FFRX1001
Short Title:	INNOVATIVE HARVESTING SOLUTIONS
Contract ref:	CONT-23140-PGP-FFR
Expression of Interest detail reference:	PGP06-09002a
Investment Process Name:	PRIMARY GROWTH PARTNERSHIP
Approved funding for year 6 - MPI (GST excl.)	$706,106
Industry Co-funding for year 6 (GST excl.)	$656,106 plus $50,000 in kind contribution
Maximum MPI funding (GST exclusive)	$3,262,500 as per the business case
Total Industry funding (GST exclusive)	$3,262,500 as per the business case
Number of years funding:	6 years
MPI Sector:	Forestry and Wood Products as per the MPI website
Contractor:	Future Forests Research Ltd (FFR)
Contact Person:	Russell Dale
Programme Leader:	Keith Raymond
Payment Schedule:	Quarterly upon invoice or claim unless otherwise agreed.
Start Date:	01/07/2010
End Date:	30/06/2016

Personnel

FFR Programme Leader:	Keith Raymond, FFR
Harvesting Research Leader (Scion):	Spencer Hill, Scion
Programme Steering Group (PSG):	Russell Dale, FFR Peter Keach, FFR Robert Miller, MPI Stuart Anderson, MPI
Technical Steering Team (TST):	Russell Dale, FFR (Chair) Daniel Fraser, Hikurangi Forest Farms Ltd, Gisborne Joseph Graham, City Forests Ltd, Dunedin David Hilliard, Juken NZ Ltd, Masterton David Little, Crown Forestry Ltd, Rotorua Hamish Macpherson, PF Olsen Ltd, Rotorua Don McMurray, NZ Forest Managers Ltd, Turangi Tim Petro, Ernslaw One Ltd, Gisborne Mike Soper, Rayonier Matariki Forests, Tauranga Glenn Sutton, MPI, Rotorua (TBA) Barry Wells, Blakely Pacific Ltd, Timaru
Research Team:	Professor XiaoQi Chen, University of Canterbury Tony Evanson, Scion Dr Hunter Harrill, University of Canterbury Kerry Hill, Trinder Engineers Ltd Spencer Hill, Scion Allister Keast, contract to Scion Daniel Lamborn, contract to Scion Dr Hamish Marshall, Interpine Forestry Ltd Chris Meaclem, PhD, University of Canterbury Dr Paul Milliken, contract to Scion Bart Milne, PhD, University of Canterbury Alejandro Olivera, PhD, University of Canterbury Colin Olsen, Awdon Technologies Ltd Steve Palmer, Scorpion Ltd Dr Richard Parker, Scion Don Scott, Awdon Technologies Ltd Brett Vincent, Tramroad Ltd Dr Rien Visser, University of Canterbury

Background

This Research Plan details the annual plan for the delivery of the “Innovative Harvesting Solutions” programme over the period 1 July 2015 to 30 June 2016. The Business Plan for the six-year period from July 2010 to June 2016 has a budget of $6.525 million (excluding GST) and identifies net direct economic benefits of over $100 million by 2016. These benefits are arising from both cost savings over current practices and machine sales (domestic and export). The plan has also identified indirect benefits associated with: improving the safety and quality of the workplace environment; building technical capability in harvesting and machinery development; and further reducing the environmental footprint of harvesting in New Zealand.

The Programme Steering Group (PSG) provides programme governance and strategic direction, and comprises two representatives of FFR (Mr Russell Dale and Mr Peter Keach) representing the forest industry investors, and two representatives of the Ministry for Primary Industries (MPI) representing PGP (Mr Stuart Anderson and Mr Robert Miller).

The FFR Harvesting Theme Technical Steering Team (TST) manages the delivery of projects, guides the technical research team and ensures effective end-user research interface and technology transfer. The TST comprises 9 representatives of FFR's 35 industry co-investors and one representative of MPI.

The technical research team comprises researchers from Scion and University of Canterbury, forestry consultants, engineering company engineers and forest harvesting specialists. Recognising the need to move well beyond business-as-usual approaches in harvesting, the team has incorporated diverse skills, such as mechatronics and engineering design.

Programme Vision

The expected programme outcomes are unchanged from the "Innovative Harvesting Solutions" Business Plan prepared for the Primary Growth Partnership (PGP) in February 2010.

The programme vision is for low cost steep country forest harvesting operations in New Zealand carried out in safer and better working conditions by a well-trained, highly motivated workforce using sophisticated technology. This is encapsulated in the vision statement: "no worker on the slope, no hand on the chainsaw".

The primary goal is to reduce the cost of harvesting on steep country by introducing new technology that is more productive and cost effective compared with existing equipment. The secondary goal is to remove workers from the hazardous tasks of manual tree felling, breaking out and unhooking.

The contract goal is to deliver steep country tree harvesting improvements that have a total economic impact, from baseline 2010 figures, of $169 million by 2016 through:

- a reduction of 25% in steep country harvesting cost per tonne ($8.00/tonne)
- reducing to zero the lost time injuries in felling, breaking out and extraction phases of steep country harvesting operations which adopt this system
- a reduction of 10% in energy (fuel) consumption in steep country harvesting
- developing and commercially implementing three new machinery types for the harvesting industry (felling machine, grapple carriage and innovative yarding system) for both domestic use and export.

This programme features four intermediate outcomes, three of which are science and technology development projects and one covering programme management with 3 key management objectives to monitor progress against overall investment performance indicators. Over the duration of the entire programme there are seven research objectives with 32 critical milestone steps identified to provide a critical pathway to the desired outcomes.

The vision and contract statement set out the aspirational targets which will be delivered if all milestones are achieved. However, the programme is not business as usual. Fine-tuning of research and development plans will be required, and issues will invariably arise as the environment changes and the programme develops. These milestones may evolve and change as more detailed plans are developed under the guidance of the Programme Steering Group.

A further challenge for FFR and the sector participants in achieving the targets is the relationship with harvesting contracting firms which are contracted by forest owners and management companies to undertake harvesting operations. The industry is almost entirely subcontracted with arms-length business relationships between the parties. The contractors play a critical role in the uptake and use of new technology and new methods, and finding the right mechanisms to secure contractor engagement in the programme and communication of outcomes to contractors is an important component of the programme.

Approach

The scope of the Programme is harvesting on steep terrain and in particular on the felling, breaking out and extraction phases of harvesting, including the opportunity to alter current practices on the

landing to enable the entire system from stump to truck to be more cost efficient. This is the area with the greatest potential to deliver benefits to this part of the value chain.

The Programme will:

- eliminate manual chainsaw tree felling through development of a felling machine for steeper terrain (using the traction winch-assisted excavator concept)
- develop and evaluate alternative systems for improving payload (by bunching felled trees at the yarding corridor and yarding bunched trees)
- improve working conditions, safety and work load of extraction in steep terrain harvesting through eliminating manual breaking-out and unhooking roles by introducing grapple extraction.
- create opportunities to increase cable extraction productivity through yarding bunched wood using grapples (reducing cycle time) and increasing the width of the yarding corridor (reducing the frequency of line shifts). Development of new systems or techniques, including automation, vision systems, remote control and teleoperation, will aim to increase hauler productivity and safety.

The approach over the life of the Programme to date has been to run a suite of complementary and mutually supporting projects targeted at a range of points along the value chain, from felling to extraction to the landing. Each project has an intermediate outcome that can be utilised in its own right, results of which will feed in to the final achievement of an Innovative Harvesting System. The systems design approach will be adaptive i.e. it will have the potential to respond to on-going development and changes in the environment such as market pressures, new technology, forestry organisational structural development, regulatory environment etc.

As the development programme described below is primarily engineering development a standard methodology has been used:

1. **Feasibility** – brainstorming what's out there that can be adapted, development of concepts etc.

2. **Simulation** – computer modelling to test if it can deliver the expected benefits, identify the flaws and ability to develop some very early stage prototype.

3. **Alpha prototype** – development of lab or bench top prototypes to test the concept and develop the specifications for a working model.

4. **Beta prototype** – development of a working prototype that can be field tested under carefully monitored conditions and used as the basis for a commercial design.

5. **Commercialisation** – going from the Beta prototype to production of the commercial unit, and securing uptake of the unit by industry through technology transfer and extension.

The specific outputs of the development programme are:

1. A new steep slope harvester, the ClimbMAX, available from ClimbMAX Equipment Ltd.
2. A low cost on-board navigation application, called HarvestNav, available as a download from Interpine Group Ltd.
3. Application of teleoperation control system on a commercially available feller buncher.
4. A new tree-to-tree felling machine, to alpha prototype stage, that can be teleoperated (remote controlled).
5. An advanced hauler vision system, the CutoverCam, available from Cutover Systems Ltd.
6. An improved lightweight hydraulic grapple carriage, the Alpine Grapple, which is controlled remotely by the yarder operator.
7. A computer tablet-based tension monitoring application displaying skyline tensions to the yarder operator.
8. An improved mechanical felling wedge, the Jackson Beckham Lifting Wedge.
9. A remote-controlled powered felling wedge for improved directional tree felling.

10. An innovative yarding system, to alpha prototype stage, comprising a mobile tail-hold carriage and yarder operated remote control system for remote controlled line-shifting that results in increased productivity of cable yarding.

All together, these developments provide innovative harvesting solutions for steep country harvesting and fulfil the original 2010 aim of the PGP Harvesting programme – to improve productivity and safety on steep slopes and to create direct savings of over $100 million by 2020.

Table 1: Summary of Development Plan Outputs against original Business Plan objectives

Output	Name of Output	Planned commercial pathway (from original Business Plan)	Stage of development at programme completion
1.	ClimbMAX steep slope harvester	Development of machine system to commercialisation stage	Commercially available from ClimbMAX Equipment Ltd.
2.	HarvestNav on-board navigation application	Additional tool not originally planned for commercialisation	Commercially available as a download from Interpine Group website
3.	Teleoperation control system	Remote controlled steep terrain-capable machine to alpha prototype stage	Alpha prototype completed and demonstrated by Scion.
4.	Robotic tree-to-tree felling machine.	Remote controlled (or robotic) steep terrain-capable machine to alpha prototype stage	Alpha prototype completed and demonstrated by Scion.
5.	CutoverCam hauler vision system	Development of hauler vision system (camera, monitor, communication system) to beta prototype stage	Commercially available from Cutover Systems Ltd.
6.	Alpine Grapple Carriage	An improved remote-controlled grapple carriage system developed to simulation stage	Commercially available from Logpro Ltd, New Zealand's Alpine supplier.
7.	Computer tablet-based tension monitoring application	Additional tool not originally planned for commercialisation	Commercially available as a download from FFR website.
8.	Jackson Beckham Lifting Wedge	Additional tool not originally planned for commercialisation	Commercially available from Jackson Beckham Ltd, Whangarei.
9.	Koller remote-controlled powered felling wedge	Additional tool not originally planned for commercialisation	Commercially available from Koller Forsttechnik GmbH of Austria.
10.	Awdon remote-controlled mobile tail hold carriage	An innovative high production yarding system developed to alpha prototype stage	Beta prototype completed and demonstrated by Awdon Technologies Ltd.

Table 2: Intellectual Property Register

Output	Name of Intellectual Property	Owner of Intellectual Property	Utilisation of IP
1.	ClimbMAX Steep Slope Harvester	ClimbMAX Equipment Ltd, Nelson.	Manufactured by Trinder Engineers Ltd, commercialisation by ClimbMAX Equipment Ltd.
2.	HarvestNav on-board navigation application	FFR	Commercially available as a download from Interpine Group Ltd website.
3.	Teleoperation control system	FFR	Licencing to commercial partner.
4.	Robotic tree-to-tree felling machine	Scion/FFR	Patented by Scion. Licencing to commercial partner.
5.	CutoverCam hauler vision system	FFR	Licensing to Cutover Systems Limited.
6.	Alpine Grapple Carriage	Alpine Yarding Systems of South Africa.	Manufactured by Alpine Yarding Systems, and marketed in NZ by LogPro Limited.
7.	Computer tablet-based tension monitoring application	FFR	Commercially available as a download from FFR website.
8.	Jackson Beckham Lifting Wedge	Jackson Beckham Ltd, Whangarei.	Manufactured by, and commercially available from Jackson Beckham Ltd.
9.	Koller remote-controlled powered felling wedge	Koller Forsttechnik GmbH of Austria.	Manufactured by, and commercially available from Koller Forsttechnik GmbH of Austria.
10.	Awdon remote-controlled mobile tail hold carriage	Awdon Technologies Ltd, Gisborne.	Commercialisation by Awdon Technologies Ltd.

Programme Budgets

This Annual Plan allocates research plan budget for 2015/16 of $1,329,073 to 13 separate development projects according to the priorities received from industry and MPI during the programme development process during March-June 2015 in order to complete the objectives of the original PGP Harvesting Business Plan of February 2010. This Annual Plan has been developed with input from FFR members and the Technical Steering Team and was reviewed by the Programme Steering Group during meetings on 5th May and 21st May, 2015.

Table 3: Summary of Research Plan Costs by Intermediate Outcome ($ '000)

Year	**1**	**2**	**3**	**4**	**5**	**6**		
Intermediate Outcome	**2010/11 Actual**	**2011/12 Actual**	**2012/13 Actual**	**2013/14 Actual**	**2014/15 Forecast**	**2015/16 Budget**	**Grand Total**	**Business Plan**
1: Mechanisation on Steep Terrain	428.233	505.061	373.963	507.787	681.707	425.535	2,922.284	2,414.250
2: Increased Productivity of Cable Extraction	309.188	230.189	293.102	539.548	306.912	604.998	2,283.937	2,936.250
3: Development of Operational Efficiencies	84.939	51.161	150.814	102.247	257.562	298.541	945.263	750.375
Research Plan Total	822.360	786.411	817.879	1,149.582	1,246.180	1,329.073	6,151.485	6,100.875
FFR Overhead	49.407	48.260	47.852	70.354	74.502	83.140	373.515	424.125
Total Expenditure	871.767	834.671	865.731	1,219.936	1,320.682	1,412.213	6,525.000	6,525.000

PGP Investment	435.884	417.335	432.866	609.968	660.341	706.106	3,262.500	3,262.500
Industry Cash	373.634	373.390	351.178	542.755	560.341	656.106	2,857.404	2,700.000
Industry In Kind	62.250	43.945	81.688	67.213	100.000	50.000	405.096	562.500
Industry Investment	435.884	417.335	432.866	609.968	660.341	706.106	3,262.500	3262.500

Table 4: Summary of Research Plan Costs by Objective ($ '000)

Year	1	2	3	4	5	6	Total
Objective	2010/11 Actual	2011/12 Actual	2012/13 Actual	2013/14 Actual	2014/15 Forecast	2015/16 Budget	$'000
1.1	318.070	306.520	75.019	129.057	24.996	52.971	906.633
1.2	110.163	198.540	298.944	378.729	656.711	372.564	2,015.651
2.1	202.928	128.903	44.413	50.417	2.500	0.000	429.161
2.2	106.260	70.090	148.174	198.672	68.078	207.714	798.989
2.3	0.000	31.196	100.515	290.459	236.334	397.284	1,055.787
3.1	0.000	0.000	59.663	0.000	0.000	0.000	59.663
3.2	84.939	51.161	91.151	102.247	257.562	298.541	885.600
Research Plan	822.360	786.410	817.879	1,149.582	1,246.180	1,329.073	6,151.485
- In Kind Contribution	62.250	43.945	81.688	67.213	100.000	50.000	405.096
= Research Cash	760.110	742.466	736.191	1,082.369	1,146.180	1,279.073	5,746.389
+ FFR Overhead	49.407	48.260	47.852	70.354	74.502	83.140	373.515
= Total Cash	809.517	790.726	784.043	1,152.723	1,220.682	1,362.213	6,119.904
Total Expenditure	871.767	834.671	865.731	1,219.936	1,320.682	1,412.213	6,525.000

Table 5: 2015/16 Quarterly Budget by Objective ($)

Quarter	1	2	3	4	Year
Objective	2015/16	2015/16	2015/16	2015/16	Total
1.1	11,976	10,887	10,706	11,431	45,000
1.2	84,230	76,573	75,296	80,401	316,500
2.1	-	-	-	-	-
2.2	46,960	42,691	41,980	44,826	176,457
2.3	89,819	81,653	80,292	85,736	337,500
3.1	-	-	-	-	-
3.2	67,495	61,359	60,336	64,427	253,616
Research Direct Cost	300,479	273,163	268,610	286,821	1,129,073
Project Management	39,919	36,290	35,685	38,105	150,000
Research Cash Cost	340,398	309,453	304,296	324,926	1,279,073
In Kind Contribution	13,306	12,097	11,895	12,702	50,000
Research Plan	353,705	321,550	316,191	337,627	1,329,073
FFR Overhead	22,126	20,114	19,779	21,120	83,140
Total Expenditure	375,831	341,664	335,970	358,748	1,412,213

PGP Funding	187,915	170,832	167,985	179,374	706,106

The Programme has been divided into three Intermediate Outcomes:

1. Mechanisation of felling and bunching on steep terrain.
2. Increased productivity of cable extraction.
3. Development of operational efficiencies.

The following is a summary of the Intermediate Outcomes achieved to date.

Intermediate Outcomes Summary: Programme to Date

Intermediate Outcome Statement	Objective	Intended outputs by end of programme	Programme outcomes towards which this Objective contributes	Likelihood of commercial success (high/med/low)	% complete	Requirements to complete development	Priority ranking for investment 2015-16
Intermediate Outcome 1: Develop a prototype step change harvesting machine for felling and directionally positioning tree stems on steep country.	1.1: Development & commercialisation of the steep slope feller buncher system, prototyped by Kelly Logging Ltd and Trinder Engineering Ltd by 30 June 2013.	• ClimbMAX Steep Slope Harvester • HarvestNav on-board navigation application • Tension monitoring guidelines	• 25% reduction in harvesting costs • Zero lost time injuries • Expand manufacturing sales by $27 million by 2020	High. Benefits were accrued early in the Programme, in order to achieve rapid returns to industry investors. Five ClimbMAX machines have been sold and 26 downloads of the 'app' registered.	95%	1.1.1 Complete analysis of tension monitoring of cable winch-assisted harvesting machines to identify overloading risks and provide guidance to operators and planners to eliminate risks.	Priority ranking #5
	1.2 Development to alpha prototype stage of a remote controlled (teleoperated) machine that is capable of felling and/or bunching trees in steep terrain forests by 30 June 2016.	• Installation of teleoperation control system to a harvesting machine • Alpha prototype of new tree felling robot for steep terrain forests	• Zero lost time injuries • 10% reduction in energy costs • New harvesting machinery	Task A: High. A manufacturing partner to be identified which has agreed further development. Task B: Medium. A commercialisation plan will be finalised.	Task A: 70% Task B: 50%	1.2.1 and 1.2.2 Task A: Complete installation, test and demonstrate the teleoperation control system in the harvesting machine. 1.2.3 Task B: Complete development of the alpha prototype model of the tree-to-tree mobility system and felling head.	Priority ranking #1 & #2 Priority ranking #10

Intermediate Outcome Statement	Objective	Intended outputs by end of programme	Programme outcomes towards which this Objective contributes	Likelihood of commercial success (high/med/low)	% complete	Requirements to complete development	Priority ranking for investment 2015-16
Intermediate Outcome 2: Provide technology which improves the productivity of the extraction phase of the cable logging operation and ultimately to develop alternative systems to those that have traditionally been used to extract wood from steep terrain.	2.1 Development and commercialisation of a hauler vision system to improve productivity of cable yarding, and eliminate the role of the manual spotter, by June 2013.	• Development and commercialisation of CutoverCam hauler vision system	• 25% reduction in harvesting costs • Zero lost time injuries • New harvesting machinery	High. Product is commercially available and two CutoverCam systems have been sold to date. Marketing on-going.	100%	Nil. This project is now completed.	No investment
	2.2 Develop an improved high speed grapple carriage control system where the grapple carriage can be remotely controlled, in order to eliminate manual breaking out and unhooking, and reduce element times for the hook on and break out parts of the hauling cycle, by June 2013.	• Develop and field test an improved high speed remote control grapple carriage (Alpine Grapple Carriage) • Develop additional products to improve grapple payload and directional felling	• 25% reduction in harvesting costs • Zero lost time injuries • New harvesting machinery	High. Six Alpine Grapple Carriages have been sold to harvesting companies and six more units are on order to be manufactured. High. An improved felling wedge is in development with a manufacturing partner	90% 50%	2.2.1 Develop a tension monitoring “App” that can provide visual feedback to the operator on skyline tension data. 2.2.2 Continue development of remote controlled felling wedge to assist felling direction and remove manual faller from the hazard zone.	Priority ranking #12 Priority ranking #8

Intermediate Outcome Statement	Objective	Intended outputs by end of programme	Programme outcomes towards which this Objective contributes	Likelihood of commercial success (high/med/low)	% complete	Requirements to complete development	Priority ranking for investment 2015-16
Intermediate Outcome 2: Provide technology which improves the productivity of the extraction phase of the cable logging operation and ultimately to develop alternative systems to those that have traditionally been used to extract wood from steep terrain.	2.2 Develop an improved high speed grapple carriage control system where the grapple carriage can be remotely controlled, in order to eliminate manual breaking out and unhooking, and reduce element times for the hook on and break out parts of the hauling cycle, by June 2013.	• Develop additional products to improve grapple payload and directional felling	• 25% reduction in harvesting costs • Zero lost time injuries	High. Previous work by UC Forestry to build on.	75%	2.2.5 Tension monitoring of motorised grapple carriage rigging configurations to identify overloading risks and improve operator performance.	Priority ranking #13
				High. Previous work by UC Forestry to build on.	25%	2.2.6 Investigate new wire rope technology for grapple carriage systems	Priority ranking #14
			• New harvesting machinery	Medium. Some risks justifying a feasibility analysis.	10%	2.2.7 Undertake an initial technical and economic feasibility study of the Storm Active felling carriage for a swing yarder	Priority ranking #16

Intermediate Outcome Statement	Objective	Intended outputs by end of programme	Programme outcomes towards which this Objective contributes	Likelihood of commercial success (high/med/low)	% complete	Requirements to complete development	Priority ranking for investment 2015-16
Intermediate Outcome 2: Provide technology which improves the productivity of the extraction phase of the cable logging operation and ultimately to develop alternative systems to those that have traditionally been used to extract wood from steep terrain.	2.3 Redesign and develop a new alternative yarding system to alpha-prototype stage which improves cable productivity and reduces cost of cable yarding, by 31 March 2016.	• remote controlled mobile tail hold carriage	• 25% reduction in harvesting costs through reduced hauler system capital costs (though suitability for 2-drum yarders and eliminating tail hold machines); increasing hauler productivity through faster cycle times and increased width of the yarding corridor through providing lateral hauling ability (and reducing the frequency of line shifts). • Zero lost time injuries through mechanising line shifts • New harvesting machinery	Medium. High priority on completion of mobile tail hold carriage. No manufacturing partner identified as yet.	50%	2.3.1 & 2.3.2 Complete build and field testing of Beta Prototype mobile tail hold carriage	Priority ranking #6 & #7

Intermediate Outcome Statement	Objective	Intended outputs by end of programme	Programme outcomes towards which this Objective contributes	Likelihood of commercial success (high/medium/low)	% complete	Requirements to complete development	Priority ranking for investment 2015-16
Intermediate Outcome 3: Undertake system feasibility studies into cable harvesting system design and integration of harvesting system processes to improve efficiency, increase productivity and reduce cost.	3.1 Determination of feasibility of delimbing and log processing on steep slopes, by 31 December 2014.	Method for safe and productive on-slope delimbing and cutting-to-length (CTL) prior to extraction through application of felling and processing machinery on steep terrain	• 25% reduction in harvesting costs • 10% reduction in energy costs	Nil	10%	Project terminated due to low industry priority	Priority ranking #38 and #39 (No investment)
	3.2 Investigate new yarder technologies through a programme of international technology watch and a comprehensive benchmarking system of cost and productivity in steep country harvesting	Feasibility of new technologies; annual benchmarking measures; Harvesting Technology Watch; Peer review of programme to quantify benefits	• 25% reduction in harvesting costs • New harvesting machinery • 10% reduction in energy costs	High. Previous work by developer to build on. High. Previous work by UC Forestry to build on. High. Previous work by Scion/UC Forestry to build on. High. Previous work by Scion/UC Forestry to build on.	35% 85% 50% 85%	3.2.2 Further development of quick coupler attachment 3.2.4 Continuation of Benchmarking project to maintain harvesting cost and productivity database 3.2.1 Further trials of Koller remote controlled yarder 3.2.3 Harvesting Tech Watch	Priority ranking #3 Priority ranking #4 Priority ranking #9 Priority ranking #11

INTERMEDIATE OUTCOME 1: MECHANISATION ON STEEP TERRAIN

Intermediate Outcome Statement

Intermediate Outcome 1

Title	Mechanisation on steep terrain
IO Statement	The aim is to develop a prototype step change harvesting machine for felling and directionally positioning tree stems on steep country to present them for rapid extraction by the cable yarding system. In achieving these objectives the benefits need to be accrued early in the Programme, both to achieve rapid returns to industry investors and to recognise the need to mitigate the high level of technical risk of achieving the larger vision. Success Measures: • Development and commercialisation of the steep slope feller buncher system, prototyped by Kelly Logging Ltd and Trinder Engineering Ltd by 30 June 2013. • Development to alpha prototype stage of a remote controlled (teleoperated) low footprint machine that is capable of felling and/or bunching trees in steep terrain forests by 30 June 2016.
Start date	01/07/2010
End date	30/06/2016
IO Leaders	Keith Raymond and Spencer Hill

Personnel

Intermediate Outcome Leaders:
Keith Raymond (FFR) and Spencer Hill (Scion)

Scion:
Tony Evanson
Daniel Lamborn and Allister Keast (under contract)
Dr Paul Milliken (under contract)
Dr Richard Parker

University of Canterbury:
Prof XiaoQi Chen (UC Mechatronics)
Bart Milne (UC Mechatronics)
Chris Meaclem (UC Mechatronics)
Final year Engineering students (UC Mechatronics)
Dr Rien Visser (UC Forestry)
Dr Hunter Harrill (UC Forestry)

Trinder Engineering Ltd:
Kerry Hill

Interpine Forestry Ltd:
Dr Hamish Marshall

OBJECTIVE 1.1

Steep Slope Feller Buncher

Objective Leader: Keith Raymond (FFR)

Objective Description – "The Problem"
Felling on steep country is one of the most dangerous and physically demanding roles in harvesting, and mechanising the felling on steep terrain will eliminate this dangerous role and allow the felled stems or logs to be better accumulated and presented for attachment to the grapple carriage. A critical component in cable yarding productivity is the time taken for an optimum load to be secured to the cable, and mechanised felling and bunching can lead to significant improvements in this function. This project aims to improve the tractive capacity of ground-based machinery on steep terrain to enable mechanical felling, bunching and presentation of wood to the hauler grapple carriage.

Achievement Measure – "Ultimate Vision"
A viable machine has been developed that can operate on steep terrain to accumulate loads and present bunched wood to the hauler grapple carriage in a safe and efficient manner.

Start Date: 01/07/2010 (Year 1)
Finish Date: 30/06/2015 (Year 5)

Project Team:
Tony Evanson (Scion)
Dr Hunter Harrill (UC Forestry)
Kerry Hill (Trinder Engineering Ltd)
Dr Hamish Marshall (Interpine Forestry Ltd)
Dr Richard Parker (Scion)
Dr Rien Visser (UC Forestry)

Background – "What has been done?"
The alpha prototype "Kelly Logging System" designed by programme co-investors Trinder Engineers Ltd and Kelly Logging Ltd in Nelson, was capable of safely operating on slopes over 45 degrees on a range of soil types. An economic analysis by Scion of the alpha prototype showed the advantages of bunching with this machine included an average 50% increase in the number of trees hauled, compared with manual felling (Technical Note HTN03-02). A feasibility study showed that with further development it would be suitable for extending the range of ground-based machinery onto steeper terrain, either for felling and bunching in a cable logging system or "shovel-logging" in a ground-based extraction system (Report H007).

Since project commencement in 2010, FFR has provided financial assistance to Trinder Engineers Ltd to enable the steep slope harvester to progress to a commercial model. With FFR's support the companies developed a second machine or beta prototype (designated ClimbMAX 1) that is capable of operating at different angles more effectively on steep slopes. The beta prototype machine commenced commissioning trials from December 2011. In 2012, the first commercial model (ClimbMAX 2) was built. With the purchase of the first commercial machine by a harvesting company and implementation in a commercial harvesting operation, the development phase of this project was completed in 2013. The Trinder ClimbMAX steep slope harvester was trialled in the Marlborough region in January 2013 (Technical Note HTN05-07) and a second trial in Hawkes Bay was undertaken in August 2013 (Report H013).

Machine capability on steep terrain was determined through measuring actual machine performance on a range of forest slopes and soil types (Nelson and Hawkes Bay) and baseline measurements were made of winch rope tensions. One perceived barrier to uptake of the ClimbMAX Steep Slope

Harvester such as the ergonomics of a non-levelling machine were addressed in an ergonomic assessment of the operator working environment. On the basis of this assessment the levels of operator comfort were deemed satisfactory and no further improvements in operator cab design were undertaken.

Meanwhile, other FFR researchers worked on developing tools to assist the operator. In 2013 FFR researchers (Interpine Forestry Ltd) demonstrated how digital terrain models derived from aerial LiDAR (Light Detection and Ranging) data can be displayed through an on-board monitor to assist the machine operator to navigate in complex terrain (Technical Note HTN05-01). In 2014 a low cost machine navigation application, called HarvestNav, was developed for use with an on-board computer and made available as a free download to the forest industry.

Another perceived barrier to the uptake of the ClimbMAX Steep Slope Harvester and other cable-assisted machinery was identified as the risk of cable failure. This was assessed in an initial trial monitoring the cable tension of a winch-assisted machine (Technical Note HTN05-11). This area of work will be continued by University of Canterbury School of Forestry as part of this PGP programme in order to address this barrier to uptake of winch-assisted machine systems. Mechanised felling and bunching on steep slopes is now a reality with the successful commercialisation of the ClimbMAX steep slope harvester, available from ClimbMAX Equipment Ltd.

Progress to date
Year 2 (2011/12):

1. (Contract Milestone 1.1.1) The potential of LiDAR-derived DTM's to determine/improve the capability of a modified excavator base machine to operate on steep terrain was investigated (Technical Note HTN04-02) – Interpine Forestry Ltd.
2. (Contract Milestone 1.1.1) Development of an on-board stability prediction system for the steep slope feller buncher to provide information to the operator of the steep slope feller buncher on projected and actual slope; current location and profile; and projected stability – Interpine Forestry.
3. (Contract Milestone 1.1.1) Availability of steep slope mechanisation, costs and impacts of implementation was investigated (Technical Note HTN04-07), including benefits in terms of reduced harvesting costs and recommendations for development of machinery – Scion.
4. (Contract Milestone 1.1.3) The beta prototype of the steep slope feller buncher was developed – Trinder Engineers Ltd.
5. (Contract Milestone 1.1.3) A Work Plan for field trials was developed which addressed: FFR member input to trials; productivity vs. tree size; machine mobility in relation to soil type and slope; and operator issues – Scion.
6. (Contract Milestone 1.1.3) Measurement protocols were developed for forestry machines on steep slopes using GPS/digital machine levels/data loggers to test machine slope/ground slope relationships. These protocols were tested on different machines (including 3 European harvesters operating in Austria) to ensure functionality of system (Technical Note HTN05-02) – UC Forestry.
7. (Contract Milestone 1.1.4) The machinery manufacturing company (Trinder Engineers Ltd) advised that they will provide financial investment to support its development to commercial stage – Trinder.

Year 3 (2012/13):

1. (Contract Milestone 1.1.4) A field trial was carried out to assess the first commercial steep slope feller buncher (Technical Note HTN05-07). This trial was designed to provide data for the commercialisation of the Trinder ClimbMAX Steep Slope Harvester – Scion.
2. (Contract Milestone 1.1.4) A trial was undertaken to determine the environmental impact (footprint) of the steep slope feller buncher – Scion.
3. (Contract Milestone 1.1.4) The performance of the first tethered steep slope feller buncher (developed by Ross Wood) with specific reference to critical slope factors was measured by a variety of sensors: LiDAR, Accelerometer, GPS, Video. This helped to determine the effect of slope factors on the tractive performance of the machine and identify the types of sensors and

data that provide the best information for effective monitoring and management of the machine – UC Forestry.

4. (Contract Milestone 1.1.4) Further development and field testing of the on-board stability prediction system for the commercial model steep slope feller buncher to provide information to the operator on projected and actual slope and projected stability, coupled with real-time GPS sensor measurements of machine position, recent track, machine speed (Technical Note HTN05-01) – Interpine Forestry Ltd.

Year 4 (2013/14):

1. (Contract Milestone 1.1.4) A productivity and environmental field trial was completed to assess the ClimbMAX Steep Slope Harvester in a forest with steep terrain and unstable soils (Report H013) – Scion.
2. (Contract Milestone 1.1.4) An assessment of the ClimbMAX Steep Slope Harvester was undertaken with specific reference to critical slope factors, rope tensions and the effect of slope and soil factors on the tractive performance of the machine (Report H013) – Scion and UC Forestry.
3. (Contract Milestone 1.1.4) An ergonomic assessment of the ClimbMAX Steep Slope Harvester operators was undertaken (Report H013) – Scion.
4. (Contract Milestone 1.1.5) Development of the ClimbMAX Steep Slope Harvester to commercialisation stage. The commercial model of the steep slope harvester has been implemented by a harvesting company – Trinder Engineering.
5. (Contract Milestone 1.1.5) An open day was organised involving a demonstration of the ClimbMAX harvester where the findings of the ergonomic assessment and environmental trials were presented – Scion.
6. (Contract Milestone 1.1.6) The HarvestNav on-board navigation system was developed to commercialisation stage and the system was approved by the TST and the software was released to the industry – Interpine Forestry Ltd.

Year 5 (2014/15):

1. (Contract Milestone 1.1.6) Further development of the HarvestNav on-board navigation system to integrate with mobile communications. Coupled with real-time GPS sensors of other machines and crew provide monitoring of all machines and crew positions, proximity, recent track, speed etc. – Interpine Forestry Limited.
2. (Contract Milestone 1.1.6) Extension of the HarvestNav on-board stability prediction system – Interpine Forestry Ltd.

Approach – "What is required to achieve the project?"

This research programme has helped develop, design and test cable-assist machinery which is proving to have cost-efficiency benefits when coupled with cable yarding extraction, and be safer for felling trees on steep terrain. Understanding, and managing, the tension in these new cable-assist machines is critical to successful implementation, including adhering to the specific safe operating requirements in the ACOP (2012). The final element of this project is to complete analysis of tension monitoring of cable winch-assisted harvesting machines under a range of conditions to identify overloading risks and provide guidance to operators and planners to eliminate risks. This is to address one of the major barriers to uptake identified (winch rope failure).

Research Plan Resources (incl. project management and in-kind contribution): Objective 1.1

	Year							
Objective 1.1	1 2010/11	2 2011/12	3 2012/13	4 2013/14	5 2014/15	6 2015/16	Total	Business Plan
Total	$318,070	$306,520	$75,019	$129,057	$24,996	$52,971	$906,633	$456,750

Objective Statement 1.1

Objective	1.1
Objective title	Mechanisation on steep terrain – Steep slope feller buncher
Objective description	To improve the tractive capacity of ground-based machinery on steep terrain to enable bunching and presentation of wood to the hauler grapple carriage.
Objective Achievement Measure	Development of a viable harvesting machine that can operate on steep slopes; accumulate loads and present bunched wood to a cable hauler grapple carriage in a safe and efficient manner.
Start date	01/07/2010
End date	30/06/2014

Objective 1.1 Contract Milestones

Milestone 1.1.1	Steep slope feller buncher – technical and economic evaluation
Description	A commercialisation plan for a steep slope feller buncher has been developed based on a technical/economic review indicating that it has the potential to improve cable hauler payload by at least 15% thus increasing productivity by 15% over current practice.
Achievement Measure	The Harvesting Programme Steering Group (PSG) approves a commercialisation plan for a steep slope feller buncher based on a technical/economic review indicating that it has the potential to improve cable hauler payload by at least 15% thus increasing productivity by 15% over current practice.
Start Date	01 July 2010
End Date	31 December 2010 COMPLETED

Milestone 1.1.2	Steep slope feller buncher – Alpha prototype development.
Description	An alpha prototype of the steep slope feller buncher has been developed which is capable of operating on slopes up to 45 degrees on the commonly-occurring soil types found in the main forestry regions of NZ.
Achievement Measure	1. An alpha prototype development plan has been developed for the steep slope feller buncher and approved by the PSG that specifies the operational parameters and performance standards by 31 December 2010. 2. An alpha prototype of the steep slope feller buncher has been developed which is capable of operating on slopes up to 45 degrees on the main forestry soil types in New Zealand by 30 June 2011. 3. A machinery manufacturing company has advised that they will provide the financial investment to support its further development to beta prototype stage, and agreements are executed by 30 June 2011.
Start Date	01 January 2011
End Date	30 June 2011 COMPLETED

Milestone 1.1.3	Steep slope feller buncher – Beta testing development
Description	First prototype steep slope feller buncher is successfully tested at Beta level.
Achievement Measure	First prototype steep slope feller buncher is successfully tested at Beta level and meets the operational parameters and performance standards as defined in the alpha prototype development plan.
Start Date	01 July 2011
End Date	30 June 2012 COMPLETED

Milestone 1.1.4	Steep slope feller buncher – first commercial product
Description	The first commercial steep slope feller buncher has been successfully tested in the field.
Achievement Measure	The first commercial steep slope feller buncher has been successfully tested in the field and meets the operational parameters and performance standards as defined in the alpha prototype development plan.
Start Date	01 July 2012
End Date	30 June 2014 COMPLETED

Milestone 1.1.5	Steep slope feller buncher system – commercial production
Description	The first commercial steep slope feller buncher machine has been implemented by a harvesting company.
Achievement Measure	The first commercial steep slope feller buncher machine has been purchased or leased by a harvesting company and implemented in a commercial harvesting operation.
Start Date	01 April 2013
End Date	30 June 2014 COMPLETED

Milestone 1.1.6	Steep slope feller buncher – additional tools
Description	A commercial application to assist the operator of the steep slope feller buncher machine has been implemented by a harvesting company.
Achievement Measure	Commercial applications to assist the operator of the steep slope feller buncher in terms of actual and projected machine slope and rope tension have been developed and implemented in a commercial harvesting operation.
Start date	01 July 2012
Finish date	30 June 2016

Project Milestones and Outputs

Year 6 (2015/16):

6.1 (Contract Milestone 1.1.6) Tension monitoring of cable-assisted machines. Complete tension monitoring of three different cable-assisted machine operations under a range of conditions, especially with regard to identifying overloading risks. Specific project tasks comprise: (a) develop the methodology and test equipment to successfully capture continuous cable tension data; (b) complete data capture of three different systems and ensure it covers a range of slopes as well as tasks such as moving, felling and shovelling; (c) analyse and report results in a Technical Note; (d) develop a set of guidelines for operators and planners to eliminate risks associated with overloading the cable; (e) make analyses techniques and results available to NZ manufacturers to develop integrated tension monitoring and operator feedback systems – UC Forestry, $45,000; by 30 June 2016.

Objective 1.1 Budget

1.1 Steep Slope Feller Buncher		1	2	3	4	5	6
Contract Milestones	Total	June '11	June '12	June '13	June '14	June '15	June '16
1.1.1	$92,508	$60,827	$31,681				
1.1.2	$195,852	$179,065	$16,787				
1.1.3	$189,139		$154,139	$35,000			
1.1.4	$21,079			$21,079	$0		
1.1.5	$172,000			$0	$107,000	$20,000	$45,000
Research Materials	$65,000	$20,000	$45,000	$0	$0	$0	$0
Research Direct Cost	$735,578	$259,892	$247,607	$56,079	$107,000	$20,000	$45,000
In-kind Contribution	$60,242	$24,077	$17,128	$7,493	$7,546	$2,006	$1,993
Project Management	$110,813	$34,101	$41,785	$11,447	$14,512	$2,990	$5,978
Total Research Plan	$906,633	$318,070	$306,520	$75,019	$129,057	$24,996	$52,971
Provider	Total	June '11	June '12	June '13	June '14	June '15	June '16
Scion	$165,693	$50,827	$16,787	$21,079	$77,000	$0	$0
Scion Materials	$0	$0	$0	$0	$0	$0	$0
Trinder Engineering	$343,204	$179,065	$154,139	$0	$10,000	$0	$0
Trinder Eng. Materials	$65,000	$20,000	$45,000	$0	$0	$0	$0
Consultant	$87,681	$10,000	$17,681	$20,000	$20,000	$20,000	$0
Univ. of Canterbury	$74,000	$0	$14,000	$15,000	$0	$0	$45,000
Univ. of Cant. Materials	$0						
Other Engineering	$0						
Engineering Materials	$0						
Research Direct Cost	$735,578	$259,892	$247,607	$56,079	$107,000	$20,000	$45,000

OBJECTIVE 1.2

Teleoperated Felling Machine for Steep Country Harvesting

Objective Leader: Spencer Hill (Scion)

Objective Description – "The Problem"
The aim of this project is to employ remote control (teleoperation) where terrain, ground roughness or soil type limits manned felling/bunching machine operation. Remote operation will enable the isolation of the operator from a hazardous area and provide opportunities for improved working conditions, lower work load and through the implementation of new technologies possibly improve productivity of felling and bunching operations. Lighter weight machines with lower centre of gravity than existing felling machines will minimise ground disturbance (and reduce fuel consumption). The project will develop a remote controlled feller buncher capable of felling and/or delimbing and bunching trees on steep terrain. Once achieved, this technology will help to enable FFR's vision of future logging operations with "no worker on the slope, no hand on the chainsaw", removing workers from hazardous situations.

Achievement Measure – "Ultimate Vision"
Development of a viable remote controlled harvesting machine to alpha-prototype stage that can operate on steep slopes, fell trees, accumulate loads and present bunched wood to a cable hauler grapple carriage and meets the operational parameters and performance standards as defined by the Programme Steering Group.

Start Date: 01/07/2010 (Year 1)
Finish Date: 30/06/2016 (Year 6)

Project Team:
Prof XiaoQi Chen (University of Canterbury)
Daniel Lamborn and Allister Keast (contracted to Scion)
Chris Meaclem (University of Canterbury)
Dr Paul Milliken (contracted to Scion)
Bart Milne (University of Canterbury)
Dr Richard Parker (Scion)
Final year Engineering students (University of Canterbury)

Background – "What has been done?"
The natural progression from mechanised felling (Objective 1.1) to this research programme (Objective 1.2) is to eliminate the need for an operator sitting in the felling machine through the development of remote control and teleoperation. This project aims to develop initially remote control and later full teleoperation of a feller buncher capable of traversing New Zealand forest terrain and felling and bunching trees typical of New Zealand forestry conditions.

Over the past four years the groundwork has been laid for a remote control system capable of operating a feller buncher on steep terrain. Scion commenced this project in Year 1 of the project (2010) undertaking a feasibility analysis (Report H008) and investigating the human factors of the transition to teleoperation in harvesting (Technical Note HTN04-03).

University of Canterbury (UC) which has strong research competencies in Robotics, Mechatronics, and Forestry joined this Project in 2011. It has made significant contributions to the PGP Programme which is strategic to the New Zealand forestry industry and the manufacturing sectors in the value chain.

The project scope covers two key research tasks:

- Task A: Development of teleoperation, navigation and control of a ground-based harvesting machine on steep country. One post-graduate student has been working on the UC

Mechatronics Teleoperated Felling Machine project in Task A, and one Scion researcher has been working on installation of a system into a commercial-sized felling machine.

- Task B: Development of a novel forest locomotion system for a lightweight teleoperated felling machine. Scion initially developed a small-scale simulation model tree-to-tree mobility prototype with end effectors to grip trees and move through the forest on steep terrain using standing trees as a means of locomotion, in order to demonstrate the concept. The realised approach will be a step change in terms of technology advancement and productivity and safety gains. This research task has generated intellectual property that may be patented by Scion. The carrier will initially be remotely controlled (teleoperated) and ultimately could be totally robotic.

Progress to date

Year 2 (2011/12):

1. (Contract Milestone 1.2.1) Task A: A concept design and technical/economic feasibility report (Report H008) outlining the concept and proposed progression of the use of teleoperation in steep slope harvesting was published. The economic analysis demonstrated the potential for improved safety and productivity from a new teleoperated machine for steep country harvesting. The TST approved taking this concept to the next stage (a simulation study).
2. (Contract Milestone 1.2.2) Task A: Alpha Prototype Development Plan (HDP009) that specified the operational parameters and performance standards was developed.
3. (Contract Milestone 1.2.1) Task A: A post-graduate student was enrolled on the UC Mechatronics Teleoperated Felling Machine Task A project in January 2012. A research report of state-of-the-art teleoperation, user requirements, and concept of a teleoperation system on steep country harvesting, and identification of suitable technologies was undertaken by UC Mechatronics (Technical Note HTN04-09).
4. (Contract Milestone 1.2.2) Task A: Detailed design of the teleoperated excavator. Initially a small hydraulic circuit was designed as a lab-based platform to test teleoperation functions (Technical Note HTN04-11). Commercial off-shelf electromechanical components (actuators, sensors, drives, and communication) were used and Scion documented the detailed design including bill-of-materials, drawings of any fabricated parts and assembly instructions.
5. (Contract Milestone 1.2.2) Task A: Scion commissioned the construction of the teleoperation test bed and this was installed at University of Canterbury Mechatronics.
6. (Contract Milestone 1.2.1) Task B: Concept design (Report H011) of the new tree felling machine that can move on steep forested terrain, using trees and stumps to assist locomotion (tree-to-tree mobility system).
7. (Contract Milestone 1.2.1) Task B: A comparative study by UC Mechatronics of different felling approaches for the tree felling machine (Report H011) was completed.

Year 3 (2012/13):

1. (Contract Milestone 1.2.2) Task A: Current options for hardware for binocular vision were evaluated. This includes binocular cameras and 3D screens. Also the human-factors considerations for 3D vision systems were reviewed – Scion.
2. (Contract Milestone 1.2.2) Task A: Design and build a hydraulic circuit test bed to test teleoperation functions. Commercial off-shelf electromechanical components (actuators, sensors, drives, and communication) were used to control the hydraulic ram through a wireless remote-control system. Initial control was via a command-line interface, and design included operation over an 802.11 wireless bridge – Scion and UC Mechatronics (First PhD student).
3. (Contract Milestone 1.2.2) Task A: A video–audio feedback system was developed by Scion that can be applied to the remote-controlled hydraulic circuit. This part of the project was informed by Objective 2.1 Hauler Vision System. The system included one or more cameras and audio feedback – Scion.
4. (Contract Milestone 1.2.2) Task A: Developed imaging-based teleoperation system. Investigated the sensory systems to be installed. Transducers added to the remote-controlled hydraulic ram circuit such as encoders, Hall-effect sensors etc. – Scion and UC Mechatronics (First PhD student).

5. (Contract Milestone 1.2.2) Task A: Implemented an autonomous control loop on the remote-controlled ram using the signals from one or more of the transducers. This will simulate semi-autonomous behaviour such as collision-avoidance – UC Mechatronics (First PhD student).
6. (Contract Milestone 1.2.2) Task A: Haptic-feedback interface that can be integrated with the remote controlled ram was investigated (Technical Note HTN06-02). Force feedback was a function of the output of a signal from a transducer and was designed to be implemented with a servo motor – Scion and UC Mechatronics (First PhD student).
7. (Contract Milestone 1.2.2) Task B: One post-graduate student was enrolled on the UC Mechatronics Teleoperated Felling Machine Task B project in January 2013. Concept development of a prototype tree climbing machine. A technical and economic feasibility report on prototype tree climbing concept and cutting method, integrative mobile tree felling and cutting system – Scion and UC Mechatronics (Second PhD student).
8. (Contract Milestone 1.2.2) Task B: Detailed design of a new tree tree-to-tree mobility system to simulation stage. Documentation of the detailed design including bill-of-materials, quotes for components and design drawings for the tree-to-tree mobility system – Scion and UC Mechatronics (Second PhD student).

Year 4 (2013/14):

1. (Contract Milestone 1.2.2) Task A: Control system for teleoperated machine for steep country harvesting developed to simulation stage that demonstrates that the operator can control the hydraulic arm from a remote location (within line-of-sight) – UC Mechatronics (First PhD student).
2. (Contract Milestone 1.2.2) Task A: The teleoperation control system installed into a machine for steep country harvesting and tested to meet the operational parameters and performance standards defined in the Alpha Prototype Development Plan and documented – Scion.
3. (Contract Milestone 1.2.2) Task B: In 2013, four Final Year Engineering students developed a prototype of the Task B mobility model as a platform for a robot tree felling machine. A working model of the tree to tree mobility system was designed and developed to simulation stage – UC Mechatronics (Second PhD student plus Final Year students).
4. (Contract Milestone 1.2.2) Task B: Work commenced on the design and development of a working model of the felling head for the tree to tree mobility system to simulation stage – UC Mechatronics (Second PhD student plus Final Year students).

Year 5 (2014/15):

1. (Contract Milestone 1.2.3) Task A - Stage 2: The installation of the teleoperation control system for full remote control of a steep country harvesting machine was completed and tested to ensure it met the operational parameters and performance standards defined in the Development Plan (Technical Note HTN07-04) – Scion.
2. (Contract Milestone 1.2.3) Task A: The teleoperated machine for steep country harvesting was demonstrated to the PSG so that the operator can control the machine from a remote location (within line-of-sight). PSG confirmed further development to alpha prototype stage – Scion.
3. (Contract Milestone 1.2.3) Task A: Development and testing of software concepts that provide semi-autonomous operation of some of the functions of the excavator was completed. A Technical Report was published on the outcomes of the testing (Report H021) and all the source code was provided – UC Mechatronics (First PhD student).
4. (Contract Milestone 1.2.3) Task A: Detailed documentation of all the hardware and software for the excavator installation was provided. This included a comprehensive bill-of-materials, assembly drawings and all the source-code – UC Mechatronics (First PhD student).
5. (Contract Milestone 1.2.3) Task B: A Development Plan assessing operational parameters and performance standards, scale-up issues, potential markets and economic analysis of the tree-to-tree mobility system was presented to PSG. PSG confirmed further development of alpha prototype – Scion.
6. (Contract Milestone 1.2.3) Task B: Detailed design of the electrically-actuated alpha prototype working model was completed for the tree-to-tree mobility system and felling head that met the operational parameters and performance standards as defined in the Development Plan – UC Mechatronics (Second PhD student).

7. (Contract Milestone 1.2.3) Task B: Documentation of detailed design including all design drawings, a comprehensive bill-of-materials and all source code for the tree-to-tree mobility system was provided – Scion.
8. (Contract Milestone 1.2.3) Task B: Integration of tree felling head with mobility system. Development, fabrication and assembly of the electrically-actuated alpha prototype working model of the tree-to-tree mobility system and felling head was completed – UC Mechatronics (Second PhD student).

Approach – "What is required to achieve the project?"

Task A. Tele-Operation, Navigation and Control

The teleoperation control system developed is being installed in a commercial felling machine. This will ensure results are applicable to commercial forestry. Contractor Ross Wood of Nelson has agreed to pilot the teleoperation system in his John Deere 909 feller buncher. . Potential capabilities of the machine include felling, bunching, and feeding the grapple carriage. In 2014/15 the machine was initially remote controlled from a safe position in the field (Stage 2). In 2015/16 full teleoperation from a remote location was employed (Stage 3). Technology currently exists in other high hazard industries (such as mining) where machines are controlled by a remote operator in a 'cab' that simulates the actual environment being encountered by the machine itself. Advancing developments in sensing systems and machine vision technology will allow the detection of the surrounding terrain including features such as uneven terrain and stumps that would impede the movement of the excavator. Remote control of some functions of the machine was tested in July 2014, and the aim is to have remote control of all functions by 30 June 2015 and full teleoperation by 30 June 2016.

The outputs of Task A will be:

1. The ability to operate a felling machine without line-of-sight.
2. The integration of an embedded computer running a real-time operating system that will provide a platform for further software development.
3. Some level of processing that will result in feedback and alarms to the operator and/or semi-automation to enhance the performance and safety of the felling machine.

The path to market is that a machinery manufacturing company will agree to provide financial investment to support the development of the beta prototype of the teleoperated machine to commercial stage, by 30 June 2016. The machinery manufacturing partner will determine the future commercialisation of the technology.

Task B. Novel Forest Locomotion Machine for Tree Felling

The outputs of this project will include:

1) A mobile teleoperated machine designed to carry a payload such as a felling head and move around a forest on steep terrain. The machine is designed to be able to use trees to stabilise itself and assist locomotion via two (biped) arms with gripping devices (grapples). Design of the mobility system is aimed at having the capability to operate on typical steep forest terrain (on slopes exceeding 26 degrees). The power source initially will be battery but subsequent designs could be powered by hydraulics (powered by small diesel engine for mobility and hydraulic pressure only, not load carrying) or hybrid (diesel-electric) power. This could be constructed of alternative lightweight materials to reduce its weight and environmental footprint.
2) Initial capability is designed to carry a chainsaw felling head to fell and bunch trees. A modified chainsaw, weighing approximately 10 kilograms, will be the target payload for the initial concept. Design of a new remote controlled lightweight felling head is underway. New cutting methods have been investigated to reduce the machine payload, increase its portability, and reduce chain throw and maintenance.
3) Subsequent work will integrate developments from Task A of semi-autonomous and robotic functions. Simulation software tools and physical prototypes are being used to develop design

concepts and study machine kinematics and dynamics. The machine will include an embedded single-board-computer as a platform for semi-autonomous operations. Human-machine interactions and impacts of automation/robotics on human workload, job satisfaction and training will be investigated.

4) Once the first parts of Task B have been completed, advancing the autonomy of the harvester will be investigated. Simultaneous Localisation and Mapping (SLAM) has been widely used for ground vehicles in logistics and mining on relatively flat terrain. The SLAM technique will require more in-depth research and innovation to adapt to NZ's steep country. A breakthrough in this area would allow the harvester machine to autonomously or semi-autonomously navigate on steep country, which would further improve productivity. This task might also include investigating the feasibility of optimisation software which looks at the decision factors involved in how the machine cuts the stand i.e. which tree it cuts first and in which order it then cuts the stand. These decision factors may include tree location relative to terrain and obstacles, tree size, tree lean etc.

The vision of this objective is to combine the teleoperation control system arising from Task A with the alpha-prototype lightweight innovative felling machine from Task B to achieve the final project outcome of a lightweight teleoperated felling machine that is capable of traversing typical New Zealand forest terrain and felling and bunching trees typical of New Zealand forestry conditions. The Development Plan for the final year of the programme includes milestones to ensure the alpha prototype is developed and fully tested and includes a plan for continuing its development and potential commercialisation post-programme completion in 2016.

Research Plan Resources (incl. project management and in-kind contribution): Objective 1.2

	Year							
Objective 1.2	1 2010/11	2 2011/12	3 2012/13	4 2013/14	5 2014/15	6 2015/16	Total	Business Plan
Total	$110,163	$198,540	$298,944	$378,729	$656,711	$372,564	$2,015,651	$1,957,500

Objective Statement 1.2

Objective	1.2
Objective title	Teleoperated Felling Machine for Steep Country Harvesting.
Objective description	The aim of this project is to employ remote control (teleoperation) where terrain, ground roughness or soil type limits manned felling/bunching machine operations. The project will develop a remote controlled feller buncher capable of felling and/or delimbing and bunching trees on steep terrain.
Objective Achievement Measure	Development of a viable remote controlled harvesting machine to alpha prototype stage that can operate on steep slopes, fell trees, accumulate loads and present bunched wood to a cable hauler grapple carriage, that meets the operational parameters and performance standards as defined by the PSG.
Start date	01/03/2011
End date	30/06/2016

Objective 1.2 Contract Milestones

Milestone 1.2.1	Teleoperated felling machine – concept feasibility analysis
Description	A technical and economic feasibility study is completed which demonstrates the potential for improved productivity and safety from a new teleoperated machine for steep country harvesting.
Achievement Measure	The Harvesting Programme Steering Group (PSG) approves a technical and economic feasibility study that demonstrates the potential for improved productivity and safety from a new teleoperated machine for steep country harvesting and approves investment in taking this concept to a simulation study.
Start Date	01 January 2011
End Date	31 December 2011 COMPLETED

Milestone 1.2.2	Teleoperated felling machine – concept simulation
Description	Complete a modelled demonstration of the teleoperated machine to simulation stage under a range of field conditions.
Achievement Measure	1. An alpha prototype development plan that specifies the operational parameters and performance standards has been developed and approved by the PSG by 31 March 2012. 2. The teleoperated machine for steep country harvesting has been demonstrated in a simulation study and has met the operational parameters and performance standards in the alpha prototype development plan. PSG has approved further development to alpha prototype stage, by 30 June 2014.
Start Date	01 January 2012
End Date	30 June 2014 COMPLETED

Milestone 1.2.3	Teleoperated felling machine – Alpha prototype development
Description	Complete a demonstration of the Alpha prototype teleoperated machine and develop a commercialisation strategy for this machine.
Achievement Measure	1. The teleoperated machine for steep country harvesting has been successfully demonstrated in the field to the operational parameters and performance standards in the alpha prototype development plan, by 31 Dec 2015. 2. A commercialisation strategy is developed for and approved by the PSG by 31 March 2016.
Start Date	01 July 2014
End Date	31 March 2016

Milestone 1.2.4	Teleoperated felling machine – commercialisation support
Description	Obtain the financial support of a machinery manufacturing company to provide financial investment to further develop the teleoperated machine.
Achievement Measure	1. A machinery manufacturing company has agreed to provide financial investment for development of the beta prototype of the teleoperated machine for steep country harvesting. 2. The field testing of the beta prototype has commenced. This testing will continue after the end date of the contract.
Start Date	01 April 2016
End Date	30 June 2016

Project Milestones and Outputs

Year 6 (2015/16):

6.1 Task A: (Contract Milestone 1.2.3): Teleoperation Stage 4: Complete the installation of the teleoperation control system for full teleoperation of the steep country harvesting machine and test to ensure it meets the operational parameters and performance standards defined in the Development Plan – Scion, by 30 June, 2016; $220,000.

6.2 Task A: (Contract Milestone 1.2.3): Teleoperation Demonstration. Teleoperation of the steep country harvesting machine will be demonstrated that the operator can safely fell trees from a remote location (beyond line-of-sight) – Scion, by 30 June, 2016; $5,000.

6.3 Task A: (Contract Milestone 1.2.4): Commercialisation: A machinery manufacturing company has agreed to provide financial investment to support the development of the beta prototype of the teleoperated machine to commercial stage, by 30 June 2016 – Scion and Engineering Company (TBA).

6.4 Task B: (Contract Milestone 1.2.3): Development of Alpha Prototype: Complete development, fabrication and assembly of the second prototype model of the tree-to-tree felling machine (integrated mobility system and felling head). This includes final year engineering students' modifications to design (strengthening frame, adding wrist rotator and remote controlled power source) – by 30 September, 2015; UC Mechatronics, $41,500, Scion $6,000.

6.5 Task B: (Contract Milestone 1.2.3): Field Testing: Test the alpha prototype tree-to-tree mobility system so that it can move on steep terrain, and can be operated by remote-control within line-of-sight. A technical report assessing the prototype tree felling technology is completed – Scion and machinery manufacturing company, by 31 December, 2015; $10,000.

6.6 Task B: (Contract Milestone 1.2.3): Demonstration: The teleoperated steep terrain-capable felling machine has been successfully demonstrated in the field and meets the operational parameters and performance standards defined in the Alpha Prototype Development Plan by 31 December 2015 – Scion, by 31 December, 2015; $7,000.

6.7 Task B: (Contract Milestone 1.2.3): Economic Analysis: Final report on economic analysis of teleoperated machine is completed which demonstrates the productivity and cost of a teleoperated machine for steep country harvesting – Scion, by 31 March, 2016, $10,000.

6.8 Task B: (Contract Milestone 1.2.4): Commercialisation: A commercialisation plan is developed and agreed by the PSG, and a machinery manufacturing company agrees to provide financial investment to support further development of the teleoperated tree-to-tree mobility system and felling head to Beta Prototype stage – Scion and machinery manufacturing company, by 30 June, 2016; $17,000.

Objective 1.2 Budget

1.2 Teleoperated Felling Machine							
		1	2	3	4	5	6
Contract Milestones	Total	June '11	June '12	June '13	June '14	June '15	June '16
1.2.1	$90,013	$90,013					
1.2.2	$615,851		$155,381	$166,470	$294,000		
1.2.3	$647,260					$402,760	$244,500
1.2.4	$17,000						$17,000
Research Materials	$259,700	$0	$5,000	$57,000	$20,000	$122,700	$55,000
Research Direct Cost	$1,629,824	$90,013	$160,381	$223,470	$314,000	$525,460	$316,500
In-kind Contribution	$138,148	$8,339	$11,095	$29,858	$22,143	$52,698	$14,016
Project Management	$247,679	$11,811	$27,065	$45,616	$42,586	$78,553	$42,048
Total Research Plan	$2,015,651	$110,163	$198,540	$298,944	$378,729	$656,711	$372,564
Provider	Total	June '11	June '12	June '13	June '14	June '15	June '16
Scion	$932,124	$90,013	$118,881	$56,970	$166,250	$275,010	$225,000
Scion Materials	$155,000	$0	$0	$42,000	$0	$63,000	$50,000
Trinder Engineering	$0	$0	$0	$0	$0	$0	$0
Trinder Eng. Materials	$0	$0	$0	$0	$0	$0	$0
Consultant	$0	$0	$0	$0	$0	$0	$0
Univ. of Canterbury	$438,000	$0	$36,500	$109,500	$127,750	$127,750	$36,500
Univ. of Cant. Materials	$60,000	$0	$5,000	$15,000	$20,000	$15,000	$5,000
Other Engineering	$44,700					$44,700	
Engineering Materials	$0						
Research Direct Cost	$1,629,824	$90,013	$160,381	$223,470	$314,000	$525,460	$316,500

INTERMEDIATE OUTCOME 2: INCREASED PRODUCTIVITY OF CABLE EXTRACTION

Intermediate Outcome Statement

Intermediate Outcome 2

Title	Increased Productivity of Cable Extraction
IO Statement	The objective of this research is to provide technology which improves the productivity of the extraction phase of the cable logging operation and ultimately to develop alternative systems to those that have traditionally been used to extract wood from steep terrain. Initially the Programme will focus on improving hauler vision to improve productivity of cable yarding (particularly grapple yarding systems). The Programme will then aim to improve the loading phase of grapple systems, which is a first step towards the development of an innovative high speed cable yarding system. Success Measures: • Development and commercialisation of a hauler vision system to improve productivity of cable yarding, and in the case of grapple yarding, eliminate the role of the manual spotter, by 30 June 2013. • Develop an improved high speed grapple carriage control system where the grapple carriage can be remotely controlled, in order to eliminate manual breaking out and unhooking, and reduce element times for the hook on and break out parts of the hauling cycle, by 30 June 2013.. • Redesign and develop a new alternative yarding system to alpha-prototype stage which improves cable deflection, increases productivity and reduces cost of cable yarding by 31 March 2016.
Start date	01/7/2010
End date	30/06/2016
IO Leader	Spencer Hill

Personnel

Intermediate Outcome Leader:
Spencer Hill

Awdon Technologies Ltd:
Don Scott
Colin Olsen
Koller Foresttechnik:
Roland Fuerst
Scion:
Tony Evanson
Dr Paul Milliken
Scorpion Ltd:
Steve Palmer
Tramroad Ltd:
Brett Vincent
Trinder Engineering Ltd:
Kerry Hill
University of Canterbury (School of Forestry):
Dr Rien Visser
Dr Hunter Harrill

OBJECTIVE 2.1

Advanced Hauler Vision System

Objective Leader: Spencer Hill (Scion)

Objective Description – "The Problem"
New Zealand steep country harvesting terrain and conditions results in much of the extraction being done blind (to the yarder operator), with breaker outs (or in the case of grapple yarding a manual "spotter") directing the yarder operator through the "hook on" or log grappling process. This slows down the rate of log uplift. Clear vision will allow the operator to quickly locate the grapple carriage adjacent to the load, decreasing the grapple carriage loading cycle times compared to conventional systems. This will improve the effective use of grapples to replace carriages with strops which require manual "breaking out". The aim of this project is to develop advanced hauler vision systems to improve the visibility to the hauler operator of the grapple carriage and breaking out operation in order to achieve a reduction in "outhaul", "load" and "break-out" elements of the hauler cycle time compared to conventional systems.

Achievement Measures – "Ultimate Vision"
- Development of Advanced Hauler Vision Systems to enable the cable hauler operator to achieve a reduction of 10% in total hauler cycle time
- Facilitation of commercial implementation of a hauler vision system and approval by the PSG
- Further industry investment secured to take this technology to market

Start Date: 01/07/2010 (Year 1)
Finish Date: 30/06/2014 (Year 4)

Project Team: Tony Evanson (Scion)
Kerry Hill (Trinder Engineering Ltd)
Dr Paul Milliken (Scion)
Dr Richard Parker (Scion)

Background – "What has been done?"
Previous studies showed dramatic improvements in productivity from improved vision when fitted to ground based machinery which allows the operator to see behind and to the side of the machine without having to stop and alter body position. In cable logging better visibility to the operator eliminates the role of the manual "spotter" in the case of conventional grapple yarding operations and increases productivity.

Existing overseas technology used in other industries such as mining, using cameras to allow teleoperation were investigated. The ability to provide 3D vision to give depth of field was also explored. A technical report on the economic feasibility of the vision system showed benefits in terms of productivity and logging cost (Report H006). Two streams to this project, one developing a grapple camera system and one developing a system with cameras in multiple locations, both demonstrated benefits. This system will encourage the more effective use of grapples to displace the use of carriages with strops which require manual "breaking out" - hence removing one of the most hazardous activities in cable logging.

This project investigated the optimal method of providing vision of the grapple carriage to the yarder operator. The best camera sites were determined given the variable conditions of forest harvesting (bright sun, deep shadow, fog, haze, rain etc.) Options tested included the top of the yarder tower, in the cutover, on the mobile tail hold, and on the grapple carriage. The resulting technology, the CutoverCam, has the ability to be retrofitted to existing cable yarders, a critical success factor to encourage maximum uptake within industry. The CutoverCam is now commercially available and units are being implemented.

Progress to date

Year 2 (2011/12):

1. (Contract Milestone 2.1.1) Technical and economic feasibility study of the concept completed, demonstrating potential for productivity improvements (Report H006) – Scion.
2. (Contract Milestone 2.1.2) Completed field testing on alpha prototype of cutover camera (fixed camera system) – Scion.
3. (Contract Milestone 2.1.3) Completed design of beta prototype of grapple camera system and presented to PSG – Trinder Engineers Ltd.
4. (Contract Milestone 2.1.3) A vision system for hauler grapple (cameras, sensors, monitors, communication system) to beta-prototype stage was completed – Trinder Engineers Ltd.
5. (Contract Milestone 2.1.4) Further industry investment was secured to take this technology to market – Trinder Engineers Ltd.

Year 3 (2012/13):

1. (Contract Milestone 2.1.3) Field testing of beta prototype hauler vision system (power-tilt-zoom, or PTZ system) in a grapple operation was completed to determine the effectiveness of the hauler vision system (Technical Note HTN05-03) – Scion.
2. (Contract Milestone 2.1.3) Investigated uptake of the hauler vision system and identified barriers to uptake of vision systems. Developed a commercialisation strategy in conjunction with Trinder Engineers that addressed identified barriers, cost of system, potential markets and intended marketing of system. Commercialisation strategy was approved by the TST – Scion.
3. (Contract Milestone 2.1.4) Undertook programme of trials and modifications to the beta prototype cutover camera system to address identified barriers, and assist in development and marketing of commercial model – Scion.
4. (Contract Milestone 2.1.4) Detailed specifications of the commercial model of the advanced hauler vision system for the cutover were finalised. Potential commercial suppliers of both systems were identified and recommendations made of suitable commercial arrangements enabling the transfer of the technology to the forest industry – Scion.

Year 4 (2013/14):

1. (Contract Milestone 2.1.4) Field testing and modifications completed to the first commercial hauler vision system to address identified barriers to uptake of the hauler vision system (carried over from 2012/13) – Scion.
2. (Contract Milestone 2.1.4) Detailed specifications of the commercial model of the advanced hauler vision system finalised. The commercialisation plan was updated addressing commercial suppliers, cost of system, potential markets and intended marketing of system. The commercialisation plan was approved by the TST – Scion.
3. (Contract Milestone 2.1.4) Application of the hauler vision system to an "after dark" capable cable logging operation. Further development of the hauler vision system was investigated to incorporate lights – Scion.
4. (Contract Milestone 2.1.5) Two field days were organised to demonstrate the CutoverCam System to enable the transfer of this technology to the forest industry – Scion.

Year 5 (2014/15):

1. (Contract Milestone 2.1.4) Application of the hauler vision system to an "after dark" capable cable logging operation was completed. The economic feasibility of the extended shift cable logging system was determined and a Technical Note (HTN07-02) was published – Scion.

Approach – "What is required to achieve the project?"

This project is now completed. The advanced hauler vision system has been commercialised as the CutoverCam, and is available from Cutover Systems Ltd.

Research Plan Resources (incl. project management and in-kind contribution): Objective 2.1

	Year							
Objective 2.1	1 2010/11	2 2011/12	3 2012/13	4 2013/14	5 2014/15	6 2015/16	Total	Business Plan
Total	$202,928	$128,903	$44,413	$50,417	$2,500	$0	$429,161	$358,875

Objective Statement 2.1

Objective	2.1
Objective title.	Increased Productivity of Cable Extraction – Advanced Hauler Vision Systems
Objective description	The aim of this project is to develop advanced vision systems to enable the cable hauler operator to achieve a reduction of 10% in log retrieval and out-haul cycle times compared to conventional systems.
Objective Achievement Measure.	1. Advanced hauler vision systems will be developed to enable the cable hauler operator to achieve a reduction of 10% in log retrieval and out-haul cycle times; 2. Facilitation of commercial implementation of a hauler vision system to the satisfaction of the Programme Steering Group, and 3. Further industry investment obtained to take this technology to market.
Start date	01/07/2010
End date	30/06/2015 COMPLETED

Objective 2.1 Contract Milestones

Milestone 2.1.1	Advanced hauler vision systems – feasibility analysis
Description	Carry out a comprehensive technical and economic feasibility study of the concept with a view to development of the concept to alpha testing stage.
Achievement Measure	Based on a comprehensive technical and economic feasibility study of the concept demonstrating at least a 10% improvement in productivity over current industry levels, the Harvesting Programme Steering Group (PSG) approves development of the concept to alpha testing stage.
Start Date	01 July 2010
End Date	31 December 2010 COMPLETED

Milestone 2.1.2	Advanced hauler vision systems – Alpha prototype development
Description	Complete the alpha testing phase of prototype advanced hauler vision system.
Achievement Measure	1. An alpha prototype development plan that specifies the operational parameters and performance standards has been developed and approved by the PSG by 31 December 2010. 2. The alpha prototype of the advanced hauler vision system has been demonstrated and has met the operational parameters and performance standards in the alpha prototype development plan by 30 June 2011.
Start Date	01 December 2010
End Date	30 June 2011 COMPLETED

Milestone 2.1.3	Advanced hauler vision systems – Beta testing development
Description	Complete the beta testing development of the advanced hauler vision system under carefully monitored conditions and used as the basis for a commercial design.
Achievement Measure	1. A commercialisation strategy is developed for a beta prototype advanced hauler vision system and approved in writing by the PSG by 30 September 2011. 2. Successful beta testing of the advanced hauler vision system, that meets the operational parameters and performance standards defined by the PSG has been carried out by 31 March 2012.

	3. Based on this, the PSG approves a commercialisation plan for the development of a commercial advanced hauler vision system by 31 March 2012.
Start Date	01 July 2011
End Date	31 March 2012 COMPLETED

Milestone 2.1.4	Advanced hauler vision systems – commercial support
Description	Develop a beta prototype to the stage where a manufacturing company is prepared to financially support development of the concept to commercialisation.
Achievement Measure	1. A beta prototype has been developed that meets the operational parameters and performance standards agreed to by the PSG by 30 June 2013. 2. A manufacturing company has advised that they will provide the financial investment to support its commercial development and agreements are executed by 30 June 2014.
Start Date	01 April 2012
End Date	30 June 2014 COMPLETED

Milestone 2.1.5	Advanced hauler vision systems – first commercial product
Description	Implementation of the first commercial hauler vision system by a harvesting company.
Achievement Measure	The first commercial system is purchased or leased and installed in a yarder by a harvesting company.
Start Date	01 July 2012
End Date	30 June 2014 COMPLETED

Objective 2.1 Budget

2.1 Advanced Hauler Vision		1	2	3	4	5	6
Contract Milestones	Total	June '11	June '12	June '13	June '14	June '15	June '16
2.1.1	$50,357	$50,357					
2.1.2	$95,454	$95,454					
2.1.3	$70,682		$55,682	$15,000			
2.1.4	$88,446		$38,446	$18,200	$31,800		
2.1.5	$12,000				$10,000	$2,000	$0
Research Materials	$30,000	$20,000	$10,000	$0	$0	$0	$0
Research Direct Cost	$346,939	$165,811	$104,128	$33,200	$41,800	$2,000	$0
In-kind Contribution	$30,148	$15,361	$7,203	$4,436	$2,948	$201	$0
Project Management	$52,073	$21,756	$17,572	$6,777	$5,669	$299	$0
Total Research Plan	$429,161	$202,928	$128,903	$44,413	$50,417	$2,500	$0
Provider	Total	June '11	June '12	June '13	June '14	June '15	June '16
Scion	$239,896	$117,142	$45,754	$33,200	$41,800	$2,000	$0
Scion Materials	$20,000	$20,000	$0	$0	$0	$0	$0
Trinder Engineering	$77,043	$28,669	$48,374	$0	$0	$0	$0
Trinder Eng. Materials	$10,000	$0	$10,000	$0	$0	$0	$0
Consultant	$0						
Univ. of Canterbury	$0						
Univ. of Cant. Materials	$0						
Other Engineering	$0						
Engineering Materials	$0						
Research Direct Cost	$346,939	$165,811	$104,128	$33,200	$41,800	$2,000	$0

OBJECTIVE 2.2

Improved Grapple Carriage Control System

Objective Leader: Spencer Hill (Scion)

Objective Description – "The Problem"

Cable yarding system productivity is determined by: yarder type, yarding distance, stem volume and bunching strategy. The rate limiting step in cable yarding is the speed at which wood can be extracted from the point of attachment to the landing site where it is unloaded from the hauler. Previous comparisons of different yarding systems have identified the advantages of grapple yarding; mainly due to the very short loading times ("load grapple") relative to the time to manually attach chokers ("hook on").

The aim of this project is to increase cable extraction productivity through yarding bunched wood using improved grapple carriages instead of use of manual chokers, and improve working conditions and safety of extraction in steep terrain harvesting through eliminating the manual roles of breaking-out and unhooking, by using mechanised grapple extraction. The target is to reduce cable hauler element times for "position grapple carriage", "load grapple" and "break out" by at least 20% resulting in improved productivity by 25% over current conventional practice.

Achievement Measures - "Ultimate Vision"

- Develop and field test to alpha prototype stage an improved high speed grapple carriage control system where the grapple carriage can be controlled by the bunching machine.
- Approval of the alpha prototype by the Harvesting Programme Steering Group (PSG)
- Further investment secured to commercialise this technology.

Start Date: 01/07/2010 (Year 1)
Finish Date: 30/06/2015 (Year 5)

Project Team:
Tony Evanson (Scion)
Dr Hunter Harrill (UC Forestry)
Dr Paul Milliken (Scion)
Steve Palmer (Scorpion Ltd)
Dr Richard Parker (Scion)
Brett Vincent (Tramroad Ltd)
Dr Rien Visser (UC Forestry)
Roland Fuerst (Koller Forsttechnik)

Background - "What has been done?"

In 2012 there were approximately 300 hauler operations in New Zealand of which only approximately 40 operations used high productivity grapple configurations (less than 15%). Harvesting using grapples in New Zealand has been limited mostly to swing yarders. With only a small percentage of grapple operations, a large number of loggers are exposed to the very hazardous role of manual breaking out. For the logging industry to reduce or eliminate the large number of accidents to breaker outs, it must increase the number of grapple logging operations in New Zealand, and address the barriers to uptake of these systems.

In Year 1 this project proposed to develop an improved grapple carriage control system instead of use of manual chokers, eliminating the roles of the breaker out and pole man, and reducing the time to "hook on" and unhook logs using chokers (Work Plan HDP001). In 2010/11 the international literature on developments in grapple carriage technology was reviewed (Report H004). The Project Plan defined the development of a control system for transfer of control of the grapple carriage from the yarder operator to the "breaker-out" or "spotter" to allow better control of grapple positioning and

faster “grapple load” and “break out” element times. The aim was to build on existing technologies including electro-hydraulic control systems, such as the Harvestline Hauler (manufactured by EMS Ltd in Rotorua) with a focus on innovations such as auto-return and remote control technologies. EMS Ltd however was unable to commit the resources required for this project.

A technical and economic feasibility study was undertaken analysing the economic feasibility of the system, assessing potential markets and scale-up issues was completed which was quite promising (Report H005). The potential of the improved remote-control grapple carriage system to reduce costs by 20% and remove hazards to the “breaker out” and “unhooker” roles in the logging operation was demonstrated.

Initially the project focussed on measuring the improvements of grapple systems over butt rigging and choker systems through better control of grapple carriage positioning. In 2011/12 a project was undertaken aimed at developing a cost effective system for improved control of existing grapples. A grapple restraint for rope-controlled grapples was developed and extended to the industry (Technical Note HTN04-10). The project then moved into development of a remote controlled grapple carriage system.

This project also proposed to investigate and address the barriers to contractors operating higher efficiency cable logging rigging configurations and carriage types, such as grapples and motorised carriages. International literature on cable logging rigging configurations was reviewed (Report H019) and the rigging configurations and carriage types used in New Zealand were investigated by University of Canterbury School of Forestry (Technical Note HTN03-11). The next stage of this work was to define the advantages and disadvantages of the various rigging configurations in different harvesting conditions (Technical Note HTN04-06). Work then started to focus on improving the industry’s understanding of skyline tension/deflection/payload relationships for the major rigging configurations used in New Zealand. A model yarder was used to simulate skyline tensions (Technical Note HTN05-12). Little is known about the skyline tensions generated in the new generation hydraulic grapple carriages and motorised carriages and this area of work will be continued by University of Canterbury School of Forestry as part of this PGP programme in order to address this barrier to uptake of grapple carriage systems.

Progress to date

Year 2 (2011/12):

1. (Contract Milestone 2.2.1) The barriers to contractors operating higher efficiency cable logging rigging configurations and carriage types in New Zealand were explored through a survey Forestry (Technical Note HTN03-11) – University of Canterbury, School of Forestry.
2. (Contract Milestone 2.2.2) The grapple restraint for improved control of rope grapples to enhance positioning and grapple loading time was developed – Scion.
3. (Contract Milestone 2.2.2) As an alternative to the original project milestone, a project was commenced in 2012 whereby a prototype remote controlled hydraulic grapple carriage was sourced from overseas. The opportunity was taken to fit the grapple camera (from Task 2.1) to the hydraulic grapple on arrival in NZ. The Alpine hydraulic clamping grapple carriage was implemented in a hauler operation and a production study and cost benefit analysis was completed (Technical Note HTN05-08) – Scion.

Year 3 (2012/13):

1. (Contract Milestone 2.2.1) Technical and economic feasibility studies of cable rigging configurations was undertaken to address the barriers to contractors operating higher efficiency cable logging rigging configurations and carriage types (such as grapples and motorised carriages (Technical Note HTN04-06) – University of Canterbury School of Forestry.
2. (Contract Milestone 2.2.2) The Grapple Restraint developed in 2011-12 was implemented into the operations of three candidate grapple harvesting contractors. The commercial model specifications and economic analysis was released. A technical report of trial performance in a swing yarder operation (Technical Note HTN04-10) was published to complete the transfer of this technology to the forest industry – Scion.

3. (Contract Milestone 2.2.2) The Alpine hydraulic clamping grapple carriage was installed in a hauler operation in the Gisborne District and trialled briefly until the barriers to uptake of the new grapple were identified. Recommendations were made for modifications and improvements to the grapple carriage – Scion.
4. (Contract Milestone 2.2.2) An ergonomic and productivity evaluation of a Falcon motorised grapple carriage was undertaken (Technical Note HTN05-06) and further work focussed on solving some performance limitations (Report H009) – UC Forestry.
5. (Contract Milestone 2.2.2) Uptake of both the hydraulic clamping grapple carriage and motorised hydraulic grapple carriage was investigated and the barriers to uptake were identified. A commercialisation strategy for the Alpine Grapple was developed in conjunction with the machinery manufacturing company to address identified barriers, cost of system, potential markets and intended marketing – Scion.
6. (Contract Milestone 2.2.2) Commenced a programme of trials and modifications to the Alpine hydraulic clamping grapple carriage to address identified barriers, and assist in development and marketing of commercial model – Scion.

Year 4 (2013/14):

1. (Contract Milestone 2.2.1) Work continued in the Cable Rigging Configurations Efficiency project. This involved detailed elemental time studies to determine productivity, cable tensions and fuel consumption of different cable rigging configurations in similar conditions. A review of cable logging literature was published (Report H019) – UC Forestry.
2. (Contract Milestone 2.2.3) Completed the programme of trials and modifications to the Alpine hydraulic clamping grapple carriage that addressed identified barriers to uptake. Detailed specifications of the commercial model of the Alpine hydraulic clamping grapple carriage were finalised in conjunction with Alpine Logging Ltd (Technical Note HTN06-09). The commercialisation plan for the Alpine grapple carriage was finalised in conjunction with Alpine Logging Ltd that addressed identified barriers, cost of system, potential markets and intended marketing of system. The commercial supplier of the Alpine grapple carriage system in NZ was confirmed and suitable commercial arrangements made enabling the transfer of this technology to the forest industry. Two field days were organised to demonstrate the Alpine hydraulic clamping grapple carriage system to the forest industry – Scion.
3. (Contract Milestone 2.2.3) Design and development of the innovative Scorpion grapple was commenced. An independent engineers report was commissioned to review feasibility of design. The initial development of the alpha prototype Scorpion grapple was documented (Report H016) – Scorpion Ltd and Scion.
4. (Contract Milestone 2.2.3) Technologies for outhaul distance measurement (drum counters, GPS etc.) were investigated as a step towards automated high speed return of the grapple carriage to the next load without being guided by a manual “breaker-out” or external “spotter” (Technical Note HTN06-08) – Scion.
5. (Contract Milestone 2.2.3) Options for improved hauler controls to address the identified barrier to uptake of grapples were investigated (Report H015) – Scion.
6. (Contract Milestone 2.2.3) Improved directional felling wedge: Trials were undertaken of a directional felling wedge to assist felling direction and reduce the impact of stem breakage during felling and breakout. Results of the hydraulic felling wedge trial were analysed and barriers to uptake identified (Report H010) – Tramroad Limited (B.M. Vincent).

Year 5 (2014/15):

1. (Contract Milestone 2.2.1) Cable Rigging Efficiency project: Dr Hunter Harrill’s work involving determining productivity, cable tensions and rope wear of different cable configurations to identify higher efficiency cable rigging configurations continued. A Technical Report of the production studies to determine productivity, cable tensions and fuel consumption of different cable rigging configurations was published (Report H020). Extension of this work to industry was completed by way of workshops for logging practitioners – UC Forestry.
2. (Contract Milestone 2.2.3) Design and development of the innovative Scorpion grapple continued from 2013/14. Development of the alpha prototype Scorpion grapple to date was documented and this project was completed – Scion.

3. (Contract Milestone 2.2.3) Improved directional felling wedge: In conjunction with Scion and a machinery manufacturing company, an improved felling wedge, the Jackson Beckham Wedge, was developed, trialled and modified (Report H018). A commercialisation plan was developed that addressed identified barriers, cost of system, potential markets and intended marketing of the new light weight felling wedge – Tramroad Limited (B.M. Vincent).

Approach – "What is required to achieve the project?"

- Cable Rigging Efficiency: Live skyline grapple carriage systems have been developed and tested as part of this programme and offer the opportunity for higher production and safer operations. However the weight of the carriage and operating technique can cause high loading and high rate of wear of the skyline. Both these issues have been identified as barriers to uptake of grapple carriages. Completion of this project will address the optimising of payload and overloading risks through the use of tension monitors and provide guidance to improve operator performance. An operational trial using tension monitors to optimise yarding operations will demonstrate the benefits to logging operators. Final outputs will be an operational tension monitoring application to provide immediate operator feedback with regard to both safety and payload optimisation, and recommendations regarding the use of new wire rope technology that has greater breaking strength and wear characteristics when used in motorised grapple carriage systems. The cost benefit of the new wire rope technology will be determined and extended to the industry for adoption. The 'app' will be completed by 30 June 2016, and the commercialisation pathway is for it to be made available to the industry as a download from the FFR website.
- Felling Grapple Carriage for a Swing Yarder: Since the development of the alpha prototype Scorpion grapple stalled during the year, and further investment by FFR has been deferred, a proposal was made by a member company during the development of the 2015/16 programme, to support the development of an innovative felling grapple carriage for operation with a swing yarder. The developers of this project, Turoa Merritt of Storm Logging Ltd and Tony Henderson of Active Equipment Ltd., have conducted preliminary research with the objective to improve safety by eliminating manual felling and breaking out through the use of a felling head mounted on a skyline carriage. This proposal was considered by the Technical Steering Team (TST) in April, 2015 to co-fund this development. The objectives were clearly aligned with industry priorities for health and safety (removes men on ground), and quality (reduces stump to truck time). It was also important that the programme support contractor/engineering company proposals to develop new products, but this was balanced by concerns regarding technical and economic feasibility of the project. As only conceptual information was provided on which the TST could decide whether to support this project, the decision was taken to support an initial feasibility analysis of the project, prior to any further FFR investment. Dr Rien Visser of University of Canterbury School of Forestry has agreed to undertake this initial feasibility analysis.
- Improved Directional Felling Wedge: Earlier project partners Jackson Beckham Ltd have decided not to continue with development of the remote controlled powered felling wedge. Koller Forsttechnik GmbH of Austria have a commercialised manual felling wedge and have expressed interest in co-developing a remote controlled powered felling wedge. It is proposed to complete development of this improved directional felling wedge to assist felling direction and reduce the impact of stem breakage during felling and breakout. The remote controlled powered felling wedge will be co-developed with Koller Forsttechnik GmbH of Austria to assist felling direction and remove manual faller from the hazard zone during felling.

Research Plan Resources (incl. project management and in-kind contribution): Objective 2.2

	Year							
Objective 2.2	1 2010/11	2 2011/12	3 2012/13	4 2013/14	5 2014/15	6 2015/16	Total	Business Plan
Total	$106,260	$70,090	$148,174	$198,672	$68,078	$207,714	$798,989	$293,625

Objective Statement 2.2

Objective	2.2
Objective title.	Increased Productivity of Cable Extraction – Improved Grapple Carriage Control
Objective description	This Project will aim to develop an improved grapple/carriage control system to reduce cable hauler cycle time by at least 20% and improved productivity by 25% over current conventional practice.
Objective Achievement Measure	1. Development to field test prototype stage of an improved high speed automated grapple/carriage control system where the grapple/carriage can be controlled by the bunching machine. 2. Approval of the field test prototype by the PSG. 3. Investment secured to commercialise this system.
Start date	01/07/2010
End date	30/06/2016

Objective 2.2 Contract Milestones

Milestone 2.2.1	Improved Grapple Carriage Control System – feasibility analysis
Description	Carry out a comprehensive technical and economic feasibility study of a concept improved grapple/carriage control system, indicating at least a 25% improvement in productivity over current industry levels.
Achievement Measure	1. A comprehensive technical and economic feasibility study of a concept improved grapple carriage control system, indicating at least a 25% improvement in productivity over current industry levels is completed by 31 December 2010. 2. The Harvesting Programme Steering Group (PSG) approves development of the concept to simulation stage.
Start Date	01 July 2010
End Date	31 March 2014 COMPLETED

Milestone 2.2.2	Improved Grapple Carriage Control System – concept simulation
Description	Development of a commercialisation plan for an improved grapple/carriage control system based on a successful simulation and a market/technical and economic analysis.
Achievement Measure	1. A development plan that specifies the operational parameters and performance standards for an improved grapple carriage control system is approved by the PSG by 31 March 2011. 2. An improved grapple carriage control system is demonstrated in a simulation study that meets the operational parameters and performance standards, by 31 March 2012. 3. A commercialisation plan for an improved grapple carriage control system is approved by the PSG by 31 March 2012.
Start Date	01 January 2011
End Date	31 March 2012 COMPLETED

Milestone 2.2.3	Improved Grapple Carriage Control System – commercial support
Description	A manufacturing company has agreed to provide the financial investment to support the further development of the improved grapple/carriage control system to commercialisation stage.
Achievement Measure	A machinery manufacturing company has agreed to provide financial investment to support the further development of the improved grapple carriage control system to commercialisation stage.
Start Date	01 April 2012
End Date	30 June 2014 COMPLETED

Milestone 2.2.4	Improved Grapple Carriage Control System – commercial production
Description	The first commercial machine is implemented by a harvesting company.
Achievement Measure	The first commercial grapple carriage is purchased or leased by a harvesting company and is in use in a commercial harvesting operation by 30 June 2014.
Start Date	01 July 2012
End Date	30 June 2014 COMPLETED

Milestone 2.2.5	Improved Grapple Carriage Control System – additional products
Description	Additional products are developed to improve grapple payload and directional felling of trees for grapple extraction.
Achievement Measure	An innovative improved felling wedge to improve directional felling of trees for grapple extraction has been developed and implemented in a commercial harvesting operation.
Start date	01 July 2013
Finish date	30 June 2016

Project Milestones and Outputs

Year 6 (2015/16):

6.1 (Contract Milestone 2.2.5) Cable Rigging Efficiency: Skyline Tension Monitoring to Optimise Yarding Operations. Dr Hunter Harrill's earlier work involving determining cable tension loading and productivity of different cable configurations showed it was possible to identify opportunities for higher efficiency operation by management of skyline tension and payload through the use of skyline tension monitors. Specific project tasks comprise: (a) install skyline tension monitors into three tower yarders; (b) measure and monitor skyline tensions during normal operations; (c) demonstrate to operators how tension data can be used to optimise payloads and manage shock-loading; (d) report results, including productivity data to quantify these benefits, in a Technical Note detailing cost, installation and benefits; (e) develop a module to add to the Cable Rigging Workshops run by UC Forestry to extend the findings to industry – UC Forestry + Brian Tuor, $45,217; by 30 June 2016.

6.2 (Contract Milestone 2.2.5) Cable Rigging Efficiency: Tension Monitoring Application. Dr Hunter Harrill's earlier work has shown that wire rope tensions are often very high during operations and this poses a safety risk. This project, which follows on from Milestone 6.1, will develop a Tension Monitoring Application, for use with existing tension monitors to provide both instantaneous feedback regarding overloading, and allow the operator to review skyline tension data in real-time. The application will be tested to ensure it will provide visual feedback of skyline tension data to the operator to improve operator and system performance. Like GPS tracking in trucks, it can also be used to monitor and review data from previous hauler cycles to reduce risky behaviour. The 'app' will be made freely available through FFR – UC Forestry, $20,000; by 30 June 2016.

6.3 (Contract Milestone 2.2.5) New Wire Rope Technology for Grapple Carriage Systems. The high rate of wear through both high loading and bending in the skyline associated with live skyline grapple carriage systems will be addressed through the investigation of the cost benefit of improved wire rope technology. Commercially available improved Plastic Filled Valley (PFV) wire rope will be installed on two yarder operations working with motorised grapple carriage systems. The rate of wear and tear will be tested with regards to both strength and fatigue characteristics through monitoring at 2-monthly intervals. The cost-benefit of the PFV wire rope will be calculated and related to production volume. Main findings will be published in a Technical Note with recommendations for the industry – UC Forestry + in-kind support from contract logging crews (skyline purchase) + a NZ based wire rope manufacturer and distributor (Bridon Cookes), $35,000; by 30 June 2016.

6.4 (Contract Milestone 2.2.5) Felling Grapple Carriage for a Swing Yarder. Undertake an initial technical and economic feasibility study of the Storm Active felling carriage designed for efficient felling and extraction in a swing yarder operation. This prototype comprises a modified grapple

processor and motorised grapple carriage and integrates mechanised felling (Objective 1.1) and efficient grapple extraction (Objective 2.2) – UC Forestry, $10,000; by 31 December 2015.

6.5 (Contract Milestone 2.2.5) Improved directional felling wedge: Complete design and development of beta prototype of remote controlled powered felling wedge to assist felling direction and removes manual faller from the hazard zone during tree felling. Beta prototype presented to and approved by TST – Scion $66,240 / Tramroad Limited (B.M. Vincent) / Koller Forsttechnik (in-kind contribution); by 30 June 2016.

Objective 2.2 Budget

2.2 Improved Grapple Carriage Control							
		1	2	3	4	5	6
Contract Milestones	Total	June '11	June '12	June '13	June '14	June '15	June '16
2.2.1	$121,045	$54,829	$11,216	$20,000	$17,500	$17,500	
2.2.2	$168,163	$31,995	$45,403	$90,765			
2.2.3	$93,217				$93,217	$0	$0
2.2.4	$0				$0	$0	$0
2.2.5	$267,429				$54,000	$36,972	$176,457
Research Materials	$0	$0	$0	$0	$0	$0	$0
Research Direct Cost	$649,854	$86,824	$56,619	$110,765	$164,717	$54,472	$176,457
In-kind Contribution	$51,653	$8,044	$3,917	$14,799	$11,616	$5,463	$7,814
Project Management	$97,483	$11,392	$9,555	$22,610	$22,340	$8,143	$23,443
Total Research Plan	$798,989	$106,260	$70,090	$148,174	$198,672	$68,078	$207,714
Provider	Total	June '11	June '12	June '13	June '14	June '15	June '16
Scion	$345,148	$74,824	$45,403	$63,992	$89,689	$5,000	$66,240
Scion Materials	$0	$0	$0	$0	$0		$0
Trinder Engineering	$0						
Trinder Eng. Materials	$0						
Consultant	$55,273	$0	$0	$19,773	$3,528	$31,972	$0
Univ. of Canterbury	$195,433	$12,000	$11,216	$27,000	$17,500	$17,500	$110,217
Univ. of Cant. Materials	$0						
Other Engineering	$54,000	$0	$0	$0	$54,000	$0	$0
Engineering Materials	$0	$0	$0	$0	$0	$0	$0
Research Direct Cost	$649,854	$86,824	$56,619	$110,765	$164,717	$54,472	$176,457

OBJECTIVE 2.3

Innovative Yarding System

Objective Leader: Spencer Hill (Scion)

Objective Description – "The Problem"
The New Zealand industry is heavily reliant on either ageing second hand cable yarders out of North America, or New Zealand built models such as the Brightwater Yarder, Madill 124 and Harvestline. In a 2012 survey of cable haulers in New Zealand (Visser, 2013) only 38 out of 305 haulers (12%) were recently manufactured New Zealand models (Brightwater or Harvestline haulers). There is a need for the cable hauler machinery industry in New Zealand to grow substantially to future-proof the industry.

Steep country harvesting costs are a key bottleneck to greater profitability in forestry. Cable logging is the lowest productivity, most hazardous, most labour intensive and least mechanised process in the forest industry. The combined effect of these issues is that cable logging costs are the highest of all costs in forestry value chain. The industry has recognised that these costs need to be reduced by 25% by improving productivity, and that the cost and social impact of accidents must be reduced by making harvesting jobs safer and more desirable for logging workers.

Overseas harvesting equipment developments are focused primarily on small tree size and hence machines are often smaller. NZ's unique combination of soils, terrain, climate, forest type and infrastructure means we cannot rely on overseas research to solve our problems. Elements of these developments however can be transferred to this programme. Radio-controlled yarder carriages are used in smaller yarders in Europe (for example, Syncrofalke, Koller and Valentini) incorporating automation of part of the cycle to deliver the carriage to the point of the previous load. Elements of this system are proposed in this programme to direct the grapple carriage to the next load. At that point, the yarder operator takes over control using state of the art vision systems to direct the grapple carriage to the load, even in conditions of poor visibility. The computer again controls inhaul, stopping the grapple carriage just before it reaches the drop zone (landing) to prevent safety issues.

Achievement Measures – "Ultimate Vision"
- Redesign and develop to alpha-prototype stage a new alternative yarding system which increases productivity and reduces cost of cable yarding
- Reduce diesel fuel consumption (in litres per tonne of wood produced) through development of a lighter weight, more fuel efficient constant load system
- Demonstrate a new cable harvesting system incorporating all the key elements above
- The potential of the system for commercial development is confirmed by the PSG
- Secure industry investment to commercialise the yarding system

Start Date: 01/07/2011 (Year 2)
Finish Date: 30/06/2016 (Year 6)

Project Team:
Spencer Hill (Scion)
Dr Paul Milliken (Scion)
Dr Richard Parker (Scion)
Don Scott (Awdon Technologies Ltd)
Colin Olsen (Awdon Technologies Ltd)
Brett Vincent (Tramroad Ltd)
Dr Rien Visser (UC Forestry)

Background – "What has been done?"
While conventional approaches to harvesting are being developed and trialled it is important that other more innovative solutions to address the problems identified in cable extraction are explored.

This Project will aim to investigate development of alternative new extraction systems based on a high speed, mobile, long span yarder capable of high volume productivity at low cost. This system has the potential to eliminate much of the interactive delay time inherent in conventional cable yarding. Preliminary simulation indicates the combination of felling, bunching and grapple yarding to deliver net cycle time benefits of about 30%. This project recognises the need to move well beyond business-as-usual approaches in cable harvesting. The ultimate development of the Programme is an innovative yarding system that will increase productivity and produce a step change reduction in the cost of steep terrain harvesting.

The project commenced in Year 2 (2011/12) with a review of the international literature (Technical Note HTN06-05) in innovative yarding systems. The Project was initially divided into two Tasks: Task A was the development of a mobile platform for a yarding system that would be capable of traversing extreme terrain. Task B, used a brainstorming approach via a number of workshops throughout New Zealand to seek and generate ideas for the development of an innovative yarding system that would be high productivity, lower cost and able to maximise skyline deflection, and therefore payload.

Task A: Mobile platform for an Innovative Yarding System
This Task commenced in 2011 when Awdon Technologies Ltd proposed to develop a mobile platform for an innovative cable yarding system, dubbed the Hill Country Harvester. This system had the potential to combine Intermediate Outcome 1 “Mechanisation on Steep Terrain” (development of the Steep Slope Feller Buncher and Teleoperated Felling Machine) with Intermediate Outcome 2 “Increased Productivity of Cable Extraction”. A Development Plan was completed, detailing the concept and preliminary design. The TST approved the development of the first two milestones in the project method: the design of the mobility platform.

This design was innovative in that it used a different traction system to enable it to traverse the steepest terrain with minimal ground disturbance. The ground contact pressures for the vehicle, calculated by dividing gross vehicle weight by projected surface area in contact with the ground would provide the lowest environmental footprint of common ground-crawling equipment (less than 3.0psi or 20kPa) while maximising traction (tractive force) and minimising slip. This approach would provide the opportunity for redesign of the current cable hauling system to provide integrated felling/bunching and cable yarding, enabling directional felling in conjunction with extraction (i.e. multiple harvesting functions).

A Concept Design for the Hill Country Harvester steep slope mobility system was researched and electronically modelled by Awdon Technologies Ltd. Draft design using 3D CAD drawings was completed and demonstrated to PSG. Initial machine specifications were provided and a solution was evaluated with FFR using workshops addressing feasibility of design. It was decided not to pursue this design as there were concerns about complexity of design, cost of construction and maintenance. Instead, on the advice of the expert panel, elements of this design were incorporated into a low cost yarder.

Task B: Concepts for an Innovative Yarding System
This Task aimed to generate and develop concepts for an innovative yarding system through a series of industry workshops commenced in Year 3 (2012/13). All ideas and concepts were open for suggestion and discussion (Technical Note HTN05-09). The concepts generated were subsequently analysed for technical feasibility, economic viability and potential for further development (Technical Note HTN05-10).

The vision of this objective was to combine the design of the mobile extreme terrain platform arising from Task A with the alpha-prototype innovative yarding system from Task B to achieve the project outcome of the development of an innovative yarding system with extreme terrain capability.

A yarding concept based on the “spider-cam” multiple winch aerial camera system used in sports stadiums was explored. After engineering analysis showed that the power requirements for this concept were very high, this concept was not pursued further. Elements of the concepts for an innovative yarding system generated during the series of industry workshops were developed

further, such as systems for rapid line shifting, lateral yarding and fast grapple carriages. This programme has built on technologies developed in other parts of the programme (including electro-hydraulic control systems, use of radio remote control, camera systems and semi-automation).

The ability to retrofit existing equipment is a key component of this project to encourage maximum uptake within industry. This project is a step towards the development of a fully automated "intelligent" grapple system (through automation and mechatronics) that automates the process of securing the stem or a bunch of stems to the cable.

Progress to date

Year 3 (2012/13):

1. (Contract Milestone 2.3.1) Task A: Feasibility of Concept Hill Country Harvester: The initial solution was modified based on FFR evaluation workshops. An animated video was made to demonstrate the machine performing specific functions. An FFR expert panel was set up to evaluate concept development. The solution was discussed and evaluated with FFR expert panel – Awdon Technologies Ltd.
2. (Contract Milestone 2.3.1) Task A: An independent Mechanical Engineering consultant report has been commissioned to evaluate the engineering feasibility of the concept – FFR.
3. (Contract Milestone 2.3.1) Task B: A series of workshops (4) was run in Gisborne, Masterton, Dunedin and Rotorua to generate and develop concepts for an innovative cable harvesting system. As a result of these workshops the best eight concepts were shortlisted by an FFR expert panel, by 30 September 2012 – Scion and University of Canterbury.
4. (Contract Milestone 2.3.1) Task B: Technical feasibility and broad economic analysis was undertaken on the eight concepts to select the best new concept for a cable harvesting system (yarding phase). Each concept was analysed to determine which has the potential to provide at least 30% productivity improvement or cost gains over current systems, by 31 December 2012 – Scion.
5. (Contract Milestone 2.3.1) Task B: A technical feasibility and economic analysis paper evaluating the best new cable harvesting system that demonstrates the measured benefits in terms of reduced extraction cycle time, and increased productivity, will be completed by 30 June 2013 – Scion.

Year 4 (2013/14):

1. (Contract Milestone 2.3.1) Task A: Project Evaluation and Review of Hill Country Harvester: FFR conducted a mid-Project review prior to construction of the simulation model. An independent Mechanical Engineering consultant was commissioned to evaluate the engineering feasibility of the concept. The solution was discussed and evaluated by the FFR expert panel, and it was decided not to proceed with the Hill Country Harvester in its current design. The Harvesting Programme Steering Group (PSG) did not approve further development to simulation stage – UC Mech. Eng. and Scion.
2. (Contract Milestone 2.3.1) Investigation of technologies for alternative yarding systems internationally; including Central Europe, South Africa, Canada etc.
3. (Contract Milestone 2.3.1) Generating conceptual/theoretical models for all proposed harvesting systems and comparing modelled performance to the ideal to highlight potential areas for improvement.
4. (Contract Milestone 2.3.1) Task B: Design of Innovative Yarding System. A proposal for an alternative yarding system comprising three carriages, a control system and a low cost yarder was received from Awdon Technologies that met the original operational parameters and performance standards for an innovative yarding system (Technical Note HTN07-01). The FFR expert panel evaluated the solution and machine specifications were modified based on this evaluation – Scion and Tramroad Limited (B.M. Vincent) and Awdon Technologies Ltd (Don Scott).
5. (Contract Milestone 2.3.2) Task B: Development of Innovative Yarding System to simulation stage. A simulation model of the Innovative Yarding System comprising a miniature model using actuators and other electrical components was built that demonstrated machine functions and the capability to meet the operational parameters and performance standards. The new cable

yarding system was demonstrated to the TST in Rotorua. A technical and economic feasibility analysis of the system was published (Technical Note HTN07-01) – Awdon Technologies Ltd.

6. (Contract Milestone 2.3.3) Task B: Based on successful simulation modelling of the yarding system, an Alpha Prototype Development Plan that specified the operational parameters and performance standards of an innovative yarding system was completed. The PSG approved this plan for development of the innovative yarding system to alpha prototype stage – Scion and Awdon Technologies Ltd.
7. (Contract Milestone 2.3.3) Task B: Design and construct Alpha Prototype of the innovative yarding system comprising a one-eighth scale working model of the carriages and yarder with control system. The working model was electrically actuated and demonstrated "real-life" movement capability to meet the operational parameters and performance standards specified in the Alpha Prototype Development Plan – Awdon Technologies Ltd.

Year 5 (2014/15):

1. (Contract Milestone 2.3.3) Design and build Innovative Yarding System: A one-eighth scale electrically actuated working model of the alpha prototype tail hold carriage and control system was completed – Awdon Technologies Ltd.
2. (Contract Milestone 2.3.3) Innovative Yarding System: The alpha prototype tail hold carriage and control system was field tested under carefully monitored conditions to ensure the working model is capable of demonstrating performance of the new system under real harvesting conditions – Scion.
3. (Contract Milestone 2.3.3) Innovative Yarding System: The alpha prototype tail hold carriage and control system was successfully demonstrated to the TST and met the operational parameters and performance standards approved by the PSG – Scion.
4. (Contract Milestone 2.3.3) Innovative Yarding System Development Plan: Based on successful field testing of the Alpha Prototype yarding system a development plan to beta prototype was completed that specified operational parameters and performance standards, and the next stages of the development.
5. (Contract Milestone 2.3.3) Innovative Yarding System: The beta prototype tail hold carriage design was completed (including cost and weight calculations). A bill-of-materials was completed for the beta prototype.
6. (Contract Milestone 2.3.3) Project Evaluation and Review: An independent Mechanical Engineering consultant will be commissioned to review and evaluate the engineering drawings and specifications of the tail hold carriage. The independent consultant report will be discussed and evaluated by the FFR expert panel and further development to beta prototype will be approved by the PSG by 30 June 2015 – Mech. Eng. Consultant and UC Forestry.

Approach – "What is required to achieve the project?"

Further project elements include: Integration of the outputs of Objective 1.2 (remote control) and Objective 2.1 (camera systems) to result in an improved mobile tail hold and line shifting system. Determining the benefits of the design relating to application/practicality include:

- improvements to yarder set up time through the improved tail hold rigging system
- addressing issue of an effective cable tensioning mechanism to correctly compensate for payload, wind, and rope length variations to minimise shock loading of the yarding system.

Complete development of a new yarding system, comprising a remote control system suitable for 2-drum yarders controlling a remote controlled mobile tail hold carriage (eliminating tail hold machines), and enabling increased width of the yarding corridor through providing lateral hauling ability (and reducing the frequency of line shifts). This project will be completed when the mobile tail hold carriage and the remote control system have been constructed and a manufacturing partner has been confirmed. The ability to retrofit existing yarding equipment is a key success factor to encourage maximum uptake within industry.

Beta prototype design of the mobile tail hold carriage is about 2 months behind schedule and will be completed at the end of May 2015. This delay has a flow on effect on the completion of the independent evaluation of the engineering feasibility of the mobile tail hold carriage prior to approval

to construct the beta prototype (full scale) tail hold carriage, and the purchase of components for the beta prototype. The design of the Self-propelled Grapple Carriage and economic feasibility analysis of the Grapple Carriage would not have been completed prior to 30 June 2015 resulting in a high risk that the grapple carriage development would not be completed before 30 June 2016. The proposal to the TST is that the project be re-prioritised to focus on the completion of the mobile tail hold carriage and that further work on the grapple carriage be terminated

During the development of the 2015/16 programme the TST accepted that the Self-propelled Grapple part of the project could not be completed with the time and resources available in 2015/16 and that this part of the project had been ranked lower in terms of industry priorities. This effectively meant a reallocation of funding of approximately $150,000 to other projects, according to industry priorities.

Research Plan Resources (incl. project management and in-kind contribution): Objective 2.3

	Year							
Objective 2.3	1 2010/11	2 2011/12	3 2012/13	4 2013/14	5 2014/15	6 2015/16	Total	Business Plan
Total	$0	$31,196	$100,515	$290,459	$236,334	$397,284	$1,055,787	$2,283,750

Objective Statement 2.3

Objective	2.3
Objective title	Increased Productivity of Cable Extraction – Innovative yarding system
Objective description	This Project will aim to develop an alternative new extraction system based on a high speed, mobile, long span yarder capable of high volume productivity at low cost. This system has the potential to eliminate much of the interactive delay time inherent in conventional cable yarding such as positioning the grapple and line shifting. More constant power and continuous loading using hydraulic rather than mechanical systems will also reduce engine wear and reduce fuel consumption.
Objective Achievement Measure	1. Redesign and develop to alpha-prototype stage a new alternative yarding system which increases productivity and reduces cost of cable yarding. 2. Reduce diesel fuel consumption (in litres per tonne of wood produced) through development of a lighter-weight, more fuel efficient constant load system, and increased productivity. 3. Demonstrate a simulated new cable harvesting system incorporating all the key elements above. 4. The potential of the system for commercial development is confirmed by the PSG. 5. Have secured industry investment to commercialise the yarding system.
Start date	01/07/2011
End date	30/06/2016

Objective 2.3 Contract Milestones

Milestone 2.3.1	Innovative yarding system - concept feasibility analysis
Description	Carry out a technical and economic feasibility study to demonstrate the potential of an improved cable yarding system that has the potential to provide at least 30% productivity improvement over current systems.
Achievement Measure	Based on a technical and economic feasibility study demonstrating the potential of an improved cable yarding system to provide at least 30% productivity improvement over current systems, the Harvesting Programme Steering Group (PSG) approves the development of the concept to simulation stage by 31 March 2014.
Start Date	01 July 2011
End Date	31 March 2014 COMPLETED

Milestone 2.3.2	Innovative yarding system - concept simulation
Description	Simulation modelling of the various yarding system concepts and approval to alpha prototype development.
Achievement Measure	1. A development plan that specifies the operational parameters and performance standards for simulation modelling of an improved cable yarding system is approved by the PSG by 31 December 2013. 2. The improved cable yarding system has been demonstrated in a simulation modelling study and has met the operational parameters agreed by the PSG, by 31 March 2014. 3. Based on successful simulation modelling of the yarding system the PSG approves a project plan for development of an improved cable yarding system to alpha prototype stage, by 30 June 2014.
Start Date	01 April 2013
End Date	30 June 2014 COMPLETED

Milestone 2.3.3	Innovative yarding system - alpha prototype development
Description	Test an alpha prototype of the innovative yarding system
Achievement Measure	1. A development plan that specifies the operational parameters and performance standards for the alpha prototype cable yarding system has been approved by the PSG by 30 September 2014. 2. An alpha prototype of the innovative yarding system for steep country harvesting has been successfully demonstrated in the field and has met the operational parameters and performance standards approved by the PSG, by 31 March 2016. 3. A commercialisation strategy is developed for the innovative yarding system and approved by the PSG, by 31 March 2016.
Start Date	01 July 2014
End Date	31 March 2016

Milestone 2.3.4	Innovative yarding system – commercial support
Description	Secure financial investment from a machinery manufacturing company for the innovative yarding system.
Achievement Measure	1. A machinery manufacturing company has agreed to provide financial investment for further development of the innovative yarding system, by 30 June 2016. 2. The field testing of the alpha prototype cable yarding system has commenced. (This testing will continue after the end date of the contract).
Start Date	01 April 2016
End Date	30 June 2016

Milestone 2.3.5	Innovative yarding system – first commercial product
Description	Field test the beta prototype innovative yarding system
Achievement Measure	The beta prototype innovative yarding system is field tested (No PGP investment).
Start Date	01 July 2016
End Date	30 June 2017

Project Milestones and Outputs

Year 6 (2015/16):

6.1 Beta Prototype Mobile Tail Hold Carriage - Commercialisation Plan (Contract Milestone 2.3.4): A commercialisation plan is developed for the Tailhold Carriage and approved by the PSG, by 30 June 2015 – Awdon Technologies Ltd, $5,000; Scion, $5,000 (carried over from 2014/15).

6.2 Beta Prototype Mobile Tail Hold Carriage - Commercial Support (Contract Milestone 2.3.4): A machinery manufacturing company has agreed to provide financial investment to design and build the commercial tailhold carriage to beta prototype stage – Awdon Technologies Ltd, $7,500; by 30 June 2015 (carried over from 2014/15).

6.3 Beta Prototype Mobile Tail Hold Carriage (Contract Milestone 2.3.4): Economic analysis (cost and weight calculations) of beta prototype tailhold carriage – Scion, $13,750; UC Forestry $2,500; by 30 June 2015 (carried over from 2014/15).

6.4 Beta Prototype Mobile Tail Hold Carriage (Contract Milestone 2.3.4): Complete bill-of-materials for Beta Prototype mobile tail hold carriage and purchase components (payment on proof of invoices) – Awdon $65,000; Scion $7,500; by 30 September 2015 (carried over from 2014/15).

6.5 Beta Prototype Mobile Tail Hold Carriage (Contract Milestone 2.3.4): Complete build of beta prototype tail-hold carriage. Plan field trials – Awdon $60,000; Scion $2,500; by 31 December 2015.

6.6 Beta Prototype Mobile Tail Hold Carriage (Contract Milestone 2.3.4): Field test beta prototype tail hold carriage and undertake modifications and correct any issues – Awdon $35,000; Scion $25,000; UC Forestry $2,500; by 31 March 2016.

6.7 Beta Prototype Mobile Tail Hold Carriage (Contract Milestone 2.3.4): Complete series of production trials of Beta Prototype mobile tail hold carriage – Scion $82,500; UC Forestry $2,500; by 30 April 2016.

6.8 Pre-Commercial Mobile Tail Hold Carriage (Contract Milestone 2.3.4): Redesign and finalise engineering drawings of pre-commercial tail hold carriage. Complete project reporting – Awdon $15,000; Scion $25,000; UC Forestry $5,000; by 30 June 2016.

6.9 Pre-Commercial Mobile Tail Hold Carriage (Contract Milestone 2.3.4): Full Patent achieved for Mobile Tail Hold Carriage – Awdon $10,000; by 30 June 2016.

Objective 2.3 Budget

2.3 Innovative Yarding System		1	2	3	4	5	6
Contract Milestones	Total	June '11	June '12	June '13	June '14	June '15	June '16
2.3.1	$77,844	$0	$25,200	$20,138	$32,506		
2.3.2	$159,155			$55,000	$104,155	$0	
2.3.3	$160,488				$104,155	$56,333	$0
2.3.4	$370,267					$132,767	$237,500
2.3.5	$35,000						$35,000
Research Materials	$65,000	$0	$0	$0	$0	$0	$65,000
Research Direct Cost	$867,754	$0	$25,200	$75,138	$240,816	$189,100	$337,500
In-kind Contribution	$62,675	$0	$1,743	$10,039	$16,982	$18,965	$14,946
Project Management	$125,358	$0	$4,253	$15,338	$32,660	$28,269	$44,838
Total Research Plan	$1,055,787	$0	$31,196	$100,515	$290,459	$236,334	$397,284
Provider	Total	June '11	June '12	June '13	June '14	June '15	June '16
Scion	$306,709		$0	$51,599	$58,010	$54,600	$142,500
Scion Materials	$0		$0	$0	$0	$0	$0
Trinder Engineering	$0						
Trinder Eng. Materials	$0						
Consultant	$43,045		$0	$6,539	$24,506	$12,000	$0
Univ. of Canterbury	$30,000		$0	$2,000	$8,000	$10,000	$10,000
Univ. of Cant. Materials	$0						
Other Engineering	$423,000		$25,200	$15,000	$150,300	$112,500	$120,000
Engineering Materials	$65,000		$0	$0	$0	$0	$65,000
Research Direct Cost	$867,754	$0	$25,200	$75,138	$240,816	$189,100	$337,500

INTERMEDIATE OUTCOME 3: DEVELOPMENT OF OPERATIONAL EFFICIENCIES

Intermediate Outcome Statement

Intermediate Outcome 3

Title	Development of Operational Efficiencies
IO Statement	The aim of this research is to undertake system feasibility studies into cable harvesting system design and integration of harvesting system processes to improve efficiency, increase productivity and reduce cost. Two projects have been included as system feasibility studies on the basis that future operational developments may drive cutting stems to log length prior to extraction; and regulatory pressures over accumulation of residue material and dispersal in the forest may also drive change. Success Measures 1. Determination of feasibility of delimbing/log processing on steep slopes, by 31 December 2014. 2. A gain in operational efficiencies through integrating other functions into the cable yarder by 30 June 2016. 3. International monitoring new hauler technology 4. Benchmarking cost and productivity of NZ operations
Start date	01/7/2010
End date	30/06/2016
IO Leaders	Keith Raymond and Dr Richard Parker

Personnel

Intermediate Outcome Leaders:
Keith Raymond and Dr Richard Parker

Scion:
Tony Evanson
Spencer Hill
Dr Paul Milliken
Dr Richard Parker
Interpine Forestry Ltd:
Dr Hamish Marshall
University of Canterbury (School of Forestry):
Dr Rien Visser
Alejandro Olivera

OBJECTIVE 3.1

Delimbing and Cut-to-Length Systems on Slopes

Objective Leader: Dr Richard Parker (Scion)

Objective Description – "The Problem"
The systems design approach will be adaptive and responsive to changes in the harvesting environment such as market changes, new technology, and supply chain developments. Feasibility studies have been included in this Intermediate Outcome on the basis that if some aspects of the Programme change, some things that were not previously thought feasible may become feasible. For example, regulatory pressures and costs of slash disposal on the landing, or requirements for reduced site disturbance and improved distribution of slash across the forest floor may drive a requirement for in-forest delimbing. Another example is the cost or feasibility of a shift to cutting-to-length (CTL) logging systems. Although it is not in the scope of this Programme to develop log processing optimisation, the impact of increasing piece size of the forest resource or the development of future innovative yarding systems (arising from Project 2.3) may drive a requirement to reduce extracted piece size by using existing optimising harvester heads down the slope.

This Project will aim to develop improved unit cost operations through investigating the feasibility, and demonstrating the benefits of mechanised delimbing on the slope and cutting to log length using log optimisation processes on the slope, including impact on subsequent operations. The obvious trade-offs against the advantages of assembling all the value-adding tasks in a more controlled environment, such as a landing or log yard, will be evaluated.

Achievement Measures - "Ultimate Vision"
Improved unit cost of operations in steep country harvesting through development of:

- Ability for on-slope delimbing to disperse limbs and tops produced across the slope
- Ability to economically cut-to-length on slopes with similar value recovery results to on-landing processing

Start Date: 01/07/2012 (Year 3)
Finish Date: 30/06/2016 (Year 6)

Project Team: Tony Evanson (Scion)
Dr Paul Milliken (Scion)
Dr Richard Parker (Scion)

Background - "What has been done?"

In Intermediate Outcome 1 the capability of machinery to operate on steep slopes has been developed. After the mechanisation of felling and bunching on steep slopes is achieved, the feasibility, costs and benefits of mechanised delimbing and cutting to log length on hauler slopes was scheduled to be investigated.

This project commenced in mid-Programme (commencement of Year 3, July 2012) once the development of the steep slope feller buncher on steep terrain had been sufficiently advanced. This creates the opportunity to disperse residues (tree limbs and tops) produced across the harvesting area, creating a mat for machine travel thus substantially reducing the environmental footprint. Delimbing on the slope offers potential advantages in terms of haul mass (through not hauling bark, limbs and tops volume), while still enabling high production payloads through bunching of tree stems. This volume hauled to the landing currently has no market, and represents an environmental hazard and a disposal cost. Delimbing on the slope also avoids the operational and environmental issues associated with accumulating wood residues on the landing.

Success of Intermediate Outcome 2 results in the ability to haul smaller pieces at a faster rate thus enabling economic hauling of logs instead of tree stems and providing the opportunity to develop lighter and cheaper yarding equipment. Cutting to log length on the slope using log optimisation processes will provide a production option if no economic market exists for woody biomass, and will also eliminate the residue problem arising on cable landings, as off cuts arising from log manufacture will be dispersed across the slope.

Progress to date

Year 3 (2012/13):

1. (Contract Milestone 3.1.1) A project plan was completed identifying concepts for testing new delimbing and cut-to-length applications on the slope aimed at improving productivity and cost by at least 20% over current systems – Scion.
2. (Contract Milestone 3.1.2) Delimbing on the slope was tested by undertaking a brief field trial – Scion.
3. (Contract Milestone 3.1.2) A technical paper was completed that investigated the feasibility, costs and benefits of mechanised delimbing on the slope, including impact on subsequent operations (Report H012) – Scion.

On the basis of initial feasibility analysis and low priority ranking from industry members the TST recommended deferral of this project until later in the Programme (beyond 2014/15). This objective was reviewed as part of the development of the 2015/16 Research Plan and based on industry priorities it was decided not to pursue this project further in this Programme.

Approach – "What is required to achieve the project?"

It was planned to also investigate the economic feasibility of cutting to log length using log optimisation processes on the slope. Potential advantages with bunching logs instead of tree stems include enabling design of smaller / cheaper yarding machines in the future (lower capital cost and lower fuel consumption) and also potentially mitigating the impact of increasing piece size of the future forest resource by cutting to log length.

Project elements would have included:

- Investigating feasibility, productivity and cost of delimbing on steep terrain. This Project will be informed by Project 1.1. New methods of delimbing will be investigated, such as using slope or gravity to push stems through a delimber.
- Previous work on the cost impacts of this material on subsequent forest operations will also be summarised.
- Investigating the potential to cut-to-length utilising log optimisation on the slope.
- Addressing potential issues such as log movement on the slope
- Addressing issues with effective methods of extraction, including utilising the output of Project 2.3, (e.g. a new high performance yarding system, with a bunching machine feeding the yarding system).

Research Plan Resources (incl. project management and in-kind contribution): Objective 3.1

	Year							
Objective 3.1	1 2010/11	2 2011/12	3 2012/13	4 2013/14	5 2014/15	6 2015/16	Total	Business Plan
Total	$0	$0	$59,663	$0	$0	$0	$59,663	$293,625

Objective Statement 3.1

Objective	3.1
Objective title.	Operational efficiencies – Delimbing and Cut-to-Length on Slopes
Objective description	The target of this research programme is to develop improved unit operations with steep country harvesting, including delimbing and cut-to-length operations on the harvesting slope.
Objective Achievement Measure.	Improved unit operations with steep country harvesting, reflecting: 1. Ability for on-slope delimbing to disperse limbs and tops produced across the slope 2. Ability to economically cut-to-length on slopes with similar value recovery results to on-landing processing
Start date	01/07/2012
End date	30/06/2016 NOT COMPLETED

Objective 3.1 Contract Milestones

Milestone 3.1.1	Delimbing and Cut-to-Length on Slopes – concept feasibility analysis
Description	Develop a project plan for testing delimbing and cut to length applications on slope, based upon improving productivity and cost by at least 20% over current systems.
Achievement Measure	The Harvesting Programme Steering Group (PSG) approves a project plan for testing delimbing and cut-to-length applications on the slope based upon improving productivity and cost by at least 20% over current systems.
Start Date	01 July 2012
End Date	31 December 2015 COMPLETED BUT NOT APPROVED

Milestone 3.1.2	Delimbing and Cut-to-Length on Slopes – commercial evaluation
Description	Develop a commercial evaluation and implementation plan for development of systems to improve unit operations, including delimbing and cut to length operations on the slope, based on full technical and economic evaluation.
Achievement Measure	The PSG approves an implementation plan for development of systems to improve unit operations including delimbing and cut-to-length operations on the slope, based on full technical and economic evaluation.
Start Date	01 July 2015
End Date	30 June 2016 PROJECT TERMINATED

Milestone 3.1.3	Delimbing and Cut-to-Length on Slopes – commercial implementation
Description	Secure, if required, third party investment for further implementation. Harvesting companies implement the first application in cut-to-length and on-slope delimbing.
Achievement Measure	1. The PSG approves third party investment, if required, for further implementation of delimbing and cut-to-length systems on the slope, and executes agreements with investors by 31 December 2015. 2. A harvesting company implements the first application of cut-to-length and on-slope delimbing in a commercial harvesting operation by 30 June 2016.
Start Date	01 July 2015
End Date	30 June 2016 PROJECT TERMINATED

Milestone 3.1.4	Operational efficiencies – new unit innovations
Description	Develop a programme to investigate other unit operations capable of making at least 20% productivity improvements in harvesting over current systems.
Achievement Measure	1. Based on systems analysis the Harvesting PSG approves and supports a programme to investigate other operations capable of making at least 20% productivity improvements in steep country harvesting. 2. A development plan for this programme will include detailed checkpoints and an investment plan, by 30 June 2016.
Start Date	01 January 2016
End Date	30 June 2016 PROJECT TERMINATED

Objective 3.1 Budget

3.1 Operational Efficiencies - Delimb / CTL on Slopes							
		1	2	3	4	5	6
Contract Milestones	Total	June '11	June '12	June '13	June '14	June '15	June '16
3.1.1	$16,650	$0	$0	$16,650			
3.1.2	$27,950			$27,950	$0	$0	$0
3.1.3	$0					$0	$0
3.1.4	$0						
Research Materials	$0	$0	$0	$0	$0	$0	$0
Research Direct Cost	$44,600	$0	$0	$44,600	$0	$0	$0
In-kind Contribution	$5,959	$0	$0	$5,959	$0	$0	$0
Project Management	$9,104	$0	$0	$9,104	$0	$0	$0
Total Research Plan	$59,663	$0	$0	$59,663	$0	$0	$0
Provider	Total	June '11	June '12	June '13	June '14	June '15	June '16
Scion	$44,600		$0	$44,600	$0	$0	$0
Scion Materials	$0		$0	$0	$0	$0	$0
Trinder Engineering	$0						
Trinder Eng. Materials	$0						
Consultant	$0						
Univ. of Canterbury	$0						
Univ. of Cant. Materials	$0						
Other Engineering	$0						
Engineering Materials	$0						
Research Direct Cost	$44,600	$0	$0	$44,600	$0	$0	$0

OBJECTIVE 3.2

New Hauler Technology & International Monitoring

Objective Leader: Keith Raymond (FFR)

Objective Description – "The Problem"
While overseas harvesting research and equipment development is focused primarily on mechanised operations on flat terrain, there are benefits in monitoring overseas developments which may, with modification, be applicable to NZ's unique combination of soils, terrain, climate, forest type and infrastructure. The challenges of maintaining international competitiveness in harvesting costs and productivity will increase over time as New Zealand forestry moves onto steeper land (>20^{O} slope). Therefore a benchmarking project to measure our performance against our competitors and over time is necessary. This benchmarking project is also a tool by which the overall Programme will measure its success in terms of improved productivity and reduced logging costs.

A Programme to investigate new yarder technologies is a key part of this objective. Potential developments include integrating functions of the cable yarder to utilise existing production delay (during automated "out-haul", "hook-on" and "break-out" phases of the cycle) and/or spare engine capacity of the yarder during this idle time to either undertake existing functions (such as clearing the yarder chute, or loading trucks) or to introduce new processing capability to the landing. The potential to retrofit machine capability to existing yarder equipment will be investigated.

The target of this project is to: investigate new yarder technologies through a programme of international Technology Watch; sustain a comprehensive benchmark analysis of industry productivity in steep country harvesting; inform future harvesting research projects such as development and use of steep slope feller bunchers, new yarding systems; and integration of multiple functions such as delimbing, processing or sorting into the materials handling functions of cable haulers.

Achievement Measures - "Ultimate Vision"
- Produce technical reports on evaluation and feasibility of new technologies
- Produce an annual Benchmarking report that measures the improvements in productivity and cost of the New Zealand harvesting sector
- Produce bi-annual Technology Watch reports summarising new international developments in steep country harvesting.
- Complete peer review of programme to quantify benefits of the Programme
- All outputs will be reviewed and accepted by the Programme Steering Group

Start Date: 01/07/2010 (Year 1)
Finish Date: 30/06/2016 (Year 6)

Project Team: Spencer Hill (Scion)
Dr Hamish Marshall (Interpine Forestry Ltd)
Dr Richard Parker (Scion)
Dr Rien Visser (UC Forestry)
Alejandro Olivera (UC Forestry)

Background - "What has been done?"
A comprehensive benchmark analysis of industry productivity in steep country harvesting, and a Technology Watch project to maintain an international monitoring watch on new technology in steep country harvesting was commenced in 2008.

Feasibility of integrating multiple functions into a cable yarder was explored. This included investigating the feasibility of installation of a boom/arm and grapple or optimising processing head

operating from the hauler, to allow the machine to clear the chute eliminating the need for a separate loader, or to delimb and/or process stems from the stockpile (Technical Note HTN04-04).

Feasibility of installation of a chipper run from the hauler power source was also explored. If installed this would allow residue material (limbs and tops) to be safely, quickly and effectively converted to wood fuel or disposed of – either to a recovery container for removal as hog fuel or to be distributed over the site, avoiding build up and subsequent environmental issues such as "birds nest" collapse (Technical Note HTN05-05).

Progress to date

Year 2 (2011/12):

1. (Contract Milestone 3.2.1) A technical paper was completed evaluating the feasibility of installation of a chipper run from the hauler power source to allow integrated production of wood fuels on the landing (Technical Note HTN05-05) – Scion.
2. (Contract Milestone 3.2.1) A projection of the harvesting conditions in New Zealand over the next 10 years was completed, including demand for haulers (Technical Note HTN05-04) – Interpine Forestry.
3. (Contract Milestone 3.2.2) Bi-annual Technology Watch reports summarised new NZ and international developments in steep country harvesting (HTW-008 and HTW-009) – Scion.
4. (Contract Milestone 3.2.2) FFR regional meetings were held in Wellington (August 2011) and in Gisborne (March 2012) that demonstrated the outcomes of this Programme and promoted uptake of its outputs by the logging industry – Scion.
5. (Contract Milestone 3.2.3) Annual Benchmarking technical report summarised productivity and cost drivers of the New Zealand harvesting sector for 2011 (Technical Note HTN04-08) – UC School of Forestry.

Year 3 (2012/13):

1. (Contract Milestone 3.2.1) A technical paper evaluating the potential gain in operational efficiencies through incorporating other power sources (e.g. hybrid systems) into cable yarders (Technical Note HTN06-04) – Scion.
2. (Contract Milestone 3.2.2) Bi-annual Technology Watch reports summarising new NZ and international developments in steep country harvesting (HTW-010 and HTW-011) – Scion.
3. (Contract Milestone 3.2.2) Harvesting Technology Watch report summarising new developments in European yarder technology (Technical Note HTN04-01) – UC School of Forestry.
4. (Contract Milestone 3.2.2) FFR regional meetings were held in Rotorua (Sept 2012) and Gisborne (March 2013) that demonstrated the outcomes of this Programme and promoted uptake of its outputs by the logging industry – Scion.
5. (Contract Milestone 3.2.2) The annual project evaluating new technology gathered through the Harvesting Technology Watch programme for 2013 was an evaluation of the remote controlled Valentini V-1500 cable yarder. The Valentini V-1500 hydrostatic drive yarder has computer control which allows total machine control, cable tension assessment and full diagnostics. The study assessed performance in conditions similar to NZ (Technical Note HTN06-01) – Scion.
6. (Contract Milestone 3.2.3) Annual Benchmarking technical report summarised productivity and cost drivers of the New Zealand harvesting sector for 2012 (Technical Note HTN05-13) – UC School of Forestry.

Year 4 (2013/14):

1. (Contract Milestone 3.2.2) Applications of GPS/Geospatial information for mechanised harvesting. A literature review of precision forestry concepts was completed including an analysis of the potential benefits of integrating GPS/geospatial information with harvester production data (Report H017). – UC School of Forestry.
2. (Contract Milestone 3.2.2) Bi-annual Technology Watch reports summarising new NZ and international developments in steep country harvesting:
    a. Investigated technologies available locally and worldwide for optimised harvest planning and road layout and its relevance to NZ, such as the optimised road layout model used by Forestal Mininco in Chile (Technology Watch HTW-013) – Scion.

b. Evaluation of the consistency and accuracy of cable harvesting analysis packages (CHPS, LoggerPC, CYANZ, SkylineXL, vector analyses, and LIRO Logging Handbook equations. Results were cross-referenced with actual cable tension/payload measurements – UC School of Forestry.

3. (Contract Milestone 3.2.2) FFR regional meetings were held in Rotorua (Nov 2013) and Dunedin (April 2014) that demonstrated the outcomes of this Programme and promoted uptake of its outputs by the logging industry – Scion.
4. (Contract Milestone 3.2.3) Annual Benchmarking technical report summarised productivity and cost drivers of the New Zealand harvesting sector for 2013 (Technical Note HTN06-06) – UC School of Forestry.

Year 5 (2014/15)

1. (Contract Milestone 3.2.2) New Hauler Technology: The annual project undertaken to evaluate new technology gathered through the Harvesting Technology Watch programme was aimed at assisting Koller Forsttechnik GmbH of Austria to introduce a remote controlled cable yarder for trialling in NZ. A production study and a field demonstration during the trial period was organised – Koller (in-kind support); Scion and UC School of Forestry.
2. (Contract Milestone 3.2.2) Harvesting Technology Watch: Two short studies summarised new NZ and international developments in steep country harvesting:
    a. International review of professional training and safety programmes in steep terrain operations. Summary report to specify components that are immediately relevant to NZ industry – UC School of Forestry
    b. Investigation of the economic viability of a quick coupler attachment for rapid switching from grapple to processor head without leaving the operator cab. The economic potential for smaller harvesting operations to process and load logs with a single base machine through the use of the quick coupler was determined. Further work in 2015/16 will develop a quick coupler for the NZ industry – Scion.
3. (Contract Milestone 3.2.2) Precision Forestry: Continuation of PhD candidate Alejandro Olivera's project on GPS/Geospatial information for mechanised harvesting (carried over from 2013/14). Integration of harvester head data and GPS geospatial data to evaluate effects of stand and terrain on machine productivity was investigated (Technical Note HTN07-03) – UC School of Forestry.
4. (Contract Milestone 3.2.2) FFR regional technical meetings were held in Rotorua (Nov 2014) and Dunedin (March 2015) to demonstrate the outcomes of this Programme and promote uptake of its outputs by the logging industry – Scion.
5. (Contract Milestone 3.2.3) An annual Benchmarking technical report summarising productivity and cost drivers of the New Zealand harvesting sector was completed – UC School of Forestry.
6. (Contract Milestone 3.2.4) Programme Review: An external peer review of the Programme outcomes against contract targets was undertaken by two forestry consultants to inform research management and future research direction – Independent consultants.

Approach – "What is required to achieve the project?"

Project elements will include:

- A Technology Watch project to maintain international monitoring of new technology in steep country harvesting – This will be a development of a quick coupler attachment first seen at Elmia Wood in Sweden in 2013. The unit will be designed and developed for NZ harvesting conditions. The output from the investment will be a quick coupler attachment that will enable harvesting crews to reduce the number of machines on the landing, reducing cost and improving landing safety.
- To support the development of other projects in the programme, one annual project will be undertaken that evaluates new technology and information gathered through the Harvesting Technology Watch programme. In 2010 the original Business Plan saw a need to adopt European technology for automated carriage return and transfer of carriage control to the breaker out to allow better control of carriage positioning. This project will complete the evaluation of the Koller remote controlled automated cable yarder imported to New Zealand in 2014.This will involve testing it in European conditions of roadside operation with few log sorts produced to

confirm suitability for future NZ operation. The benefits to NZ if this technology is adapted to NZ hauler manufacturers would be huge.

- A technology transfer programme to encourage maximum uptake of the whole Programme within the New Zealand forest industry – both new developments in Europe and outputs of the FFR programme will be extended to industry through Technology Watch reports and regional technical meetings.
- The Benchmarking database was developed within this FFR research programme to measure the improvements in productivity and cost of the New Zealand harvesting sector. Data on actual logging costs and productivity by harvest area has been captured annually and analysed by the School of Forestry, University of Canterbury. The database has been maintained from the base year of 2008/09 and enables monitoring of progress over time of key PGP programme objectives in steep land harvesting. Data collection will continue beyond the completion of this Programme in order to focus further research direction.
- A review of all commercialisation plans and results to date will be undertaken to assist with commercialisation of all outputs from the Programme.
- A review of the Programme outcomes against contract targets to inform research management and future research direction will be undertaken in 2016 and end-of-programme reporting will be completed.

Research Plan Resources (incl. project management and in-kind contribution): Objective 3.2

	Year							
Objective 3.2	1 2010/11	2 2011/12	3 2012/13	4 2013/14	5 2014/15	6 2015/16	Total	Business Plan
Total	$84,939	$51,161	$91,151	$102,247	$257,562	$298,541	$885,600	$456,750

Objective Statement 3.2

Objective	3.2
Objective title	Operational efficiencies – New Yarding Technologies and International Monitoring
Objective description	The key targets of this project are to; • Sustain a benchmark analysis of industry productivity in steep country harvesting. • Sustain a programme of international technology watch. • Sustain a peer review of the programme outcomes against contract targets and to inform future harvesting research.
Objective Achievement Measure	1. Provide technical reports on evaluation and feasibility of new hauler technologies 2. Produce an annual benchmarking report that measures the improvements in productivity and cost of the New Zealand harvesting sector 3. Produce bi-annual technology watch reports summarising new international developments in steep country harvesting. 4. Complete peer-review of programme to quantify benefits of the programme. 5. All outputs will be reviewed and accepted by the PSG.
Start date	01/07/2010
End date	30/06/2016

Objective 3.2 Contract Milestones

Milestone 3.2.1	New Hauler Technology – concept feasibility analysis
Description	Produce a technical and economic feasibility study demonstrating the potential of multiple-function yarding to improve productivity and reduce cost of steep country harvesting.
Achievement Measure	Based on current industry analysis and investigation of international technologies, the Harvesting PSG approves a technical and economic feasibility report demonstrating the potential of multiple-function yarding to improve productivity and reduce cost of steep country harvesting.
Start Date	01 July 2010
End Date	30 June 2011 COMPLETED

Milestone 3.2.2	New Hauler Technology – International Technology Watch
Description	Industry analysis and investigation of international technologies, together with wide industry consultation.
Achievement Measure	Based on current industry analysis, investigation of international technologies and worldwide industry consultation, bi-annual International Technology Watch reports to increase uptake of the programme outputs around the New Zealand forest industry and to maximise achievement of overall programme targets. The Harvesting PSG approves the undertaking of further scoping of promising technologies arising from the Harvesting Technology Watch.
Start Date	01 July 2010
End Date	30 June 2016

Milestone 3.2.3	New Hauler Technology – National Forest Industry Benchmarking
Description	Publication of annual Industry Benchmarking report based on collection of harvesting data and current industry analysis and wide industry consultation.
Achievement Measure	Based on current industry analysis of steep country harvesting and wide industry consultation, the PSG approves the publication of the annual results of the national harvesting cost and productivity benchmarking programme that measures the achievements of the overall programme across the Harvesting Theme members' operations that are included in the benchmarking survey.
Start Date	01 July 2010
End Date	30 June 2016

Milestone 3.2.4	Programme review and improvement
Description	Complete peer review, whole programme analysis, international trends and wide industry consultation.
Achievement Measure	Based on a peer review, a whole of programme analysis, international trends and wide industry consultation, the PSG presents the review to its investor stakeholders and makes recommendations to its investors on future harvesting research programmes.
Start Date	01 July 2014
End Date	30 June 2016

Project Milestones and Outputs

Year 6 (2015/16)

6.1 Contract Milestone 3.2.2) Harvesting Technology Watch – Quick Coupler Attachment: An annual project will be undertaken that evaluates new technology and information gathered through the Harvesting Technology Watch programme. Complete the development commenced in 2014/15 of the quick coupler attachment for rapid switching from grapple to processor head without leaving the operator cab – Scion, $58,638; Southstar Equipment Ltd, $40,000; by 30 June 2016.

6.2 (Contract Milestone 3.2.2) Harvesting Technology Watch – New Hauler Technology: Complete further trials in NZ radiata pine with the Koller K602 remote controlled cable yarder manufactured by Koller Forsttechnik GmbH of Austria, including human factors comparison of cab vs remote control. A comprehensive time and motion study with at least 20 days in the field will be carried out to determine the effect of stand and terrain parameters on productivity, as well as being able to make a comparison with similar sized NZ yarder systems (UC Forestry Masters student) – Scion $52,428; UC School of Forestry, $17,000; by 30 June 2016.

6.3 (Contract Milestone 3.2.2) Harvesting Technology Watch – New European Steep Terrain Developments: Attend the major international forest engineering conference (FORMEC) focusing on steep terrain harvesting, and the AustroFOMA 2015 machinery demonstration to be held in Austria in October 2015. Two Technology Watch reports will be published summarising new international developments in steep country harvesting – UC Forestry, $12,000; by 31 March 2016.

6.4 (Contract Milestone 3.2.3) Benchmarking Cost and Productivity: Continuation of the Benchmarking project to develop and maintain harvesting cost and productivity database. An

annual Benchmarking technical report will be published that summarises productivity and cost drivers of the New Zealand harvesting sector – UC School of Forestry, $28,550; by 30 June 2016.

6.5 (Contract Milestone 3.2.2) Regional Technical Meetings: Three technical meetings will be held in different regions of New Zealand to demonstrate the outcomes of this Programme and promote uptake of its outputs by the logging industry – Scion, by 30 June 2016; $15,000.

6.6 (Contract Milestone 3.2.4) Commercialisation Review: A review of all commercialisation plans and results to date will be undertaken by an external marketing expert to assist with commercialisation of all outputs from the Programme – Consultant, $30,000; by 30 June 2016.

6.7 (Contract Milestone 3.2.4) Programme Review: Based on the external programme review undertaken in July 2014, analysis of programme progress to date, current and future international industry trends and wide industry consultation, FFR will present a review to the PSG and the investor stakeholders and make recommendations to its investors on future harvesting research programmes – FFR; by 30 June 2016.

Objective 3.2 Budget

3.2 Operational Efficiencies - New Technologies and International Monitoring							
		1	2	3	4	5	6
Contract Milestones	Total	June '11	June '12	June '13	June '14	June '15	June '16
3.2.1	$21,306	$21,306	$0				
3.2.2	$488,843	$18,887	$24,628	$51,438	$58,372	$140,452	$195,066
3.2.3	$145,020	$29,210	$16,700	$16,700	$26,400	$27,460	$28,550
3.2.4	$68,173					$38,173	$30,000
Research Materials	$0	$0	$0	$0	$0	$0	$0
Research Direct Cost	$723,342	$69,403	$41,328	$68,138	$84,772	$206,085	$253,616
In-kind Contribution	$56,270	$6,430	$2,859	$9,104	$5,978	$20,668	$11,231
Project Management	$105,989	$9,107	$6,974	$13,909	$11,497	$30,808	$33,693
Total Research Plan	$885,600	$84,939	$51,161	$91,151	$102,247	$257,562	$298,541
Provider	Total	June '11	June '12	June '13	June '14	June '15	June '16
Scion	$325,807	$30,193	$17,128	$46,188	$25,872	$80,360	$126,066
Scion Materials	$0	$0	$0	$0	$0	$0	$0
Trinder Engineering	$0						
Trinder Eng. Materials	$0						
Consultant	$90,923	$10,000	$7,500	$5,250	$0	$38,173	$30,000
Univ. of Canterbury	$254,020	$29,210	$16,700	$16,700	$58,900	$74,960	$57,550
Univ. of Cant. Materials							
Other Engineering	$52,592					$12,592	$40,000
Engineering Materials	$0						
Research Direct Cost	$723,342	$69,403	$41,328	$68,138	$84,772	$206,085	$253,616

INTERMEDIATE OUTCOME 4: PROGRAMME MANAGEMENT

Intermediate Outcome Statement

Intermediate Outcome 4

Title	Programme Management
IO Statement	This will be achieved through the Board of Future Forests Research Ltd (FFR) which has ultimate accountability for the contract and the delivery of the planned outcomes. Oversight of the programme will be done by the FFR Harvesting Theme Technical Steering Team (TST) which will comprise representatives of industry investors and the Ministry for Primary Industries (MPI). The TST will advise the Programme Steering Group (PSG) comprising two representatives from FFR and two from MPI. The PSG will be accountable to the FFR Board and to MPI for the delivery of the programme. The programme will focus on harvesting on steep terrain and in particular on the felling, breaking out and extraction phases of harvesting. This is the area with the greatest potential to deliver benefits to this part of the value chain. The particular focus of the programme will be : • Alternative tree felling systems with the aim of eliminating manual chainsaw felling • Evaluation of alternative systems for improving payload with the aim of eliminating manual breaking out and unhooking roles • Evaluation of opportunities to improve hauling productivity through new systems or techniques including automation, vision systems, remote control and alternative hauler designs • Evaluation of full tree hauling versus cut to length options once log making prior to extraction becomes feasible through application of machinery on steep terrain. By ensuring that the intermediate outcomes and objectives contribute toward achieving the key performance indicators, the successful completion of this programme will contribute to the transformation of forest harvesting on steep terrain in New Zealand. The outcome target is that after six years the programme will add $169M of value to the forestry sector. This equates to $2,027 per hectare of steep forest harvested.
Start Date	1 July 2010
End Date	30 June 2016
IO Leader	Russell Dale (FFR)

Objective Statement 4.1

Objective sequence	4.1
Objective Title	Programme Management
Objective description	The PSG will provide governance of the programme and meet all the reporting, planning and communication requirements including: • Oversight of the PGP contract and ensuring that the content of the contract is implemented in line with the principles of the partnership. • Ensure the programme is implemented in accordance with the Annual Plan. • Reporting to the investors (MPI and FFR), the Investment Advisory Panel, and NZFOA (high level reporting only). • Provide quarterly updates to MPI of programme achievements which can be added to the MPI website or other sources of information to inform the public about the programme. • Approval of communications policy and plan. • Review Annual Plan and budgets at least annually and review expenditure against budget at least quarterly. • Balance investments and cash flow across the entire programme. • Ensure financial management to GAAP. • Remove hindrances to progress and/or realign investments, including consulting investors and/or the IAP as appropriate. • Ensure best-practice project records and IP registers are maintained. The PSG will be advised on all aspects of the programme by the Harvesting Theme Technical Steering Team, comprising representatives of the industry investors and MPI.
Objective Achievement Measure	1. A new Annual Plan is reviewed, and approved by the PSG by 10 June each year. 2. A contract variation adopting the new Annual Plan is agreed by the parties and incorporated into Schedule 7 of the contract by 30 June each year. 3. Updated cash flow forecast is approved by the PSG (materially within original annual approved) and amended in the Annual Plan by 10 June each year. 4. During the implementation of the Annual Plan, any material changes to project work plans and funding which do not require a contract variation are reported to, and approved by, the PSG. 5. A Quarterly progress report is provided to the PSG within 1 month of the end of each quarter.
Start Date	1 July 2010
End Date	30 June 2016

Objective Statement 4.2

<table>
<tr><td>Objective sequence</td><td>4.2</td></tr>
<tr><td>Objective Title</td><td>Key indicators</td></tr>
<tr><td>Objective description</td><td>The Programme Steering Group (PSG) will monitor and report performance against key performance indicators of the programme annually to MPI and industry investors including:
• critical milestones
• expenditure against budget including aligned funding
• actual performance against the schedule of direct economic benefits presented in the business plan as below, to be reported in the Final Programme Report, due by 31 August 2016.
• spillover benefits.

<table>
<tr><th>Economic Benefits (per year)</th><th>2011</th><th>2012</th><th>2013</th><th>2014</th><th>2015</th><th>2016</th><th>Total</th></tr>
<tr><td>Harvesting Cost Savings $M</td><td>0.0</td><td>6.1</td><td>14.3</td><td>25.0</td><td>38.4</td><td>54.5</td><td>138.3</td></tr>
<tr><td>ACC Claims Savings $M</td><td>0.0</td><td>0.1</td><td>0.1</td><td>0.2</td><td>0.3</td><td>0.4</td><td>1.1</td></tr>
<tr><td>Energy use Savings $M</td><td>-0.2</td><td>-0.5</td><td>0.0</td><td>0.8</td><td>2.2</td><td>4.1</td><td>6.4</td></tr>
<tr><td>Equipment Sales $M</td><td>0.0</td><td>1.6</td><td>3.4</td><td>5.3</td><td>7.9</td><td>11.6</td><td>29.8</td></tr>
<tr><td>Total value $M</td><td>-0.2</td><td>7.3</td><td>17.8</td><td>31.3</td><td>48.8</td><td>70.6</td><td>175.6</td></tr>
<tr><td>Total Value $/ha steep forest harvest</td><td>-11</td><td>261</td><td>615</td><td>1024</td><td>1496</td><td>2027</td><td></td></tr>
</table>

The PSG will be meeting its expected role if it is demonstrating that it is actively managing contract performance through:
• Balancing investment through managing cash flow and key “go-no go” milestones
• Redirecting funds to advance delivery of the outcomes and benefits
• Terminating or putting on hold projects that are not achieving agreed milestones and outcomes
• Annual reporting of programme outputs and outcomes</td></tr>
<tr><td>Objective Achievement Measure</td><td>The PSG shall:
1. Actively manage performance issues and, if material changes are required, consult with investors before requesting approval for such changes from MPI.
2. Report annually on contract performance against key performance indicators to MPI and industry investors by 30 September.
3. Conduct an independent review of contract outcomes in year 5 and report to MPI and industry stakeholders by 30 June 2015.</td></tr>
<tr><td>Start date</td><td>1 July 2010</td></tr>
<tr><td>Finish date</td><td>30 June 2016</td></tr>
</table>

Progress to date

Year 5 (2014/15):

1. (Contract Milestone 4.2.3) An external peer review of the PGP Harvesting Programme outcomes against contract targets was conducted by Mr Rob van Rossen, independent forestry consultant (Lead Reviewer) and Mr Mark Brown, USC, Australia (Technical Reviewer) in July-August 2014 to inform research management and future research direction. The review report was delivered by 31 August 2014 and included the Terms of Reference, scope of the Review, key findings and ten recommendations. The recommendations were:

1.1 Rec 1: Initiate a project to establish transparent measures to track and report on achievement against the expected outcomes of the project. (Note – since completing the field work for this review the reviewers have been made aware that MPI have initiated a project that is consistent with this recommendation).
Action: Supported by PSG. An MPI project is underway to develop these measures of success across all PGP programmes. The PSG to discuss further and agree measures.

1.2 Rec 2: Introduce international technology scan and awareness into each of the current projects rather than maintain Technology Watch as a stand-alone project.
Action: Not supported by PSG. Rather than incorporating Tech Watch in each project, a literature review is done for each project at the start. PSG supported retaining a stand-alone Tech Watch project on other innovations outside of the current research projects.

1.3 Rec 3: Review management across existing work programmes to enhance structured and formal collaboration between research providers.
Action: Supported by PSG. It was accepted that a meeting of researchers, either annually or half-yearly, to ensure everyone is up to date on other projects would be of value. Meetings have been held with FP Innovations in January 2015 and May, 2015 and contact will be maintained on a half-yearly basis.

1.4 Rec 4: Initiate a concerted campaign to enrol more direct contractor participation for the balance of the programme with the purpose of achieving greater engagement from this group to facilitate commercialisation and uptake.
Action: Supported by PSG. Wider contractor membership could be gained through targeting individual contractors as members and through FFR member companies getting their contractors involved in the programme. FFR has put more resources into expanding and updating the contractor database.

1.5 Rec 5: Review all current work programmes with a view to prioritisation of outputs such that as many as possible are moved along the development path towards being able to be commercialised, or at least have enough momentum to continue in some form, by the end of this programme.
Action: Supported by PSG. Prioritisation of projects that lead to commercialisation of technology has been actioned in the Innovative Yarding System project to focus on the mobile tail hold carriage.

1.6 Rec 6: Review all current commercialisation plans and results and enlist external expertise to assist with learning from the experience to date within the programme, and to inject knowledge and learning from outside the programme to ensure the commercialisation aspect of the current work programmes is better understood, and appropriately resourced and managed for the balance of the programme.
Action: Supported by PSG. FFR's role has been to get the product to the commercial or pre-commercial stage and the development partner responsible for making sales to engage the marketing assistance. Review and development of the Commercialisation Plans would assist most projects to ensure commercialisation is appropriately managed. External marketing advice will be commissioned in 2015/16 to assist with commercialisation to date.

1.7 Rec 7: Continue promotion of outputs and delivery of outcomes from the programme through workshops and field days.
Action: Supported by PSG. FFR has continued to run workshops, field days and demos. A demo of the Koller Cable Yarder and Innovative Yarding System was held in February 2015 and workshops on the Cable Rigging Efficiency project have been held in March, 2015 and May, 2015.

1.8 Rec 8: Increase the emphasis on operational trials for outputs at or near commercialisation for the balance of the programme.
Action: Supported by PSG. Performance and limitations of products is measured in operational trials and these trials are generally done, for example, trials of the Improved Felling Wedge are underway. It was accepted that field days were a better way to demonstrate this to the contractor workforce.

1.9 Rec 9: Have the Programme Steering Group, Programme Leader, and Technical Steering Committee produce a clean sheet plan for the last 12 months of the programme in March 2015 for approval and implementation in June 2015.
Action: Supported by PSG. The 2015/16 Annual Plan provides a stocktake of progress to date and each year the balance of the programme is reworked to programme end to determine what was necessary to achieve the outcomes required.

1.10 Rec 10: Canvas programme stakeholders and stakeholders outside of the current programme with the view to developing a plan for what might come next in the space of Harvesting Research in New Zealand, which could include transitioning some work from the existing FFR Steep Land Harvesting Programme.
Action: Supported by PSG. FFR has organised two industry-wide research forum workshops, in Rotorua in November, 2014 and in Balclutha in March, 2015, to develop ideas for a new harvesting and logistics programme beyond June 2016. After the results of these workshops are consolidated to form some common research themes, the industry's priorities for the new harvesting and logistics research programme will be determined. FOA/FFR will then work towards developing research funding bid(s) in November 2015.

Project Milestones and Outputs

Year 6 (2015/16)

6.1 (Contract Milestone 4.2.2) Final Programme Report: FFR shall prepare a final report for the programme by 31 August 2016 setting out the achievements of the programme against the original programme objectives as set out in the Business Plan. This will include, but not be limited to:

- the outputs of the programme
- the extent to which programme outputs have been taken up by the forest industry
- the direct economic benefits of the programme
- progress towards achieving other outcomes of the programme as set out in the Outcome Logic Model.

The content of the Final Programme Report shall be determined by the PSG by 30 June, 2016.

Objective Statement 4.3

Objective sequence	4.3
Objective Title	Industry End User Engagement
Objective description	Industry end user input into the design, field testing and evaluation is a critical component of the programme. Industry benefits are only achieved if contractors purchase and implement equipment in commercial harvesting operations and achieve improvements in safety and productivity.
Objective Achievement Measure	1. Industry participants in the Technical Steering Team are actively participating in each quarterly programme review meeting. 2. The programme manager is providing quarterly updates to all members of FFR Harvesting. 3. FFR technology transfer mechanisms will be used to ensure programme outcomes are communicated and end users made aware of the programme and the benefits of the outcomes. Field demonstrations and workshops will be arranged as needed, but on no less than an annual basis throughout the life of the programme.
Start Date	1 July 2010
End Date	30 June 2016

Cashflow Summary

PGP CASH	2010/11 Actual	2011/12 Actual	2012/13 Actual	2013/14 Actual	2014/15 Forecast	2015/16 Budget	Total
IO1	$214,116	$252,530	$186,981	$253,893	$340,853	$212,767	$1,461,142
IO2	$154,594	$115,095	$146,551	$269,774	$153,456	$302,499	$1,141,968
IO3	$42,470	$25,581	$75,407	$51,124	$128,781	$149,270	$472,632
IO4	$24,704	$24,130	$23,926	$35,177	$37,251	$41,570	$186,758
TOTAL MPI PGP	**$435,884**	**$417,336**	**$432,865**	**$609,968**	**$660,341**	**$706,106**	**$3,262,500**

Co-investor Cash Contribution	2010/11 Actual	2011/12 Actual	2012/13 Actual	2013/14 Actual	2014/15 Forecast	2015/16 Budget	Total
IO1	$181,700	$224,307	$149,631	$224,204	$286,150	$196,759	$1,262,751
IO2	$131,190	$102,232	$117,277	$238,228	$128,828	$279,739	$997,492
IO3	$36,040	$22,722	$60,344	$45,146	$108,113	$138,039	$410,403
IO4	$24,704	$24,130	$23,926	$35,177	$37,251	$41,570	$186,758
TOTAL FFR CASH	**$373,634**	**$373,391**	**$351,178**	**$542,755**	**$560,341**	**$656,106**	**$2,857,404**
							$6,119,904

Co-investor In Kind Contribution	2010/11 Actual	2011/12 Actual	2012/13 Actual	2013/14 Actual	2014/15 Forecast	2015/16 Budget	Total
IO1	$32,416	$28,223	$37,350	$29,689	$54,704	$16,009	$198,391
IO2	$23,405	$12,863	$29,274	$31,546	$24,628	$22,760	$144,476
IO3	$6,430	$2,859	$15,063	$5,978	$20,668	$11,231	$62,229
IO4	$0	$0	$0	$0	$0	$0	$0
TOTAL FFR IN KIND	**$62,250**	**$43,945**	**$81,688**	**$67,213**	**$100,000**	**$50,000**	**$405,096**

Co-investor Total Contribution	**$435,884**	**$417,336**	**$432,865**	**$609,968**	**$660,341**	**$706,106**	**$3,262,500**

Payment Schedule

MPI will make payments of funding in accordance with the following:

i. payment will be made against valid, satisfactory, tax invoices that are complete (with supporting documentation) and approved by the Programme Steering Group;

ii. invoices for work completed in a Programme must be submitted to MPI at least quarterly at the end of September, December, March and June quarters;

iii. invoices that are to be paid by MPI in a calendar month must be received by MPI by 5.00pm on the 5th working day of that calendar month;

iv. invoices that are not received within the specified timeframe will be deferred to the following calendar month;

v. invoices that are not complete will not be approved for payment and will be discussed with FFR to achieve completeness;

vi. upon receipt of valid, satisfactory, tax invoices that are complete (with supporting documentation) and approved by the Programme Steering Group, MPI will promptly pay the invoice;

vii. where MPI has not approved payment of an invoice, or part thereof, MPI will discuss the reasons for this with FFR and seek to resolve these with FFR such that further MPI approval may be obtained;

viii. with each invoice submitted FFR will submit a quarterly report in support of the invoice including any relevant matters in accordance with clause 9 of the agreement; and

ix. a rolling 12 month forecast of expenditure to be incurred in the Programme including PGP funding and industry co-funding requirements to meet those costs must be submitted, at least annually.

Reporting and Review Requirements

Due date	Document	Description
5 May 2015	Annual Plan	Draft Plan for 2015-16 for PSG input
21 May 2015	Progress Report	Quarterly report Q3 2014-15
12 June 2015	Annual Plan	Final Plan 2015-16 approved by PSG
28 July 2015	Progress Report	Quarterly report Q4 2014-15
12 November 2015	Progress Report	Quarterly report Q1 2015-16
25 February 2016	Progress Report	Quarterly report Q2 2015-16
21 April 2016	Progress Report	Quarterly report Q3 2015-16
21 July 2016	Progress Report	Quarterly report Q4 2015-16
31 August 2016	Final Report	Final programme report
31 July 2017	Progress Report	Progress towards achieving programme outcomes and benefits
31 July 2018	Progress Report	Progress towards achieving programme outcomes and benefits
31 July 2019	Progress Report	Progress towards achieving programme outcomes and benefits